A CASE STUDY APPROACH TO THE SUPPLIER SELECTION PROCESS

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A project submitted in partial fulfillment of the requirements for the degree of

MASTER OF ENGINEERING

in

Management Systems Engineering

UNIVERSITY OF PUERTO RICO

MAYAGÜEZ CAMPUS

2003

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ABSTRACT

This work presents a comparative evaluation of supplier selection processes in different corporate environments using a multiple exploratory case study approach and the ISO 9000 standards. The corporate environments examined were a pharmaceutical, an agricultural equipment company, and an injection molding organization. This research indicates that the supplier performance measurement criteria most commonly used by these industries are quality, delivery and service. Also, depending on the corporate environment of these industries, the importance of these performance metrics can vary. In general, quality is the most important criterion in the organizations studied. Delivery is a critical supplier's performance measure in the pharmaceutical industry, since the reliability of the suppliers is affected in case of delivery failure in this sensitive market. Finally, these organizations continuously review and implement effective quality systems following the rigorous ISO 9000 series of standards and most companies have developed in-house procedures and softwares for the supplier selection process.

RESUMEN

Este trabajo presenta una evaluación comparativa de procesos de selección de proveedores en diferentes ambientes corporativos, usando la metodología de múltiples casos de estudio y los estándares de ISO 9000. Los ambientes corporativos examinados fueron una farmacéutica, una organización de equipos de agricultura y una manufacturera de moldeo de inyección. Esta investigación muestra que los criterios más comúnmente usados en las medidas de desempeño de los proveedores en estas industrias son calidad, entrega y servicio. Además, dependiendo del ambiente corporativo de estas industrias, varía la importancia de estas métricas. En general, la calidad es el criterio más importante en las organizaciones analizadas. La entrega es una medida crítica de desempeño de suplidores en la industria farmacéutica, ya que, la confiabilidad del suplidor puede ser afectada en caso de que la entrega falle en este mercado. Finalmente, estas organizaciones revisan continuamente e implementan sistemas de calidad basados en los estándares de ISO 9000.

DEDICATORY

This project is dedicated first of all to God for always guiding me and helping me accomplish my goals. To my lovely parents, José and Marianela, for being who they are, inspiring me to be a better person, teaching me the important things in life and for supporting and trusting me in all my decisions. To my sisters, Ana María and Aimee, whom I love with all my heart for being my unconditional friends. To my boyfriend Iván, for being always there for me, I love you very much. To my special friends, whom I consider my sisters, for all the given support, Karina, Jeannette, Jamell, Patricia and Delsa, thank you for all of your advice, I love you guys. To all my friends in Puerto Rico, who are very special to me, thank you guys for being there for me and making this stay in Puerto Rico so wonderful.

ACKNOWLEDGMENTS

I am so grateful for the help given to me by my advisor, Dr. Viviana Cesaní. Her knowledge, guidance and advice were vital for the accomplishment of this project. I also would like to express my thanks to Prof. Rita Vázquez, her understanding in this subject contributed greatly in this investigation and to extend my gratitude to Dr. José Deliz and Dr. Yolanda Ruiz, for helping me with the completion of this project. Also, I want to thank the University of Puerto Rico, specially the Industrial Engineering Department for giving me the opportunity to be a part of their master's program.

I give special thanks to Claribel Bonilla, the Supply Management Senior Engineer of Deere and Company, for providing me with all the information requested and for always being available to help. To Marta Rivera, Purchasing Manager of Baxter San Germán Division, and Marlyn Rodríguez, Planner Buyer of Baxter San Germán Division, for all their support, thank you for your time. To Eng. María Emanuelli, Materials Manager of Techno Plastics Industries, for all the help given. Thank you all for helping me to accomplish this project.

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CHAPTER I

INTRODUCTION

1.1. Justification

Traditionally organizations have been divided in operative functions such as marketing, planning, production, purchasing, finance, etc. Supply chain is a strategy that integrates these functions creating a general plan for the organization, which satisfies the service policy, maintaining the lowest possible cost level due the incredible competition environment that they are exposed to. A supply chain is a network of departments, which is involved in the manufacturing of a product from the procurement of raw materials to the distribution of the final products to the customer. Purchasing commands a significant position in most organizations since purchased parts, components, and supplies typically represent 40 to 60 percent of the sales (Ballow, 1999) of its end products. This means that relatively small cost reductions gained in the acquisition of materials can have a greater impact on profits than equal improvements in other cost-sales areas of the organization.

There has been an evolution in the role and structure of the purchasing function through the nineties. The purchasing function has gained great importance in the supply chain management due to factors such as globalization, increased value added in supply, and accelerated technological change. Purchasing involves buying the raw materials, supplies, and components for the organization. The activities associated with it include selecting and qualifying suppliers, rating supplier performance, negotiating contracts, comparing price, quality and service, sourcing

goods and service, timing purchases, selling terms of sale, evaluating the value received, predicting price, service, and sometimes demand changes, specifying the form in which goods are to be received, etc. A key and perhaps the most important process of the purchasing function is the efficient selection of suppliers, because it brings significant savings for the organization. The objective of the supplier selection process is to reduce risk and maximize the total value for the buyer, and it involves considering a series of strategic variables. Among these variables is the time frame of the relationship with suppliers, the choice between domestic and international suppliers, and the number of suppliers, that is, choosing between single or multiple sourcing and the type of product.

Some authors have identified several criteria for supplier selection, such as the net price, quality, delivery, historical supplier performance, capacity, communication systems, service, geographic location, among others (Dickson 1966; Dempsey 1978; Weber, Current, and Benton 1991). These criteria are a key issue in the supplier assessment process since it measures the performance of the suppliers.

In general, this research intends to provide empirical evidence of the criteria and the procedures for the supplier selection process used in different corporate environments. Also, it plans to evaluate if these processes follow rigorous regulations as the ISO 9000 standards. Finally, identify the suitability of the Analytical Hierarchical Process (AHP) to assist in decision making to resolve the supplier selection problem.

1.2. Objectives

The major objective of this research is to perform a comparative evaluation of supplier selection processes in different corporate environments using a multiple exploratory case study approach and evaluate their supplier selection processes using the ISO 9001:2000 standards. Some more specific objectives are:

- Identify the supplier selection processes used by the companies.
- Study companies in different corporate environments.
- Identify key performance measures.
- Recognize in which criteria the company focuses.
- Identify the company's purchasing policy.
- Compare the companies' supplier selection processes vs. ISO 9001:2000.
- Examine the continuous improvement efforts in these companies.

In addition, this study is conducted to address the following research questions:

Research question 1: Do the key performance measures of the supplier selection processes vary depending on the corporate environment?

Research question 2: Do the supplier selection processes of the organizations follow a reliable set of quality standards, as ISO 9000 requires?

Research question 3: Are the theoretical methods suitable for the supplier selection process?

The answers to these questions provide key insight needed to understand the current supplier selection processes and their relationship with the corporate environments.

1.3. Scope

The scope of this project is to compare the supplier selection process across and within companies using both qualitative and quantitative approaches. The focus is limited to companies from different manufacturing sectors in USA and Puerto Rico, including pharmaceuticals, agricultural equipments, and plastics organizations. Also, the focal point process in this research is the selection and evaluation of suppliers.

1.4. Methodology

This study aims to finding the relationship between the corporate environments and the supplier selection processes since there is no evidence in the literature of this particular relationship. The nature of this research required a methodology that could be flexible to allow open questions to collect information since the organizations under study have many different settings.

The methodology suitable for this project is the case study approach, which allows a picture or model to be built up that, illustrates relationships and patterns of interaction between variables. The data used in this research are mainly collected through different sources of evidence such as: semi-structured face-to-face interviews, questionnaires, phone interviews, organization's written procedures, web sites, onsite visits, and e-mail correspondence.

In this research, the analysis of the data is divided in two phases, a within and across case analysis. Some conclusions within the company are presented in each case study. Subsequently, a discussion of results is presented with conclusions across companies expressing the relationships, similarities and differences among cases.

1.5. Organization of the Document

This project is organized in the following order. First, the literature review is presented in Chapter II in which some of the methods and softwares currently available for the supplier selection process and of the ISO 9000 standards as a system for comparison are presented. The following chapter, Chapter III, includes the methodology where the case study approach used in this study is discussed. Chapter IV contains the three companies studied including their particular sourcing strategy, supplier selection process and evaluation criteria, and the discussion of results. Also, in this chapter a comparison with the ISO 9000 standards for the case studies is presented. Chapter V presents an application of the Analytical Hierarchical Process using actual supplier assessment information. The final chapter, Chapter VI, presents the conclusions and future work of this research.

CHAPTER II

LITERATURE REVIEW

One of the most important processes performed in organizations today is the evaluation, selection, and continuous improvement of suppliers. This review first will include the general framework used in the supplier selection process and the different types of suppliers. Next, some of the methods currently available are discussed followed by a supplier evaluation system: ISO 9000. Finally, several software packages useful for this process are presented.

2.1. Supplier Selection Process

Experts agree that no best way exists to evaluate and select suppliers, and thus organizations use a variety of approaches. The overall objective of the supplier evaluation process is to reduce risk and maximize overall value to the purchaser. An organization must select suppliers it can do business with over an extended period of time.

Supplier evaluations often follow a rigorous, structured approach through the use of a survey. An effective supplier survey should have certain characteristics such as comprehensiveness, objectiveness, reliability, flexibility and finally, has to be mathematically straightforward. To ensure that a supplier survey has these characteristics is recommended a step-by-step process when creating this tool. Figure 2.1 presents the steps to follow when developing such a system (Monczka, Trent, Handfield, 2002). This general framework is explained in detail next.

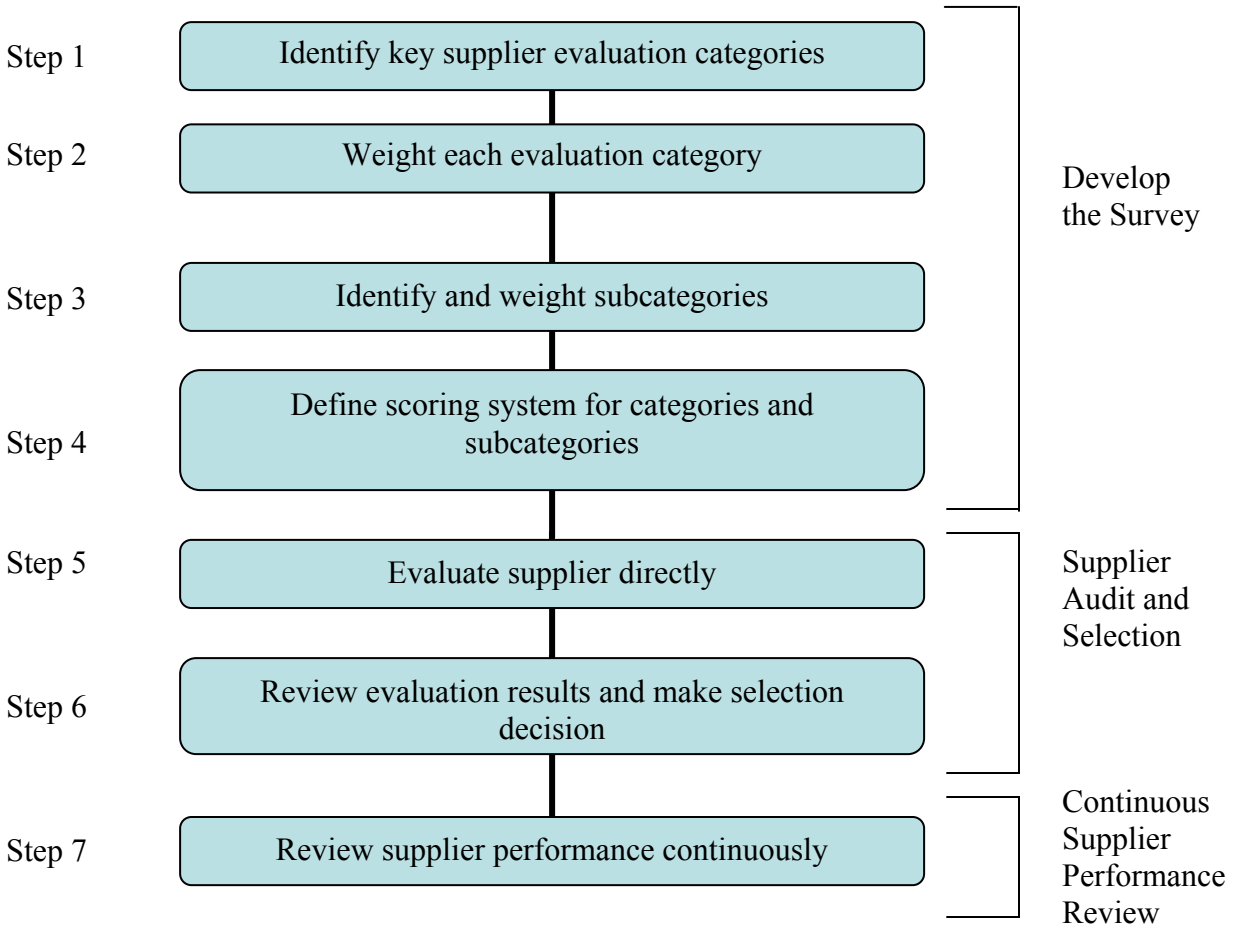

Figure 2.1 Initial Supplier Evaluation and Selection Audit Development.

The framework includes seven steps:

Step1. Identify key supplier evaluation categories

One of the first steps when developing a supplier survey is for the purchaser to decide which performance categories to include. The primary criteria are cost/price, quality and delivery, which are generally the most obvious and most critical areas that affect the buyer. For many items, these three performance areas would be enough, however for critical items needing an in-depth analysis of the supplier's capabilities, a more detailed supplier evaluation study is required. These criteria are typically the following:

a. Supplier management capability

This is an important manner to evaluate, since management runs the business and makes the decisions that affect the future competitiveness of the supplier.

b. Overall personnel capabilities

This measurement requires an evaluation of non-management personnel. The benefit that a highly trained, stable, and motivated workforce can provide should not be underestimated.

c. Cost structure

Understanding a supplier's total cost structure helps a buyer determine how efficiently a supplier can produce an item. A cost analysis also helps identify potential areas of cost improvement.

d. Total quality performance, systems, and philosophy

A major part of the evaluation process addresses a supplier's quality management processes, systems and philosophy.

e. Process and technological capability, including the supplier's design capability

A supplier's selection of a production process helps define its required technology, human resource skills, and capital equipment requirements.

f. Environmental regulation compliance

This is important given that purchasers do not want to be associated with known environmental polluters from a public relations or potential liability standpoint.

g. Financial capability and stability

A numerous of purchasers view the financial assessment as a screening process or preliminary condition that the supplier must pass before a detailed evaluation can begin.

h. Production scheduling and control systems, including supplier delivery performance

The purpose behind evaluating the production scheduling and control system is to identify the degree of control the supplier has over its scheduling and production process.

i. Information systems capability (e.g., EDI, bar coding, ERP, CAD/CAM)

Evidence that the supplier is using these technologies can provide reasonable assurance that the supplier is staying current with new e-commerce technologies.

j. Supplier purchasing strategies, policies, and techniques

These criteria are together one way to gain greater insight and understanding of the supply chain of the suppliers.

k. Longer-term relationship potential

Assessing a supplier's willingness to develop longer-term relationships that may evolve into alliances or partnerships is increasingly becoming part of the evaluation process.

In addition, the most important and common issues concerning the supplier selection process include the physical distribution items (on time delivery, and accurate order processing and delivery), management issues (commitment to quality

and improvement), pricing items (competitive pricing), relationship items (reliability, responsiveness, cooperation, professionalism, customer service, ethical values, timely communications, and trusting relationship), quality items (outgoing quality control, quality management, in-process quality control, and quality control documentation), and service items (quick response and technical assistance) (Siguaw and Simpson, 2002). These issues offer the greatest potential for a supplier to add value to a buyer firm, through cost savings and revenue enhancement.

Step 2. Weight each evaluation category

The performance categories usually receive a weight that reflects the relative importance of the category. The total of each weight must equal 1.0. An important characteristic of an effective evaluation is flexibility. One way that management achieves this flexibility is by assigning different weights or adding or deleting performance categories as required.

Step 3. Identify and weight subcategories

This process requires identifying any performance subcategories, if they exist, within each broader performance category. The sum of the subcategory weight must equal the total weight of the performance category.

Step 4. Define scoring system for categories and subcategories

A clearly defined scoring system takes criteria that may be highly subjective and develops a quantitative scale for measurement. Scoring metrics are effective if different individuals interpret and score the same performance categories under review. For illustrative purposes, an example is a 10-point scale where 1-2= poor, 3-4= weak, 5-6= marginal, 7-8= qualified, 9-10= outstanding.

Step 5. Evaluate supplier directly

A purchaser can compare objectively the scores of different suppliers competing for the same purchase contract or select one supplier over another based on the evaluation score. It is also possible, based on the evaluation, that a supplier does not qualify at this time for further purchase consideration. Purchasers should have minimum acceptable performance requirements that suppliers must satisfy before they can become part of the supply base.

Step 6. Review evaluation results and make selection decision

The primary output from this step is a recommendation about whether to accept a supplier for a business. A purchaser may evaluate several suppliers who might be competing for a purchaser contract. The purpose of the evaluation is to qualify potential suppliers for current or expected future purchase contracts.

Step 7. Review supplier performance continuously

When a purchaser decides to select a supplier, the supplier must then perform according to the purchaser's requirements. The emphasis shifts from the initial evaluation and selection of suppliers to evidence of continuous improvement by suppliers.

This framework should have certain characteristics such as: be comprehensive, objective, reliable, flexible, and be mathematically straightforward. The use of weights and points should be simple enough so that each individual involved in the evaluation understands the mechanics of the scoring and selection process. This step-by-step process is recommended to ensure that a supplier survey has the right characteristics.

2.2. Types of Suppliers

Suppliers are essential to any business, and the process of identifying and selecting suppliers is both relevant and important. Sometimes suppliers will contact the purchasing organization through their sales representatives, but more often, the buyer will need to locate them themselves either at trade shows, wholesale showrooms and conventions, or through buyers directories, industry contacts, the Business-to-Business Yellow Pages and trade journals.

To understand better this approach, it is significant to present that suppliers can be divided into four general categories: manufacturers, distributors, independent craftspeople and importation sources (Lesonsky, 2001). The first category is the manufacturers in which most retailers buy through company salespeople or independent representatives who handle the wares of several different companies. Prices from these sources are usually lowest, unless the retailer's location makes shipping freight costly.

The second type of suppliers are the distributors who also are known as wholesalers, brokers or jobbers, distributors buy in quantity from several manufacturers and warehouse the goods for sale to retailers. Although their prices are higher than a manufacturer’s, they can supply retailers with small orders from a variety of manufacturers. A lower freight bill and quick delivery time from a nearby distributor often compensates for the higher per-item cost.

Another kind are the independent craftspeople that are exclusive distributors of unique creations frequently offered by these independent craftspeople, who sell through representatives or at trade shows.

The last category of suppliers is the importation sources in which many retailers buy foreign goods from a domestic importer, who operates much like a domestic wholesaler. Or, depending on the company's familiarity with overseas sources, it may want to travel abroad to buy goods.

2.3. Supplier Selection Methods

There are several supplier selection methods available in the literature. Some authors propose linear weighting models in which suppliers are rated on several criteria and in which these ratings are combined into a single score. These models include the categorical, the weighted point (Timmerman, 1986) and the analytical hierarchical process (Nydick and Hill, 1992). Total cost approaches attempt to quantify all costs related to the selection of a vendor in monetary units, this approach includes cost ratio (Timmerman, 1986) and total cost of ownership (Ellram, 1995). Mathematical programming models often consider only the more quantitative criteria; this approach includes the principal component analysis (Petroni and Braglia, 2000) and neural network (Wei, 1997).

The categorical method relies heavily on the experience and ability of the individual buyer (Timmerman, 1986). People in charge of purchasing, quality, production, and sales all express their opinions about the supplier's performance on the basis criteria which are important to them. These departments assign either a

preferred, unsatisfactory, or neutral rating for each of the selected attributes for every contending supplier. At periodic evaluation meetings, the buyer discusses the rating with department members. The buyer then determines the supplier's overall scores. The primary advantage of the categorical approach is that it helps structure the evaluation process in a clear and systematic way. This method is quite simple, it is not supported by objective criteria, and rarely leads to performance improvements. The main drawback of this method is that the identified attributes are weighted equally and the decisions made using this system tend to be fairly subjective.

Another method is the weighted point which considers attributes that are weighted by the buyer. The weight for each attribute is then multiplied by the performance score that is assigned. Finally, these products are totaled to determine a final rating for each supplier (Timmerman, 1986).

All measurement factors are weighted for importance in each purchasing situation. Typically this system is designed to utilize quantitative measurements.
The advantages of the weighted point method include the ability for the organization to include numerous evaluation factors and assign them weights according to the organization's needs. The subjective factors on the evaluation are minimized.

The major limitation of this approach is that it is difficult to effectively take qualitative evaluation criteria into consideration.

The following example summarizes the weighted point method:

Example: Assume that there are four criteria that are being used to evaluate suppliers, quality, price, service and delivery. These attributes were weighted with the relative importance considered by the buyer on a 0 (less important) to 1(most

important) scale, as shown in Table 2.1. Further, assume that proposals from four suppliers are being considered (Supplier 1, Supplier 2, Supplier 3 and Supplier 4). Table 2.2 presents the final results.

Table 2.1 WPM Example: Matrix with weighted attributes

	Weights	Supplier1	Supplier2	Supplier3	Supplier4
Quality	0.46	0.48	0.55	0.47	0.33
Price	0.30	0.24	0.27	0.35	0.33
Service	0.14	0.12	0.09	0.12	0.22
Delivery	0.11	0.16	0.09	0.06	0.11

As an illustrative example the following equation presents how Table 2.2 is calculated:

$$\text{Supplier 1} = (0.46*0.48) + (0.30*0.24) + (0.14*0.12) + (0.11*0.16) = 0.32$$

Table 2.2 WPM Example: Final Scores

Supplier 1	0.32
Supplier 2	0.35
Supplier 3	0.34 ←
Supplier 4	0.29

According to the previous results, the higher weight belongs to supplier 2, and is judged to be the best overall.

The cost-ratio is an additional method that relates all identifiable purchasing costs to the monetary value of the goods received from vendors (Timmerman, 1986). The higher the ratio of costs to value, the lower the rating applied to the vendor. The choices of costs to be incorporated in the evaluation depend on the products involved. The costs associated with quality include the costs of visits to a vendor's plants and sample approval, inspection costs of incoming shipments, and the costs associated with defective products such as unusual inspection procedures, rejected parts and manufacturing losses due to defective goods. Quality costs can be determined and

documented by the quality control department, with the help of other departments such as production and receiving. The usual costs associated with delivery include communications, settlements and emergency transport costs (for example air shipments). The same tabulation procedure is followed as for the quality costs. The cost-ratio method establishes a "norm" of supplier services and evaluates vendors above and below the norm in relation to price. The subjective elements common to other methods are thus reduced.

The cost ratio method is based on cost analysis that considers cost ratios for product quality, delivery, customer service and price. The cost ratio measures the cost of each factor as a percentage of total purchase for the supplier. Due the flexibility of this method, any company in any market can adopt it. The drawback of the method is its complexity and requirement for a developed cost accounting system.

Similarly the total cost of ownership method attempts to quantify all of the costs related to the purchase of a given quantity of products or services from a given supplier (Degraeve and Roodhooft, 1999). Optimum use of all discounts available can lead to substantial savings. In addition to the price component, other cost factors also play an important role, including the costs associated with quality shortcomings, a supplier's unreliable delivery service, transport costs, ordering costs, reception costs, and inspection costs. This method uses activity- based costing which is a management accounting technique that attempts to assign costs to cost generating activities within a business. This technique uses activity analysis, which defines the various activities performed by an organization. The first step of the total cost of ownership method is to define all the activities related to external purchasing. These are specific to every

enterprise and should be expressed through the activity analysis. Subsequently, costs must be assigned to the different activities. The next step is to define factors which raise the cost of a given activity (cost drivers). Finally, one must identify which activities are generated in the purchasing organization by each individual supplier. This approach enables substantial cost savings to be achieved and, at the same time, allows various purchasing policies to be compared with one another.

In addition, the principal component analysis (PCA) method is a multi-objective approach to vendor selection that attempts to provide a useful decision support system for a purchasing manager faced with multiple vendors and trade-offs such as price, delivery, reliability, and product quality (Petroni and Braglia, 2000). This multivariate statistical method is a data reduction technique used to identify a small set of variable that account for a large portion of the total variance in the original variance. This technique is also used to identify "latent" dimensions in the data. In fact, the principal component analysis computes linear combinations of variables. The first linear combination of variables, accounts for the largest amount of variation in the sample; the second for the next largest amount of variance in a dimension independent of the first; and so on. This method is also a popular ranking method in multidimensional analysis. The principal component analysis methodology has the advantage to be fairly simple to exploit, since it has been accessible for decades. This method has proved to be capable of handling multiple conflicting attributes inherent in supplier selection while simultaneously trading-off key supplier selection criteria. To illustrate this method the following example is presented.

Example: The methodology proposed was applied to the supplier selection process of a medium-sized manufacturer of bottling machinery and complete packaging lines (Petroni and Braglia, 2000). Principal Component Analysis was applied to the evaluation of the performances of the suppliers of the "grip heads", one of the most critical components used both for rinsers and for fillers. Table 2.3 shows the supplier's attributes.

Table 2.3 PCA Example: Suppliers attributes

Supplier	Management Capabilities	Production Facilities and Capacity	Technological Capabilities	Price	Quality	Delivery Compliance
1	0.622	0.261	0.667	0.958	0.100	0.122
2	0.500	0.333	0.571	1.000	0.200	0.200
3	0.737	0.429	0.400	0.935	0.133	0.167
4	0.683	0.286	0.444	0.983	0.182	1.000
5	0.452	0.353	0.400	0.958	0.400	0.040
6	0.509	1.000	0.800	0.975	0.167	0.032
7	1.000	0.500	0.571	0.943	0.333	0.179
8	0.778	0.667	0.571	0.983	1.000	0.093
9	0.596	0.176	0.444	0.920	0.167	0.060
10	0.528	0.545	1.000	1.000	0.222	0.049

Six output/input ratios for the supplier's attributes were defined as:

d1= product price/technological capability

d2= product price/ management capabilities

d3= shipment quality/ management capabilities

d4= shipment quality/ technological capability

d5= delivery compliance/ production capacity, and

d6= delivery compliance/ management capabilities.

The decision maker would like to select the supplier that provides the best combination of the performance parameters. In statistical terms, these suppliers are extreme observations that lie away from the rest of the data. PCA is a procedure that

identifies outlying suppliers regardless of the importance the purchasing manager attaches to each performance parameter of the vendor and is employed to identify the principal components that are respectively different linear combinations of the performance variables so that the principal components can be multiplied by their eigenvalues to obtain a weighted measure of the variables.

The first step in PCA consists of testing whether the variables shows a sufficient level of correlation. To this extent, both the correlation matrix (Table 2.4) and the Bartlett's test of sphericity have been analyzed. In this case the null hypothesis is rejected at the 0.001 level.

Table 2.4 PCA Example: Correlation matrix

	d1	**d2**	**d3**	**d4**	**d5**	**d6**
d1	1.000	-0.192	0.253	-0.203	-0.278	-0.104
d2	-0.192	1.000	-0.096	0.198	0.222	-0.071
d3	0.253	-0.096	1.000	0.704	-0.236	-0.121
d4	-0.203	0.198	0.704	1.000	-0.018	-0.032
d5	-0.278	0.222	-0.236	-0.018	1.000	0.900
d6	-0.104	-0.071	-0.121	-0.032	0.900	1.000

A rule-of-thumb for determining the number of components to extract is to consider the "eigenvalue grater than one" criterion. The eigenvalue scree plot is often useful in graphically determining the number of factors extracted (Figure 2.2). In the present analysis, three components are a workable solution (since the residual components have all eigenvalues less than 1).

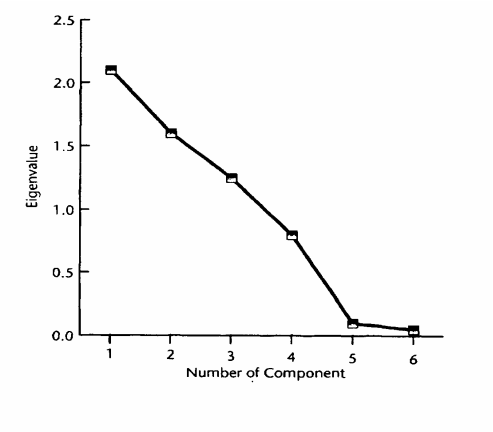

Figure 2.2 PCA Example: Eigenvalue Scree Plot

Components 1, 2 and 3 account for approximately 83 percent of the total variance of the variables (Table 2.5). The percentage of variance explained by each component represents its relative importance.

Table 2.5 Total PCA Example: Total variance explained by the components

Weights of the rotated component			
Component	**Total**	**% of Variance**	**% Cumulative**
1	1.913	31.885	31.885
2	1.710	28.508	60.393
3	1.377	22.949	83.342

The interpretation of Table 2.6 leads the decision maker to conclude that component 1 loads on matters concerning delivery compliance, component 2 loads on matters concerning product quality, and component 3 loads on matters concerning price.

Table 2.6 PCA Example: Matrix of rotated components (Loadings smaller than 0.1 are omitted)

Variable	Component		
	1	2	3
d6	0.987		
d5	0.946		0.247
d3	0.115	0.923	0.256
d4		0.918	0.282
d2			0.778
d1	0.171		0.749

For each variable considered (d1, d2, d3, d4, d5 and d6), a coefficient w_i (i=1 to 6) is obtained by multiplying the loadings on each component by the percentage of variance explained by the component. For instance, w1 is obtained as fallows:

$$w_1 = 0.171*0.31885 + 0*0.28508 + 0.749*0.22949 = 0.2264$$

The coefficients w_2 to w_6 are obtained in the same way. Each coefficient is then multiplied by the value of the corresponding variable (d1 to d6) for each supplier to get a final supplier score (Table 2.7). Based on these scores the final ranking is obtained.

Table 2.7 PCA Example: Final ranking of suppliers

SCORE	SUPPLIER NUMBER
2.292	4
1.798	14
1.658	5
1.639	8
1.622	17
1.482	11
1.396	18
1.391	22
1.356	2
1.271	12
1.241	20
1.224	13
1.209	9
1.180	19
1.168	23
1.151	16
1.091	3
1.066	21
1.013	7
0.974	15
0.937	10
0.915	1
0.857	6

Summing up, supplier number 4 ends up as the supplier that provides the best performances with respect to the three components identified.

Another useful method is the Analytical Hierarchical Process (AHP), a decision-making method developed by Saaty (1980) for prioritizing alternatives when multiple criteria must be considered and allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels. Generally, the hierarchy has at least three levels: the goal, the criteria, and the alternatives. For the supplier selection problem, the goal is to select the best overall supplier (Nydick and Hill, 1992). The criteria can be quality, price, service, delivery, etc. The alternatives are the different proposals supplied by the suppliers.

The AHP offers a methodology to rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each alternative. For this reason, AHP is ideally suited for the supplier selection problem.

The problem hierarchy lends itself to an analysis based on the impact of a given level on the next higher level. The process begins by determining the relative importance of the criteria in meeting the goals. Next, the focus shifts to measuring the extent to which the alternatives achieve each of the criteria. Finally, the results of the two analyses are synthesized to compute the relative importance of the alternative in meeting the goal.

Managerial judgments are used to drive the AHP approach. These judgments are expressed in terms of pairwise comparisons of items on a given level of the hierarchy with respect to their impact on the next higher level. Pairwise comparisons express the relative importance of one item versus another in meeting a goal or a criterion. Each of the pairwise comparisons represents an estimate of the ratio of the weights of the two criteria being compared. Because AHP utilizes a ratio scale for human judgments, the alternatives weights reflect the relative importance of the criteria in achieving the goal of the hierarchy.

The use of the AHP approach offers a number of benefits. One important advantage is its simplicity. The AHP can also accommodate uncertain and subjective information, and allows the application of experience, insight, and intuition in a logical manner.

The AHP approach, as applied to the supplier selection problem, consists of the following five steps (Nydick and Hill, 1992):

1. Specify the set of criteria for evaluating the supplier's proposals.
2. Obtain the pairwise comparisons of the relative importance of the criteria in achieving the goal, and compute the priorities or weights of the criteria based on this information.
3. Obtain measures that describe the extent to which each supplier achieves the criteria.
4. Using the information in step 3, obtain the pairwise comparisons of the relative importance of the suppliers with respect to the criteria, and compute the corresponding priorities.
5. Using the results of steps 2 and 4, compute the priorities of each supplier in achieving the goal of the hierarchy.

This procedure is summarized in the following example.

Example: Assume that there are four criteria that are being used to evaluate suppliers, quality, price, service and delivery (Nydick and Hill, 1992). Further, assume that proposals from four suppliers are being considered (supplier 1 (S1), supplier 2 (S2), supplier 3 (S3) and supplier 4 (S4)). Figure 2.3 shows the structure of this hierarchy.

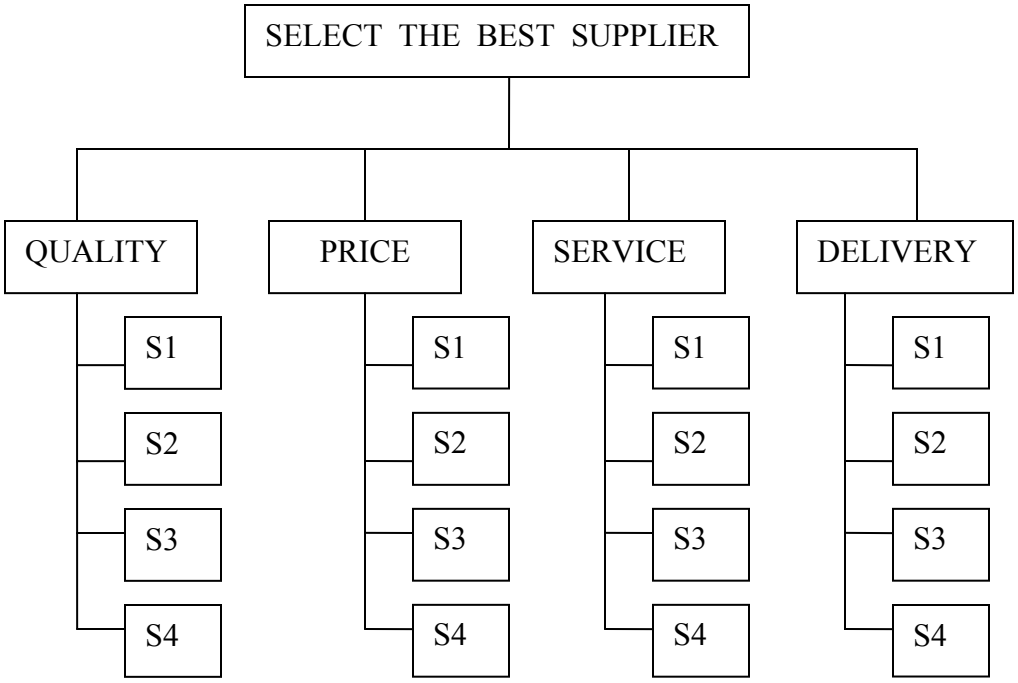

Figure 2.3 Hierarchy of the AHP example

Table 2.8 presents a scale used for quantifying managerial judgments for AHP analysis. For example, if a buyer believes that quality is moderately more important than delivery, then this judgment is represented by a 3. Judgments are required for all the criterion comparisons, and for all the alternative comparisons for each criterion. This information is usually provided by the buyer.

Table 2.8 AHP Measurement scale

MEASUREMENT SCALE	
Verbal Judgement of Preference	Numerical Rating
Extremelly Preferred	9
Very Strongly Preferred	7
Strongly Preferred	5
Moderately Preferred	3
Equally Preferred	1
The intermediate values of 2, 4, 6, and 8 provide additional levels of discrimination	

The buyer must now develop a set of pairwise comparisons to define the relative importance of the criteria to complete the following matrix (Table 2.9).

Table 2.9 AHP Example: Original Matrix

	Quality	Price	Service	Delivery
Quality	1.00	2.00	4.00	3.00
Price	0.50	1.00	3.00	3.00
Service	0.25	0.33	1.00	2.00
Delivery	0.33	0.33	0.50	1.00
Total	2.08	3.67	8.50	9.00

The data in the matrix can be used to generate a good estimate of the criteria weights. The weights provide a measure of the relative importance of each criterion. This process is summarized in the following three steps, and shown in the Table 2.10:

1. Sum the elements in each column
2. Divide each value by its column sum
3. Compute row averages

Table 2.10 AHP Example: Normalized Matrix

	Quality	Price	Service	Delivery	Weights
Quality	0.48	0.55	0.47	0.33	0.46
Price	0.24	0.27	0.35	0.33	0.30
Service	0.12	0.09	0.12	0.22	0.14
Delivery	0.16	0.09	0.06	0.11	0.11
Total	1.00	1.00	1.00	1.00	1.00

Next, the four suppliers must be compared pairwise for each criterion. This process is virtually identical to the procedure that was used to develop the criteria comparison matrix. The only difference is that there is a supplier comparison matrix for each criterion. Therefore, the decision maker compares each pair of suppliers with respect to the quality criterion, as shown in Table 2.11:

Table 2.11 AHP Example: Quality matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Supplier 1	1.00	5.00	6.00	0.33
Supplier 2	0.20	1.00	2.00	0.17
Supplier 3	0.17	0.50	1.00	0.13
Supplier 4	3.00	6.00	8.00	1.00
Total	4.37	12.50	17.00	1.63

Table 2.12 AHP Example: Normalized quality matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Weights
Supplier 1	0.23	0.40	0.35	0.21	0.30
Supplier 2	0.05	0.08	0.12	0.10	0.09
Supplier 3	0.04	0.04	0.06	0.08	0.05
Supplier 4	0.69	0.48	0.47	0.62	0.56
Total	1.00	1.00	1.00	1.00	1.00

Furthermore, the price criterion is compared with each pair of suppliers (Table 2.13 and Table 2.14):

Table 2.13 AHP Example: Price matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Supplier 1	1.00	0.33	5.00	8.00
Supplier 2	3.00	1.00	7.00	9.00
Supplier 3	0.20	0.14	1.00	2.00
Supplier 4	0.13	0.11	0.50	1.00
Total	4.33	1.59	13.50	20.00

Table 2.14 AHP Example: Normalized price matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Weights
Supplier 1	0.23	0.21	0.37	0.40	0.30
Supplier 2	0.69	0.63	0.52	0.45	0.57
Supplier 3	0.05	0.09	0.07	0.10	0.08
Supplier 4	0.03	0.07	0.04	0.05	0.05
Total	1.00	1.00	1.00	1.00	1.00

Also, the service criterion is compared with each pair of suppliers (Table 2.15 and Table 2.16):

Table 2.15 AHP Example: Service matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Supplier 1	1.00	5.00	4.00	8.00
Supplier 2	0.20	1.00	0.50	4.00
Supplier 3	0.25	2.00	1.00	5.00
Supplier 4	0.13	0.25	0.20	1.00
Total	1.58	8.25	5.70	18.00

Table 2.16 AHP Example: Normalized service matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Weights
Supplier 1	0.63	0.61	0.70	0.44	0.60
Supplier 2	0.13	0.12	0.09	0.22	0.14
Supplier 3	0.16	0.24	0.18	0.28	0.21
Supplier 4	0.08	0.03	0.04	0.06	0.05
Total	1.00	1.00	1.00	1.00	1.00

Consequently, the delivery criterion is compared with each pair of suppliers (Table 2.17 and Table 2.18):

Table 2.17 AHP Example: Delivery matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Supplier 1	1.00	3.00	0.20	1.00
Supplier 2	0.33	1.00	0.13	0.33
Supplier 3	5.00	8.00	1.00	5.00
Supplier 4	1.00	3.00	0.20	1.00
Total	7.33	15.00	1.53	7.33

Table 2.18 AHP Example: Normalized delivery matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Weights
Supplier 1	0.14	0.20	0.13	0.14	0.15
Supplier 2	0.05	0.07	0.08	0.05	0.06
Supplier 3	0.68	0.53	0.66	0.68	0.64
Supplier 4	0.14	0.20	0.13	0.14	0.15
Total	1.00	1.00	1.00	1.00	1.00

The final step of the AHP analysis is summarized in the following table.

Table 2.19 AHP Example: Summary of Results

	Quality	Price	Service	Delivery	Weights
Supplier 1	0.14	0.09	0.08	0.02	0.32
Supplier 2	0.04	0.17	0.02	0.01	0.24
Supplier 3	0.02	0.02	0.03	0.07	0.14
Supplier 4	0.26	0.01	0.01	0.02	0.29
				Total	1.00

According to the previous results, the higher weight belongs to supplier 1, and is judged to be the best overall.

The neural network for supplier selection is another method that has been developed to help selecting the best supplier. Comparing to conventional models for decision support system, neural networks save a lot of time and money of system development. The supplier-selecting system includes two functions: one is the function measuring and evaluating performance of purchasing (quality, quantity, timing, price and costs) and storing the evaluation in a database to provide data sources to neural network (Wei, 1997). The other is the function using neural network to select suppliers. Most of the neural-network paradigms commonly used have three layers: input layer, output layer, and hidden layer. It should be decided which Artificial Neural Network (ANN) model should be used, and the number of nodes in the input layer, hidden layer and output layer. Back-propagation network (BPN) is the most popular neural network model and has the highest success rate. Although preliminary results appear very promising, some special cases and history data still need to be represented and its responses need to be evaluated.

As a comparative analysis of these models, Table 2.20 is presented. This table summarizes all of the previous methods, presenting their advantages and disadvantages.

To summarize, the categorical model is a simple method, is also the quickest, easiest, and less costly to implement, but may be influenced by recent events, usually implies a high level of subjectivity and is imprecise. The weighted point model is also easy to implement, flexible, and rather efficient in the optimization of supplier selection decisions, is more costly than the categorical, but tends to be more objective, even though it relies on the buyer's assessment of the supplier performance. The cost ratio method is very flexible and less subjective than the previous ones. It's a complex method that requires a developed cost accounting system. The total cost model is precise, expensive to implement due its complexity, requires more time, and implies the ability to identify the more important elements. The principal component analysis method has the advantage that is accessible and is capable of handling multiple conflicting attributes. The analytical hierarchy process is relatively simple to use and understand. This method incorporates qualitative and quantitative criteria. The neural network model saves money and time of system development. The weakness of this model is that demands a software and requires qualified personnel expert on this subject.

Table 2.20: Comparison of the supplier selection methods

Method	Reference	Quantitative/ Qualitative parameters	Advantages	Disadvantages
Categorical	Timmerman (1986)	-Quality -Delivery -Service -Price	-The evaluation process is clear and systematic -Inexpensive -Requires a minimum performance data	-Attributes are weighted equally -Subjective -Imprecise
Weighted Point	Timmerman (1986)	-Quality -Delivery -Service -Price	-Attributes are weighted by importance	-Subjective -Difficult to effectively consider qualitative criteria
Cost ratio	Timmerman (1986)	-Quality -Delivery -Service -Price	-Subjectivity is reduced -Flexibility	-Complexity and requirement for a developed cost accounting system -Performance measures (cost ratios) are artificially expressed in the same units
Total Cost of Ownership	Ellram (1995)	-Price -Quality costs -Unreliable delivery service costs -Transport costs -Ordering costs -Reception costs -Inspection costs	-Substantial cost savings -Allows various purchasing policies to be compared with one another	-Complex

Table 2.20 (Continued)

Method	Reference	Quantitative/ Qualitative parameters	Advantages	Disadvantages
Principal Component Analysis	Petroni & Braglia (2000)	-Price -Delivery reliability -Quality	-Considers simultaneously multiple inputs and outputs without priori assignment of weights	-Knowledge of advanced statistical methods is required
Analytic Hierarchical Process	Nydick & Hill (1992)	-Quality -Price -Delivery -Service	-Simplicity -Captures both qualitative and quantitative criteria	-Inconsistency on the method
Neural Network	Siying Wei (1997)	-Performance -Quality -Geography -Price	-Saves a lot of time and money of system development	-Lack of expertise -Requires a software

In conclusion, these methods are apparently useful for the supplier selection process, however after contacting the authors, they have no evidence that these processes are currently been employed by organizations.

2.4. ISO 9000 Standards

Another topic concerning this study, is comparing the supplier selection issues in each organization with a supplier evaluation system as the ISO 9000 standards.

This quality system was chosen as a structure for comparison because is recognized as a required quality standard in many parts of the global marketplace. Besides, the three companies under study are either ISO 9000 certified or structured therefore comparison can be established by the procedures actually used by these

organizations in the vendor selection process and the key metrics used in this process, with these quality standards.

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies, which prepares international standards to facilitate trade. The ISO 9000 standards provide a tool that can be used in supplier-customer contracts since many of the clauses focus on this relationship. ISO registration helps suppliers demonstrate their capabilities to meet quality requirements. In addition to specifying product and service requirements, a customer (e.g. buyer) can also require that a supplier has a quality management system that meets the requirements of one of the ISO 9001 standards.

It is in the best interest of the suppliers to pursue ISO 9000 certification, particularly if buyers value the certification. Buying firms can also benefit from ISO 9000 registration since few buying firms have the size or resources to develop and conduct comprehensive supplier certification audits. ISO 9000 provides insight into a supplier's quality system conformance that a buyer may otherwise lack.

The latest version of these standards is the ISO 9001:2000 which have modifications in the Purchasing section as presented in the following clauses.

1. Purchasing:

Purchasing control:

The organization shall ensure that purchased product conforms to specified requirements. The type and extent of control applied to the supplier and the product shall be dependent upon the impact of the purchased product on subsequent product realization or the final product.

The organization shall evaluate and select suppliers based on their ability to supply product in accordance with the organization's requirements. Criteria for selection, evaluation and re-evaluation shall be established. The results of evaluations and subsequent follow-up actions shall be recorded.

Purchasing information:

Purchasing information shall describe the product to be purchased, including where appropriate:

a. requirements for approval of product, procedures, processes, facilities and equipment

b. requirements for qualification of personnel

c. quality management system requirements.

The organization shall ensure the adequacy of specified requirements prior to their communication to the supplier.

Verification of purchased product:

The organization shall establish and implement the inspection or other activities necessary for ensuring that purchased product meets specified requirements. Where the organization or its customer intends to perform verification activities at the supplier’s premises, the organization shall specify the required verification arrangements and method of product release in the purchasing information.

In the purchasing section, there are several added requirements:

a. Need to establish criteria for selection of our suppliers

b. Need to have records of evaluations against the selection criteria

c. Need to describe the approval requirements for product, procedures, process, facilities and equipment, along with qualification of suppliers personnel

If it is decided that any of these requirements are appropriate, or that we have had requirements imposed on our company from the customers or standards under which we work, we need to establish clear methods of control.

For "criteria", we can range from price and availability to pre-qualification by customer to full qualifications as suggested in (c) above.

"Records" will depend on the qualification methods. They can range from simple listings showing price comparisons done annually to full history files of control plans, process analysis, materials analysis, and statistical studies to copies of operator and inspector qualifications.

It suggests that the evaluation criteria may extend to include a wide range from relevant experience with your type of product or service to logistics as follows: "These processes may include:

- Evaluation of relevant experience,
- Review of product quality, price, delivery performance and response to problems,
- Audits of supplier management systems and evaluation of their potential capability to provide the required products efficiently and within schedule,
- Checking references for customer satisfaction,
- Financial assessment to assure the viability of the supplier throughout the intended period of supply,

- Service and support capability,

- Logistic capability including locations and resources."

In addition the new standard states in a separate section an added supplier management criterion:

2. Analysis of data:

The organization shall determine, collect and analyze appropriate data to determine the suitability and effectiveness of the quality management system and to evaluate where improvements of the quality management system can be made. This shall include data generated by monitoring and measuring and other relevant sources. The analysis of data shall provide information relating to:

a) Customer satisfaction;

b) Conformance to product requirements;

c) Characteristics and trends of processes and products including opportunities for preventive action; and

d) Suppliers.

In order to stay compliant with the new ISO 9001:2000, has to be performed some sort of data analysis on suppliers. The standard gives no suggestions with respect to what to monitor or measure since it is not prescriptive.

On the draft ISO 9004, it can lead to doing analysis of problems, improvements, and supplier contributions and so on with little effort on our part to dig out what we could include in the measurement system for supplier performance. It does not yet suggest any measures of total supplier performance or supplier rating systems.

It may be suggested by the tone in 9004 that, at a minimum, you should look to tracking supplier problems or deviations. In addition, delivery on time is always important data to have on hand. Beyond that, a supplier performance rating system can be applied as wish.

The current supplier selection process is compared with this standard in these organizations.

2.5. Supply Chain Softwares

There are many software packages in the market useful for the supplier selection process, such as, Expert Choice (McLean, VA: Decision Support Software, Inc., 1983) which is a multi-objective decision support tool based on the Analytical Hierarchical Process (AHP); a method described earlier.

Another software package is SAP R/3 3.0 (Whang, Gilland & Lee,1995) which implements vendor evaluation as a part of the Material Management Module (MM). The scoring plan used by MM's Vendor Evaluation System is the weighted point method. The SAP Standard System offers the buying organization a scoring range from 1 to 100 points, which is used to measure the performance of a vendor on the basis of five main criteria. The organization can then determine and compare the performance of its vendors by reference to their overall scores. The main criteria available in the standard system are: price, quality, delivery, general service/support, and external service. The first four criteria serve as a basis for the evaluation of vendors from whom the buying organization procures materials. The fifth criterion serves as a basis for the evaluation of vendors the buying organization uses as external service providers. Other criteria can be defined as required and different

weights can be assigned to the individual criteria. The vendor's overall score is computed taking into account the weighted scores awarded for each of the main criteria. The Vendor Evaluation System ensures that evaluation of vendors is objective, since all vendors are assessed according to uniform criteria and the scores are computed automatically, because scores are calculated by the system on the basis of existing data. In this way, subjective impressions and judgments can be largely avoided.

Oracle is another software package suitable for this purpose, specially the procurement section. Using Oracle Procurement, companies can identify savings opportunities with spend analysis; source, negotiate, and collaborate more effectively with suppliers; automate employee requisitioning and receiving, while lowering costs with streamlined supplier collaboration.

The Ariba Supplier Management Solution is another package that effectively supports supplier discovery, evaluation, and relationship management for deeper, more sustainable spend reductions. Automated catalog management, order routing, invoice reconciliation, supplier communications dramatically reduce cycle times and increase efficiency throughout the spend lifecycle. Existing transactions are continually updated, giving buyers and suppliers extensive visibility from order through shipment. Electronic communication capabilities allow buyers and suppliers to collaborate online in real time ensure efficient and profitable relationships with key suppliers.

Another software is the PeopleSoft Strategic Sourcing, a key component of the PeopleSoft 8 Supplier Relationship Management (SRM) solution, is a

comprehensive, internet-based solution that harnesses multiple bidding formats and performance analysis to deliver significant value to the organization, making sourcing truly strategic. Strategic Sourcing enables the business to select the best suppliers and negotiate strong sourcing agreements for goods and services. An organization can optimize its sourcing process using three high-level components within PeopleSoft Strategic Sourcing. First, create the buying event by determining the type of sourcing event (auction or formal RFx, for example), selecting suppliers for participation, and defining the criteria for evaluating supplier responses. Second, invite suppliers to register, receive event details, and provide a response to the sourcing event. Finally, use event analysis to easily determine the optimal supplier or suppliers for each event. With Strategic Sourcing, a business can customize its sourcing process to fit the company's needs. Whether a long-term contract with a key strategic supplier is desired or simply wants to drive down the price of a commodity spot-buy through a public auction.

Another software is the J.D. Edwards Procurement Management which facilitates supplier relationship management with integration of all purchasing activities, from replenishing strategic components to subcontracting outside services, to buying spare parts and operating supplies. The company gains end-to-end visibility of the procurement process and unparalleled flexibility to define procurement order types and workflows that fit your business requirements. For items that do not require a bid, automatic purchase order generation saves substantial time. All relevant information is available online to validate item status and make necessary changes to quantities, dates, or suppliers.

When items must go out for bid, Procurement Management streamlines the process. The manager has the capability to: combine requisitioned items on a single request for quote; view supplier performance ratings for rapid selection of those eligible to receive bid opportunities; print quote requests for submission to preferred suppliers and track status of open quotes and bids to a particular supplier, account, or buyer for targeted procurement decisions.

With the Baan solutions for Supplier Relationship Management (SRM), businesses can: analyze their spend and supply base as well as their product lifecycle and production needs; plan commodity, procurement and supplier management strategies; source raw materials, components, goods, services and capital equipment with an emphasis on obtaining best total cost; procure items from negotiated contracts to sustain savings; measure supplier performance and contract compliance while tracking savings and facilitate the execution of traditional purchases to increase supply chain agility at reduced cost.

As a comparative analysis of these models, Table 2.21 is presented. This table summarizes all of the previous software packages, presenting their target clients, advantages and disadvantages (Information System, 2001).

Table 2.21: Comparison of the software packages

Software Package	Target	Pros	Cons
Expert Choice	▪ Individuals ▪ Organizations	▪ More justifiable decisions ▪ Strategic alignment ▪ A structured decision-making approach ▪ Simple, easy- to-use interface	▪ Inconsistency on the AHP method
SAP	▪ Clients are big international companies	▪ The world's leading vendor of ERP systems ▪ Integration with standard PC applications. Easy interaction with o Excel o Word o Access	▪ Harder to learn than other ERP solutions
Oracle	▪ Large Enterprises	▪ Advanced capabilities of relational database design	▪ Has prioritized marketing rather than functionality or value for the money
Ariba	▪ Large Enterprises	▪ Integrates the company's e-procurement, dynamic sourcing, and strategic sourcing technologies to target the corporate spend	▪ Late in delivering an integrated e-procurement and e-sourcing platform
PeopleSoft	▪ US market	▪ Well-developed modules in o Manufacturing o Distribution o Financials	▪ Not a complete ERP vendor ▪ Too US-centric to make a serious challenge to the market
J. D. Edwards	▪ Mid-size corporations	▪ Flexibility ▪ Functionality ▪ Scalability	▪ Inconsistency for decision making
Baan	▪ Electronics ▪ Defense ▪ Aerospace	▪ Concentrates on manufacturing and logistic systems	▪ Difficulty to isolate where a problem is

Summarizing, Expert Choice is an easy to use software for the supplier selection process, however the major drawback of this software is the same showed

by the AHP, where there is inconsistency in the methods. The SAP is the world's leading vendor of Enterprise Resource Planning (ERP) systems due to its versatility and easy integration with companies' applications. Although, is harder to learn than other ERP softwares available in the market. Additionally, Oracle and Ariba have ERP advanced capabilities, opposite to PeopleSoft which is not a complete ERP vendor. Also, J. D. Edwards is a flexible and functional software package but it can bring inconsistency on decision making. Finally, Baan mainly focus on logistic systems. It presents major difficulty in the isolation of a problem.

In conclusion, these software packages are employed by many organizations which aimed to record the performance of vendor's transactions in an objective manner. Also, none of the softwares presented in this chapter are currently used by the analyzed organizations.

2.6. Concluding Remarks

In conclusion, focusing on selecting only the best suppliers possible will make a major contribution to the competitiveness of the entire organization. This main task requires careful evaluation, selection, and continuous measurement of the suppliers that provide the goods and services that help satisfy the needs of an organization's final customers.

In other words, once a supplier is selected, the focus must shift from supplier evaluation to the continuous measurement of supplier performance. An organization must have the tools to measure, manage, and develop the performance of its supply base. Supplier performance measurement includes the methods and systems to collect and provide information to measure, rate, or rank supplier performance on a

continuous basis. Supplier performance measurement differs from the process used to initially evaluate and select supplier, given that is a continuous process.

In addition, the literature review described earlier presents several mathematical methods for the supplier selection process, however after contacting the authors, they have no evidence that these processes are currently been employed by organizations. For that reason, the aim of this research is to identify the procedures actually used by organizations in the vendor selection process and to recognize the key metrics used in this process.

The next chapter presents the methodology of this research using a multiple exploratory case study approach in the companies studied.

CHAPTER III

METHODOLOGY

3.1. Introduction

There is no best way to evaluate and select suppliers, that's why organizations use a variety of different approaches, implementing the one that suits best depending on the company's particular requirements.

This research is based on a comparative evaluation of supplier selection processes in different corporate environments using a multiple exploratory case study approach.

This section is organized in the following order. First, the case study approach is introduced, explaining the basis for choosing this research methodology and the study setting. Then, the four-stage procedure of the case study approach is presented.

3.2. Case Study Approach Overview

Case study research is a traditional approach to the study of topics in social science and management. Case study is an ideal methodology when a holistic, in-depth investigation is needed (Feagin, Orum, and Sjoberg, 1991).

Bell (1992) states that case study research operates much in the same way as all other research: "evidence is collected systematically, the relationship between variables is studied and the study is methodically planned".

The case study approach allows a picture or model to be built up that illustrates relationships and patterns of interaction between variables. Typically, the use of observation and interviews are employed for data collection. However, no

method is excluded and the methods used for collecting information are chosen with regard to the suitability of the task (Bell, 1992).

Exploratory cases are considered as a prelude to social research (Yin, 1994) and are implemented when there is little or no existing theory that can be used to develop or test hypothesis. The purpose is to do an in-depth exploration of the territory, to identify and describe the phenomena, or to identify the key concepts. This type of detailed inquiry is often part of a qualitative research design or, at a minimum, requires the use of qualitative data.

Multiple-case studies follow replication logic. Multiple cases therefore serve to strengthen the results by replicating the pattern matching, thus increasing the level of confidence in the robustness of the theory. Each individual case study consists of a "whole" study, in which facts are gathered from various sources and conclusions are drawn on these facts.

3.3. Reasons for Conducting a Case Study

Researchers have identified several reasons for us to conduct a case study. These include:

1. The exploration of a question, program, population, issue or concern in order to determine appropriate research questions to facilitate future research.
2. The explanation of linkages between causes and effects.
3. The description of the real-life context in which an intervention has occurred.
4. The description of the intervention itself.

5. The exploration of those situations in which the intervention being evaluated has no clear set of outcomes.

As for the case studies themselves, they have become a staple source of valuable information to other researchers and students alike. In fact, the use of such case studies are so widely regarded, they have become an integral part of the education system in a variety of disciplines, including business, law, medicine, technical and philosophical courses. On top of the information they provide, they are also useful in education as the practice of reading such cases, analyzing them and coming up with your own interpretation of the results is an excellent way to develop the necessary critical thinking skills. These are skills that can only come through such hands-on practical studies, and cannot be taught in a normal classroom environment.

There are a variety of benefits to conducting a case study approach to research, especially in comparison with other methodologies. One such benefit is that the information provided is usually more concrete and contextual, specifically due to the in depth analysis it offers of the case being studied. Some may consider the body of literature in case study research to be primitive and limited in comparison to that of experimental or quasi-experimental research. However, the requirements and inflexibility of the latter forms of research sometimes make case studies the only viable alternative, or an even better option. For example, this methodology is better than a purely quantitative technique of analysis, which may obscure some of the important information being sought, such as in trying to assess the effectiveness of educational initiatives.

The case study methodology also has another advantage over other quantitative methods, in that it is able to provide change data that is not yet available, or not measurable, quantitatively, thus providing an elaboration for existing quantitative data or as additional complementary data. Researchers are also able to use this method to engage a wide range of audiences in data gatherings and findings, as well as to employ a host of different approaches to gathering the information they desire while conducting the case study. Finally, one of the biggest advantages is the ability to use the results of the case study as a springboard for framing quantitative questions, which can then be analyzed in greater depth in future analysis.

This study aims to finding the relationship with the corporate environments and the supplier selection processes since there is no evidence in the literature of this particular relationship. The nature of this research required a methodology that could be flexible to allow open questions to recollect information since the organizations under study have many different settings.

This study considers a research methodology based on a multiple exploratory case study approach since it allows a picture of the supplier selection processes on different corporate environments to be built up that illustrates relationships and patterns of interaction between supplier's performance metrics and quality systems. Therefore, this methodology is suitable for these purposes since plenty qualitative information is described and, typically, interviews and questionnaires are employed as data collection tools (Bell, 1992).

3.4. Study Setting

This investigation focuses on the selection and evaluation of suppliers. At first, an invitation to participate in this field study was made to nine manufacturing organizations of different industry sectors throughout Puerto Rico and USA. Then, the invitational letter sent to these companies (Appendix B), was followed up by telephone calls regarding inquiring about their willingness to participate in this project. Finally, three companies were chosen as part of this research, and these were a pharmaceutical, an agricultural equipment company, and an injection molding organization.

These three organizations were chosen since they provide particular corporate environments and this may influence their supplier selection process across and within companies. The particular settings of these companies are the following: the first organization under study is a manufacturing worldwide corporation. The second one is a particular subsidiary of a pharmaceutical corporation. The last one is local manufacturing company of injection molding.

3.5. Case Study Methodology

Before continuing, it will help to clearly list down the steps to be taken in conducting a case study methodology. These steps are as follows Yin (1994):

1. Design the case study protocol: The protocol should include an overview of the case study project (objectives, issues), field procedures (data sources), case study questions and a guide for the case study report.

2. Conduct the case study

   a. Prepare for data collection

   The data used in this research are mainly collected through different sources such as: semi-structured face-to-face interviews, questionnaires, phone interviews, organization's written procedures, web sites, onsite visits, and e-mail correspondence.

   b. Distribute questionnaire (Appendix A)

   The questionnaire developed for this investigation is administered to purchasing managers and planner buyers on the studied organizations. This questionnaire addresses the following issues:

   - Company's sourcing strategy (Monczka, Trent and Handfield, 2001):
     - Single versus multiple supply sources
     - Buy directly from the manufacturer or through a distributor
     - Short-term versus long-term purchase contracts
     - Developing a close working relationship versus traditional purchasing
     - Influences of the purchase such as social, political and environmental concerns
   - Geographical location of sources
   - Supplier selection process
   - Sources of information about suppliers
   - Forms of negotiations with final suppliers

- Supplier selection working teams
- Evaluation criteria
- Variation of the evaluation measures depending on the product
- Personnel in charge of the supplier selection process
- Measurement of the evaluation criteria
- Supplier evaluation categories
- Supplier communication relations
- Supplier summary reports
- Improved aspects since the implementation of the procedure.

In addition, in this study the ISO 9000 standards are used as a supplier evaluation system source for evaluating the issues involving the supplier selection process. This quality system was chosen as a structure for comparison because is recognized as a required quality standard in many parts of the global marketplace. Besides, the three companies under study are either ISO 9000 certified or structured therefore comparison can be established by the their vendor selection processes and the key metrics used in this process, with these quality standards.

The ISO 9000 issues are acquired from the 7.4.3 clauses which are summarized as follows:

- The establishment of criteria for selection of the suppliers. These processes may include:
    - Evaluation of relevant experience,
    - Review of product quality, price, delivery performance and response to problems,

- Audits of supplier management systems and evaluation of their potential capability to provide the required products efficiently and within schedule,
- Checking references for customer satisfaction,
- Financial assessment to assure the viability of the supplier throughout the intended period of supply,
- Service and support capability,
- Logistic capability including locations and resources.

- Enclosure of records of evaluation against the supplier criteria.
- Approval requirements for product, procedures, process, facilities and equipment, along with qualification of supplier personnel.

c. Conduct interviews.

The interviews were accomplished by visiting the purchasing managers and planner buyers of these companies and completing the questionnaires. The interview protocol used in this study is the following: at the beginning of each interview I will request the company's profile. Next, the established questions were asked and when it was necessary, additional information was required along the interview. Finally, when it was possible, examples of supplier evaluations ware requested to these companies.

3. Analyze the case study evidence.

"Data analysis consists of examining, categorizing, tabulating, or otherwise recombining the evidence to address the initial propositions of a study" (Yin

1994). In this case, the study is conducted to answer the following research questions:

1) Do the key performance measures of the supplier selection processes vary depending on the corporate environment?

2) Do the supplier selection processes of the organizations follow a reliable set of quality standards, as ISO 9000 requires?

3) Are the theoretical methods suitable for the supplier selection process?

The across cases analysis is the main tool used to evaluate and compare the collected information of the three case studies.

4. The final step of the case study methodology is to develop conclusions, recommendations and implications based on the evidence.

3.6 Conclusions

This study aims to finding the relationship among corporate environments and the supplier selection processes since there is no evidence in the literature of this particular relationship. The nature of this research required a methodology that could be flexible to allow open questions to recollect information since the organizations under study have many different settings. The case study approach is suitable for this kind of situation.

The following chapter presents the three case studies. The format of these case studies is the overview, sourcing strategy, key metrics and the supplier selection process of each company. Also, some conclusions are made within and across companies. Finally, this section presents a comparison with ISO 9000 standards.

CHAPTER IV

CASE STUDIES

4.1 Introduction

The case study method emphasizes in-depth qualitative analysis and is useful for answering questions regarding what, why, and how. Further, the case study methodology provided an opportunity to explore issues of interest in greater detail and identify particular supplier selection processes. The following case studies are composed from several sources of evidence, and are included to provide specific information regarding the evaluation of supplier selection processes used in different corporate environments.

The particular settings of these companies are the following: the first organization studied is a worldwide manufacturing corporation: Deere and Company. The second one is a particular subsidiary of a pharmaceutical corporation: Baxter Transfusion Therapies, San Germán Division. The last one is a sole proprietorship local manufacturing company of injection molding: Techno Plastics Industries.

The data for Deere and Company's case study is mainly collected by phone interviews, organization's procedures via fax, web sites and e-mails. These sources are less personal because of the location factor of this company which is USA.

In the case of Baxter Transfusion Therapies, San Germán Division and Techno Plastics Industries, the information is collected through semi-structured face-to-face interviews, questionnaires, organization's evaluation procedures, web sites, onsite visits and, emails correspondence.

4.2 Case Studies

The following format is used to present these cases:

1. Overview of the company
2. Company's sourcing strategy
3. Description of the supplier selection process and evaluation criteria
4. Conclusions

Case A: Deere and Company

1. Overview

Deere and Company is one of the top industrial equipment manufacturers by sales (Hoover, 2003). In addition, is a worldwide corporation that does business in more than 160 countries and employs approximately 40,000 people worldwide. The headquarters of Deere and Company are located in Georgia, USA. It is one of the oldest industrial companies in the United States.

This company is guided today, as it has been since its beginning, by John Deere's original values of quality, innovation, integrity and commitment. One of the main efforts is to create shareholder value through the pursuit of continuous improvement and profitable growth.

This corporation comprises several relevant issues discussed next. First of all, this organization has a huge variety of products including four manufacturing divisions which are Agricultural Equipment - creating fine products for the farmsite; Commercial and Consumer Equipment - creating lawn and grounds care equipment for the homeowner, golf and turf professionals, and grounds care specialists;

Construction and Forestry Equipment - building products that help improve the forest; and finally, John Deere Power System - creating the engines and components that power their equipments and other products around the globe. This corporation has hundreds of different products among all divisions.

In addition, the worldwide net income was $13,947 millions in 2002. This corporation has sites in all the continents, its worldwide locations include North America, South America, the Caribbean, Europe, Africa, Near and Middle East, and Australia. Deere's major competitors are Caterpillar, CNH Global, and Mitsubishi.

Also, Deere and Company employs some regulations such as the ISO 9000 standards. Finally, some of the supply sources of this organization are experience, industry, sales representatives, and customer.

2. Company's sourcing strategy

Deere & Company has the strategy of using single sourcing and multiple sourcing for purchasing a specific component. Most of them are multiple sourcing, although the goal is try to reduce the number of suppliers. There is some sole sourcing for the indirect products and the commodities, this is because control and tracking issues. Most of Deere's suppliers are from the United States. Deere buys raw material directly from manufacturers not from distributors.

There is no specific criterion for the length of the purchasing contracts with the suppliers in this organization. Sometimes Supply Base managers for the different divisions make the decision to try to guarantee business to the supplier (usually 3 years) in exchange for % cost reduction every year and other negotiable items. On occasions the suppliers ask for the Long Term Agreement (LTA) contract, and Deere uses that as a negotiation tool. The suppliers sustain a very close relationship due to the continuous communication they maintain with monthly reports of supplier performance.

3. Supplier selection process:

Deere and Company has the policy of following a seven phases and steps process for strategic sourcing. The strategic sourcing process is described in more detail in Figure 4.1.

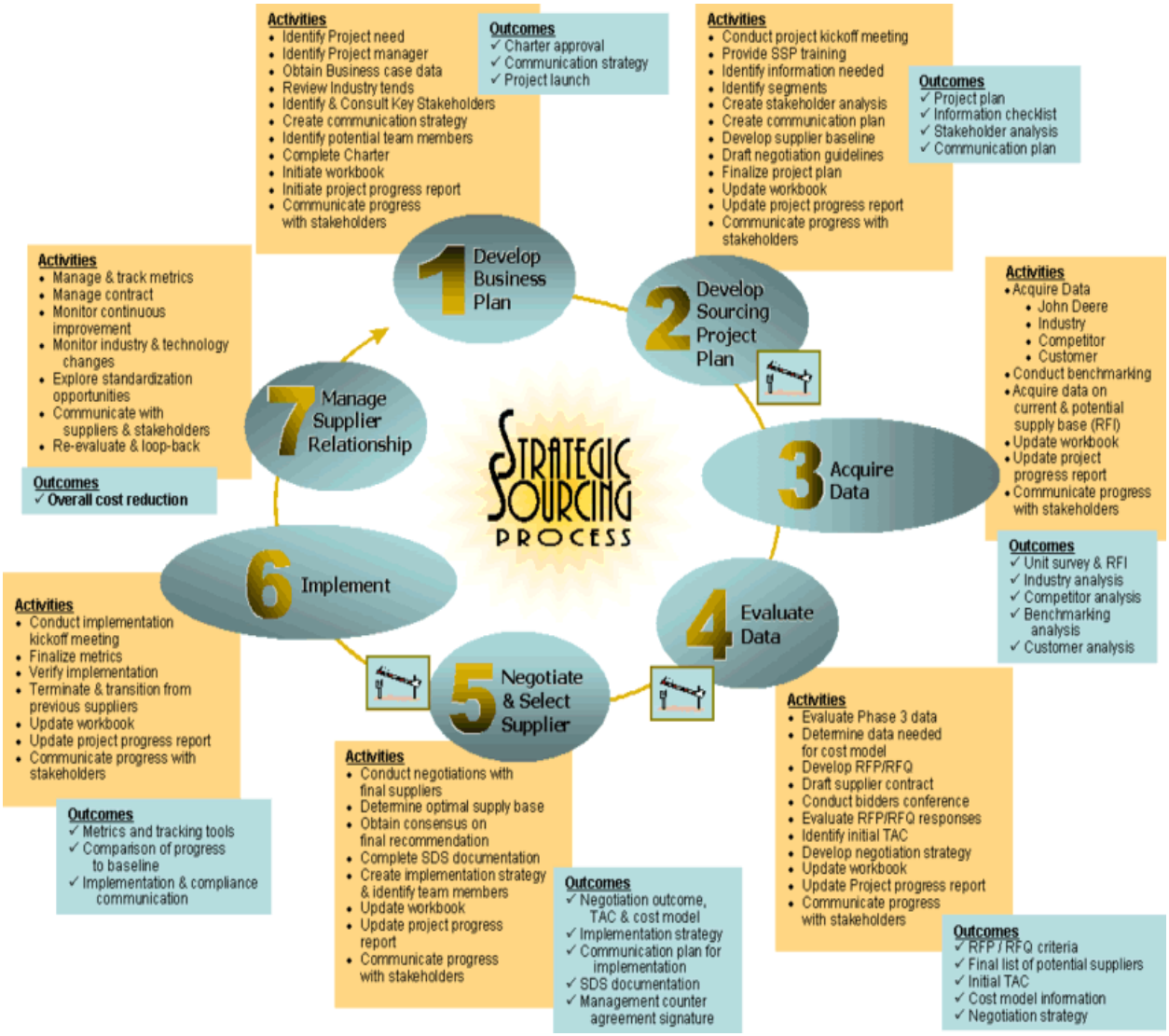

Figure 4.1 Deere and Company Strategic Sourcing Process

This method consists of seven phases and steps, which is responsibility of the general company supply management. The seven steps are summarized as follow: develop a business plan, develop sourcing project plan, acquire data, evaluate data, negotiate and select supplier, implement and the final step is to manage supplier relationship. These seven phases are explained in detail next.

Strategic Sourcing Process: Tools:

Phase I: Develop Business Plan

Objective

Develop and document the business case in sufficient detail to secure management approval of the Sourcing Project charter.

Definition

- Team uses information and analysis tools on current expenditures to identify the potential project benefits ,i.e. financial impact
- Investigative analysis is required during Phase I
    - What is required? / What are the current needs?
    - Who are the potential users (Units) of items / services (i.e., stakeholders)?
    - Are there potential costs or performance implications involved with using alternative suppliers?"

  - What are the opportunities when considering hidden costs and barriers to implementation?

- Stakeholders must be involved to insure buy-in.

  - Define what is currently being purchased to fulfill a need for whom
  - Include potential users of products or services
  - Clearly define the current situation to assess future opportunities

- Phase 1 includes the following key steps:

  - Identification of the Project Manager and team
  - Collection of high level data to support the business case (charter development)
  - Review of industry trends
  - Involvement of key stakeholders
  - Development of a communication strategy
  - Leadership approval to proceed with the project

- Phase 1 is complete with management support to proceed (approved charter)

Phase II: Develop Sourcing Project Plan

Objective

Develop the Strategic Sourcing Project Plan used by the team to monitor and assess project progress.

Definition

- Use of a project plan provides the team with specific checkpoints to monitor progress throughout the project
- To develop the project plan, the team must start to identify information that needs to be collected including
    - Existing data / information
    - Segmentation
    - More detailed stakeholder information
    - Supplier baseline data
- Phase 2 includes the following key steps:
    - Conduct the team's kick-off meeting
    - Provide Strategic Sourcing Training
    - Identify high-level data needed
    - Identify initial segments
    - Perform stakeholder analysis
    - Create communication plan
    - Develop supplier baseline
    - Draft initial negotiation ground rules and guidelines
    - Finalize project plan with specific assignments
- Phase 2 is complete with the approval of:

- Updated workbook
- Project plan
- Information needed checklist
- Stakeholder analysis and communication plan

Phase III: Acquire Data

Objective

Acquire data and complete research necessary to develop and refine initial sourcing hypotheses.

Definition

- The team concentrates its efforts on acquiring the data that will eventually lead to final supplier selection.
- Information is collected from various sources including Deere units, industry, competitors, customers, benchmarking, and current and potential supply base.
- Phase 3 includes the following steps:
    - Acquire John Deere data
    - Acquire Industry data (complete Industry Analysis)
    - Acquire competitive data
    - Acquire customer data
    - Conduct benchmarking activities
    - Acquire data on current and potential supply base Request for Information (RFI)

- Phase 3 is complete with the review and approval of:
    - Unit survey and RFI
    - Industry analysis
    - Competitor analysis
    - Benchmarking analysis
    - Customer analysis.

Phase IV: Evaluate Data

Objective

Evaluate data collected in previous phases to develop the key elements of a sourcing strategy. During the evaluation phase, the following become apparent:

- Risks
- Challenges
- Required actions
- Final list of potential suppliers.

Definition

- The team analyzes and evaluates the data collected in previous phases to determine:
    - Elements of a sourcing strategy
    - Challenges to accomplishing goals

  - Needs of units vs. enterprise
  - Barriers, risks, considerations affecting implementation
  - Action plans

- Phase 4 includes the following key steps:

  - Evaluate data collected in Phase 3
  - Determine data needed for cost model
  - Develop Request for Proposal (RFP) / Request for Quote (RFQ)
  - Draft supplier contract
  - Conduct a Bidder's Conference
  - Receive & evaluate RFP / RFQ responses
  - Identify transition costs, risk and initial Total Acquisition Cost (TAC)
  - Develop negotiation strategy

- Phase 4 is complete with the review and approval of:

  - RFP / RFQ evaluation criteria
  - Final list of potential suppliers
  - Initial Total Acquisition Cost (TAC) and Cost Model Information
  - Final negotiation strategy

Phase V: Negotiate and Select Supplier

Objective

Select supplier(s) based upon negotiations with the final list of potential suppliers developed in Phase 4. Directors and Management approve supplier selection before agreements / contracts are signed.

Definition

- The team focuses efforts on the negotiation process with the final top list of suppliers.
- Negotiation strategies are tested and fine-tuned early in this phase.
- Selection of an optimal supply base may include sourcing business to new suppliers or with current suppliers.
- An assessment of costs, benefits and risks are factored into the final selection.
- Supplier Development may be called into develop action plans needed to bring suppliers up to expected performance levels.
- Phase 5 includes the following key steps:
    - Conduct negotiations with final list of potential suppliers
    - Determine optimal supply base
    - Obtain team consensus on final recommendation
    - Complete Small Diverse Supplier SDS documentation (for SDS suppliers included in the negotiation process)

  - Create implementation strategy and identify potential implementation team members

- Phase 5 is completed with the approval of:

  - Final negotiations outcome, TAC and Cost Models
  - Implementation strategy with baseline unit information
  - Communication plan for implementation strategy
  - SDS website documentation
  - Leadership's decision to counter sign agreement(s) / contract(s)

Phase VI: Implement

Objective

Implement sourcing strategies developed and approved in the previous 5 phases. The implementation strategy identified in Phase 5 is solidified into specific plans to implement at all involved units/facilities.

Definition

- The implementation phase comprises a majority of the project's timeline.
- Phase 6 establishes the foundation for future savings and continuous improvement associated with the sourcing strategy.
- Metrics are developed to measure supplier compliance within the agreement
- The implementation team will also be responsible for overseeing the implementation at other units
- Phase 6 includes the following key steps:

- Conduct implementation team kickoff meeting
- Finalize metrics to measure agreed-to service levels
- Verify implementation at all units
- Terminate and transition from previous supplier relationships

- Phase 6 is complete with the review of:
  - Metrics - tracking tools
  - Implementation progress compared to baseline
  - Communication for implementation and compliance

Phase VII: Manage Supplier Relationship

Objective

Measure supplier performance and monitor Industry & Technology to assess opportunities for cost reduction, service improvements and standardization.

Definition

- Phase 7 continues throughout the life of the agreement and will be monitored at specific milestones.
- The establishment of metrics focused on continuous improvement insures that suppliers continue to meet expected performance levels and mutually agreed-to objectives.
- It is essential that team membership and reporting are focused and results-driven in order to obtain benefits outlined in the sourcing strategy.

- Significant changes within Deere or the industry may require strategy revision / re-evaluation. (Loop back to Phase 1 in the Strategic Sourcing Process.)
- Phase 7 includes the following key steps:
    - Measure and track metrics
    - Manage contract
    - Monitor continuous improvement
    - Monitor industry and technology changes
    - Explore standardization opportunities
    - Communicate with suppliers and stakeholder
    - Strategy re-evaluation and loop back to leadership
    - Unlike the previous 6 phases, Phase 7 is NOT completed with a gatekeeper review session since it involves the perpetual process of managing supplier relationships.

Using the strategic sourcing process has the potential to produce the following (Deere Enterprise Strategic Sourcing Process):

- Commodities and services are leveraged.
- Commodities are managed using achieving excellence process by a supply base manager.
- Focused group of leveraged suppliers delivering to units services that exceed expectations.

Furthermore, the strategic sourcing process is structured around ISO 9000 and thus many of the supplier selection clauses are part of this process.

Also, the selection criteria of these suppliers are based upon several factors including but not limited to:

- Consistent superior product and service
- Ease of billing and payment
- Effective methods of communication
- Quick conflict resolution
- Financial Stability
- Consistent cost-effective prices
- Little or no receiving issues
- Environmental Friendly
- Technological advances
- Reliable delivery schedules.

Also, for the evaluation process, this company has implemented the Achieving Excellence Program, which is a procedure aimed at developing relationships through a supplier evaluation process and promoting communication and continuous improvement throughout the entire product cycle. The achieving excellence web site is a tool used by suppliers and the buying organization's employees to aid in the communication process. Achieving Excellence (AE) is accessed though its intranet using Internet explorer or Netscape. In general, the mission of this program is to set

consistent performance standards, communicate results, demonstrate improvement, and recognize outstanding achievements.

The supplier performance, in this program, is to be measured in five AE criteria. These are Quality PPM (Parts Per Million), Delivery PPM, Wavelength, Technical and Cost Management. Suppliers are classified in categories according to their achievements in these aspects. The four categories are Partner, Key, Approved and Conditional. Tables 4.1 and 4.2 present the requirements of every supplier category on each one of the criteria.

Table 4.1 Quality and Delivery Requirements

	Quality	Delivery
Partner	≤ 500 PPM	≤ 15000 PPM
Key	≤ 1100 PPM	≤ 36000 PPM
Approved	≤ 2200 PPM	≤ 60000 PPM
Conditional	> 2200 PPM	> 60000 PPM

Table 4.2 Technical Support, Wavelength and Cost Management Requirements

	Technical Support, Wavelenght, and Cost Management
Partner	≥ 92 - 100%
Key	≥ 80 - 92%
Approved	≥ 70 - 80%
Conditional	< 70%

In addition, is important to notice how the final categorization of the supplier is made at Deere and Company. For example, if a given supplier is qualified on the five criteria as shown in Table 4.3, the supplier is categorized by the lowest level, therefore in this case the supplier is considered Approved.

Table 4.3 Deere and Company Categories Example

Criteria	Category
Quality	Key
Delivery	Approved
Technical Support	Partner
Wavelength/Relationship	Key
Cost Management	Approved

Supply Management is responsible of reviewing monthly supplier performance, resolve current supplier performance issues, and complete a minimum of one review per year per AE supplier. Suppliers are notified and encouraged to review changes (via online Supply Network) in status and trend on a monthly basis as an aid toward planning for continuous improvement. The information of supplier's performance is provided by the departments of Quality, Engineering, Purchasing, Materials and Manufacturing.

Some of the supplier summary reports used by this company are: Supplier performance summary, Quality nonconformance report, Delivery nonconformance report and Net cost reduction performance report.

Table 4.4 illustrates a more detailed criteria approach of this organization, presenting the weights aiming to reflect the relative importance of the category, the forms of measurement and the frequency of calculation of each rating.

Table 4.4 Deere & Company supplier assessment criteria

Category	Weight	How Measured	Frequency
1. Quality PPM	20%	(Quality Nonconformance)/ (Supplied Pieces) * 10^6	Periodically
2. Delivery PPM	20%	(Delivery Nonconformance)/ (Recieved Pieces) * 10^6	Periodically
3. Technical Support	20%	Accumulated weighted score/ maximum weighted score*100	Annually
Product Technology and Innovation		(5-point scale, 5= Max)	
Product Delivery Process (where applicable)		(5-point scale)	
Manufacturing Process		(5-point scale)	
Supplier's Manufacturing Cycle		(5-point scale)	
4. Wavelenght/Relationship Rating	20%	Accumulated weighted score/ maximum weighted score*100	Annually
Information Sharing		(5-point scale)	
Problem Resolution		(5-point scale)	
Responsiveness to Requests		(5-point scale)	
Business Relationship		(5-point scale)	
Alignment to Business Processes/Initiatives		(5-point scale)	
5. Cost Management	20%	Accumulated weighted score/ maximum weighted score*100	Annually
Cost Reduction Suggestions		(5-point scale)	
Net Cost Reduction Performance		(5-point scale)	
Cost Management Initiative		(5-point scale)	
Performance during Product Delivery Process		(5-point scale)	
Total	100%		

The scoring systems of Deere's supplier evaluation criteria use both objective and subjective measures. The objective criteria include Quality PPM and Delivery PPM, which are measured periodically in a year using specific formulas of supplier performance. The subjective criteria include Wavelength, Technical Support and Cost Management which all use the weighted method, a method found in the literature review for the supplier assessment process.

4. Conclusions

This corporation has a strategic sourcing process to select its suppliers, as a part of its supply management strategy, based on the ISO 9000 standards. In addition, this procedure is consistent with the step by step framework by Monczka presented in the literature review, including the evaluation of the supplier directly for the final selection and the continuous review of the supplier performance.

Deere's supplier assessment criteria are weighted equally to achieve excellence in supply chain performance. It is important to notice that one of the supplier performance criteria of the AE program is the Cost Management measure. The importance of this performance measure in this corporate environment could be to find ways to decrease costs of purchasing and therefore to have competitive price on Deere's products. Also, it is noticed that the weighted method, a theoretical method presented in the literature review, is employed as a scoring system for the subjective measures including wavelength (service criterion), technical support and cost management.

Furthermore, the achieving excellence web site is the software support of Deere and Company for the continuous evaluation of suppliers and the communication process. The sourcing strategy of this business includes single and multiple supply sources for the direct and indirect materials, respectively. The nature of this industry cannot have a single source for the purchase of all the direct materials, because there are a huge variety of purchased components bought to several

suppliers, even though the aim is to strive to reduce the number of suppliers to built stronger relationships with them.

Finally, to summarize, this manufacturing company has a specific corporate environment that includes an assembly organization in a highly competitive industry, all the supplier base responsibility relies on a structured Supply Management Division, its supplier sourcing strategy is mainly multiple supply sourcing due to the vast diversity of products and also, the geographic location of the suppliers are from the USA and International countries.

Case B: Baxter Transfusion Therapies Division:

1. Overview

Baxter International Inc. is one of the top medical equipment manufacturers by sales (Hoover, 2003). Baxter Healthcare Corporation is a worldwide health care company that operates in more than 110 countries at more than 250 facilities around the world with 48,000 employees. This company was founded on the year 1931 as the first manufacturer of commercially prepared intravenous solutions. This corporation provides through its subsidiaries, critical therapies for people with life-threatening conditions. The three key businesses of this corporation are Baxter's Bioscience, Medication Delivery and Renal Products and Services which are used to treat patients with some of the most challenging medical conditions including cancer, hemophilia, immune deficiencies, infectious diseases, kidney disease and trauma.

Baxter Transfusion Therapies Business is a leading provider of products and services for the collection, separation, storage and transfusion of blood and its components. Baxter's Transfusion Therapies Division provides a broad portfolio of products and technologies to serve the needs of blood centers, plasma centers, blood banks and transfusion services. This business is a leader in the field of transfusion medicine for over 40 years, and they continue to develop innovative technologies to enhance the safety and quality of transfusion products and to maximize donor comfort and safety. One of its manufacturing facilities is located in San Germán, Puerto Rico. The validation of this facility (FDA approval) was in 1994 and the manufacturing of the medical devices began in 1995 in a 103,000 sq ft plant. This facility has 580 employees and works three production shifts.

This organization comprises several relevant issues discussed next. First of all, the medical devices exclusively manufactured by this site are Amicus Disposable and Plasmacell Device Assembly. The Amicus Disposable is used to separate and collect platelets during the recollection of blood. This product has 250 components purchased from five intercompany suppliers, that is from other Baxter subsidiaries, and from seventeen external suppliers. And the Plasmacell Device Assembly is used to separate plasma during the recollection of blood. This product has 13 components purchased from seven suppliers.

In addition, the worldwide net sales were $8,110 millions in 2002. This unit has clients in North America, Europe, Japan, China, and India. Baxter's major competitors are Johnson and Johnson, GE Medical Systems, and Guidant Corporation. Also, some of the supply sources of this organization are experience, trade directories, and sales representatives.

Finally, this division is regulated by the FDA (Federal and Drug Administration) and TUV Quality Systems Assessment. The FDA is one of the most respected consumer protection agencies and its mission is to promote and protect the public health by helping safe and effective products reach the market in a timely way, and monitoring products for continued safety after they are in use. The FDA develops and implements national programs to protect the public health in the medical devices field. These programs are intended to assure the safety, effectiveness, and proper labeling of medical devices. These regulations establish that manufacturers of medical devices must consider when they design devices, or when they manufacture,

contract manufacture, remanufacture, process, repack, or relabel finished medical devices intended to be commercially distributed. Some of the FDA controls of the medical devices field are described next.

Manufacturers are required to have procedures to ensure all purchased or otherwise received product and services conform to their specified requirements. A lack of adequate control over purchases has resulted in a significant number of recalls due to component failures. FDA is not regulating component suppliers, therefore the purchasing control requirements should provide manufacturers with additional assurance that only acceptable components are used to manufacture finished devices. Some of the FDA's purchasing requirements of the medical devices organizations are:

a. Verify that the firm's written procedures include requirements, including quality requirements, that suppliers, contractors and consultants must meet.
b. Verify that the firm evaluates and selects potential suppliers, contractors and consultants on the basis of their ability to meet the specified requirements.
c. Verify that the type and extent of control needed over the product, suppliers, services, contractors and consultants has been defined and is based on the evaluation results.
d. Verify that there are records of acceptable suppliers, contractors and consultants.

e. Verify that the firm has written, approved, and specified requirements, including quality requirements, for purchased or otherwise received products and services.

Whenever possible, the approved purchasing documents should include an agreement that the suppliers, contractors and consultants will notify the manufacturer of any changes in the product or service. Manufacturers must evaluate these changes to determine whether they affect the quality of their finished devices.

The quality audit is the foundation of the quality assurance program. Furthermore, it is necessary to determine if the manufacturer has a written procedure for conducting quality audits and how often these audits are conducted. It is recommended that the time between audits not exceed a 12-month period. More frequent audits may be recommended if the firm has a serious Good Manufacturing Practices (GMP) problem.

The TUV Quality Systems Assessment is a private organization that helps companies achieve a certified quality system that is timely and cost effective (ISO9001: 2000). Also, this company has experienced professional auditors that can make registration attainable and a reality, like it was done for Baxter Transfusion Therapies. T.U.V. are the German initials of this “Third Party” company.

2. Company’s sourcing strategy

Baxter Transfusion Therapies Division of San Germán has the policy of single sourcing for a given item. This type of vendor is denominated key supplier, which is

the main supplier. There is also another category, backup supplier, which is a secondary supplier in case of a key supplier failure. This site has 25 to 30 suppliers, most of them from Puerto Rico.

The purchasing contracts in Baxter with the suppliers are made of periods from one to three years. The suppliers sustain a very close relationship due to the continuous communication they maintain with monthly reports of supplier performance. Monthly a Supplier Quality Index (SQI) report is made to Baxter's suppliers. Also, every trimester is described a performance report internally at Baxter.

3. Supplier selection process

Baxter Transfusion Therapies Division uses the Supplier Quality Index (SQI) for the supplier evaluation process. The purpose of this assessment is to establish a procedure for measuring and communicating raw material supplier performance and the process for the monthly supplier's meetings. This procedure applies to the San Germán plant.

The responsibility of this process relies on the departments of quality, engineering, purchasing and materials, which are in charge of measuring suppliers' performance every month and to provide this information to the Planner/Buyers. The Planner/Buyers are responsible of publishing on a monthly basis the supplier measurements results by issuing the SQI report to the external suppliers and to local and Divisional Purchasing. The final decision of the supplier's selection relies on the Headquarters based on local feedback.

Table 4.5 illustrates the weights, forms of measurement and frequency of calculation of each rating of the SQI report.

Table 4.5 Baxter supplier assessment criteria

Category	Weight	How Measured	Frequency
1. Quality	50%	Weighted scores	Monthly
Incoming/Manufacturing Results		30%	
Response to Quality Audit Observations		10%	
Response to Corrective Actions Requests		10%	
2. Delivery	40%	Weighted scores	Monthly
3. Service	10%	Weighted scores	Monthly
Proactive		0-10 pts	
Responsiveness		0-10 pts	
Extraordinary Arrangements		0-5 pts	
Accessible		0-5 pts	
Flexibility (Bonus criteria)		0-5 pts	
Total	100%		

The Quality indicator is based on in-coming/in-process acceptance on a lot by lot basis, prompt response to audit reports and, corrective and preventive actions requests (CAPA).

The Incoming/Manufacturing Results is based on a percent of accepted or rejected during the month. Includes rejects defected at the manufacturing area. This criterion is divided in three settings which are testing components, certifying components, and lot monitoring. Forty percent of all the inspected components are tested, this is a random inspection depending on the component specification. Sixty percent of the pieces are either certified or monitored. The certification consists of certifying the components if there is no problem with the supplier within a year, this is that no inspection is required. The certification can be done with all the

components with the exception of the chemical raw materials. During lot monitoring, one of every five lots is tested as long as there are ten consecutive lots without a problem. If there is a problem, all the lots are tested in incoming inspection.

Response to Quality Audit Observations are based on days elapsed for receiving a formal answer of the audit. Answer should be received in less than 30 calendar days by the Baxter Supplier Quality Engineer. Monthly status should be received for any pending audit item, if not received a penalty of 5% will be deducted from this item. Response to Corrective Actions Request are based on days elapsed for receiving a formal answer to corrective action requests. If answers are received in less than 30 calendar days by the Baxter CAPA Coordinator, no penalties will be taken. Monthly follow-up should be received by the CAPA Coordinator on any open issue, if not 5% penalty will be taken from this item. The penalty associated to CAPA's will be based on the number of CAPA's due from the total process.

The Delivery criterion is based on 100% receipt of the agreed upon purchase order (P. O.) line item quantity within +/- one (1) day of the agreed upon P. O. line item ship date.

The service rating is based on the following criteria:

- Proactive: Initiate communication on potential non-conformance. Early warning, written or verbal, on issues that might affect Quality and Delivery.
- Responsiveness: Quick response on requests such as, but not limited to missing documents, quotations, lead-time information, and non-conforming material return authorizations corrective actions.

- Extraordinary Arrangements: Urgent plant visits to address Quality issues; Follow through on special shipping instructions/requests.
- Accessible: Answer/return calls promptly, courteously.
- Flexibility: Positive response to out of lead time, re-schedule requests. Bonus criteria; will only work in supplier's favor.

The overall supplier score resulting from the sum of the lot quality, delivery and service scores is called the Supplier Quality Index (SQI). The SQI report applies to the raw material suppliers.

The minimum accepted rating of the SQI report of a given supplier is 90%. A supplier with less than this percentage is required to improve its performance.

An example of the SQI report used by this company is presented in Figure 4.2.

Company: _____

Date: _____

Quality Performance (50 % SQI)

Performance Due to Lots Inspected (30 % of Quality)

Lots Inspected	Lots Accepted	Percent Accepted	Rating Due to Lots Accepted	Total

Performance Due to Open Audit Observations or Monthly Status Report (10 % of Quality): _____

Performance Due to Open CAPA's or Monthly Status Report (10 % of Quality: _____

Total Quality = Performance	Rating Due to + Lots Accepted	Total Audit Initial Plan OR Total for Audit Monthly Status Report	Total for CAPA's Initial Plan OR Total for Audit Monthly Status Report

Delivery Performance (40 % SQI)

Performance Due to lots Inspected

Lots Requested	Lots Received on Time	Percent Accepted	Rating Due to Delivery	Total

Service Performance (10 % SQI)

Criteria	Points Awarded
1. Proactive Communication (10pts.)	
2. Responsiveness (10pts.)	
3. Extraordinary Arrangements (5pts.)	
4. Accessible/ Diligent (5pts.)	
5. Flexibility (5pts.) will only be in favor	
Total Points (30 pts.)	
Percent for Service (Points Obtained/30)*10%	

Total Supplier Quality Index: _____

Figure 4.2: Baxter's SQI Report

The scoring system of Baxter's supplier evaluation criteria uses both objective and subjective measures. The objective criteria include Quality and Delivery using specific formulas of supplier performance. The subjective criteria include Service and its correspondent subcriteria which all use the weighted method, a method found in the literature review for the supplier assessment process. The scores are of 10-point scale and 5-point scale where a score of 10 or 5, depending on the subcriteria, are the maximum values.

4. Conclusions

Baxter's supplier evaluations use a structured approach through the use of a survey as the general framework by Monczka presented in Chapter II section 2.1. Particularly, this unit developed an in-house procedure, the Supplier Quality Index (SQI), for the supplier evaluation process based on the ISO 9000 standards.

The main focus of this company is the quality of its components since it manufactures critical therapies for human life-threatening conditions and the patient's lives depend on its products and services. Also, delivery is a critical supplier's performance measure in Baxter Transfusion Therapies, since in the case of a delivery failure, this could result in a late end product to the final customer and this delay could be lethal for the client. Moreover, it is noticed that the weighted method, a theoretical method presented in the literature review, is employed as a scoring system for the subjective measure which is service. The price criterion does not appear to be a key performance measure to evaluate suppliers and this may be because people need medical attention regardless of economic conditions therefore, businesses in the medical equipment industry are not driven by the whims of consumers or interest rates (Hoover, 2003).

In addition, the AS400 Systems is the software support of this unit, however the Supplier Quality Index is calculated manually using Excel worksheets. Another issue is that the corporate environment of this organization demands strict quality regulations such as the FDA regulations and the ISO 9000 standards because of the nature of the products that this organization produces which are medical devices.

Finally, the sourcing strategy of this organization includes single raw material's supply sources. The nature of this industry seems to be single sourcing because the components used in their products are critical and the aim is to develop strong relationships with the supplier, perform audits to supplier's processes and certify all the purchased components.

Case C: Techno Plastics Industries:

1. Overview

Techno Plastics Industries is an injection molding organization founded in 1992 with 31,000 sq ft facility located in Añasco, Puerto Rico. Techno Plastics Industries, with more than 10 years of experience in mold making, also offers design, construction and repair of molds and tools services to its customers. The company has 109 employees and works three production shifts of eight hours ach. Techno Plastics Industries has perfected the manufacturing process to meet the requirements in the field of high precision molding. Techno Plastics Industries produces in its "class 100,000 clean rooms" (100,000 0.5 micron particles per cubic foot of atmosphere) high precision molded parts with emphasis on medical devices and items for the pharmaceutical industry. In addition, the company has the flexibility to mold parts for other types of enterprises, if the molds do not require the use of mold release agents.

It is important to mention that this company is a supplier of Baxter Transfusion Therapies, San Germán Division. In addition, Techno Plastics has seven clients including sectors such as image printing business, plasma cells, cardiovascular products, intra ocular lenses, relay business, surgical kits, and electromagnetic healing devices.

2. Company's sourcing strategy

The resin is the main raw material that Techno Plastics Industries buys from its suppliers. This organization has seven international suppliers of resin. Generally, this material is bought directly to the manufacturers. The purchase contracts are long

term agreement that range from periods of three to four years and thus, allowing a close working relationship with the suppliers. The organization is ISO 9000 structured.

Techno Plastics maintain continuous communications with its suppliers, and in case of poor performance, corrective actions are required. At this company, when improvement is not accomplished by a supplier, this supplier is changed; this has only happened in a few cases.

3. Supplier selection process:

Techno Plastics Industries does not currently has a supplier selection process because the suppliers of raw material are specified by the clients. This is due to the types of clients this company has, including big international FDA regulated clients, which previously designate the suppliers for its products.

However, this company employs an evaluation procedure report to assess its suppliers and is the main responsibility of the Quality department. The main criteria in this organization are quality, service and delivery. The scoring system of the evaluation report is very subjective and consist of a 2-point scale where 2= Excellent, 1=Regular, and N/A= not apply. The criteria used in this evaluation employ the weighted method in all of the characteristics of the procedure. Table 4.6 shows the aspects that compose this report with its respective weights.

Table 4.6: Techno-Plastics Quality System Evaluation

CHARACTERISTIC	SCORE (1-2)	WEIGHT	FINAL SCORE
Quality Manual		10	
Quality Policy		3	
Management Commitment		5	
Documents and Data Control		4	
Purchasing		3	
Product Identification and Tracking		3	
Process Control		9	
Reception, Inspection and Tests		3	
Inspection Control, Measures and Testing Equipments		4	
Not Conform Product Control		4	
Corrective and Preventive Actions		4	
Handling, Storage, Packing, Preservation and Delivery		2	
Quality Control Reports		3	
Internal Audits		4	
Training		3	
Services		2	
Statistical Techniques		3	
TOTAL			(140 max)

After the values in Table 4.6 are determined, the final scores are calculated. The highest qualification is given to suppliers whose total scores are between 120 and 140 points. If the scores are between 85 and 119 points, a minimum qualification is satisfied. Finally, if the supplier scores 84 or less, this is considered not favorable, and an improvement plan is required in order to qualify.

It is important to notice that this organization only employs the evaluation report previously presented, when the supplier is not ISO 9000 certified.

The core presented in Table 4.6 is explained later in more detail. The assurance of product quality is the main responsibility of the manufacturing personnel at the molding press. In addition "Quality Assurance", a special group of associates, confirms compliance with product specifications ("product quality").

Techno Plastics' quality control system is mainly based on a statistical in-process inspection. The inspectors use a dynamic approach in which patrol inspections are done at the operator's workstation. The product is immediately release or rejected at this point. Therefore, this feedback to the operator, who constantly verifies parts at the machine, allows him/her to take immediate corrective action.

Inspectors also make dimensional inspections at the beginning of each shift. The data collected are used to generate process control charts and process capability studies for specific characteristics as per customer request. The main quality aspects employed by this organization are:

- ISO 9000 Document Structure
- Medical Device Traceability

- Quality Manual
- Controlled Environment
- Process Capability Studies
- In-Process Monitoring (Cpk)

In addition to producing quality molded parts, Techno Plastics also offers Management services at no additional cost.

As an illustrative example of these services, following a customer's suggestion, the company initiated inventory management services, which resulted in a reduction of 66% of the customer's in-house inventory, thus freeing up warehouse space without affecting the production line and increasing the inventory turnover. All customers who have availed themselves of the Inventory Management Service have reported similar results.

The success of this project, a substantial reduction in inventory levels, relies on the delivery of quality parts in a consistent manner. Techno Plastics' manufacturing process and quality control assure consistency in this effort.

Another issue is that Techno Plastics Industries works with the latest technological equipment. The expertise of its staff is essential to the success of this company. The commitment to service and quality helps to distinguish Techno Plastics from other molding companies.

When a new product is developed at Techno Plastics, request for quotes (RFQ) are asked to several resins' suppliers and the price is discussed. In this case, the price

criterion is important, besides the other evaluation criteria, since these suppliers are selected directly by Techno Plastics; unlike the other cases explained earlier where the suppliers were specified by the clients. These suppliers give quotes with range of prices which differ depending on the purchased quantity.

4. Conclusions

Techno Plastics Industries is a sole proprietorship which actually is a supplier of Baxter's Transfusion Therapies of San Germán Division. Therefore, all the supplier's performance measures demanded by Baxter are fulfilled by Techno Plastics Industries. The specific performance measures include quality, delivery and service.

The main clients of Techno Plastics Industries are medical devices organizations, having very similar corporate environments. In this organization, the purchase of raw materials is specified by the clients since typically these are FDA regulated. Therefore, the suppliers are selected by the clients and not by Techno Plastics. These suppliers are mostly international. Therefore, the supplier evaluation approach used by Techno Plastics Industries does not follows all the steps presented by Monczka in the literature review. Techno Plastics' responsibility in this general framework is only step 7: "Review supplier performance continuously" using the evaluation report presented in Table 4.6. The other steps are responsibility of the clients. This evaluation report is only used on suppliers that are not ISO 9000 certified. The weighted method is the scoring system used by this procedure for all the characteristics which are very subjective.

This organization is not currently certified by any regulations, however is ISO 9000 structured, and thus the supplier evaluation procedure is based on these standards. Additionally, there is no software support at Techno Plastics Industries for the supplier evaluation process, therefore this report is filled manually with rating scores. The sourcing strategy of this organization includes single raw material's supply sources similar to Baxter Transfusion Therapies.

Summarizing, this organization does not have a formal tool to select suppliers. Although, Techno Plastics Industries is ISO 9000 structured and supplies FDA regulated companies which are very demanding.

4.3 Discussion of Results

Several conclusions can be made after analyzing the three case studies across companies. Table 4.7 presents the main issues considered in this analysis. These issues are the company's location, type of company, industry sector, type of products, supplier selection responsibility, supply sources, quantity and location of suppliers, supplier selection working teams, supplier selection criteria, supplier selection categories, software support, and ISO 9000 certification.

Table 4.7 Comparison across cases

	Deere and Company	**Baxter**	**Techno Plastics Industries**
Company's Location	Georgia, USA	San Germán, Puerto Rico	Añasco, Puerto Rico
Type of Company	Corporation	Subsidiary of Corporation	Sole Proprietorship
Industry Sector	Manufacturing (Assembly)	Pharmaceutical	Manufacturing (Injection Molding)
Type of Products	▪ Agricultural Equipment ▪ Commercial and Consumer Equipment ▪ Construction and Forestry Equipment ▪ Power System	▪ Medical Devices: Blood Transfusion Therapies	▪ Plastic Parts for electronic assembly

Table 4.7 (continued): Comparison across cases

	Deere and Company	**Baxter**	**Techno Plastics Industries**
Supplier Selection Responsibility	Supply Management	Headquarters with Local Feedback	Given by the client
Supply Sources	▪ Experience ▪ Sales Representative ▪ Trade Directories	▪ Experience ▪ Sales Representative ▪ Trade Directories	Given by the client
Number of raw material Suppliers	Hundreds	25-30 suppliers	7 suppliers
Geographic location of Suppliers	▪ USA ▪ International	▪ Puerto Rico ▪ USA	▪ International
Single Vs. Multiple supply sources	Multiple	Single	Single
Supplier Selection Working Teams	▪ Quality ▪ Engineering ▪ Purchasing ▪ Materials ▪ Manufacturing	▪ Quality ▪ Engineering ▪ Purchasing ▪ Materials	N/A
Supplier Selection Criteria	▪ Quality 20% ▪ Delivery 20% ▪ Wavelength 20% ▪ Tech. Support 20% ▪ Cost Mgt. 20%	▪ Quality 50% ▪ Delivery 40% ▪ Service 10%	▪ Quality 70% ▪ Delivery 10% ▪ Service 20%

4.7 (continued): Comparison across cases

	Deere and Company	**Baxter**	**Techno Plastics Industries**
Supplier Selection Categories	▪ Partner ▪ Key ▪ Approved ▪ Conditional	▪ Key ▪ Backup	▪ Single
Software Support	Achieving Excellence web site	AS400 System	N/A
ISO 9000 Certification	Certified	Certified	ISO 9000 structured

The main issues presented in Table 4.7 are discussed next.

1. Supplier Selection Responsibility

Primarily, in the responsibility of the supplier selection process issue, all of these companies differ. For instance, Deere and Company is a worldwide organization which has its own supply management division specially designed for handling all the aspects concerning the supplier selection and evaluation process. On the other hand, Baxter Transfusion Therapies Division also a worldwide organization, is specialized in medical devices and thus, the purchase of material is regulated by the FDA (Food and Drug Administration) and therefore, decisions in this organization are more centralized, headquarters are in charge of the responsibility of selecting new suppliers based on local feedback. Lastly, Techno-Plastics Industries is a local

organization that depends entirely of its client requirements, that's why it has limited responsibility in the supplier selection process.

2. Supplier Selection Criteria

Another issue under study is the supplier selection criteria. In the three cases examined there are several criteria in which the suppliers are evaluated. All the companies include quality and delivery as important criteria. The quality criterion is important because of the market requirements while delivery is a key criterion to ensure short lead times.

In John Deere's case, the supplier assessment criteria are weighted equally as presented in Table 4.4, to achieve excellence in supply chain performance. One of the reasons that the five criteria: Quality, Delivery, Wavelength, Technical Management and Cost Management are equally important could be because this is a manufacturing company, and thus, the specific assembly nature and the market of this organization has the tendency to consider all factors significant, unlike others businesses types such as the food and pharmaceutical sectors which the core criterion is quality above all. John Deere Green is recognized worldwide by the slogan "Nothing runs like a Deere", as a reliable and quality product. This is the strength of this company, the characteristic that distinguishes it from the competition because when a client buys a Deere's product, they pay for a premium one and the value last forever.

In the case of Baxter Transfusion Therapies Division, the higher weight in the supplier selection criteria is given to quality, with a 50 % of importance. This is due to the nature of this business which is a medical devices organization and the strict requirements that these products demand. Quality is the main focus of Baxter

Transfusion Therapies Division because this company produces critical therapies for human life-threatening conditions and the patient's lives depend on its products and services. Also, delivery is a critical supplier's performance measure in the pharmaceutical industry, since in the case of a delivery failure, this could result in a late end product to the final customer and this delay could be lethal for the client. For this reason, is very important in Baxter the on time delivery of the suppliers, having this criterion a weight of 40% of importance as shown in the SQI report.

In the Technoplastics case study, the supplier assessment criteria such as quality, service and delivery are considered important, but specifically all details concerning with the supplier selection process are given by the client.

In conclusion, quality, delivery and service are the main supplier assessment criteria of the studied organizations. However, Deere and Company has two additional evaluation criteria significant in the manufacturing assembly industry which are Technical Support, for the continuous maintenance of the supplied components, and Cost Management to find ways to decrease costs of purchasing and therefore to have competitive price on Deere's products.

3. Supplier Selection Categories

The next issue in this analysis is the supplier selection categories. John Deere is a huge manufacturing organization, and the materials purchased by this company are produced by numerous certified suppliers, reason why they have a greater range of selection of vendors and therefore these suppliers can be classified in categories according to their achievements in each one of the supplier selection criteria, explained earlier. These categories are presented in Table 5.1.

On the other hand, Baxter Transfusion Therapies Division is more restricted since it is a medical devices company. Its materials are more critical, and its certified suppliers have to be approved by the FDA and thus reducing significantly the range of selection of the vendors. In this case, there are two categories of suppliers, the key supplier and the backup, if the key supplier fails. Lastly, Technoplastics is a single sourcing organization since they place all purchasing orders, for a given type of resin, with one supplier, which is provided by the client.

The three organizations under study have different and similar ways to measure their supplier selection criteria. For example, the supplier's quality in Deere and Company is measured with the total number of supplied pieces that were rejected during inspection. In the same way, at Baxter Transfusion Therapies Division, one of the subcriteria of quality is the Incoming/Manufacturing Results which is based on a percent of accepted or rejected during the month; including rejects defected at the manufacturing area. In addition, Techno Plastics' quality control system is mainly based on a statistical in-process inspection.

In addition, the delivery criterion in Deere and Company is calculated by the ratio of Delivery Nonconformance (pieces not delivered within specified delivery window) and Received Pieces (total pieces received by unit) during a period of time. The lower the value of delivery, the better the performance. In a similar way at Baxter, the delivery criterion is based on 100% receipt of the agreed upon purchase order (P. O.) line item quantity within +/- one (1) day of the agreed upon P. O. line item ship date. Additionally, at Techno Plastics Industries the delivery criterion is

assessed by identifying a system to protect the raw material during and after the delivery.

The service criterion at Deere and Company is the wavelength/relationship rating which is a composite analysis of the supplier's initiative, attitude, responsiveness, attention to detail, and communication performance with a unit. At Baxter San Germán Division, the service rating is based on if the supplier is proactive, the supplier's responsiveness, extraordinary arrangements, accessibility and flexibility of the suppliers. At Techno Plastics Industries, the service criterion is based on the management commitment of the suppliers, training and documentation of the supplier's services.

Aside from these criteria, Deere and Company has two additional supplier's performance metrics which are Technical Support and Cost Management. The Technical Support is required since in this type of industry the innovation of technology is very important. Also, the Cost Reduction opportunities suggested by the suppliers are very important since this is a very competitive environment.

4. Supplier Selection Working Teams

Since Deere and Company is a worldwide corporation with a structured supply management division, the departments of quality, engineering, purchasing, materials and manufacturing are all involved with the supplier assessment process. The reason is because these departments are implicated in one way or another with this process, providing information to assess suppliers. At Baxter Transfusions Therapies, a similar situation is developed since the departments of quality, engineering, purchasing and materials are involved in meetings and they are in charge

of measuring suppliers' performance every month and to providing this information to the Planner/Buyers. Techno Plastics Industries does not currently has a supplier selection process because the suppliers of raw material are specified by the clients. However, this company employs an evaluation procedure report to assess its suppliers. This is responsibility of the Quality department.

5. Software Support

At Deere and Company, there is a structured software for the supplier assessment process, the achieving excellence web site is a tool used by suppliers and the buying organization's employees to aid in the communication process. Achieving Excellence (AE) is accessed though its intranet using Internet explorer or Netscape. At Baxter Transfusion Therapies Division, there is no formal software for the supplier evaluation process; the SQI report is calculated manually using Excel worksheets. Similarly, at Techno Plastics Industries the supplier evaluation procedure report is filled manually with rating scores.

4.4 Comparison with ISO 9000 Standards

As discussed earlier, Deere and Company and Baxter Transfusion Therapies Division are ISO 9000 certified and Techno Plastics Industries is ISO 9000 structured. Table 4.8 compares the ISO 9000 supplier selection clauses with the current supplier selection process in the three organizations examined in this study. The check mark specifies which clauses are considered in each company.

Table 4.8: Comparison of ISO-9000 vs. supplier selection processes across cases

ISO-9000 Standards	Deere and Company	Baxter	Techno-Plastics
Establishment of supplier selection criteria	✓	✓	✓
Documentation of supplier evaluation	✓	✓	✓
Review of product supplier's quality, price, delivery performance and response to problem	✓	✓	✓
Audits of supplier management systems	✓	✓	✓
Checking references for customer satisfaction	✓	✓	✓
Financial assessment to assure the viability of the supplier throughout the intended period of supply	✓	✓	✓
Service and support capability	✓	✓	✓

The supplier selection clauses presented on Table 4.8 and how they are pursued by each one of the organizations are described next.

4.4.1 Establishment of supplier selection criteria

Purchasers usually evaluate potential suppliers across multiple categories using their own selection criteria with assigned weights. According to the ISO-9000 standards, an organization must have clearly defined its supplier selection criteria.

In Deere and Company the supplier selection criteria and its acceptance levels of performance are clearly established. As presented in section 4, the criteria in this company are Quality, Delivery, Wavelength, Technical and Cost Management and each of them has its minimum performance requirements. Also, this chapter shows that all five criteria are equally important to this company.

In addition, Baxter Transfusion Therapies Division has identified its supplier selection criteria which are Quality, Delivery and Service. These criteria are also divided in sub-criteria which are presented on the Baxter's Case Study.

Finally, Techno Plastics Industries for the supplier assessment process uses several metrics which can be classified as Quality, Service and Delivery.

4.4.2 Documentation of supplier evaluation

Organizations that are successful over time recognize the need for continuous improvement of their operations. Performance measurement provides a continuing base for evaluating progress. The importance of documentation is because purchasing operations reports communicate key performance measures to purchasing managers and senior management to evaluate the performance of the supply function, providing

comparisons between current period operations with similar figures over previous periods and with budgeted or forecasted performance levels.

In the case of Deere and Company, this organization has implemented the Achieving Excellence Program, which is a procedure aimed at developing relationships through a supplier evaluation process and promoting communication and continuous improvement throughout the entire product cycle. The documentation stage is accomplished by several suppliers' summary reports which are: Supplier performance summary, Quality nonconformance report, Delivery nonconformance report and Net cost reduction performance report.

In the case of Baxter Transfusion Therapies Division, the suppliers sustain a very close relationship due to the continuous communication they maintain with monthly reports of supplier performance. Monthly a SQI report is made to Baxter's suppliers. Also, every trimester is described a performance report within Baxter.

As a final point, Techno Plastics Industries uses an evaluation procedure report to qualify its suppliers. This documentation, which is ISO 9000 structured, is based on issues such as Quality Policy, Management Commitment, Purchasing, Internal Audits, Services, among others.

4.4.3 Review of product supplier's quality, price, delivery performance and response to problem

This section is very similar to the supplier evaluation explained previously on section 4.4.2. except for the new topic that is the response to problem issue that are completed by corrective actions which are implementations of effective solutions that result in the elimination of identified product, service and process problems.

This issue is assessed by Deere and Company given that the Wavelength/ Relationship Rating analyses the supplier's performance using several criteria and one of them is the Problem Resolution matter in which suppliers demonstrates ability to be proactive in problem resolution with implemented corrective action. This includes timeliness and accountability of determining the root cause of the problem and the degree of Deere assistance required to achieve closure with the appropriate corrective action.

In the case of Baxter Transfusion Therapies Division, within its Quality criteria there are the corrective and preventive actions (CAPA) issue, which is measured on days elapsed for receiving a formal answer to corrective actions requests.

Techno Plastics Industries includes, in its evaluation procedure to qualify suppliers, the corrective and preventive actions topic. This topic includes issues such as: If the supplier has the procedure to document and implement the corrective actions of no conformity process and product. In addition, the corrective actions comprise the description, preventive recommendations, cause and effect analysis, no conformity analysis, client's complaints analysis, and effective monitoring of

corrective actions. Finally, an additional aspect is: If the preventive actions have the necessary controls to guarantee that inconformity won't take place again.

4.4.4 Audits of supplier management systems

In a supplier audit, the buying organization establishes the criteria it wants to verify that the supplier meets. Some of the criteria should be standard for all suppliers of the organization, while others are more commodity or industry specific.

It is important for a buyer to evaluate a supplier's management capability since management runs the business and makes the decisions that affect the future competitiveness of the supplier.

Deere and Company has implemented the Achieving Excellence Program, which is a procedure aimed at developing relationships through a supplier evaluation process and promoting communication and continuous improvement throughout the entire product cycle. In general, the mission of this program is to set consistent performance standards, communicate results, demonstrate improvement, and recognize outstanding achievements.

In the case of Baxter Transfusion Therapies Division, within the Quality criteria is the Response to Quality Audit Observations which are based on days elapsed for receiving a formal answer for an audit. This is done on a monthly basis.

Techno Plastics Industries performs audits to selected raw material suppliers. This procedure has to fulfill the specifications and requirements of its clients. These audits are completed to the suppliers that are not ISO-9000 certified.

4.4.5 Checking references for customer satisfaction

The importance of customer satisfaction is because the main judge of the quality of work is the customer, thus if the customer/buyer is not satisfied, the work does not have quality. If the customers are highly satisfied with a particular item, the need to improve is low and vice versa.

Through the communication process and continuous evaluation process of buyers and suppliers it can be determined the degree of the buyer satisfaction. Since the studied organizations expect their evaluation criteria, discussed in section 4.4.1, to be satisfied by the suppliers, and buyers are evaluated based on their supplier performace, then buyer satisfaction can be a measure of the supplier's performance.

4.4.6 Financial assessment to assure the viability of the supplier throughout the intended period of supply

An assessment of a potential supplier's financial condition almost always occurs during the initial evaluation process. Some purchasers view the financial assessment as a screening process or preliminary condition that the supplier must pass before a detailed evaluation can begin. An organization may use a financial rating service to help analyze a supplier's financial condition. If the supplier is a publicly held company other financial documents will be readily available. Because buyers rely on fewer suppliers today to support their purchase requirements, it is important to reduce risk by selecting financially sound suppliers expected to remain in business for the long term.

One of the main supplier selection criteria in Deere and Company is the financial stability of its potential suppliers. This evaluation is done in phase IV of

Deere's Strategic Sourcing Process with the Request of Proposal (RFP)/ Request of Quote (RFQ) where an in-depth financial study is done to the suppliers.

The solidity of the supplier is one of the main issues on the screening process of Baxter's suppliers. In the same way as Deere, this company studies the financial background of its potential suppliers through RFP and RFQ.

In the case of Techno Plastics Industries, this financial assessment is not completed by this organization since the raw material suppliers are specified by the clients who are in charge of this financial evaluation.

4.4.7 Service and support capability

The subject 'support services' comprise many issues such as communication, responsiveness to requests, and problem solving. The communication is a significant factor in building successful relationships with suppliers. Communication between purchasing and suppliers emphasizes both the human interaction between companies and electronic data exchange so as to cut paperwork and staff time on frequent small orders. This section is related to the documentation of supplier evaluation (4.4.2) and review of response to problems (4.4.3), both explained earlier.

In conclusion, Table 4.8 presents that all three of the companies in one way or another follow these supplier selection clauses, and the importance of this comparison is that these organizations, for its supplier selection processes, are based on international reliable standards. In addition, it can be concluded that all of the seven sections of ISO- 9000 explained here are interrelated, as one section is connected in a way to the other, which it's evident since all of them have the same goal.

4.5 Findings

This study reveals that in most cases, the methodologies used by these companies for the evaluation of suppliers are based on the step by step general framework: "Initial Supplier Evaluation and Selection Audit Development", presented in the literature review. In Techno Plastics is an exception since it do not have to complete all the steps, only step 7: "Review supplier performance continuously" using the evaluation report presented in Chapter IV section 4.2. The other steps are responsibility of Techno Plastic's clients.

Additionally, this research signals that the supplier performance measurement criteria commonly used by the manufacturing and pharmaceutical industries are quality, delivery and service. In general, quality is the most important criterion in the organizations studied. It was found also that in most organizations the weighted method is employed as a scoring system for subjective measures like the service criterion. This method is presented in the literature review.

In the case of the pharmaceutical industry, the supplier's quality is a critical characteristic to ensure that stringent controls such as the FDA, demanded by the US government, and ISO 9000 are met. In this particular environment, these regulations are focusing more in the importance of the supply chain issues, to avoid counterfeit and adulterated drugs, reduce terrorist activity and finally to drive manufacturers to critically evaluate current practices. Furthermore, in the manufacturing business this issue is noticed since these organizations can also be ISO 9000 certified.

In addition, delivery is a critical supplier's performance measure in the pharmaceutical industry, since in case of a delivery failure, this brings as a

consequence a late end product to the final customer and this delay could be lethal for the client.

These findings are consistent with the findings presented in a study made by Aberdeen Group, a leading provider of technology market consulting and research, and iSource Business, a leading supply and demand chain multi-tiered media company. In their report, "The Supplier Performance Measurement Benchmarking Report" completed on December 2002, they highlight that the main supplier performance measurement criteria are quality, on-time delivery, service, price, and quality being the most important one overall. This analysis examines the increased requirements for effective performance measures and included manufacturers, such as automotive manufacturing and pharmaceutical/chemical manufacturing industries.

Also, in this research is important to point out that the price criterion is only particularly important in Deere and Company. This could be because this manufacturing industry is highly competitive and besides competing with quality and reliable products, it is important to decrease costs by managing them with cost reduction suggestions.

Furthermore, all of these organizations assure the installation and use of an effective quality system which are often based on rigorous standards such as the ISO 9000 series of standards. Some approaches for assessment are developed in-house using these standards such as the Strategic Sourcing Process, Supplier Quality Index, and an evaluation procedure report employed by Deere and Company, Baxter Transfusion Therapies Division and Techno Plastics Industries, respectively.

CHAPTER V

SUPPLIER ASSESSMENT EXAMPLES

This chapter addresses one of the research questions which deals the suitability of the theoretical models to resolve the supplier selection process. To demonstrate the consistency of the results given by the theoretical models with the results of the supplier selection in-house procedures of the companies under study, some supplier assessment cases are presented as an illustrative example, which are compared with the Analytical Hierarchical Process (AHP) model discussed in Chapter II section 2.3. This particular theoretical method was chosen for comparison, to capture both qualitative and quantitative measures.

The others theoretical methods presented in the literature review could not be used for comparison because:

- The Categorical method is too simple to use for comparison since attributes are weighted equally, which is not the case here.
- The Weighted method is used as a scoring system by Baxter for the subjective measures, therefore another method is required for comparison.
- The Cost ratio and the Total Cost of Ownership are not used because of the data restriction of the SQI reports, where costs are not specified.
- The Principal Component Analysis is not used for comparison, because the sample size is too small. Only three suppliers are assessed in this case, thus this method does not apply.

- The Neural Network requires a software and also, the geographic locations of the suppliers have to be known and this criterion is not evaluated by the SQI reports.

In conclusion, the AHP is an appropriate method to compare with the information given in the SQI report, since weights are computed of the relative importance of the criteria in achieving the goal, select the best supplier, and with the suppliers to achieve the evaluation's criteria.

5.1 Baxter Transfusion Therapies Division Example

Several suppliers of Baxter San Germán Division were assessed using the SQI report on the same product on a given month. The names of the suppliers are changed, for confidentiality purposes, to Premium International, ABC Enterprises and MS Industries.

The SQI reports of these suppliers are presented as follows on Figures 5.1, 5.2, and 5.3.

PREMIUM INTERNATIONAL

Quality Performance (50 % SQI)

Performance Due to Lots Inspected (30 % of Quality)

Lots Inspected	Lots Accepted	Percent Accepted	Rating Due to Lots Accepted	Total
24	23	95.8	0.30*(Percent Accepted)	28.8

Performance Due to Open Audit Observations or Monthly Status Report (10 % of Quality):10

Performance Due to Open CAPA's or Monthly Status Report (10 % of Quality):10

Total Quality = Performance	Rating Due to + Lots Accepted	Total Audit Initial Plan OR Total for Audit Monthly Status Report	Total for CAPA's Initial Plan OR Total for Audit Monthly Status Report
48.8	28.8	10	10

Delivery Performance (40 % SQI)

Performance Due to lots Inspected

Lots Requested	Lots Received on Time	Percent Accepted	Rating Due to Delivery	Total
18	18	100	0.40*(Percent on Time)	40

Service Performance (10 % SQI)

Criteria	Points Awarded
1. Proactive Communication (10pts.)	10
2. Responsiveness (10pts.)	10
3. Extraordinary Arrangements (5pts.)	5
4. Accessible/ Diligent (5pts.)	5
5. Flexibility (5pts.) will only be in favor	0
Total Points (30 pts.)	30
Percent for Service (Points Obtained/30)*10%	10

Total Supplier Quality Index: 98.8

Figure 5.1: Premium International Example

ABC ENTERPRISES

Quality Performance (50 % SQI)

Performance Due to Lots Inspected (30 % of Quality)

Lots Inspected	Lots Accepted	Percent Accepted	Rating Due to Lots Accepted	Total
9	9	100	0.30*(Percent Accepted)	30

Performance Due to Open Audit Observations or Monthly Status Report (10 % of Quality):10

Performance Due to Open CAPA's or Monthly Status Report (10 % of Quality):10

Total Quality = Performance	Rating Due to + Lots Accepted	Total Audit Initial Plan OR Total for Audit Monthly Status Report	Total for CAPA's Initial Plan OR Total for Audit Monthly Status Report
50	30	10	10

Delivery Performance (40 % SQI)

Performance Due to lots Inspected

Lots Requested	Lots Received on Time	Percent Accepted	Rating Due to Delivery	Total
5	5	100	0.40*(Percent on Time)	40

Sevice Performance (10 % SQI)

Criteria	Points Awarded
1. Proactive Communication (10pts.)	10
2. Responsiveness (10pts.)	10
3. Extraordinary Arrangements (5pts.)	5
4. Accessible/ Diligent (5pts.)	5
5. Flexibility (5pts.) will only be in favor	0
Total Points (30 pts.)	30
Percent for Service (Points Obtained/30)*10%	10

Total Supplier Quality Index: 100

Figure 5.2: ABC Enterprises Example

MS INDUSTRIES

Quality Performance (50 % SQI)

Performance Due to Lots Inspected (30 % of Quality)

Lots Inspected	Lots Accepted	Percent Accepted	Rating Due to Lots Accepted	Total
1	1	100	0.30*(Percent Accepted)	30

Performance Due to Open Audit Observations or Monthly Status Report (10 % of Quality):0

Performance Due to Open CAPA's or Monthly Status Report (10 % of Quality):10

Total Quality = Performance	Rating Due to + Lots Accepted	Total Audit Initial Plan OR Total for Audit Monthly Status Report	Total for CAPA's Initial Plan OR Total for Audit Monthly Status Report
40	30	0	10

Delivery Performance (40 % SQI)

Performance Due to lots Inspected

Lots Requested	Lots Received on Time	Percent Accepted	Rating Due to Delivery	Total
1	1	100	0.40*(Percent on Time)	40

Sevice Performance (10 % SQI)

Criteria	Points Awarded
1. Proactive Communication (10pts.)	10
2. Responsiveness (10pts.)	10
3. Extraordinary Arrangements (5pts.)	5
4. Accessible/ Diligent (5pts.)	5
5. Flexibility (5pts.) will only be in favor	0
Total Points (30 pts.)	30
Percent for Service (Points Obtained/30)*10%	10

Total Supplier Quality Index: 90

Figure 5.3: MS Industries Example

5.2 The AHP Comparison

In this section, a comparison is made of the three suppliers assessed with the SQI evaluation, to test if the results are consistent with the AHP model. A hierarchy is developed, based on the SQI reports of the three suppliers. The first level of this hierarchy is the goal which is selecting the best supplier. The next level is the three supplier selection criteria, Quality, Delivery and Service. Then, the following levels are the subcriteria which are the specific supplier selection criteria in which the suppliers are evaluated. Subsequently, the rating levels are presented in which the subcriteria are measured. Finally, the alternatives are presented which are the three different suppliers used in this study. The proposed hierarchy is presented in Figure 5.4.

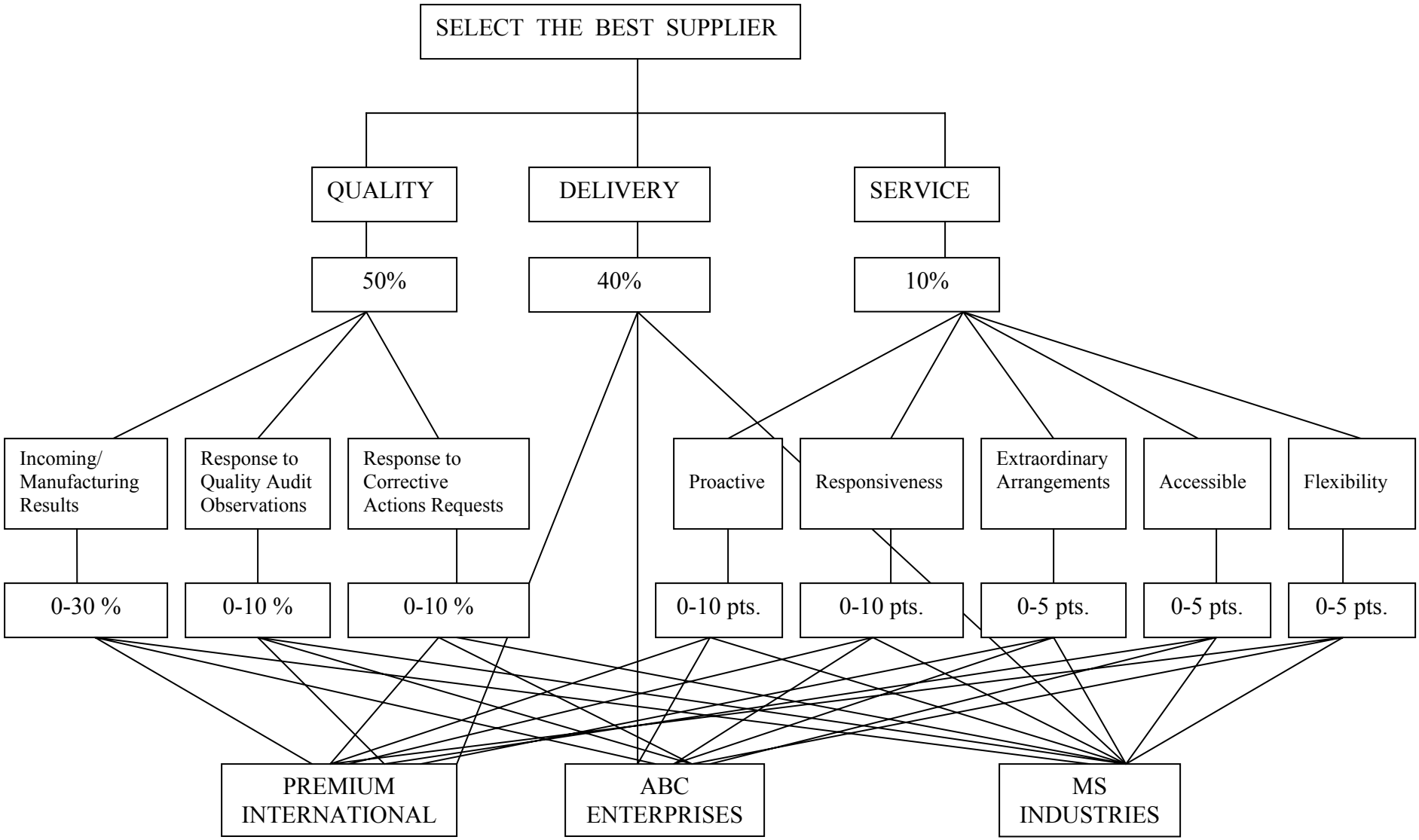

Figure 5.4: AHP Hierarchy

The following tables present these evaluations, employing the AHP model with the pairwise comparisons of the relative importance of the suppliers with respect to the criteria. Table 5.1 presents the weight correspondent to each one of the criteria, according to Baxter San Germán Division (see Table 2.8). Table 5.2 presents the normalized values of Table 5.1, where the last column presents the weights of the criteria based on Baxter's data.

Table 5.1 AHP Original Matrix

	Quality	Service	Delivery
Quality	1.00	6.00	2.00
Service	0.17	1.00	0.20
Delivery	0.50	5.00	1.00
Total	1.67	12.00	3.20

As an illustrative example the following equations present how Table 5.2 is calculated from the values of Table 5.1:

First cell of the first column = (1.00/1.67) = 0.60

First cell of the last column = Row Average = (0.60+0.50+0.63)/3= 0.58

Table 5.2 AHP Normalized Matrix

	Quality	Service	Delivery	Total Row	Weights
Quality	0.60	0.50	0.63	1.73	0.58
Service	0.10	0.08	0.06	0.25	0.08
Delivery	0.30	0.42	0.31	1.03	0.34
Total	1.00	1.00	1.00		1.00

Comparison is made for each pair of suppliers with respect to the quality criterion, as shown in Table 5.3. The normalized values of this table are presented on Table 5.4.

Table 5.3 AHP Quality matrix

	Premium international	ABC Enterprises	MS Industries
Premium international	1.00	0.50	3.00
ABC Enterprises	2.00	1.00	4.00
MS Industries	0.33	0.25	1.00
Total	3.33	1.75	8.00

Table 5.4 AHP Normalized quality matrix

	Premium international	ABC Enterprises	MS Industries	Weights
Premium international	0.30	0.29	0.38	0.32
ABC Enterprises	0.60	0.57	0.50	0.56
MS Industries	0.10	0.14	0.13	0.12
Total	1.00	1.00	1.00	1.00

Furthermore, the service criterion is compared with each pair of suppliers as presented in Table 5.5):

Table 5.5 AHP Service matrix

	Premium international	ABC Enterprises	MS Industries
Premium international	1.00	1.00	1.00
ABC Enterprises	1.00	1.00	1.00
MS Industries	1.00	1.00	1.00
Total	3.00	3.00	3.00

Table 5.6 AHP Normalized service matrix

	Premium international	ABC Enterprises	MS Industries	Weights
Premium international	0.33	0.33	0.33	0.33
ABC Enterprises	0.33	0.33	0.33	0.33
MS Industries	0.33	0.33	0.33	0.33
Total	1.00	1.00	1.00	1.00

Also, the delivery criterion is compared with each pair of suppliers (Table 5.7):

Table 5.7 AHP Delivery matrix

	Premium international	ABC Enterprises	MS Industries
Premium international	1.00	1.00	1.00
ABC Enterprises	1.00	1.00	1.00
MS Industries	1.00	1.00	1.00
Total	3.00	3.00	3.00

Table 5.8 AHP Normalized delivery matrix

	Premium international	ABC Enterprises	MS Industries	Weights
Premium international	0.33	0.33	0.33	0.33
ABC Enterprises	0.33	0.33	0.33	0.33
MS Industries	0.33	0.33	0.33	0.33
Total	1.00	1.00	1.00	1.00

Table 5.9 AHP Summary of Results

	Quality	Service	Delivery	Weights
Premium international	0.18	0.03	0.11	0.33
ABC Enterprises	0.32	0.03	0.11	**0.46**
MS Industries	0.07	0.03	0.11	0.21
Total				1.00

The results presented on Table 5.9 are very similar to the ones shown in the SQI report where the ABC Enterprises has the highest score.

5.3 Validation of the AHP model

One of the strengths of the AHP is the ability to measure the degree of consistency present in the subjective managerial judgment. Therefore, it can be measured the magnitude of departure from perfect consistency (Canada, 1996).

The local consistency ratio (C. R.) is an approximate mathematical indicator, or guide, of the consistency of pairwise comparisons. It is a function of what is called the “maximum eigenvalue” and size of the matrix (called a “consistency index”), which is the compared against similar values if the pairwise comparisons had been merely random (called a “random index”). If the ratio of the consistency index to the random index (called a “consistency ratio”) is no greater than 0.1, Saaty suggests the consistency is generally quite acceptable for pragmatic purposes.

The consistency ratios (C.R.) of the AHP model are calculated next. From Table 5.1 and Table 5.2, the C.R. = 0.03, which is smaller than 0.1, thus the previous pairwise comparisons are reasonably consistent. Similarly, is calculated the

consistency ratio of Table 5.3 and Table 5.4 which is 0.02. Finally, the consistency ratios from Table 5.5 and Table 5.6, and Table 5.7 and Table 5.8 are both C. R. = 0. In conclusion, the overall consistency ratio is 0.025, which is no greater than 0.1, therefore the pairwise comparisons of the example showed consistency.

5.4 Conclusions

This chapter presented a comparison made with the SQI report which is Baxter's supplier assessment procedure, and the AHP model, to test the suitability of both methods. The SQI examples illustrate the supplier's rating in each case and the supplier named ABC Enterprises, resulted with the higher score, followed by Premium International, and the least preferred is MS Industries. The same ranking sequence is appreciated in the AHP results, so both methods showed consistency.

In previous chapters, it was argued that there was no evidence of the practical use of this method in real settings. This analysis showed that the AHP model could be used as an alternative method for the supplier selection process. Also, as a complementary method when two suppliers have the same score and managerial judgment is required to decide which supplier will be selected.

CHAPTER VI

CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

The supplier selection processes are very important to organizations nowadays since choosing the one that fits best the company's needs, can bring significant savings. These processes can vary across companies depending on many factors. One of these factors is the focus criteria of the company that depends on its competitive market. These criteria may vary from quality, cost/price, delivery, financial capability and stability, supplier management capability, overall personnel capabilities, process and technological capability, environmental regulation compliance, supplier purchasing strategies, policies and techniques, among others.

This research indicates that the supplier performance measurement criteria most commonly used by manufacturing and pharmaceutical industries are quality, delivery and service. These are the main criteria in the organizations studied since other supplier's evaluation criteria such as financial capability stability or process and technological capability, are met by the ISO 9000 standards and since these companies are ISO 9000 structured, they do not include these additional criteria as their focal point.

In general, quality is the most important criterion in the organizations studied. In addition, delivery is a critical supplier's performance measure in the pharmaceutical industry, since in case of a delivery failure, this could result in a late

end product to the final customer and this delay could be lethal for the client. Furthermore, in the manufacturing business this issue is noticed since these organizations can also be ISO 9000 certified.

The methodology selected for this study (multiple exploratory case study) was appropriate to address the research questions initially proposed. Regarding research question 1, Do the key performance measures of the supplier selection processes vary depending on the corporate environment?, it can be concluded that the key supplier performance measures are the same in the three corporate environments studied, however, the relative importance or weight assigned to each one of them, vary depending on the industry.

Related to research question 2, Do the supplier selection processes of the organizations follow a reliable set of quality standards, as ISO 9000 requires?, it can be concluded that all of these organizations assure the installation and use of an effective quality system which are often based on rigorous standards such as the ISO 9000 series of standards. Furthermore, the supplier assessment processes used by these companies are developed in-house adjusted to its requirements.

Regarding the final proposition, Are the theoretical methods suitable for the supplier selection process?, it can be concluded that although most organizations use the weighted method as a scoring system, other methods such the ones included in the literature review could be also used. Furthermore, the practical applicability of one of these theoretical methods model (AHP) was successfully applied to the supplier selection process using the information provided from one of the companies.

Finally, a comparison including factors such as the supplier selection criteria, supplier selection processes, complexity of these processes and regulations is made across the different corporate environments. First of all, in the case of the criteria for supplier selection, the importance of these performance metrics can vary depending on the nature of the industries. The supplier selection processes in the organizations studied are developed in-house according to each industry specific requirements. Furthermore, the complexity of the supplier selection process varies depending on the number of products and quantity of suppliers in the organization. The study shows that the supplier selection processes are more complex when the companies have a large variety of products and suppliers. In contrast, these processes are simpler when the organization produces a limited number of products and has a few suppliers. Another issue is the regulations, in the pharmaceutical industry rigorous quality systems are in placed in order to comply with the FDA regulations. Additionally, these organizations are ISO 9000 certified. The FDA regulations are not required by the manufacturing business, but this industry often follows reliable quality principles as the ISO 9000 standards.

6.2 Research Contributions

The major contribution of this study is the empirical evidence gathered on the supplier selection process. The information collected and the findings of the study help to close the gap between theoretical work and actual practice. The findings of this investigation are important in expanding the understanding of the variables that affect the supplier selection process. Specific information is provided addressing:

- The criteria used by organizations for the supplier selection process.

- The methodologies used by companies for the evaluation of suppliers compared with the step by step procedure: "Initial Supplier Evaluation and Selection Audit Development", which is a general framework, presented in the literature review.
- The procedures used by organizations for the supplier selection process.
- The scoring systems commonly used by organizations for their supplier's performance criteria.

6.3 Future Work

For future work, other corporate environments can be explored such as the textile industry or the food industry, among others. Using this information comparison of the different supplier selection and evaluation processes across industries can be established and key supplier's performance metrics identified. Also, other organizations of the same industry type could be studied, in order to explore whether they are consistent with the results of this project.

Another area for future research is to examine what additional criteria are considered by companies that are not ISO-9000 structured and to compare them with the ones used by ISO structured companies. In addition, the suitability of other theoretical methods such as the Principal Component Analysis, to assist in the decision making process can be explored.

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Appendix

A. Questionnaire

Aspectos Generales

1. *Perfil de la empresa (# de productos, etc.)*
2. *¿Cuántos suplidores poseen (locales, USA, internacionales)?*
3. *¿Cuál es su política de compra, mantener pocos vs. varios suplidores?*

Proceso de Selección

1. *¿Poseen un plan estratégico para la selección de suplidores?*
2. *¿Quién tiene el poder de decisión (headquarters, etc)?*
3. *¿De qué forma adquieren la información para la búsqueda de suplidores potenciales (encuestas, etc.)?*
4. *¿Realizan análisis de benchmarking para elegir a sus suplidores?*
5. *¿Cómo evalúan la información obtenida de los suplidores potenciales?*
6. *¿Cómo realizan las negociaciones con sus suplidores finales (duración del contrato)?*
7. *¿Asignan equipos de trabajos para que se encarguen del proceso de calificar a los suplidores?*
8. *¿Cuáles criterios utilizan para calificar a los suplidores?*

PROCESO DE EVALUACIÓN

1. *¿Poseen algún procedimiento para la evaluación de sus suplidores (software, método)?*
2. *¿Cómo fue seleccionado este software o método (por consenso, a nivel corporativo) y cuáles características requerían?*
3. *¿Quiénes son los responsables de manejar y medir el desempeño de los suplidores?*
4. *¿Cuáles son los criterios en que se evalúa los suplidores? ¿Varían por producto?*

5. *¿En cuál de estos criterios se enfoca la compañía?*
6. *¿Poseen algún estándar mínimo de cumplimiento de estos criterios y cómo los miden?*
7. *¿Poseen alguna clasificación de sus suplidores, de acuerdo al cumplimiento de estos criterios?*
8. *¿Cómo incentivan las relaciones de comunicación con sus suplidores?*
9. *¿Cada cuánto tiempo se actualiza la información de los suplidores?*
10. *¿Poseen reportes sobre el desempeño de sus suplidores?¿ Frecuencia?*
11. *¿Cuáles aspectos han mejorado después de haber implementado este proceso (costo, calidad, entrega) y en qué porcentaje?*
12. *¿Están dispuestos a probar otro método?*

B. Invitational Letters

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Distinguido Sr. o Sra:

Mi nombre es Marlene Suárez Bello y soy estudiante en el Programa de Maestría de Ingeniería de Sistemas Gerenciales del departamento de Ingeniería Industrial en la Universidad de Puerto Rico, Recinto Universitario de Mayagüez. Estoy trabajando bajo la supervisión de la Dra. Viviana Cesaní en el área de "Supply Chain Management", específicamente en los métodos de selección y evaluación de suplidores. El enfoque de este proyecto es identificar cuales criterios son relevantes en el proceso de selección y evaluación de suplidores y realizar un análisis comparativo de estos métodos. Mi inquietud es saber su interés en este proyecto y si me pueden recibir en sus instalaciones para discutir posibles áreas de colaboración entre su organización y el departamento de Ingeniería Industrial.
En la próxima semana me comunicaré con ustedes para saber su opinión al respecto.

Con las gracias anticipadas, se despide

Atentamente,

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Distinguido Sra. Emmanuel:

Mi nombre es Marlene Suárez Bello y soy estudiante en el Programa de Maestría de Ingeniería de Sistemas Gerenciales del departamento de Ingeniería Industrial en la Universidad de Puerto Rico, Recinto Universitario de Mayagüez. Estoy trabajando bajo la supervisión de la Dra. Viviana Cesaní en el área de "Supply Chain Management", específicamente en los métodos de selección y evaluación de suplidores. El enfoque de este proyecto es identificar cuales criterios son relevantes en el proceso de selección y evaluación de suplidores y realizar un análisis comparativo de estos métodos. Mi inquietud es saber su interés en este proyecto y si me pueden recibir en sus instalaciones para discutir posibles áreas de colaboración entre su organización y el departamento de Ingeniería Industrial.
En la próxima semana me comunicaré con ustedes para saber su opinión al respecto.

Con las gracias anticipadas, se despide

Atentamente,

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