The Islamic University-Gaza

Higher Education Deanship

Commerce College

Business Administration Department

The Use of Analytic Hierarchy Process in Supplier Selection: Vendors of Photocopying Machines to Palestinian Ministry of Finance as a Case Study

Prepared by:

Maher H. Al-Rafati

Supervised by:

Prof. Dr.: Yousif H. Ashour

"A Thesis Submitted in Partial Fulfillment of the Requirements for the MBA Degree"

محرم 1429 هـ January 2008

Abstract

The supplier selection problem is one of the most important component of the purchasing function. Some of the common and influential criteria are quantitative and some are qualitative criteria in the selection of a supplier. Forty of decision makers in the Palestinian National Authority (PNA) ministries were surveyed to identify the importance of the supplier selection criteria. As a result, quality, price, service, business overall performance, technical capability and delivery were identified to be the major selection criteria along with thirty four sub-criteria.

The multi-criteria decision making (MCDM) is suggested to be a viable method for supplier selection. The analytic hierarchy process (AHP) has been used as a tool for MCDM. The identified criteria were used in conjunction with the AHP theory concept and a computerized software program "Expert Choice" based on AHP in structuring the supplier selection model (SSM). The SSM was used for solving the supplier selection problem. An application of the SSM for a case study is presented along with sensitivity analysis to choose the best supplier. SSM is proposed to choose the best photocopying machines supplier to the ministries of PNA.

خلاصة الرسالة

تعتبر مشكلة اختيار المورد العنصر من العوامل الأكثر أهمية لوظيفة الشراء. إن بعــض المعــايير الشائعة والمؤثرة في اختيار المورد كمية والبعض الآخر وصفية، لذلك تم عمل مسح لتحديد أهمية معــايير اختيار الموردين، وقد شمل البحث استقصاء أربعين من متخذي قرار الشراء في وزارات الســلطة الوطنيــة الفلسطينية. ونتيجة لذلك المسح تم تحديد المعايير الرئيسية التالية: الجودة والسعر والخدمــة والأداء العــام للمنشأة والقدرات التقنية والتسليم والتي تفرع منها أربعة وثلاثين معيار فرعي.

يعتبر اتخاذ القرار متعدد المعايير طريقة قابلة للتطبيق في اختيار المورد. وتستخدم عملية التحليــل الهرمي كأداة من أدوات اتخاذ القرار متعدد المعايير. لذلك تم استخدام المعايير الســابقة المحــددة مقرونــة بنظرية التحليل الهرمي وبرنامج الحاسب الآلي ''Expert Choice'' والذي تم إعداده على أســاس نظريــة التحليل الهرمي في تكوين نموذج اختيار المورد (SSM) واستخدامه في حل مشكلة اختيار المورد. لذلك تم تطبيق هذا النموذج مع استخدام تحليل الحساسية على حالة دراسية لاختيار أفضل مورد لماكينات التصــوير لوزارات السلطة الوطنية الفلسطينية.

Especially dedicated

to my beloved family

Acknowledgments

I am so grateful for the help given to me by my advisor, Pro. Dr. Yousif Ashour. His knowledge, guidance and advice were vital for the accomplishment of this thesis. I also would like to express my thanks to Prof. Dr. Rifat Rostum and Dr. Salah Al-Agha, for revising this thesis.

Also, I want to thank the Islamic University in Gaza, specially the Commerce College for giving me the opportunity to be a part of their master's program.

Thank you all for helping me to accomplish this thesis.

Table of Contents

Chapter Three
Multiple Criteria Decision Making (MCDM)

Chapter Four
Research Methodology

Chapter Five
Data Analysis and Discussion

Chapter Six
Model Formulation

Chapter Seven
Model Validation with a Case Study

Chapter Eight
Conclusion and Recommendations

List of Tables

List of Figures

List of Appendices

Appendix no.	Description	Page
A	Survey Questionnaire	166
B	Pair-wise Comparison Questionnaire	174
C	List of Ministries	189
D	Names of Questionnaire Referee	190

List of Abbreviations

Abbreviation	Description
AHP	Analytic Hierarchy Process
ANP	Analytical Network Process
CA	Cluster analysis
CBR	Case-based Reasoning
CI	Consistency Index
CPAR	Country Procurement Assessment Report
CR	Consistency Ratio
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EC	Expert Choice
ELECTRE	Elimination and Choice Translating Reality
ISMT	Intelligent Supplier Management Tool
LP	Linear Programming
MADM	Multi-Attribute Decision Analysis
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision Making
MDDM	Multi-Dimensions Decision-Making
MoF	Ministry of Finance
MP	Mathematical Programming
NN	Neural Network
PCA	Principal Component Analysis
PCM	Pair-wise Comparison Matrices
PGP	Preemptive Goal Programming
PNA	Palestinian National Authority
QFD	Quality Function Deployment
RI	Ratio Index
RCI	Random Consistency Index
SSM	Supplier Selection Model
TCO	Total Cost Ownership
W	Weighted Sum Vector

Chapter One

General Introduction

1.1 Introduction

1.2 Research Problem

1.3 Research Objectives

1.4 Importance of the Research

1.5 Research Methodology

1.6 Data Collection

1.7 Organization of the Research

Chapter One

General Introduction

1.1 Introduction:

Today, many organizations are facing rapid changes stimulated by technological innovations and changing customer demands. These organizations realize that the effort to obtain products at the right cost, in the right quantity, with the right quality at the right time from the right source is crucial for their survival (Oboulhas et al., 2004). Therefore, an efficient supplier selection process needs to be in place and of paramount importance for successful supply chain management (Sonmez, 2006). It begins with the realization of the need for a good supplier; determination and formulation of decision criteria; pre-qualification (initial screening and drawing up a shortlist of potential suppliers from a large list); final supplier selection; and the monitoring of the suppliers selected (i.e. continuous evaluation and assessment).

Evaluation and selection of suppliers are a typical multiple criteria decision making (MCDM) problem involving multiple criteria that can be both tangible and intangible. The analysis of criteria for selecting and measuring the performance of supplier has been the focus of many researchers and purchasing practitioners as to provide a comprehensive view of the important criteria in the supplier selection decision (Noorul Haq and Kannan, 2006). Supplier selection process requires a formal, systematic and rational selection model. In this study, a very comprehensive application of Analytic Hierarchy Process (AHP) for a case is presented along with sensitivity analysis to choose the best supplier.

The AHP is designed to solve complex multi-criteria decision problems. It is based on the innate human ability to make sound judgments about small problems. It facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision (Saaty, 1990). The scale used for comparisons in AHP enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion (Bayazit and Karpak, 2005).

The general supplies department started its functions in 2002 as an independent department linked to the Minister of Finance of the Palestinian National Authority (PNA). The department purchases commodity related to the ministries' and governmental directorates according to the active Bylaw of the General Supplies. The selection of a competent supplier to provide the best supplies is a very weak procedure and a challenging task in the public sector in Gaza Strip. This is due to many factors influencing the selection process, such as strong opposition to the present practices for suppliers selection, complexity and availability of many suppliers with different levels of experience, specialization, staffing and after sales services. From 2002 up to 2005, the ministry of finance purchased annually photocopying machines to the tune of US$ 600,000[1]. A case study of the ministry of finance in the PNA with an AHP model will be discussed in an attempt to select the best photocopying machine supplier.

1.2 Research Problem:

The ministries of the PNA need essential capital assets that enable them to perform their duties and responsibilities assigned to their efficiently and effectively. The Palestinian general supplies law leaves the tender's evaluators unguided to select the

---

[1]Unpublished release, the Ministry of Finance, PNA

3

best supplier based on developed and adopted selection criteria. This indicates that there is no consistent approach to select the suppliers. The evaluators are performing the supplier selection procedures without full consideration to professional qualifications. The research will deal with supplier selection process in an attempt to improve the selection process among the general supplies department in the ministry of finance in Gaza Strip.

There are general restrictions imposed on the selection procedure based on the lowest price, which may not easily accomplish the selection process. Therefore this research takes into consideration the whole criteria and sub-criteria that control the supplier selection process. This research will try to develop a model for selecting the best supplier who is capable of satisfying certain criteria.

1.3 Research Objectives:

The main objective of this research is to capture both the subjective and the objective evaluation measures in order to solve supplier selection especially when different organizations have different combinations of qualitative and quantitative criteria and sub-criteria. To achieve that, it is important to develop the supplier selection model based on AHP since it is a good candidate for these kinds of selection problem.

The other objectives of this research related to developing AHP model are:

- To identify the selection criteria upon which the major factors influencing the supplier selection process depends.
- To determine the most important priorities to be adopted in the supplier selection process.
- To calculate the weights of each criterion.

- To enable decision makers to examine the strengths and weaknesses of the suppliers' selection by comparing them with respect to appropriate criteria and sub- criteria.

1.4 Importance of the Research:

After conducting this research, the main objective of the selection process will be determined by identifying and handling multiple criteria that will enable considering a number of both qualitative and quantitative factors when assessing the supplier. Then the identified selection criteria will be used to develop a supplier selection model, which will enable the public sector to mitigate the selection of incompetent supplier.

Besides, the researcher is working in the Palestinian Ministry of Finance (MoF) as a director of the technical support department. The proposed model will enable the researcher objectively to evaluate the suppliers.

1.5 Research Methodology:

The decision of selecting the best supplier to deliver goods or services is often very complex. Supplier selection problems are multi-objective problems which have many qualitative and quantitative concerns (Bayazit and Karpak, 2005).

The objectives of the research will be achieved through three stages:

Stage one, to identify the major supplier selection criteria and sub-criteria that should be considered by purchasing experts. The available literature on supplier selection methods were comprehensively searched and studied to identify the major selection criteria. In addition, data will be gathered through direct interviews with the purchasing managers in the public sector and a sample of suppliers.

Stage two: The selected criteria that had been identified in stage one were used as a basis for formulating the questionnaire survey which consists of these criteria. A respondent to the questionnaire will be selected randomly from different functional areas of the experts and decision makers who are directly involved in materials supplied by the suppliers. They were asked to rate the selection criteria in order of importance. Based on the survey conducted, the major influencing criteria and sub-criteria involved in supplier selection will be determined.

Stage three: To implement these selected criteria and the AHP as a decision analysis tool, in order to develop a supplier selection model to solve supplier selection problems in the ministries of PNA. After that it was important to validate the supplier selection model with a case study to calculate priorities, consistency ratio and conducting overall synthesis to the model. A series of sensitivity analysis conducted to investigate the impact of changing the priority of the criteria on the suppliers' ranking.

1.6 Data Collection:

The main sources for the required data for this research are:

a) Primary Data

- Questionnaire survey to the criteria and sub-criteria used in the public sector and their importance.
- Pair-wise comparison questionnaire to compare each pair of the criteria and sub-criteria used in the supplier selection, to identify to what extent one criterion is more/less important/preferred to another. The respondents to this questionnaire are experts in the field of public purchasing.

b) Secondary Data

This research depends on the previous studies conducted on supplier selection, published researches, papers, documents and other related literature.

1.7 Organization of the Research:

This research discusses the supplier selection in the ministries of PNA in Gaza Strip and the identification of the main criteria and sub-criteria involved in the supplier selection Identification of these criteria and sub-criteria and their weights will be the core subject of this research.

Research plan:

The research plan will be divided into eight chapters as follows:

Chapter 1 (General Introduction): It gives a general introduction that briefly describes the research problem, set out the objectives, importance and content of the research.

Chapter 2 (Literature Review): It is intended to present a brief look into the ministries of PNA and their purchasing procedures and selection process of suppliers (criteria and methods). Also it presents the previous studies that conducted on the supplier selection process.

Chapter 3 (Multiple Criteria Decision Making): This chapter is constructed to the explanation of the AHP and its advantages, basic steps and methodology to use.

Chapter 4 (The Research Methodology): This chapter is devoted to explain the research methodology.

Chapter 5 (Data Analysis and Discussion): This chapter is devoted to the description, identification, and analysis of the supplier selection criteria.

Chapter 6 (Model Formulation): This chapter is devoted to build the AHP for the development of the supplier selection model,

Chapter 7 (Model Validation with a Case Study): This chapter is devoted to describe the case study, after that implementing the model on the case study.

Chapter 8 (Conclusion and Recommendations): It is intended to present results of implementation the supplier selection model, the conclusion, recommendations based on the results of the research, and recommended future studies.

Chapter Two

Literature Review

2.1 Introduction

2.2 Types of Suppliers

2.3 Criteria, Attributes and Objectives

2.4 Supplier Selection (Decision) Criteria

2.5 Supplier Selection Methods

2.6 Supplier Selection in the Public Sector

2.7 Supplier Selection in the PNA

Chapter Two

Literature Review

2.1 Introduction:

The selection of suppliers is the responsibility of the purchasing department and requires a consideration of several factors. Liu and Hai (2005) indicated that the main function of the purchasing department includes the acquisition of required material, services and equipment for all types of organizations. If the buyer chooses the right supplier, the buyer can promote its competitive advantage in the market.

The success of supplier selection procedure depends on the quality of specific criteria. These criteria are defined specially to guarantee the accomplishment of the selection process, the quality of evaluating these criteria to arrive at the best supplier (Bello,2003). Public sector organizations should define a systematic approach represented by a set of specific criteria before final selection takes place. However, it should be remembered that even though a given set of criteria represents the minimum selection requirements, it should be identified correctly and assigned carefully to assure the objectives of supplier selection were achieved.

Previous studies had been surveyed to find out the most important criteria for supplier selection. They have indicated that supplier selection is of great importance for both the private and public sectors and should not be done without complete evaluation of those criteria influencing the selection process (Weber et al., 1991).

Some enterprises employ simple procedures with few criteria for supplier selection, while others use complex procedures with many criteria divided into sub-criteria. The complexity of the selection process depends on the size, business type and revenue of the purchasing department, the total costs involved in purchasing, and how often the purchase is to be repeated (Davidrajuh, 2000). Many papers introduced the use of different decision making methods and tools for supplier selection. These methods can be clustered into several broad categories: traditional Multiple Criteria Decision Making (MCDM) techniques, mathematical programming, artificial intelligence and expert systems, multivariate statistical analysis, group decision making and multiple methods.

This chapter is divided into six sections: (1) types of suppliers; (2) criteria and attributes; (3) supplier selection criteria; (4) supplier selection methods; (5) supplier selection in the public sector; (6) supplier selection in the PNA.

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 either at trade shows, wholesale showrooms and conventions, or through buyers directories, industry contacts, and trade journals (Bello, 2003). Suppliers can be divided into four general categories (Lesonsky, 2001): manufacturers, distributors, independent craftspeople and importation sources.

The first category is the manufacturers who most retailers buy through company salespeople or independent representatives who handle the wares of several different

11

companies. Prices from these sources are usually lowest, unless the retailer's location makes shipping freight costly.

The second type of suppliers is the distributors who are also 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 manufacturers, 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.

The third kind is 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, they may want to import goods.

2.3 Criteria, Attributes and Objectives:

A criterion can be thought of as any measure of performance for a particular supplier choice. An attribute is also sometimes used to refer to a measurable criterion. The words criterion and attribute are often used synonymously in the literature on Multi Criteria Decision Making (MCDM), which is indeed sometimes referred to as Multi-Attribute Decision Analysis (MADA) (DTER, 2000).

Criterion is a general term and includes both the concepts of attributes and objectives. An attribute is a measurable quantity whose value reflects the degree to which a particular objective is achieved. An objective is a statement about the desired state of the system under consideration (Chankong and Haimes, 1983). It indicates the directions of improvement of one or more attributes. Objectives are functionally related to, or derived from a set of attributes (Malczewski, 1999).

There might be a formal relationship between objectives and attributes, but usually the relationship is informal. To assign an attribute to a given objective, two properties which are comprehensiveness and measurability should be satisfied. An attribute is comprehensive if its value sufficiently indicates the degree to which the objective is met. And it is measurable if it is reasonably practical to assign a value in a relevant measurement scale (DTER, 2000). In this study the word criterion rather than attribute will be used.

2.4 Supplier Selection (Decision) Criteria:

Supplier selection is complicated by the fact that various criteria must be considered in the decision making process. The analysis of criteria for selecting and measuring the performance of the suppliers has been the focus of many research papers. Some papers reviewed and examined the decision criteria used for supplier selection. Most papers attempted to identify and determine the relative importance of criteria for supplier selection in various industries. The decision criteria used for supplier selection and the weightings assigned to them can be different due to a number of factors (Sonmez, 2006):

- The demographic characteristics of the purchasing managers
- The size of the buyer organization

- The existence of purchasing strategy

- The type of products and/or services purchased

2.4.1 Supplier Selection Criteria in the Previous Studies:

In the domain of supplier selection problem, a lot of criteria have been discussed. The relative importance places on evaluative criteria varies largely in accordance with the nature of the selection situation and is complicated further by the fact that some criteria are quantitative (price, quality, capacity, etc.), while others are qualitative (service, flexibility, brand image, etc.) (Garfamy, 2005). If the decision makers choose the useful and critical criteria as measuring bases, the purchasing strategy after evaluating will just provide the positive benefits for the enterprise.

In industrial buying research, explicit criteria such as quality, service, delivery and price have been found to dominate supplier selection. These criteria are also used in the public sector. Implicit criteria such as reputation and location have also been found to be important but their relative importance is the subject of debate.

Dickson (1966) reported 23 different criteria for vendors' evaluation. Of these criteria, he stated that cost, quality, and delivery times are among the most important performance measures in the selection of vendors. Weber et al. (1991) reviewed 74 articles which address supplier selection criteria in manufacturing and retail environment published from 1966 to 1991. They provided a comprehensive view of the criteria that might be considered in supplier selection decisions. They showed that quality, delivery and net price have received the great amount of attention. According to their investigation, they ranked price as the most important factor in the selection process followed by lead-time and quality factors. Production facility, geographical

location, financial position and capacity generated an intermediate amount of attention. Palaneeswaran et al. (2006) derived the following supplier selection criteria: lessen costs, achieve delivery in the right amount of time, ensure better quality, obtain better services and avoid risks. Noorul Haq and Kannan (2005) used both qualitative and quantitative criteria for the selection of vendors in a supply chain. They divided the criteria into main criteria and sub-criteria. The seven main criteria: quality, delivery, production capability, service, technical capability, business structure and price, then they presented 32 sub-criteria. Ghodsypour and O'Brien (1998) agreed that cost, quality and service are the three main categories when deciding on supplier selection parameters. This revealed that the supplier selection process usually made on the basis of cost, service and quality has been recognized as a major decision making process.

Choi and Hartley (1996) identified eight principal factors out of the initial 26: finances, also including willingness of the supplier to reveal its financial records; consistency; relationship (comprising communication openness and long-term relationships); flexibility; design and technical capabilities; reliability (encompassing incremental improvement capability); customer service; and price. It was worth noting that consistency and relationships were the most important factors at all levels of the automotive supply chain. Conversely, price has the lowest importance, regardless of the position of the buyer in the supply chain.

Davidrajuh, 2000 listed the top ten most important criteria for supplier selection discussed in numerous research papers, which was adopted from Weber et al, 1991, as shown in table (2.1). He indicated that the (net) price, delivery (time) and quality as the most important supplier selection criteria, as these criteria were cited in 80%, 58% and 53% of the research papers. Consequently, his supplier selection modeling approach and

his methodology for automating supplier selection are based on these three most important criteria only.

*Table 2.1: Supplier selection criteria**

	Supplier selection criteria	*No. of research papers*	*%*
1	**Net price**	61	80
2	**Delivery**	44	58
3	**Quality**	40	53
4	Production capability	23	30
5	Geographic location	16	21
6	Technical capability	15	20
7	Management and organization	10	13
8	Reputation and position in industry	8	11
9	Financial position	7	9
10	Performance history	7	9

*Adopted by Davidrajuh (2000)

Some researchers added some factors, Ellram (1990) developed some additional factors that should be considered in the selection of supply partners besides quality, cost, on-time delivery, and service. These factors were categorized into four groups: financial issues, organizational culture and strategy, technology and a group of miscellaneous factors. Pearson and Ellram (1995) argue that quality, cost, current technology and design capabilities are the most important selection criteria and the focus on these criteria supports the trend toward an increasing emphasis on strategic flexibility for the firm. Chan and Chan (2004) reported the most important strategic criteria to be considered in the supplier selection problem. These criteria are cost, delivery, flexibility, innovation, quality and service. These main criteria have corresponding sub-criteria. Wang et al. (2004) predefined supplier selection criteria considering each supplier's production capacity. They determined both criteria and sub-

criteria which have an influence on order quantities. The four main criteria were: delivery reliability, flexibility and responsiveness, cost and assets. Petroni and Braglia (2000) added criteria such as management capability, production capacity and flexibility, design and technological capability, financial stability, experience and geographical location, with the intent of pondering the integration capabilities of viable suppliers, providing an updated framework of criteria in the era of integrated supply chain management.

Seven selection criteria were introduced by Min (1994) for the selection of suppliers from foreign countries, namely financial terms, quality assurance, perceived risks, service performance, buyer–supplier partnerships, cultural and communicational barriers and trade restrictions.

The findings of previous researches indicate that the importance of supplier selection criteria does vary based on the type of purchase and product and there is no common list of criteria used across supplier selection studies (Pearson & Ellram 1995). To conclude, the supplier selection process should not only consider price, but also a wide range of factors such as quality, organization and relationship with a view to decision making by considering the whole supplier capability in a long-term and strategic way.

2.4.2 Supplier Selection Criteria Description:

The aforementioned studies revealed that in selecting vendors, three main criteria (quality, service and price) and a lot of sub-criteria are followed. Table (2.2) summarizes the supplier selection criteria and sub-criteria that may be used in the public sector according to the literature review.

2.4.2.1 Cost / Price:

Cost/price is an obvious consideration for any purchase, many researchers mentioned cost as an important factor in selecting suppliers. In ordinary usage, price is the quantity of payment or compensation for something. In business, the cost may be one of acquisition, in which case the amount of money expended to acquire it is counted as cost. In this case, money is the input that is gone in order to acquire the thing (Wikipedia, 2007). The cost/price factor has been measured on the basis of the importance of the following cost/price dimensions in the buying organization's supplier selection: total cost (evaluating a supplier's cost structure involves providing detailed cost data by the supplier), payment procedures understanding, offering the supplier to competitive pricing, quantity discount (suitability of discount scheme implemented on payment of invoices within time frame) and payment terms (suitability of terms and conditions regarding payment of invoices, open accounts, sight drafts, credit letter and payment schedule) (Keskar, 1999).

Table 2.2: Supplier selection criteria and sub-criteria*

Criterion	Sub-Criterion
Quality	Product durability (i.e. Lifespan)
	Product reliability (e.g., Quality over a given period of time, Consistency)
	Quality systems
	Percent rejection
	Adherence to quality tools (e.g., Check sheet, Histogram, Cause-and-effect diagram,…)
	Reputation and position in the market
Price	Competitive pricing
	Total cost
	Quantity discount
	Payment terms
	Payment procedures understanding
Service	Spare parts availability
	Handling of complaints
	Ability to maintain product/service
	After sales services (e.g., Warranties and Claims policies)
	Training aids
	Flexibility (Payment, Freight, Price reduction, Order frequency & amount)
Business overall performance	Financial stability
	Quality performance (e.g., ISO 9000 accreditation)
	Knowledge of the market
	Information systems
	Management capability
	Performance history
Technical capability	Offering technical support
	Technical know (how know why)
	Understanding of technology
	Responsiveness
	Personnel capabilities
Delivery	Delivery lead time
	Delivery speed
	Upcoming delivery commitments
	Ability and willingness to expedite an order
	Safety and security components
	Modes of transportation facility

*Adopted by the researcher from the literature review

19

2.4.2.2 Quality:

Just as the role of price has reduced as a criterion in supplier selection in many sectors, so quality has become a more important factor. The supplier's capability to reduce his price in the future and to further optimize his quality potential comes into play as well. In addition, the understanding of the concept 'quality' has been transformed. Quality no longer simply applies to the product itself but also applies to the service and other received aspects of the supplier-manufacturer relationship (Keskar, 1999). For instance, a good relationship is a prerequisite to good problem solving and co-operation in product modification. Supplier quality has been established as a primary concern in the supplier selection process for decades (De Boer et al., 1998). The quality factor was measured in terms of suppliers' ability to provide inputs that are reliable and durable (measure of useful life of the product), possessing the supplier to quality systems, adherence to quality tools, percent rejection and supplier reputation and position in the market.

2.4.2.3 Delivery:

Another criterion that needs to be considered is on-time delivery. If a vendor submits the lowest price, it doesn't mean much to the firm if the vendor is also late two or three weeks on all contracts (De Boer and Der Wegan, 2003). The delivery factor has been measured on the basis of the importance of the following delivery dimensions in the buying firm's supplier selection process: ability and willingness to expedite an order, how quickly a supplier can deliver, the amount of time that it takes a supplier to deliver the supplies, upcoming delivery commitments, safety and security components during the transportation and modes of transportation facility.

2.4.2.4 Service:

The service factor has been measured on the basis of the importance of the service dimensions in the buying firm's supplier selection. These included the supplier's attitude to handling complaints, and the ability and willingness to provide technical support and training the technician in the public sector, the ability to maintain product/service, after sales services and the supplier flexibility (the ability and willingness of the supplier to change order volumes and to change the mix of ordered items).

2.4.2.5 Technical Capability:

Technical capability factor has been measured on the basis of the importance of technical capability dimensions in the buying organization's supplier selection process: ability of the vendor to provide technical support, the use of current technology, technical know (how know why), understanding of technology, responsiveness of the vendor to changes in purchase quantities and due dates and personnel capabilities (the overall skills and abilities of the workforce especially with regard to the level of education and training received and highly experienced employees).

2.4.2.6 Business Overall Performance:

A numerous of purchasers view the business overall structure factor as a screening process or preliminary condition that the supplier must pass before a detailed evaluation can begin. The business overall performance factor has been measured on the basis of the importance of the following dimensions in the buying firm's supplier selection process: the supplier's financial stability (indicator of excessive asset price volatility, the unusual drying up of liquidity, interruptions in the operation of payment systems, excessive credit rationing etc.), if the supplier has quality performance (e.g.,

ISO 9000 accreditation), knowledge of the market and if the supplier is using information systems, management capability (includes management's commitment, and willingness to develop a closer working relationship with the buyer) and performance history of the supplier which relates to the supplier's reputation for performance.

2.5 Supplier Selection Methods:

There is no specific method for every problem because each problem is unique. To work reasonably in the supplier selection, a large number of methods would be needed. Nevertheless it is possible to find a method or a combination of methods that meets all or most of the demands of analysts or decision makers with respect to the problem at hand. The great number of methods available also presents a weakness, as it is not clear which method should be used for which situation.

A number of studies has been devoted to examining vendor selection methods. The common conclusion of these studies is that the supplier selection is a Multi Criteria Decisions Making problem (Nydick and Hill, 1992; De Boer et.al., 2001). Sonmez (2006) reviewed the decision making methods for supplier selection and clustered them into several broad categories (as shown in Table 2.3):

- Artificial intelligence and expert systems
- Mathematical programming.
- Traditional (conventional) Multiple Criteria Decision Making (MCDM) techniques.
- Multivariate statistical analysis.
- Two more categories that are somewhat different from the categories mentioned earlier: group decision making and multiple methods.

Table 2.3: Decision making methods and tools for supplier selection*

	Category	Method
1	Artificial intelligence & expert systems	Neural networks (NN) Case-based reasoning (CBR)
2	Mathematical programming	Total cost based approaches Non-linear programming Mixed integer programming Linear programming Integer programming Goal programming Data envelopment analysis (DEA)
3	MCDM	AHP Outranking methods Multi-attribute utility theory (MAUT) Linear weighted point Judgmental modeling Interpretive structural modeling Categorical method Fuzzy sets
4	Multivariate statistical analysis	Structural equation modeling Principal component analysis Factor analysis Cluster analysis
5	Other decision making tools	Group decision making Multiple methods

* Adopted from Sonmez (2006)

Artificial intelligence based models are based on computer-aided systems that in one way or another can be "trained" by a purchasing expert or historic data. Wei et al. (1997) in their paper discuss about the neural network (NN) for the supplier selection. Comparing to other models for decision support system, NNs save a lot of time and money for 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. The other is the function using the neural network to select suppliers. This method incorporates qualitative and quantitative criteria. The NN

method saves money and time of system development. The weakness of this method is that it demands software and requires a qualified personnel expert on this subject.

Case-based reasoning (CBR) is a method for solving problems by making use of previous similar situations and reusing information and knowledge about such situations (Aamodt and Plaza, 1994).

Mathematical programming (MP) models allows the decision-maker to formulate the decision problem in terms of a mathematical objective function that subsequently needs to be maximized (e.g. maximize profit) or minimized (e.g. minimize costs) by varying the values of the variables in the objective function (e.g. the amount ordered with supplier X).

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

24

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.

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). Total cost of ownership (TCO) models attempt to include all quantifiable costs in the supplier choice that are incurred throughout the purchased item's life cycle. Degraeve and Roodhooft (1999) developed a mathematical programming model that uses total cost of ownership information to simultaneously select suppliers and determine order quantities over a multi-period time horizon.

Kasilingam and Lee (1996) develop a mixed-integer programming model to select the suppliers and determine the order quantities. The stochastic nature of demand is discussed in this model.

Karpak, et al. (1999) presented a visual interactive goal programming procedure that assists purchasing teams in the supplier selection process. Goal programming is a branch of multi-objective optimization, which in turn is a branch of multiple-criteria decision making (MCDM). It can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Each of these measures is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimized in an achievement function. This can

be a vector or a weighted sum dependent on the goal programming variant used. As satisfaction of the target is deemed to satisfy the decision maker, an underlying satisfying philosophy is assumed (Wikipedia, 2007).

Data envelopment analysis (DEA) is a mathematical programming method for assessing the comparative efficiencies of decision-making units (DMUs) where the presence of multiple inputs and outputs makes comparison difficult. DEA is a non-parametric method that allows efficiency to be measured without having to specify either the form of the production function or the weights for the different inputs and outputs chosen. This methodology defines a non-parametric best practice frontier that can be used as a reference for efficiency measures (Braglia and Petroni, 2000). Weber et al. (1998), Braglia and Petroni (2000) and Liu et al. (2000) used this approaches for supplier selection problem.

Particular stress was given to MCDM models used for the final supplier choice phase. Among them, many authors proposed the use of AHP (Saaty 1980) as a consistent and robust methodology to determine both the relative importance of criteria and the performance of candidates versus each criterion. More details about the AHP will be discussed in chapter three.

De Boer et al. (1998) explored the applicability of outranking methods to the problem of supplier selection. According to the authors, the main advantage of these techniques is twofold: on the one hand, outranking methods, such as ELECTRE (elimination and choice translating reality), make it possible to deal with uncertainty and vagueness featuring some selection criteria; on the other hand, these methods are compensatory, thus allowing alternatives comparison.

In early 1986, Timmerman (1986) proposed linear weighting models in which suppliers are rated on several criteria and in which these ratings are combined into a single score. The weighted point method 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 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 are fairly subjective.

Petroni and Braglia (2000) discuss the Principal Component Analysis (PCA) method which 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. The major limitation of this approach is it requires the knowledge of advanced statistical technique.

Cluster analysis (CA) is a basic method from statistics, which uses a classification algorithm to group a number of items, described by a set of numerical attribute scores put in such a way that the differences between items within a cluster are minimal while the differences between items from different clusters are maximal (Holt, 1998).

Single or multiple suppliers are selected depending on the sourcing strategy followed by the buying organization. If a firm follows a single sourcing strategy, the task is to select the 'best' supplier among all alternatives that satisfies the firm's requirements. In such a case, a single decision making method capable of ranking alternative suppliers, such as Multiple Attribute Utility Theory (MAUT) and AHP, can be used (Sonmez, 2006).

Multiple methods may be needed for selecting multiple suppliers if a multiple sourcing strategy is followed. This is because there are two types of decisions when a multiple sourcing strategy pursued by the buyer:

(i)   How many and which suppliers to select?

(ii)   How much purchase should be made from each supplier selected?

Some of the articles combined different models to deal with supplier selection process. Choy et al. (2002) for example, developed an Intelligent Supplier Management Tool (ISMT) using the Case-Based Reasoning (CBR) and Neural Network (NN) techniques to select and benchmark suppliers. Oboulhas et al.(2003) proposed to integrate a CBR, Analytical Network Process (ANP) and Linear Programming (LP) to solve the supplier selection problem. Ghodsypour and Brien (1998) integrated AHP and linear programming for the supplier selection. Most of these articles considered only supplier evaluation criteria (quality, cost, time, and environment) and the supplier's constraints to select suppliers.

2.6 The AHP and the Other Methods:

After summarizing the supplier selection methods in the previous section, it is necessary to explain the reasons for using this approach. Yahya and Kingsman (1999) analyzed different methods for decision-making problems, concluding that AHP is the more practical and flexible one.

The main drawback of the mathematical programming method is that it is limited to quantitative criteria (Sonmez, 2006). Another significant problem with using mathematical programming models is that most of them are too complex for practical use by operating managers. Artificial intelligence based models demand software, require a qualified personnel expert on this subject and use the previous similar situations and reusing information and knowledge about such situations. Multivariate statistical analysis requires the knowledge of advanced statistical technique.

The supplier selection methodology developed in this research is structured, unified, and capable of dealing with tangible and intangible measures. It is based on the

AHP. Most of the articles which employed MCDM models used AHP. It is a modern multi-criteria decision-making approach that provides a problem-solving framework and a systematic procedure for representing the elements of any problem (Saaty, 1990). It first structures the problem in the form of a hierarchy, to capture the criteria, sub-criteria, and alternatives. All the criteria are compared fairly to determine their relative weights. Then, the alternatives are compared fairly with regard to each criterion. The final outcome of the procedure is a score for each alternative.

AHP avoids the main drawback of the traditional linear scoring model, which assigns weights and scores arbitrarily. At the same time, it can make trade-off between the quantitative and qualitative criteria. The important advantages of AHP are its simplicity, robustness, and the ability to incorporate "intangibles" into the decision-making process (Saaty, 1980). Also, the user acceptability and confidence in the analysis provided by the AHP methodology is high compared with other multi-attribute decision approaches. It is a relatively easy approach to understand and apply. Even so, it has certain difficulties that arise when developing an appropriate framework that is acceptable and useful for management. It is a relatively practical method in supplier selection. Chapter three describes the basics of the AHP approach.

2.7 Supplier Selection in the Public Sector:

In most countries, government organizations are a major buyer of goods and services. Government organizations typically require suppliers to submit bids, and normally they award the contract to the lowest bidder. In some cases, the government purchases departments will make allowance for the supplier's superior quality or reputation for completing contracts on time. Government will also buy on a negotiated contract bases, primarily in the case of complex projects and in cases where there is

30

little competition (Kotler and Keller, 2006). Government purchases departments tend to favor domestic suppliers, so each country showed favoritism toward its nationals in spite of superior offers available from foreign firms.

It seems that the reviewed articles studied the purchasing activities of the private sector organizations. Surprisingly, there was no evidence of any research on how public organizations evaluate and select suppliers. This may be either because such research reported within contractor selection literature or the purchasing activities are carried out according to constrained laws, which would only provide a brief report to the organization concerned (Sonmez, 2006). It is known that the evaluation and selection of suppliers and/or contractors by public organizations is more complicated than by the privately owned organizations. Since the government ministries decisions are subject to public review, they require considerable paperwork from the suppliers, who often complain about excessive paperwork, bureaucracy, regulations, decision making relays, and frequent shifts in procurement personnel. While the final decision to select suppliers is made by the public ministries based on the principle "the best value for money", it seems that the private sector companies do not base their selection decisions solely on price but also other criteria such as quality, on-time delivery, after-sale services, buyer-seller relationships and so on.

Since the supplier selection is one of the most repeated and complex problems facing public sector ministries, its success requires consideration and comparison of many criteria for multiple alternatives selection (Bello,2003). Currently, selecting supplier from the long list available is carried out by the application of human judgment based on the committee members' experience and intuitions. Inconsistencies and the lack of flexibility in evaluating selection criteria limit this method (Chan,2003).

Therefore it will be extremely appropriate to utilize one of the MCDM approaches to solve supplier selection procedure difficulties, to rank the alternatives, and to come up with the best alternative for final selection.

2.8 Supplier Selection in the PNA:

The Palestinian National Authority (PNA) buys goods and services valued at $70 million yearly (CPAR, 2004). That makes it the largest buyer in the Palestinian territories. For businesses of all sizes, the PNA has been trying to simplify the contracting procedure and make bidding more attractive. Some firms participate in the government bids to enhance their position in the market and enhance their reputations by producing strong communications, preparing bids carefully, participating in the product specification phase.

The supplier selection in PNA faces many problems, but currently manages to function in a reasonably organized and acceptable manner, mainly because much of government procurement for purchasing goods is financed by donors. Donors are insisting on using sound procurement procedures in line with their own procurement guidelines, and much of the government procurement activity makes use of donor standard document formats and procedures. Purchasing goods financed in whole or in part by a loan or a credit or grant from the World Bank and other donors is governed by the procurement of goods, works, and services guidelines (World Bank, 2004).

Unfortunately, the general supplies department which is responsible for buying commodity related to the ministries' and governmental directorates according to the active Bylaw no.(9) for the year 1999 of the general supplies follows a very weak procedure and a challenging task in the selection of suppliers. This is due to many

factors influencing the selection process, such as strong opposition to the present practices for suppliers selection, unclear criteria for evaluating the suppliers, complexity and validity of many suppliers with different levels of experience, specialization, staffing and after sales services. Also the selection of suppliers is not done from predetermined list of suppliers. This may cause a failure to the selection process since it is necessary to do pre-qualification for the suppliers according to predetermined set of selection criteria.

The criteria and methodology for supplier selection of the successful bidder are not outlined clearly in the bidding documents (CPAR, 2004). The factors other than price to be used for determining the lowest evaluated bid should be expressed in monetary terms, or given a relative weight in the evaluation provisions in the bidding documents. The evaluation of bids submitted by the suppliers should specify the relevant factors in addition to price to be considered in bid evaluation and the manner in which they would be applied for the purpose of determining the lowest evaluated bid. For goods and equipment, other factors may be taken into consideration including, among others, payment schedule, delivery time, operating costs, efficiency and compatibility of the equipment, availability of service and spare parts, and related training, safety, and environmental benefits.

Chapter Three

Multiple Criteria Decision Making (*MCDM*)

3.1 Introduction

3.2 Influential Factors of the Decision

3.3 MCDM on Supplier Selection Problem

3.4 MCDA Methods

3.5 The Analytic Hierarchy Process (AHP)

3.6 Making Group Decisions

3.7 The Decision Support System

Chapter Three

Multiple Criteria Decision Making (MCDM)

3.1 Introduction:

Multiple Criteria Decision Making (MCDM) approaches are major parts of decision theory and analysis. They are efficient tools for making critical decisions in many fields. They are utilized when decision-makers are faced with difficulties because of more than one objective or criteria that have to be satisfied in order to arrive at a successful and final selection from the available alternatives (Belton, 1990). The MCDM approach involves structuring the problem, evaluation of criteria and alternatives, prioritization, and synthesis.

In the MCDM, the first task is to obtain a set of objectives or requirements for the achievement of the overall objective. In this study, supplier selection will be the overall objective and the applicable criteria considered for the supplier selection are listed in section (2.4). Identification of these objectives or requirements constitutes an important component of the MCDM (Saaty, 1980).

The procedure will carry out comprehensive evaluations of alternatives and objectives for the purpose of selecting the best alternative. The decision makers will have to determine the criteria that are important to the selection procedure and each criterion is assigned a weight according to relative importance. After listing all the applicable criteria and determining their degree of importance, a list of alternatives would be proposed and subjected to rigorous evaluation considering all of the established criteria. Alternatives that satisfy the predetermined important criteria will be

ranked accordingly, and the alternative that scores the highest should be selected as the best solution to the selection's overall objective.

AHP is a multiple criteria decision-making approach based on the reasoning, knowledge, experience, and perceptions of experts in the field. It is a robust technique that allows managers to determine preferences of criteria for selection purposes, quantify those preferences, and then aggregate them across diverse criteria (Saaty, 1980). It is a relatively easy approach to understand and apply. Moreover, there has been a wide application of AHP in many fields and a lot of literature was found to report the use of AHP as a decision-making tool in the process of supplier selection. Thus, AHP was used in this study to overcome the inconsistency associated with the selection problem whose decision criteria are expressed in subjective measures. This consistency is exactly what we need during any supplier selection procedure.

3.2 Influential Factors of the Decision:

In order to derive a particular set of criteria and employ pair-wise comparisons of selection criteria for use in this study, it is necessary to identify the influential factors to do that. In this study, we will take the opinion of the decision maker to do pair-wise comparisons of selection criteria. Decision maker is the person with whom the decision analysis is referred. He occupies a central place in the study process. Sometimes, the decision maker is not an individual people but a group of different actors, such as purchasing managers and the experts in the field of purchasing (Tille and Dumount, 2003).

The subjectivity of the decisions is the faithful reflection of the system of proper values of the decision maker. However this grid of evaluation on which the decision is

based, in a conscious way or not, doesn't depend intrinsically on the characteristics of the decision maker. He is being indeed strongly conditioned by many external factors. Tille and Dumount (2003) showed that in Figure 3.1 and as follow:

- **Institutional constraints** (lawful frame of the political institutions, structure of distribution of the power, traditions) which create a model of behavior conditioning the decision maker.

- **Legal constraints**: the legislative texts must be respected by the decision maker, what can appear very constraining as for its independence of action.
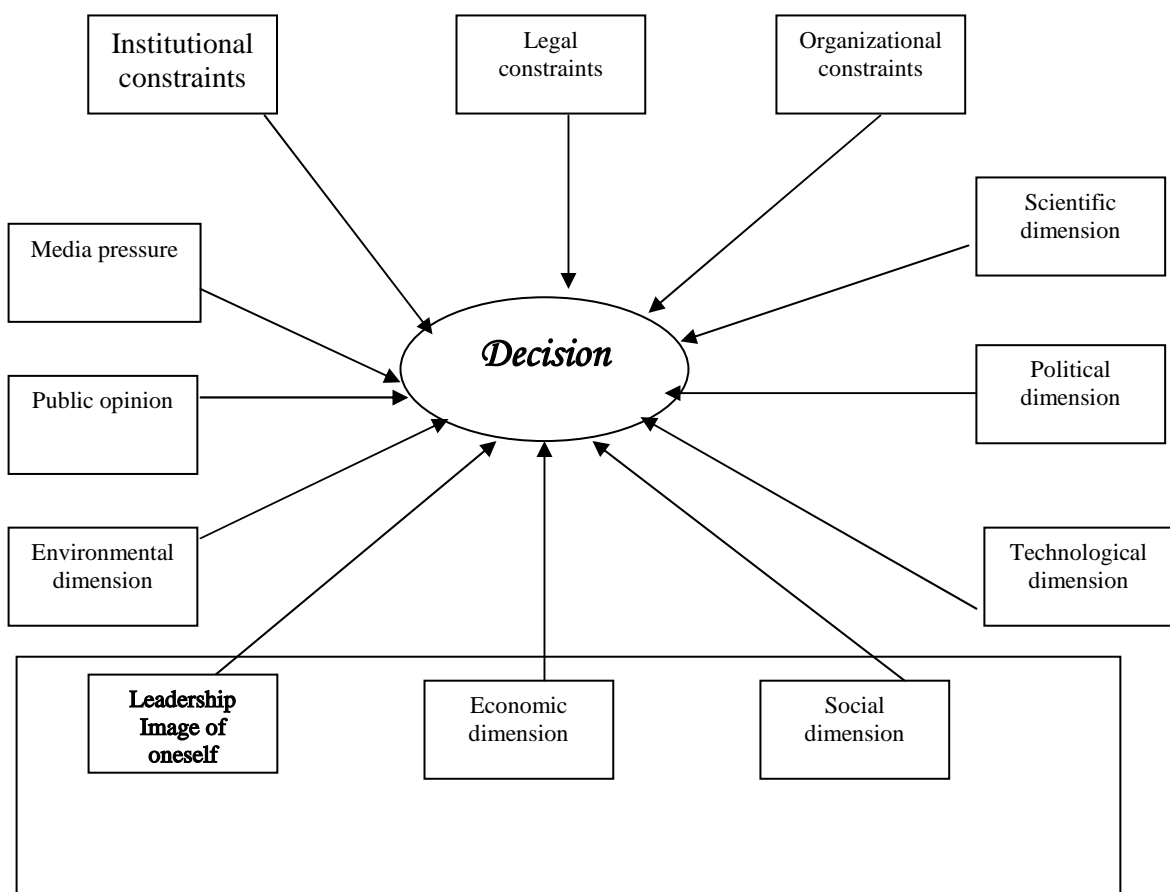
Figure 3.1: Influential factors of the decision (Tille and Dumount, 2003)

- **Organizational constraints**: distribution of competences and relations between the various services of the administration.

- **Scientific dimension**: the experts can have contradictory opinions what can involve the decision maker to delay his decision to have more elements for make his analysis.

- **Political dimension**: various special interest groups can influence directly or indirectly the decision. The ideological values (conservative, progress, etc.) defended by the decision maker influence also his decision.

- **Technological dimension**: trust or reserve in the effects of technology.

- **Social dimension**: effects on the population, accessibility with a mobility of quality, principles of equity as well as the values and beliefs of the decision maker

- **Economic dimension**: public financial statement and direct and indirect effects on the economic activities

- **Environmental dimension.**

- **Public opinion**: the democracy consists in delegating to the decision maker a power which can be significant but which is limited in time. The public satisfaction of the public opinion, by extension of the voters, is essential for a political actor.

- **Media pressure**: certain projects have a significant media cover

- **Image of oneself and leadership** : to make a decision is in oneself an act of being able.

3.3 MCDM on Supplier Selection Problem:

MCDM problem exists everywhere in our daily life. The range of MCDM is from the simple problem of selecting an adviser or an university to complex engineering application problems, and to more complicated social problems of designing alternative future outcomes of a developing country, evaluating political candidacies and so on (Lee et al., 2001). "MCDM *is the study of methods and procedures by which concerns*

about multiple conflicting criteria can be formally incorporated into the management planning process", as defined by the International Society on MCDM. It is also referred to as:

- *Multi-Criteria Decision Analysis (MCDA)*

- *Multi-Dimensions Decision-Making (MDDM)*

- *Multi-Attributes Decision Making (MADM)*

The process of MCDM is always confused with decision makers, because it must have a trade-off between all criteria. MCDM system can usually help decision makers quantify and evaluate each criterion and rank all alternatives. Opricovic and Tzeng (2004) defined the main steps of multi-criteria decision-making as the following:

(1) Establishing system evaluation criteria relating system capabilities to goals;

(2) Developing alternatives systems for achieving the goals i.e. generating alternatives;

(3) Assessing alternatives in terms of criteria;

(4) Employing a standard multi-criteria analysis tool or techniques;

(5) Accepting one alternative as optimal choice from the analysis outcome of step (4);

(6) Aggregating new information and going into the next iteration of multi-criteria optimization if the final solution is not accepted.

Weber et al. (1991) pointed out that some criteria may be conflicting by nature, therefore a strategic evaluation approach may require some compensatory trade-offs, where poor scores on some criteria may be compensated by high scores on other ones. Incidentally, this is indeed the main reason why MCDM methods can be usefully adopted for supplier evaluation (Bottany and Rizzi, 2005).

Supplier selection is also a multi-criteria decision making problem (Saaty, 1980). In general, every supplier stands his advantages in some particular positions, but he maybe has some weaknesses in the other directions. A suppliers ability in every aspect can't simultaneously conform to all standards that the buyer requests. Consequently, the buyer must make several appropriate criteria firstly. Then, to each supplier, the buyer performs the comprehensive and consistent evaluation based on these criteria. Finally, we can cooperate with a supplier that gets the optimal rating through a series of systematic measurement method.

3.4 MCDA Methods:

There are many different MCDA methods. MCDA methods evolved as a response to the observed inability of people to effectively analyze multiple streams of dissimilar information.. They are based on different theoretical foundations such as optimization, goal, or outranking models, or a combination of them (Linkov et al., 2004). The common purpose of these diverse methods is to be able to evaluate and choose among alternatives based on multiple criteria using systematic analysis that overcomes the observed limitations of unstructured individual and group decision-making.

The main role of the techniques is to deal with the difficulties that human decision-makers have been shown to have in handling large amounts of complex information in a consistent way. Different methods require different types of raw data and follow different optimization algorithms. Some techniques rank options, some identify a single optimal alternative, some provide an incomplete ranking, and others differentiate between acceptable and unacceptable alternatives. In recent years, several

methods have been proposed to deal with MCDA problems. These are (Belton and Stewart, 2002):

- **Value function methods**: These methods synthesize assessments of the performance of alternatives against individual criteria, together with inter-criteria information reflecting the relative importance of the different criteria, to give an overall evaluation of each alternative indicative of the decision makers' preference.

- **Goal and reference point methods**: The decision maker specifies some goals to be achieved; if they are achieved the decision maker is assumed to be satisfied; if not the method seeks to get as "close as possible" to the goals.

- **Outranking methods**: These methods attempt pair-wise or global comparison among alternatives. An alternative *a* is said to outrank another alternative *b* if, taking into account all the available information regarding the problem and the decision maker's preferences, there is a strong enough argument to support a conclusion that *a* is at least as good as *b* and no strong argument to the contrary.

MCDA methods differ, however, in the way the idea of multiple criteria is considered, the application and computation of weights, the mathematical algorithm utilized the model to describe the system of preferences of the individual facing decision-making, the level of uncertainty embedded in the data set in the process (De Montis et al., 2000). The MCDA technique selected will typically need to (De Montis et al., 2000):

- Deal with complex situations (criteria), consider different scales and aspects (geographical scales, micro-macro-link), social/technical issues and type of data (uncertainties)

41

- Involve more than one decision maker (actors, communication, and transparency)

- Inform stakeholders in order to increase their knowledge and change their opinion and behavior (problem structuring, tool for learning, transparency).

The review literature also revealed that there are a large number of decision making methods and tools proposed for supplier selection and their number is still rising. *According to DTER (2000) there are several reasons why this is so:*

- There are many different *types of decision* which fit the broad circumstances of MCDA.

- The *time* available to undertake the analysis may vary.

- The amount or nature of *data* available to support the analysis may vary.

- The *analytical skills* of those supporting the decision may vary.

- The *administrative culture and requirements* of organizations vary.

3.5 The Analytic Hierarchy Process:

In the complex world system, the human is forced to deal with more problems than the resources to handle. To deal with such complex and unstructured problems, the need to order the priorities, to agree that one objective outweighs another, and to make trade-offs to serve the greatest common interest or overall objective. But with complex problems where a wide margin of error is possible in making the tradeoffs, it is always difficult to agree on which objective outweighs the other and to reach the best solution. The above difficulty proves the need to a framework, so the problems can be viewed in a complex but organized framework that allows for interaction and interdependence among factors and yet still enables the human to think about them in a simple way. The AHP provides this kind of framework (Bayazit and Karpak, 2005).

The AHP method is used for MCDM extensively and has been successfully applied to many practical decision-making. The AHP provides the relative ease but theoretically strong multi-criteria methodology for evaluating alternatives. It enables decision makers to use a simple hierarchy structure to deal with a complicated problem and to evaluate both quantitative and qualitative data in a systematic methodology under conflicting multi-criteria (Lee et at., 2001).

AHP is a powerful decision-aiding tool that can deal with the intuitive, the rational, and the irrational when making decisions considering the suitability of large number of selection factors and alternatives. AHP is an appropriate MCDM approach for conducting both deductive and inductive evaluation that allows the consideration of several criteria and alternatives at a time, along with the benefit of a feedback mechanism and numerical tradeoffs. It is becoming a more popular and practical tool, because it enables the decision-makers to resolve complex problems by simplifying and expediting the natural decision making processes. Basically AHP is a method designed to examine complex issues by breaking down the complex, unstructured problem into the following four stages: constructing a hierarchy, pair-wise comparisons, priority vector generation and synthesis (Saaty, 1980).

The evaluation is conducted by using the developed pair-wise comparison judgments that result in the numeric representation of each comparison by a point estimate. The calculation of priorities (or prioritization) is carried out using the Eigenvector method, and the synthesis is done using the linear additive value function.

The AHP provides an effective structure for group decision making by imposing a discipline on the group's thought processes. In addition, the consensual nature of

group decision making improves the consistency of the judgments and enhances the reliability of the AHP as a decision-making tool. The AHP combines the deductive and system approaches into one integrated, logical framework. The deductive approach focuses on the parts whereas the system approach concentrates on the working of the whole (Saaty, 1990).

3.5.1 The AHP Applications:

The applications of AHP to complex decision situations have numbered in the thousands and have produced extensive results in problems involving alternative selection, planning, resource allocation, and priority setting. AHP can also be applied to a group decision where judgments made by all the individuals in a group are combined (Saaty and Vargas, 2005). Broad areas where AHP has been successfully employed include: selection of one alternative from many; resource allocation; forecasting; total quality management; business process re-engineering; quality function deployment, and the balanced scorecard (Saaty and Vargas, 1991). The AHP, however, is best used along with or in support of other methodologies: when deciding how many servers to employ in a queuing situation, in conjunction with queuing theory to measure and synthesize preference with respect to such objectives as waiting times, costs, and human frustration. When using a decision tree to analyze alternative choices or chance situations, the AHP is used to derive probabilities for the choice nodes of the decision tree, as well as to derive priorities for alternatives at the extremities of the decision tree.

Many such applications are never reported to the outside world, because they take place at high levels of large organizations where security and privacy considerations prohibit their disclosure (Barbarosoglu and Yazgac,1997). But some uses of AHP are discussed in the literature. Recently these have included:

- Deciding how best to reduce the impact of global climate change (Berrittella, 2007).

- Quantifying the overall quality of software systems in Microsoft Corporation (McCaffrey, 2005)

- Selecting university faculty in Bloomsburg University of Pennsylvania (Grandzol, 2005).

- Deciding where to locate offshore manufacturing plants (Atthirawong, 2002),

- Assessing risk in operating cross-country petroleum pipelines for American Society of Civil Engineers (Dey, 2003).

- Deciding how best to manage U.S. watersheds (U.S. Department of Agriculture) (De Steiguer, 2003)

- AHP was recently applied to a project that uses video footage to assess the condition of highways in Virginia. Highway engineers first used it to determine the optimum scope of the project, then to justify its budget to lawmakers (Larson, 2007)

An application of the AHP to the supplier selection process was first described by Barbarosoglu and Yazgac (1997). It has subsequently been compared with the Total Cost of Ownership method (Bhutta and Huq 2002), applied on vendor selection (Chan 2003), used to tackle multi-item/person/criterion decisions (Chan and Chan 2004), used along with the grey rational scale by Tseng and Lin (2005) to rate suppliers and used by Masella and Rangone (2000) as a contingency approach for supplier selection depending on the time frame and the content of co-operative customer/supplier relationships.

3.5.2 AHP Steps:

The AHP approach, as applied to the supplier selection problem, consists of the following five steps (Bello, 2003):

1. Specify the set of criteria for evaluating the supplier's proposals, then construct a decision hierarchy by breaking down the decision problem into a hierarchy of its elements..

2. Obtain the pair-wise 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, then determine whether the input data satisfy a consistency test; if not, redo the pair-wise comparisons.

4. Using the information in step 3, obtain the pair-wise 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, a final priority vector of each supplier is obtained by synthesizing all the priority vectors to achieve the goal of the hierarchy.

3.5.2.1 Establishment of a Structural Hierarchy:

The first step in the AHP is constructing the hierarchy of the decision problem. There is no certain rule that can be followed for constructing a hierarchy. This step allows a complex decision to be structured into a hierarchy descending from an overall objective to various criteria, sub-criteria, and so on until the lowest level. The main principle is brainstorming the complex problem, listing all of the important ideas,

factors and alternatives, and then arranging them in a hierarchy that will enable the comparison of the elements of lower levels with some or all elements in the next higher level. It is a creative way of exploiting human mind's ability to simplify a problem by breaking it down into the constituent elements that include the overall goal, the criteria and the decision alternatives (Saaty, 1990). Following this process large amount of information can be integrated into the structure of the problem to form a more complete picture of the whole system. Figure (3.2) illustrates such a hierarchy.

The objective or the overall goal of the decision is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the last level of the hierarchy. According to Saaty (2001) a hierarchy can be constructed by creative thinking, recollection and using people's perspectives. He further notes that there is no set of procedures for generating the levels to be included in the hierarchy. Zahedi (1986) commented that the structure of the hierarchy depends upon the nature or type of managerial decision. Also, the number of the levels in a hierarchy depends on the complexity of the problem being analyzed and the degree of detail of the problem that an analyst requires to solve. As such, the hierarchical representation of a system may vary from one person to another.
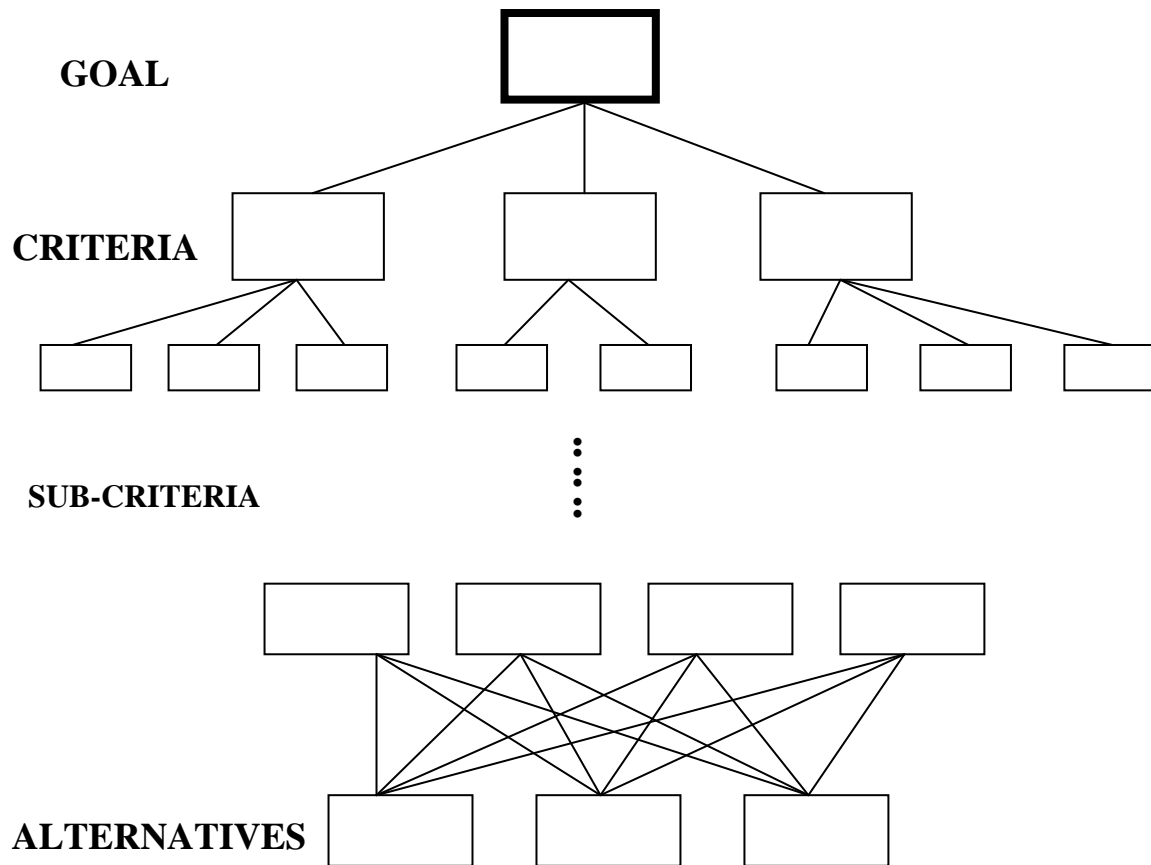
Figure 3.2: General guidelines for constructing hierarchy (Chan and Chan, 2004)

The completed hierarchy can be modified as needed to accommodate new and important elements that were not included during the development of the hierarchy. The uses of computer programs based on AHP are constructed with this flexibility in mind. The overall depth of detail of the hierarchy depends on the person's experience and familiarity with the subject, which will determine what to include and where to include it. When constructing hierarchies one must include enough relative detail (Saaty, 1990):

- To represent the problem as thoroughly as possible, but not so thoroughly as to lose sensitivity to change in the elements.

- To consider the environment surrounding the problem.

- To identify the issues or attributes those contribute to the solution.

- To identify the participants associated with the problem.

3.5.2.2 Pair-wise Comparison:

Once the hierarchy has been structured, the next step is to establish the priorities for elements (criteria and alternatives) presented in the hierarchy. The AHP uses the pair-wise comparison to do this. The first step is to make pair-wise comparison. It is to compare the elements in pairs against a given criterion. A set of comparison matrices of all elements in a level of the hierarchy with respect to an element of the immediately higher level are constructed so as to prioritize and convert individual comparative judgments into ratio scale measurements. The preferences are quantified by using a nine-point scale. The meaning of each scale measurement is explained in Table 3.1

Table 3.1: Scale of preference between two elements*

Preference Weights/ Level of Importance	Definition	Explanation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extremely	The evidence favoring one activity over another is of the highest degree possible of affirmation
2,4,6,8	Intermediate values	Used to represent compromise between the preferences listed above
	Reciprocals for inverse comparison	

*Adopted from Saaty (1996)

The pair-wise comparisons are given in terms of how much element A is more important than element B. The nodes in the hierarchy represent alternatives to be

prioritized, and the lines reflect the relationship between the alternatives of two levels. Each relationship is weighted according to the strength of influence that an alternative at the same level K exerts on alternative at level K-1, where K = 1,2,3, ….. N. The element that appears in the left-hand column of the matrix is always compared with an element appearing in the top row, and the value is given to the element in the column as it is compared with the element in the row. If element A dominates element B, then the integer is entered in row B column A. But, if element B dominates element A then the reverse occurs. For n elements there are n (n-1)/2 judgments required to develop the required matrix (Saaty, 1996).

As a general rule of thumb, a hierarchy is developed from more general upper levels to the particular bottom levels (evaluating the importance of the criteria and then the preference for the alternatives) or from the uncertain or uncontrollable upper levels to the more certain or controllable bottom levels (evaluating the preference of the alternatives with respect to each criterion before evaluating the importance of the criteria), as shown in Fig.(3.2). By doing this, decision-maker gains insights into the tradeoffs involved and will be in a better position to evaluate the relative importance of the criteria.

The final solution results in the assignment of weights to the alternatives located at the lowest hierarchical level (level K). This represents the sample pair-wise comparison matrix (D). Let H1, H2, . . ., Hn be the set of elements, while aij represents a quantified judgment on a pair of elements Hi, Hj . The relative importance of two elements is rated using a scale with the values 1, 3, 4, 5, and 9 given by Saaty (1996) and is explained in the Table (3.1) gained an n-by-n matrix D as follows:

$$D = [a_{ij}] \quad \begin{array}{c|cccc} & H_1 & H_2 & \ldots & H_n \\ \hline H_1 & 1 & a_{12} & \ldots & a_{n1} \\ H_2 & 1/a_{12} & 1 & \ldots & a_{n2} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ H_n & 1/a_{1n} & 1/a_{2n} & \ldots & 1 \end{array}$$

where $a_{ii} = 1$ and $a_{ji} = 1/a_{ij}$, i, j = 1, 2, . . ., n.

In matrix D, the problem becomes one of assigning to the n elements H_1, H_2,.., H_n.

Thus D is a reciprocal matrix.

3.5.2.3 The Synthesis of Priorities:

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number of elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it links to. After all matrices are developed and all pair-wise comparisons are obtained, eigenvectors or the relative weights (the degree of relative importance among the elements), global weights, and the maximum eigenvalue (λ_{max}) for each matrix are calculated (Saaty, 1990).

Analytic, the first word in AHP, means separating a material or abstract entity into its constituent elements. In contrast, synthesis involves putting together or combining parts into a whole. The synthesis proceeds in the three following steps (Saaty, 1980):

- Sum the value of each column of pair wise comparison matrix.

- Divide each entry in the pair-wise comparison matrix by its column total. This will produce the normalized pair-wise comparison matrix.

- Then, determine the average of each row of the normalized matrix by adding the value in each row of the normalized matrix and dividing by the number of entries in each row. This provides the relative priorities of the elements being compared (Saaty, 1996).

Further, AHP uses the synthesis to develop an overall priority for ranking. The relative weights of various levels obtained are aggregated to produce a vector of composite weights which will serve as a ranking of the decision alternatives in achieving the most general objective of the problem (Saaty, 1980). The composite relative weight vector of elements at K^{th} level with respect to that of the first level may be computed by the following equation:

$$C (I, K) = \prod_{l=2}^{k} B_i \qquad (3.1)$$

Where:

- C (I , K) is the vector of composite weights of elements level k with respect to the element on level I,
- B is the n_{i-1} by n_i matrix rows consisting of estimating W vectors.
- n_i represents the number of elements at level i.

Repeating the aggregation process yields relative weights of elements that are at the lowest level of the hierarchy with respect to the decision at the first level.

3.5.2.4 Consistency:

Being consistent is often thought of as a prerequisite to clear thinking. Depending on the decision needed, the consistency is a useful way to test the consistency of the decision-maker's judgment in providing his judgments to the

comparison matrix. However, it is very difficult to achieve perfect consistency. Analytic Hierarchy Process is useful to check the judgments provided in each hierarchy. An inconsistency ratio of about 10% or less is usually considered acceptable, but the particular circumstance may warrant the acceptance of a higher value (Saaty, 1990).

W (weighted sum vector), **CI** (consistency index), **CR** (consistency ratio), and **RI** (ratio index) are used for checking the consistency.

w is determined from the following equation:

$$\mathbf{D.w} = \lambda_{max}\,\mathbf{w} \qquad\qquad (3.2)$$

Where D is the observed matrix of pair-wise comparison, λ_{max} is the principal eigenvalue of D; w is its right eigenvector. The λ_{max} value is an important validating parameter in AHP. It is used as a reference index to screen information by calculating the consistency ratio CR of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation. The consistency ratio is calculated as per the following steps (Saaty, 1990):

(i) Calculate the eigenvector or the relative weights and λ_{max} for each matrix of order *n*

(ii) Compute the consistency index for each matrix of order *n* by the formula:

$$\mathbf{CI} = (\lambda_{max} - n)/(n - 1) \qquad\qquad (3.3)$$

(iii) The consistency ratio is then calculated using the formula:

$$\mathbf{CR = CI / RI} \qquad\qquad (3.4)$$

where RI is a known random consistency index obtained from a large number of simulation runs and varies depending upon the order of matrix. In the above equation, the closer the λ_{max} is to *n,* the more consistent are the observed values of D, and hence the algebraic difference between λ_{max} and n is a measure of consistency (Saaty, 1996).

Table 3.2 shows the value of the random consistency index (RCI) for matrices of order 1–10 obtained by approximating random indices using a sample size of 500.

Table (3.2) Average Random Consistency Index (RCI) based on matrix size*

N	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

*Adopted from Saaty (1996)

According to Saaty (1996) the acceptable CR range varies according to the size of matrix i.e. 0.05 for a 3-by-3 matrix, 0.08 for a 4-by-4 matrix and 0.1 for all larger matrices, $n \geq 5$. If the value of CR is equal to, or less than that value, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved.

In general, a CR value of 10% or less is acceptable. But any CR value of more than 10% is not acceptable and the judgments in D matrix table should be reconsidered to resolve inconsistency judgments provided in pair wise comparison (Saaty, 1996). An approximation to the eigenvalue can be calculated by multiplying the total of each column in a judgment matrix by its corresponding vector of weights. The approximation is exact when the exact vector of priorities is used.

The consistency index of the entire hierarchy is obtained by multiplying the Consistency Index of each matrix by the priority of the criterion used for the comparisons, and all such quantities.

To check the consistency of the entire hierarchy, compare the CI of the hierarchy with its counterpart when the consistency indices of all matrices are replaced by average random judgment consistency indices for matrices of the same size (Table 3.2). The CR should not exceed l0%. If it is more than l0%, then the quality of the judgments should be improved, perhaps by revising the manner in which the questions are asked in making the pair-wise comparisons. If this fails to improve consistency, then it is likely that the problem should be more accurately structured, that is, grouping similar elements under more meaningful criteria. A return to priority setting would be required, although only the problematic parts of the hierarchy may need revision (Saaty, 1996).

3.5.3 Advantages of AHP to Supplier Selection Problems:

To deal with complex problems, we must get away as much as possible from complicated manners and methods anticipate the solution of complex problems. Unlike many traditional decision-making methods used to deal with these complex problems, the proposed process should not require a constant specialized expertise to layout the appropriate steps leading to the required solutions (Saaty, 1996).

Sarkis and Surrandaj (2005) claimed that, "the AHP approach offers several advantages over the other techniques, despite certain drawbacks such as rank reversal and the number of judgment elicitations that are needed". AHP is the methodology which, if carefully conducted, will successfully satisfy the above objectives, and will have the following usage advantages (Chan, 2003):

- First, as compared to other MCDM approaches, AHP is not proportionately complicated, and this helps improve management understanding and transparency of the modeling technique.

- Second, it has the supplemental power of being able to mix quantitative and qualitative factors into a decision.

- Third, this approach can be fit together with other solution approach such as optimization, and goal programming.

- Fourth, AHP may use a hierarchical structuring of the factors involved. The hierarchical structuring is universal to the composition of virtually all complex systems, and is a natural problem-solving paradigm in the face of complexity.

- Fifth, in AHP, judgment elicitations are completed using a decompositional approach, which has been shown in experimental studies to reduce decision-making errors.

- Sixth, AHP has also been validated from the decision makers perspective as well in recent empirical studies.

- Seventh and last, AHP is a technique that can prove valuable in helping multiple parties (stakeholders) arrive at an agreeable solution due to its structure, and if implemented appropriately can be used as a consensus-building tool.

3.5.4 Disadvantages of AHP to Supplier Selection Problems:

A number of criticisms have been launched at AHP over the years:

- Use of this statistical method is clearly not straightforward for most users and it makes the process quite cumbersome (De Boer et al., 2001).

- Consensus may need to be reached by reviewing of the models with team members, i.e. it may be a time-consuming activity (Barbarosoglu and Tazgac, 1997).

- There is no single hierarchy for most supplier selection problems (Rebstock and Kaula, 1996).

- Heavily based on the principle that experience, knowledge and judgment of decision-makers are at least as valuable as the data they use, but human judgment is always subjective and has bias towards their own intuitive thought processes (Rebstock and Kaula, 1996).

- Cannot effectively take into account risk and uncertainty in assessing the supplier's potential performance because it presumes that the relative importance of criteria affecting supplier's performance is known with certainty.

- Characteristic property of AHP is that it is fully compensatory that this might not always be realistic. In addition, the assumption of comparability is not valid due to lack of information or unwillingness to compare two alternatives with respect to some criterion, i.e. it is costly to obtain the necessary information (De Boer et al. 1998).

3.6 Making Group Decisions:

The AHP allows group decision making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve it by the AHP steps. Brainstorming and sharing ideas and insights (inherent in the use of Expert Choice in a group setting) often leads to a more complete representation and understanding of the issues (Al-Harbi, 2001). Group discussion is the preferred approach when judgments must be made about the value of different alternatives. As

stated by the well known scientist Saaty (1990): "The AHP can be used successfully with a group. In fact, brainstorming and sharing ideas and insights often lead to a more complete representation and understanding of the issues than would be possible for a single decision-maker. But group sessions can also pose special problems."

When the analytic hierarchy process is used in a group session, the group members structure the problem, provide the judgments, debate the judgments, and make a case for their values until consensus or compromise is reached. In an ideal situation, the group is small and the participants well informed, highly motivated, and in agreement on the basic question being addressed (Rebstock, and Kaula, 1996). They are also willing to participate fully in a rigorous, structured process whose outcome will partly determine their future activities, no matter what differences of opinion still surround the results of the process. Again ideally, the group is patient enough to reconsider the subject so that, through iteration, the remaining differences of opinion are debated and an agreement is reached or at least the range of differences is narrowed.

But such a scenario is the exception. Often the participants are unequal in their expertise, influence, and perspective and cooperation may take some coaxing by the leader. Patience on the part of the leader and the group is highly desirable; an unhurried, structured group discussion can yield a more satisfactory outcome than one achieved quickly and with little debate (Rebstock, and Kaula, 1996).

3.6.1 Preliminary Steps:

First the participants should be comfortable and well provided with writing materials, refreshments, adequate lighting, and so on. If the AHP is being used for the

first time, explaining how it works, illustrating it with simple applications and allowing for a question-and-answer period are necessary.

A computer terminal makes it possible to obtain answers immediately and to test the consequences of judgments with respect to sensitivity and consistency. A good way to begin the session is by brainstorming the overall focus of the problem or plan. Several suggestions may be made, from which one is selected as most representative of the current overall concern. The important thing is to define the objective of the discussion clearly at the very beginning.

3.6.2 Constructing the Hierarchy:

Breaking down a complex issue into different levels is particularly useful for a group with widely varying perspectives. Each member can present his or her own concerns and definitions, no matter what the level may be. Then the group is assisted in identifying the overall structure of the issue. In this way agreement can be reached on the higher-order and low-order aspects of the issue through a clustering and ordering of all the concerns that members have expressed (Al Besher, 1998).

The group then agrees on how it will proceed to enter judgments. The whole group might start at the top level and then progress to lower ones. It may delegate to subgroups the responsibility of considering, subdividing further, or setting priorities on a particular level, or it may choose a combination of these alternatives.

3.6.3 Setting Priorities and Synthesizing:

Group priority setting is by nature interactive and noisy and involves bargaining and persuasion. This lively interaction need not be perfectly orchestrated, the

participants may feel regimented and intimidated. Those who have no patience for the process should be allowed simply to observe or, if they wish, to leave the room and return when the process is completed (Al Besher, 1998). Some need coaxing and encouragement to participate or to express their feeling. In a large group the process of setting priorities is easier to handle by dividing the members into smaller, specialized sub-groups, each dealing with an issue of particular interest or one in which members have special expertise. When the subgroups rejoin for a final justification, the values in each matrix can be debated and revised if desired.

The debate could be eliminated and individual opinions taken by questionnaire. The final values are derived from the geometric mean of the judgments. Taking the geometric mean of individual judgments is one way to solve a lack of consensus on values after debate. Another method of resolving conflict is to vote on the proposed values. The final solution can also be obtained as a range of values that represent the range of judgments.

The AHP does not subvert or force human nature. There is no guarantee that all aspects of dissent can be harnessed, nor should they be. Dissent is a valuable basic process that should not be banned in a group interaction. But dissent must eventually lead to some kind of cooperation if anything is to be accomplished (Saaty, 2001).

3.7 The Decision Support System:

3.7.1 Introduction:

The human mind is a mysterious tool of the human's body that makes decisions in mysterious but systematic ways. Basic instincts, preferences, environmental factors,

and an individual's previous experience are factors that influence the human mind (Al Besher, 1998). This causes it to make biased decisions. There is no way to remove these factors from human decision-making, but we can employ a framework to help make more logical and less biased decisions, taking our feelings and intuition into consideration. The Expert Choice (EC) version 11.5 is a practical tool for the implementation. The EC system is a valuable and flexible software package for performing multiple criteria decision analysis, with its capacity to conduct massive computations (EC, 2007).

EC is a powerful software tool based on the Analytic Hierarchy Process (AHP). It assists the decision makers in solving complex problems involving many criteria and several alternatives. It organizes the various factors of a problem into an upside-down tree hierarchy. Its solution to a problem reflects the expertise of the decision maker, not the computer. The judgments of decision makers form the basis of the EC evaluation process, and the decision maker makes true logical decisions using the helps of EC to make an informed choice based on his knowledge, experience and preferences.

The following suggestions and recommendations are suggested in the Expert Choice software manual (EC, 2007).

1. Group decisions involving participants with common interests are typical of many organizational decisions. Even if it is assumed a group with common interests, individual group members will each have their own motivations and, hence, will be in conflict on certain issues. Nevertheless, since the group members are supposed to be striving for the same goal and have more in common than in conflicts, it is usually best to work as a group and attempt to

achieve consensus. This mode maximizes communication as well as each group member's stake in the decision (Saaty, 2001).

2. An aspect of using EC is that it minimizes the difficult problem of group think or dominance by a strong member of the group. This occurs because attention is focused on a specific aspect of the problem as judgments are being made, eliminating drift from topic to topic as so often happens in group discussions. As a result, a person who may be shy and hesitant to speak up when a group's discussion drifts from topic to topic will feel more comfortable in speaking up when the discussion is organized and attention turns to his area of expertise (Rebstock, and Kaula, 1996). Since EC reduces the influences of group think and dominance, other decision processes such as the well known Delphi technique may no longer be attractive. The Delphi technique was designed to alleviate group-think and dominance problems. However, it also inhibits communication between members of the group. If desired, EC could be used within the Delphi context (Saaty, 2001).

3. When EC is used in a group session, the group can be shown a hierarchy that has been prepared in advance. They can modify it to suit their understanding of the problem. The group defines the issues to be examined and alters the prepared hierarchy or constructs a new hierarchy to cover all the important issues. A group with widely varying perspectives can feel comfortable with a complex issue, when the issue is broken down into different levels. Each member can present his own concerns and definitions. Then, the group can cooperate in identifying the overall structure of the issue. In this way, agreement can be reached on the higher-order and lower-order objectives of the problem by including all the concerns that members have expressed (Rebstock, and Kaula,

1996). The group would then provide the judgments. If the group has achieved consensus on some judgment, input only that judgment. If during the process it is impossible to arrive at a consensus on a judgment, the group may use some voting technique, or may choose to take the `average' of the judgments. The group may decide to give all group members equal weight, or the group members could give them different weights that reflect their position in the project. All calculations are done automatically on the computer screen (Al Besher, 1998).

4. The Group Meeting: While EC is an ideal tool for generating group decisions through a cohesive, rigorous process, the software does not replace the components necessary for good group facilitation. There are a number of different approaches to group decision-making, some better than others. Above all, it is important to have a meeting in which everyone is engaged, and there is buy-in and consensus with the result (Al Besher, 1998).

3.7.2   The Theory behind Expert Choice:

Decision making is often difficult because tradeoffs must be made among competing objectives, and in order to make tradeoffs, we must be able to evaluate and measure each aspect of the decision, some quantitative, some qualitative and very important, and some not so important. Uncertainties and competing interest groups also add to the complexity of decision making. This complexity is minimized by the use of EC based on the Analytic Hierarchy Process, (AHP). Making effective decisions in the face of complexity can be significantly increased using EC.

Expert Choice is based on the AHP; a methodology for decision making that was developed by the mathematician Thomas L. Saaty at the Wharton School of the

University of Pennsylvania. The AHP makes it possible to deal with both tangible and intangible factors. It organizes the data, thoughts, and intuition in a logical, hierarchical structure, It can express our understanding and experience with pair-wise comparisons about the relative importance, preference or likelihood of all relevant factors.

Chapter Four

The Research Methodology

4.1 Introduction

4.2 Data Collection

4.3 Research Design

4.4 Research Population

4.5 Criteria Arbitration

4.6 The Questionnaire Assessment

4.7 Development of Supplier Selection Model (SSM)

4.8 Application of SSM Model

Chapter Four

Research Methodology

4.1 Introduction:

The main objectives of this research were first of all to identify the major supplier selection criteria that must be considered by the public sector. The second objective of this research is using these selection criteria and the AHP to develop Supplier Selection Model (SSM) to solve the supplier selection problems in the public sector. The SSM will help the public sector in selecting the best supplier.

This chapter describes the methodology that was used in this research. The adopted methodology to accomplish this research uses the following techniques: data collection, the information about the research design, research population, questionnaire assessment, questionnaire design, statistical data analysis, content validity and reliability of the research.

4.2 Data Collection:

The main sources of the required data for this research are:

4.2.1 Primary Data:

- Questionnaire survey to determine the criteria and its importance.

- Pair-wise comparison questionnaire to compare each pair of the criteria, sub-criteria and alternatives (suppliers) used in the supplier selection and to identify to what extent one criterion or alternative is more/less important/preferred to another. The respondents to this questionnaire are a committee of experts in the field of public purchasing.

4.2.2 Secondary Data:

The main sources for the required data for this research were previous studies conducted on supplier selection, the prevailing or current selection practice in the PNA, published researches, documents and other literature related.

4.3 Research Design:

In an attempt to achieve the objectives of this research, the methodology adopted for the research consisted of five main stages:

Stage 1: The available literature on supplier selection criteria and methods were comprehensively searched and studied to identify the major selection criteria (Table 2.1). These criteria and methods were described in chapter one (Section 2.4).

Stage 2: The selection criteria that were identified in stage one were used as a basis for formulating the first questionnaire form (Appendix A). Since there was no research done in the PNA in the field of supplier selection, criteria arbitration and assessment were conducted, where purchasing experts, purchasing managers and academics were contacted. The main objectives of this stage were:

- To make sure that the important supplier selection criteria were identified, and comprehensively covered.

- To add more possible important criteria which were not included.

- Finalize the questionnaire form.

Stage 3: In this stage, the questionnaire form shown in (Appendix A) was distributed to forty purchasing managers and purchasing experts working in the public sector. Also the questionnaire was distributed to the five suppliers of photocopying

machines. They were asked to rate the selection criteria in order of importance and to assess the current system in selecting the suppliers.

Stage 4: Development of the supplier selection model includes the establishment of supplier selection criteria, list prospective suppliers, construction of the AHP model, design of an evaluation questionnaire (Appendix B) to develop the priority ratings in Saaty's 9-point scale for the AHP-based supplier selection framework analysis of the questionnaire result and finally synthesis of the model.

Stage 5: validate and apply the model using a case study, discuss the results of the application and give any necessary recommendations. Figure 4.1 summarized the five stages.

Stage 1	Identify major supplier selection criteria
Stage 2	Criteria evaluation
Stage 3	Rate the selection criteria in order of importance
Stage 4	Development of the supplier selection model
Stage 5	Validate and apply the model using a case study

Figure 4.1: The methodology adopted for the research

4.4 Research Population:

This research targets most of the decision makers in the purchasing process and supplier selection in the public sector in the PNA such as purchasing managers and technicians committee. Also it targets the photocopying machines suppliers who deal with trade of photocopying machines. Twelve of the PNA ministries (as shown in Appendix C) were selected to fill in the questionnaire (Appendix A). These 12 PNA ministries of 26 ministries that have departments and specialists in purchasing, therefore they were selected. Number of purchasing managers in these 12 ministries is 40, so the

questionnaire distributed to them. Both the decision makers and the suppliers were asked to rate the selection criteria (Appendix A) in order of importance to the supplier selection process.

A total of 37 completed questionnaires were received back from the public sectors ministries (Appendix A). This represents 92.5 % of the total distributed questionnaires. Table 4.1 shows the total sample and the respondents. The names of the ministries participated are shown in appendix C.

Table 4.1: Number of participants in the survey

No.	Description	No. of questionnaires			%
		Total	Public sector	Suppliers	
1	Total no. of the questionnaires that were handed out.	45	40	5	-
2	Total no. of questionnaires complete and returned.	42	37	5	92.5
3	Total no. of respondents who did not return questionnaire.	3	3	0	7.5

Twelve purchasing managers had filled the pair-wise comparison questionnaire to compare each pair of the criteria, sub-criteria used in the supplier selection, to identify to what extent one criterion is more/less important/preferred to another (Appendix B, Part I). Also a technical committee composed of 7 members was formed to assess the alternatives (suppliers) and fill pair-wise comparison matrices (Appendix B, Part II).

4.5 Criteria Arbitration:

According to the literature review to the criteria that are used in the supplier selection and for developing a reliable and valid research, the initial survey criteria were assessed and revised to satisfy the face validity to ensure its readability, clarity, completeness, relevance and applicability. It was done based on the feedbacks obtained from some academics and purchasing experts. The criteria list was compiled from previous studies discussed in chapter two section (2.4) in order to ensure that all the criteria that used in the selection of suppliers are listed. As a result of this arbitration, Table (4.2) summarizes the most six main criteria and 34 sub-criteria that may be used in the supplier selection in the public sector.

4.6 The Questionnaire Assessment:

Experts representing two panels were contacted to assess the questionnaire validity. The first panel was asked to verify the validity of the questionnaire topics and its relevance to the research objectives. The second panel, which consisted of experts in statistics who were asked to identify the validity of the instrument used, the questionnaire design and tests among variables. The names and addresses of the referees are shown in (Appendix D). When the questionnaire is completed it is then the design of the questionnaire is concluded and any arrangement for its administration is finalized (Gill & Johnson, 2002).

Table 4.2: Supplier selection criteria and sub-criteria*

Criterion	Sub-Criterion
Quality	Product durability (i.e. Lifespan)
	Product reliability (e.g., Quality over a given period of time, Consistency)
	Quality systems
	Percent rejection
	Adherence to quality tools(e.g., Check sheet, Histogram, Cause-and-effect diagram,…)
	Reputation and position in the market
Price	Competitive pricing
	Total cost
	Quantity discount
	Payment terms
	Payment procedures understanding
Service	Spare parts availability
	Handling of complaints
	Ability to maintain product/service
	After sales services (e.g., Warranties and Claims policies)
	Training aids
	Flexibility (Payment, Freight, Price reduction, Order frequency & amount)
Business overall performance	Financial stability
	Quality performance (e.g., ISO 9000 accreditation)
	Knowledge of the market
	Information systems
	Management capability
	Performance history
Technical capability	Offering technical support
	Technical know (how know why)
	Understanding of technology
	Responsiveness
	Personnel capabilities
Delivery	Delivery lead time
	Delivery speed
	Upcoming delivery commitments
	Ability and willingness to expedite an order
	Safety and security components
	Modes of transportation facility

*Adopted by the researcher

71

4.7 The Questionnaire Design:

After interviewing academics and experts who were dealing with the subject at different levels, the questionnaire was developed with closed ended questions (Appendix A). The criteria list was compiled from previous studies discussed. The questionnaire developed for this investigation is administered to purchasing managers and technician committee members in PNA ministries. The questionnaire was designed in both the Arabic and English languages as most members of the targeted population were unfamiliar with the English language to ensure that the criteria used in this questionnaire are understandable. The questionnaire was provided with a covering letter which explained the purpose of the study, the way of responding, the aim of the research and the security of the information in order to encourage high response.

This questionnaire consists of the following parts:

- **Part I** contained information about the sample.

- **Part II** addressed the criteria and the sub-criteria in relative to their importance in the supplier selection process included six fields as follows:

    - The first field contained information about **Quality**

    - The second field contained information about **Price**.

    - The third field contained information about **Service**

    - The fourth field contained information about **Business overall performance**

    - The fifth field contained information about **Technical capability**.

    - The sixth field contained information about **Delivery**

- **Part III** investigated of the respondents' satisfaction of the current supplier selection process in their organizations, the need to change current system and use a new evaluation process.

4.8 Questionnaire Analysis:

Sex: Table (4.3) shows that **85.7** % of the respondents are male and 14.3% of the respondents are female.

Table 4.3: Sample **Sex**

Sex	Frequency	percentages
Male	36	85.7
Female	6	14.3
Total	42	100.0

Age: Table (4.4) shows that **23.8**% of the respondents are age ranged from 20 to less than 30 years, and **50.0** % of the respondents are age ranged from 30 to less than 40 years, and **26.2** % of the respondents are age more than 50 years.

Table 4.4: Sample Age

Age	Frequency	Percentages
20-less than30 years	10	23.8
30- less than 40 years	21	50.0
more than 50 years	11	26.2
Total	42	100.0

Occupation: Table (4.5) shows that **21.4** % of the respondents are occupation general manager and **40.5** % of the respondents are occupied manager, and **38.1** % of the respondents occupied manager assistant**.**

Table 4.5: Sample Occupation

Occupation	Frequency	Percentages
General manager	9	21.4
Manager	17	40.5
Manager assistant	16	38.1
Total	42	100.0

Specialization: Table (4.6) shows that **21.4** % of the respondents are specialize as engineering, and 71.4% of the respondents are specialize as commerce, and **7.1** % of the respondents are specialize as others

Table 4.6: Sample Specialization

Specialization	Frequency	Percentages
Engineering	9	21.4
Commerce	30	71.4
Others	3	7.1
Total	42	**100.0**

Work field within: Table (4.7) shows that **85.7** % of the respondents are work field as Public Sector, and 14.3 % of the respondents are work field as Supplier.

Table 4.7: Sample Work field within

Work field within	Frequency	Percentages
Public Sector	36	85.7
Supplier	6	14.3
Total	42	**100.0**

Experience: Table (4.8) shows that **11.9**% of the respondents are experience ranged from 1-4 years, and **45.2** % of the respondents are experience ranged from 5-10 years, and **42.9**% of the respondents are experience more than 10 years.

Table 4.8: Sample Experience

Experience	Frequency	Percentages
1-4 years	5	11.9
5-10 years	19	45.2
more than10 years	18	42.9
Total	42	**100.0**

Education: Table (4.9) shows that **83.3**% of the respondents are Bsc, and that **14.3**% of the respondents are Msc., and that **2.4** % of the respondents are Phd.

Table 4.9: Sample Education

Education	Frequency	Percentages
Bsc	35	83.3
Msc	6	14.3
PhD	1	2.4
Total	42	100.0

4.9 The Research Validity:

Validity refers to the degree to which an instrument measures what it is supposed to be measuring (Polit and Hunger, 1985). Validity has a number of different aspects and assessment approaches. There are two ways to evaluate instrument validity: content validity and statistical validity, which include criterion-related validity and construct validity.

4.9.1 Content Validity of the Questionnaire:

Content validity test was conducted by consulting two groups of experts. The first was requested to evaluate and identify whether the questions agreed with the scope of the items and the extent to which these items reflect the concept of the research problem. The other was requested to evaluate that the instrument used is valid statistically and that the questionnaire was designed well enough to provide relations and tests between variables. The two groups of experts did agree that the questionnaire was valid and suitable enough to measure the concept of interest with some amendments.

4.9.2 Statistical Validity of the Questionnaire:

To insure the validity of the questionnaire, two statistical tests were applied. The first test is criterion-related validity test (Pearson test) which measures the correlation coefficient between each item in the field and the whole field. The second test is structure validity test (Pearson test) that is used to test the validity of the questionnaire structure by testing the validity of each field and the validity of the whole questionnaire. It measures the correlation coefficient between one field and all the fields of the questionnaire that have the same level of similar scale.

4.9.2.1 Criterion Related Validity:

Internal consistency of the questionnaire is measured by finding the correlation coefficients between each paragraph in one field and the whole field. Table (4.10) below shows the correlation coefficient and the p-value for each field items. As show in the table the p-values are less than 0.05 or 0.01, so the correlation coefficients of this field are significant at $\alpha = 0.01$ or $\alpha = 0.05$, so it can be said that the paragraphs of this field are consistent and valid to be measure what it was set for.

Table 4.10: The correlation coefficient and the p-value for each field items

Criteria	Spearman correlation	p-value
Questionnaire part II		
1. Quality		
1. Product durability (i.e. Lifespan)	**0.500**	**0.011**
2. Product reliability	**0.578**	**0.002**
3. Quality systems	**0.601**	**0.002**
4. Percent rejection	**0.863**	**0.000**
5. Adherence to quality tools	**0.891**	**0.000**
6. Reputation and position in the market	**0.807**	**0.000**
2. Price		
1. Competitive pricing	**0.622**	**0.001**
2. Total cost	**0.885**	**0.000**
3. Quantity discount	**0.919**	**0.000**
4. Payment terms	**0.930**	**0.000**
5. Payment procedures understanding	**0.744**	**0.000**

3. Service		
1. Spare parts availability	**0.614**	**0.001**
2. Handling of complaints	**0.893**	**0.000**
3. Ability to maintain product/service	**0.870**	**0.000**
4. After sales services	**0.639**	**0.001**
5. Training aids	**0.813**	**0.000**
6. Flexibility	**0.712**	**0.000**
4. Business overall performance		
1. Financial stability	**0.790**	**0.000**
2. Quality performance	**0.676**	**0.000**
3. Knowledge of the market	**0.764**	**0.000**
4. Information systems	**0.845**	**0.000**
5. Management capability	**0.806**	**0.000**
6. Performance history	**0.826**	**0.000**
5. Technical capability		
1. Offering technical support	**0.857**	**0.000**
2. Technical know (how know why)	**0.837**	**0.000**
3. Understanding of technology	**0.867**	**0.000**
4. Responsiveness	**0.865**	**0.000**
5. Personnel capabilities	**0.577**	**0.000**
6. Delivery		
1. Delivery lead time	**0.715**	**0.000**
2. Delivery speed	**0.420**	**0.036**
3. Upcoming delivery commitments	**0.486**	**0.014**
4. Ability and willingness to expedite an order	**0.543**	**0.005**
5. Safety and security components	**0.470**	**0.018**
6. Modes of transportation facility	**0.704**	**0.000**
Questionnaire part III		
1. Determine your satisfaction of the current supplier selection process in your firm.	**0.781**	**0.000**
2. Determine the degree to which you need to change current system and have to use a new evaluation process.	**0.520**	**0.008**

4.9.2.2 Structure Validity of the Questionnaire:

Structure validity is the second statistical test that used to test the validity of the questionnaire structure by testing the validity of each field and the validity of the whole questionnaire. It measures the correlation coefficient between one field and all the fields of the questionnaire that have the same level of Likert scale.

As shown in Table (4.11), the significance values are less than 0.05 or 0.01, so the correlation coefficients of all the fields are significant at α = 0.01 or α = 0.05, so it can be said that the fields are valid to be measured what it was set for to achieve the main aim of the study.

Table 4.11: The structure validity of the questionnaire

	Main criteria	Spearman correlation coefficient	p-value
Questionnaire part II	**Quality**	**0.864**	**0.000**
	Price	**0.779**	**0.000**
	Service	**0.801**	**0.000**
	Business overall performance	**0.915**	**0.000**
	Technical capability	**0.787**	**0.000**
	Delivery	**0.771**	**0.000**
Questionnaire part III		**0.500**	**0.011**

4.10 Reliability of the Research:

The reliability of an instrument is the degree of consistency which measures the attribute; it is supposed to be measuring (Polit & Hunger, 1985). The less variation an instrument produces in repeated measurements of an attribute, the higher its reliability. Reliability can be equated with the stability, consistency, or dependability of a measuring tool. The test is repeated to the same sample of people on two occasions and then compares the scores obtained by computing a reliability coefficient (Polit & Hunger, 1985).

It is difficult to return the scouting sample of the questionnaire that is used to measure the questionnaire validity to the same respondents due to the different work conditions to these samples. Therefore two tests can be applied to the scouting sample in order to measure the consistency of the questionnaire. The first test is the Half Split Method and the second is Cronbach's Coefficient Alpha.

4.10.1 Half Split Method:

This method depends on finding Pearson correlation coefficient between the means of odd rank questions and even rank questions of each field of the questionnaire. Then, correcting the Pearson correlation coefficients can be done by using Spearman Brown correlation coefficient of correction. The corrected correlation coefficient (consistency coefficient) is computed according to the following equation:

Consistency coefficient = 2r/(r+1), where r is the Pearson correlation coefficient. The normal range of corrected correlation coefficient (2r/ r+1) is between 0.0 and + 1.0. As shown in Table (4.12), all the corrected correlation coefficients values are between 0.7843 and 0.8780 and the significant (α) is less than 0.05 so all the corrected correlation coefficients are significance at α = 0.05. It can be said that according to the Half Split method, the dispute causes group are reliable.

Table 4.12: The corrected correlation coefficients values of Split-Half method

Number	Main criteria	Spearman correlation coefficient	Spearman-Brown Coefficient	p-value
Questionnaire part II	Quality	0.6569	0.792927	0.000
	Price	0.748	0.855835	0.000
	Service	0.7113	0.831298	0.000
	Business overall performance	0.7936	0.884924	0.000
	Technical capability	0.6628	0.79721	0.000
	Delivery	0.5726	0.728221	0.000
Questionnaire part III		0.5457	0.706088	0.000
All items		0.7181	0.835923	0.000

4.10.2 Cronbach's Coefficient Alpha:

This method is used to measure the reliability of the questionnaire between each field and the mean of the whole fields of the questionnaire. The normal range of Cronbach's coefficient alpha value between 0.0 and + 1.0, and the higher values reflects a higher degree of internal consistency. As shown in Table (4.13), the Cronbach's coefficient alpha was calculated for the first field of the causes of claims, the second

field of common procedures and the third field of the Particular claims. The results were in the range from 0.8127 and 0.9245. This range is considered high; the result ensures the reliability of the questionnaire.

Table 4.13: Cronbach's Alpha for Reliability

Number	Main criteria	No. of items	Cronbach's Alpha
Questionnaire part II	Quality	6	0.8316
	Price	5	0.8811
	Service	6	0.8463
	Business overall performance	6	0.8849
	Technical capability	6	0.8654
	Delivery	6	0.5344
Questionnaire part III			
All items		36	0.9461

4.11 Development of Supplier Selection Model (SSM):

To achieve the second objective of this research, the supplier selection criteria were identified and then these identified criteria were modified (as required) to suit supplier selection in PNA. The final identified criteria, the Analytic Hierarchy Process (AHP), and computerized software" Expert Choice Version 11.5" based on AHP were used to develop the Supplier Selection Model (SSM). The significance of using the computer was simply to avoid excessive manual computation.

4.12 Application of SSM Model:

The SSM was implemented by surveying purchasing experts (in the public sector) to show the consistency and completeness of the model for supplier selection. The survey involved twelve ministries involved heavily in supplier selection for photocopying machines. The seven members in the purchasing committee were asked to fill in their judgments in the pair-wise comparison matrices. The judgmental data was entered in the pair-wise comparison matrices (Appendix B), and hence were used to calculate the priorities of the model's alternatives.

Chapter Five

Data Analysis and Discussion

5.1 Introduction

5.2 Data Measurement

5.3 Results and Analysis

Chapter Five

Data Analysis and Discussion

5.1 Introduction:

This chapter explains how the data from the survey were analyzed and discusses the results of this analysis. The selection criteria in order of importance are identified and the first objective of the research was accomplished.

5.2 Data Measurement:

In order to be able to select the appropriate method of analysis, the level of measurement must be understood. For each type of measurement, there is/are an appropriate method/s that can be applied and not others (Naoum, 1998). In this research, ordinal scales were used. Ordinal scale is a ranking or a rating data that normally uses integers in ascending or descending order. The numbers assigned to the agreement or degree of influence (1, 2, 3, 4, 5) do not indicate that the interval between scales are equal, nor do they indicate absolute quantities. They are merely numerical labels (Naoum, 1998). Based on Likert scale we have the following:

Item	Unimportant	Little Importance	Moderately Important	Important	Very Important
Scale	1	2	3	4	5

5.2.1 Statistical Manipulation:

To achieve the research goal, researcher used the Statistical Package for the Social Science (SPSS) for manipulating and analyzing the data (SPSS, 2007).

5.2.2 Statistical Methods:

The analysis of the data and the results were presented by using the following statistical methods:

1- Frequencies and Percentile.

2- Alpha-Cronbach Test for measuring reliability of the items of the questionnaires.

3- Spearman correlation coefficients for measuring validity of the items of the questionnaires.

4- Spearman –Brown Coefficient

5- Relative importance Index Formula.

5.3 Results and Analysis:

The respondents were asked to provide their opinions on the importance of the supplier selection criteria used in the public sector by scores 1 to 5, where "1" represent the least important and "5" the most important.

To determine the relative ranking of the factors, these scores were then transformed to importance indices based on the formula:

Formula Relative importance Index $= \dfrac{\sum w}{AN} = \dfrac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$

Where W is the weighting given to each factor by the respondent, ranging from 1 to 5, (n_1 = number of respondents for Unimportant, n_2 = number of respondents for Little Importance , n_3 = number of respondents for Moderately Important , n_4 = number of respondents for Important , n_5 = number of respondents for Very Important. A is the highest weight (i.e 5 in the study) and N is the total number of samples. The relative importance index ranges from 0 to 1. Tables below show the relative importance index of each clause.

Table 5.1: Relative importance Index and ranks for each sub-criterion

No.		Criteria	Public Sector		Supplier		all	
			R.I	Sub-Field Rank	R.I	Sub-Field Rank	R.I	All Field Rank
I: Quality								
1	1	Product durability	0.9167	1	0.7667	2	0.8952	**2**
2	2	Product reliability	0.8889	2	0.7667	3	0.8714	**5**
3	3	Quality systems	0.8000	3	0.7667	4	0.7952	**12**
4	4	Percent rejection	0.5722	6	0.6667	5	0.5857	**25**
5	5	Adherence to quality tools	0.6944	5	0.5000	6	0.6667	**23**
6	6	Reputation and position in the market	0.7500	4	0.9000	1	0.7714	**14**
II: Price								
7	1	Competitive pricing	0.9500	1	0.6333	2	0.9048	**1**
8	2	Total cost	0.7000	3	0.5333	5	0.6762	**21**
9	3	Quantity discount	0.7444	2	0.5667	4	0.7190	**17**
10	4	Payment terms	0.6000	5	0.6333	3	0.6048	**24**
11	5	Payment procedures understanding	0.6778	4	0.8667	1	0.7048	**18**
III: Service								
12	1	Spare parts availability	0.8889	1	0.9000	1	0.8905	**3**
13	2	Handling of complaints	0.5500	6	0.7667	5	0.5810	**26**
14	3	Ability to maintain product/service	0.8444	3	0.8333	2	0.8429	**7**
15	4	After sales services	0.8611	2	0.7667	3	0.8476	**6**
16	5	Training aids	0.5667	5	0.5333	6	0.5619	**27**
17	6	Flexibility	0.6500	4	0.7667	4	0.6667	**23**
IV: Business overall performance								
18	1	Financial stability	0.6778	4	0.8000	1	0.6952	**19**
19	2	Quality performance	0.7943	2	0.6000	6	0.7659	**15**
20	3	Knowledge of the market	0.8333	1	0.7333	3	0.8190	**9**
21	4	Information systems	0.6889	3	0.7000	4	0.6905	**20**
22	5	Management capability	0.6778	5	0.7667	2	0.6905	**20**
23	6	Performance history	0.5889	6	0.7000	5	0.6048	**24**
V: Technical capability								
24	1	Offering technical support	0.7500	3	0.9000	1	0.7714	**14**
25	2	Technical know (how know why)	0.7444	4	0.8333	3	0.7571	**16**
26	3	Understanding of technology	0.6500	5	0.8000	5	0.6714	**22**
27	4	Responsiveness	0.7833	2	0.8333	2	0.7905	**13**
28	5	Personnel capabilities	0.8056	1	0.8000	4	0.8048	**11**
VI: Delivery								
29	1	Delivery lead time	0.8229	3	0.8000	4	0.8195	**8**
30	2	Delivery speed	0.8857	2	0.8000	3	0.8732	**4**
31	3	Upcoming delivery commitments	0.9056	1	0.5000	6	0.8476	**6**
32	4	Ability and willingness to expedite an order	0.7889	4	0.9333	1	0.8095	**10**
33	5	Safety and security components	0.7611	5	0.8333	2	0.7714	**14**
34	6	Modes of transportation facility	0.4667	6	0.7000	5	0.5000	**28**

5.3.1 Statistical Results for Questionnaire (Appendix A, Part II):

The decision makers in the public sector and the suppliers were asked regarding their points of view about the selection criteria upon which the major criteria influencing the supplier selection process. Table (5.1) shows the statistical results including relative index (R.I), sub field rank and field rank respondents by the public sector and supplier points of view.

5.3.2 Statistical Results Discussion (Appendix A, Part II):

I: Quality:

1. The public sector respondents rank "Product durability (i.e. Lifespan)" as the first positions with a relative index value equal 0.9167, and supplier respondents rank as second positions with a relative index value equal 0.7667, and in all fields is listed as the second position with a relative index value equal 0.8952

2. The public sector respondents rank "Product reliability (e.g., quality over a given period of time, consistency)" as second positions with a relative index value equal 0.8889, and supplier respondents rank as third positions with a relative index value equal 0.7667, and in all fields is listed as the fifth position with a relative index value equal 0.8714

3. The public sector respondents rank "Quality systems" as third positions with a relative index value equal 0.8000, and supplier respondents rank as forth positions with a relative index value equal 0.7667, and in all fields is listed as the eleventh position with a relative index value equal 0.7952

4. The public sector respondents rank "Percent rejection" as sixth positions with a relative index value equal 0.5722, and supplier respondents rank as fifth

positions with a relative index value equal 0.6667, and in all fields is listed as the twenty five position with a relative index value equal 0.5857

5. The public sector respondents rank "Adherence to quality tools (e.g., check sheet, histogram, cause-and-effect diagram,…) " as the sixth positions with a relative index value equal 0.6944, and supplier respondents rank as the fifth positions with a relative index value equal 0.5000, and in all fields is listed as the twenty three position with a relative index value equal 0.6667

6. The public sector respondents rank "Reputation and position in the market" as forth positions with a relative index value equal 0.7500, and supplier respondents rank as the first positions with a relative index value equal 0.9000, and in all fields is listed as the fourteenth position with a relative index value equal 0.7714

II: Price:

1. The public sector respondents rank "Competitive pricing" as the first positions with a relative index value equal 0.9500, and Supplier respondents rank as the second positions with a relative index value equal 0.6333, and in all fields is listed as the first position with a relative index value equal 0.9048.

2. The public sector respondents rank "Total cost" as the third positions with a relative index value equal 0.7000, and supplier respondents rank as the fifth positions with a relative index value equal 0.5333, and in all fields is listed as the twenty one position with a relative index value equal 0.6762

3. The public sector respondents rank "Quantity discount" as the second positions with a relative index value equal 0.7444, and supplier respondents rank as the fourth positions with a relative index value equal 0.5667, and in all fields is listed as the seventeenth position with a relative index value equal 0.7190

4. The public sector respondents rank "Payment terms" as the fifth positions with a relative index value equal 0.6000, and supplier respondents rank as the third positions with a relative index value equal 0.6333, and in all fields is listed as the twenty four position with a relative index value equal 0.6048

5. The public sector respondents rank "Payment procedures understanding" as the fourth positions with a relative index value equal 0.6778, and supplier respondents rank as the first positions with a relative index value equal 0.8667, and in all fields is listed as the eighteenth position with a relative index value equal 0.7048

III: Service:

1. The public sector respondents rank "Spare parts availability" as the first positions with a relative index value equal 0.8889, and supplier respondents rank as the first positions with a relative index value equal 0.9000, and in all fields is listed as the third position with a relative index value equal 0.8905

2. The public sector respondents rank "Handling of complaints" as the sixth positions with a relative index value equal 0.5500, and supplier respondents rank as the fifth positions with a relative index value equal 0.7667, and in all fields is listed as the twenty sixth position with a relative index value equal 0.5810

3. The public sector respondents rank "Ability to maintain product/service" as the third positions with a relative index value equal 0.8444, and supplier respondents rank as the second positions with a relative index value equal 0.8333, and in all fields is listed as the seventh position with a relative index value equal 0.8429

4. The public sector respondents rank "After sales services (e.g., warranties and claims policies)" as the second positions with a relative index value equal 0.8611, and supplier respondents rank as the third positions with a relative index value equal 0.7667, and in all fields is listed as the sixth position with a relative index value equal 0.8476

5. The public sector respondents rank "Training aids" as the fifth positions with a relative index value equal 0.5667, and supplier respondents rank as the sixth positions with a relative index value equal 0.5333, and in all fields is listed as the twenty seventh position with a relative index value equal 0.5619

6. The public sector respondents rank "Flexibility (payment, freight, price reduction, order frequency & amount)" as the fourth positions with a relative index value equal 0.6500, and supplier respondents rank as the fourth positions with a relative index value equal 0.7667, and in all fields is listed as the twenty three position with a relative index value equal 0.6667

IV: Business overall performance:

1. The public sector respondents rank "Financial stability" as the forth positions with a relative index value equal 0.6778, and supplier respondents rank as the first positions with a relative index value equal 0.8000, and in all fields is listed as the nineteenth position with a relative index value equal 0.6952

2. The public sector respondents rank "Quality performance (e.g., ISO 9000 accreditation)" as the second positions with a relative index value equal 0.7943, and supplier respondents rank as the sixth positions with a relative index value equal 0.6000, and in all fields is listed as the fifteenth position with a relative index value equal 0.7659

3. The public sector respondents rank "Knowledge of the market" as the first positions with a relative index value equal 0.8333, and supplier respondents rank as the third positions with a relative index value equal 0.7333, and in all fields is listed as the ninth position with a relative index value equal 0.8190

4. The public sector respondents rank "Information systems" as the third positions with a relative index value equal 0.6889, and supplier respondents rank as the forth positions with a relative index value equal 0.7000, and in all fields is as the twenty position with a relative index value equal 0.6905

5. The public sector respondents rank "Management capability" as the fifth positions with a relative index value equal 0.6778, and supplier respondents rank as the second positions with a relative index value 0.7667equal , and in all fields is listed as the twenty position with a relative index value equal 0.6905

6. The public sector respondents rank "Performance history" as the sixth positions with a relative index value equal 0.5889, and supplier respondents rank as the fifth positions with a relative index value equal 0.7000, and in all fields is listed as the twenty forth position with a relative index value equal 0.6048

V: Technical capability

1. The public sector respondents rank "Offering technical support" as the third positions with a relative index value equal 0.7500, and supplier respondents rank as the first positions with a relative index value equal 0.9000, and in all fields is listed as the fourteenth position with a relative index value equal 0.7714

2. The public sector respondents rank "Technical know (how know why)" as the forth positions with a relative index value equal 0.7444, and supplier respondents rank as the third positions with a relative index value equal 0.8333,

and in all fields is listed as the sixteenth position with a relative index value equal 0.7571

3. The public sector respondents rank "Understanding of technology" as the fifth positions with a relative index value equal 0.6500, and supplier respondents rank as the fifth positions with a relative index value equal 0.8000, and in all fields is listed as the twenty two position with a relative index value equal 0.6714

4. The public sector respondents rank "Responsiveness" as the second positions with a relative index value equal 0.7833, and supplier respondents rank as the second positions with a relative index value equal 0.8333 , and in all fields is listed as the thirteenth position with a relative index value equal 0.7905

5. The public sector respondents rank "Personnel capabilities" as the first positions with a relative index value equal 0.8056, and supplier respondents rank as the forth positions with a relative index value equal 0.8000, and in all fields is listed as the eleventh position with a relative index value equal 0.8048

VI: Delivery

1. The public sector respondents rank "Delivery lead time" as the third positions with a relative index value equal 0.8229, and supplier respondents rank as the forth positions with a relative index value equal 0.8000, and in all fields is listed as the eight position with a relative index value equal 0.8195

2. The public sector respondents rank "Delivery speed" as the second positions with a relative index value equal 0.8857, and supplier respondents rank as the third positions with a relative index value equal 0.8000, and in all fields is listed as the fourth position with a relative index value equal 0.8732

3. The public sector respondents rank "Upcoming delivery commitments" as the first positions with a relative index value equal 0.9056, and supplier respondents rank as the sixth positions with a relative index value equal 0.5000, and in all fields is listed as the sixth position with a relative index value equal 0.8476

4. The public sector respondents rank "Ability and willingness to expedite an order" as the forth positions with a relative index value equal 0.7889, and supplier respondents rank as the first positions with a relative index value equal 0.9333, and in all fields is listed as the tenth position with a relative index value equal 0.8095

5. The public sector respondents rank "Safety and security components" as the fifth positions with a relative index value equal 0.7611, and supplier respondents rank as the second positions with a relative index value equal 0.8333, and in all fields is listed as the fourteenth position with a relative index value equal 0.7714

6. The public sector respondents rank "Modes of transportation facility" as the sixth positions with a relative index value equal 0.4667, and supplier respondents rank as the fifth positions with a relative index value equal 0.7000, and in all fields is listed as the twenty eighth position with a relative index value equal 0.5000

5.3.3 Statistical Results for Questionnaire (Appendix A, Part III):

The decision makers in the public sector and the suppliers were asked regarding their points of view in relative to their importance in the supplier selection process. Table (5.2) shows the statistical results including relative index (R.I), sub field rank and field rank respondents by the public sector and supplier points of view.

Table 5.2: Relative importance Index and ranks for part III

No.	Questions	Public Sector	Supplier	All
		R.I	R.I	R.I
1	**Determine your satisfaction of the current supplier selection process in your firm.**	0.3944	0.4000	0.3952
2	**Determine the degree to which you need to change current system and have to use a new evaluation process**.	0.8556	0.7333	0.8381

5.3.4 Statistical Results Discussion (Appendix A, Part III):

1. this section discusses the investigation of respondents' preferences and satisfaction of the current supplier selection process in their firm and the degree to which the organization need to change current system and to use a new evaluation process. Both the public sector and the supplier were not satisfied of the current supplier selection process with a relative index value equal 0.3952, and they emphasis on changing supplier selection process with a relative index value equal 0.8381

5.3.5 Statistical Results for the Main Criteria:

1. The public sector respondents rank "**Price**" as the fifth positions with a relative index value equal 0.7269 , and supplier respondents rank as the fifth positions with a relative index value equal 0.6467 , and in all field is listed as the fifth position with a relative index value equal 0.7219

2. The public sector respondents rank "**Service**" as the sixth positions with a relative index value equal 0.7161, and supplier respondents rank as the second positions with a relative index value equal 0.7611 , and in the overall claim

causes (all field ranks) it is listed as the forth position with a relative index value equal 0.7317

Table 5.3: Relative importance Index and ranks for the main criteria

No.	Main criteria	Public Sector		Supplier		all	
		R.I	Sub-Field Rank	R.I	Sub-Field Rank	R.I	All Field Rank
1	**Quality**	0.7344	4	0.7278	3	0.7643	**2**
2	**Price**	0.7269	5	0.6467	5	0.7219	**5**
3	**Service**	0.7161	6	0.7611	2	0.7317	**4**
4	**Business overall performance**	0.7467	2	0.7167	4	0.7162	**6**
5	**Technical capability**	0.7702	1	0.8333	1	0.7590	**3**
6	**Delivery**	0.7344	3	0.7611	2	0.7689	**1**

3. The public sector respondents rank "**Business overall performance**" as the second positions with a relative index value equal 0.7467, and supplier respondents rank as the forth positions with a relative index value equal 0.7167, and in all field is listed as the sixth position with a relative index value equal 0.7162

4. The public sector respondents rank "**Technical capability**" as the first positions with a relative index value equal 0.7702 , and supplier respondents rank as the first positions with a relative index value equal 0.8333, and in all field is listed as the third position with a relative index value equal 0.7590

5. The public sector respondents rank "**Delivery**" as the third positions with a relative index value equal 0.7344, and supplier respondents rank as the second positions with a relative index value equal 0.7611, and in all field is listed as the first position with a relative index value equal 0.7689

Chapter Six

Model Formulation

6.1 Introduction

6.2 Development of the Supplier Selection Model (SSM)

Chapter Six

Model Formulation

6.1 Introduction:

Development of the supplier selection model includes the establishment of supplier selection criteria, development of the respondent sample base, construction of the AHP model, design of an evaluation questionnaire, respondent interview, analysis of the questionnaire result and finally, synthesis of the model. The model must be flexible and simple in performance, easy to review, adaptable for both individual and group, and does not require inordinate specialization to master and communicate. This chapter discusses the development and formulation of the supplier selection model (SSM).

6.2 Development of the SSM:

The development of the SSM was based on the previously obtained supplier selection criteria (Table 4.2), that were identified as a result of literature search and by examining the selection criteria of the public sector. These criteria were used as main factors that must be considered during the supplier selection process. Careful consideration of these criteria will contribute to establishment of minimum and acceptable requirements, and ultimately lead to the selection of the best supplier.

6.2.1 Formation of the Supplier Selection Criteria:

To ensure the effectiveness of the model, the predetermined criteria and sub-criteria must be objective. In order to meet the user's full satisfaction, these criteria must be positively satisfying the main goal of the process "To select the best supplier".

All these criteria with corresponding sub-criteria are presented in an aggregated manner in (Fig. 6.1) at the second and third levels of hierarchy respectively.

6.2.2 List Prospective Suppliers:

Once the selection main measures "criteria and sub-criteria" are identified, then the next step in developing the SSM is to list the candidates available for selection alternatives (the prospective suppliers). These alternatives (suppliers) can be obtained using the predetermined list of suppliers in the ministry of finance. The number of listed suppliers should not be less than three suppliers to conduct a wide and fair prequalification.

6.2.3 Building the AHP Model:

Because of the complexity of the prevailing selection process in dealing with maybe myriad or endless factors that affect the achievement of goal and consistency of judgments of selecting the best supplier, AHP was used to solve the selection model. The complexity of the selection process can be handled and best understood by applying the principle and techniques of AHP, breaking it down into its constituent elements, structuring elements hierarchically, and then composing, or synthesizing judgments on the relative importance of the elements at each level of the hierarchy into a set of overall priorities.

LEVEL 1
Goal

LEVEL 2
Criteria

LEVEL 3
Sub-criteria

LEVEL 4
Alternatives

Selecting the Best Supplier

| Quality | Price | Service | Business overall performan | Technical capability | Delivery |

Quality
- Product durability
- Product reliability
- Quality systems
- Percent rejection
- Adherence to quality tools
- Reputation and position in the market

Price
- Competitive pricing
- Total cost
- Quantity discount
- Payment terms
- Payment procedures understanding

Service
- Spare parts availability
- Handling of complaints
- Ability to maintain product
- After sales services
- Training aids
- Flexibility

Business overall performan
- Financial stability
- Quality performance
- Knowledge of the market
- Information systems
- Management capability
- Performance history

Technical capability
- Offering technical support
- Technical know
- Understanding of technology
- Responsiveness
- Personnel capabilities

Delivery
- Delivery lead time
- Delivery speed
- Upcoming delivery commitments
- Ability and willingness to expedite an order
- Safety and security components
- Modes of transportation facility

Supplier1   Supplier2   Supplier3   Supplier4   Supplier5

Figure 6.1: The significant criteria and sub-criteria for supplier selection problem used in the case study

97

The goal of our problem is to select the best supplier that can provide the best photocopying machines. This goal is placed on the first level of the hierarchy, as shown in Fig. 6.1. Thus, six main criteria namely quality, cost, service, business overall performance, technical capability and delivery, are identified to achieve this goal, which form the second level of the hierarchy. The third level of the hierarchy occupies the sub-criteria. The criteria and sub-criteria used in these two levels of the AHP hierarchy can be assessed using the basic AHP approach of pair-wise comparisons of elements in each level with respect to every parent element located one level above. A set of priority weights can then be determined for each of the sub-criteria by multiplying local weights of the sub-criteria with weights of all parent nodes above it.

The lowest level of the hierarchy consists of the alternatives, namely the different suppliers to be evaluated in order to be selected as the best supplier. As shown in Fig. 6.1, five suppliers are picked for the PNA to evaluate because they are dealing with the MOF and offered to its tenders. The AHP model shown in Fig. 6.1 is generally applicable to the supplier selection problem for different kinds of photocopying machines. This application is detailed by using the computerized decision support system Expert Choice, version EC pro 11.5 to structure the selection model.

6.2.4 Data Collection and Performing Pair-wise Comparisons:

The nine-point scale as suggested by Saaty (1990) is used to assign pair-wise comparisons of all elements at each level of the hierarchy (Table 6.1). As suggested by Saaty (1990), the geometric mean approach, instead of the arithmetic approach, is

used to combine the individual pair-wise comparison matrices (PCMs) to obtain the consensus PCMs for the entire team.

Using this approach, a questionnaire is shown in (Appendix B part I). was designed, and 12 respondents from twelve different ministries, which are frequently involved directly or indirectly in supplier selection process, were selected as the questionnaire population. The twelve ministries are listed in appendix C.

Table 6.1: The fundamental scale, a scale of absolute numbers used to assign numerical values mad by comparing two elements*

Intensity of importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor on activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another. Its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest degree possible of affirmation
2,4,6,8	Intermediate values	Used to represent compromise between the preferences listed above
Reciprocals	Reciprocals for inverse comparison	

*Adopted from Saaty (1990)

Essentially, the technique employs pair-wise comparisons of selection criteria so as to enhance objectivity and downplay too much subjectivity (Saaty, 1990). Pair-wise comparison forces the decision maker to compare each criterion with all the remaining ones.

Table 6.2 presents an Example of the pair-wise comparison matrix used in this study. For example, considering the second row, pair-wise comparison involves comparing the criterion of quality with that of price, then with that of service and so on across the row in a scale of importance. The scale of importance used in this study is also shown in Table 6.1. As an illustration, if quality is considered to be very strongly more important compared with service in the selection of a the best supplier, a '7' is inserted in the juncture cell between quality and service and if price is considered to be moderate important compared with quality in the selection of a the best supplier, a '1/3' is inserted in the juncture cell between quality and price. The shaded portion of the comparison matrix need not be completed because these cells should be the reciprocals of the corresponding cells in the non-shaded portion. The Expert Choice software (EC, 2007) used in this study handles this task automatically.

Example: If price is considered to be moderate important compared with quality and quality is very strongly more important than service, the then the rating assignment in the matrix should appear as:

Table 6.2: An example of the pair-wise comparison matrix used in the study

Main criteria	Quality	Price	Service	Business overall performance	Technical capability	Delivery
Quality	1	1/3	7			
Price		1				
Service			1			
Business overall performance				1		
Technical capability					1	
Delivery						1

6.2.5 Test for Consistency:

Once the selection problem is completely structured and comparison matrices are developed, then examining consistency is a step that must be carried out. The measurement of consistency ratio (CR) is to be conducted to check if the utilized judgments are consistent enough, and that the decision to come up with a successful supplier selection is not based on low consistency. Basically, a CR should be 10% or less. If it is more than 10%, then judgments must be revised as required. This application is explained in section 7.4.3.

6.2.6 Repeat Pair-wise Comparison:

In some cases, CR values are more than 10 percent and the revision of the judgments alone is not good enough to minimize CR values to an acceptable level of consistency. In this case it advisable to go back to check details and the structure of the framework of the hierarchy. It may be necessary to gather more input information and revise as required.

6.2.7 Synthesis: Finding a Solution to the Problem:

After recording all preferences and important comparing alternatives "suppliers" and criteria with respect to the goal, then the next step is to synthesize for the overall result of supplier selection. This is achieved by generating the global weights of the nodes by combining the local priorities throughout the entire model. It is the process of converting the local priorities into the global priorities of the selection model, and gives the alternatives global weights. The distributive mode is used to perform this synthesis from the goal node to get the overall selection results. The application of overall synthesis and detail are shown in table 7.3 and figure 7.44.

6.2.8 Rank the Suppliers:

As a result of the overall synthesis, the distributive synthesis mode prioritizes prospective suppliers with respect to their relative worth. The distributive synthesis mode can be used to perform the synthesis from the goal node to get the overall selection results. The distributive synthesis mode ranks the prospective suppliers, placing the best supplier in the top. Unlike the ideal synthesis mode, it allows rank to reverse when a change is made to the priorities. Detail of this application is shown in Figure 7.44.

6.2.9 Select the Supplier:

The resulting ranked list of the suppliers forms a solid foundation from which to choose the most appropriate supplier to supply the required photocopying machine. Those suppliers whose qualifications are not compatible with the requirements have now been eliminated from the list. Usually it is advisable to pre-select the top three suppliers for an oral presentation and evaluation.

6.2.10 Negotiate and Agree with Supplier:

After the evaluation of oral presentations has been completed, customarily, at least three selected suppliers will make the final selection. Negotiation for signing a contract is the follow. The selected suppliers will be ranked first, second, third, and so on. Negotiation begins with the supplier ranked first. During this negotiation the scope of work, contract terms, and legal and contractual requirements are completely reviewed and included in the discussions. If and when an agreement is reached with the negotiating supplier, then a supply contract will be prepared for signing to contractually commit the supplier to supply the required photocopying machine.

If an agreement is not reached with the supplier ranked first, then negotiations with that supplier is terminated and the supplier ranked second is invited for negotiations and so on until a supplier is selected and a satisfactory agreement is reached.

Global weights set for criteria and sub-criteria for supplier selection problem used in the case study are shown in figure 6.2. The SSM model's schematic is shown in figure 6.3
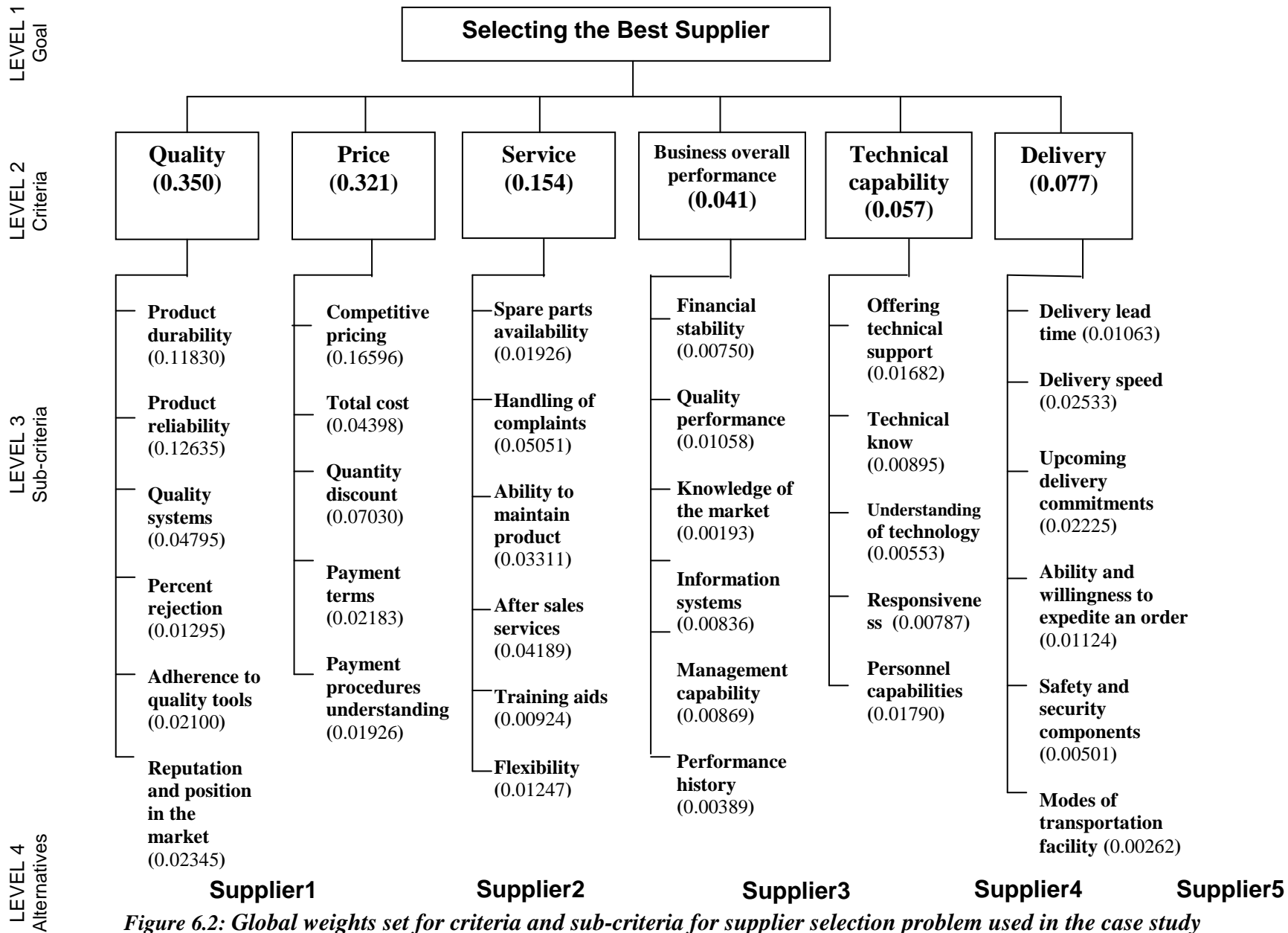
Figure 6.2: Global weights set for criteria and sub-criteria for supplier selection problem used in the case study
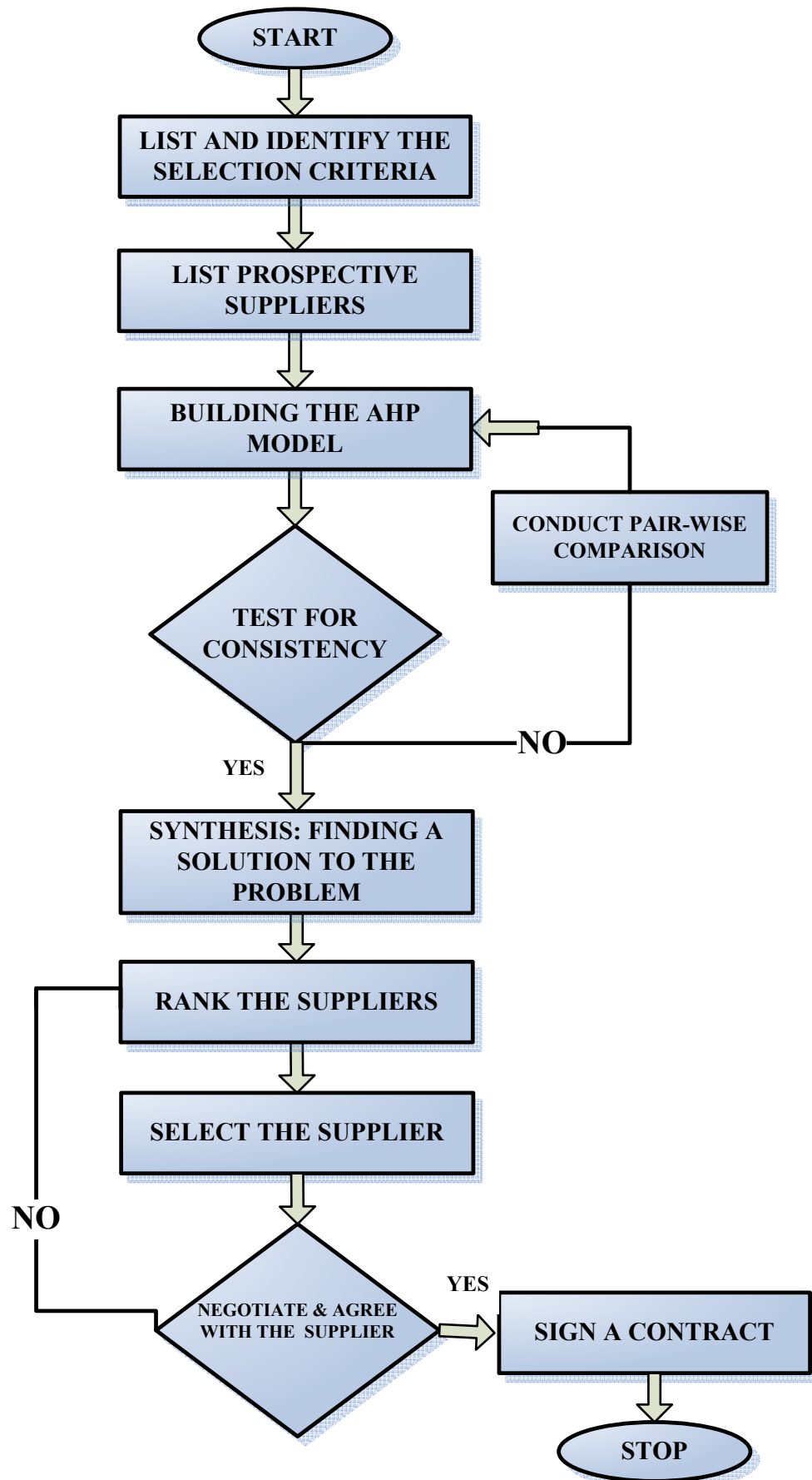
Figure 6.3: Development of the Supplier Selection Model (SSM)

Chapter Seven

Model Validation with a Case Study

7.1 Introduction

7.2 The Case Study Background

7.3 Structuring the Hierarchy

7.4 Performing Pair-wise Comparisons

7.5 Synthesizing the Results

7.6 Sensitivity Analysis

<center>**Chapter Seven**</center>

<center>**Model Validation with a Case Study**</center>

7.1 Introduction:

This chapter describes the use of the SSM in selecting the best photocopying machine supplier to the (PNA). After determining the criteria and sub-criteria used in the supplier selection, the criteria, sub-criteria and alternatives were inserted in the pair-wise comparison matrices (appendix B). Group decision team was requested to compare each pair by identifying to what extent one criterion is more/less important/preferred to another. Then the judgments provided were inserted into the Expert Choice software for calculating priorities, consistency ratio and conducting overall synthesis.

7.2 The Case Study Background:

The general supplies department started its functions in 2002 as an independent department linked to the Minister of Finance of the PNA. The department formulates the public policy for managing the supplies according to the General Supplies Bylaw no.(9) for the year 1999. Also, the department purchases commodity related to the ministries' and governmental directorates according to the active Bylaw of the General Supplies.

From 2002 up to 2005, the general supplies department has purchased annually photocopying machines to the tune of US$ 600,000[2]. Supplier selection is one of the main activities of the general supplies department, but there are shortcomings of the current Supplies Bylaw no. (9) in selecting the suppliers:

---

[2]Unpublished release, the Ministry of Finance, PNA

- ➢ The weakness and accuracy of existing specifications for products purchased.

- ➢ The general supplies department is used to accepting the lowest prices if the supplier comply the existing specifications.

- ➢ Supplies Bylaw no. (9) takes into consideration two criteria: price and quality without any mean to measure them quantitatively, so it doesn't consider other important criteria in the selection process and this reduces the transparency of the supplier selection.

- ➢ There isn't a systematic way to evaluate the suppliers.

- ➢ The suppliers are not provided with feedback or justification if not awarded a contract.

This section will discuss a case study about the ministry of finance central tender for the year 2007 and for supplying the photocopying machines to the ministries of PNA. Five companies specializing in supplying these machines offered to this tender, these companies are as follow: Modern Center for Electronics with product type "Sharp", Qaraman company with product type "Konica Minolta", CopyMax company with product type "Xerox", Al-Jazeera company with product type "Canon" and Gaza Strip company with product type "Olivetti".

Therefore, A technical committee composed of 7 members was formed to assess the specialized suppliers, the committee takes its resolution unanimously. Its role is to:

1. Study the entire needed document from the suppliers.

2. To make sure that it meets General Supplies Bylaw no.(9) conditions and rules.

3. Study and analyze the proposals, the bill of quantities and check the prices.

4. The committee has to consult who they considered appropriate.

The committee have the right to neglect any proposal does not meet the requirement and to refuse any one without giving reasons. Furthermore, the committee has the right to award the contract not to the lowest price. The committee does not reveal any information considered of selecting, evaluation, explanation, or comparison of suppliers to any person even the suppliers.

A supplier will be chosen to be the successful bidder according to the SSM using the AHP. An AHP study will be applied on the problem because supplier selection problems deal with a relatively large number of criteria within a hierarchical framework.

7.3 Structuring the Hierarchy:

The goal is to choose the best photocopying machine supplier for the PNA ministries. The goal is placed at the top of the hierarchy. The hierarchy descends from the more general criteria in the second level to sub-criteria in the third level to the alternatives at the bottom or fourth level. General criteria level involved six major criteria: quality, cost, service, business overall performance, technical capability and delivery. The decision-making team considered five photocopying machine suppliers for the decision alternatives, and located them on the bottom level of the hierarchy. Figure 7.1 shows a hierarchical representation of the selecting best photocopying machine supplier selection model.

7.4 Performing Pair-wise Comparisons:

After constructing the hierarchy, pair-wise comparisons were performed systematically to include all the combinations of criteria and sub-criteria relationships. The criteria and sub-criteria were compared according to their relative importance with

respect to the parent element in the adjacent upper level. Prior to the study, it is hoped to go through pair-wise comparisons together with the decision makers. It was not possible due to the differences among the schedule of the managers. Hence, questionnaire (appendix B, Part I) including all possible pair-wise comparison combinations were distributed to the decision makers (12 respondents from twelve different ministries). They first made all the pair-wise comparisons using semantic terms from the fundamental scale and then translated them to the corresponding numbers, separately. The questions to ask when comparing two criteria being compared, which is considered more important by the decision-maker selecting the best supplier, and how much more important is it with respect to selection of the best supplier. After performing all pair-wise comparisons by the decision-makers, the individual judgments were aggregated using the geometric mean as Saaty suggested (Saaty, 1990). The judgments were based upon the gathered information through the questionnaires. The results are then combined by applying the geometric mean.

LEVEL 1
Goal

LEVEL 2
Criteria

LEVEL 3
Sub-criteria

LEVEL 4
Alternatives

Selecting the Best Photocopying Machine Supplier

Quality

Price

Service

Business overall performan

Technical capability

Delivery

Product durability

Product reliability

Quality systems

Percent rejection

Adherence to quality tools

Reputation and position in the market

Competitive pricing

Total cost

Quantity discount

Payment terms

Payment procedures understanding

Spare parts availability

Handling of complaints

Ability to maintain product

After sales services

Training aids

Flexibility

Financial stability

Quality performance

Knowledge of the market

Information systems

Management capability

Performance history

Offering technical support

Technical know

Understanding of technology

Responsiveness

Personnel capabilities

Delivery lead time

Delivery speed

Upcoming delivery commitments

Ability and willingness to expedite an order

Safety and security components

Modes of transportation facility

Supplier1   **Supplier2**   **Supplier3**   **Supplier4**   **Supplier5**

Figure 7.1: A hierarchical representation of the selecting best photocopying machine supplier selection model

7.4.1 Types of Comparison:

There are three comparison types used in the Expert Choice to choose one of them: *importance*; is appropriate when comparing one criterion with another, *likelihood*; is appropriate when comparing probability of outcome. (It can be used with either criteria or alternative), and *preference*; used when comparing the alternatives.

7.4.2 Modes of Comparison:

Expert Choice provides various options for comparing criteria, sub-criteria and alternatives, so there are three comparison modes: numerical, verbal and graphical. Numerical options where the decision makers can enter numerical values between 1 and 9; verbal option where semantic terms can be used; and graphical option where the decision makers can make comparisons by contrasting the graphical bars. Direct estimation is where the user simply produces a set of values reflecting the relative preference for the compared elements. Prior to the study, numerical pair-wise comparison mode should be chosen.

7.4.3 Pair-Wise Analysis:

The twelve purchasing managers have filled the pair-wise comparison matrices. The responses of each purchasing manager were analyzed using Expert Choice Pro 11.5 to calculate the consistency ratio (CR) and the weighting vectors of each main criterion and sub-criterion.

As mentioned earlier, the pair-wise comparison matrices obtained from the 12 respondents are combined using the geometric mean approach at each hierarchy level to obtain the corresponding consensus pair-wise comparison matrices, as shown in

Figures (7.2) to (7.8). Each of these matrices is then translated into the corresponding largest eigenvalue problem and is solved to find the normalized and unique priority weights for each criterion.

According to Saaty (1980) the judgment of a purchasing manager is accepted if CR ≤ 0.10. The results of the pair-wise comparison of deliberations were presented back to the expert group. The mean values of the Eigenvector comparisons were calculated. The inconsistencies in the results were explained. Discussions were held on the inconsistencies. A few of participants were able to achieve acceptable level of consistency. The results of each evaluator were sent back again to be reconsidered. They were requested also to carefully evaluate the weighted vector compared to other purchasing manager's results and to the overall average results. All purchasing managers were free to make suitable amendments.

Main criteria	Quality	Price	Service	Business overall performance	Technical capability	Delivery
Quality	1	1	3	7	6	5
Price		1	3	6	5	4
Service			1	4	3	3
Business overall performance				1	1/2	1/2
Technical capability					1	1/2
Delivery						1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier

Quality .350
Price .321
Service .154
Business overall performance .041
Technical capabilities .057
Delivery .077
Inconsistency = 0.02
with 0 missing judgments.
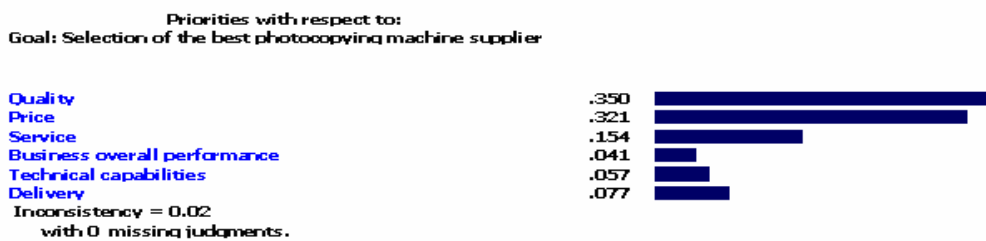
Figure 7.2: Pair-wise matrix & priorities for main criteria

Sub criteria	Product durability	Product reliability	Quality systems	Percent rejection	Adherence to quality tools	Reputation and position in the market
Product durability	1	1	3	7	6	5
Product reliability		1	4	7	6	5
Quality systems			1	5	3	2
Percent rejection				1	1/2	1/2
Adherence to quality tools					1	1
Reputation and position in the market						1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Quality

Product durability   .338
Product reliability   .361
Quality systems   .137
Percent rejection   .037
Adherence to quality tools   .060
Reputation and position in the market   .067
Inconsistency = 0.02
   with 0 missing judgments.

Figure 7.3: Pair-wise matrix & priorities for quality

Sub criteria	Competitive pricing	Total cost	Quantity discount	Payment terms	Payment procedures understanding
Competitive pricing	1	4	3	7	7
Total cost		1	1/2	2	3
Quantity discount			1	3	4
Payment terms				1	1
Payment procedures understanding					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Price

Competitive pricing   .517
Total cost   .137
Quantity discount   .219
Payment terms   .068
Payment procedures understanding .060
Inconsistency = 0.01
   with 0 missing judgments.

Figure 7.4: Pair-wise matrix & priorities for price

Sub criteria	Spare parts availability	Handling of complaints	Ability to maintain product	After sales services	Training aids	Flexibility
Spare parts availability	1	6	2	1	5	5
Handling of complaints		1	1/4	1/5	1/2	1/2
Ability to maintain product			1	1	4	3
After sales services				1	5	4
Training aids					1	1/2
Flexibility						1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Service

Spare parts availability	.328
Handling of complaints	.045
Ability to maintain product	.215
After sales services	.272
Training aids	.060
Flexibility	.081

Inconsistency = 0.02
with 0 missing judgments.
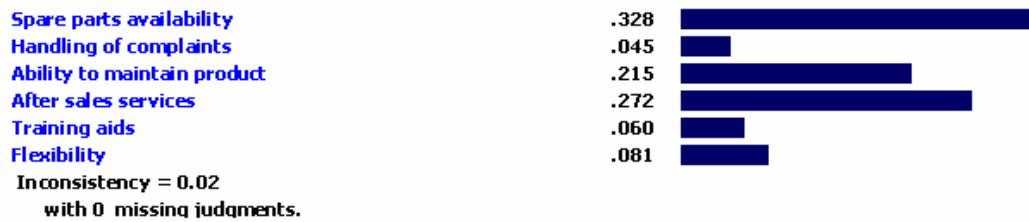
Figure 7.5: Pair-wise matrix & priorities for service

Sub criteria	Financial stability	Quality performance	Knowledge of the market	Information systems	Management capability	Performance history
Financial stability	1	1/2	4	1	1	2
Quality performance		1	5	1	1	3
Knowledge of the market			1	1/4	1/5	1/2
Information systems				1	1	2
Management capability					1	2
Performance history						1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Business overall performance

Financial stability	.183
Quality performance	.258
Knowledge of the market	.047
Information systems	.204
Management capability	.212
Performance history	.095

Inconsistency = 0.00821
with 0 missing judgments.

Figure 7.6: Pair-wise matrix & priorities for business overall performance

Sub criteria	Offering technical support	Technical know (how know why)	Understanding of technology	Responsiveness	Personnel capability
Offering technical support	1	2	3	2	1
Technical know (how know why)		1	2	1	1/2
Understanding of technology			1	1	1/4
Responsiveness				1	1/2
Personnel capability					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Technical capabilities

Offering technical support	.295
Technical know	.157
Understanding of technology	.097
Responsiveness	.138
Personnel capabilities	.314

Inconsistency = 0.01
with 0 missing judgments.

Figure 7.7: Pair-wise matrix & priorities for technical capability

Sub criteria	Delivery lead time	Delivery speed	Upcoming delivery commitments	Ability and willingness to expedite an order	Safety and security components	Modes of transportation facility
Delivery lead time	1	1/3	1/2	1	3	5
Delivery speed		1	1	3	5	7
Upcoming delivery commitments			1	2	4	6
Ability and willingness to expedite an order				1	3	5
Safety and security components					1	3
Modes of transportation facility						1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Delivery

Delivery lead time	.138
Delivery speed	.329
Upcoming delivery commitments	.289
Ability and willingness to expedite an order	.146
Safety and security components	.065
Modes of transportation facility	.034

Inconsistency = 0.03
with 0 missing judgments.

Figure 7.8: Pair-wise matrix & priorities for delivery

116

7.4.4 Final Weights of Each Criterion:

To find the final (global) weight of each sub-criterion, the results of the weighting vector for standing criteria list was arranged in Table 7.1. The main criteria weighting vectors (1) are multiplied by the corresponding sub-criteria weighting vectors (2) to obtain the (global) criteria weight (3). The ten highest weighted sub-criteria for standing list were: ***competitive pricing; product reliability; product durability; quantity discount; spare parts availability; quality systems; total cost; after sales services; ability to maintain product/service*** and **delivery speed**. These weights and other weights will subsequently be used to evaluate the supplier's attributes that will be fed into the model for supplier selection.

Table 7.1: Priority weights for criteria and sub-criteria used in the case study

Criterion	Local Weight (1)	Sub-criterion	Local Weight (2)	Global Weight (3)
Quality	0.350	Product durability	0.338	0.11830
		Product reliability	0.361	0.12635
		Quality systems	0.137	0.04795
		Percent rejection	0.037	0.01295
		Adherence to quality tools	0.060	0.02100
		Reputation and position in the market	0.067	0.02345
Price	0.321	Competitive pricing	0.517	0.16596
		Total cost	0.137	0.04398
		Quantity discount	0.219	0.07030
		Payment terms	0.068	0.02183
		Payment procedures understanding	0.060	0.01926
Service	0.154	Spare parts availability	0.328	0.05051
		Handling of complaints	0.045	0.00693
		Ability to maintain product/service	0.215	0.03311
		After sales services	0.272	0.04189
		Training aids	0.060	0.00924
		Flexibility	0.081	0.01247
Business overall performance	0.041	Financial stability	0.183	0.00750
		Quality performance	0.258	0.01058
		Knowledge of the market	0.047	0.00193
		Information systems	0.204	0.00836
		Management capability	0.212	0.00869
		Performance history	0.095	0.00389
Technical capability	0.057	Offering technical support	0.295	0.01682
		Technical know	0.157	0.00895
		Understanding of technology	0.097	0.00553
		Responsiveness	0.138	0.00787
		Personnel capabilities	0.314	0.01790
Delivery	0.077	Delivery lead time	0.138	0.01063
		Delivery speed	0.329	0.02533
		Upcoming delivery commitments	0.289	0.02225
		Ability and willingness to expedite an	0.146	0.01124
		Safety and security components	0.065	0.00501
		Modes of transportation facility	0.034	0.00262
Total	**1.000**	**Total**		**1.000**
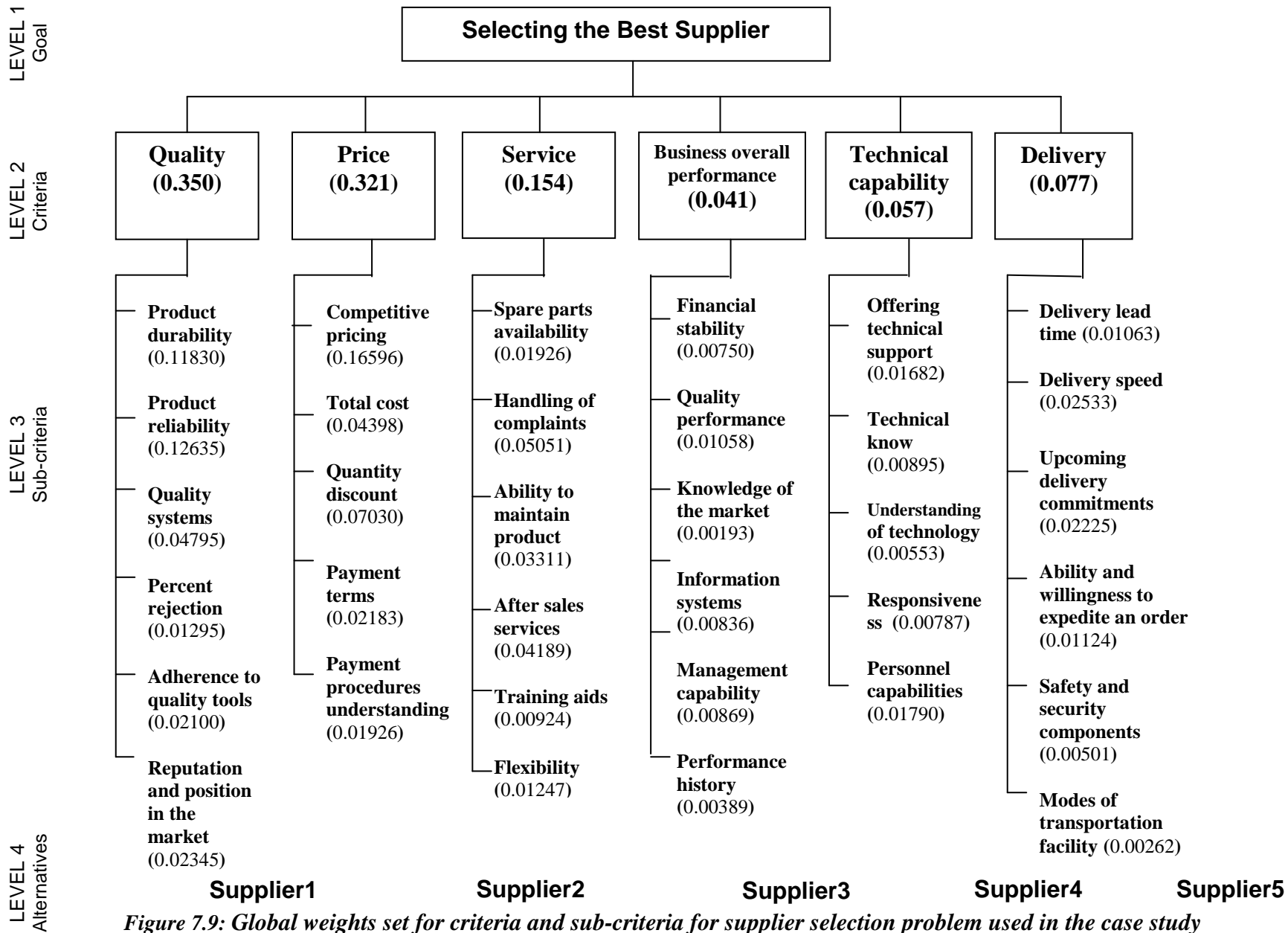
Figure 7.9: Global weights set for criteria and sub-criteria for supplier selection problem used in the case study

7.4.5 The Alternatives Pair-Wise Comparison:

The final step in the pair-wise comparison is comparing each pair of alternatives (suppliers) with respect to each sub-criterion. In comparing the five suppliers, the decision-making committee was asked which supplier is preferred with respect to each sub-criterion in level 3. Table 7.2 shows the suppliers names and their products and Figures from (7.10 - 7.43) explain the pair-wise matrix and priorities for each sub-criterion.

Table 7.2: The suppliers' names and their products

No.	Name	Supplier	Product
1	Supplier no. 1	**Modern Center for Electronics**	**Sharp**
2	Supplier no. 2	**Qaraman**	**Konica Minolta**
3	Supplier no. 3	**CopyMax**	**Xerox**
4	Supplier no. 4	**Al-Jazeera**	**Canon**
5	Supplier no. 5	**Gaza Strip**	**Olivetti**

Product durability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	5	4	7	3
Supplier no. 2		1	1/2	3	1/4
Supplier no. 3			1	4	1/2
Supplier no. 4				1	1/5
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
    >Quality
        >Product durability

Supplier No. 1	.487
Supplier No. 2	.086
Supplier No. 3	.141
Supplier No. 4	.044
Supplier No. 5	.242

Inconsistency = 0.04
    with 0 missing judgments.

Figure 7.10: Pair-wise matrix & priorities for product durability

Product reliability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	4	5	7	3
Supplier no. 2		1	2	5	1/2
Supplier no. 3			1	4	1/4
Supplier no. 4				1	1/6
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Quality
>Product reliability

Supplier No. 1	.481
Supplier No. 2	.145
Supplier No. 3	.090
Supplier No. 4	.038
Supplier No. 5	.246

Inconsistency = 0.05
with 0 missing judgments.

Figure 7.11: Pair-wise matrix & priorities for product reliability

Quality systems	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1	1	2	2
Supplier no. 2		1	1	2	3
Supplier no. 3			1	2	2
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Quality
>Quality systems

Supplier No. 1	.247
Supplier No. 2	.269
Supplier No. 3	.247
Supplier No. 4	.123
Supplier No. 5	.114

Inconsistency = 0.00447
with 0 missing judgments.

Figure 7.12: Pair-wise matrix & priorities for quality systems

Percent rejection	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	2	4	3	3
Supplier no. 2		1	3	2	2
Supplier no. 3			1	1/2	1/3
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Quality
  >Percent rejection

Supplier No. 1   .400
Supplier No. 2   .242
Supplier No. 3   .073
Supplier No. 4   .135
Supplier No. 5   .149
Inconsistency = 0.02
    with 0 missing judgments.

Figure 7.13: Pair-wise matrix & priorities for percent rejection

Adherence to quality tools	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1	2	3	3
Supplier no. 2		1	2	3	3
Supplier no. 3			1	2	3
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Quality
  >Adherence to quality tools

Supplier No. 1   .310
Supplier No. 2   .310
Supplier No. 3   .192
Supplier No. 4   .097
Supplier No. 5   .091
Inconsistency = 0.01
    with 0 missing judgments.

Figure 7.14: Pair-wise matrix & priorities for adherence to quality tools

Reputation and position in the market	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	5	4	7	3
Supplier no. 2		1	1/2	2	1/3
Supplier no. 3			1	3	1/2
Supplier no. 4				1	1/4
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Quality
>Reputation and position in the market

Supplier No. 1	.498
Supplier No. 2	.086
Supplier No. 3	.139
Supplier No. 4	.053
Supplier No. 5	.224

Inconsistency = 0.02
with 0 missing judgments.
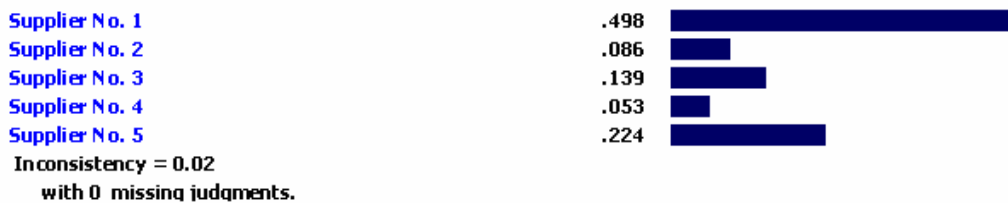
Figure 7.15: Pair-wise matrix & priorities for reputation and position in the market

Competitive pricing	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1/3	1/7	1/5	1/2
Supplier no. 2		1	1/3	1/2	2
Supplier no. 3			1	2	4
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Price
>Competitive pricing

Supplier No. 1	.060
Supplier No. 2	.261
Supplier No. 3	.433
Supplier No. 4	.155
Supplier No. 5	.091

Inconsistency = 0.02
with 0 missing judgments.
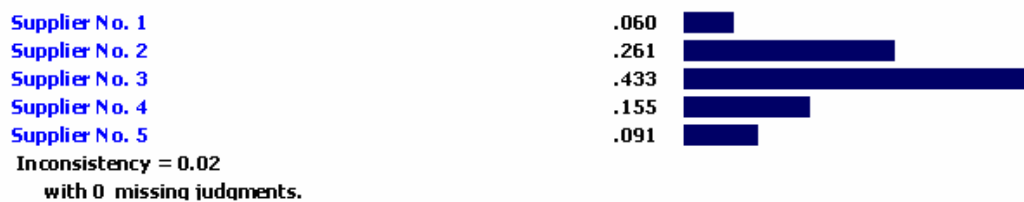
Figure 7.16: Pair-wise matrix & priorities for competitive pricing

Total cost	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1/4	1/7	1/3	1/2
Supplier no. 2		1	1/2	2	4
Supplier no. 3			1	3	4
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Price
    >Total cost

Supplier No. 1	.055
Supplier No. 2	.271
Supplier No. 3	.430
Supplier No. 4	.154
Supplier No. 5	.089

Inconsistency = 0.01
  with 0 missing judgments.

Figure 7.17: Pair-wise matrix & priorities for total cost

Quantity discount	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1/4	1/6	1/2	1/3
Supplier no. 2		1	1/2	4	3
Supplier no. 3			1	5	4
Supplier no. 4				1	1/2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Price
    >Quantity discount

Supplier No. 1	.056
Supplier No. 2	.284
Supplier No. 3	.447
Supplier No. 4	.082
Supplier No. 5	.131

Inconsistency = 0.03
  with 0 missing judgments.

Figure 7.18: Pair-wise matrix & priorities for quantity discount

Payment terms	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	7	2	3	5
Supplier no. 2		1	1/4	1/3	1/2
Supplier no. 3			1	2	4
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Price
    >Payment terms

Supplier No. 1	.443
Supplier No. 2	.055
Supplier No. 3	.267
Supplier No. 4	.152
Supplier No. 5	.084

Inconsistency = 0.01
  with 0 missing judgments.

Figure 7.19: Pair-wise matrix & priorities for payment terms

Payment procedures understanding	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	3	1	2	3
Supplier no. 2		1	1	2	3
Supplier no. 3			1	3	2
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Price
    >Payment procedures understanding

Supplier No. 1	.332
Supplier No. 2	.209
Supplier No. 3	.253
Supplier No. 4	.108
Supplier No. 5	.099

Inconsistency = 0.04
  with 0 missing judgments.

Figure 7.20: Pair-wise matrix & priorities for payment procedures understanding

Spare parts availability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	4	3	5	1
Supplier no. 2		1	1/2	2	1/3
Supplier no. 3			1	3	1/2
Supplier no. 4				1	1/3
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Service
>Spare parts availability

Supplier No. 1	.373
Supplier No. 2	.100
Supplier No. 3	.165
Supplier No. 4	.068
Supplier No. 5	.294

Inconsistency = 0.02
with 0 missing judgments.

Figure 7.21: Pair-wise matrix & priorities for spare parts availability

Handling of complaints	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	6	5	3	2
Supplier no. 2		1	1/2	1/4	1/5
Supplier no. 3			1	1/2	1/3
Supplier no. 4				1	1/2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Service
>Handling of complaints

Supplier No. 1	.435
Supplier No. 2	.052
Supplier No. 3	.088
Supplier No. 4	.163
Supplier No. 5	.263

Inconsistency = 0.01
with 0 missing judgments.
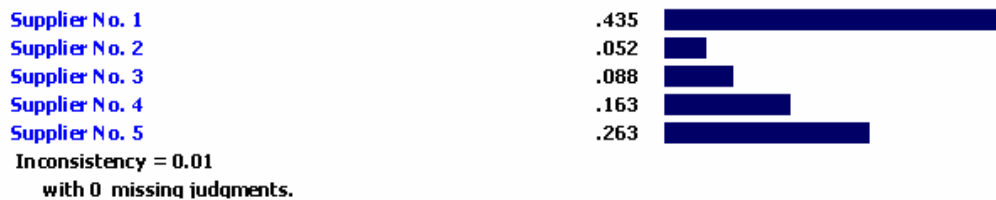
Figure 7.22: Pair-wise matrix & priorities for handling of complaints

Ability to maintain product/service	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	4	3	5	2
Supplier no. 2		1	1/2	2	1/3
Supplier no. 3			1	3	1/2
Supplier no. 4				1	1/5
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Service
>Ability to maintain product

Supplier No. 1   .416
Supplier No. 2   .096
Supplier No. 3   .158
Supplier No. 4   .059
Supplier No. 5   .271
Inconsistency = 0.02
with 0 missing judgments.

Figure 7.23: Pair-wise matrix & priorities for ability to maintain product/service

After sales services	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	6	2	4	3
Supplier no. 2		1	1/4	1/2	1/3
Supplier no. 3			1	3	2
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Service
>After sales services

Supplier No. 1   .429
Supplier No. 2   .059
Supplier No. 3   .262
Supplier No. 4   .111
Supplier No. 5   .139
Inconsistency = 0.01
with 0 missing judgments.
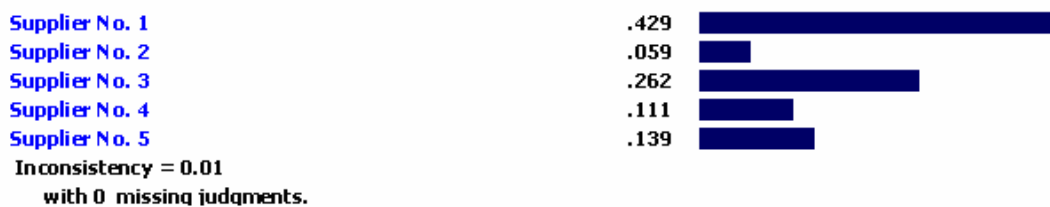
Figure 7.24: Pair-wise matrix & priorities for after sales services

Training aids	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1/2	1/3	1/5	1/4
Supplier no. 2		1	1/2	1/4	1/3
Supplier no. 3			1	1/3	1/3
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Service
    >Training aids

Supplier No. 1   .061
Supplier No. 2   .095
Supplier No. 3   .147
Supplier No. 4   .412
Supplier No. 5   .285
Inconsistency = 0.03
    with 0 missing judgments.

Figure 7.25: Pair-wise matrix & priorities for training aids

Flexibility	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	7	2	4	5
Supplier no. 2		1	1/4	1/3	1/2
Supplier no. 3			1	3	4
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Service
    >Flexibility

Supplier No. 1   .454
Supplier No. 2   .053
Supplier No. 3   .282
Supplier No. 4   .129
Supplier No. 5   .081
Inconsistency = 0.02
    with 0 missing judgments.

Figure 7.26: Pair-wise matrix & priorities for flexibility

Financial stability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	2	8	6	4
Supplier no. 2		1	5	4	3
Supplier no. 3			1	1/2	1/4
Supplier no. 4				1	1/2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
    >Business overall performance
        >Financial stability

Supplier No. 1	.466
Supplier No. 2	.282
Supplier No. 3	.045
Supplier No. 4	.075
Supplier No. 5	.132

Inconsistency = 0.02
    with 0 missing judgments.
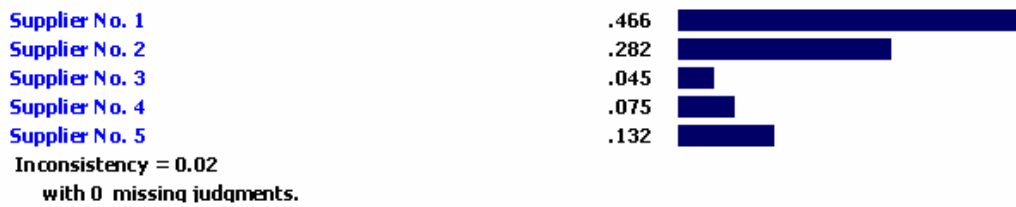
Figure 7.27: Pair-wise matrix & priorities for financial stability

Quality performance	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1	1	2	3
Supplier no. 2		1	1	2	3
Supplier no. 3			1	2	3
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
    >Business overall performance
        >Quality performance

Supplier No. 1	.260
Supplier No. 2	.260
Supplier No. 3	.260
Supplier No. 4	.138
Supplier No. 5	.082

Inconsistency = 0.00224
    with 0 missing judgments.
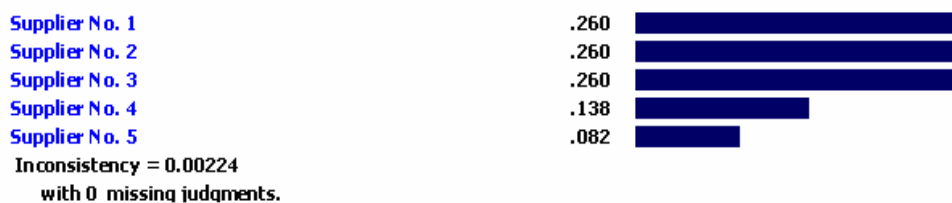
Figure 7.28: Pair-wise matrix & priorities for quality performance

129

Knowledge of the market	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	5	2	3	4
Supplier no. 2		1	1/4	1/3	1/2
Supplier no. 3			1	3	4
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Business overall performance
>Knowledge of the market

Supplier No. 1	.408
Supplier No. 2	.060
Supplier No. 3	.298
Supplier No. 4	.144
Supplier No. 5	.089

Inconsistency = 0.03
with 0 missing judgments.
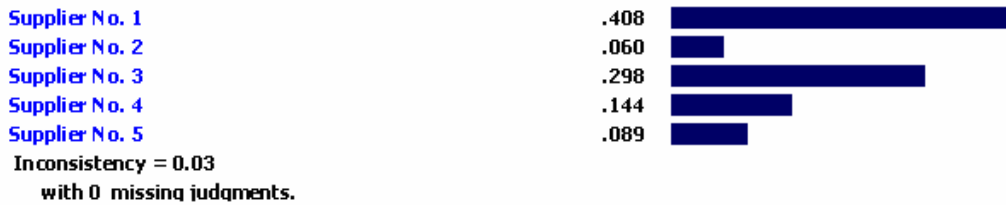
Figure 7.29: Pair-wise matrix & priorities for knowledge of the market

Information systems	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1/5	1/4	1/2	2
Supplier no. 2		1	2	4	6
Supplier no. 3			1	2	4
Supplier no. 4				1	4
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Business overall performance
>Information systems

Supplier No. 1	.082
Supplier No. 2	.452
Supplier No. 3	.261
Supplier No. 4	.151
Supplier No. 5	.053

Inconsistency = 0.02
with 0 missing judgments.

Figure 7.30: Pair-wise matrix & priorities for Information systems

Management capability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	2	7	4	5
Supplier no. 2		1	4	2	3
Supplier no. 3			1	1/4	1/3
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Business overall performance
>Management capability

Supplier No. 1	.462
Supplier No. 2	.245
Supplier No. 3	.048
Supplier No. 4	.150
Supplier No. 5	.095

Inconsistency = 0.03
with 0 missing judgments.

Figure 7.31: Pair-wise matrix & priorities for management capability

Performance history	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	6	4	5	2
Supplier no. 2		1	1/4	1/2	1/5
Supplier no. 3			1	2	1/2
Supplier no. 4				1	1/3
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Business overall performance
>Performance history

Supplier No. 1	.455
Supplier No. 2	.051
Supplier No. 3	.152
Supplier No. 4	.087
Supplier No. 5	.256

Inconsistency = 0.02
with 0 missing judgments.

Figure 7.32: Pair-wise matrix & priorities for performance history

131

Offering technical support	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	7	5	6	3
Supplier no. 2		1	1/3	1/2	1/5
Supplier no. 3			1	2	1/2
Supplier no. 4				1	1/3
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Technical capabilities
>Offering technical support

Supplier No. 1	.521
Supplier No. 2	.049
Supplier No. 3	.128
Supplier No. 4	.079
Supplier No. 5	.223

Inconsistency = 0.02
    with 0 missing judgments.

Figure 7.33: Pair-wise matrix & priorities for offering technical support

Technical know	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	2	1/4	1/2	3
Supplier no. 2		1	1/5	1/3	2
Supplier no. 3			1	2	5
Supplier no. 4				1	3
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Technical capabilities
>Technical know

Supplier No. 1	.149
Supplier No. 2	.091
Supplier No. 3	.453
Supplier No. 4	.242
Supplier No. 5	.065

Inconsistency = 0.02
    with 0 missing judgments.

Figure 7.34: Pair-wise matrix & priorities for technical know

Understanding of technology	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	2	1/2	1/4	3
Supplier no. 2		1	1/3	1/4	2
Supplier no. 3			1	1/2	4
Supplier no. 4				1	6
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
 >Technical capabilities
   >Understanding of technology

Supplier No. 1	.147
Supplier No. 2	.093
Supplier No. 3	.354
Supplier No. 4	.349
Supplier No. 5	.057

Inconsistency = 0.05
   with 0 missing judgments.

Figure 7.35: Pair-wise matrix & priorities for understanding of technology

Responsiveness	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	2	4	6	5
Supplier no. 2		1	2	5	3
Supplier no. 3			1	3	2
Supplier no. 4				1	1/2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
   >Technical capabilities
     >Responsiveness

Supplier No. 1	.457
Supplier No. 2	.258
Supplier No. 3	.143
Supplier No. 4	.054
Supplier No. 5	.088

Inconsistency = 0.01
   with 0 missing judgments.

Figure 7.36: Pair-wise matrix & priorities for responsiveness

Personnel capability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	6	4	7	3
Supplier no. 2		1	1/3	2	1/5
Supplier no. 3			1	3	1/2
Supplier no. 4				1	1/4
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Technical capabilities
>Personnel capabilities

Supplier No. 1	.496
Supplier No. 2	.068
Supplier No. 3	.145
Supplier No. 4	.051
Supplier No. 5	.240

Inconsistency = 0.04
with 0 missing judgments.
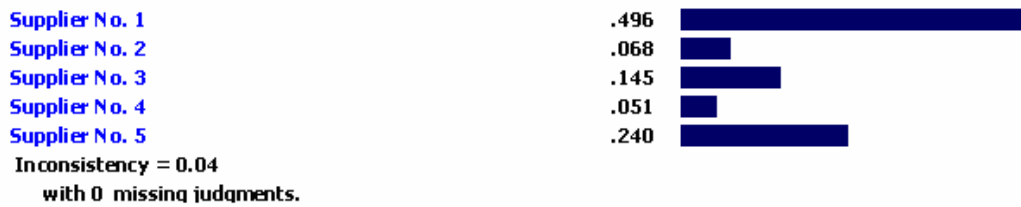
Figure 7.37: Pair-wise matrix & priorities for responsiveness

Delivery lead time	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	5	3	4	6
Supplier no. 2		1	1/3	1/2	2
Supplier no. 3			1	3	4
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Delivery
>Delivery lead time

Supplier No. 1	.487
Supplier No. 2	.087
Supplier No. 3	.247
Supplier No. 4	.120
Supplier No. 5	.060

Inconsistency = 0.03
with 0 missing judgments.

Figure 7.38: Pair-wise matrix & priorities for delivery lead time

Delivery speed	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	5	3	4	7
Supplier no. 2		1	1/2	1/2	3
Supplier no. 3			1	2	3
Supplier no. 4				1	3
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Delivery
>Delivery speed

Supplier No. 1	.500
Supplier No. 2	.104
Supplier No. 3	.199
Supplier No. 4	.144
Supplier No. 5	.053

Inconsistency = 0.03
with 0 missing judgments.

Figure 7.39: Pair-wise matrix & priorities for delivery lead time

Upcoming delivery commitments	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	4	3	6	8
Supplier no. 2		1	1/2	2	4
Supplier no. 3			1	3	7
Supplier no. 4				1	2
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Delivery
>Upcoming delivery commitments

Supplier No. 1	.505
Supplier No. 2	.139
Supplier No. 3	.237
Supplier No. 4	.077
Supplier No. 5	.042

Inconsistency = 0.02
with 0 missing judgments.
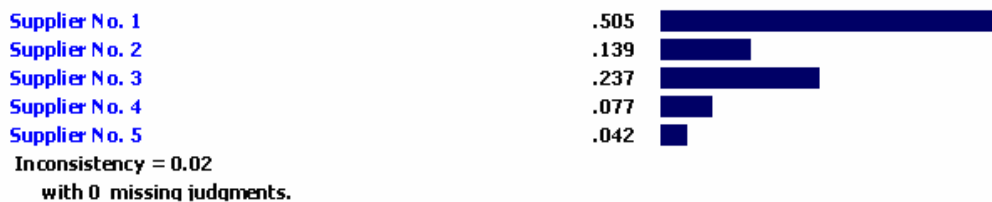
Figure 7.40: Pair-wise matrix & priorities for upcoming delivery commitments

135

Ability and willingness to expedite an order	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1	2	2	2
Supplier no. 2		1	2	2	2
Supplier no. 3			1	1	1
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Delivery
    >Ability and willingness to expedite an order

Supplier No. 1	.286
Supplier No. 2	.286
Supplier No. 3	.143
Supplier No. 4	.143
Supplier No. 5	.143

Inconsistency = 0.
  with 0 missing judgments.

Figure 7.41: Pair-wise matrix & priorities for ability and willingness to expedite an order

Safety and security components	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	6	4	5	2
Supplier no. 2		1	1/3	1/2	1/5
Supplier no. 3			1	2	1/2
Supplier no. 4				1	1/3
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
  >Delivery
    >Safety and security components

Supplier No. 1	.457
Supplier No. 2	.054
Supplier No. 3	.143
Supplier No. 4	.088
Supplier No. 5	.258

Inconsistency = 0.01
  with 0 missing judgments.

Figure 7.42: Pair-wise matrix & priorities for safety and security components

136

Modes of transportation facility	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1	1	2	2	2
Supplier no. 2		1	2	2	2
Supplier no. 3			1	1	1
Supplier no. 4				1	1
Supplier no. 5					1

Priorities with respect to:
Goal: Selection of the best photocopying machine supplier
>Delivery
>Modes of transportation facility
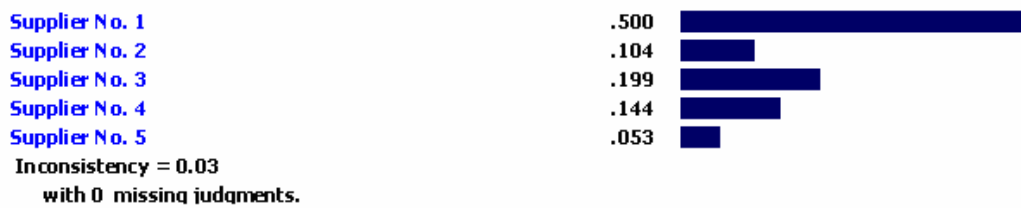
Supplier No. 1   .286
Supplier No. 2   .286
Supplier No. 3   .143
Supplier No. 4   .143
Supplier No. 5   .143
Inconsistency = 0.
   with 0 missing judgments.

Figure 7.43: Pair-wise matrix & priorities for modes of transportation facility

7.5 Synthesizing the Results:

Expert Choice 11.5 provides two ways of synthesizing the local priorities of the alternatives using the global priorities of their parent criteria: the distributive mode and the ideal mode. In the distributive mode the weight of a criterion reflects the importance that the decision maker attaches to the dominance of each alternative relative to all other alternatives under that criterion. In our case, the distributive mode would be the way to synthesize the results. After deriving the local priorities for the criteria and the alternatives through pair-wise comparisons, the priorities of the criteria are synthesized to calculate the overall priorities for the decision alternatives. As shown in table 7.3, the suppliers are ranked according to their overall priorities. Supplier no.1 (**Modern Center for Electronics 'Sharp")** turns out to be the most preferable supplier among the five suppliers, with an overall priority score of **0.309.**

Table 7.3: Overall rating of five vendors identified by MOF using AHP

Criterion	Local Weight (1)	Sub-criterion	Local Weight (2)	Local Weight (3)					Global Weight (4)				
				S. no.1	S. no.2	S. no.3	S. no.4	S. no.5	S. no.1	S. no.2	S. no.3	S. no.4	S. no.5
Quality	0.350	Product durability	0.338	0.487	0.086	0.141	0.044	0.242	0.0576	0.0102	0.0167	0.0052	0.0286
		Product reliability	0.361	0.481	0.145	0.090	0.038	0.246	0.0608	0.0183	0.0114	0.0048	0.0311
		Quality systems	0.137	0.247	0.269	0.247	0.123	0.114	0.0118	0.0129	0.0118	0.0059	0.0069
		Percent rejection	0.037	0.400	0.242	0.073	0.135	0.149	0.0052	0.0031	0.0009	0.0017	0.0019
		Adherence to quality tools	0.060	0.310	0.310	0.192	0.097	0.091	0.0065	0.0065	0.0040	0.0020	0.0019
		Reputation and position in the market	0.067	0.498	0.086	0.139	0.053	0.224	0.0117	0.0020	0.0033	0.0012	0.0053
Price	0.321	Competitive pricing	0.517	0.060	0.261	0.433	0.155	0.091	0.0100	0.0433	0.0719	0.0257	0.0151
		Total cost	0.137	0.055	0.271	0.430	0.154	0.089	0.0024	0.0119	0.0189	0.0068	0.0039
		Quantity discount	0.219	0.056	0.284	0.447	0.082	0.131	0.0039	0.0200	0.0314	0.0058	0.0092
		Payment terms	0.068	0.443	0.055	0.267	0.152	0.084	0.0097	0.0012	0.0058	0.0033	0.0018
		Payment procedures	0.060	0.332	0.209	0.253	0.108	0.099	0.0064	0.0040	0.0049	0.0021	0.0019
Service	0.154	Spare parts availability	0.328	0.373	0.100	0.165	0.068	0.294	0.0188	0.0051	0.0083	0.0034	0.0149
		Handling of complaints	0.045	0.435	0.052	0.088	0.163	0.263	0.0030	0.0004	0.0006	0.0011	0.0018
		Ability to maintain product/service	0.215	0.416	0.096	0.158	0.059	0.271	0.0138	0.0032	0.0052	0.0020	0.0090
		After sales services	0.272	0.129	0.059	0.262	0.111	0.139	0.0054	0.0025	0.0110	0.0046	0.0058
		Training aids	0.060	0.061	0.095	0.147	0.412	0.285	0.0006	0.0009	0.0014	0.0038	0.0026
		Flexibility	0.081	0.454	0.053	0.282	0.129	0.081	0.0057	0.0007	0.0035	0.0016	0.0010
Business overall performance	0.041	Financial stability	0.183	0.466	0.282	0.048	0.075	0.132	0.0035	0.0021	0.0004	0.0006	0.0010
		Quality performance	0.258	0.260	0.260	0.260	0.138	0.082	0.0028	0.0028	0.0028	0.0015	0.0009
		Knowledge of the market	0.047	0.408	0.060	0.298	0.144	0.089	0.0008	0.0001	0.0006	0.0003	0.0002
		Information systems	0.204	0.082	0.452	0.261	0.151	0.053	0.0007	0.0038	0.0022	0.0013	0.0004
		Management capability	0.212	0.462	0.245	0.048	0.150	0.095	0.0040	0.0021	0.0004	0.0013	0.0008
		Performance history	0.095	0.455	0.051	0.152	0.087	0.256	0.0018	0.0002	0.0006	0.0003	0.0010

Table 7.3: Overall rating of five vendors identified by MOF using AHP continued

Technical	0.057	*Offering technical support*	*0.295*	*0.521*	*0.049*	*0.128*	*0.079*	*0.223*	*0.0088*	*0.0008*	*0.0022*	*0.0013*	*0.0037*
capability		Technical know	0.157	0.149	0.091	0.453	0.242	0.065	0.0013	0.0008	0.0041	0.0022	0.0006
		Understanding of technology	0.097	0.147	0.093	0.354	0.349	0.057	0.0008	0.0005	0.0020	0.0019	0.0003
		Responsiveness	0.138	0.457	.0258	0.143	0.054	0.088	0.0036	0.0002	0.0011	0.0004	0.0007
		Personnel capabilities	0.314	0.496	0.068	0.145	0.051	0.240	0.0089	0.0012	0.0026	0.0009	0.0043
Delivery	0.077	Delivery lead time	0.138	0.487	0.087	0.247	0.120	0.060	0.0052	0.0009	0.0026	0.0013	0.0006
		Delivery speed	0.329	0.500	0.104	0.199	0.144	0.053	0.0127	0.0026	0.0050	0.0036	0.0013
		Upcoming delivery	0.289	0.505	0.139	0.237	0.077	0.042	0.0112	0.0031	0.0053	0.0017	0.0009
		Ability and willingness to	0.146	0.286	0.286	0.143	0.143	0.143	0.0032	0.0032	0.0016	0.0016	0.0016
		Safety and security components	0.065	0.457	0.054	0.143	0.088	0.258	0.0023	0.0003	0.0007	0.0004	0.0013
		Modes of transportation facility	0.034	0.286	0.286	0.143	0.143	0.143	0.0007	0.0007	0.0004	0.0004	0.0004
Total	**1.000**				*Overall Priority*				**0.309**	**0.181**	**0.248**	**0.105**	**0.158**
					Rank				**1**	**3**	**2**	**5**	**4**

Figure 7.44: Synthesizing the local priorities of the alternatives

Synthesis with respect to: Goal: Selection of the best photocop...

Overall Inconsistency = .02

Supplier No. 1	.309
Supplier No. 2	.181
Supplier No. 3	.248
Supplier No. 4	.105
Supplier No. 5	.158

7.6 Sensitivity Analysis:

It is necessary to examine the sensitivity of the alternatives due to changes in the priorities of the (SSM) model's main criteria with respect to the goal. A series of sensitivity analyses were conducted to investigate the impact of changing the priority of the criteria on the suppliers' ranking. The Expert Choice software has the ability to deal with such changes and has five ways to display the result of such changes. These ways include gradient sensitivity, two-dimensional sensitivity, performance sensitivity, dynamic sensitivity and weighted differences sensitivity.

For this research, *Dynamic and performance* sensitivity were performed. Dynamic sensitivity analysis is used to dynamically change the priorities of the criteria to determine how these changes affect the priorities of the alternative choices. The performance sensitivity shows the relative importance of each of the objectives as bars, and the relative preference for each alternative with respect to each objective as the intersection of the alternatives' curves with the vertical line for each objective.

The impact of changing the priority of six main criteria on overall results was investigated. As shown in Figures (7.45 - 7.50), the results indicate that the suppliers' ratings are not sensitive to changes in the importance of the *quality, price, service, business overall performance, technical capabilities and delivery* criteria. The priorities of the model's main criteria were changed one at a time with respect to the goal as follows:

➢ When the importance of *quality* is increased from 0.35 to 0.462 or decreased from 0.35 to 0.248, overall rank of the final outcome is preserved.

➢ The relative importance of *price* is increased from 0.321 to 0.524 or decreased from 0.321 to 0.177. In this analysis, overall rank of the final outcome is preserved.

➢ When the importance of *service* is increased from 0.154 to 0.307 or decreased from 0.154 to 0.096, overall rank of the final outcome was preserved.

➢ When the importance of *business overall performance* is increased from 0.041 to 0.307, overall rank of the final outcome was preserved.

➢ When the importance of *technical capabilities* is increased from 0.057 to 0.196, overall rank of the final outcome was preserved.

➢ When the importance of *delivery* is increased from 0.077 to 0.226, overall rank of the final outcome was preserved.

It is concluded from dynamic sensitivity analysis that these results are not sensitive to any changes in the main criteria, so when the importance of all the criteria decreased and increased, the results indicated that supplier no.1 (**Modern Center for Electronics 'Sharp")** is the best alternative for all priorities.

Performance sensitivity analysis may help decision makers to see what may happen if the weight of the factors changes (Figure 7.51). To see the impact of the changes, e.g., when the importance of *price* is increased to 0.6, supplier no.3 has become the best alternative (Figure 7.51).
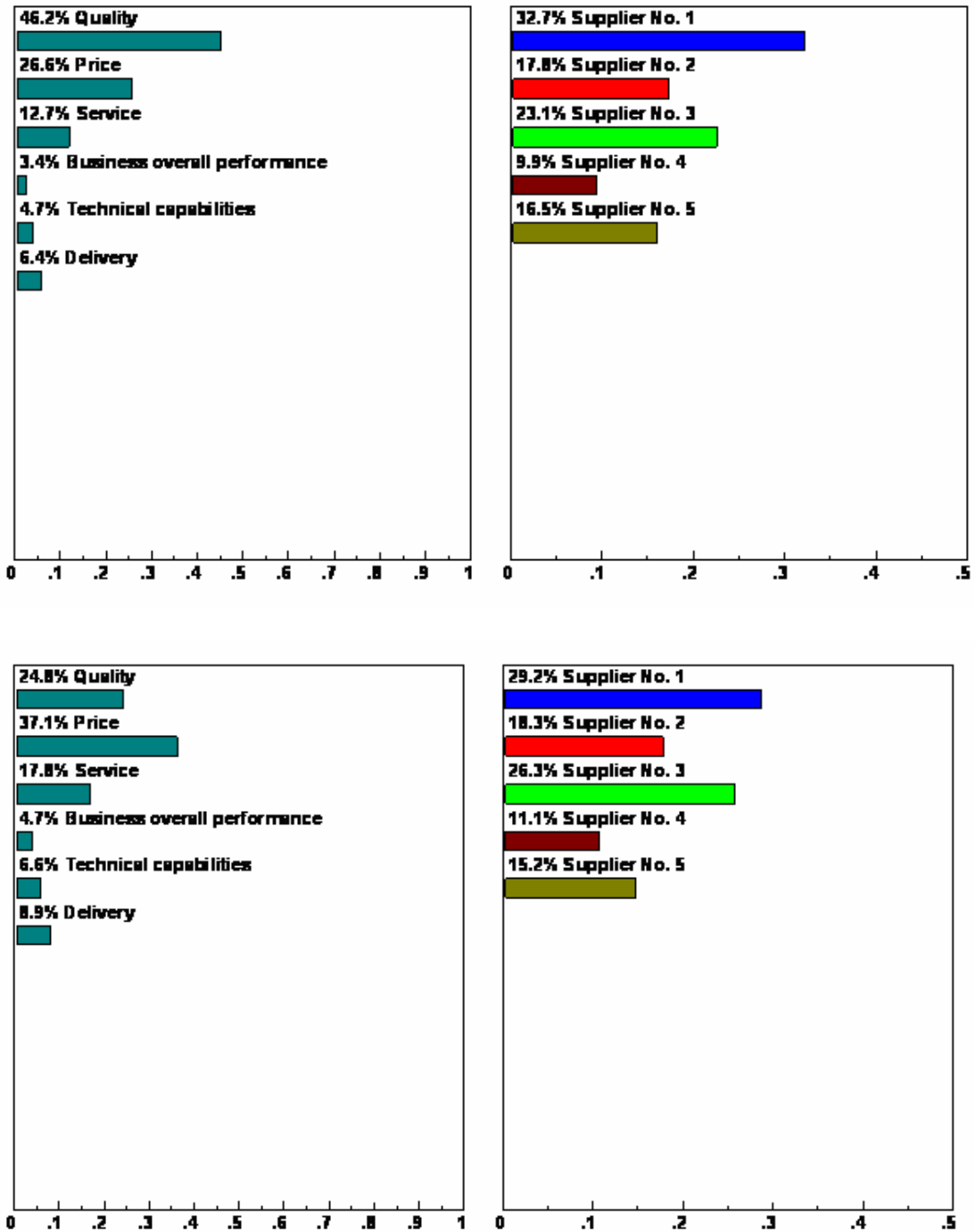
Figure 7.45: Change in alternatives' priorities due to change in quality

Dynamic Sensitivity for nodes below: Goal: Selection of the best photocopying machine supplier
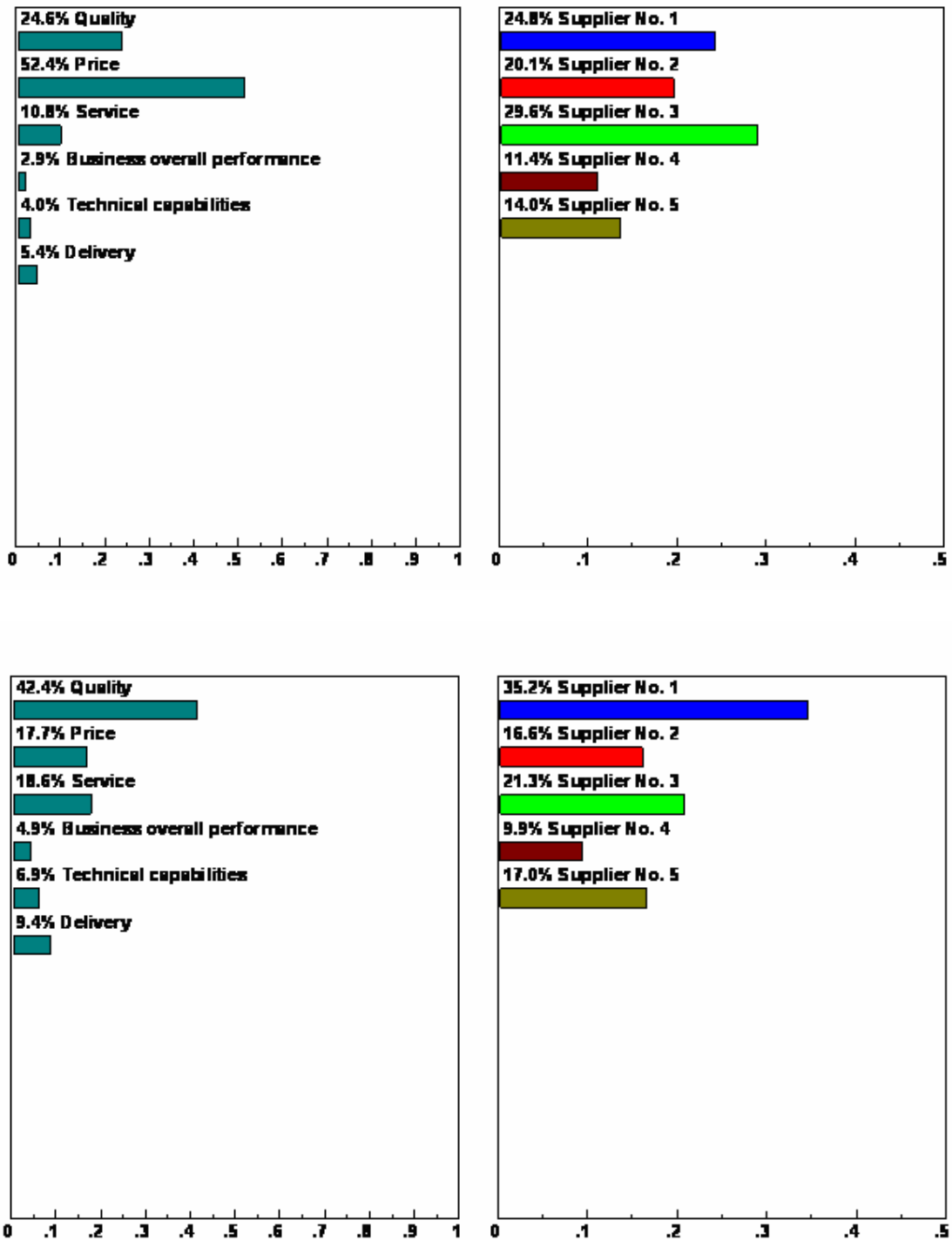
Figure 7.46: Change in alternatives' priorities due to change in price

143

Dynamic Sensitivity for nodes below: Goal: Selection of the best photocopying machine supplier
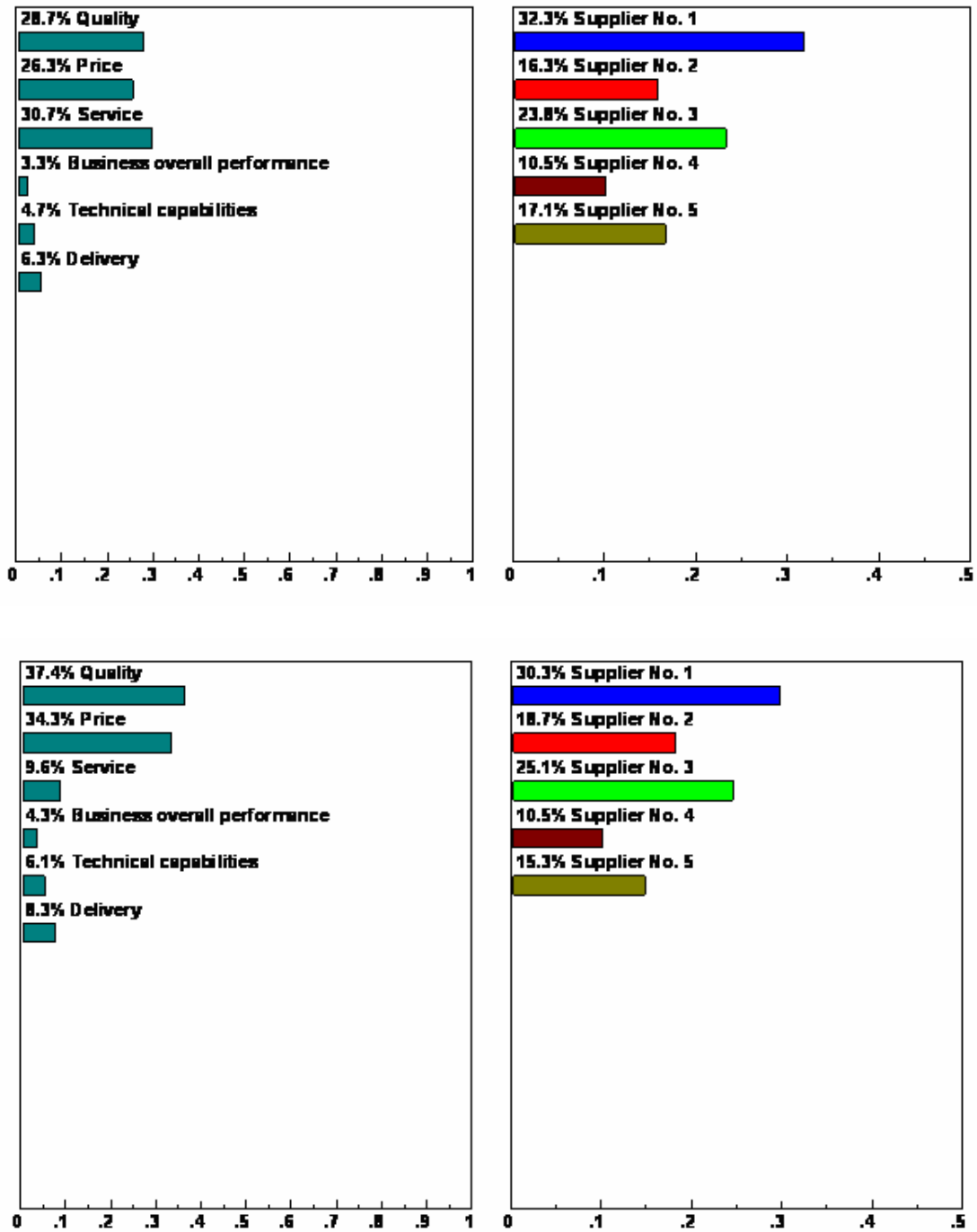
Figure 7.47: Change in alternatives' priorities due to change in service
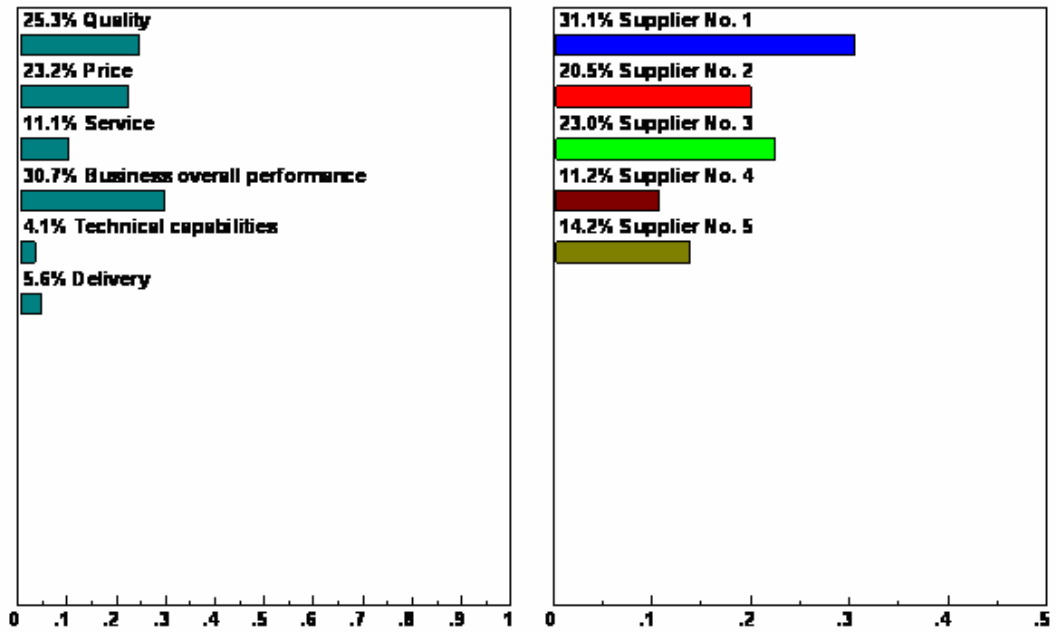
Figure 7.48: Change in alternatives' priorities due to change in business overall performance
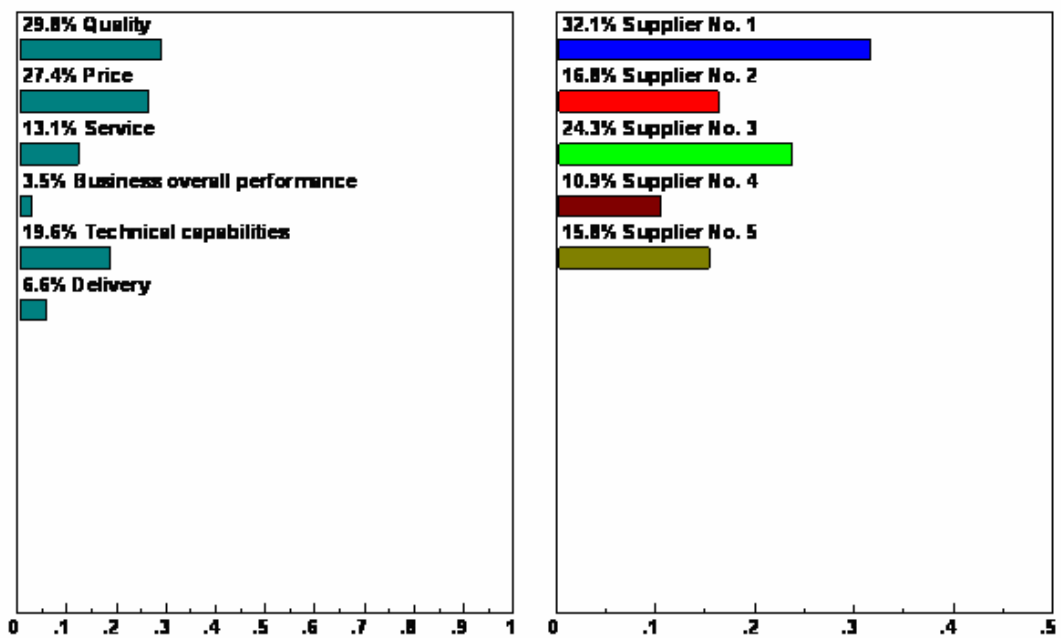
Figure 7.49: Change in alternatives' priorities due to change in technical capabilities

145
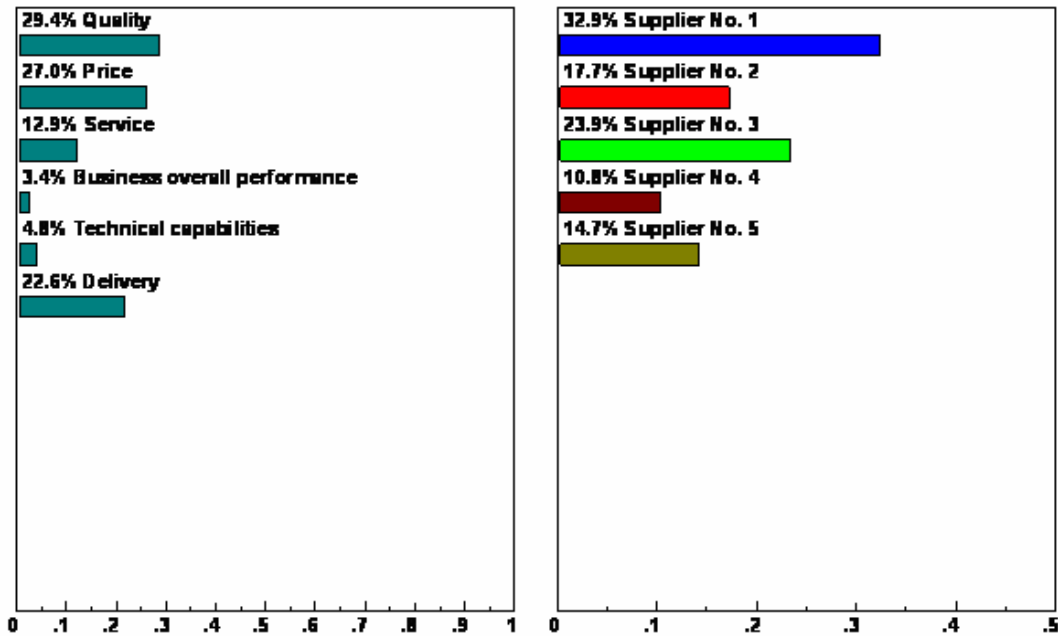
Figure 7.50: Change in alternatives' priorities due to change in delivery
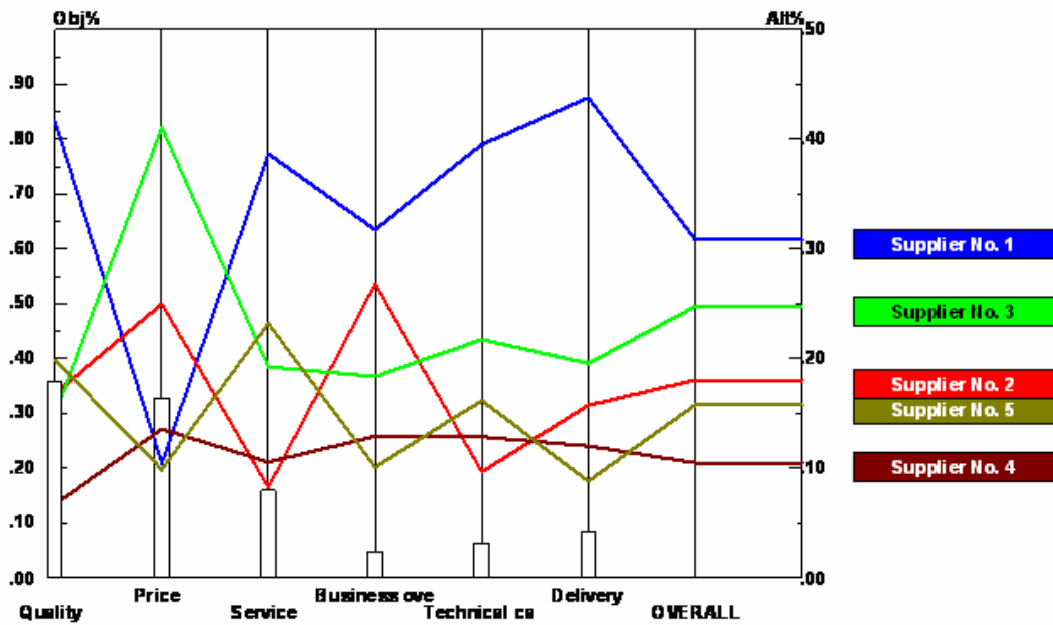
Figure 7.51: Performance sensitivity analysis for the main criteria
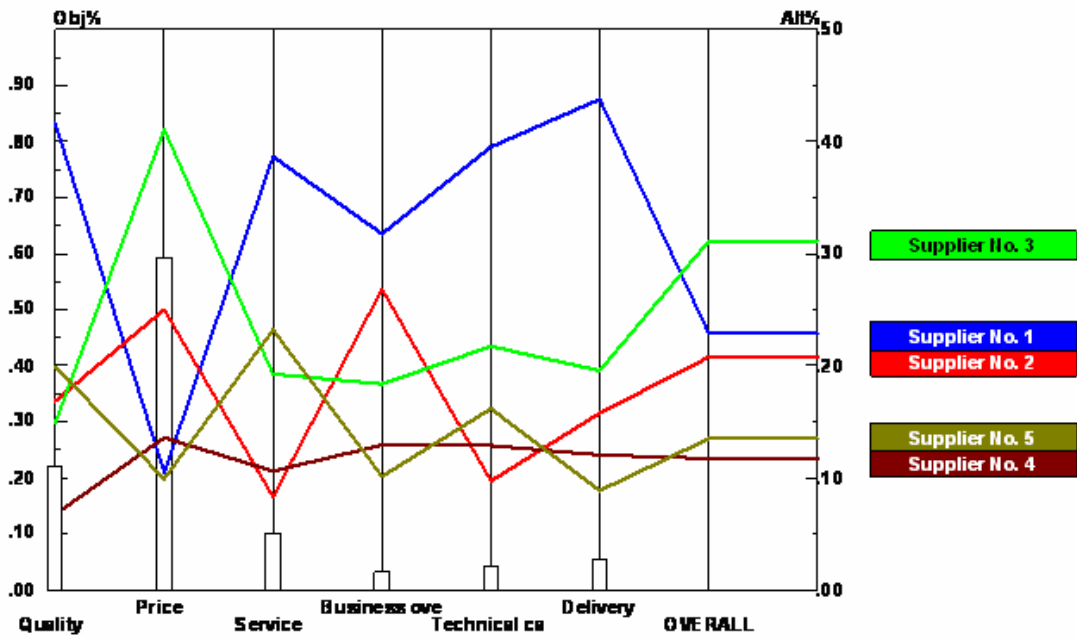
Figure 7.52: Performance sensitivity analysis for the change in price

Chapter Eight

Conclusion and Recommendations

8.1 Introduction

8.2 Major Findings

8.3 Conclusions

8.4 Recommendations

8.5 Future Researches

Chapter Eight

Conclusion and Recommendations

8.1 Introduction:

When an organization is dealing with selecting the best supplier to deliver a good or service, the decision can often be very complex. Supplier selection problems are multi-criteria problems which have many qualitative and quantitative concerns. This research has presented the AHP as a decision analysis tool in supplier selection problems. An AHP model was proposed to select the best photocopying machine supplier for the PNA ministries. This chapter summarized the major findings, conclusion and recommendations that were derived from combined results of literature review, methodology and the case study.

8.2 Major Findings:

As a result of the data analysis about the supplier selection process in the PNA were analyzed, the following findings were noted:

1. The research revealed that there are a large set of supplier selection criteria. These criteria are developed and ranked by purchasing managers and suppliers in order to understand their view with the help of questionnaire survey. The main supplier selection criteria were identified and ranked by the public sector as follows:

    - Quality

    - Price

    - Service

    - Delivery

- Business overall performance

- Technical capability

2. The "Quality" main criterion is ranked first. This is due to the fact that public sector considers "Quality" is the most important criterion that must be evaluated for successful selection, and for any positive indication that might be realized for the supplier. The "Price" main criterion is ranked second since it is an obvious consideration for any purchase.

3. The first supplier selection sub-criteria were identified and ranked by the public sector as follows:

Sub-criterion	Global Weight
Competitive pricing	0.16596
Product reliability	0.12635
Product durability	0.11830
Quantity discount	0.07030
Spare parts availability	0.05051
Quality systems	0.04795
Total cost	0.04398
After sales services	0.04189
Ability to maintain product/service	0.03311
Delivery speed	0.02533
Total	**0.72368**

4. The first supplier selection sub-criteria weigh 72.4 % of the total weight of the selection criteria. This is due to the fact that they are major sub-criteria that play a major role in the supplier selection.

5. The research revealed that the supplier selection is concerned with manufacturing related industries and the contractor selection is mainly associated with the construction industry. It seems that there was no evidence of any research on how public organizations evaluate and select suppliers. This may be either because such

research reported within contractor selection literature or the purchasing activity is carried out by the private sector only.

6. The research revealed that there are a large number of decision making methods and tools proposed for supplier selection. the decision making methods for supplier selection are clustered into several broad categories:

- Artificial intelligence and expert systems

- Mathematical programming.

- Traditional MCDM techniques.

- Multivariate statistical analysis.

- Group decision making and multiple methods.

7. AHP was se1ected as a methodological basis for this study. This research proposes an AHP model (SSM) for the selection of the suppliers in the PNA ministries. The major advantages of this research is that it can be used for both qualitative and quantitative criteria. Pair-wise comparison used in this work reduces the dependency of the model on human judgment. The results show that the model has the capability to be flexible and apply in selecting the best supplier. The final priority weight of each alternative at the last level of the hierarchy will lead to a recommended best option. It can be concluded that the model could facilitate decision making. The approach could help in reducing time consuming efforts in the supplier selection process. The existence of easy-to-use commercial software (Expert Choice) help in developing the model and synthesizing the results.

8. Supplier Selection Model (SSM) enables decision-maker to deal with inconsistent judgments systematically. The pair-wise comparison procedure is

able to capture relative judgments of two elements at one time in a trustworthy manner and ensure consistency of these values.

9. AHP model is capable of handling multiple criteria and enabled us to incorporate 34 both qualitative and quantitative factors, when assessing the supplier. It is concluded that supplier no.1 (Modern Center for Electronics) is the best supplier with an overall priority score of 0.309.

10. The AHP method of ranking suppliers suffers from some shortcomings. The first is that although the AHP helps to stay consistent when assigning weights, a great deal of subjectivity remains embedded in the method **.** The second is that if a new criterion is added, the classification might be modified. The third is that the method does not consider situations where multiple suppliers may be used.

8.3 Conclusion:

The main objective of the research "Identifying the major selection criteria and the development of a Supplier Selection Model (SSM)", was accomplished. The SSM model was implemented for solving the complicated selection problem, in a practical way by comparing prospective suppliers in terms of selection criteria. The SSM's concept is concerned with the selecting a capable and competent supplier based on several criteria to supply the required materials (photocopying machines) within a given time, with an appropriate price and with the required quality. The implementation proved that the SSM model is a consistent, practical, and effective selection tool for selecting the best supplier.

8.4 Recommendations:

Based on the result of application of the SSM, the PNA ministries are recommended to use the SSM for the following reasons:

- The model can be used in the evaluation and selection of the best photocopying machines supplier for the PNA.

- The model can represent a framework that can be used in the public sector ministries.

- The model ensures fast but accurate evaluation and successful supplier selection.

- The model can handle single as well as group judgments, making it easy to consider the judgments' of different levels of management.

- The flexibility of the model enables the user to modify it as required.

8.5 Future Researches:

This research may be expanded in a number of different directions.

First of all, this is the primary model for supplier selection problem in the public sector in PNA, further research is required to review the suitability of the hierarchy structure, the validity and significance of the selection criteria and sub-criteria, and their weights.

Secondly, photocopying machines are only one type of the supplies purchased by the public sector, it is suggested that research on the application of the AHP model in other kinds of supplies is conducted in the future. This will help in further verification and fine tuning of the model.

Thirdly, there are some limitations of the approach. AHP assumes linear independence of criteria and alternatives. A comparative study between AHP and other

MCDM is recommended in the supplier selection field. If there is dependence among the criteria, Analytic Network Process (ANP) (Saaty, 2001) is more appropriate yet ANP requires far more comparisons which may be formidable in practical decision environment. This is a new area of research to explore.

Finally, criteria included in the supplier selection process may frequently contradict each other (lowest price against poor quality). Therefore, it requires substantial judgment to assess the wide range of trade-offs present, to recognize all the alternatives available and to make a decision, which balances both the short- and long-term needs of an organization. It is importance to analyze the tradeoffs among the selection criteria which may be increased over time.

References & Appendices

References

1. Aamodt, A. and Plaza E. (1994) "Case-based reasoning: Foundational issues, methodological variations and system approaches, "AICom-Artificial Intelligence Communications 7(1) 39–59.

2. Al-Besher, M. (1998) "Conceptual model for consultant selection in Saudia Arabia" [Master thesis], King Fahd University of Petroleum and Minerals, Dhahran, Saudia Arabia.

3. Al-Harbi, K. (2001) "Application of the AHP in project management." International journal of project management 19 (2001) 19-27

4. Atthirawong, W. (2002), "An Application of the Analytical Hierarchy Process to International Location Decision-Making", in Gregory, Mike, Proceedings of The 7th Annual Cambridge International Manufacturing Symposium: Restructuring Global Manufacturing, Cambridge, England: University of Cambridge, pp. 1-18

5. Barbarosoglu, G. and Yazgac, T. (1997) "An application of the analytic hierarchy process to the supplier selection problem." Production and inventory management journal, 38(1), 14-21.

6. Bayazit O. and Karpak B. (2005) "An AHP application in vendor selection", ISAHP, Honolulu, Hawaii, July 8-10

7. Bello, Marlene (2003) "A case study approach to the supplier selection process", [Master dissertation], University of Puerto Rico.

8. Belton V. (1990) "Multiple criteria decision analysis: practically the only way to choose in" Hendry LC, Eglese RW, editors. Operational research tutorial papers. pp. 53-102.

9. Belton, V. and Stewart, T.J. (2002) "Multiple criteria decision analysis: An integrated approach." Boston/Dordrecht/London: Kluwer academic publishers.

10. Berrittella, M. (2007) "An Analytic Hierarchy Process for the Evaluation of Transport Policies to Reduce Climate Change Impacts", Fondazione Eni Enrico Mattei (Milano).

11. Bhutta, K. S. and Huq, F., (2002), "Supplier selection problem: a comparison of the total cost of ownership and analytical hierarchy process approaches", Supply Chain Management, 7, p126

12. Bottani, E., and Rizzi, A. (2005) "A fuzzy multi-attribute framework for supplier selection in an e-procurement environment" International Journal of Logistics: Research and Applications, v. 8, No. 3, September 2005, 249–266.

13. Braglia, M. and Petroni, A. (2000), "A quality assurance-oriented methodology for handling trade-offs in supplier selection", International Journal of Physical Distribution & Logistics Management, Vol. 30 No. 2, pp.96-111.

14. CPAR, (2004) " West Bank and Gaza: Country procurement assessment report" Document of the World Bank, Operational core services.

15. Chan F. T. S.(2003) "Interactive selection model for supplier selection process: an analytical hierarchy process approach", International Journal of Production Research, vol. 41, no. 15, 3549–3579

16. Chan F. T. S. and Chan H. K. (2004) "Development of the supplier selection model a case study in the advanced technology industry", Journal of Engineering Manufacture Vol. 218 Part B.

17. Chankong, V. and Haimes, Y.Y., (1983) "Multiobjective Decision Making: theory and Methodology". North Holland, New York.

18. Choi, T.Y. and Hartley, J.L., (1996) "An exploration of supplier selection practices across the supply chain." Journal of Operations Management, 14, 333–343.

19. Choy, K. L., Lee W. B. and Lo, V. (2002) "An intelligent supplier management tool for benchmarking suppliers in outsource manufacturing," Int. J. Expert Systems with Applications 22(3) 213–224.

20. Davidrajuh, Reggie (2000) "Automating supplier selection procedures." [Doctoral dissertation], Narvik Institute of Technology, Narvik, Norway.

21. De Boer, L., Labro, E. and Morlacchi, P. (2001) "A review of methods supporting supplier selection." European Journal of Purchasing and Supply Management, 7, 75–89.

22. De Boer, L. and Der Wegen, L. V. (2003) "Practice and promise of formal supplier selection: a study of four empirical cases.", Journal of Purchasing and Supply Management, 9(3): p. 109-118.

23. De Boer, L., Der Wegen, L. V. and Telgen, J. (1998) "Outranking methods in support of supplier selection." European journal of purchasing and supply management, 4, 109–118.

24. Degraeve Z. and Roodhooft F. (1999) "Improving the efficiency of the purchasing process using total cost of ownership information: The case of heating electrodes at Cockerill Sambre S. A." European J. Operational Research, 112 42–53.

25. De Montis A., De Toro P., Droste-Franke B., Omann I. and Stagl S. (2000) "Criteria for quality assessment of MCDA methods." Proc. 3rd Bienn. Conf. Eur. Soc. Ecol. Econ. Vienna. May 3-6.

26. De Steiguer, J.E. (2003), "The Analytic Hierarchy Process as a Means for Integrated Watershed Management", in Renard, Kenneth G., First Interagency Conference on Research on the Watersheds, Benson, Arizona: U.S. Department of Agriculture, Agricultural Research Service, pp. 736-740

27. Dey, P. K. (2003). "Analytic Hierarchy Process Analyzes Risk of Operating Cross-Country Petroleum Pipelines in India". Natural Hazards Review 4 (4): 213-221. Retrieved on 2007-08-20.

28. Dickson, G.W. (1966), "An analysis of vendor selection systems and decisions", Journal of Purchasing 2/1, 5-17.

29. DTER, (2000) "multi-criteria analysis manual." DTER, London. www.communities.gov.uk/embedded_object.asp?id=1142252

30. EC (2007) Expert Choice, Pro 11.5, Inc., Expert Choice software and manual. 4922 Elsworth Ave., Pittsburgh, PA 15213, USA. http://www.expertchoice.com/products/grouptrialreg.html

31. Ellram L.M. (1990) "The supplier selection decision in strategic partnerships", Journal of Purchasing and Materials Management (Fall, 1990) 8–14.

32. Ellram L.M. (1995) "Total cost of ownership: an analysis approach for purchasing." International Journal of Physics and Distribution Logistics. 25(8):163–184

33. Garfamy R. M. (2005) "Supplier Selection and Business Process Improvement" [Doctoral Thesis Proposal], University of Autonoma De Barcelona.

34. Gill, J., and Johnson, P. (2002) "Research methods for managers" 3rd ed., Sage Publications, London.

35. Ghodsypour, S. H. and O'Brien, C. (2001), "The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constrains", International Journal of Production Economics, Vol. 73, pp.15-27.

36. Grandzol, J. R. (2005). "Improving the Faculty Selection Process in Higher Education: A Case for the Analytic Hierarchy Process". IR Applications 6. Retrieved on 2007-08-21

37. Holt, G. D. (1998) "Which contractor selection methodology?" Int. J. Project Management 16(3) 153–164.

38. International Society on Multiple Criteria Decision Making, from http://www.rfp-templates.com/Multi-Criteria-Decision-Making-MCDM.html and http://www.terry.uga.edu/mcdm/

39. Kahraman, C., Cebeci, U. and Ulukan, Z.(2003) "Multi-criteria supplier selection using fuzzy AHP." Logistics Information Management, 16, 382–394.

40. Kasilingam, R.G., Lee, C.H., (1996) "Selection of vendors-A mixed-integer programming Approach", Computer and Industrial Engineering, vol:31, p:347-350

41. Karpak, B., Birsen, K., Rammohan, R. and Kumcu, E. (1999). "Multi-Objective Decision Making in Supplier Selection: An Application of Visual Interactive Goal Programming", Journal of Applied Business Research, 15 (2), 57-71.

42. Keskar, Harshal (1999) "Supplier selection metrics and methodology" [Master thesis], University of Pune, Pune, India.

43. Kotler, P., Keller, K. L. (2006) "Marketing management" 12th ed., Pearson, Prentice Hall, New Jersey.

44. Larson, C. D. (2007), "Application of the Analytic Hierarchy Process to Select Project Scope for Video logging and Pavement Condition Data Collection", 86th Annual Meeting Compendium of Papers CD-ROM, Transportation Research Board of the National Academies

45. Lee, E. K., Ha, S. and Kim, S. K. (2001) "Supplier selection and management system considering relationships in supply chain management." IEEE Transactions on Engineering Management, 47(4): 307-318.

46. Lesonsky (2001) "Your own business: The only start-up book you'll ever need." Entrepreneur media Inc., 2nd ed.

47. Linkov, I., Varghese, A., and JAMIL, S. (2004) "Multi-criteria decision analysis: a framework for structuring remedial decisions at contaminated sites" ICF Consulting, 33 Hayden Ave., Lexington, MA 02421, USA.

48. Liu, J., Ding, F. Y. and Lall, V. (2000), "Using data envelopment analysis to compare suppliers for supplier selection and performance improvement", Supply Chain Management—An International Journal, Vol. 5 No. 3, pp. 143-150.

49. Liu, F.H. and Hai, H.L. (2005) "The voting analytic hierarchy process method for selecting supplier" International Journal of Production Economics, In press, Corrected Proof, Available online 14 January 2005.

50. Malczewski, J.,(1999) "GIS and Multicriteria Decision Analysis" John Wiley and Sons, New York.

51. Masella, C. and Rangone, A.(2000) "A contingent approach to the design of vendor selection systems for different types of co-operative customer/supplier relationships." International Journal of operation Production management, 20, 70–84.

52. McCaffrey, J. (2005). "Test Run: The Analytic Hierarchy Process". MSDN Magazine. Retrieved on 2007-08-21.

53. Min, H., (1994) "International supplier selection: a multi-attribute utility approach." International Journal of Physical Distribution and Logistics Management, 24, 24–33.

54. Naoum, S.G., (1998) " Dissertation research and writing for construction students", Reed , Educational and professional publishing Ltd.

55. Noorul Haq A. and Kannan G. (2005) " Fuzzy analytical hierarchy process for evaluating and selecting a vendor in a supply chain model", International Journal of Advanced Manufacturing Technology, 29:826-835.

56. Noorul Haq A. and Kannan G. (2006) "An Integrated approach for selection a vendor using Grey Relational Analysis", International Journal of Information Technology & Decision Making, Vol. 5, No. 2 277–295.

57. Nydick RL, Hill R.P. (1992) "Using the analytic hierarchy process to structure the supplier selection procedure." International Journal of purchasing Management 28(2) : 31–36

58. Oboulhas C., Xiaofei X., Zhan D. and Sha L. (2003) "An integrated model for supplier selection process", J. Harbin Institute of Technology 10(1) 43–50.

59. Oboulhas O., Xiaofei X., and Zhan D. (2004). "A decision support system for supplier selection process", International Journal of Information Technology & Decision Making Vol. 3, No.3 453–470 World Scientific Publishing Company.

60. Opricovic, S. and Tzeng, G.H. (2004) " Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS." European Journal of Operational Research, 156, 445-455.

61. Palaneeswaran E., Ng S.T., Kumaraswamy M. and Chan W.H.K. (2006) "Analytic Hierarchy Process Based Supplier Selection Framework for Construction Contractors", The construction and building research conference of the Royal Institution of Chartered Surveyors, http://www.rics.org/NR/rdonlyres/.

62. Pearson, J. N. & Ellram, L. M. (1995), 'Supplier selection and evaluation in small versus large electronics firms', Journal of Small Business Management, 33, 4, 53-65.

63. Petroni A. and Braglia M. (2000) "Vendor selection using principal component analysis." Journal of Supply Chain Management: A Global Rev. Purchasing Supply 36(2) : 63–69.

64. Polit, D. and Hunger, B. (1985), Essentials of Nursing Research: Methods and Application, J.B. Lippincott Co., Philadelphia.

65. Rebstock, S. E. and Kaula, R. (1996) "The effectiveness of an analytic hierarchy process in group decision making: a case study." International journal of computer applications in technology, 9, 95–105.

66. Saaty, T. L. and Vargas L. G. (2005), "The possibility of group welfare functions", International Journal of Information Technology & Decision Making 4(2) 167–176.

67. Saaty, T. L. and Vargas L. G. (1991), "Prediction, Projection and Forecasting in Applications of the Analytical Hierarchy Process in Economics, Finance, Politics, Games and Sports" Kluwer Academic Publishers, Boston, 1991.

68. Saaty, T. L., (2001) "Decision making in complex environments: the analytic network process for decision making with dependence and feedback", RWS Publications, USA.

69. Saaty, T. L., (1990) "How to make a decision: The analytic hierarchy process.", European Journal of Operational Research, 48:9-26,

70. Saaty, T. L. (1996) "Multi-criteria Decision Making: The analytic hierarchy process: planning, priority setting, resource allocation." Pittsburgh.

71. Saaty, T. L. (1980) "The analytic hierarchy process: planning, priority setting, resource allocation." McGraw-Hill, New York .

72. Sarkis, J., Sundarraj, R.P. (2005) "Evaluation of Enterprise Information Technologies: A Decision Model for High-Level Consideration of Strategic and Operational Issues", IEEE Transactions on Systems, Man., and Cybernetics Part C: Applications and Reviews, 1-14.

73. Sonmez, Mahmut (2006) "A Review and Critique of Supplier Selection Process and Practices.", Occasional Papers Series, Loughborough University, UK. www.lboro.ac.uk/departments/bs/research/2006-1.pd

74. SPSS (2007), "Statistical Package for the Social Science", version 13, SPSS Inc.

75. Tille M. and Dumount A. (2003) "Methods of multicriteria decision analysis within the road projects like an element of the sustainability." STRC 03 Conference paper session decision support, 3 rd Swiss transport research conference.

76. Timmerman E. (1986) "An approach to vendor performance evaluation." Journal of Supply Chain Management 22(4):2–8.

77. Tseng, Y., Lin, Y.(2005) "A Model for Supplier Selection and Tasks Assignment", Journal of American Academy of Business, Cambridge, 6(2), p197-207

78. Wang, G., Huang, S. H. and Dismukes, J. P. (2004) "Product-driven supply chain selection using integrated multi-criteria decision-making methodology." International Journal of Production Economics, 91(1): p. 1-15.

79. Weber, C. A., Current, J. R. and Benton, W.C. (1991). "Vendor selection criteria and methods", European Journal of Operational Research 50(1)2-18

80. Weber, C. A., Current, J. and Desai, A. (1998) "Non-cooperative negotiation strategies for vendor selection." European Journal of Operational Research, 108(1): p. 208-223.

81. Weber, C. A., Current, J. and Desai, A. (2000) "An optimization approach to determining the number of vendors to employ.", Supply Chain Management: An International Journal, 5(2): p. 90-98.

82. Weber C. A. and Ellram L. M.(1992) "Supplier selection using multi-objective programming: A decision support system approach" Int. J. Physical Distribution & Logistics Management 23(2) (1992) 3–14.

83. Wei SY, Jinlong Z, Zhicheng LI (1997) "A supplier-selecting system using a neural network." IEEE International Conference on Intelligent Processing Systems 1:468–471.

84. Wikipedia (2007) on line, The page was last modified 15:09, 11 September 2007. http://en.wikipedia.org/wiki/Goal_programming

85. World Bank (2004) "Guidelines: procurement under IBRD loans and IDA credits" Washington, DC.

86. Yahya, S. and Kingsman, B.(1999) "Vendor rating for an entrepreneur development programme: a case study using analytic hierarchy process method." J. Operating Res. Soc., 50, 916–930.

87. Yaralioglu, K. and Koksal, H. (2002) "Analytic hierarchy process as a managerial decision tool in the evaluation of new product idea." http://eab.ege.edu.tr/pdf/3/C1-S1-2-M11.pdf

88. Zahedi F (1986) 'The analytic hierarchy process: a survey of the method and its applications." Interfaces 16 (4) :96–108.

THE ISLAMIC UNIVERSITY -GAZA
HIGHER EDUCATION DEANSHIP
FACULTY OF COMMERCE
MBA PROGRAM

Dear Sir;

The aim of this research is to identify the selection criteria upon which the major criteria influencing the supplier selection process. This questionnaire aims to collect information about the importance of different criteria in supplier evaluation and selection process. In order to build a model for supplier selection which is transparent and away from bias based on the analytic hierarchy process AHP. The research will help toward improved evaluation process to arrive to successful final selection.

All of data collected from you will be used else only for scientific purpose.

All thanks and appreciation for contribution in enhancement of scientific search process.

> **Researcher:**
> **Eng. Maher Al-Rafati**
> **Supervisor :**
> **Prof. Dr. Yousif Ashour**

<u>Questionnaire part I</u>

- **Sex**   **Male** ☐   **Female** ☐

- **Age:**   **20-less than30Y** ☐   **30- less than 40Y** ☐   **more than 50Y** ☐

- **Occupation**   **General manager** ☐   **Manager** ☐   **Manager assisstant** ☐

- **Specialization**   **Engineering** ☐   **Commerce** ☐   **Others** ☐

- **Work field within**   **Public Sector** ☐   **Supplier** ☐   **Others** ☐

- **Experience**   **1-4** ☐   **5-10** ☐   **more than 10 Y** ☐

- **Education**   **Bsc** ☐   **Msc** ☐   **PhD** ☐

Questionnaire part II

please rate these criteria in relative to their importance in the supplier selection process

Criteria	5 Very Important	4 Important	3 Moderately Important	2 Of Little Importance	1 Unimportant
2. Quality					
7. Product durability (i.e. Lifespan)	5	4	3	2	1
8. Product reliability (e.g., Quality over a given period of time, Consistency)	5	4	3	2	1
9. Quality systems	5	4	3	2	1
10. Percent rejection	5	4	3	2	1
11. Adherence to quality tools (e.g., Check sheet, Histogram, Cause-and-effect diagram,…)	5	4	3	2	1
12. Reputation and position in the market	5	4	3	2	1
3. Price					
6. Competitive pricing	5	4	3	2	1
7. Total cost	5	4	3	2	1
8. Quantity discount	5	4	3	2	1
9. Payment terms	5	4	3	2	1
10. Payment procedures understanding	5	4	3	2	1
4. Service					
7. Spare parts availability	5	4	3	2	1
8. Handling of complaints	5	4	3	2	1
9. Ability to maintain product/service	5	4	3	2	1
10. After sales services (e.g., Warranties and Claims policies)	5	4	3	2	1
11. Training aids	5	4	3	2	1
12. Flexibility (Payment, Freight, Price reduction, Order frequency & amount)	5	4	3	2	1
7. Business overall performance					
7. Financial stability	5	4	3	2	1
8. Quality performance (e.g., ISO 9000 accreditation)	5	4	3	2	1
9. Knowledge of the market	5	4	3	2	1
10. Information systems	5	4	3	2	1
11. Management capability	5	4	3	2	1
12. Performance history	5	4	3	2	1
6. Technical capability					
6. Offering technical support	5	4	3	2	1
7. Technical know (how know why)	5	4	3	2	1
8. Understanding of technology	5	4	3	2	1
9. Responsiveness	5	4	3	2	1
10. Personnel capabilities	5	4	3	2	1

7. Delivery					
7. Delivery lead time	**5**	**4**	**3**	**2**	**1**
8. Delivery speed	**5**	**4**	**3**	**2**	**1**
9. Upcoming delivery commitments	**5**	**4**	**3**	**2**	**1**
10. Ability and willingness to expedite an order	**5**	**4**	**3**	**2**	**1**
11. Safety and security components	**5**	**4**	**3**	**2**	**1**
12. Modes of transportation facility	**5**	**4**	**3**	**2**	**1**

Questionnaire part III

please rate these questions in relative to their importance in the supplier selection process

Questions	5 Very Important	4 Important	3 Moderately Important	2 Of Little Importance	1 Unimportant
1. Determine your satisfaction of the current supplier selection process in your firm.	**5**	**4**	**3**	**2**	**1**
2. Determine the degree to which you need to change current system and have to use a new evaluation process.	**5**	**4**	**3**	**2**	**1**

SURVEY QUESTIONNAIRE IN ARABIC

الجامعة الإسلامية – غزة

عمادة الدراسات العليا

كلية التجارة

قسم إدارة الأعمال

بسم الله الرحمن الرحيم

أخي الفاضل   المحترم

تحية طيبة وبعد ،،

تهدف هذه الاستبانة معدة لجمع البيانات حول "**أهم المعايير لتقويم الموردين** " وذلك لمعرفة المعايير المهمة التي يتم بناء عليها تقويم الموردين ومدى استخدامها في القطاع العام وإعطاءها الوزن المناسب. وذلك بهدف بناء نموذج متكامل لاختيار المورد بعيدا عن التحيـز و يتميز بالشفافية اعتمادا على هذه المعايير و باستخدام أسلوب التحليل الهرمي.

نرجو من سيادتك تعبئة هذه الاستبانة ، مع العلم أنها لن تستخدم إلا في مجال البحث العلمـي فقط.

وتفضلوا بقبول فائق الاحترام وجزيل الشكر

الطالب : م. ماهر الرفاتي

تحت إشراف: أ. د. يوسف عاشور

- الجنس :   ☐ ذكر   ☐ أنثى

- العمر : ☐ 20 – أقل من 30 سنة   ☐ 30 – أقل من 40 سنة   ☐ 40 – أقل من 50 سنة   ☐ أكثر من 50 سنة

- الوظيفة: ☐ مدير عام   ☐ مدير دائرة   نائب مدير

- التخصص: ☐ مجال الهندسة   ☐ مجال التجارة   ☐ اخرى

- طبيعة العمل: ☐   موظف قطاع عام

    ☐   مورد

    ☐   اخرى

- الخبرة: ☐ 1-4 سنوات   ☐ 5-10سنوات   ☐ أكثر من 10 سنوات

- المؤهل العلمي☐ بكالوريوس   ☐ ماجستير   ☐ دكتوراة

الجزء الثاني: ضع دائرة حول الدرجة المناسبة بالنسبة لمدى أهمية كل معيار في عملية اختيار الموردين حيث أن درجة 5

تدل على الأكثر أهمية ودرجة 1 تدل على عدم الأهمية

1 غيرمهم	2 اقل أهمية	3 أهمية متوسطة	4 مهم	5 مهم جدا	المعيار
I. الجودة				
1	2	3	4	5	1. ديمومة المنتج ومتانته (مدة استخدام المنتج)
1	2	3	4	5	2. الثقة بالمنتج (جودة المنتج خلال فترة زمنية، انسجام المنتج وتناسقه)
1	2	3	4	5	3. استخدام أنظمة الجودة
1	2	3	4	5	4. نسبة المنتجات المرجعة
1	2	3	4	5	5. إتباع أدوات الجودة (قائمة لفحص المواد، شكل بياني للسبب والنتيجة،...)
1	2	3	4	5	6. سمعة المورد وموقعه في السوق
II. السعر				
1	2	3	4	5	1. تقديم أسعار تنافسية
1	2	3	4	5	2. التقييم على أساس السعر الإجمالي
1	2	3	4	5	3. تقديم خصم كمية
1	2	3	4	5	4. شروط الدفع
1	2	3	4	5	5. فهم آلية الدفع (خاصة التعامل مع القطاع العام)
III. الخدمة المقدمة				
1	2	3	4	5	1. توفر قطع الغيار
1	2	3	4	5	2. مدى تعامل المورد مع الشكاوى
1	2	3	4	5	3. قدرة المورد على تقديم الصيانة للمنتج أو الخدمة
1	2	3	4	5	4. تقديم المورد خدمة ما بعد البيع (ضمانات، إرجاع المنتج لخلل ما)
1	2	3	4	5	5. وسائل تدريبية للزبون على استخدام المنتج
1	2	3	4	5	6. مرونة المورد (الدفع، الشحن والنقل، تخفيض الأسعار، كمية الطلبية)
IV. الأداء العام للمنشأة				
1	2	3	4	5	1. وجود استقرار مالي للمورد
1	2	3	4	5	2. حصول المورد على شهادة الجودة
1	2	3	4	5	3. معرفة المورد بالسوق
1	2	3	4	5	4. امتلاك المورد أنظمة معلومات
1	2	3	4	5	5. القدرة الإدارية والتنظيمية للمورد
1	2	3	4	5	6. الأداء السابق للمورد
V. القدرات التقنية والفنية				
1	2	3	4	5	1. قدرة المورد على تقديم الدعم الفني
1	2	3	4	5	2. امتلاك المورد للمعرفة الفنية والتقنية
1	2	3	4	5	3. فهم المورد للتكنولوجيا الحديثة
1	2	3	4	5	4. استجابة المورد للتغييرات في الكمية والمواعيد
1	2	3	4	5	5. قدرات العاملين في المنشأة

					VI. التسليم
1	2	3	4	5		1. مدة التوريد
1	2	3	4	5		2. سرعة التوريد
1	2	3	4	5		3. الالتزام المستقبلي بالتوريد وبمواعيد التوريد
1	2	3	4	5		4. القدرة على إرسال الطلبية
1	2	3	4	5		5. توفر عناصر الأمن والسلامة للمنتج أثناء النقل
1	2	3	4	5		6. وجود وسائل النقل

الجزء الثالث: ضع دائرة حول الدرجة المناسبة بالنسبة للأسئلة التالية في عملية اختيار الموردين حيث أن درجة 5 تدل على الأكثر أهمية ودرجة 1 تدل على عدم الأهمية

1 غير مفضل	2 اقل تفضيل	3 أهمية تفضيلا	4 مفضل	5 مفضل جدا	المعيار
1	2	3	4	5	حدد درجة رضاك عن النظام الحالي المتبع في مؤسستك في عملية اختيار الموردين
1	2	3	4	5	حدد حاجة النظام الحالي إلى تغيير واستخدام طريقة أخرى لتقييم الموردين

PAIRWISE COMPARISON QUESTIONNAIRE IN ENGLISH

THE ISLAMIC UNIVERSITY -GAZA

HIGHER EDUCATION DEANSHIP

FACULTY OF COMMERCE

MBA PROGRAM

Dear Sir;

This is the second survey done in the subject of supplier selection. As you have effectively participated in the first questionnaire which aimed at identification of supplier selection criteria. You are herby again connected to establish weights for these criteria. In order to build a model for supplier selection which is transparent and away from bias based on the analytic hierarchy process AHP. The research will help toward improved evaluation process to arrive to successful final selection.

All of data collected from you will be used else only for scientific purpose.

All thanks and appreciation for contribution in enhancement of scientific search process.

Researcher:
Eng. Maher Al-Rafati
Supervisor :
Prof. Dr. Yousif Ashour

Guide lines for filling and establishing relative importance

Each criterion will be rated according to its degree of relative importance to another criterion within the group in the bases of pair wise comparison. The consistency of replies will be tested. The results will be sent to the respondent to think about his replies where no consistency achieved. Participants who did not achieve acceptable level of consistency will be requested to refill the questionnaire until they reach an acceptable level of consistency.

The scale used to find pair wise relative importance is nine point scales as follows:

(1) Equally important/preferred

(3) Moderately important/preferred

(5) Strongly important/preferred

(7) Very strongly important / preferred

(9) Extremely important/preferred.

You can add any scale between 1 and 9

Main criteria	Quality	Price	Service
Quality	1	1/2	3
Price	2	1	7
Service	1/3	1/7	1

Any criteria can take a degree between 1 to 9 if they are equally or more important. However, if the criteria are less important it can take the inverse of the scale. In the above table you find that when the criteria have an equal importance it takes score (1). This usually happened when you compare the criteria with itself. When one criterion is from equally to moderately important it takes the score (2) and so on you can continue to evaluate to how much each criterion is preferred than the other. In the table, quality is moderately important than service while the price is very strongly important than service. This means that when service compared with price then the service is preferred by 1/7 of price.

Part I: Relative importance/preference of criteria for supplier selection

2.1 Select the degree of relative importance/preference of each main criterion compared to each other according to the following scale:

(1) Equally important /preferred (3) Moderately important /preferred (5) Strongly important /preferred (7) Very strongly important /preferred (9) Extremely important /preferred. You can add any scale between 1 and 9

Main criteria	Quality	Price	Service	Business overall performance	Technical capability	Delivery
Quality	1					
Price		1				
Service			1			
Business overall performance				1		
Technical capability					1	
Delivery						1

2.2 Select the degree of relative importance/preference of each sub criterion for quality compared to each other

Sub criteria	Product durability	Product reliability	Quality systems	Percent rejection	Adherence to quality tools	Reputation and position in the market
Product durability	1					
Product reliability		1				
Quality systems			1			
Percent rejection				1		
Adherence to quality tools					1	
Reputation and position in the market						1

2.3 Select the degree of relative importance/preference of each sub criterion for price compared to each other

Sub criteria	Competitive pricing	Total cost	Quantity discount	Payment terms	Payment procedures understanding
Competitive pricing	1				
Total cost		1			
Quantity discount			1		
Payment terms				1	
Payment procedures understanding					1

2.4 Select the degree of relative importance/preference of each sub criterion for service compared to each other

Sub criteria	Spare parts availability	Handling of complaints	Ability to maintain product/service	After sales services	Training aids	Flexibility (Payment, Freight, Price, etc.)
Spare parts availability	1					
Handling of complaints		1				
Ability to maintain product/service			1			
After sales services (e.g., Warranties and Claims policies)				1		
Training aids					1	
Flexibility (Payment, Freight, Price, etc.)						1

2.5 Select the degree of relative importance/preference of each sub criterion for business structure of short list criteria

Sub criteria	Financial stability	Quality performance (e.g., ISO 9000 accreditation)	Knowledge of the market	Information systems	Management capability	Performance history
Financial stability	1					
Quality performance (e.g., ISO 9000 accreditation)		1				
Knowledge of the market			1			
Information systems				1		
Management capability					1	
Performance history						1

2.6 Select the degree of relative importance/preference of each sub criterion for technical capability compared to each other

Sub criteria	Offering technical support	Technical know (how know why)	Understanding of technology	Responsiveness	Personnel capability
Offering technical support	1				
Technical know (how know why)		1			
Understanding of technology			1		
Responsiveness				1	
Personnel capability					1

2.7 Select the degree of relative importance/preference of each sub criterion for delivery of short list criteria

Sub criteria	Delivery lead time	Delivery speed	Upcoming delivery commitments	Ability and willingness to expedite an order	Safety and security components	Modes of transportation facility
Delivery lead time	1					
Delivery speed		1				
Upcoming delivery commitments			1			
Ability and willingness to expedite an order				1		
Safety and security components					1	
Modes of transportation facility						1

Part II: Relative preference of alternatives for supplier selection

2.8 Select the degree of relative preference of each alternative with respect to each sub-criterion

Product durability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.9 Select the degree of relative preference of each alternative with respect to each sub-criterion

Product reliability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.10 Select the degree of relative preference of each alternative with respect to each sub-criterion

Quality systems	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.11 Select the degree of relative preference of each alternative with respect to each sub-criterion

Percent rejection	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.12 Select the degree of relative preference of each alternative with respect to each sub-criterion

Adherence to quality tools	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.13 Select the degree of relative preference of each alternative with respect to each sub-criterion

Reputation and position in the market	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.14 Select the degree of relative preference of each alternative with respect to each sub-criterion

Competitive pricing	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.15 Select the degree of relative preference of each alternative with respect to each sub-criterion

Total cost	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.16 Select the degree of relative preference of each alternative with respect to each sub-criterion

Quantity discount	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.17 Select the degree of relative preference of each alternative with respect to each sub-criterion

Payment terms	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.18 Select the degree of relative preference of each alternative with respect to each sub-criterion

Payment procedures understanding	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.19 Select the degree of relative preference of each alternative with respect to each sub-criterion

Spare parts availability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.20 Select the degree of relative preference of each alternative with respect to each sub-criterion

Handling of complaints	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.21 Select the degree of relative preference of each alternative with respect to each sub-criterion

Ability to maintain product/service	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.22 Select the degree of relative preference of each alternative with respect to each sub-criterion

After sales services	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.23 Select the degree of relative preference of each alternative with respect to each sub-criterion

Training aids	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.24 Select the degree of relative preference of each alternative with respect to each sub-criterion

Flexibility	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.25 Select the degree of relative preference of each alternative with respect to each sub-criterion

Financial stability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.26 Select the degree of relative preference of each alternative with respect to each sub-criterion

Quality performance	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.27 Select the degree of relative preference of each alternative with respect to each sub-criterion

Knowledge of the market	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.28 Select the degree of relative preference of each alternative with respect to each sub-criterion

Information systems	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.29 Select the degree of relative preference of each alternative with respect to each sub-criterion

Management capability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.30 Select the degree of relative preference of each alternative with respect to each sub-criterion

Performance history	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.31 Select the degree of relative preference of each alternative with respect to each sub-criterion

Offering technical support	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.32 Select the degree of relative preference of each alternative with respect to each sub-criterion

Technical know	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.33 Select the degree of relative preference of each alternative with respect to each sub-criterion

Understanding of technology	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.34 Select the degree of relative preference of each alternative with respect to each sub-criterion

Responsiveness	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.35 Select the degree of relative preference of each alternative with respect to each sub-criterion

Personnel capability	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.36 Select the degree of relative preference of each alternative with respect to each sub-criterion

Delivery lead time	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.37 Select the degree of relative preference of each alternative with respect to each sub-criterion

Delivery speed	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.38 Select the degree of relative preference of each alternative with respect to each sub-criterion

Upcoming delivery commitments	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.39 Select the degree of relative preference of each alternative with respect to each sub-criterion

Ability and willingness to expedite an order	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.40 Select the degree of relative preference of each alternative with respect to each sub-criterion

Safety and security components	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

2.41 Select the degree of relative preference of each alternative with respect to each sub-criterion

Modes of transportation facility	Supplier no. 1	Supplier no. 2	Supplier no. 3	Supplier no. 4	Supplier no. 5
Supplier no. 1	1				
Supplier no. 2		1			
Supplier no. 3			1		
Supplier no. 4				1	
Supplier no. 5					1

Note: Names of Suppliers

No.	Name	Supplier	Product
1	Supplier no. 1	**Modern Center for Electronics**	**Sharp**
2	Supplier no. 2	**Qaraman**	**Konica Minolta**
3	Supplier no. 3	**CopyMax**	**Xerox**
4	Supplier no. 4	**Al-Jazeera**	**Canon**
5	Supplier no. 5	**Gaza Strip**	**Olivetti**

Appendix C

List of Ministries

No.	PNA ministries
1	Ministry of Finance
2	Ministry of General Works and Housing
3	Ministry of Health
4	Ministry of Education and Higher Education
5	Energy Authority and Natural Resources
6	Palestinian Water Authority
7	Ministry of Social Affairs
8	Ministry of Communication and Information Technology
9	Ministry of Transportation
10	Ministry of National Economy
11	Ministry of Religious Affairs
12	Ministry of Interior

Appendix D

Names of questionnaire referees

- *Prof. Dr. Yousef Ashour, faculty of commerce, Islamic University in Gaza*

- *Dr. Majed Al-Farra, faculty of commerce, Islamic University in Gaza*

- *Dr. Rushdi Wadi, faculty of commerce, Islamic University in Gaza*

- *Dr. Sami Abu Al-Roos, faculty of commerce, Islamic University in Gaza*

- *Dr. Yousef Bahar, faculty of commerce, Islamic University in Gaza*

- *Dr. Nafez Barakat, faculty of commerce,Islamic University in Gaza*