A NEW HYBRID MODEL BASED DECISION SUPPORT SYSTEM FOR SUPPLIER SELECTION PROCESS: A CASE STUDY FROM PURCHASING DEPARTMENT, UTP

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TITLE PAGE

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A New Hybrid Model Based Decision Support System for Supplier Selection Process: A Case Study from Purchasing Department, UTP

By

Arif Abdelwhab Ali Elhaj

A THESIS

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BANDAR SERI ISKANDAR,

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FEBRUARY, 2009

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I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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ABSTRACT

Decision making process is a huge and crucial activity that must be given high attention by decision makers and managers as it affects all business strategies in organizations. Computer Based Decision Support System (DSS) is built and developed to assist decision makers in the activity of decision making process. DSS includes different components that integrate together out of which the most important part is the model based system. As a result of the rapidly increasing and sustainable needs of organizations, suppliers have become essential to any business. On the other hand, decision makers and managers face challenges when they are about to select suppliers due to the strong competitiveness among suppliers, obstacles that they will face when poor decisions are made, and many other reasons. Evaluating and selecting suppliers has been considered as the most critical and important process among the whole purchasing processes. However most of the existing models that have been proposed to support supplier selection decisions have various shortcomings. All the drawbacks of these models will be discussed during this research in details which indicates the urgent need for new suitable model. This research intends to develop a new hybrid model base DSS for supplier selection process that can guarantee better decision making. The new proposed model provides a suitable tool for assisting decision makers and managers to make the right decisions and select the most suitable supplier. The proposed model depends upon linear weightage model and Analytic Hierarchy Process (AHP) approach. The proposed hybrid model will be applied using a real life case study to assess its effectiveness. In addition, What-if analysis technique will be used for model validation purpose. Finally, DSS software will be developed to utilize the proposed model to assist supplier selection decisions.

ABSTRAK

Proses membuat keputusan merupakan satu aktiviti kritikal dan sangat berat yang mesti diberi perhatian lebih oleh pembuat keputusan dan pengurus oleh kerana ianya mempengaruhi semua strategi perniagaan dalam organisasi. Sistem Sokongan Keputusan Berasas Komputer (DSS) telah dibina dan dibangunkan untuk membantu pembuat keputusan dalam aktiviti process membuat keputusan. DSS merangkumi komponen-komponen berbeza yang sama-sama keluar bergabung yang mana bahagian paling penting adalah sistem berasas model. Berdasarkan keputusan yang meningkat dengan mendadak dan keperluan berterusan organisasi, pembekal menjadi keperluan kepada mana-mana perniagaan. Selain daripada itu, pembuat keputusan dan pengurus berdepan pelbagai cabaran terutamanya ketika disaat memilih pembekal kerana daya saing yang kuat dikalangan pembekal-pembekal, halangan-halangan yang akan dihadapi mereka apabila keputusan teruk dibuat, dan banyak faktor-faktor lain lagi. Memilih dan menilai pembekal dianggap sebagai proses paling penting dan kritikal diantara keseluruhan proses-proses membeli. Tetapi kebanyakan model-model sedia ada yang telah dicadangkan bagi menyokong keputusan pemilihan pembekal mempunyai pelbagai kekurangannya. Semua kelemahan model-model ini akan dibincangkan dalam kajian ini secara terperinci yang mana ianya menunjukkan keperluan segera bagi kesesuaian model baru. Kajian ini bertujuan untuk membangun satu model hybrid baru berasaskan DSS untuk proses pemilihan pembekal yang boleh menjamin membuat keputusan yang lebih baik. Model baru yang dicadangkan menyediakan alat yang bersesuaian bagi membantu pembuat keputusan dan pengurus untuk membuat keputusan yang betul dan memilih pembekal yang paling sesuai. Model yang dicadangkan bergantung pada pendekatan model 'weightage' lurus dan Proses Hirarki Analisis (AHP). Model hybrid yang dicadangkan akan diaplikasi dalam kehidupan sebenar kajian kes untuk menilai keberkesanannya. Tambahan lagi, teknik analisis Apa-jika akan digunakan untuk tujuan pengesahan model. Akhirnya, perisian DSS akan dibangunkan untuk memanfaatkan model yang dicadangkan bagi membantu keputusan pemilihan pembekal.

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TABLE OF CONTENTS

TABLE OF CONTENS- CONTINUED

TABLE OF CONTENS- CONTINUED

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

1.1 Introduction

This chapter represents background in the first section which is giving brief information about this research. The second section provides a discussion about the problem statement .The subsequent sections discuss objectives, scope of the research, contributions, and limitations of research respectively. And finally structure of the thesis.

1.2 Background

1.2.1 Decision Making

Decision making is one of the crucial activities conducted in organizations by managers. It involves multiple participants and requires conflicting resolution as well as multiple information sources. The outcome of the decision making process absolutely affect company. Supporting those decision makers is highly recommended and desirable.

Computerized systems have abilities that able to support and facilitate decision making. (Turban and Aronson, 2001) mentioned the following benefits of DSS:

- A computer enables the managers to achieve many computations quickly and at a low cost in a short time, and a hug number of alternatives can easily be evaluated in a few seconds.
- In some cases, decisions are made by group of decision makers who may be in different locations, so collaboration among teams of managers could materialize using web tools.
- Computers could improve the quality of decisions made as a result of providing ability to access more data and more alternatives could be evaluated. Furthermore, the views of experts can be collected quickly and at a reduced cost.

- Human mind has only limited ability to process and store information, thus computerized systems enable people to overcome this problem by fast accessing and processing a huge amount of stored information.
- Many decisions involve complex computations in which data could be stored in different data bases anywhere in the organization or even at web sites outside the organization.

All the above and more other capabilities are provided when using computerized decision support.

1.2.2 Decision Support System

(Turban, 2007) mentioned that the main concepts of Decision Support System (DSS) were expressed in the early 1970's by Scott-Morton and he defined DSS as "interactive computer-based systems which help decision makers utilize data and models to solve unstructured problems".

(Wei-kang, Wu, Chang, & Hao, 2006) mentioned various definitions for DSS, they were addressed below.

- Decision support system is an interactive software-based computerized information system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and business models to identify and solve problems and to make decisions.
- An interactive computerized system that gathers and presents data from a wide range of sources to help people make decisions. Applications are not single information resources, such as a database or a graphics program, but rather the combination of integrated resources working together.
- A cohesive and integrated set of programs that share data and information and provide the ability to query computers on an ad-hoc basis, analyze information, and predict the impact of possible decisions.

- DSS is a computer based tool that aid the managerial decision making process by presenting various effective alternatives.

(Marakas, 1999) has introduced other definition as ”Decision Support Systems are designed, built and used to assist in the activity that they are named for supporting the decision making process .

DSS has facilitated the decision making activity by providing managers with a valuable and robust support in different business directions and it assists them to make their optimum decisions. Besides, it can improve the business performance by enhancing the decision quality. Furthermore, DSS can guarantee that final decision to be done fairly.

In addition, DSS should never replace managers at all, but it must be eventually positioned for enabling them to take the ultimate decision, so decision makers are often in charge of any outcomes. DSS was broadly used in various types of business and fields, furthermore it serves as a tool for consultant in the decision making process.

1.2.3 Decision Support System Framework

DSS has three major components which are combined together to construct the structure of its framework. These components integrates together to construct the DSS framework which are data base management, model base management, and user interface. There is another optional component which might exist in some DSS and it’s referred to as knowledge base management. Figure1-1 depicts the DSS architecture.

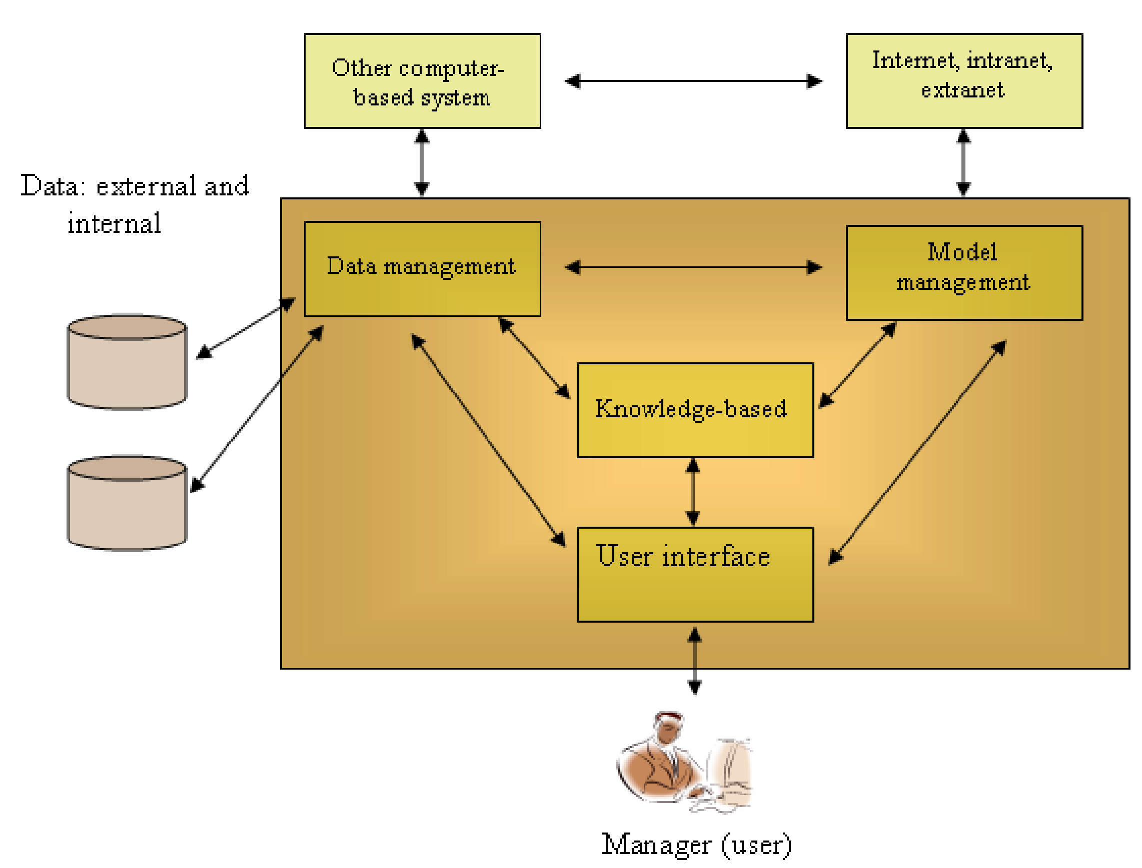


Figure1-1. Major Components of DSS Architecture (adopted from Turban 2007)

1.2.4 Data Base Management System (DBMS)

The database management system is the first component of DSS. The database encompasses whole data and it represents the store of all data may be needed in interacting with other components of DSS such as the users. DSS database includes internal and external data. Internal data includes information regarding sales, purchases, cost, personal, and other transactions of organization. The other type of data is external data, which represents all information about one or more factors outside the company. External data can be derived from an organization's traditional data repositories, or from external sources such as the Internet. DSS database has the capability to include multimedia objects such as pictures, maps, and sounds.

The huge amount of data that can be structured into files and databases must be managed, and this important job falls to the DBMS. Several databases can be used in one DSS. Moreover, DSS database can share a DBMS with other systems. There are two main responsibilities for DBMS:

- Management of all functions associated to storing and accessing information in the database and distributing information to the community of DSS users.
- Maintenance of logical independence between the data sustained in the DSS database and the DSS application.

Most communications-driven DSSs are targeted at internal teams, including partners. Its purpose is to help conduct a meeting, or for users to facilitate collaboration. The most common technology used to deploy the DSS is a web or client server.

1.2.5 Model Base Management System (MBMS)

The main difference between DSS and other information systems lies in the model component. There are different parts have been integrated in MBMS, such as special statistical, financial, forecasting, management discipline, and other quantitative models that offer analysis capabilities in DSS. These models represent the rules that any DSS software should include as it illustrates how the system is going to make the right decision and what type of operations should be followed to achieve that goal.

Model-driven DSSs are complex systems that help analyze decisions or choose between different options. These are used by managers and staff members of a business, or people who interact with the organization, for a number of purposes depending on how the model is set up - scheduling, decision analyses etc. These DSSs can be deployed via software/hardware in stand-alone PCs, client/server systems, or the web.

1.2.6 Dialog Generation Management System (DGMS)

DGMS covers the whole aspects of communications between user and the DSS and it called user interface management system as well. It includes also factors that deal with ease of use, accessibility, and human machine interaction (Turban & Aronson, 2001).

DGMS allows managers/decision makers to change a decision variable and then instantly gets a new result for an outcome variable. DGMS introduces more than one analysis methods such as what if analysis and sensitivity analysis, to meet its objectives. Decision makers can use what if analysis to evaluate the model driven DSS and how variations of the input variables of the model affects the output results such as what profits margins can a company expects ,if its product price has been decreased?. Thus, the sensitivity analysis method may be used in term of determining how sensitive the result would be to a small change of a parameter.

1.2.7 Purchasing Management

Purchasing functions in organizations have been rapidly increased due to satisfying the sustainable and renewed needs of firms and corporations. Therefore, in different fields companies have been forced to deal with other firms who are known as suppliers or vendors in order to obtain their entire needs for keeping the business processes running smoothly and with no troubles. The needs of a company vary pertaining to type of a company's business and size of the company as well. Suppliers or vendors are those companies who can furnish goods and services to the buyer/customer.

Procurement is another term that could be appears in the literature which generally refers to the same previous concept. Actually, this term covers many aspects and various processes which can be defined in the process of buying. Furthermore it combines the understanding of the needs, finding, selecting a supplier, making some negotiation about the price besides ensuring the delivery time (Moynihan, Puneet, & Fonseca, 2006).

Companies either have one purchase department which means all purchases are centralized in one department and this is called centralize purchasing or every section inside the organization should make its own purchasing decision which is called decentralized purchasing (Waller, 2003).

1.2.8 Supplier Selection

Organizations have been more concerning about the suppliers or vendors regarding the rapid increasing of purchasing materials and services which have been playing an important role in business process. Suppliers are necessary to any business and affecting the whole business processes, therefore the process of selecting suppliers is extremely important. According to (Wei-Kang, et al., 2006), supplier selection and evaluation is the process of finding the suppliers who are capable of providing customers with the products or services that have the right quality, right price, right quantity, and at the right time.

Although purchasing function is encompassing various numbers of processes, supplier selection was considered as the most important and critical, and it has been one of the vital research areas. Supplier selection is a complicated and complex process that requires more awareness. Moreover, attention should be given to supplier selection problem by decision makers/managers in order to make the right decisions. Supplier selection process is multi attribute problem which involve both qualitative criteria as well as quantitative.

Usually there are huge numbers of suppliers existing in the market and that leads to high level of competitiveness among them. On the other hand, supplier evaluation and selection decision have become more strategic and critical. Supplier decisions are one of the most important aspects that companies should include into their strategic processes. Due to the increasing importance of the purchasing processes, supplier management decisions have become more strategic as organizations become more dependent on suppliers (Marvin, & Gioconda, 2004).

Decision makers and managers often face challenges when they are about to select the best supplier among the candidate suppliers in their final decisions. There are different existing methods and models dealing with supplier selection problem for supporting the decision of selecting the best supplier among pool of candidates' suppliers. When supplier selection is taking place, managers should be paying attention to the whole criteria that involve in the process. Finally, the selected supplier is the one who able to satisfy the customer needs.

The inappropriate supplier chosen in some cases as a result of poor decision could negatively affect the entire business processes within the organization. Although the complexity of the supplier selection problem and how difficult to deal with such decisions, DSS is still highly regarded as a robust and effective tool that can absolutely handle the situation of helping decision makers and managers to come up with the right decision of selecting the best supplier among whole various alternatives wisely.

1.3 Problem Statement

Supplier selection decisions are usually dependent upon various involved criteria which influence the decision making process. Decision makers/managers often concentrate on the price of purchased materials or services due to their prompt attempt to reduce the cost and unfortunately they give less attention to the rest of the criteria which leads to poor decision. Even in some firms where they use software to help in the supplier selection decision still we can clearly notice those software focus on the cheapest price as well. The poor decision might be taken definitely will be affecting the entire business processes within the organizations. Obviously, Managers/decision makers are having difficulty in supplier selection.

On the other hand, most of the existing models which are dealing with supplier selection problem can be clustered into three major categories. The first category is mathematical programming models which consider just the quantitative criteria. However the process involves both qualitative criteria as well as quantitative criteria. The second category of models dealing with supplier selection decisions called linear weighting models. This category is more dependent upon human judgment and decision maker experience which varies from one to another and that lead to variation in the final decisions. The third category represents statistical models which are so complex. Moreover, statistical models are rarely used in supplier selection decisions due to their complicated processes and computations. In addition, they also find that understanding of the mathematical models is not an easy job for them regarding the gap between DSS and the knowledge backgrounds of those managers.

Obviously, there is an urgent need for a method that can handle the selection decision to provide the required support to decision makers/managers, besides the ability to yield optimum and fair decisions concerning multi attributes that usually involve in supplier selection problem.

1.4 Objectives

Regarding the great role that has been played by suppliers in the business world beside the importance of selection decisions in organizations, supplier selection problem has been a research area for long time and it became an interesting topic for researchers to figure out what is the best possible method for achieving the supplier selection decisions successfully concerning the aid of DSS. All the previous researches were trying to support the decision makers/ managers for being able to make their right decisions and being capable of handling the decision making activity by proposing different methods and various suggestions.

This research intends to introduce an optimal solution for the supplier selection problem by achieving the followings:

1. Develop a new hybrid model for supplier selection decisions.
2. Test the proposed model through a case study in the purchasing department in UTP.
3. Validate the proposed model using what-if analysis technique.
4. Develop DSS software for supplier selection process that utilizes the proposed model.

1.5 Scope of Research

This research concentrates on enhancing the performance of the decision making activity within organizations, especially in supplier selection decisions. It intends to improve the models which are using as methods in DSS when decision making activity is taking place. This research proposes a hybrid model to be used in supplier selection decisions. The proposed model is considered as an affective model as it encompasses the concepts of two powerful existing models and solves the drawbacks of both models.

Moreover, the proposed model shows improvement in terms of time needed to harvest the final decisions. In addition, the proposed model offer less calculations and does not involve complicate mathematical computations. This is noticed in terms of the reduction in the number of matrices that needed to be solved.

1.6 Research Contributions

The main contributions of this research are illustrated in the following points:

- The proposed model is really represents a suitable model for supplier selection process as it integrates the advantages of both linear weightage and AHP models.

- The proposed model eliminates the drawbacks of that existed in linear weightage model using pairwise comparisons which enable generating the weights of criteria instate of directly assigning weights to criteria by decision maker.

- The proposed model represents a sufficient tool without the need for performing long procedures of calculation as it should be done in AHP model. So the proposed model does save time and effort and that will strongly accelerate the supplier selection decision as well as improving the whole business processes within organizations in turn.

- The proposed model can be considered as a core of DSS when designing DSS for supplier selection problem. It can play vital role through taking control of model base management system in DSS framework.

- The pairwise comparisons provide the proposed model with the capability to eliminate human judgment on suppliers that participate in the purchase process, beside the human judgment on criteria as well. There is no doubt that eliminating of human judgment on both suppliers and criteria lead to improve the decision quality.

- What if analysis is used as a common and beneficial technique that helps pointing out the reliability and effectiveness of the proposed model, “what- if analysis” allows managers/decision makers to change a decision variable and then immediately get a new result for an outcome variable. Regarding the use of “what-if analysis”, the proposed model has shown high degree of sensitivity towards any changes in the input variables. Considering the case study of the new hybrid model which has been proposed in this research, it can obviously emphasize its reliability and sensitivity. Consequently, when the decision maker changes in two of the input variables the ultimate decision indicates the first supplier as the best supplier instead of the second supplier was recommended before the input variables changes.

1.7 Limitations of Research

In this research only one case study has been used to test the proposed model. All the results are based upon one this case study.

Sometimes decision makers urge to select more than one supplier, as a result of no one supplier can satisfy all the requirements. The proposed model only considers the concepts of single source supplier.

1.8 Structure of Thesis

This thesis is structured in six chapters. The first chapter gives an introduction to the whole research in addition to brief background on all the concepts involved in this work , the problem statement is discussed, objectives, contributions, limitations, and finally scope of research. Chapter two provides related works and mentions review of literature. Methodology of this research is illustrated in chapter three. Chapter four discusses linear weightage model with a case study besides AHP approach and provides a case study as well. A new hybrid model is proposed tested and validated during chapter four as well. Chapter five is on the software development for supplier selection system that uses the proposed model. The last chapter is the conclusion which concludes this research and it does include some recommendations for further research directions.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter shows the DSS software that have been developed for assisting decision makers in different business directions and particularly supplier selection decisions and all various criteria that may involve in its relative importance. This chapter also discusses the complexity of this process. This chapter is provides all methods and approaches that have been proposed and used in supplier selection decisions in literature.

2.2 Supplier Selection Decision

Supplier selection decision is one of the most important aspects that organizations must take into their account when considering strategies (Kaur, Verma, & Chakraborty, 2007). Regarding the increasing importance of purchasing process, supplier decisions have become more strategic.

The literature shows the great importance of purchasing process and vendor/supplier selection in Supply Chain Management (SCM), (Weber, Current & Benton, 1991) mentioned that in the automotive industry, cost of purchased components and items may total more than 50% cost of the total cost for high technology companies, beside that supplier selection decisions have an effect on the management of different services of the firm as well as its competitive position in the market.

In the literature, the importance of purchasing processes can be easily observed. Some researches have mentioned a statistical operation that shows the percentage of the amount of money paid for purchased materials. More details declare by (Moynihan, Saxena, & Fonseca, 2006) mentioning 60% of the manufacturer's sales dollars are paid to supplier for purchased materials. However, automobile manufacturers spend about 60%

of the total manufacturing cost, oil refineries spend about 80%, food processors spend about 70%, and about 65% paid to supplier in the case of farm-manufacturers. From these percentages mentioned above, the importance of purchasing processes can clearly be observed and that leads to more attention have to be paid by decision makers towards this critical process.

Supplier selection problem typically consists of four stages as reported in (Chuo, & Chang, 2007, Aboulhas, Xiaofel, & Dechen, 2004). These four stages namely:

(1) Defining the problem and realizing the needs.

(2) Formulation of decision criteria.

(3) Qualification of potential suppliers.

(4) Final selection of supplier.

2.3 Supplier Selection Criteria

Supplier selection is multi-criteria problem as it has been described in literature and it does involve various criteria. These criteria can be divided into qualitative and qualitative criteria (Reza, 2005, Ghodspour, & Brien, 1998).

There are many criteria which might be involved in the process of selecting an appropriate supplier and here some of them are given below:

- Product price: It should be concerning the unit price, price for large quantities, and the ability of any negotiations may lead to discount. Companies give a lot of attention to product prices, as a result of their willing to obtain the requested products and services against reasonable prices. More than often, companies tend to reduce the cost of purchased materials and make a trade off between quality and price.

- Quality of material: Does the supplier have quality certification such as International Organization of Standardization (ISO) or it is certified by the buying company? Does the supplier meet the quality of materials which required by the buyer?. Such questions can be taken into account to insure that supplier is able to provide high quality of materials and services.
- Reliability: It represents the Supplier’s history of meeting the requirements of the customers /buyers consistently.
- After sales services: Most of the suppliers provide some kind of Services such as replacement of defective parts, instructions on equipment use, repairs or update of products and so on. All these services and others make the supplier more preferable.
- Warranty: In addition, the length of warranty that the supplier has provided to the customer /buyer is one of the main factors that play a major role in supplier evaluation to determining and influencing after sale services.
- Supplier location: Location of supplier can impact delivery time, transportation costs, and respond for rush or replacement order, firms may choose to purchase in the country in which they operate rather than overseas. Also firms might decide to buy locally in order to participate in the strategy of improving the local economy.

Throughout the history of purchasing process, suppliers have been selected according to the criteria which have mentioned in the previous paragraph in addition to many other criteria. The most common criteria ever use in supplier selection that mentioned by (Dickson, 1966), he ranked a number of various criteria taking the relative importance of each criterion into consideration.

Based on empirical data gathered from 170 purchasing managers and members of national association of purchasing management, Disckon identify quality, cost, and delivery performance history as the three most important criteria in supplier selection. According to (Nelson et. al, 2005) recent review, 74 articles discussed about supplier selection criteria, quality was deemed to be the most important, followed by delivery performance and cost. Dickson’s criteria have become the most commonly used in supplier selection decisions (Dan, Yezhuang, & Yunaquan, 2004). Dickson’s criteria are depicted in Table 2-1.

Table 2-1. Dickson's Supplier Selection Criteria

Rank	Factor
1	Quality
2	Delivery
3	Performance history
4	Warranties and claim policies
5	Production facilities and capacity
6	Price
7	Technical capability
8	Financial position
9	Procedural compliance
10	Communication system
11	Reputation and position in industry
12	Desire for business
13	Management and organization
14	Operating controls
15	Repair services
16	Attitude
17	Impression
18	Packaging ability
19	Labor relation record
20	Geographical location
21	Amount of past business
22	Training aids
23	Reciprocal arrangements

The evaluating and selecting supplier criteria also have been discussed by (Reza, 2005) in terms of the relative importance of each criterion, the number of criteria involved, and so on. The relative importance of the evaluative criteria varies depending upon many factors such as the place, the time, purchase and evaluation situation, and the nature of the selection situation

The six most mentioned criteria were price, delivery, quality, facilities and capacity, geographic location, and technical capability, although the numbers of selection criteria can be adjusted regarding rules in different firms, to go well with the individual company policies(Shuo, & Chang,2007).

Once the relative importance of the supplier selection criteria have been decided upon and that implies some criteria have the greatest impact whilst some other have less influence. Decision makers/managers concentrate on different levels of importance while they dealing with the supplier selection criteria. Different organizations assess their supplier using different criteria. (Huang, & Hsu, 2006) list some of those criteria by types of business.Table2-2 shows the seven kinds of companies which are considered in this research. Undoubtedly, price, quality, and delivery are the three most important criteria for vendor selection.

Table2-2. Application of Selected Attributes

SNO	Lines of business	Attributes/Criteria
1	Baby food manufacturer	Price, Quality, Delivery
2	Bicycle manufacturer	Quality, Delivery, Price, Facility, Technical capability, Financial position, Past performance attitude, Flexibility, Service.
3	Bottling machinery industry	Product price, Shipment quality, delivery performance.
4	Equipment manufacturer	Acquisition cost, Product quality, delivery reliability.
5	High-tech company	Technical, Market, Organizational.
6	Public road and rail transportation	Make-up, Processing time, Prototyping time, Design revision time, Quality system, Co-design, Technological level.
7	Telecommunications company	Cost (capital expenditure, operating expenditure), Quality (technical, operational, vendor).

Source: (Huang, & Hsu, 2006)

An empirical study done by (Dan, et al., 2004) in which data for this study have been collected from the United states, the United kingdom, Norway, China, and Australia; it is found that quality of products or services as the most influencing factors in supplier selection decisions. It tallies with Dickson's ranking of the evaluation criteria.

2.4 Complexity of Supplier Selection Problem

Decision makers or managers are often responsible for making purchasing decisions which is definitely not an easy job. They should be aware of choosing the appropriate and the right supplier among pool of potential suppliers. The best supplier also should be selected among others according to the capability of satisfying whole materials or services which have been requested by the buyer.

On the other hand, suppliers have to be recognized that business can perform in a better way when they understand and satisfy all the needs of the customers (Chee & Ching, 2002).

It's agreed in the literature that supplier selection decision is so complicated and difficult to deal with. According to (Mahmut, 2006 , Dongjoo, et .al, 2006, Shi, et. al, 2000, Hongwei, Benyoucef, & Xiaollan, 2003, Wei-kang et. al, 2006, Shuo-Yan, & Chang, 2007, Reza, 2005, Ding-Zhong, Chen, & Jiang, 2005, Mosaad, & Mohammed, 2004), there are many reasons which are making supplier selection problem is a complex process.

First, supplier selection involves a huge number of criteria. Therefore, decision makers or managers have been forced to consider all of them. Beside that they should also taking the relative importance of the criteria into their account.

Second, supplier selection problem is complicated by involving multiple evaluated criteria that some of them are quantitative such as the price, delivery while others are qualitative such as flexibility, services.

Third, it may become more complicated as a result of conflicts among criteria; low price could be conflicting to the quality and so on. Frequently, these evaluation criteria involve tradeoffs. For example, one supplier may offer cheap parts of below average quality, while another supplier may offer higher quality items, with uncertain delivery time. Therefore, setting up tradeoffs is extremely important.

Fourth, changing in criteria itself may happen across time and place, beside the number of selection criteria can be adjusted due to the certain strategy in various firms. Furthermore, the importance of criteria differs from one purchase to another.

Finally, the huge number of alternatives might be including in selection process due to the competitiveness among them. This number of alternatives may also create a vast amount of information. Moreover, decision makers are required to achieve further series of comparisons when more alternatives involved.

From other point of view, (Ching, & Bai-Sheng, 2006) reported the following points that play a vital role in the complexity of supplier selection problem

- Selecting suppliers only on the basis of managers' personal knowledge is neither efficient nor scientific according to inherent risk of subjective decision and lack of systematic analysis.
- Several evaluation models such as total cost of ownership (TCO), linear weighting (LW), and mathematical programming (MP). Obviously, LW models seem not to include quantitative criteria, while the mathematical programming models do not include qualitative criteria.
- In practical application of supplier selection model, there is shortage in decision support system in supporting organization in the evaluation and selection of suppliers which aggravates the complexity of the mathematical analysis.

All decisions that could possibly be made by decision makers can be classified into three types. Structure decisions, Semi-structured decisions, and unstructured decisions. (Turban, 2007) defined structured decision as those kind of decision when every thing is clear and easy to predict the outcome results. However, unstructured decisions are those types of decisions when everything is not clear and so difficult to predict the outcome results, Semi-structured decisions are in between. In fact, DSS is useful for both semi-structured and unstructured decisions. Once, supplier selection has been considered as semi-structured decision that makes DSS is totally useful for supplier selection decisions in particular.

DSS plays a vital role and provides companies with various capabilities which integrate together to improve the quality of decision making process. DSS has the ability to support solutions to complex problems. Moreover, it provides fast response to frequent changes in scenarios. DSS can facilitate communication and improve the teamwork. In addition, DSS saves cost by reducing incorrect decision making. For these advantages and others DSS has become a promising solution for the complexity of decision making process and it has been applied in different files of business to support the decision making activity.

2.5 DSS in Different Platforms

Although, the complexity of the supplier selection problem and how difficult to deal with such decisions, DSS presents a robust and effective tool that can absolutely handle that situation by helping decision makers and managers to come up with the right decision, specially selecting the best supplier among the whole various alternatives wisely.

Over the years, many of DSSs are developed and applied either in different business directions or other fields, all of them are been assist and support organizations in terms of decision making process. On the other hand, there are many software systems developed to deal with supplier selection problems in different platforms and from various points of view. Some of those DSSs software provide capability of building a collaborated team through the internet technology in order to make the right decisions. Other types of DSSs software are performing the same function, without the needs of constructing a team of collaborated decision makers.

(Wei-Kang, et. al, 2006) presented a new framework for knowledge-based decision support systems (KDSSVSB) for government vendor selection and bidding. The system integrate a database, rule base and model base as tool for managers in the decision making problems via internet. KDSSVSB is developed to offer real-time information which can be used by decision making representatives to quickly and accurately infer and generate. The primary components of KDSSVSB are a database, a rule base, and a model base with an Analytic Hierarchy Process (AHP) to select the qualified vendors.

(Dongjoo, et. al, 2006) developed BestChoice which is a DSS for supplier selection. It uses Multi Attribute Utility Theory (MAUT) to create rules for evaluating the utility of alternatives in addition to AHP. BestChoice architecture is consists of three tier system which are database layer, a logic layer and an interface layer. Once AHP use simple pairwise comparison to determine the importance of factors and calculate numeral value called weight, BestChoice provides a graphical user interface for the pairwise comparison of factors, as well as for the manual setting of weights.

ES^3-Electronic supplier selection system is another DSS developed by (Ramani, Shunk, & Henderson, 2000). ES^3 can select the appropriate supplier from potential suppliers and match the requirements of the customer to supplier. ES^3 works in web platform that allows dynamic customer-supplier interaction, inventory and pricing issues and calculate real-time estimates.

Other articles present a number of DSS have been developed to support the evaluation of tenders. AHP was proposed by (Bertolini, Braglia, & Carmignani, 2006) to be used in the selection of the best discount in dealing with the tenders for public works contracts.

In other work (Rapacsak, et. al, 2000) developed group decision support system (GDSS) for evaluation of tenders in ICT equipments. The processes were based on Multi Criteria Decision Making (MCDM) methods. The winner of the tender was the one who made the best offer. The ranking of the offers were based on the prices and a huge number of criteria.

Similar purpose of the evaluating tenders appeared through that DSS developed by (Sirajuddin A.M.Y, and Al-Bulahid F.K, 1996) who proposed an evaluation process of maintenance tenders by utilizing mathematical model.

In agricultural field DSS also takes place as well as other fields. In particular, Great Plains Framework for Agriculture Resources Management (GPFARM) was developed by Great Plains Research Unit (GPRU) and Colorado state university (CSU). The main purpose of this DSS is to serve as a whole-farm DSS in strategic planning across the Great Plains, this system is one of the few DSS for agriculture (Acough II et al., 2005).

A web based collaborative system was developed by (Shi et al., 2000). Its main purpose is to facilitate the supplier selection procedure. A collaborated team can be built up when purchasing procedure has been started. All members use the web browsers such as Netscape's Navigator and Microsoft's Internet Explorer to participate in the team working with the system. Then the team of members can work together to evaluate the suppliers. When the market or other factors cause the variation in criteria for supplier selection, enterprise managers able to gather together for defining criteria and calculate weights using web-based system.

A prototype decision support system for procurement was developed by (Moynihan, et. al, 2006). It concentrates on procurement operations in a manufacturing environment. The system helps purchasing manager in his/her decision making process containing supplier selection and development of procurement policy.

A decision support system was built for assisting in the activity of making decision by (Besharati, Azram, & Kannan , 2005). The main function of this system is selecting the final design of new product taking three major factors into consideration. Market demand, designer's preferences, and uncertainty in performing the predicted design attitude levels; those factors affect the successes or failure of products in the market. This system uses generalized purchase modeling approach that consider the previous three factors and develop a customer based expected utility metric suit that supports the selection in product design.

Housing evaluation is a complicated decision. The complexity of the factors impact this kind of evaluation in addition to the volume of information involved. DSS for housing evaluation was presented by (Eduardo, Joao, & Carlos H, 2007). It integrates a problem editor, a data base management module, a set of multiple criteria decision which incorporates a satisfactory human computer interface, which can be integrated with Geographic Information System (GIS) tools.

Other decision support system has been developed by (Sanja,& Francesco, 2000), technological advances influence all aspects of society, recent history is filled with technological changes which affect our communities, and countries. Hence, technology selection decision is so important for the successful development of society. The authors developed a DSS for holistic assessment technology. Actually, the holistic assessment refers to making a global, artificial judgment of relevant aspects. The proposed DSS tries to make technology assessment as multi-disciplinary as possible. It combines skills and competencies of different experts together in realistic software applications.

Obviously, DSS plays vital role in every fields and presents the optimal support to managers/ decision makers whenever and wherever it exists. The importance of such systems is rapidly increasing due to critical circumstances and uncertainty environment that one often faced by decision makers. Moreover, DSS is very valuable and beneficial when there is lack of information as it’s more difficult for managers to make decisions under such situations.

2.6 Supplier Selection Models

Different types of models have been introduced for supplier selection problem. A suitable model and optimum approach for supplier selection decision has been interested topic for researchers. Complexity of supplier selection problem needs to be solved by utilizing an efficient method in order to support decision makers.

These methods could be organized in a number of categories, (Mahmut, 2006) clustered decision making methods reported in the literature into several wide categories, each category consists of number of methods.

The first category is mathematical programming which includes Total cost based approaches, Non Linear Programming, Mixed Integer Programming, Linear Programming, Integer Programming, Heuristics, Goal Programming and Data Envelopment Analysis (DEA).

The second category is traditional MCDM techniques which encompassing Analytic Hierarchy Process AHP, out ranking methods, MAUT, linear weighted point, judgmental modeling, interpretive structural modeling, categorical method, and fuzzy set.

Artificial intelligence and expert system represent the third category; it's containing neural networks, case-based reasoning, and Bayesian belief networks.

The fourth category is multivariate statistical analysis, structural equation modeling, principle component analysis, factor analysis, and confidence interval; approach are including in fourth category. (Mahmut, 2006) identified two additional categories under names of group decision making, and multiple methods.

In one of the broad studies which has conducted by (Ammar, 2005) all the supplier evaluation and selection methods have been categorized in various groups. The study categorizes the supplier evaluation and selection methods into three major categories depending on the content of each study: rating, mathematical, and hybrid methods. The method is listed under the rating methods otherwise listed under mathematical methods. On the other hand, if it integrates the performance evaluation as well as criteria tradeoff, the method is listed under the hybrid methods. Rating methods include two subcategories, criteria ranking and cost methods. The mathematical category encompasses four subcategories: operation research, linear weighting, statistical, and artificial intelligence methods.

Other clustering for decision making methods could be found in other publications, (Huan, & Hsu, 2006) divided MCDM techniques into five categories: multi-attribute decision making or a general view of linear weighting models, multi-objective optimization or a general view of mathematical/linear programming models, statistical/probabilistic approaches, intelligent approaches, and others. Besides that the authors gave the relative approaches for each category as its shows in Table2-3 which is adopted from (Huan, & Hsu, 2006).

Table 2-3. Taxonomy of Approaches of Vendor Evaluation

SNO	Category	Approach
1	MADM Models	AHP Conjoint analysis Linear Weighting method Outranking method
2	MODM models	3-Constraint methods DEA Goal programming
3	Statistical/probabilistic approach	Categorical method Cluster analysis Uncertainty analysis
4	Intelligence approach	Case-based reasoning Expert system Genetic algorithm Neural network
5	Others	Activity-based costing Interpretive structure modeling

Source: (Huan, & Hsu, 2006)

(Weber, et al., 1991) conducted a wide review that included 74 articles and grouped all the quantitative approaches of vendor selection into three general categories as follows:

(1) Linear Weighting Models.
(2) Mathematical Programming Models.
(3) Statistical/probabilistic approaches.

(Weber, et al., 1991) indicate that the most utilized approach has been linear weighting models. It assigns a weight to each criterion and calculates the total score for each vendor by summing up the vendor's performance on the criteria multiplied by these weights. It mentioned all the articles that proposed using linear weighting models as follows: (Wind & Robinson, 1968, Lamberson et al., 1976, and Mazurak, & Trecha, 1985) endorsed using a weighted linear model of multiple criteria for supplier selection. (Monczka, & Trecha, 1988) developed multiple criteria vendor services factor rating and on overall supplier performance index using linear weighting models.

In the same study, the authors found that just only ten articles have proposed mathematical programming models to be used for supplier selection and order quantity decisions. Those mathematical models which have been proposed are linear programming, mixed integer programming, and goal programming. This review also pointed out that (Moore, & Fearon, 1973) was the first of four articles to discuss the use of linear programming models for supplier selection, but there was no actual mathematical formulation yet. However, the objective of the conceptual model was to optimize the mix of vendor awards based on price. (Anthony, & Buffa, 1977) formulated a linear programming model to minimize total purchasing and storage cost. Linear programming has been proposed by (Kingsman, 1988) to be used for commodity buying situations, but the author did not formulate the linear programming model. (Pan, 1989) formulated a linear programming model to minimize the total cost of purchasing.

Four of the articles proposed the use of mixed integer optimization models for supplier selection. (Gaballa, 1974) formulated mixed integer optimization models to determine suppliers and order quantities for two classes of items orders by the Australian post office. The purpose of mixed integer optimization was to minimize total cost of purchase where price and value discounts were given. (Bender et. al, 1985) describe a mixed integer optimization model to minimize the sum of purchasing, transportation, and inventory cost over multiple time periods. The model formulated by (Narasimhan, &

Stoynoff, 1986) to determine vendors and order quantities for multiple production plants. The purpose of this model is to minimize the total of costs associated with transportation and inefficient utilization of vendor capacities.

Two articles structured the vendor selection problem in terms of multi-objective mathematical programming techniques. (Jackson, 1983) formulated the problem as goal program. Goal in the model addressed quality, price, and delivery criteria.

The third category is statistical approaches, which contain three articles. (Hinkle et. al, 1969) used cluster analysis to generate supplier rating. (Roben, & Trietsch, 1988) developed a stochastic EOQ model as apart of a decision support system for purchasing items for large projects. (Soukup, 1987) modified the linear weighting method by using probabilistic for the criterion weights.

As a result of several studies which have been conducted by (Ozden, & Birsen, 2005) to scan vendor selection methods. It's found that linear weighting models, mathematical programming models, and statistical/probabilities approaches are the most common used approaches. Besides that some other operation research methods such as total cost approaches, linear programming, and artificial intelligence-based models have been used in purchasing literature. Obviously, this findings almost agree with what mentioned before in that study which done by (Weber, et al., 1991)

Several methods for assisting the vendor selection process have been reported in the literature without clustering or dividing these methods into categories. (Aboulhas, et al., 2004) presented the most important methods, a brief description for each as follows:

- Categorical methods – they are qualitative models, they calculate the total rate for each supplier by assigning good (+), neutral (0), unsatisfactory (-) to each criteria for all suppliers.

- Data envelopment analysis (DEA): DEA enables the concurrent analysis of multiple inputs to multiple outputs, a multifactor productivity approach.
- Cluster analysis (CA): it's based on statistical concept using classification algorithm for grouping a number of items, this algorithm implies that the differences among items within same cluster are minimal, while the differences among the items from various clusters are maximal.
- Linear weighting models: in such models all criteria should be given weights considering that the highest weight must be given to the highest important criteria. The supplier with highest overall score can be suggested as the best supplier.
- Case-based reasoning (CBR) systems: CBR is a method for solving problems by making use of similar circumstances and reusing information and knowledge about such situations.
- Total cost of Ownership (TCO) models: try to include all measurable costs in the supplier selection that are incurred during the purchased item's life cycle.
- Statistical models: deal with the stochastic uncertainty associated with the vendor selection. Although uncertainty existing in most types of purchasing situations, e.g. without recognizing accurately how the internal demand for the items or services purchased will develop.
- Discrete Choice Analysis (DCA): it's an effective methodology for analyzing choices in complicated decision making situations (such supplier selection). It is also known as choice-based conjoint analysis.
- Mathematical programming (MP): models allow the decision maker to formulate the decision problem in terms of mathematical objective function that subsequently needs to maximized (profit) or minimized (cost) by changing the values of the variable in the objective function(e.g. the amount ordered with supplier x).
- Artificial intelligence (AI) models: are based on computer–aided systems that in one way or another can be qualified by a purchasing expert or historic data.

A summary of approaches to supplier selection presented by (khurrum, Butta, & Faizul, 2002) illustrated that total cost approach, multiple attribute utility theory, multiple objective programming, total cost ownership, and AHP are some of the main preferable models in the literature.

Supplier selection decision is one of the most essential decision making problems, since selection of the right suppliers extensively reduces purchasing costs and improves companies' competitiveness. (Ferhan, & Demet, 2003) conducted a wide review on several articles, and several methods have been proposed and used in supplier selection problem as they are depicted in Table2-4.

Table 2-4. Proposed and Used Methods in Supplier Selection Problem

Author	Method
Weber & Ellram 1993	Multi objective programming
Ghodsypour & O'Brien 1998	Integrated AHP and Linear Programming approach
Chen 2001	A multi criteria decision making model based on fuzzy set theory
Ghodsypour and O'Brien 2001, T. Dai and X.Qi, 2007	Proposed Mixed integer non-linear programming model
Weber et al.,1996 ,Liu et al., 2000 , & Weber et al., 2000	Used Data Envelopment Analysis (DEA) as mathematical programming tool.
Akbari et. al, 2001, Sirajuddin, & Al-Bulahid , 1996	Proposed mathematical model maximizing the total utility of supplier.
Bertolini et al., 2006	AHP
Ahmet & Bozubra, 2008	Fuzzy AHP

On the other hand, a few studies which focus on a specific part of purchasing management. These researches discuss purchasing globally. In some cases manufacturers choose the international purchasing, however it has many obstacles. (Min, & Galle, 1991) ranked the obstacles of international purchasing as follows:

- Transportation delays
- Foreign exchange fluctuations
- Travel cost
- Quality assurance
- Language
- Paper work, and
- Inspection procedures.

Lesser Developing Countries LDC supplier selection model has been proposed by (Jaideep et. al, 1999) to support a firm in determining and purchasing quality from suppliers in LDC countries. The proposed model can be used as a tool in leading a firm in purchasing internationally.

Other publications direct towards mentioning that, traditional supplier evaluation and selection methods are all often based on quoted price which ignore the important direct and indirect cost materials. (Reza, 2006) attempted to direct managers and decision makers to understand all that indirect costs should be taken into account, although the traditional supplier evaluation and selection methods hide these type of costs. Moreover, additional costs have been reported such as cost of ordering, receiving, inspecting and using purchased goods, the major reason of ignoring these additional cost is the limitations in the traditional accounting systems. The author used TCO concept to analyze some costs associated with purchased parts. Besides, DEA approach uses the results of TCO to determine the right supplier.

2.7 Integrated Models for Supplier Selection

On the other hand there are some studies attempted to come up with much better methods which can enhance the performance of decision making process. For achieving this goal, researchers integrate different type of methods together and propose to use that new integrate methods in decision making activity. This idea aims to develop new type of integrating models by merging the concepts of either mathematical, weighting, or statistical models in order to build new models that can encompasses various advantages. Moreover the new integrated models always try to avoid the shortcomings in each one of the integrated approaches.

As one of these studies done by (Fadihlah et al., 2007), which its main purpose is proposing a framework for improving single criteria decision model. Authors proposed a model that integration of statistical, weight, and Guided Analytic Hierarchy Process (GAHP) model. GAHP is a proposed term for AHP data entry matrices compound with a systematic guidance for a decision maker to enter data into the system.

In (Prabjot et al., 2007) an integration of standard score and linear programming is proposed to consider tangible and intangible attributes as well. The proposed approach used for selecting the best vendors. Besides, it situates the optimal order quantities among vendors.

Some authors have applied mixed integer, goal and multi-objective programming to supplier selection problem. Because these models are mathematical, they are not capable of considering qualitative attributes which are so significant for supplier selection decisions. (Ghodsypour, & O'Brien, 1998) proposed an integration of analytic hierarchy process and linear programming to consider both tangible and intangible factors when choosing the best supplier. The model applies AHP which uses pairwise comparison to make trade off between tangible and intangible factors and calculate suppliers' rating, and then using these rating as coefficients of an objective function in linear programming distributes order quantities among suppliers.

In other article, an integrated model for supplier selection has been developed by (Ching, & Bai-Sheng, 2006). It does include the use of AHP method to systematically integrate different judgments from various evaluators and obtain the weights of qualitative criteria, in addition to application of Grey Relational Analysis (GRA) that adopts qualitative and quantitative criteria. The integrated model includes four steps as shown in figure2-2.

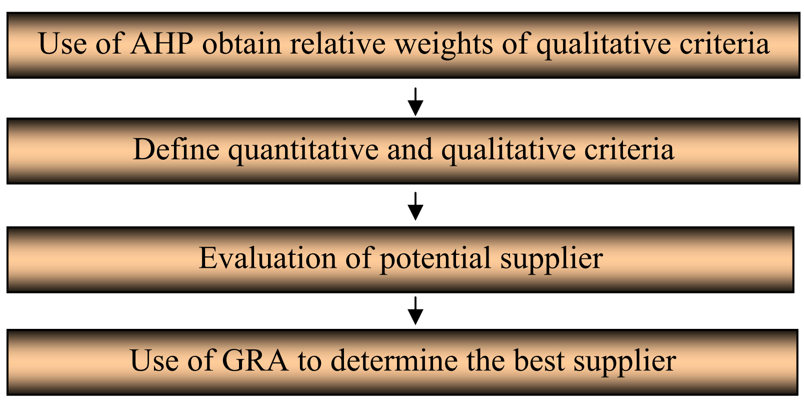


Figure 2-2. Integrated Model by Combing AHP and GRA

Based on the related works and all the existing models a new hybrid model for supplier selection decisions will be proposed in the coming chapters. This proposed hybrid model intends to eliminate the shortcomings that exist in most models to produce better decisions and enhance the quality of the decision making outcomes.

2.8 Summary

In this chapter, supplier selection decision process is discussed in terms of its important role in purchase management and business environment, besides the stages of supplier selection problem. This chapter provides a wide study of the supplier selection criteria and specifies all factors that complicate this process. Various DSSs that have been developed to support decision making process in different fields and particularly in supplier selection are illustrated too. Finally, the chapter discusses supplier selection methods that have been proposed and used in the literature and their different categorizations from different aspects and researcher's view points. This research has been achieved through variety of progresses and different steps. In the next chapter the research methodology that has been used to successfully complete this research will be discussed in details.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter includes several ideas which are all about explaining the core contribution of the research beside the base of this research. Moreover, this chapter provides all the sequence steps that have been followed in order to satisfy the research objectives.

3.2 Purpose of Research

Researchers and practitioners often seek for the most appropriate method that can provide reliability, simplicity and satisfactory performance to enhance supplier selection decisions. On the other hand, decision makers would like to have an efficient method to assist them throughout the activity of decision making particularly in supplier selection problem.

The main objective of this research is to develop and propose a hybrid model for supplier selection decision. The proposed model is based on two of the most common used models in supplier selection decision which they named linear weightage model and Analytic Hierarchy Process (AHP) approach. The proposed model is more powerful and reliable, as it’s based on those two robust approaches. Moreover, it combines all advantages of both models and avoids most of the shortcomings that exist in linear weightage and AHP models. To achieve the research objectives successfully and carry out the desirable targets from this research, a series of sequence progresses and steps have been adopted. Figure 3-1 depicts the research stages.

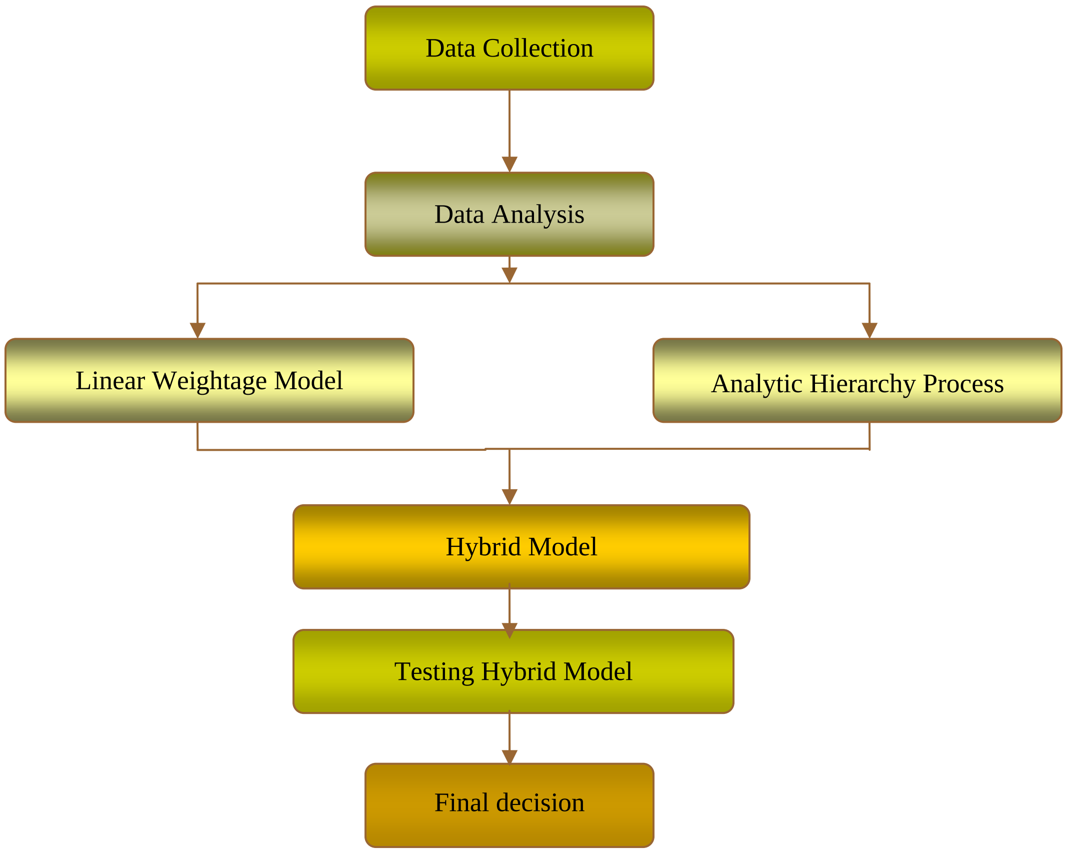


Figure 3-1. Research Stages

Figure 3-1 illustrates different phases of this research starting with data collection and continues throughout data analysis, linear weightage model, AHP, develops a new hybrid model, tests the proposed model in a real business case study. Finally some comparisons among the new proposed model, the linear weightage and AHP models will be looked at.

3.3 Data Collection

In this research, all data for this case study have been collected from the procurement department which is accountable for the whole purchasing processes in Universiti Teknologi PETRONAS (UTP). The data was collected through different quotations which received from eleven suppliers. This data has been gathered from those quotations and organized in table format as it will be shown in the case study section via the next chapter. This case study provides complete information about one of the supplier selection decision within UTP. This case study has been used to provide all the needed input for the proposed model of supplier selection. Besides, all the information of the strategies that usually followed by decision makers are collected in order to offer deep understanding of the entire purchasing process.

3.4 Data Analysis

The second phase is data analysis which gives deep understanding about the collected data and provides all required information to keep the study carrying on. Not only the collected data is describes a case study of supplier selection process, but also explains the strategy of all purchasing process that most probably followed by many organizations.

Generally, companies either have one purchase department that means all purchased items centralized during one department and this called centralize purchasing or every section within the organization makes its own purchasing decision which is called decentralize purchasing (Derek, 2003). Actually, UTP follows the centralize purchasing through the procurement department.

Usually purchasing processes start with request from a department within UTP to determine the need for new product or services. When procurement department receive the requisition form all the information could be found on it. Requisition form includes the type of products or services, quantity, unit of measure, quality and estimate price. Then a Request for Quotation (RFQ) will be sending to several vendors which their number is differing from process to another. Each invited vendor replies with a quotation that includes all the products and services attributes beside their prices and delivery time.

The most critical process is taking place after receiving and opening quotations. Manger/decision maker has to complete the vendor selection process and make an appropriate decision by selecting the right vendor. After that procurement department sends purchase order and confirms the approval of quotation to the selected vendor. The final step in the purchasing process is receiving the requested products and confirming the quality and all criteria. Figure 3-2 illustrates all the processes included in procurement department strategy.

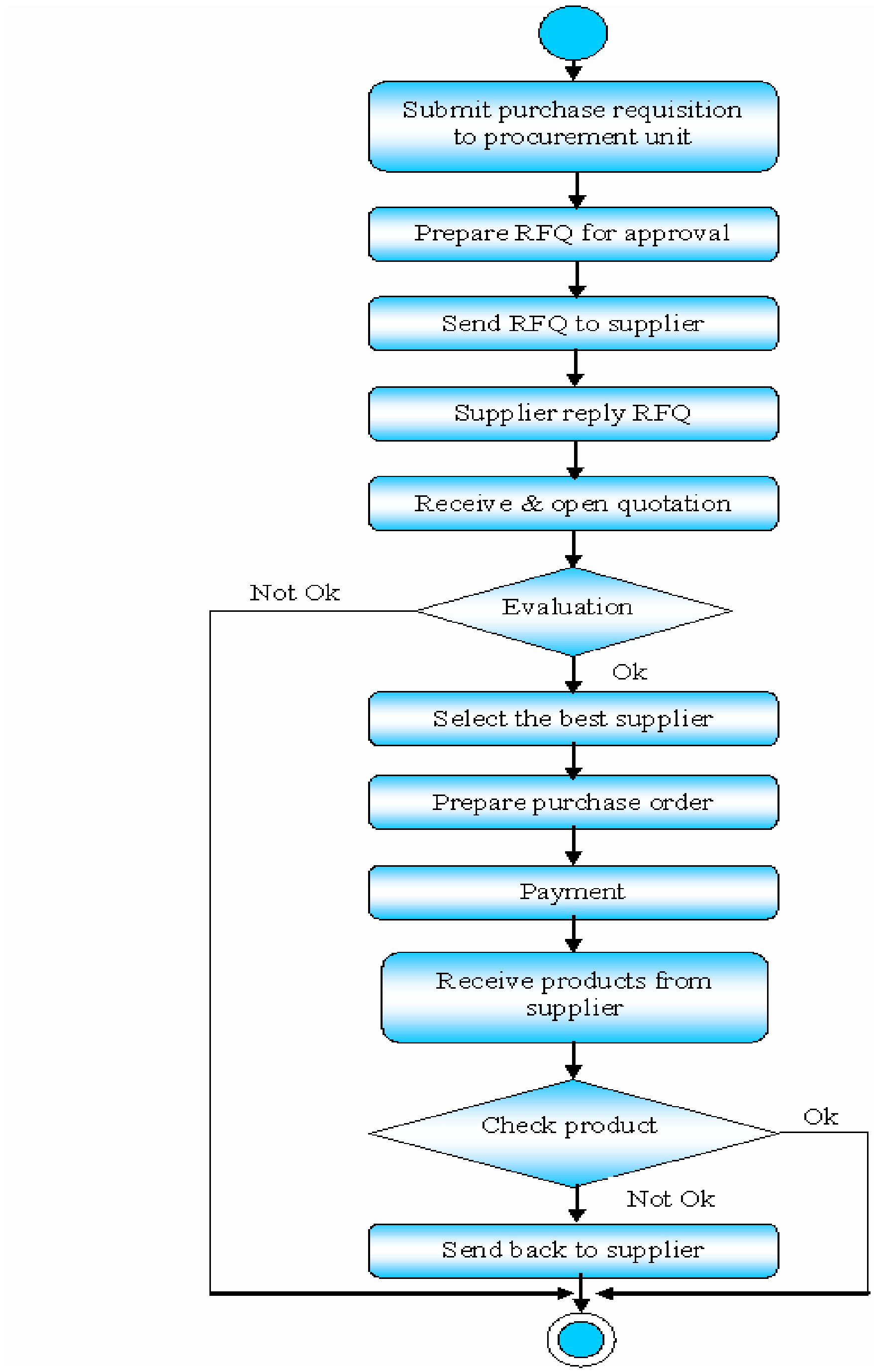


Figure3-2.Activity Diagram for Purchasing Process in a Procurement Department

3.5 Model Development

The core of this research is mainly focused on model development. This phase concerns various view points and different aspects that should be given attention in order to yield sufficient results. It starts with scanning most of the existing models in the literature and determining the most commonly used models in supplier selection problem. Based on the previous studies there are some models which have shown their capabilities and sufficiency when applied in supplier selection decision. Those models have been under the focus and so can easily specify the strengths as well as shortcomings. The urgent need for a robust and efficient model becomes so obvious. It has been found that weighting models are the most common category among all other categories which mentioned in the previous chapter. Since supplier selection is multi-criteria decision problem, the proposed model is based on two of MCDM methods and thus it can be categorized as MCDM model as well.

Linear weightage model is multi criteria method as well as AHP approach. The way of integrating, the limitation in each model, the strength of the proposed model and other concepts will be widely discussed in the next chapters. Moreover, composing and formulating the proposed model taking into account concepts of linear weightage model and AHP. Then testing and evaluation of the hybrid model will be taking place, the proposed model should be tested in the real business world by conducting one of the real case studies of supplier selection process.

3.6 Testing the Proposed Model

The last step is depending upon the results of the previous ones. Actually, it’s about discussing the results besides performing comparisons among (AHP), linear weightage model, and the proposed model in terms of how each model satisfied the goals, the ease of use, accuracy, efficiency and capabilities of handling complicated situations, in addition to arguing drawbacks of the proposed model if any. Moreover, the proposed model will be validated using validation technique which is called “what-if” analysis.

3.7 Summary

In this chapter all the sequence and several stages that have been followed in this research to successfully accomplish the objectives is clearly discussed. This chapter also introduces the research motivation and how the proposed model is able to contribute in developing the supplier selection decisions performance. Discussing the proposed model and how has it been built and its case study and other progress of validation will be shown in the next chapter.

CHAPTER FOUR: DEVELOPMENT OF HYBRID MODEL

4.1 Introduction

This chapter discusses two different types of models that have been used commonly in decision making activities. These two models are considered as the two main concepts that this research depends upon which are linear weightage model and AHP approach. In this chapter a deep understanding is provided and also a real case study for each model is applied and the final results is illustrated in form of final decisions. This chapter also presents the core of this research and shows the new proposed model for supplier selection decisions. Discussion of the idea and details of the new model is provided. Moreover, how the proposed model is going to overcome the limitations that face both of linear weightage and AHP model. The chapter also includes a case study to employ the proposed model and show the final decision that could be made and how effective is the proposed model. Besides, a comparison has been made to evaluate the efficiency of the proposed model. Finally, “what if analysis” technique is used to assess and evaluate the reliability of the proposed model.

4.2 Linear Weightage Model

Linear weightage model represents one of the weighting models that can be used in decision making process. Here is proposing linear weightage model for supplier selection decision. This model is dependent upon decision maker’s judgment as they have to assign weights to the criteria that involve in decision making process. In most cases there are some criteria considered as more important than others, such as quality, product price, and delivery time.

Managers/decision makers should assigned weight to each individual criterion in order to determine the relative importance of each one. Hence decision makers/ managers should be conscious and precise when assigning weights to these criteria besides taking the preference of criteria into their considerations. These weights are playing vital role in decision making process and extremely affect the final decision.

Many of the existing decision methods and models are considering just the quantitative criteria, although the supplier selection problem involves both quantitative and qualitative factors (Ching, & Bai-Sheng, 2006). In this section, linear weightage model have been proposed as it can easily handle both tangible and intangible criteria of evaluating and selecting the best vendor/supplier.

Linear weightage model consists of sequence functions and mathematical calculations should be followed to make the final decision. First of all decision maker/ manager have to identify all criteria that involve in the certain process first before performing any other steps. After identifying all the attributes/ criteria related to supplier selection decision, manager/decision maker has to determine thresholds for each attribute/criterion. In fact, threshold can be divided into two types maximum and minimum hence, each attribute/criterion either has maximum or minimum threshold. To establish a threshold to criterion, manager should classify all criteria into two groups. The first group known as “Larger is better” while the other known as “Smaller is better”. The best supplier location is required to be the closest one to the buyer company or the customer, the short delivery time is desirable, and low cost of products is preferable, so delivery time, supplier location, and product cost can be categorized as “Smaller is better” and the threshold for this type of criteria must be maximum. On the other hand, most of the qualitative criteria can be considered as “larger is better” such as warranty where thresholds must be minimum.

After determining the thresholds for the whole criteria or attributes, calculate the vendor values have to be established. It is often represented in the form of matrix which contains various numerical values for each vendor in respect with each single attribute or criterion. These vendor's values have to be calculated according to two different formulas. Once the attribute was considered as maximum type of thresholds, formula 1 should be used.

$$V_{\max} = \frac{Max - VendorValue}{Max - Min} \qquad (1)$$

Where

V_{max} = vendor value that has maximum type of threshold in respect with a particular attribute/criterion.

Vendor Value = specific vendor that is considered at a time.

Max = maximum value of particular attribute/criteria among all vendors/suppliers.

Min = minimum value of the same attribute among the whole suppliers.

In the other case when the attribute was classified under the minimum type of threshold, formula 2 is the solely one option for calculating the vendor's value.

$$V_{\min} = \frac{vendorValue - \min}{\max - \min} \qquad (2)$$

Where

V_{min} = vendor value that has minimum type of threshold in respect with a particular attribute/criterion.

Vendor Value= specific vendor that is considered at a time.

Max = maximum value of a particular attribute/criterion among all suppliers.

Min = minimum value of the same attribute among the whole suppliers.

The idea of using formula 1 and formula 2 is extremely valuable because they provide a method that enables the comparisons among decision criteria. Usually decision criteria have different units of measure so any comparisons among those criteria are not logically acceptable. By using the data normalization concepts which represented in formula 1 and formula 2, all the criteria will be having weights instead of variety of measurement units and then the comparisons can simply made.

On the other hand, the decision makers/ managers should not only be aware of the whole criteria that involved into the supplier selection process but also to which degree each criterion is more important than the other. Regarding this concept the managers/decision makers should assign weight to each criterion in accordance with the relative importance of the criterion among the others and that has been considered as the major limitation in this model.

When all values of the criteria matrix are calculated, series of calculations should be achieved by multiplying weights of criteria by the whole values within the matrix. The total should also be calculated for each vendor which represents the vendors' scores. The final decision table includes a score for each vendor/ supplier and the one who gains the highest score is recommended as the best vendor/supplier.

4.3 A Case Study of Supplier Selection

The data for this case study have been collected from the procurement department which is accountable for the whole purchasing processes in Universiti Teknologi PETRONAS (UTP). Actually, data collection has different types of techniques can be followed as they stated earlier, however interview has been conducted for the data collection purpose in this case study.

This case study represents one of the purchasing and supplier selection processes during last year. This process has begun with a request form sent by one of the departments within UTP to the procurement department telling that all products needed and their attributes and specifications. According to the request, procurement department has invited a number of suppliers to participate in providing the requested items. Eleven suppliers have replied with a quotation form representing the products and their attributes, all of them have interest to be involved in the purchasing process.

Once the process includes eleven competitive suppliers Table 4-1 illustrates the data; the first column contains the attributes/criteria of the purchased products which are server devices. These criteria involve in the supplier selection process are eight different criteria which describe each product that has been proposed by each supplier company. The eight criteria for the server devices are processor, memory, power supply consumption, cache memory, internal storage, warranty, price, and delivery time.

The rest of the columns represent the eleven competitive suppliers. S1 in the second column refers to supplier 1 and S2 in the next column refers to supplier2 and so on till S11 which definitely refers to supplier11.

Table 4-1. Criteria and Suppliers

Attributes	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
Processor	1.86	3.66	1.86	1.6	1.65	1.75	1.86	1.68	1.6	1.57	1.58
Memory	1024	2000	1024	1024	2000	1024	2000	1024	1024	1024	1024
Power supply	835	1300	835	835	1300	1300	835	835	1300	835	1300
Cache Memory	4	1	4	4	1	2	2	1	2	2	4
Int-storage	146.8	440.4	146	146	146	73	73.4	146	73.4	146	146
Warranty	36	36	36	36	24	36	24	36	36	24	24
Price	20352	48200	25320	23405	45250	32250	24250	26400	31100	23304	32450
Delivery	4	3	6	6	4	6	4	6	4	7	4

To apply linear weightage model on this case study and yields the results in form of a final decision table, a threshold should firstly be given to each single criterion. It can obviously be noticed that processor, memory, cache memory, internal storage and warranty are considered under the “larger is better” category, which makes their thresholds is minimum. In contrast, power supply consumption, price, and delivery time are getting maximum type of threshold. Then decision maker/manager should assign weights of criteria taking the relative importance of each criterion into account in according to others. Table 4-2 shows thresholds and weights of criteria. In addition, it also illustrates the measurement unit of these attributes. They are Giga Hertz for processor, Mega Byte for both memory and cache memory, Watt for power supply consumption, Giga Byte for the internal storage, while warranty has been measured in months, the price in Malaysian Ringgit. Finally week represents the measurement unit of delivery time.

Table 4-2.Thresholds, Weights and Units

Attributes	Thresholds	Weights	Measurement Unit
Processor	Min	0.20	Giga Hertz
Memory	Min	0.20	Mega Byte
Power Supply	Max	0.05	Watt
Cache Memory	Min	0.10	Mega Byte
Internal Storage	Min	0.15	Giga Byte
Warranty	Min	0.05	Month
Price	Max	0.20	RM
Delivery	Max	0.05	Week

Regarding Table4-2, it has clearly shown that processor, memory, and price are more important than the rest of attributes, they gain 20% as relative importance for each. Internal storage has 15% while cache memory has 10%. The three attributes power supply, warranty, and delivery time have the same importance of 5%.

According to the thresholds, formula 1 and formula 2 can be used to calculate the entire values in the criteria table to be in a form of weights and then the comparisons can be done easily among the alternatives. Processor, memory, cache memory, internal storage, and warranty are transformed using formula 2, while the rest attributes are transformed by using formula1. According to the calculation the results are shown below.

Processor:

$$S1 = \frac{1.86 - 1.57}{3.66 - 1.57} \approx 0.14, \qquad S2 = \frac{3.66 - 1.57}{3.66 - 1.57} \approx 1.00 \quad \ldots \quad S11 = \frac{1.58 - 1.57}{3.66 - 1.57} \approx 0.00$$

Memory:

$$S1 = \frac{1024 - 1024}{2000 - 1024} = 0.00 \quad , \quad S2 = \frac{2000 - 1024}{2000 - 1024} = 1.00 \quad \ldots \quad S1 = \frac{1024 - 1024}{2000 - 1024} = 0.00$$

Cache memory:

$$S1 = \frac{4 - 1}{4 - 1} = 1.00 \quad , \quad S2 = \frac{1 - 1}{4 - 1} = 0.00 \quad \ldots \quad S11 = \frac{4 - 1}{4 - 1} = 1.00$$

Internal storage

$$S1 = \frac{146.8 - 73}{440 - 73} \approx 0.20 \quad , \quad S2 = \frac{440 - 73}{440 - 73} = 1.00 \quad \ldots \quad S11 = \frac{146 - 73}{440 - 73} \approx 0.20$$

Warranty:

$$S1 = \frac{36 - 24}{36 - 24} = 1.00 \quad , \quad S2 = \frac{36 - 24}{36 - 24} = 1.00 \quad \ldots \quad S11 = \frac{24 - 24}{36 - 24} = 0.00$$

Power supply:

$$S1 = \frac{1300 - 835}{1300 - 835} = 1.00 \quad , \quad S2 = \frac{1300 - 1300}{1300 - 835} = 0.00 \quad \ldots \quad S11 = \frac{1300 - 1300}{1300 - 835} = 0.00$$

Price:

$$S1 = \frac{48200-20352}{48200-20352} = 1.00\,,\; S2 = \frac{48200-48200}{48200-20352} = 0.00\; \ldots\; S11 = \frac{48200-32450}{48200-20352} \approx 0.57$$

Delivery:

$$S1 = \frac{7-4}{7-3} = 0.75 \qquad , \qquad S2 = \frac{7-3}{7-3} = 1.00 \qquad \ldots \qquad S11 = \frac{7-4}{7-3} = 0.75$$

At the end of the day, all vendors' values will be calculated in respect with each attribute as it depicted in Table 4-3.

Table 4-3.Attributes' Values

Attributes	Threshold	Weight	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Att1	Min	0.2	0.14	1.00	0.14	0.01	0.04	0.09	0.14	0.05	0.01	0.00	0.00
Att2	Min	0.2	0.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
Att3	Max	0.05	1.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00
Att4	Min	0.1	1.00	0.00	1.00	1.00	0.00	0.33	0.33	0.00	0.33	0.33	1.00
Att5	Min	0.15	0.20	1.00	0.00	0.20	0.00	0.00	0.00	0.20	0.20	0.20	0.20
Att6	Min	0.05	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Att7	Max	0.2	1.00	0.00	0.82	0.89	0.11	0.57	0.86	0.78	0.89	0.89	0.57
Att8	Max	0.05	0.75	1.00	0.25	0.25	0.75	0.25	0.75	0.25	0.00	0.00	0.75

The final step in linear weightage model is finding the scores of suppliers by multiplying each single vendor value by the weight of its attribute/criterion. Then the sum of each supplier/vendor should be calculated as shown in formula 3 below:

$$\text{Total Score} = \sum_{i=1}^{n} W_i X_i \Big/ \sum_{i=1}^{n} W_i \qquad (3)$$

Where:

W_i = weights of criteria.

X_i = values of suppliers.

For example, calculations of the score for the first supplier using formula 3 are given as follows:

$$\sum_{i=1}^{8} W_i = (0.2+0.2+0.05+0.01+0.15+0.05+0.2+0.05) = 1$$

Total Score of S1 = [0.2(0.14) + 0.02(0.00) + 0.05(1.00) + 0.01(1.00) + 0.15(0.20) +0.05(1.00) + 0.2(1.00) + 0.05(0.75)]/1 = 0.50

The same way of the previous numerical example is followed to yield all scores of the rest suppliers. Finally, the decision maker/manager should make the final decision by his/her self. Table 4-4 depicts the results of the final decision. And the highest score indicates to the best supplier and the winner will be suggested as the most appropriate choice among the candidates supplier.

Table 4-4. The Final Decision

	threshold	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Att1	Min	0.03	0.20	0.03	0.00	0.01	0.02	0.03	0.01	0.00	0.00	0.00
Att2	Min	0.00	0.20	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00
Att3	Max	0.05	0.00	0.05	0.05	0.00	0.00	0.05	0.05	0.00	0.05	0.00
Att4	Min	0.10	0.00	0.10	0.10	0.00	0.03	0.03	0.00	0.03	0.03	0.10
Att5	Min	0.03	0.15	0.03	0.03	0.03	0.00	0.00	0.03	0.00	0.03	0.03
Att6	Min	0.05	0.05	0.05	0.05	0.00	0.05	0.00	0.05	0.05	0.00	0.00
Att7	Max	0.20	0.00	0.16	0.18	0.02	0.11	0.17	0.16	0.12	0.18	0.11
Att8	Max	0.04	0.05	0.01	0.01	0.04	0.01	0.04	0.01	0.04	0.00	0.04
Score		0.50	0.65	0.43	0.42	0.30	0.23	0.52	0.31	0.25	0.29	0.28

From the final results supplier 2 has got the highest score which is 0.65, while supplier7 got the second highest score, followed by supplier 2 in the third order. From the results of linear weightage model, it’s obviously recommends supplier 2 to be selected as the best supplier.

4.4 Analytic Hierarchy Process (AHP)

AHP designed to solve complicated multi-criteria decision problem, besides that AHP is appropriate whenever a target is obviously declared and a set of relevant criteria and alternatives are offered (Ozden, & Birsen, 2005). AHP which developed by Saaty has become a popular approach and has been used in a broad variety of situations by a number of researchers (Selcuk, 1997). Furthermore, successful application of the AHP have been reported in marketing, finance, economics, public policy, education , medicine, and even sport. Accordingly, AHP has been proposed in recent literature as promising solution approach to large, and complicated multi-criteria decision making problems (Jiain, & Huei, 2006). Moreover, the AHP has been well-tested and shown to be supportive in many other decision situations concerning evaluation and selection processes (Ahmet, & Bozbura, 2008). The types of problems addressed by AHP contain selection, evaluation, resource allocation, benchmarking, quality management, health care and strategic planning (Hongyi, 2006).

Many of the existing decision methods and models are concentrating just on the quantitative criteria; however supplier selection decision involves qualitative criteria as well as quantitative. Once AHP can simply consider both tangible and intangible attributes that could be appeared through the process of evaluating and selecting suppliers, it has been recently proposed for supplier selection. AHP provides an environment that allows for judgment in decision making. Moreover, it is simultaneously trading off key supplier selection criteria. Thus, AHP is justified for vendor selection problem (Moynihan et. al, 2007).

In this section AHP has been proposed for supplier selection problem to support managers through the decision making activity, which aims to select the right supplier among pool of potential suppliers. In AHP the problems are usually presented in a hierarchical structure and the decision maker is guided throughout a subsequent series of pairwise comparisons to express the relative strength of the elements in the hierarchy. In general the hierarchy structure encompasses of three levels, where the top level represents the goal, and the lowest level has the supplier under consideration. The intermediate level contains the criteria under which each supplier is evaluated.

The problem hierarchy leads to an analysis based on the influence of a given level on the next higher level. The process begins by determining the relative importance of the criteria in meeting the goal. Next, the focus turn to measuring to which extend the suppliers fulfill each of the criteria. Finally, the results of the two analyses are combined to compute the relative importance of the supplier in meeting the goal. Figure 4-1 depicts the structure of problem hierarchy.

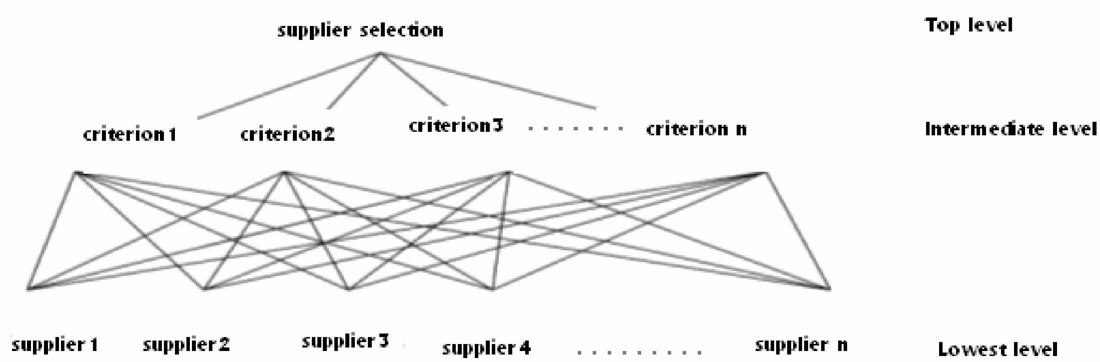


Figure 4-1.AHP Problem Hierarchy

There are many ways to obtain the preference from the decision maker, but the measurement scale proposed by (Saaty, 1980) is most commonly used. Table 4-5 gives a glimpse about decision maker judgment and preference of criteria with pairwise comparisons. This measurement scale enables the manager/decision maker determine to which degree each single criterion is preferred in comparison with others. This measure scale includes 1-9 scale points, each point represents different degree of preference.

Table 4-5. AHP Measure Scale

Value	Preference
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	For comparison between the above values

Source: (Ozden, & Birsen, 2005)

By using the measure scales and comparing each criterion to another the original matrix of criteria will be composed. The data included in the original matrix of criteria must be used to produce a very good estimate of the criteria weights. The weights provide a measure of the relative importance of each criterion. The steps are carried out as follows:

1. Compute the total values in each column.
2. Divide each single value by its column total.
3. Calculate averages of each row.

Then, the whole suppliers should be compared pairwise for each criterion. This step is almost identical to the procedure that was used to develop the criteria comparison matrix. The difference is that there is a comparison matrix for each criterion. Consequently, the decision maker has to compare each pair of suppliers with respect to each single criterion.

The final score obtain for each supplier across each criterion is calculated by multiplying the weight of each criterion with the weight of each supplier. The supplier who has got the highest score is suggested as the best supplier and decision maker may consider that one as the best decision choice.

4.5 Case Study of AHP Approach

The case study for AHP model is the same case study that has been used before by linear weightage model. AHP approach has been implemented and all the processes and calculations are provided. Besides, the final decision for supplier selection is given. The problem hierarchy for this case study consists of three levels as it's shown in Figure 4-2.

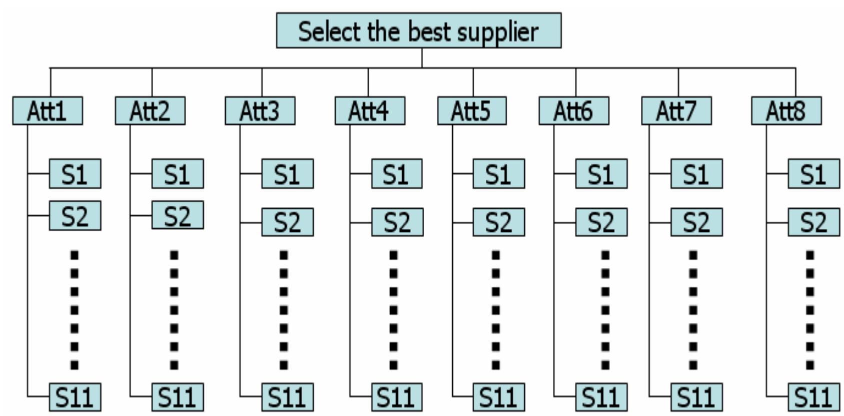


Figure 4-2.Supplier Selection Hierarchy

According to the data shown in table 4-1, the top level of hierarchy represents the goal which is selecting the best supplier in this process, the second level is illustrates the criteria of selection and the base level contains all the competitive suppliers. By using the measure scales in Table 4-5 and comparing each criterion to another the original criteria matrix will be composed. Table 4-6 gives a glimpse of decision maker judgment and preference of criteria with pairwise comparisons.

Table 4-6. Original Criteria Matrix

	processor	memory	power	cache	int-storage	warranty	price	delivery
processor	1	1	7	5	2	7	1	7
memory	1	1	7	5	2	7	1	7
power	0.14	0.14	1	0.5	0.33	1	0.14	1
cache	0.2	0.2	2	1	0.5	2	0.2	2
int-storage	0.5	0.5	3	2	1	3	0.5	3
warranty	0.14	0.14	1	0.5	0.33	1	0.14	1
price	1	1	7	5	2	7	1	7
delivery	0.14	0.14	1	0.5	0.33	1	0.14	1
total	4.12	4.12	29	19.5	8.49	29	4.12	29

Generally, for any pairwise comparison matrix 1s have been placed down the diagonal from the upper left hand corner to the lower right hand corner, then comparing the respective criteria. Considering Table 4-6, processor is equally preferred to memory therefore one has been placed in the intersection cell. Once processor is very strongly preferred to power consumption, seven has been placed in the intersection of processor and power in the first row. By applying the same way all the rest of the cells can be filled. Since comparing row 1 the other can similarly compared. On the flip side of the diagonal, when power is compared to processor it should be 1/7 and so on.

Once these comparisons have been made, the data are used to determine the weights of the criteria; the process as it summarized before in three steps: calculating the total of each column, divide each value obtained by its column total, and calculate the averages of rows. Table 4-7 depicts the results.

Table 4-7. Normalized Criteria Matrix

	processor	memory	power	cashe	int-storage	warranty	price	delivery	**weights**
processor	0.242718	0.242718	0.241379	0.25641	0.235571	0.241379	0.242718	0.241379	0.243034
memory	0.242718	0.242718	0.241379	0.25641	0.235571	0.241379	0.242718	0.241379	0.243034
power	0.033981	0.033981	0.034483	0.025641	0.038869	0.034483	0.033981	0.034483	0.033738
cashe	0.048544	0.048544	0.068966	0.051282	0.058893	0.068966	0.048544	0.068966	0.057838
int-storage	0.121359	0.121359	0.103448	0.102564	0.117786	0.103448	0.121359	0.103448	0.111847
warranty	0.033981	0.033981	0.034483	0.025641	0.038869	0.034483	0.033981	0.034483	0.033738
price	0.242718	0.242718	0.241379	0.25641	0.235571	0.241379	0.242718	0.241379	0.243034
delivery	0.033981	0.033981	0.034483	0.025641	0.038869	0.034483	0.033981	0.034483	0.033738
total	1	1	1	1	1	1	1	1	1

The last column includes weights of all the eight involved criteria in this process. It shows that the final weights of processor, memory, power, cache memory, internal storage, warranty, price, and delivery time are 0.243034, 0.243034, 0.033738, 0.057838, 0.111847, 0.033738, 0.243034, and 0.033738 respectively.

Each decision alternative or supplier is then compared with other supplier in relative isolation of the context of one criterion at a time. This process is repeated for each criterion in the decision problem. So, there will be matrix for comparing each pair of supplier with respect to processor criterion, memory criterion, power, cache memory, internal storage, warranty, price, and delivery time respectively. Firstly, processor matrix is shown in Table 4-8.

Table 4-8.Original Processor Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	0.33	1	3	5	3	0.33	5	5	7	7
S2	3	1	3	5	5	4	3	5	5	7	7
S3	1	0.33	1	3	5	3	0.33	5	5	7	7
S4	0.33	0.2	0.33	1	1	0.5	0.2	1	1	2	2
S5	0.2	0.2	0.2	1	1	0.5	0.2	1	1	2	2
S6	0.33	0.25	0.33	2	2	1	0.33	2	2	3	3
S7	3	0.33	3	5	5	3	1	5	5	7	7
S8	0.2	0.2	0.2	1	1	0.5	0.2	1	1	2	2
S9	0.2	0.2	0.2	1	1	0.5	0.2	1	1	2	2
S10	0.14	0.14	0.14	0.5	0.5	0.33	0.14	0.5	0.5	1	1
S11	0.14	0.14	0.14	0.5	0.5	0.33	0.14	0.5	0.5	1	1
total	**9.54**	**3.32**	**9.54**	**23**	**27**	**16.66**	**6.07**	**27**	**27**	**41**	**41**

Table 4-9.Normalized Processor Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.104822	0.099398	0.104822	0.130435	0.185185	0.180072	0.054366	0.185185	0.185185	0.1707317	0.170732	0.142812
S2	0.314465	0.301205	0.314465	0.217391	0.185185	0.240096	0.494234	0.185185	0.185185	0.1707317	0.170732	0.252625
S3	0.104822	0.099398	0.104822	0.130435	0.185185	0.180072	0.054366	0.185185	0.185185	0.1707317	0.170732	0.142812
S4	0.034591	0.075301	0.034591	0.086957	0.074074	0.060024	0.054366	0.074074	0.074074	0.0731707	0.073171	0.064945
S5	0.020964	0.060241	0.020964	0.043478	0.037037	0.030012	0.032949	0.037037	0.037037	0.0487805	0.04878	0.037935
S6	0.034591	0.075301	0.034591	0.086957	0.074074	0.060024	0.054366	0.074074	0.074074	0.0731707	0.073171	0.064945
S7	0.314465	0.099398	0.314465	0.217391	0.185185	0.180072	0.164745	0.185185	0.185185	0.1707317	0.170732	0.198869
S8	0.020964	0.060241	0.020964	0.043478	0.037037	0.030012	0.032949	0.037037	0.037037	0.0487805	0.04878	0.037935
S9	0.020964	0.060241	0.020964	0.043478	0.037037	0.030012	0.032949	0.037037	0.037037	0.0487805	0.04878	0.037935
S10	0.014675	0.042169	0.014675	0.021739	0.018519	0.019808	0.023064	0.018519	0.018519	0.0243902	0.02439	0.021861
S11	0.014675	0.042169	0.014675	0.021739	0.018519	0.019808	0.023064	0.018519	0.018519	0.0243902	0.02439	0.021861
total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

In the Table 4-8 each pair of suppliers is compared with respect to processor criterion, as shown above. Table 4-9 generates the weight of each supplier with respect to processor criterion. As a result, the weights of supplier1, supplier2 …, and supplier 11 are 0.142812, 0.252625, …, 0.021861 respectively. These weights have been computed by performing the following mathematical operations:

From Table 4-8, every single value has been divided by its column sum, by considering the first row in the table the calculation is done as bellow:

1/9.54 = 0.104822, 0.33/3.32 = 0.993398, 1/9.54 = 0.104822, 3/23 = 0.130435,
5/27 = 0.185185, 3/16.66 = 0.180072, 0.33/6.07 = 0.054366,
5/27 = 0.185185, 5/27 = 0.185185, 7/41 = 0.1707317, 7/41 = 0.1707317

Then the average of the row is calculated to obtain the weight.

(0.104822+0.993398+0.104822+0.130435+0.185185+0.180072+0.054366+0.185185+0.185185+0.1707317+0.1707317)/11 = **0.142812**

The result of the previous calculation represents the weight of supplier1 in accordance with processor criterion. Identically, the calculations are done for the rest of the supplier and it produced the last column in Table 4-9 which shows all weights of supplier regarding processor criterion.

Consequently, all the rest of criteria will have original and normalized matrix which yield the final weight of supplier in accordance with only one criterion at a time. These matrices are considered as following:

Table 4-10.Original Memory Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	0.2	1	1	0.2	1	0.2	1	1	1	1
S2	5	1	5	5	1	5	1	5	5	5	5
S3	1	0.2	1	1	0.2	1	0.2	1	1	1	1
S4	1	0.2	1	1	0.2	1	0.2	1	1	1	1
S5	5	1	5	5	1	5	1	5	1	1	1
S6	1	0.2	1	1	0.2	1	0.2	1	1	1	1
S7	5	1	5	5	1	5	1	5	5	5	5
S8	1	0.2	1	1	0.2	1	0.2	1	1	1	1
S9	1	0.2	1	1	1	1	0.2	1	1	1	1
S10	1	0.2	1	1	1	1	0.2	1	1	1	1
S11	1	0.2	1	1	1	1	0.2	1	1	1	1
total	**23**	**4.6**	**23**	**23**	**7**	**23**	**4.6**	**23**	**19**	**19**	**19**

Pairwise comparisons have been made by comparing each pair of suppliers with respect to memory criterion. Supplier1, supplier3, supplier6, supplier8, supplier9, supplier10, and supplier11 are equally preferred that's why they all have ones in the intersection cells. While supplier2 is strongly important than supplier1 in terms of memory criteria, the intersection cell is filled by 5. In return, the intersection cell of supplier1 and supplier2 in the first row is filled by 0.2 which is 1/5.

Table 4-11.Normalized Memory Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.043478	0.043478	0.043478	0.043478	0.028571	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.044619
S2	0.217391	0.217391	0.217391	0.217391	0.142857	0.217391	0.217391	0.217391	0.263158	0.2631579	0.263158	0.223097
S3	0.043478	0.043478	0.043478	0.043478	0.028571	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.044619
S4	0.043478	0.043478	0.043478	0.043478	0.028571	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.044619
S5	0.217391	0.217391	0.217391	0.217391	0.142857	0.217391	0.217391	0.217391	0.052632	0.0526316	0.052632	0.165681
S6	0.043478	0.043478	0.043478	0.043478	0.028571	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.044619
S7	0.217391	0.217391	0.217391	0.217391	0.142857	0.217391	0.217391	0.217391	0.263158	0.2631579	0.263158	0.223097
S8	0.043478	0.043478	0.043478	0.043478	0.028571	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.044619
S9	0.043478	0.043478	0.043478	0.043478	0.142857	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.055009
S10	0.043478	0.043478	0.043478	0.043478	0.142857	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.055009
S11	0.043478	0.043478	0.043478	0.043478	0.142857	0.043478	0.043478	0.043478	0.052632	0.0526316	0.052632	0.055009
total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Regarding table 4-11 supplier2 and supplier7 have got the same and highest weight of memory criterion which is 0.223097 for each. The lowest weight had been gotten by supplier1, supplier3, supplier4, supplier6, and supplier8 which are equal to 0.044619.

Table 4-12.Original Power Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	3	1	1	3	3	1	1	3	1	3
S2	0.33	1	0.33	0.33	1	1	0.33	0.33	1	0.33	1
S3	1	3	1	1	3	3	1	1	3	1	3
S4	1	3	1	1	3	3	1	1	3	1	3
S5	0.33	1	0.33	0.33	1	1	0.33	0.33	1	0.33	1
S6	0.33	1	0.33	0.33	1	1	0.33	0.33	1	0.33	1
S7	1	3	1	1	3	3	1	1	3	1	3
S8	1	3	1	1	3	3	1	1	3	1	3
S9	0.33	1	1	3	3	1	1	3	1	0.33	1
S10	1	3	1	1	3	3	1	1	3	1	3
S11	0.33	1	0.33	0.33	1	1	0.33	0.33	1	0.33	1
total	**7.65**	**23**	**8.32**	**10.32**	**25**	**23**	**8.32**	**10.32**	**23**	**7.65**	**23**

This matrix represents pairwise comparisons regarding to the third criterion in this case study. It does compare the preference of each supplier regarding power criterion, as it's obviously illustrated in Table 4-12.

Table 4-13.Normalized Power Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.130719	0.130435	0.120192	0.096899	0.12	0.130435	0.120192	0.096899	0.130435	0.130719	0.130435	0.121578
S2	0.043137	0.043478	0.039663	0.031977	0.04	0.043478	0.039663	0.031977	0.043478	0.0431373	0.043478	0.040315
S3	0.130719	0.130435	0.120192	0.096899	0.12	0.130435	0.120192	0.096899	0.130435	0.130719	0.130435	0.121578
S4	0.130719	0.130435	0.120192	0.096899	0.12	0.130435	0.120192	0.096899	0.130435	0.130719	0.130435	0.121578
S5	0.043137	0.043478	0.039663	0.031977	0.04	0.043478	0.039663	0.031977	0.043478	0.0431373	0.043478	0.040315
S6	0.043137	0.043478	0.039663	0.031977	0.04	0.043478	0.039663	0.031977	0.043478	0.0431373	0.043478	0.040315
S7	0.130719	0.130435	0.120192	0.096899	0.12	0.130435	0.120192	0.096899	0.130435	0.130719	0.130435	0.121578
S8	0.130719	0.130435	0.120192	0.096899	0.12	0.130435	0.120192	0.096899	0.130435	0.130719	0.130435	0.121578
S9	0.043137	0.043478	0.120192	0.290698	0.12	0.043478	0.120192	0.290698	0.043478	0.0431373	0.043478	0.10927
S10	0.130719	0.130435	0.120192	0.096899	0.12	0.130435	0.120192	0.096899	0.130435	0.130719	0.130435	0.121578
S11	0.043137	0.043478	0.039663	0.031977	0.04	0.043478	0.039663	0.031977	0.043478	0.0431373	0.043478	0.040315
total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

The highest weight of supplier in accordance with power criterion is 0.121578 which obtained by six competitive suppliers out of eight suppliers, while the rest of the two suppliers got less weights.

Identically, an original and normalized matrix should be computed for each criterion, at the end of the day any supplier will have a particular weight for each criterion as it’s shown in the following matrices.

Table 4-14. Original Cache Memory Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	5	1	1	5	3	3	5	3	3	1
S2	0.2	1	0.2	0.2	1	0.5	0.5	1	0.5	0.5	0.2
S3	1	5	1	1	5	3	3	5	3	3	1
S4	1	5	1	1	5	3	3	5	3	3	1
S5	0.2	1	0.2	0.2	1	0.5	0.5	1	0.5	0.5	0.2
S6	0.33	2	0.33	0.33	2	1	1	2	1	1	0.33
S7	0.33	2	0.33	0.33	2	1	1	2	1	1	0.33
S8	0.2	1	0.2	0.2	1	0.5	0.5	1	0.5	0.5	0.2
S9	0.33	2	0.33	0.33	2	1	1	2	1	1	0.33
S10	0.33	2	0.33	0.33	2	1	1	2	1	1	0.33
S11	1	5	1	1	5	3	3	5	3	3	1
total	**5.92**	**31**	**5.92**	**5.92**	**31**	**17.5**	**17.5**	**31**	**17.5**	**17.5**	**5.92**

Table 4-15.Normalized Cache memory Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.168919	0.16129	0.168919	0.168919	0.16129	0.171429	0.171429	0.16129	0.171429	0.1714286	0.168919	0.167751
S2	0.033784	0.032258	0.033784	0.033784	0.032258	0.028571	0.028571	0.032258	0.028571	0.0285714	0.033784	0.031472
S3	0.168919	0.16129	0.168919	0.168919	0.16129	0.171429	0.171429	0.16129	0.171429	0.1714286	0.168919	0.167751
S4	0.168919	0.16129	0.168919	0.168919	0.16129	0.171429	0.171429	0.16129	0.171429	0.1714286	0.168919	0.167751
S5	0.033784	0.032258	0.033784	0.033784	0.032258	0.028571	0.028571	0.032258	0.028571	0.0285714	0.033784	0.031472
S6	0.055743	0.064516	0.055743	0.055743	0.064516	0.057143	0.057143	0.064516	0.057143	0.0571429	0.055743	0.058645
S7	0.055743	0.064516	0.055743	0.055743	0.064516	0.057143	0.057143	0.064516	0.057143	0.0571429	0.055743	0.058645
S8	0.033784	0.032258	0.033784	0.033784	0.032258	0.028571	0.028571	0.032258	0.028571	0.0285714	0.033784	0.031472
S9	0.055743	0.064516	0.055743	0.055743	0.064516	0.057143	0.057143	0.064516	0.057143	0.0571429	0.055743	0.058645
S10	0.055743	0.064516	0.055743	0.055743	0.064516	0.057143	0.057143	0.064516	0.057143	0.0571429	0.055743	0.058645
S11	0.168919	0.16129	0.168919	0.168919	0.16129	0.171429	0.171429	0.16129	0.171429	0.1714286	0.168919	0.167751
total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

All the data in the cache memory matrix which is shown in Table 4-14 have been used to generate weights of suppliers in respect to the cache memory criterion and determine how each supplier is preferred in comparison with the rest.

The normalized cache memory matrix is calculated and here one example is provided to explain the computations that produce all the values and weights included in table 4-15.

1/5.92 = 0.168919, 3/31= 0.16129, 1/5.92 = 0.1688919, 1/5.92 = 0.1688919,

3/31= 0.16129, 3/17.5 = 0.171429, 3/17.5 = 0.171429, 5/31 = 0.16129,

3/17.5 = 0.171429, 3/17.5 = 0.171429, 1/5.92 = 0.168919.

These values are shown in the first row in the table above and to get the weight of supplier 1, average of row is calculated.

Weight of S1:

[0.168919+ 0.16129+ 0.1688919+ 0.1688919+ 0.16129+ 0.171429+ 0.171429+ 0.16129+ 0.171429+ 0.171429+ 0.168919]/11= **0.167751**

After calculating the whole rows, weights of all suppliers in respect to this criterion is given in the last column of Table 4-15.

Table 4-16. Original Storage Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	0.14	1	1	1	3	3	1	3	1	1
S2	7	1	7	7	7	9	9	7	9	7	7
S3	1	0.14	1	1	1	3	3	1	3	1	1
S4	1	0.14	1	1	1	3	3	1	3	1	1
S5	1	0.14	1	1	1	3	3	1	3	1	1
S6	0.33	0.11	0.33	0.33	0.33	1	1	0.33	1	0.33	0.33
S7	0.33	0.11	0.33	0.33	0.33	1	1	0.33	1	0.33	0.33
S8	1	0.14	1	1	1	3	3	1	3	1	1
S9	0.33	0.11	0.33	0.33	0.33	1	1	0.33	1	0.33	0.33
S10	1	0.14	1	1	1	3	3	1	3	1	1
S11	1	0.14	1	1	1	3	3	1	3	1	1
total	**14.99**	**2.31**	**14.99**	**14.99**	**14.99**	**33**	**33**	**14.99**	**33**	**14.99**	**14.99**

Table 4-17. Normalized Storage Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	weights
S1	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
S2	0.466978	0.4329	0.466978	0.466978	0.466978	0.272727	0.272727	0.466978	0.272727	0.466978	0.466978	0.410903
S3	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
S4	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
S5	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
S6	0.022015	0.047619	0.022015	0.022015	0.022015	0.030303	0.030303	0.022015	0.030303	0.0220147	0.022015	0.026603
S7	0.022015	0.047619	0.022015	0.022015	0.022015	0.030303	0.030303	0.022015	0.030303	0.0220147	0.022015	0.026603
S8	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
S9	0.022015	0.047619	0.022015	0.022015	0.022015	0.030303	0.030303	0.022015	0.030303	0.0220147	0.022015	0.026603
S10	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
S11	0.066711	0.060606	0.066711	0.066711	0.066711	0.090909	0.090909	0.066711	0.090909	0.0667111	0.066711	0.072756
total	1	1	1	1	1	1	1	1	1	1	1	1

By following the same previous steps of calculations, the normalized matrix of storage criterion is given in table 4-17. This matrix contains weight of each supplier considering the storage criterion. The second supplier had the maximum weight while three other suppliers have got the minimum weight, which are supplier6, supplier7, and supplier9.

Table 4-18. Original Warranty Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	1	1	1	5	1	5	1	1	5	5
S2	1	1	1	1	5	1	5	1	1	5	5
S3	1	1	1	1	5	1	5	1	1	5	5
S4	1	1	1	1	5	1	5	1	1	5	5
S5	0.2	0.2	0.2	0.2	1	0.2	1	0.2	0.2	1	1
S6	1	1	1	1	5	1	5	1	1	5	5
S7	0.2	0.2	0.2	0.2	1	0.2	1	0.2	0.2	1	1
S8	1	1	1	1	5	1	5	1	1	5	5
S9	1	1	1	1	5	1	5	1	1	5	5
S10	0.2	0.2	0.2	0.2	1	0.2	1	0.2	0.2	1	1
S11	0.2	0.2	0.2	0.2	1	0.2	1	0.2	0.2	1	1
total	7.8	7.8	7.8	7.8	39	7.8	39	7.8	7.8	39	39

Table 4-19. Normalized Warranty Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S2	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S3	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S4	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S5	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641
S6	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S7	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641
S8	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S9	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.128205	0.1282051	0.128205	0.128205
S10	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641
S11	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641	0.025641
total	1	1	1	1	1	1	1	1	1	1	1	1

Normalized matrix of warranty criterion is created based on the pairwise comparisons of suppliers that shown in the original matrix. The preferences of suppliers are also illustrated in the original matrix. Based upon the results in Table 4-19, it has clearly seen that each supplier either scored 0.128205 or 0.025641 as weight , because all suppliers have provided just two warranty options and all warranties that have been provided by supplier either 36 or 24 months.

Table 4-20. Original Delivery Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	2	0.33	0.33	1	0.33	1	0.33	1	0.2	1
S2	0.5	1	0.2	0.2	0.5	0.2	0.5	0.2	0.5	0.14	0.5
S3	3	5	1	1	3	1	3	1	3	0.5	3
S4	3	5	1	1	3	1	3	1	3	0.5	3
S5	1	2	0.33	0.33	1	0.33	1	0.33	1	0.2	1
S6	3	5	1	1	3	1	3	1	3	0.5	3
S7	1	2	3	3	1	0.33	1	0.33	1	0.14	1
S8	3	5	1	1	3	1	3	1	3	0.5	3
S9	1	2	0.33	0.33	1	0.33	1	0.33	1	0.2	1
S10	5	7	2	2	5	2	7	2	5	1	5
S11	1	2	0.33	0.33	1	0.33	1	0.33	1	0.2	1
total	22.5	38	10.52	10.52	22.5	7.85	24.5	7.85	22.5	4.08	22.5

Table 4-21. Normalized Delivery Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.044444	0.052632	0.031369	0.031369	0.044444	0.042038	0.040816	0.042038	0.044444	0.0490196	0.044444	0.04246
S2	0.022222	0.026316	0.019011	0.019011	0.022222	0.025478	0.020408	0.025478	0.022222	0.0343137	0.022222	0.023537
S3	0.133333	0.131579	0.095057	0.095057	0.133333	0.127389	0.122449	0.127389	0.133333	0.122549	0.133333	0.123164
S4	0.133333	0.131579	0.095057	0.095057	0.133333	0.127389	0.122449	0.127389	0.133333	0.122549	0.133333	0.123164
S5	0.044444	0.052632	0.031369	0.031369	0.044444	0.042038	0.040816	0.042038	0.044444	0.0490196	0.044444	0.04246
S6	0.133333	0.131579	0.095057	0.095057	0.133333	0.127389	0.122449	0.127389	0.133333	0.122549	0.133333	0.123164
S7	0.044444	0.052632	0.285171	0.285171	0.044444	0.042038	0.040816	0.042038	0.044444	0.0343137	0.044444	0.087269
S8	0.133333	0.131579	0.095057	0.095057	0.133333	0.127389	0.122449	0.127389	0.133333	0.122549	0.133333	0.123164
S9	0.044444	0.052632	0.031369	0.031369	0.044444	0.042038	0.040816	0.042038	0.044444	0.0490196	0.044444	0.04246
S10	0.222222	0.184211	0.190114	0.190114	0.222222	0.254777	0.285714	0.254777	0.222222	0.245098	0.222222	0.226699
S11	0.044444	0.052632	0.031369	0.031369	0.044444	0.042038	0.040816	0.042038	0.044444	0.0490196	0.044444	0.04246
total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Delivery time is one of the important criteria that always involves in most of the purchasing processes if not all of them. Based on the data from suppliers the period of delivery time is provided in the scale of minimum three weeks to seven weeks maximum. As well as the other decision criteria, weights of suppliers in terms of delivery time criterion were calculated as it shown in last column of Table4-21.

Table 4-22. Original Price Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1	1	7	3	3	7	5	3	3	5	3	5
S2	0.14	1	0.2	0.2	1	0.33	0.2	0.2	0.33	0.2	0.33
S3	0.33	5	1	1	5	3	1	1	3	1	3
S4	0.33	5	1	1	5	3	1	1	3	1	3
S5	0.14	1	0.2	0.2	1	0.33	0.2	0.2	0.33	0.2	0.33
S6	0.2	3	0.33	0.33	3	1	0.33	0.33	1	0.33	1
S7	0.33	5	1	1	5	3	1	1	3	1	3
S8	0.33	5	1	1	5	3	1	1	3	1	3
S9	0.2	3	0.33	0.33	3	1	0.33	0.33	1	0.33	1
S10	0.33	5	1	1	5	3	1	1	3	1	3
S11	0.2	3	0.33	0.33	3	1	0.33	0.33	1	0.33	1
total	**3.53**	**43**	**9.39**	**9.39**	**43**	**23.66**	**9.39**	**9.39**	**23.66**	**9.39**	**23.66**

Table 4-23. Normalized Price Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	Weights
S1	0.283286	0.162791	0.319489	0.319489	0.162791	0.211327	0.319489	0.319489	0.211327	0.3194888	0.211327	0.258208
S2	0.03966	0.023256	0.021299	0.021299	0.023256	0.013948	0.021299	0.021299	0.013948	0.0212993	0.013948	0.021319
S3	0.093484	0.116279	0.106496	0.106496	0.116279	0.126796	0.106496	0.106496	0.126796	0.1064963	0.126796	0.112628
S4	0.093484	0.116279	0.106496	0.106496	0.116279	0.126796	0.106496	0.106496	0.126796	0.1064963	0.126796	0.112628
S5	0.03966	0.023256	0.021299	0.021299	0.023256	0.013948	0.021299	0.021299	0.013948	0.0212993	0.013948	0.021319
S6	0.056657	0.069767	0.035144	0.035144	0.069767	0.042265	0.035144	0.035144	0.042265	0.0351438	0.042265	0.045337
S7	0.093484	0.116279	0.106496	0.106496	0.116279	0.126796	0.106496	0.106496	0.126796	0.1064963	0.126796	0.112628
S8	0.093484	0.116279	0.106496	0.106496	0.116279	0.126796	0.106496	0.106496	0.126796	0.1064963	0.126796	0.112628
S9	0.056657	0.069767	0.035144	0.035144	0.069767	0.042265	0.035144	0.035144	0.042265	0.0351438	0.042265	0.045337
S10	0.093484	0.116279	0.106496	0.106496	0.116279	0.126796	0.106496	0.106496	0.126796	0.1064963	0.126796	0.112628
S11	0.056657	0.069767	0.035144	0.035144	0.069767	0.042265	0.035144	0.035144	0.042265	0.0351438	0.042265	0.045337
total	1	1	1	1	1	1	1	1	1	1	1	1

To obtain the final results, the weight of the specific supplier with respect to a certain criterion should be multiplied by the weight of the criterion itself among the other criteria. Accordingly, the final score for each supplier across each criterion is given in Table 4-25. These scores are calculated by multiplying the weight of each criterion from Table 4-7 with the weight of each supplier from normalized matrix of that criterion. Table 4-24 shows the weight of each single criterion and weights of every supplier across each criterion.

Table 4-24.Weights of Criteria and Suppliers

		Weights of suppliers in respect to each criterion										
Attributes	Weights of Attributes	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Processor	0.243034	0.142812	0.252625	0.142812	0.064945	0.037935	0.064945	0.198869	0.037935	0.037935	0.021861	0.021861
Memory	0.243034	0.044619	0.223097	0.044619	0.044619	0.165681	0.044619	0.223097	0.044619	0.0525009	0.052501	0.0525009
Power	0.033738	0.121578	0.040315	0.121578	0.121578	0.040315	0.040315	0.121578	0.121578	0.10927	0.121578	0.040315
Cache memory	0.057838	0.167751	0.031472	0.167751	0.167751	0.031472	0.058645	0.058645	0.031472	0.058645	0.058645	0.167751
Int-storage	0.111847	0.072756	0.410903	0.072756	0.072756	0.072756	0.026603	0.026603	0.072756	0.026603	0.072756	0.072756
Warranty	0.033738	0.128205	0.128205	0.128205	0.128205	0.025641	0.128205	0.025641	0.128205	0.128205	0.025641	0.025641
Delivery	0.033738	0.04246	0.023537	0.123164	0.123164	0.04246	0.123164	0.087269	0.123164	0.04246	0.226699	0.04246
Price	0.243034	0.258208	0.021319	0.112628	0.112628	0.021319	0.045337	0.112628	0.112628	0.045337	0.112628	0.045337

As example supplier1 has a weight of 0.142812 in the normalized matrix with respect to processor criterion and the processor has a criterion weight of 0.243034 in the normalized criteria matrix; the product of those two weights in Table 4-24 is 0.0347082 which calculated in the first cell in Table 4-25. The same way of calculation has been followed to obtain the rest of the values as it shown in Table 4-25.

Table 4-25.The Final Decision Matrix

	Processor	Memory	Power	Cache	Storage	Warranty	Delivery	Price	Scores
S1	0.0347082	0.0108441	0.004102	0.009702	0.008137	0.004325	0.001432	0.062754	0.017
S2	0.0613966	0.0542203	0.00136	0.00182	0.045958	0.004325	0.000794	0.005181	**0.022**
S3	0.0347082	0.0108441	0.004102	0.009702	0.008137	0.004325	0.004155	0.027373	0.013
S4	0.0157838	0.0108441	0.004102	0.009702	0.008137	0.004325	0.004155	0.027373	0.011
S5	0.0092194	0.0402662	0.00136	0.00182	0.008137	0.000865	0.001432	0.005181	0.009
S6	0.0157838	0.0108441	0.00136	0.003392	0.002975	0.004325	0.004155	0.011018	0.007
S7	0.0483319	0.0542203	0.004102	0.003392	0.002975	0.000865	0.002944	0.027373	0.018
S8	0.0092194	0.0108441	0.004102	0.00182	0.008137	0.004325	0.004155	0.027373	0.009
S9	0.0092194	0.0133691	0.003686	0.003392	0.002975	0.004325	0.001432	0.011018	0.006
S10	0.0053129	0.0133691	0.004102	0.003392	0.008137	0.000865	0.007648	0.027373	0.009
S11	0.0053129	0.0133691	0.00136	0.009702	0.008137	0.000865	0.001432	0.011018	0.006

Table 4-25 depicts the final results and it does illustrate the score for each supplier, it provides the final result and scores of suppliers. Finally, Score of each supplier computed by taking the average of that certain row. The highest score indicates to the best supplier. According to the previous results, the higher score belongs to supplier 2, therefore supplier 2 is judged to be the best choice overall.

AHP is very useful approach as it offers a methodology capable of evaluating among conflicting selection criteria that might be involved. Hence there is no complex calculation included; the simplicity is also considered one of the advantages of AHP. Moreover AHP has the capability to be used in selection process that contains a large number of assortment criteria. Besides, AHP is a sufficient tool for handling tangible factors as well as intangible. From other viewpoint, constructing of the problem hierarchy forces decision maker being aware of significance and relevance of criteria which can be consider as drawback in this model.

4.6 Linear Weightage Vs AHP approach

Generally, the simplicity is absolutely a very beneficial factor that affects the performance of any model. During this research the simple way of calculation and the ease of conducting the mathematical operations can be clearly noticed when applying both linear weightage and AHP approaches to supplier selection process.

Both models can simply include a tremendous amount of criteria as well as massive number of different decision alternatives without reducing models' sufficiency's or affecting any outcomes decision. Besides, final results of both models are usually obtained in a form of scores, thus there is no doubt when the highest score indicates best supplier overall.

Linear weightage model's limitation is apparent through the direct assignment of weight for each decision criterion. These weights could be assigned by decision maker based on his/her experience they may lead to variation in the final decision. In contrast, AHP approach has much better method than linear weightage model, as it uses the 1-9 point scale as measurement scale for determining the preferences of criteria first and then generates all weights of decision criteria.

AHP involves huge number of matrices to be computed when the process contains large number of criteria or decision alternatives. Each criterion has two matrices to be considered start with the preference matrix beside the normalized one. The more criteria and suppliers the more time, effort and vast amount of matrices required.

4.7 Proposed Hybrid Model Disciplines

The new hybrid model intends to provide appropriate model that can handle the activity of supporting the supplier selection decision. The main idea of the hybrid model depends upon both concepts of the linear weightage model and AHP approach. Hence applying both models to supplier selection case studies in the previous chapter, there are some limitations could be observed. The proposed model intends to combine the features that exist in both model and mix of concepts. Moreover, the proposed model aims to eliminate the drawbacks that negatively affect the decision quality that harvested from both models. Figure 4-3 depicts where the proposed model takes place.

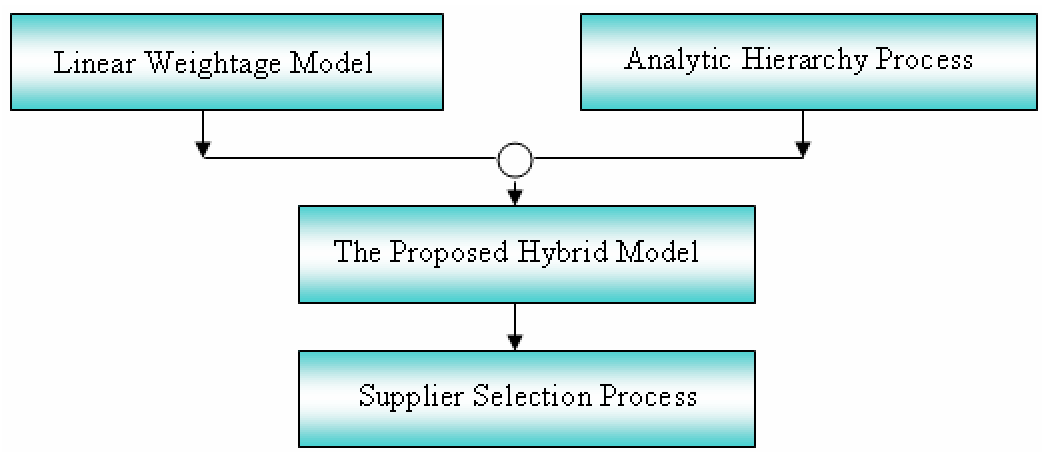


Figure 4-3. The New Hybrid Model

Linear weightage model has many features that make it able to support decision making process in general. Such features can be summarized in several points as follows:

- The simplicity of this model can be clearly witnessed when applying to supplier selection process as there are no complicated calculations or complex mathematical procedures to follow.

- The model can easily include a tremendous number of criteria as well as huge number of different decision alternatives without reducing model sufficiency or affecting any results.
- The final results are usually obtained in a form of scores, therefore there is no chance for confusion when the highest score indicates best supplier overall.
- The linear weightage model is capable of considering quantitative factors as well as qualitative.

However linear weightage model is suitable for supplier selection decision; it has its limitation apparently via the assignment of weight for each decision criterion. These weights could be assigned by decision maker based on his/her experience which they may lead to variation in the final decision.

On the other hand, AHP has been described in the literature as one of the most powerful models that can support decision making activity. It also includes all the feature points which have been mentioned in weightage model. However AHP dose not involve complex calculation, there are huge number of matrices to be computed when the process contain large number of criteria or decision alternatives. Each criterion has two matrices to be considered start with the preference matrix beside the normalized one. Once the previous case study includes the eleven competitive suppliers and eight criteria, nineteen matrices are calculated in order to yield the final decision. The supplier selection process can possibly contain more than this number of suppliers and the number of criteria can probably be huge. In such a case there will definitely be tremendous number of matrices, moreover it needs more time to achieve the procedures and obtain the results. From different point of view, it may create a chance for calculation's error which affects the final decision or it can probably produce poor decision at the end. Time is one of the most dominate factors that impact supplier selection process. Thus the model which computes faster or use less series of steps is more sufficient and preferable.

4.8 Proposed Hybrid Model Discussion

Accordingly, there is an urgent need for new model that can support the supplier selection decision and offering a powerful tool which can ultimately produce satisfactory results. This research intends to achieve this objective by proposing new hybrid model. This new model concentrates on avoiding all the shortcomings mentioned above. It combines two different aspects from both AHP and linear weightage model. The new model uses the measurement scale of AHP model to determine to which degree each single criterion is preferred in comparison with others. Once the pairwise comparisons have been made, decision maker can obtain the weights of whole criteria when specify the relative preference of criteria.

The next step in the proposed model is to assign thresholds to all criteria considering “Larger is better” or “Smaller is better”. Actually, there are two different types of threshold either maximum or minimum. Generally, if the criterion can be classified into “Smaller is better” category such as delivery time and cost, then the type of threshold should be assigned to maximum. Otherwise, the criteria will be categorized under “larger is better”, thus the threshold’s type have to be minimum.

Calculate the values for each single cell in the criteria matrix depends upon specifying the thresholds of criteria first. Regarding thresholds and the real data of suppliers the decision table matrix can be created. Calculation of the whole values in the decision table matrix has to be produced by considering the two formulas, if the threshold is maximum then formula 1 should be used, otherwise formula 2 is the one has to be considered.

$$V_{\max} = \frac{Max - VendorValue}{Max - Min} \qquad (1)$$

$$V_{\min} = \frac{VendorValue - Min}{Max - Min} \qquad (2)$$

When the whole cells that represent each supplier across only criteria will be filled with a certain value in the decision table matrix, then each column will multiply by the column of criteria weights and obtain the new values of these cells.

Now each column represents one of the competitive suppliers, the last step in the proposed model is to compute the sum of each column to get the final scores of all suppliers. The highest score indicates to the best supplier and that supplier will be recommended as the most appropriate supplier among the competitive suppliers. However, the decision making should take the ultimate decision himself/herself he/she will be responsible for the outcomes.

4.9 Case Study

For this proposed model the same case study which has been applied for AHP and linear weightage model is used, so there will be ability to compare between the proposed model and the other two models in terms of ease of use, quality of decision, reliability and satisfactory of the results, moreover its enables evaluating the final decision by examine that to which degree the result is satisfied the objectives.

The sequence of steps and procedures are obviously explained how to implement the proposed model is stated as it’s appear in Figure 4-4.

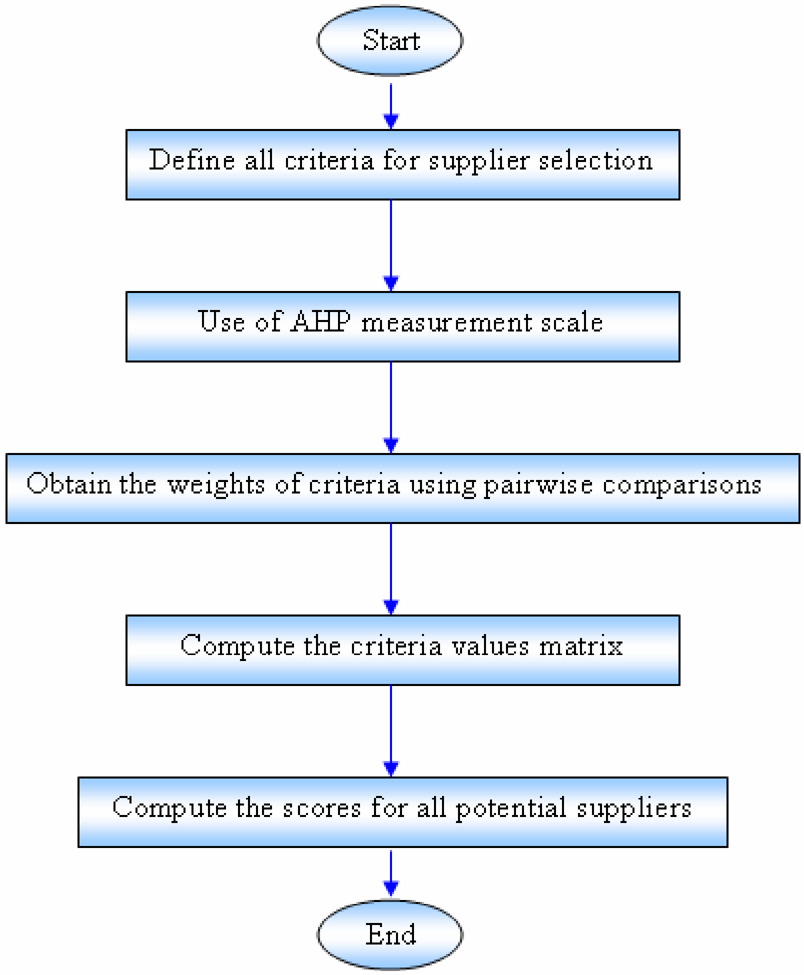


Figure 4-4.Proposed Hybrid Model Processes

Applying the proposed model to supplier selection decision implies that all the steps above have to be followed. First of all, this case study includes eight different criteria and eleven competitive suppliers as it previously illustrated in Table 4-1. The measurement scale has been used to determine the preference of criteria as it was also show in Table 4-5. Accordingly, the preference criteria matrix was obtained which compare each criterion to the others; Table 4-26 depicts the preference criteria matrix and gives a glimpse of decision maker judgment and preference of criteria in a form of pairwise comparisons.

Table 4-26. Preference Criteria Matrix

	processor	memory	power	cache	int-storage	warranty	price	delivery
processor	1	1	7	5	2	7	1	7
memory	1	1	7	5	2	7	1	7
power	0.14	0.14	1	0.5	0.33	1	0.14	1
cache	0.2	0.2	2	1	0.5	2	0.2	2
int-storage	0.5	0.5	3	2	1	3	0.5	3
warranty	0.14	0.14	1	0.5	0.33	1	0.14	1
price	1	1	7	5	2	7	1	7
delivery	0.14	0.14	1	0.5	0.33	1	0.14	1
total	4.12	4.12	29	19.5	8.49	29	4.12	29

Processor, memory and price have an equal preference of criteria that’s why the cell across each two of them is filled with ones. On other hand, memory is very strong important than power so the cell which represents memory across power in the second row and four column is filled with 7 according the AHP measure scale, and thus when compare power to memory it should be 0.14 because it’s the opposite comparison. The same concept is followed to fulfill all the pairwise comparisons.

The next step is to obtain the weight for each criterion by normalized the data in Table 4-26. Three procedures applied to preference criteria matrix and immediately the weights will be calculated.

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

Performing of the previous mathematical calculation yields normalized matrix of criteria that illustrated in Table 4-27. The averages of rows is computed in the last column indicate to the weights of criteria.

Table 4-27. Weights of Criteria

	processor	memory	power	cache	int-storage	warranty	price	delivery	**weights**
processor	0.242718	0.242718	0.241379	0.25641	0.235571	0.241379	0.242718	0.241379	0.243034
memory	0.242718	0.242718	0.241379	0.25641	0.235571	0.241379	0.242718	0.241379	0.243034
power	0.033981	0.033981	0.034483	0.025641	0.038869	0.034483	0.033981	0.034483	0.033738
cache	0.048544	0.048544	0.068966	0.051282	0.058893	0.068966	0.048544	0.068966	0.057838
int-storage	0.121359	0.121359	0.103448	0.102564	0.117786	0.103448	0.121359	0.103448	0.111847
warranty	0.033981	0.033981	0.034483	0.025641	0.038869	0.034483	0.033981	0.034483	0.033738
price	0.242718	0.242718	0.241379	0.25641	0.235571	0.241379	0.242718	0.241379	0.243034
delivery	0.033981	0.033981	0.034483	0.025641	0.038869	0.034483	0.033981	0.034483	0.033738
total	1	1	1	1	1	1	1	1	1

From the Table 4-27, the weight for the processor criterion is 0.243034 as well as memory criteria while the weight of internal storage criterion is 0.111847 and so on. The next step in the proposed model is to compute the criteria value matrix using the previous formulas relying upon the thresholds which have been already determine earlier. Once threshold of a certain criterion is maximum type, thus formula 1 should be used to compute the value of that criterion in respect to all suppliers.

$$V_{\max} = \frac{Max - Vendor}{Max - Min} \qquad (1)$$

In contrary, power, price, and delivery time criterion threshold type is maximum ,therefore the value of these criteria shall be calculated using formula 1.With respect to power consumption criterion, and threshold type all the values of suppliers(S1, S2, …, S11) can be calculated as follows.

Power :

$$S1 = \frac{1300-835}{1300-835} = 1.00 \qquad S2 = \frac{1300-1300}{1300-835} = 0.00 \qquad S11 = \frac{1300-1300}{1300-835} = 0.00$$

The same way of calculation is considered for the rest of the criteria that have the maximum type as a threshold which are price, and delivery time. Thus formula1 is used again to compute the values of price and delivery time respectively.

Price:

$$S1 = \frac{48200-20352}{48200-20352} = 1.00,\ S2 = \frac{48200-48200}{48200-20352} = 0.00\ \ldots\ S11 = \frac{48200-32450}{48200-20352} \approx 0.57$$

Delivery:

$$S1 = \frac{7-4}{7-3} = 0.75 \quad , \quad S2 = \frac{7-3}{7-3} = 1.00 \quad \ldots \quad S11 = \frac{7-4}{7-3} = 0.75$$

When it comes to the criteria that have the minimum type of threshold, formula 2 is considered to obtain the values of the suppliers in accordance with the criteria. All the rest of the criteria are belong to the minimum threshold type, therefore processor, memory, cache memory, internal storage, and warranty attributes values are all conducted using formula 2 as follows and all the values are fulfilled in Table 4-28.

Processor:

$$S1 = \frac{1.86-1.57}{3.66-1.57} \approx 0.14 \qquad S2 = \frac{3.66-1.57}{3.66-1.57} \approx 1.00 \qquad S11 = \frac{1.58-1.57}{3.66-1.57} \approx 0.00$$

Memory:

$$S1 = \frac{1024-1024}{2000-1024} = 0.00 \quad , \quad S2 = \frac{2000-1024}{2000-1024} = 1.00 \quad \ldots \quad S1 = \frac{1024-1024}{2000-1024} = 0.00$$

Cache memory:

$$S1 = \frac{4-1}{4-1} = 1.00 \quad , \quad S2 = \frac{1-1}{4-1} = 0.00 \quad \ldots \quad S11 = \frac{4-1}{4-1} = 1.00$$

Internal storage

$$S1 = \frac{146.8 - 73}{440 - 73} \approx 0.20 \quad , \quad S2 = \frac{440 - 73}{440 - 73} = 1.00 \quad \ldots \quad S11 = \frac{146 - 73}{440 - 73} \approx 0.20$$

Warranty:

$$S1 = \frac{36 - 24}{36 - 24} = 1.00 \quad , \quad S2 = \frac{36 - 24}{36 - 24} = 1.00 \quad \ldots \quad S11 = \frac{24 - 24}{36 - 24} = 0.00$$

Table 4-28 .Criteria' Values Matrix

Attributes	Threshold	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Processor	Min	0.14	1.00	0.14	0.01	0.04	0.09	0.14	0.05	0.01	0.00	0.00
Memory	Min	0.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
Power supply	Max	1.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00
Cache Memory	Min	1.00	0.00	1.00	1.00	0.00	0.33	0.33	0.00	0.33	0.33	1.00
Int-storage	Min	0.20	1.00	0.00	0.20	0.00	0.00	0.00	0.20	0.20	0.20	0.20
Warranty	Min	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Price	Max	1.00	0.00	0.82	0.89	0.11	0.57	0.86	0.78	0.89	0.89	0.57
Delivery	Max	0.75	1.00	0.25	0.25	0.75	0.25	0.75	0.25	0.00	0.00	0.75

The last step in the proposed model is to compute the final score of each supplier by multiplying each column in Table 4-29 by the weights of criteria/ attributes. Then get the sum of each column and the sum represents the score of each single supplier.

Table 4-30 depicts the final scores of suppliers. The most important thing is regarding the final results, the supplier who has the highest score is suggested as the best supplier due to the proposed model.

Table 4-29. Weights and Criteria Values

Criteria	weights	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
processor	0.243034	0.14	1	0.14	0.01	0.04	0.09	0.14	0.05	0.01	0	0
memory	0.243034	0	1	0	0	1	0	1	0	0	0	0
power	0.033738	1	0	1	1	0	0	1	1	0	1	0
Cache	0.057838	1	0	1	1	0	0.33	0.33	0	0.33	0.33	1
int-storage	0.111847	0.2	1	0.2	0.2	0.2	0	0	0.2	0	0.2	0.2
warranty	0.033738	1	1	1	1	0	1	0	1	1	0	0
price	0.243034	1	0	0.82	0.89	0.11	0.57	0.86	0.78	0.61	0.89	0.57
delivery	0.033738	0.75	1	0.25	0.25	0.75	0.25	0.75	0.25	0.75	0	0.75

The above table depicts the weights of all criteria beside the criteria values, these weights have to be multiplying by each column to generate the final decision matrix.

Table 4-30.Final Decision Matrix

Criteria	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
processor	0.034025	0.243034	0.034025	0.00243	0.009721	0.021873	0.034025	0.012152	0.00243	0	0
memory	0	0.243034	0	0	0.243034	0	0.243034	0	0	0	0
power	0.033738	0	0.033738	0.033738	0	0	0.033738	0.033738	0	0.033738	0
Cache	0.057838	0	0.057838	0.057838	0	0.019087	0.019087	0	0.019087	0.019087	0.057838
int-storage	0.022369	0.111847	0.022369	0.022369	0.022369	0	0	0.022369	0	0.022369	0.022369
warranty	0.033738	0.033738	0.033738	0.033738	0	0.033738	0	0.033738	0.033738	0	0
price	0.243034	0	0.199288	0.2163	0.026734	0.138529	0.209009	0.189567	0.148251	0.2163	0.138529
delivery	0.025304	0.033738	0.008435	0.008435	0.025304	0.008435	0.025304	0.008435	0.025304	0	0.025304
Score	**0.45**	**0.67**	**0.39**	**0.37**	**0.33**	**0.22**	**0.56**	**0.3**	**0.23**	**0.29**	**0.24**

In accordance with the results generated by the proposed model, S2 has got the highest score in comparison with the rest of potential suppliers which is 0.67. As a result, the proposed model is recommended S2 to be chosen as the best supplier at all.

On the other hand, the proposed model gives the same decision when applying AHP approach. As it's all known and as it's been mentioned in the literature AHP is considered as on of the most accurate and optimal models that can support supplier selection process. Thus the proposed model is considered as a suitable tool that can assist decision maker in the activity of supplier selection.

The most important point is that the proposed model offer fewer calculations than AHP. Considering the case study, there were eleven suppliers and eight criteria, when applying AHP there were nineteen matrices calculated in order to obtain the final decision, while only four matrices need to be computed to yields the same decision using the proposed model. Therefore it is offering easy and less mathematical operations and that makes managers/decision makers more interested.

Besides, the proposed model saves time because there are only a few computations to be done. Also it saves an effort regarding the simplicity, and that will strongly accelerate the supplier selection decision as well as improving the whole business processes within organizations in turn.

Other advantage of the proposed model is avoiding the limitation in the linear weightage model by assigning the weights of criteria directly by decision maker. The proposed model uses the AHP pairwise comparisons and the measure scale to generate the weights for the criteria which is much better and grantee more fairly preference of criteria. Thus the proposed model overcomes the absolute depending upon human judgment as in linear weightage model.

In short, the proposed model can be considered as a powerful model for supplier selection problem. It fully integrates advantages of both linear weightage model and AHP approach in addition to maintaining the shortcomings of them.

4.10 Model Assessment

The proposed model is fully support the decision making activity of supplier selection problem offering simple model, easy way of calculation and high reliability. The assessment of the proposed model, what-if analysis is used as a common and beneficial technique that helps pointing out its reliability and effectiveness. “What if analysis” allows managers/decision makers to change a decision variable and then immediately get a new result for an outcome variable. Generally, decision makers can use “what if analysis” to evaluate the model driven DSS and how variations of the input variables of the model affects the output results such as what profits can company expect ,if product price has been decreased.

Referring to the previous case study what-if analysis has been applied as follows. If the first supplier has an interest to change in the first two criteria by changing the processor criterion into new one with 3.66 GHz speed and the second criteria which is represents memory into 2000MB the output of the model will be totally different as it shown in Table 4-31.

Table 4-31. What-if Analysis Results

Criteria	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
processor	0.243034	0.243034	0.034025	0.00243	0.009721	0.021873	0.034025	0.012152	0.00243	0	0
memory	0.243034	0.243034	0	0	0.243034	0	0.243034	0	0	0	0
power	0.033738	0	0.033738	0.033738	0	0	0.033738	0.033738	0	0.033738	0
Cache	0.057838	0	0.057838	0.057838	0	0.019087	0.019087	0	0.019087	0.019087	0.057838
int-storage	0.022369	0.111847	0.022369	0.022369	0.022369	0	0	0.022369	0	0.022369	0.022369
warranty	0.033738	0.033738	0.033738	0.033738	0	0.033738	0	0.033738	0.033738	0	0
price	0.243034	0	0.199288	0.2163	0.026734	0.138529	0.209009	0.189567	0.148251	0.2163	0.138529
delivery	0.025304	0.033738	0.008435	0.008435	0.025304	0.008435	0.025304	0.008435	0.025304	0	0.025304
Score	**0.90**	**0.67**	**0.39**	**0.37**	**0.33**	**0.22**	**0.56**	**0.3**	**0.23**	**0.29**	**0.24**

Accordingly, S1 will get the highest score at all and that will be equal to 0.90. In such a case the selected supplier will definitely be S1 instead. Obviously, the proposed model shows high sensitivity of any changing in decision variables which guarantee high decisions' quality and accurate outcomes.

4.11 Summary

Two various models have been explained in this chapter started with linear weightage model discussing the concepts, the steps, and the way of calculations. Moreover a real case study of supplier selection process was provided and all its results after applying linear weightage model were shown in order to make the final decision. Consequently AHP was also discussed in detailed beginning with the problem hierarchy till the final decision. The same case study has been used to employ AHP approach and the results were obtained as well. A new hybrid model was proposed in this chapter and a discussion of its main principles was declared. This chapter was also provided a case study that explained the consequence of procedures and mathematical calculations which performed by the proposed model. Moreover, this chapter offered comparisons between the proposed model and AHP approach and linear weightage model from various viewpoints. In addition, "what if analysis" technique was used to evaluate the reliability and efficiency of the proposed model. In this research also supplier selection software is developed using the new hybrid model. The software will be explained through the next chapter.

CHAPTER FIVE: DEVELOPMENT OF SUPPLIER SELECTION SOFTWARE

5.1 Introduction

This chapter explains development of the proposed system for supplier selection decisions. It also discusses the designing of the system in matter of the software that has been used. The chapter shows the data base type and what kind of software is used to build the database and how the system components are related to each other. In addition, chapter answers all the questions about how the system communicates with the user and depicts the user interface of the proposed system.

5.2 The Proposed Supplier Selection Software

The proposed model can be set as a core of DSS software for supplier selection process system, and it will play a vital rule as MBMS among the major three components which was discussed previously in chapter one.

The database of the proposed system is a relational database which contains various tables with relationships among them. It stores all the required data and information to be considered as inputs to the model base component. It does provide the system with all the needed data in order to obtain the final decisions using the new hybrid model.

The new hybrid model fulfills the model base component in the system and this part is connected to the database component, so the model can easily get the inputs from the database. The model base is connected to the third part which is user interface as well. Graphical user interface shows the output of the model and reflects the final decision to the user (manager).

Visual basic.Net 2005 software has been used to develop the proposed supplier selection system. In addition, Microsoft Access 2003 has been used to build the relation database for the proposed system.

Basically the inputs for this model can be identified in three major groups. Firstly, all suppliers information such as supplier company name and address. Secondly, the items details that provided by suppliers. Finally the whole criteria that managers/ decision makers desire to determine for selecting the best supplier.

After performing the mathematical calculations and achieving all the pairwise comparisons of the proposed model the scores of supplier will be calculated. Considering these scores the system can give a report that ranks the suppliers starting with the supplier who has the highest score until the lowest supplier score.

Considering the case study mentioned earlier, the next section gives a glimpse of the input screens of the suggested system as well as the system output.

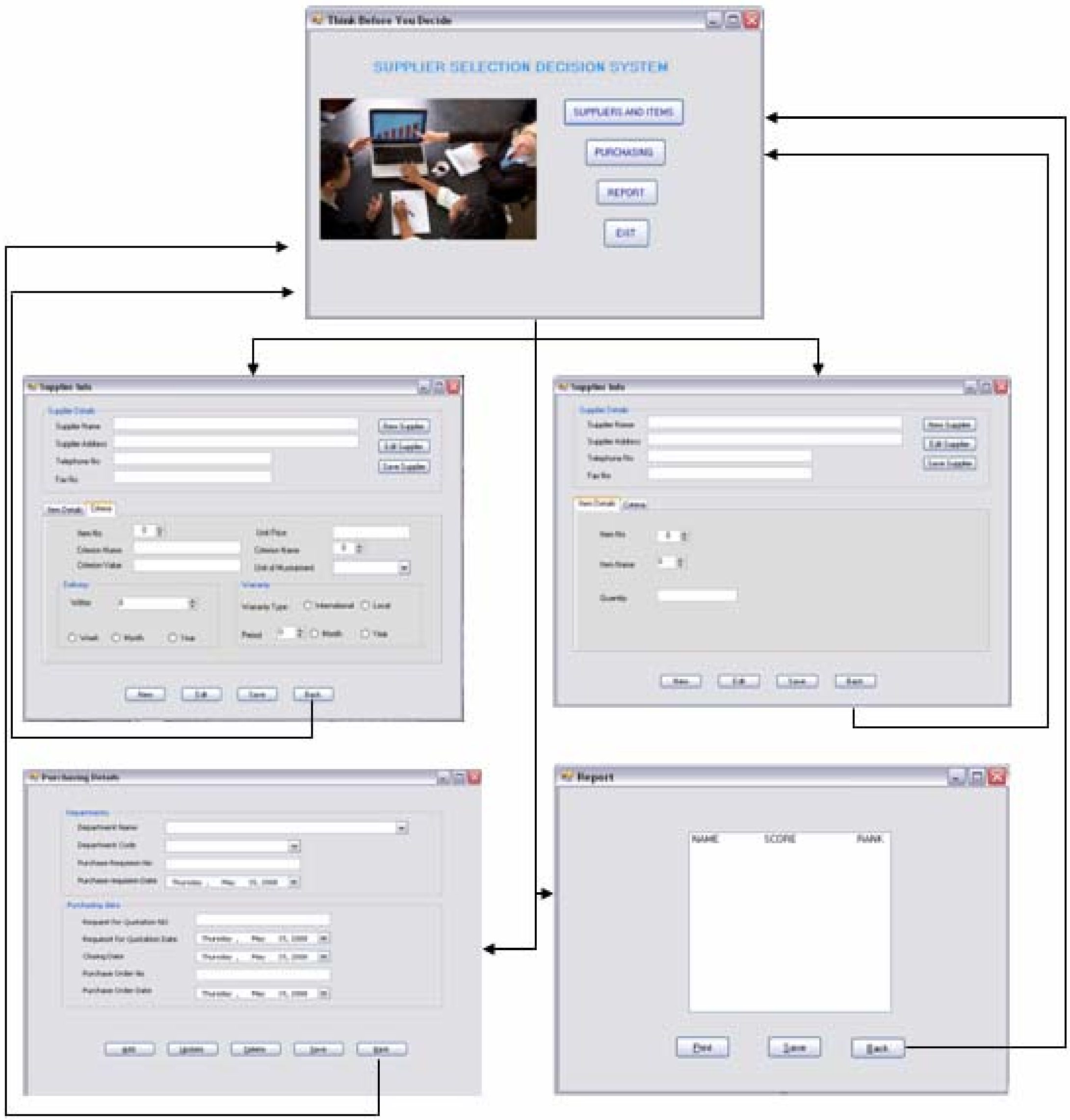


Figure 5-1. Supplier Selection System Using the Proposed Hybrid Model

From the main screen manager/decision maker has four different options available. The first, storing the basic information of suppliers and items as well and that should be by clicking the supplier info button in the main screen. The second option is storing general data about that purchasing process and the third option is getting a report in form of ranking list of supplier and that shows the out put of the proposed model the final option is closing the system using the exit button. Figure5-2 depicts the main screen of the system.

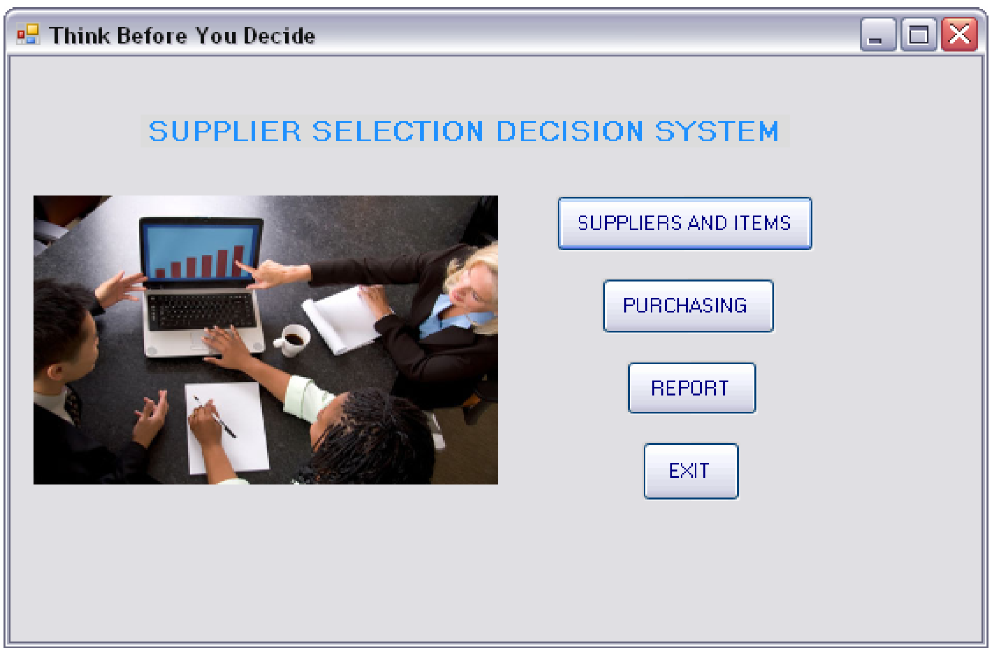


Figure 5-2. The Main Screen

When suppliers and items button has been pressed the second screen will immediately appear which is contains fields for entering the supplier data. Moreover there are two tabs one named item details ,in this tab all the details and data that needed to be store in the system about the purchased items was considered such as item name, item number, and quantity of the item, the manager can enter more items or manipulate the data using the buttons new, edit and save.

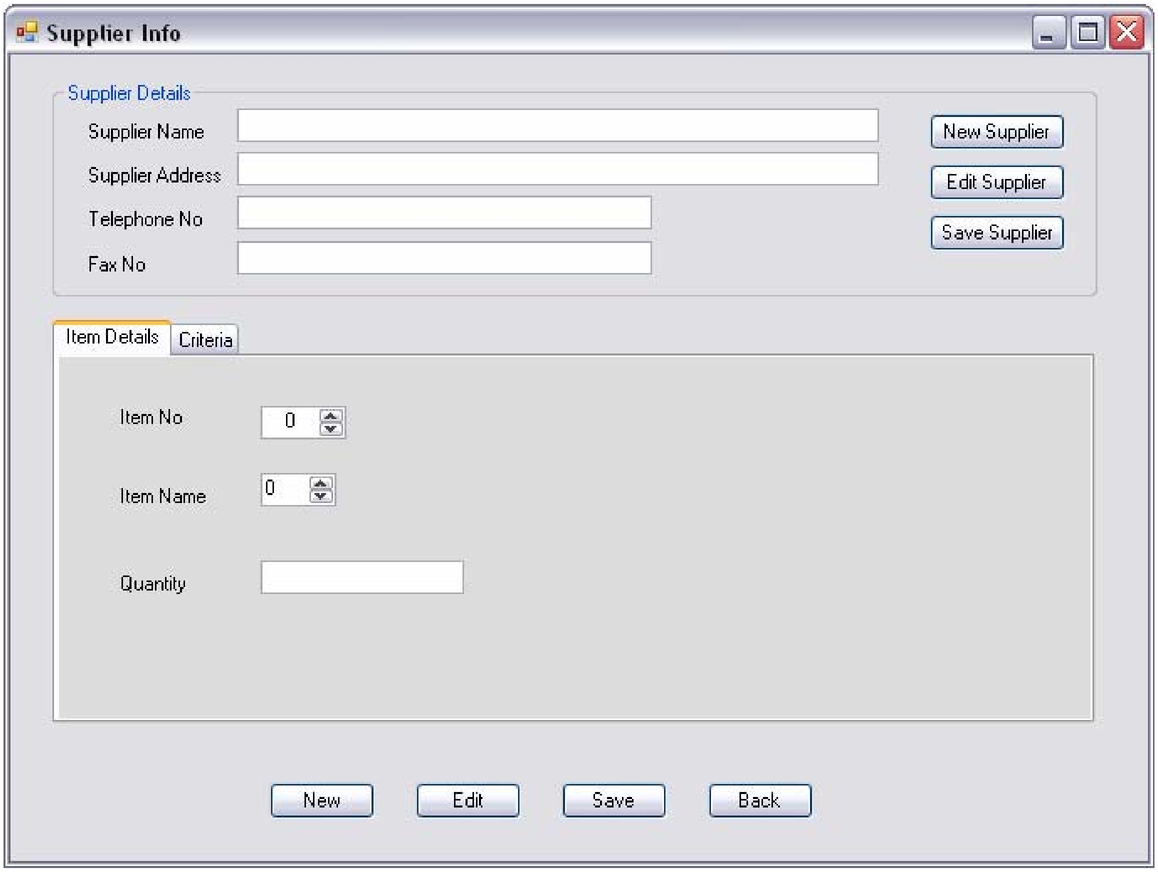


Figure 5-3. Supplier Information -1

The second tab in supplier information screen is designed to get other important data which is called criteria. After storing all the items data, the most important step is to determine the criteria of each item such as criterion name, criterion number, unit price, warranty, and delivery time. Each single item can include many criteria. Each time new supplier is added there will be item details and criteria should be stored under that supplier. Figure5-4 explains criteria tab in the same supplier information screen.

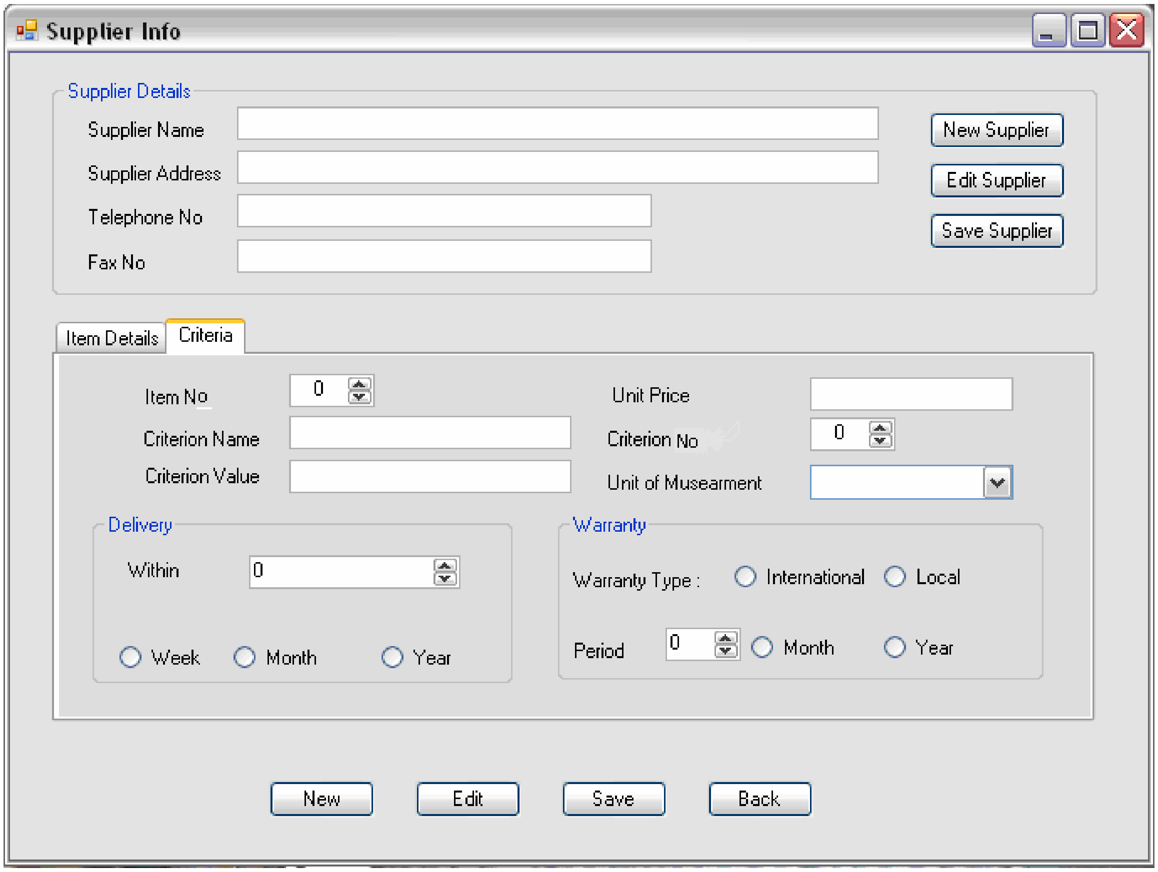


Figure 5-4. Supplier Information -2

The proposed system can include other type of information that doesn't involve in the supplier selection decision; however it does provide valuable information for the records of the buyer company. That kind of information such as the name of the department that requested the purchased items and other important dates takes place in purchasing information screen which can be accessed by hitting purchasing details button in the main screen. Figure5-5 shows purchasing details screen

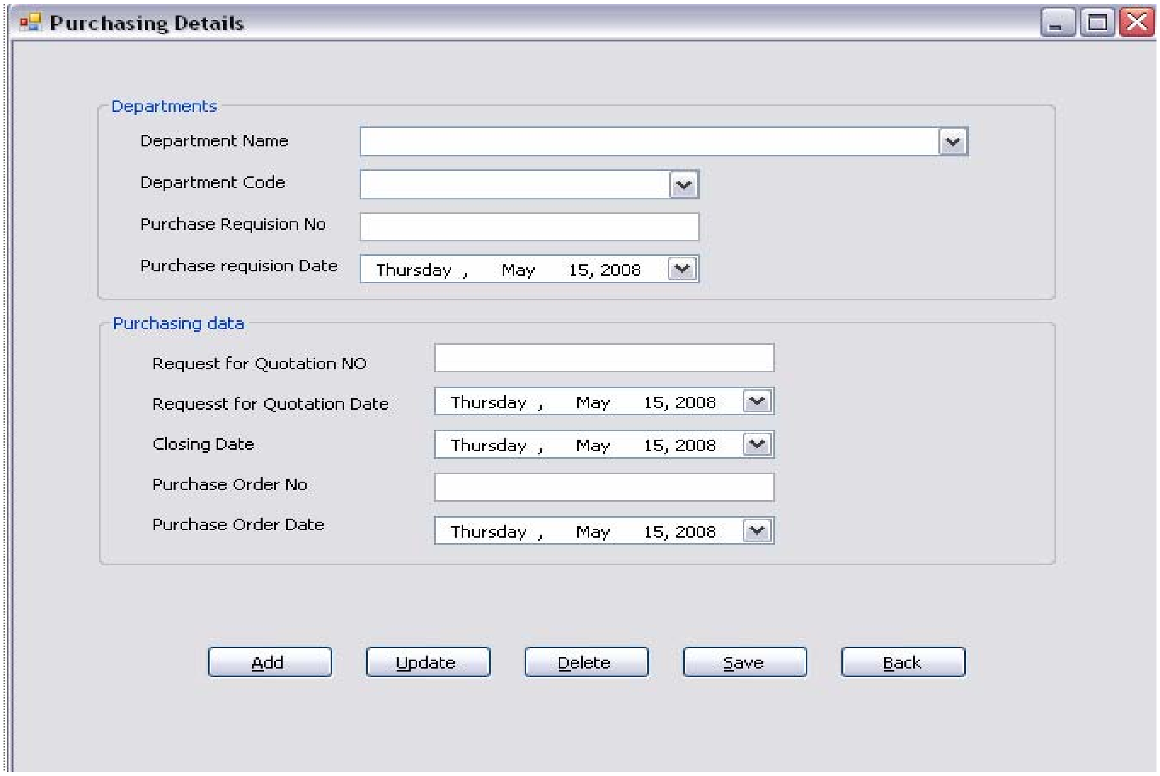
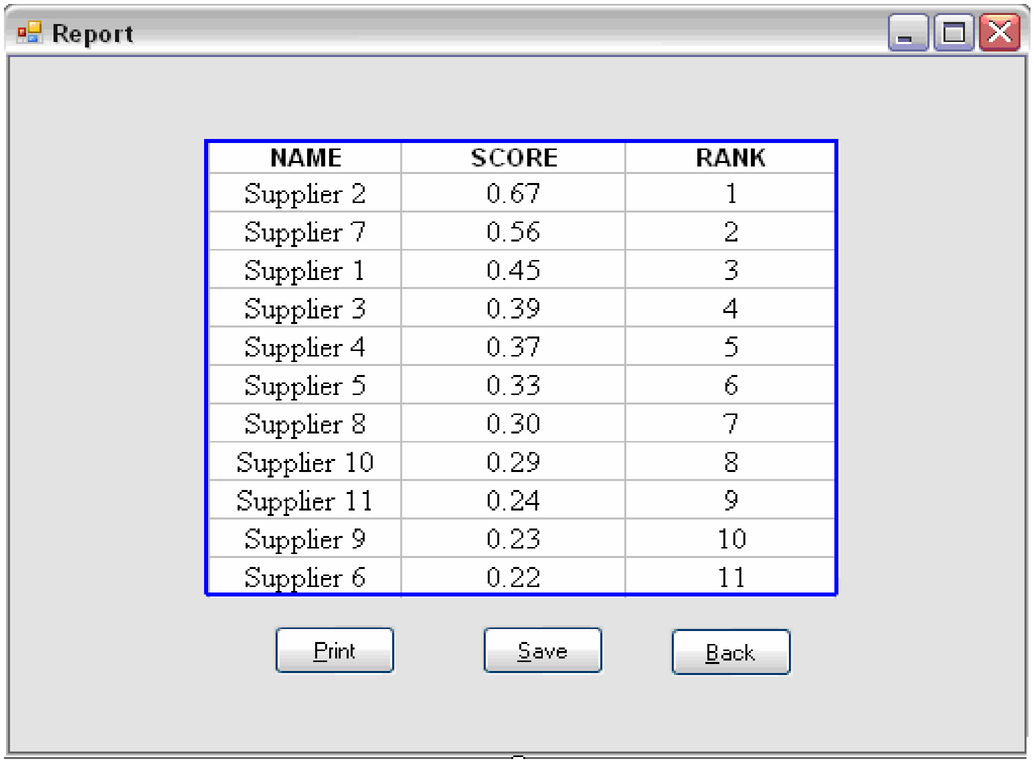


Figure 5-5. Purchasing Details

Finally report screen shows the final decision according to the mathematical calculations and procedures that followed by the proposed model. The final decision of the model can be in a form of ranking list of suppliers that shows the name of suppliers, the scores of suppliers, in addition to the rank of them. The first supplier on the list who has the rank 1 should have the highest score and usually the highest score indicates the best supplier regarding the proposed model results. Figure5-6 depicts the system output screen.



NAME	SCORE	RANK
Supplier 2	0.67	1
Supplier 7	0.56	2
Supplier 1	0.45	3
Supplier 3	0.39	4
Supplier 4	0.37	5
Supplier 5	0.33	6
Supplier 8	0.30	7
Supplier 10	0.29	8
Supplier 11	0.24	9
Supplier 9	0.23	10
Supplier 6	0.22	11

Figure 5-6. System Report

5.3 Summary

The proposed DSS software using the proposed model was explained. All the components of the system were discussed. Moreover, the tools were used to develop the proposed system were explained. In addition, the graphical user interface and its logical interaction with the user were also declared. Finally the chapter showed how the proposed system is capable to display the final decisions in form of ranking list which represents an easy way for decision maker to select the best supplier.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

This chapter mainly presents and discusses the major concepts and progresses that this research intends to achieve. Moreover, some recommendations that might be done as expected works for more improvements and better results are explained.

Since supplier selection decision is one of the most complicated problems as its involving multi criteria, the models that used to support decision maker should be capable of considering both quantitative criteria as well as qualitative criteria. These models should also consider all the factors which complicate the activity of supplier selection decisions.

This research mainly introduces a new hybrid model to be used in supplier selection decision. The main purpose of introducing this model is to evolve the performance of decision making process regarding supplier selection process and provide the ability for making better and satisfactory decisions. The proposed model takes into account both strengths and limitations that exist in most of the current models. Thus, it definitely represents a reliable model that can also fulfill the model base functions in DSS frameworks for supplier selection. The new hybrid model was applied using a real life case study which represents one of the supplier selection processes in UTP.

Once any new model should be validated, the new hybrid model has been validated using one of the validation techniques which is "what-if analysis" technique. "What-if" analysis was used to assess the model and to point out how sensitive is the proposed model. It has been considered as beneficial technique for such purposes. It also can show how sensitive the proposed model towards any small changes in the input variables. Using this technique enables determining that to which degree the proposed model able to produce satisfactory output results when any changing in the input variable happened. Base on the study presented in chapter four, the new hybrid model has shown high sensitivity and reliability which makes it a suitable solution for the supplier selection problem.

In addition, DSS software has been developed for supplier selection decisions. VB.net 2005 is used for designing the system and Microsoft Access 2003 as well. The new hybrid model has been considered as the core of the system. It successfully fulfilled the model base component which represents the main component of any DSS. The developed system can show the final decision in form of ranking list of all potential suppliers based upon the scores obtained applying the proposed model. Finally, decision maker will be able to make the right decision based on the report of the developed system without any confusion.

6.1 Recommendations

This research has several future directions that might be followed, in the following points a few future directions are addressed:

- The proposed model may be employed to other decision making process beside supplier selection process.

- Implement the proposed model to large case studies of supplier selection decision and notice the quality of the results and compare it with decisions of experts and managers.

- Apply this model to a complete DSS for supplier selection in real business world.

- The proposed model may be extended to consider multi source supplier in case of selecting more than one supplier.

PUBLICATIONS

Arif Abdelwhab Ali, and P. D. D. Dominic, “A software design for purchase decision process using decision support system framework”, *National postgraduate conference on engineering, science and technology*, March 2008.

Arif Abdelwhab Ali, P. D. D. Dominic, and Oi Mean Foong, “A case study of linear weightage model for supplier selection process”, *IEEE*, *International symposium on information technology ITSIM’08*, August 2008, Vol.3, pp.1738-1741.

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