DEVELOPMENT OF MULTI-CRITERIA DECISION ANALYSIS MODELS FOR BIDDING AND CONTRACTOR SELECTION

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Abstract

Estimating and bidding a job is one of those essential processes at the heart of a contractor's business. Risk and uncertainty are major considerations in bidding decisions for construction projects. Numerous factors need to be taken into account when making bidding decisions which make them multi-criteria decisions.

The present study focuses on developing multi-criteria decision making models to assist in bidding decisions. The Analytical Hierarchy Process (AHP), which is a multi-criteria decision making tool, is used to quantify risk encountered in bidding decisions. The AHP has been employed to model both the bid/no bid and mark-up decisions. The data required for this study was collected from thirty firms operating in Gaza Strip by way of a written structured questionnaire. The data was analysed using the Criterium Decision Plus Software based on the AHP. Ten factors were selected to affect bid/no bid decisions while eleven factors were chosen to influence mark-up decision. Results from the questionnaire survey supported previous studies that profit is not the most important factor in making bid/no bid and mark-up decisions. The results also indicate that the most important factors when making the bid/no bid decision are: the 'need for work' followed by the 'company strength in industry' and 'payment methods'. For the mark-up decision, the 'need for work', 'owner/client and consultant identity' and 'project size' are the most important factors. A real life case study was used to demonstrate the application of the two models. Twelve meetings were conducted with a contractor working in Gaza Strip construction industry in order to gather the required data for the validation. The case study consisted of three different projects, road works, electromechanical and building projects, and the contractor had to make a decision on which projects to bid for and then which of them will result in a higher mark-up. The validity of the two models was confirmed by applying a two-stage Linear Programming (LP) approach to the data obtained from the case study. The results from the LP approach agreed with the outcome from the

AHP. The developed AHP models can be easily used by the contractors to assist in making bid/no bid and mark-up decisions.

This study investigates the Fuzzy Sets Theory, which is a mathematical approach used to characterise and quantify uncertainty, as a bidding strategy. This study summarises the work that has been done to-date reviewing the fundamental concepts and applications of the Fuzzy Sets Theory in construction. Fuzzy Sets Theory was found to be used widely in construction research but most studies were found theoretical.

The research also examines the challenges of using the reverse auction as an open bidding process. In construction industry, reverse auction is one such technique that uses secured Internet technology for tendering process. Advantages of on-line bidding include: the ability to submit more than one bid, time benefits, increasing competitiveness among contractors and attracting unknown bidders. The main drawback of reverse auctions is that the award of the product/service will be based on the price rather than on the quality of the product or service. Furthermore, security and legal issues need further considerations when forming e-contracts for the procurement of construction services.

Selecting a suitable contractor to execute a particular project is an important decision for the client to take. Awarding construction contracts based on the price only is not always a successful strategy for contractor selection as it could result in construction delays and cost overruns. In addition to price, factors such as quality and safety need to be taken into account when making the contractor selection decision. In this study, two methods for contractor selection were compared: the points method and the Analytical Hierarchy Process. The two methods were applied to a real life case study for contractor selection. Financial and Quality factors were considered to affect the contractor selection decision. Both methods resulted in selecting the same contractor for executing the project under consderation. The Analytical Hierarchy process provides a flexible and computer based method for contractor selection decision.

DECLARATION

This thesis is submitted to Napier University for the Degree of Doctor of Philosophy. The work described in this thesis was carried out under the supervision of Dr. Sam Wamuziri.

In accordance with the regulations of Napier University governing the requirements for the Degree of Doctor of Philosophy, the candidate admits that the work presented in this thesis is entirely the work of the auther except where otherwise referenced.

During the period of research the following paper has been presented:

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

In this chapter, a general background to the research is provided in Section (1.2). This is followed in Section (1.3) by objectives of the study. The methodology which was adopted to achieve the objectives of the thesis is described in Section (1.4). Finally, an outline of the thesis is given in Section (1.5).

1.2 Research Background

Contractors can secure contracts by competitive tendering procedure or occasionally by direct negotiation with the promoter. The competitive bidding method has the advantage of allowing new contractors or contractors who are unknown to the design team to submit a tender for consideration. This system appears to provide maximum competition. While the procedure of direct negotiation does not have the benefits of competition, it may be appropriate in cases of urgency, or where the selected contractor's expertise is unique and the firm is well known to the promoter.

This research study focussed on the competitive tendering procedure and in particular, the uncertainty and risk involved in making bidding decisions. This study covers both forms of competitive bidding: the closed and open or auction bidding.

In competitive bidding, the first decision the contractor has to make is whether to bid or not to bid for a particular project. Once the contractor has decided to bid for a particular job, the team will start by analyzing the job and preparing a cost estimate. The final price charged by the contractor is the sum of the cost estimate and a bid mark-up. The bid mark-up covers the contractor's overhead contribution and profit. Selection of the mark-up is therefore an essential step in determining the final bid value for a particular project.

Depending on the complexity of the project, market conditions, number of competitors and the conditions of contract imposed by the client, the mark-up may also include a risk premium. The value of the risk premium may be determined either from the contractor's historical records, intuitive judgment or a quantitative analysis to take into account probabilities of occurrence of particular events and the magnitude of possible losses should the risky events materialise. Analysis of risk therefore forms an important component of the bidding process, with the overall objective of improving the decision-making process.

Many studies have been conducted to assist the bid decision-making process and numerous mathematical decision models have been formulated to analyse construction risk in bidding since 1960s. For example, Friedman (1956) and Gates (1967) have modelled the relationship between mark-up and the probability of winning a bidding competition. Several studies have also been conducted to compare the two models. Friedman's bidding model asserts that each bidder's behaviour is stochastically independent of all other bidders, while Gate's criticises this assumption. Benjamin (1972) reviewed the features of the two models and compared the results with outcomes from a Monte Carlo simulation experiment. He concluded that it took about twice the volume of work to realise about the same profit by using Friedman's model compared with using Gate's equation. Carr (1982) developed a general model, based on the assumption that it is applicable to any bidding competition provided a contractor's cost distribution and opponents' bid distributions can be estimated. He then compared the predictions of his model with Friedman's and Gate's results to determine the significance of differences in assumptions. He argued that Gate's approach is more applicable to be used in conjunction with his derived general model than Friedman's equation.

Dozzi and AbouRizk (1996) developed a utility theory based model for the determination of the mark-up values for construction projects. They used a firm's past mark-up values to determine a recommended bid mark-up. The advantages of a utility-based model are that the decision maker's attitude to risk is explicitly taken into account in the development of the marginal utility functions. They assert that their model could be successfully used to determine the bid mark-up for a construction project considering all types of bidding criteria. Yeo (1991) recommended the use of sensitivity analysis as a non-probabilistic analysis technique for evaluating risk variables. He demonstrated his approach using a case study example. A cost sensitivity index and a coefficient of variation were used to measure the level of cost risk.

Quantitative methods to determine the bid mark-up based on multiple criteria has been the subject of research by a number of investigators. For example, Ringwald (1982) developed a method for calculating a bid mark-up using the crew-day method, which relates capacity of the firm during a given time period to its particular financial goals. Griffis (1992) suggested a method to improve the probability of winning in the competitive bidding problem by obtaining additional information concerning key competitors.

Despite the development of many bidding models over the years, most contractors still completely rely on past experience and judgment in making bidding decisions. Ahmed and Minkarah (1988) conducted a questionnaire survey on bidding in construction and concluded that only 11.1% of American contractors use mathematical models in bidding situations while Shash (1993) found out that 17.6% of UK contractors rely on mathematical bidding models.

Wanous, Boussabaine and Jewis (2000) suggested the following reasons for not using these models in practice:

- The over simplicity of the models' assumptions makes them unable to represent real life situations.

- Most contractors are unwilling to struggle with sophisticated mathematical models.

This study investigates use of the Analytical Hierarchy Process (AHP) as a decision-making tool to quantify the uncertainty and risk associated with bidding decisions.
The Analytic Hierarchy Process (AHP) is a multi-criteria decision making tool developed by Saaty (1990). It is an analytical tool, which enables the decision maker to rank tangible and intangible factors against each other. It involves building a hierarchy of decision elements as each level is related to the level above and below it. The entire scheme is bound together mathematically. Once the hierarchies have been established, a pair wise comparison matrix of each element within each level is constructed. This allows for elements weighting within the same group. The AHP has a unique feature in that it measures the quality of the input data, which is used to make the decision, by calculating a consistency factor. Criterium Decision Plus is commercial software which has been developed to implement the Analytical Hierarchy Process.

The concept of Fuzzy sets was first introduced by Lukasiewicz in the 1920s (Rescher 1969) and named as possibility theory. Zadeh (1965) extended the work on possibility theory to identify Fuzzy sets as a mathematical method used to characterize and quantify uncertainty. Fuzzy Set Theory is a mathematical method used to characterize and quantify uncertainty. Fuzzy sets are useful when there is not enough data to characterize uncertainty by means of statistical measures involving the estimation of frequencies (e.g., mean, standard deviation and distribution type). The main concept of Fuzzy set theory where a set refers to a group of elements that share some characteristics is the membership function. The use of Fuzzy Set Theory to quantify uncertainty in bidding decisions is considered in this work.

In the UK construction industry, the use of reverse auctions in bidding for construction work is a subject of current debate. A reverse auction is an electronic auction where contractors bid on-line against each other for contracts against a published specification. Reverse auctions promise increased efficiency, transparency and reduced costs. The Office of Government Commerce (OGC) is championing use of reverse auctions and encouraging other government departments to use various forms of e-procurement. With 40 per cent of all construction output being procured by government departments, construction firms will need to develop strategies to capitalize on using reverse auctions to win work. This has implications for contractor selection and whether selection on the basis of best value or quality can be retained remains to be answered. The use of electronic reverse auctions in construction procurement was also considered in this study.

1.3 Research Objectives

The aims of the programme of research are to:

> ***Contribute to the construction profession's understanding of risk associated with the closed and open bidding (reverse auctions). The research also aims to improve the efficiency of the decision-making process in bidding for construction projects by quantifying the inherent uncertainity and risks.This will be achieved by using the AHP (Analytical Hierarchy Process), as a multiple criteria decision making method. The research aims to develop improved risk based quantitative models to assist contractors in formulating rational bidding decisions.***

Proceeding towards these aims, a comprehensive overview of both forms of bidding was undertaken. The specific objectives of the study are:

1 To review published research on bidding strategies and assess its relevance to decision-making by construction contractors in practice.

2 To investigate the accuracy and reliability of past bid data to determine the right project to bid for and help to improve the bid/no bid decision-making process.

3 To investigate the accuracy and reliability of past bid data to determine an optimum mark-up and help to improve the decision-making process in determining bid mark-up values.

4 To examine the pitfalls and challenges of reverse auctions.

5 To review the published research into applications of fuzzy set theory as a decision-making tool.

6 To identify the factors affecting Bid/no Bid decision-making and to structure these factors hierarchically.

7 To identify the factors affecting determination of mark-ups in bidding decisions and their relationships.

8 To develop a model to quantify the effect of the identified factors on Bid/No Bid decision-making using the AHP (Analytical Hierarchy process).

9 To develop a model to quantify the effect of the identified factors on mark-up decision-making using the AHP (Analytical Hierarchy process).

10 To develop multi-criteria decision making model to assist in contractor selection.

1.4 Research Methodology

The work started by reviewing published literature of which there is wide body on the Internet, published textbooks and Journal papers etc. Research focused on closed and open competitive bidding in the construction industry. The bidding models which have been developed over the years and the factors affecting bidding decisions were reviewed. Then, the published research into applications of fuzzy set theory for decision-making was summarized.

Research into the mathematics underlying the Analytical Hierarchy Process was carried out using books and studies published in industry journals. The available software that implements the Analytical Hierarchy process was also reviewed. Then, the study consisted of the development of quantitative multi-criteria decision making models for bidding. The work also involved close collaboration with construction contractors to obtain data required for the development of the models. The data required to construct the models were collected from top contractors in Gaza Strip by way of a written structured questionnaire.

The validation and testing of the two models were carried out using the Criterium Decision Plus Software and the Linear Programming approach. The data needed for conducting the validation and testing of the proposed models were collected from a Contractor operating in Gaza Strip. Several meetings were held with the contractor to gather the required data.

Finally, the Analytical Hierarchy Process was used to assist client in the contractor selection process. The required data was obtained from real life case study for Contractor Selection. A comparison between the points method, which has been used in the case study as a method of evaluation, and the Analytical Hierarchy Process, using the Criterium Decision Plus Software, was undertaken.

1.5 Outline of Thesis

Chapter Two is concerned with closed competitive bidding in the construction industry. It summarises the published material on factors affecting bidding decisions which include bid/no bid and mark-up decisions. The bidding models which have been developed over the years are reviewed. This chapter also provides a description of fuzzy sets theory as a tool to assist in bidding decisions.

Chapter Three reviews open competitive bidding and electronic reverse auctions. This chapter starts by giving a brief description of different types of auctions. The procedure adopted when conducting a reverse auction is explained. The advantages and disadvantages of reverse auctions are also covered in this chapter.

Chapter Four gives a brief description of the decision-making process and different decision-making techniques such as decision trees, monte carlo simulation and multi-criteria decision-making methods. Different multi-criteria decision-making methods are also presented in this chapter.

Chapter Five reviews qualitative and quantitative research methods. The features of both methods are given. Methods of qualitative research including: Focus Groups, Case Studies, Participant Observation and Action Research are explained. Major types of quantitative research methods such as Experimental, Quasi-Experimental and Surveys are also discussed.

Chapter Six gives an overview of the Analytical Hierarchy Process as a multi-criteria decision making method. It then provides an illustrative example of the Analytical Hierarchy Process applied to a decision making process. It also discusses some problematic features with the Analytical Hierarchy Process followed by a literature review of published research into applications of AHP.

Chapter Seven highlights different software available for implementing the Analytical Hierarchy Process. A comparison between four types of software: the Criterium Decision Plus, Logical Decisions, Web HIPRE and Expert Choice 2000 is included. This is followed by a detailed description of the Criterium Plus features.

Chapter Eight is concerned with data collection for development of the Analytical Hierarchy Process Models. As the data was collected from Gaza Strip, a brief history of the Gaza Strip and its effect on the construction industry is provided. An overview of the state of the current construction industry is given. The steps which were followed to collect the required data are detailed including the questionnaire survey design. Finally, a preliminary analysis of the results is provided.

Chapter Nine demonstrates how two AHP multi-criteria bid/no bid and mark-up models were developed. The results obtained from the two models are presented. Finally, discussion of the results from both models are provided.

Chapter Ten validates and tests the two AHP models using real life case studies. The validation and testing of the two models were carried out using the Criterium Decision Plus Software and the LINDO software; which implement the Linear Programming approach. A comparison between the outcomes from the two software is presented.

Chapter Eleven presented a comparison between two methods of Contractor Selection: the points method and the Analytical Hierarchy Process (using the Criterium Plus Software). The two methods are applied to a real life case study for Contractor Selection.

Chapter Twelve provides a summary of the conclusions of this study. It also gives recommendations for possible future research directions.

CHAPTER TWO

Bidding Strategies and Probabilities

2.1 Introduction

The greatest challenge facing the contractors is choosing a bidding strategy that assists them in selecting which contracts to bid for and winning the competition without overbidding. The problems and difficulties in determining of bidding strategies have been studied for more than 30 years.

This chapter provides a description of the process of closed competitive bidding in the construction industry (Section 2.2). The critical decisions encountered in submitting an offer is discussed in section (2.3). Section (2.4) summarizes the published material on the factors affecting bidding decisions. A review of the bidding models which have been developed over the years is provided in sections (2.5) and (2.6).

In section (2.7), an introduction to Fuzzy Sets Theory is proposed for selecting bidding strategies. The concept of Fuzzy sets was first introduced by Lukasiewicz in the 1920s (Rescher 1969) and named as possibility theory. Zadeh (1965) extended the work on possibility theory to identify Fuzzy sets as a mathematical method used to characterize and quantify uncertainty. Fuzzy sets are useful when there is not enough data to characterize uncertainty by means of statistical measures involving the estimation of frequencies (e.g., mean, standard deviation and distribution type). This chapter provides a brief outline of the principles of fuzzy set theory. It also provides a review of published research into applications of fuzzy set theory for decision-making in situations involved risk and uncertainty in section (2.8).

2.2 The Tendering Process

There are three distinct stages in the competitive tendering procedure leading to a final agreement between the client/promoter and contractor:

- Advertising the proposed project: Promoters normally advertise the proposed project in the local and trade publications to encourage qualified contractors to participate and submit an offer to undertake the work.
- Submitting Offers: the submission of offers by interested and qualified Contractors to undertake the proposed project.
- Bid Evaluation, consideration and acceptance of the offer: the promoter evaluating each bid and selecting the best bid leading to a contract between the promoter and one of the tenderers.

2.3 Critical Decisions Encounted in Submitting an Offer

Contractors are faced with two critical decisions when invited to submit offers for carrying out a particular project. The first decision the contractor has to make is whether to bid or not to bid for a particular project. Shash (1993) emphasises the importance of this decision due to its financial consequences. If the contractor chooses to bid he has to prepare an estimate for the direct and indirect costs for undertaking the project, which will consume time and effort from the staff and there is no guarantee that they will win the job, Wilson and Sharpe (1988). If the contractor decides not to bid, an opportunity loss might be incurred.

Once the contractor decides to bid, the second crucial task is to determine the tender price, which consists of the cost estimate plus a mark-up, Akintoye (2000). The cost estimate can be determined by analysing items of the Bill of Quantities, while the bid mark-up covers the contractor's overhead contribution and a profit margin. Overheads are all those items necessary to complete the job, but do not form part of the permanent job. This includes site overheads (such as staff, accommodation, insurance, transport, security and storage) and head office overheads (which can only be determined from a careful record of the costs associated with running a head office). Therefore, selection of the mark-up is an essential step in determining the final bid value for a particular project.

2.4 Factors Affecting Bidding Decisions

Ahmed (1988) conducted a questionnaire survey among 400 of the top general contractors in the United States to uncover the factors affecting bidding decisions (bid/no bid and mark-up decision). Contractors were asked to rank 31 factors affecting both decisions. The result of the questionnaire revealed that the type of job, need for work, owner, historic profit and degree of hazard were considered to be very important, while, equipment requirement, tax liability and season were the least important factors when making the bid/no bid decision. Degree of hazard, degree of difficulty, type of job and uncertainty in estimate were ranked as the most important factors meanwhile, job start time, season and tax liability were the least important factors influencing mark-up decision.

Shash (1993) identified 55 factors that characterize the bidding decisions through a review of the American and British literature. A questionnaire survey was then distributed among 300 top UK contractors mainly to determine the level of importance of each factor towards the bid/ no bid and mark-up decisions by assigning a scale of 1-7. Need for work, number of competitors tendering, experience in such projects and current work load were identified as the most important factors influencing the bid/no bid decision, while government regulations, insurance premium and tax liabilities were the least important. For the mark-up decision, degree of difficulties, risk involved in the nature of the work, current work load and need for work were considered by the respondents as the most important factors while, insurance premium, bond requirements and tax liabilities were the least important.

Wanous, Boussabaine and Lewis (1998) conducted a formal questionnaire survey among contractors in Syria; they identified and ranked 35 factors influencing the bid/no decision. They concluded that fulfilling the tender decisions, project size and maintaining the relationship with the client are the most important factors affecting the bid/no decision.

Shash and Abdul-Hadi (1993) tested the hypothesis that small, medium and large contractors in Saudi Arabia vary in their evaluation of different factors affecting the mark-up size decision. The data was collected by sending a questionnaire survey to 300 randomly selected construction contractors in Saudi Arabia. The contractors were asked to provide a numerical scoring for factors to express their opinion on the significance of each factor in determining the mark-up size. Results from this study revealed that the importance of factors influencing mark-up decision varies with the size of the contractor. For the small contractors, size of contract, availability of required cash, location of project and type of contract were considered the most important factors. For the medium contractors, availability of required cash, project cash flow, uncertainty in cost estimate and size of contract were the most important factors. For the large contractors, risk involved in investment, type of contract, uncertainty in cost estimate and duration were the most important factors.

Dulaimi and Shan (2002) examined the relationship between the contractor size and the factors affecting the mark-up decision. A questionnaire survey was conducted among 150 medium and large size contractors operating in Singapore. The respondents were asked to indicate on a scale of 1 to 5 the level of importance of forty factors related to the mark-up decision. Availability of work, need for work, establishing long relationship with clients and past profit in similar projects were considered by the medium size contractors as the most important factors influencing the mark-up decision. For the large size contractors, degree of difficulty, availability of work, identity/ competitiveness of competitors and risk involved in investment were identified as the most influential in the mark-up size decision.

2.5 Bidding Strategies for the Bid / No Bid Decision

Carr and Sandahl (1978) used multiple regression analysis (MRA) to develop a model to help contractors in making the decision to whether or not to estimate and bid for the project. The MRA examines the relationship between a dependent variable, which is the factor that needs to be predicted, and a set of other factors called the independent variables. Data for each job undertaken by a contractor were collected; including the value for the dependent variable LBC and the values for all the independent variables. The low bid cost ratio (LBC), which was defined as the ratio of the lowest bid of any competitor to the contractor's cost, was defined as the dependent variable while the independent variables were: X1= the ratio of the number of neighbouring state competitors to total number of competitors, X2 = Contractor's state value of nonresidential construction, X3 = Contractor's city value building permits, X4 = ratio of the number of strangers (not from the contractor's state) to total number of competitors, X5 = total number of competitors and X6 = average of previous two LBC's in applicable ownership category. The MRA model was then applied to two real life projects. They concluded that this model can assist contractors in bid/no bid decision by comparing the calculated low bid cost ratio of the project under consideration to the low bid cost ratio resulted from the MRA model. If the LBC value of the project is equal or more than the LBC value from the MRA model, the contractor should estimate and bid for the project.

Ahmed (1990) proposed a model for dealing with the bid/no bid decision by adopting two stages. Seventeen factors were considered in this study. First, he considered factors such as type of project and location deterministically. Then, the second stage was a probabilistic one which took account of uncertain criteria such as competition and risk expected. The bidding problem was decomposed into four high level criteria and 13 lower level criteria. This model was not used in real-life situations due to the number of inputs required.

AbouRizk et al (1993) proposed an expert system called 'BidExpert' to provide the user with a recommendation to bid/no bid decision. The model was developed with the help of database management program named 'BidTrack', which allow for the historical information from past bids submitted by the company and its competitors to be recovered. The information supplied by the user concerning the new project and the information recovered from the BidTrack program was then used as inputs to BidExpert which gives a bid/no bid recommendation. This technique failed to consider the company characteristics

Wanous, Boussabaine and Lewis (2000) reported a parametric approach for modeling the bid/no bid decision-making process. They modelled the most important 17 factors affecting the bid/no bid decision that has been identified through a questionnaire survey among contractors operating in Syria. Financial capability of the client, relations with the client, project size, availability of time for tendering and site clearance of obstructions were among the factors considered in their study. They used 162 real bidding situation to develop their model. Then the model was tested using another 20 real projects and proved 85% accurate in simulating the actual decisions.

Han and Diekmann (2001) proposed a risk-based go/no go decision-making model to assist contractors in their bidding decision for international projects. The developed go/no go model employed the cross impact analysis (CIA) method to assess the uncertainties associated with international construction. The CIA method is a technique that can be used to predict future events by capturing the interactions between the different variables of the model. 32 factors were considered in this model grouped under five main categories: Country conditions (such as cultural and legal conditions and political conditions) controllable variables (such as firm's current resources and owner's satisfaction), uncontrollable variables (including labour issues and currency exchange rate), successor variables (such as project cost uncertainty and possibility of future market) and outcome variables (including project profitability and other benefits to the firm). The model was then tested by applying the model to different country and project conditions and with the participation of 56 people. The main finding of this study was that the model improved the decision quality and consistency. Results from the model testing showed that the model was more helpful for inexperienced group than for experienced group.

Wanous, Boussabaine and Lewis (2003) also modelled the bid/no bid decision–making process using the artificial neural network (ANN). They identified 35 bidding factors through a formal questionnaire survey supported by six semi-structured interviews. Among those factors, 18 were considered as potential factors and used to collect data on 157 real life bidding situations from 124 contractors operating in Syria. The developed model was then applied to another 20 new projects for testing. They proved that ANN is an accurate and powerful tool for modelling the bid/no bid decision. The main problem with this technique is that ANN can be difficult to interpret.

2.6 Bidding Strategies for Mark-Up Determination

Methodologies that can be used to improve bidding decisions are of tremendous value. Increased profits can result through the use of bidding models (Fuerst 1976). Many studies have been conducted to assist the bid decision-making process and numerous mathematical decision models have been formulated to analyse construction risk in bidding since 1960s.The competitive strategy models developed considered the optimal bid to be either one that maximises the expected monetary value of the job, the product of the bid profit and the probability of winning the job with that bid, or the expected utility of the job to the bidder. Expected utility is a measure of individual's implicit value, or preference, for each policy in the risk environment.

The first approach to model the relationship between mark-up and the probability of winning a bidding competition was introduced by Friedman (1956). He found the probability of winning with a given bid to be the product of the probabilities that the bid is less than the bids of the competitors as follows:

$$P[(b_0 \langle b_1) \cap ..... \cap (b_0 \langle b_n)] = P[b_0 \langle b_1] P[b_0 \langle b_1] ..... P[b_0 \langle b_n] = \prod_{i=1}^{n} P[b_0 \langle b_i] \quad \text{---------- (2.1)}$$

in which,

b_0 = the bid of the contractor using the model

b_i, I = 1, 2, ..., n = the bids of the competitors.

This formula according to probability theory is the probability of the joint occurrence of n independent events, which implies that each bidder's behaviour is independent of all other bidders.

For the case of bidding against a known number of unknown competitors, Friedman suggested the following:

The probability of winning against n unknown competitors for a given mark-up

= (Probability of beating one 'typical' competitor)^n ---------- (2.2)

Gates (1967, 1976) strongly criticized the independence assumption underlying Friedman's model and claimed that his formula is substantially better than that used by Friedman. He outlined different competitive bidding situations where the ultimate aim was also to maximize profit (i.e. the mark-up). Most of the strategies suggested by Gates are for use by one contractor against competing contractors.

Generally, Gate's model recommended that the probability of winning a contract at a given mark-up against a number of known competitors is

$$P = \frac{1}{[(1 - P_A)/P_A] + [(1 - P_B)/P_B] + [(1 - Pc)/Pc] + ... + 1} \quad \text{---------- (2.3)}$$

Where P_A is the probability of beating A

P_B is the probability of beating B

P_C is the probability of beating C

While for the case of a known number of unknown competitors, based on the analysis that did not differentiate between the identities of any of the other bidders (similar to Friedman)

Gate's model becomes:

$$Pn = \frac{1}{n\left[\left(1 - P_{typ}\right)/ P_{typ}\right] + 1} \qquad \text{---------- (2.4)}$$

Where Pn is the probability of beating n unknown competitors

P_{typ} is the probability of beating a typical competitor.

Both models assumed that the distribution of the ratios of the true cost can be determined from the contractor's record (i.e. the ratios of competitors' past bids to the bidding company's cost estimates). Friedman suggested that this distribution follows the Gamma distribution function while Gates found the cost ratios to be Normally distributed.

There has been a controversy over the Friedman and Gates bidding models and several studies have also been conducted to compare the two models.

Rosenshine (1972) suggested that both models were correct – "Friedman's model as a tool to determine an optimum bid and Gates' model as a description of the results of bidding competitors."

Benjamin and Meador (1979) reviewed the features of the two approaches by applying the two models to a set of bids by a real contractor. The bidding history of a contractor for 131 jobs over a 3 year period was used as data for the comparison. Then they compared the results with outcomes from a Monte Carlo simulation experiment. Inputs to simulation consisted of the construction cost estimates for the 131 jobs and the lowest competitor's bids. They concluded that it took about twice the volume of work to realise about the same profit by using Friedman's model compared with using Gates equation.

Carr (1982) tried to resolve the matter by developing a general model, based on the assumption that it is applicable to any bidding competition provided a contractor's cost distribution and opponent's bid distributions can be estimated. He considered the case where the variations in bids are mainly due to the variations in costs without taking the mark-up variations into account. He then compared the predictions of his model with Friedman and Gate's results to determine the significance of differences in assumptions. He argued that Gates approach is more applicable in conjunction with his derived general model than Friedman's equation.

Ioannou (1988), Morin and Clough (1969) reported successful application of Friedman's model. Ioannou (1988) supported Friedman's approach by proving the probabilistic validity of his model by using correctly stated arguments of symmetry and he also argued that the independence assumption behind Friedman's model did not violate the axioms of probability theory.

Despite the fact that many researchers reported successful applications of Friedman and Gates models, these models failed to take into account the uniqueness of each contract, such as project characteristics and company charcteristics, as both approaches depend only on past records to determine the mark-up size.

Liu, et al. (2005) proposed a formula for the probability of winning and determining the optimal mark-up for construction contracts. The main assumption underlying their formula was that the cost estimate is normally distributed with a non zero mean value.

While in Gates and Friedman's models there is no time element, some researchers have considered time in developing their models. Ringwald (1982) developed a method for calculating a bid markup using the crew-day method, which relates the capacity of the firm during a given time period to its particular financial goals. This application of this method was illustrated by a hypothetical example; a firm had to bid for two projects with the same total cost with one general crew. He concluded that this method can be used by the contractor as a check for the mark-up decision.

Griffis (1992) recommended that the contractor's business behaviour could be described by his workload diagram. This diagram represents the contractor's cumulative work load in terms of dollar volume against time. Griffis developed a model to improve the probability of winning in the competitive bidding problem. In his model, he only considered a competitor's volume of work in hand as a risk element and the assumptions underlying his model have not been proven.

Ioannou and Leu (1993) presented a competitive bidding model for the average-bid method. The winner based on the average- bid method is the contractor whose bid satisfies a certain relationship with the average of all bid prices. The average bid method presented in this was mainly based on the theory that the winner might be the contractor whose price is closest to arithmetic average of all submitted bids. By analysing the bid process both mathematically and through Monte Carlo Simulation, it was demonstrated that this method does not promote price competition between contractors.

Quantitative methods to determine the bid mark-up based on multiple criteria has been the subject of research by a number of investigators. Dozzi and AbouRizk (1996) developed a utility theory based model for the determination of the markup values for construction projects. They used a firm's past markup values to determine a recommended bid markup. The advantages of a utility-based model are that the decision maker's attitude to risk is explicitly taken into account in the development of the marginal utility functions. They assert that their model could be successfully used to determine the bid markup for a construction project considering all types of bidding criteria.

Li and Love (1999) presented an approach for estimating a contractor's mark-up percentage for a construction project. They developed a computer-based mark-up decision support system called InMes (Integrated Mark-up estimation system) by integrating both a rule-based expert system and an artificial neural network (ANN) based expert system. The developed system was then tested using cost data obtained from a contractor's successful bids in order to select the expected mark-up for a project. They concluded that the use of this system can assist the contractor in making mark-up decisions and moreover it can provide the user with an understanding of why and how the suggested mark-up was derived.

Both quantitative approaches mentioned above can not be applied in practice by contractors. This is due to the fact that building the utility function which is the main concept underlying the utility theory is complicated. On the other hand, the artificial neural network is hard to interpret.

2.7 Fuzzy Sets Theory:

The main concept of Fuzzy set theory where a set refers to a group of elements that share some characteristics is the membership function. This represents numerically the degree by which an element belongs to a set. Fuzziness represents situations where membership in sets cannot be defined on a yes/no basis because the boundaries of sets are vague, (Zadeh 1965). According to the membership value, Fuzzy set theory can be divided as follows:

- Classical or Ordinary Set Theory: where there is a clear distinction between the members and non-members that belong to a set. Therefore, the membership value of the elements in such a situation is either 1 for members or 0 for non-members.

- Fuzzy Set Theory: where the membership value can be any real value between 0 and 1, and this value represents the degree of membership of an element belonging to a given set. The higher the membership value, the more the element belongs to the Fuzzy set. In notations, this can be represented as:

  $$\tilde{F} = \{(\omega, \mu_{\tilde{F}}(\omega)) : \omega \in \Omega; \mu_{\tilde{F}}(\omega) \in [0,1]\}$$

  Where,

  Ω is a universal or reference space consisting of ω_i points,

  $$\Omega = \{\omega_1, \omega_2, \dots\dots\dots\dots, \omega_i\}$$

$\mu_{\tilde{F}}(\omega)$ is the degree of membership of ω in the set $\tilde{F}$.

2.7.1 Operations in Fuzzy Sets Theory:

There are three basic operations in fuzzy set theory, the union of two fuzzy subsets of the same universe of discourse, the intersection of two fuzzy subsets of the same universe of discourse and the complement of a fuzzy subset.

- The union of two fuzzy subsets A and B is denoted by $A \cup B$ and is defined by: $\mu_{\tilde{A}\cup\tilde{B}}(\omega) = \max(\mu_{\tilde{A}}(\omega), \mu_{\tilde{B}}(\omega))$, i.e. the set of all elements, which are members of A or B, or both.

- The intersection of two fuzzy subsets A and B is denoted by $A \cap B$ and defined by: $\mu_{\tilde{A}\cap\tilde{B}}(\omega) = \min(\mu_{\tilde{A}}(\omega), \mu_{\tilde{B}}(\omega))$, the set of all elements, which are members of both A and B.

- The complement of A is denoted by $\tilde{A}\ c$ and is defined by: $\mu_{\tilde{A}c} = 1 - \mu_{\tilde{A}}$

2.7.2 Determination of Membership Values:

The determination of membership values of elements that belong to a fuzzy set is a fundamental task in fuzzy set theory. Klir and Yuan (1995) identified both direct and indirect methods to establish these values.

- In the direct approach, experts are expected to submit individual assessments on the degree to which elements belong to a set. By carrying out a certain calibration procedure, this raw data will become numerical numbers which represent the membership values.

- In the indirect approach, experts are requested to submit an assessment of a certain property which is related to the degree of belonging. A common property is the comparison of the degree of belonging between any two elements.

Thole, Zimmermann and Zysno (1979), argued that direct measurement should only be accepted if human errors are unlikely to occur or to keep errors within reasonable tolerances, while the indirect measurement usually requires many judgments from the experts. They suggested a combination of both types of methods as the most appropriate technique to determine membership values.

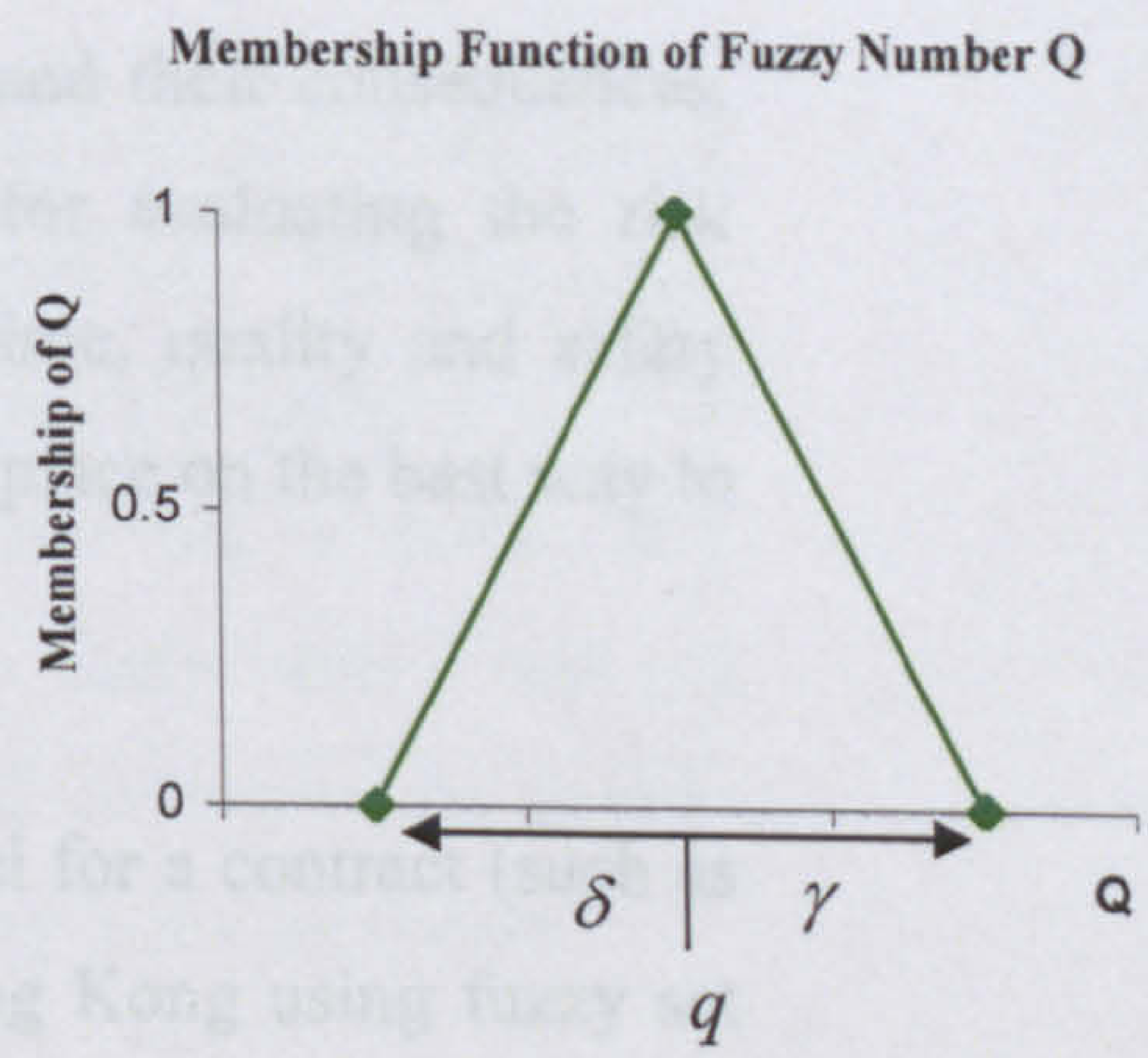
2.7.3 Establishing Fuzzy Membership Functions

The membership function of a fuzzy set can be described and divided mathematically by means of Left (L) and Right (R) functions (Dubois and Prade 1980, Dong, Shah and Wong 1985). As an example of the L-R functions, let Q be a fuzzy number, then the membership functions can be denoted by:

$$\mu(Q) = 1 - \frac{(q-Q)}{\delta}, \quad \text{Where} \quad q-\delta \le Q \le q$$

$$\mu(Q) = 1 - \frac{(Q-q)}{\gamma}, \quad \text{Where} \quad q \le Q \le q+\gamma$$

$$\mu(Q) = 0 \quad \text{Otherwise}$$



2.8 Applications of Fuzzy Sets:

Researchers did not give much attention to Fuzzy sets approach in the past, but recently there has been a rapid growth in the number of papers concerning the applications of this method. Guiffrida and Nagi (2004) presented a survey of the application of fuzzy set theory in production management. The literature review provided in their paper consisted of 73 journal articles and nine books. Furthermore, a classification of the literature based on the application of fuzzy set theory to production management was also identified.

Wang (2002) used fuzzy set theory to select and measure the quality of the product design concept; where a product concept is a description of the technology, working principles and form of the product. An outpatient syringes-design was illustrated in this study as example of concept selection method. Ease of handling, ease of use, readability of setting, doses metering accuracy, durability, ease of manufacture and portability were the criterion considered in this study. He concluded that this approach could provide additional information to help designers in the process of selection of design concepts. Friedlob and Schleifer (1999) described different types of uncertainty using fuzzy logic. They presented an example for accounting control, variance causes and effective analytics.

There have been a number of attempts to utilize fuzzy sets theory within the construction and risk management field. Tah and Carr (2000) presented on cause and effect diagrams the relationships between risk factors, risk, and their consequences. By using fuzzy estimates they presented a methodology for evaluating the risk exposure, considering the consequences in terms of cost, time, quality and safety performance measures of a project. Further research is taking place on the best way to implement such a system in practice.

To assist the client, Wong and So (1995) constructed a model for a contract (such as lump sum or management contract) decision-making in Hong Kong using fuzzy set theory. In this study, the scale of the project, the nature of the works to be carried out, the characteristics of the client, the time constraint, the source of materials for construction and the characteristics of the building design were considered as the factors determining the contract choice. They exemplify the model with two illustrative cases. They illustrated that the developed model was consistent with the experts' rules of experience as well as the contract choice in their examples.

Wong, et al (2000) applied multi-attribute utility theory and fuzzy modeling to the selection of construction projects; where the client has to decide which project to develop among a number of proposed projects. The net present value (NPV), the number of new jobs created, the number of employees from minority groups, the number of additional staff to owner's management team and the prestige of the agency were considered as attributes for evaluation. They recommended this method in the case of projects having close utility ratings.

Ng, et al (2002) conducted a study in Australia with the aim of establishing a fuzzy membership function of procurement selection criteria. They considered speed, complexity, flexibility, responsibility, quality level, risk allocation and price competition as the procurement selection criterion and derived the fuzzy membership function for each of them. These membership functions provided useful information on how experts could make the procurement decision through the fuzzy set approach.

From the contractor's point of view, Paek, Lee and Ock (1993) proposed the use of fuzzy set theory to develop risk-pricing algorithm for quantifying risk-associated consequences under uncertainty to assist contractors in deciding the bidding price of construction projects. They analysed risk that could result in a loss of money in a construction contract and illustrated their method by a case study from a real life urban highway project. They concluded that risk-associated consequences contain elements of uncertainty which can be characterized by applying fuzzy set theory.

Based on fuzzy set theory, Boussabaine and Elhag (1999) presented an approach for determining the expected value of cash flows for construction projects. They assumed that the cash flows at different stages of the project progress are ambiguous. To demonstrate their work, the cash flow curves of 30 projects were analysed and the cash flow curves were obtained using fuzzy averaging techniques. They demonstrated that fuzzy sets could be used to describe ambiguous terms that often are encountered in cash flow analysis. However, the input variables must be independent i.e. no interaction between the input variables.

The applications of fuzzy set approach to special problems in decision-making with uncertain information were suggested by Bellman and Zadeh (1970). Nojiri (1979) presented a model for the fuzzy team decision and enhanced the study by an example illustrating the team decision processes using fuzzy sets. Li (1999) proposed a model to solve decision problems with multiple judges and multiple criteria in a fuzzy environment. In this case judges were allowed to use fuzzy sets to evaluate the performance of alternatives and the importance of criteria.

Lam, et al. (2001) illustrated the use of fuzzy reasoning technique as a mathematical approach to the solution of decision making problems that combine qualitative and quantitative variables. In their study, they developed a model that can be applied to construction project management problems by suggesting an optimal path of corporate cash flow that results in the minimum use of resources, i.e. eliminating excess use or idleness of resources.

Zhang and Tam (2003) recommended fuzzy decision-making model, based on real information, for improving construction projects resource allocation i.e. minimising waiting time or queuing number of resources, minimising delay of activities, etc. In this study, objectives were described by fuzzy sets and the decision was performed through averaging membership values of alternatives. This paper showed how the developed fuzzy dynamic resource allocation model could improve construction productivity.

Paek, Lee and Napier (1992) developed a multi-criterion decision-making methodology for selecting the best design/build proposal under uncertainty using fuzzy set approach, i.e. they aimed to assist decision-makers in solving the design/build proposal selection problems where there are conflicting objectives and the value of each input variable is uncertain. They confirmed the utility of the fuzzy set approach by presenting a case study of an actual project. Using the fuzzy logic, three design/ build proposals were evaluated and ranked, based on cost and 24 technical factors such as landscaping, material quality, parking and storages. Results from this study showed that the fuzzy set approach can both represent the basic criteria selected for assessing the design/build proposals and be a useful tool for solving the design/build selection problems.

Perng, et al (2005) employed the fuzzy logic to create a structured mechanism to facilitate the decision making process for foreign investors and contractors in evaluating the business feasibility of entering the Chinese housing market. Four input criteria were considered in this study: "design/ regional environment", "economic status/policy", "price/competitiveness", "agreement/relationship". Delphi method was used to collect professional information from experts in the housing business in China. The Logic Gate Model was then used to transfer experts' knowledge into fuzzy interface models; fuzzy set membership functions were set up to predict the sales performance in China's housing. Two case studies were presented in this paper. The advantages of the developed model that it could facilitate the analysis and reduce errors. Furthermore, this model is considerably useful in the housing market investment decisions as it can deal with large number of decision input criteria.

Dweiri and Kablan (2006) presented an application of the fuzzy logic in project management. They identified project cost, project time and project quality as project internal measures of efficiency. The fuzzy decision making was used to combine these three measures into one measure called the project management internal efficiency (PMIE) which should give an indication of how well the project was managed and executed. The fuzzy decision making system was designed and implemented using the MATLAB software for evaluation of the PMIE. A case study was presented to illustrate the use of the proposed approach for the evaluation of PMIE. They concluded that this approach can be used as an indicator for the level of achievement of the project management internal objectives.

Nataraja, et al (2006) presented a fuzzy interface system (FIS) for the prediction of early strength of concrete, the 28 day's strength of concrete, in a two stage model. In the first stage, only the water-cement ratio was treated as controlling parameters for the strength of the concrete while in the second stage, water-cement ratio and aggregate-cement ratio were considered. They developed a basic model using generalized Abram's law; which states that the strength of concrete is influenced by, the ratio of cement to mixing water, the ratio of cement to aggregate, the grading, surface texture and stiffness of the aggregate and the maximum size of the aggregate.

Matlab was utilized to build up the model. To validate the model, it was then used to predict the strength of the concrete considering the two parameters and using seven cement cubes. The predicted results were compared with an experimental data. They concluded that the prediction using this model was excellent but the sensitvity of the model is to be explored for different types of cement and aggregates.

2.9 Summary:

For the contractor to bid for the appropriate job and also to achieve the maximum profit, a bidding strategy must be adopted. Many approaches to competitive bidding have been developed and tested over the years.

By reviewing the available models, the main conclusion is that bidding decisions depend on a number of factors which need to be taken into account in any bidding strategy. Such factors include: type of work, need for work, owner identity and past experience in similar projects.

Many models have been developed to assist contractors in bid/no bid and mark-up size decisions. Researchers used different methods such as multiple regression analysis, the cross impact analysis and the artifical neural network (ANN) to model the bid/no bid decision. For mark-up size decision, the first two theoretical approaches are Friedman's Model and Gate's Model. There has been a controversy over these two bidding models and several studies have been conducted to compare the two models.Some researchers gave credit to Friedman Model and others to Gates Model. Then, several models were developed for mark-up decision including the use of the day-crew method, utility theory and the artifical neural network. Most of these models are complex and hard to implement by contractors in practice.

A description of the theory of fuzzy sets as a method of decision making was given in this chapter. Contemporary developments in Fuzzy sets have proved themselves to be useful in many fields. In the light of the provided review, utilizing Fuzzy sets in bidding decisions is a potential area for further research. Further work should consider the evaluation of the readiness of fuzzy risk analysis models for industry as most studies found to be theoritical.

CHAPTER THREE

Reverse Auctions

3.1 Introduction:

This chapter is concerned with electronic reverse auction bidding. Electronic reverse auctions are an Internet-based method that enables contractors to bid on-line against each other by lowering their prices in an effort to win a contract. On-line auctions have been used widely in commerce and industry to facilitate procurement of goods and services since 1995. In the UK, the Office of Government Commerce is championing use of reverse auctions to achieve project time and cost savings. Use of reverse auctions in bidding for construction work is however a subject of current debate.

In this Chapter, a brief description of various types of auctions is given. A review of the procedures for reverse auctions in construction is provided. Section (3.3.2) provides a review of on-line auctions in the construction industry and other sector of business in different parts of the world such as Asia, USA and the UK. The advantages and disadvantages of on-line bidding from both the clients' and contractors' perspectives are also discussed.

3.2 Types of Auctions:

There are four types of auctions: English, Dutch, Sealed first price and Sealed second price auctions (Klemperer, 1999). In the English auction, auctioneer begins with the lowest acceptable price, usually the reserve price. Then, the bidding goes up in increments until a final bid is reached. English auctions are used when the supply of goods is limited or an item is unique. In a Dutch auction, also known as a multiple items auction, the auctioneer begins with a high asking price, which is lowered until a participant is willing to accept the auctioneer's price. This type of auction is used to offer multiple items for sale or when it is important to auction goods quickly.

In the sealed first-price auction, all bidders simultaneously submit bids in such a way that no bidder knows the bid of any other participant until all of the bids are opened at the time of sale. At closing, the bidder with the highest amount is revealed and that is the bidder that wins the auction. Sealed second-price auction is identical to the sealed first-price auction, except the winning bidder pays the second highest bid rather than his own. This is a good format because sellers have the incentive to bid what they think the item worth.

3.3 Reverse Auctions:

Electronic auctions are an Internet-based method of bidding for the supply of goods and services. It can be categorized as standard or reverse online auctions. In the standard online auctions, the auctioneer sets the starting bid amount and the bidders drive the price up as they compete to outbid each other. The highest bidder at the close of the auction is the winner of the auction. While in the electronic reverse auctions, the auctioneer sets the starting bid and the bidders compete in successive rounds of downward bidding for the opportunity to offer the specified product or service.

3.3.1 The On-Line Bidding Process:

In general, the on-line process as identified by The Construction Industry Council (www.cic.org.uk) is as follows:

- The owner/client invites bidders to submit a technical proposal containing everything, except the price, and to participate in the reverse auction. Drawings and specifications for the proposed contract and instructions on how to participate in the auction are available to the bidder in advance of the event.

- The client will provide software and training as necessary.
- An on-line auction is scheduled, with a specified start and closing time, and conducted on behalf of the owner/client by a third party; an IT service provider. A reserve price may be determined by the owner/client, which is usually based on a consultant's estimate.
- All bidder identities are kept confidential during the reverse auction event.
- Once the reverse auction begins, bidders submit initial prices. The submitted prices are ranked and then communicated back to all bidders, with the bidder being told of their own ranking relative to others.
- Bidders can re-submit new lower prices as many times as they want up to the specified closing time, with the new ranking communicated back to all bidders with their new ranking relative to others.
- The auction closes once no more new bids are placed and the auction time expires.
- All bidders are immediately notified of their final bid ranking.
- The auction service provider notifies the owner/client of the bidding results.
- Finally, the owner/client will contact the winning bidder to complete formal award of the contract.

3.3.2 Literature Review on On-Line Auctions

Stein, Hawking and Wyld (2003) studied an Australian example of reverse auction procurement and analysed the auction process and outcomes in view of the drivers and impacts of e-procurement. They outlined one auction event concerned with logistics and transport services conducted by an Australian manufacturer called AusBuyer. They concluded that reverse auctions can lead to savings of up to 20% of the cost.

Massad and Tucker (2000) compared on-line auctions with traditional in-person auctions from the consumer's point of view. This was achieved by testing the relationships between the sale of 60 Hummel plates and figurines at an in-person auction in Southern Pennsylvania against those of corresponding Hummel plates and figurines at an on-line auction conducted by e-bay. They suggested that dealers could make a reasonable profit by purchasing goods at in-person auctions and then selling them on-line.

Settoon and Wyld (2003) examined the potential impact of strategic implementation of reverse auctions on macroeconomic indicators and government spending in Southeast Asia. They used data from the year 2000 collected from the Asian Development Bank (ADB). The data were used to calculate cost savings for five countries (Indonesia, Malaysia, Philippines, Singapore and Thailand) using competitive bidding events. They selected Fiscal Balance, government surplus versus deficit, and Gross Domestic Product (GDP) as indicators to reflect the effect of reverse auctions. They demonstrated that the use of reverse auctions could result in cost savings, which can be applied to reduce government deficits and increase Gross Domestic Product by a factor of 8.

In the United States, a rapid spread of reverse auctions is in progress. In a study on public sector procurement in the United States, Wyld and Settoon (2004) found that reverse auctions result in 93% greater return for public sector agencies than other procurement methods. 41 interviews with purchasing professionals were conducted in the U.S.A to discuss promises, risks and conditions for reverse auctions success (Smeltzer and Carr, 2003). They identified cycle time reduction, and lower purchase price as promises from the buyers' perspective. While, from the suppliers' viewpoint, the main reasons for using reverse auctions were increased business and improved communication about the market. They also concluded that the main conditions for reverse auction success are:

- The product or service specifications must be clear and comprehensive.
- The appropriate supply market conditions must exist.
- Buyers must have professionals who can understand and implement the process.

Joia and Zamot (2002) used a single case study to discuss the efficiency, efficacy and accountability of the electronic auction system developed by the Brazilian Federal Government. They analysed the procurement process adopted by the Ministry of Social Security to purchase pharmaceutical products from several suppliers. They concluded that the existing system is efficient as savings of approximately 30% in product costs for the public sector can be achieved with a reduction in time involved. They however raised concerns about accountability of the system.

Emiliani and Stec (2001) discussed the terms and conditions that are usually established by buyers to accompany reverse auctions purchasing contracts, in particular for specific American durable goods. For the purpose of their study, terms and conditions were derived from studying reverse auctions situations conducted between 1998 and 2000. These terms include: buyer makes no commitment to purchase the forecasted quantities that helped the supplier to determine the price, the acceptance of the terms without exception, no change in the price under any circumstances and to extend payment periods to improve the cash flow. The main finding of this study was that few benefits could be gained when participating in online reverse auctions.

Emiliani and Stec (2005) conducted a survey among U.S and Canadian pallet suppliers to examine their reaction to online auctions and the impact they had on their business policies and practices. Calls for responses to the survey were made through three channels: Pallet Enterprise magazine, newsletter Pallet Profile weekly and Pallet Enterprise online message board. Most suppliers agreed that using the online reverse auctions produced no change in the following: business strategy, operating practices, production capabilities and long-term competitiveness. They also reported that adopting reverse auctions caused a decrease in the gross margin and resulted in less cooperative relationships with customers. Moreover, most suppliers considered online reverse auctions to be unethical business practice.

Tassabehji, et al. (2006) explored the reverse auction phenomenon in the U.K packaging sector from the supplier perspective. Data were collected directly from one large food-packaging supplier using five case studies of reverse auctions and by interviewing16 supplier companies in the sector. The results show that by adopting reverse auctions, the supplier-buyer relationships have been affected as suppliers' commitment and loyalty were damaged. They also reported that most suppliers found the reverse auction format stressful and that they frequently went below their pre-determined minimum price.

Hartley and Lane, (2006) examined the differences in level of concern of barriers facing the adopters and non adopters of e-auctions. The most important barriers were identified based on the literature review and information gathered through interviewing eight large multinational US companies implementing e-auctions and representing different industries: building materials, agricultural equipment, petroleum, packaging, pharmaceuticals, automotive parts, industrial equipment and engineering and construction. From the buyer point of view, two factors that influence the use of e-auction were recognized; lack of auction knowledge and information security concern. While from the supplier view point, importance of supplier relationship and lack of supplier participation were identified as barriers to the use of e-auction. Then, those factors were used to construct a survey consisting of a seven point scale ranging from not a barrier (1) to a great extent a barrier (7) and were distributed among the National Association of Purchasing Management (NAPM) members. GLM-MANOVA (multivariate analysis of variance using a general linear model) was used to test the outcome of the survey. Results revealed no significant difference between the adopters and non-adopters in their level of concern over e-auction knowledge, the impact on supplier relationships or lack of supplier participation. The factor 'information security' was less of a concern to the adopters of e-auctions than non-adopters.

In the UK construction industry, the use of reverse auctions in bidding for construction work is a subject of current debate. Every year companies, agencies and departments in the United Kingdom issue thousands of requests for proposals to companies that are seeking to secure government contracts. This process is mostly paper-based with mail, faxes and agents being used to deliver important documents. In autumn 2002, the Office of Government Commerce (OGC) published guidance to e-procurement for the public sector. Then in spring 2005, a modified guide to e-procurement for the public sector was issued. The guides provided information on how the public and the private sectors are developing e-commerce systems for public sector purchasing. The OGC conducted interviews with more than 40 public and private sector organisations implementing e-procurement programs to assess the improvements achieved through e-procurement. Among the studied cases were the National Health Services Purchasing and Supplying Agency (NHS PASA), the Defense logistics organization (DLO) and the National e-Procurement Project (NePP). The NHS PASA has used the e-procurement to purchase products for the health sector and worked on the NHS Supplier Information Data Base and NHS-e Catalogue Solution. DLO provided procurement services to the Ministry of Defense. The DLO started working with an IT systems integrator called 'GapGemini' to deliver a secure trading environment called 'The Defense Electronic Commerce Service' in August 2002. Adopting e commerce between all Ministry of Defense organizations resulted in improved efficiency and savings. Moreover the guide reported that until spring 2005, 500 suppliers and 300 Ministry of Defense users were using e procurement. The NePP was established in September 2002, as a national project and was funded by the office of the Deputy Prime Minister to help local government to meet their 2005 targets for offering e-Government services. The program aimed at assisting councils and local authorities to adopt e procurement services. The survey conducted by NePP indicated that: 125 local authorities have or are currently implementing e procurement and 110 local authorities are preparing for e-procurement. The main advantages for e-procurement stated in the guide were: savings, increased market knowledge of buyers and suppliers and improved quality of services.

The UK Government selected Accenture an online procurement services provider, to implement e-Auction Programs since 2002 to educate UK public sector organisations about electronic reverse auctions and how to use them. The Royal Mail plc is a public limited company wholly owned by the Government of the United Kingdom and the Driver and Vehicle Licensing Agency (DVLA) is an agency of the United Kingdom

Government that helps to improve road safety, collects vehicle registration fees and issues driving licenses are among organisations that used e-Auction to reduce administration and procurement costs and improve services. Accenture cooperated with both of them to provide e-Auction services such as bidder training, technical support and post-event reporting. Also, accenture conducted a case study for British Airways (BA) to evaluate the use of e-procurement to improve their procurement processes. Accenture concluded that a reduction in purchase costs of approximately US $ 260 million or 5% of BA's annual expenditure can be achieved in two years by adopting e-procurement (2001). Moreover, in the UK, INDECO Ltd. is one such company that achieved 18% savings in a recent contract for the maintenance of elevators for a European bank's offices through reverse auctions (Young, 2002).

In the UK construction industry, there has been some progress with the adoption of e-commerce despite that fact that there have been strong objections to electronic reverse auctions. The Office of Government Commerce is working with the construction industry to facilitate the adoption of electronic reverse auctions. As part of the Construction Industry Council (CIC) consultants' contract, a report is due to be published in spring 2008 detailing the scope of services for construction projects. The report will determine the tasks that should be performed by consultants and contractors to participate in an electronic auction. A liability briefing on e-business has been produced by the Construction Industry Council (www.cic.org.uk/liability). General recommendations for how to form electronic contracts and precautions that should be taken are included. According to the CIC briefing, the following are the main points to take into consideration when forming e-contracts:

- Ensure the capability of the participating contractors.
- A legally binding agreement would be formed when an offer and acceptance are exchanged by e-mails. An acknowledgment of recipient of both e-mails should be sent to make sure that the other party received the e-mail and read it.

- When dealing with transactional contracts, where the contract is formed is very important as this will determine which country's law to apply and which courts have jurisdiction in case of any disputes.
- Clients/potential bidders and IT service provider should sign a confidentiality agreement.
- Potential bidders should be trained on the methodology and the software used for the on-line bidding process.
- Security issues: as emails can be intercepted and read and can be easily sent to a wrong recipient. Security measures should be attached to the e-mails such as password to avoid such problems.
- Special care must be taken when sending e-mails via the Internet as the sender could pass viruses to the recipient and as a result might be liable for any damage caused by the viruses. Up to date protection software must be installed in all computers involved in the process.
- Hard copies of the exchanged e-mails should be kept with records of dates and times of transmission. Or it can be kept in 'Extranets'; which is a project specific website for storing drawings and other documents and usually operated by the Application Service Provider.
- The owner should revise the winning bid before the final award to consider the quality as well as the price.

3.3.3 Advantages of On-Line Bidding:

Reverse auctions promise increased efficiency, transparency and reduced costs and this can be seen clearly from the following points:

- On-line tendering is a method of standardising the procurement process.
- Bidders can be monitored.
- Increases competitiveness among contractors.
- Attracts unknown contractors.
- Easy comparison of bids.

- Time benefits: reduction in paperwork, postage and photocopying.
- Ease and speed of communication to multiple bidders.
- Ease of access to project information.
- Automatic error checking of bids before submission.
- The ability to submit more than one bid.

3.3.4 Disadvantages of On-Line Bidding

On-line reverse auctions have become a popular method for reducing the price of purchased goods and services (Emiliani 2000). Reverse auctions expose owners to the real possibility to award to the lowest cost bid rather than to the best value. This can be seen from the following points:

- While huge savings can be achieved by using reverse auctions as a method of purchasing contracts for goods and services, retaining control over the specification of the goods and services being bought is not always achievable.

- In reverse auctions, competitors have to deal with multiple rounds of bidding and as a result may encourage imprudent bidding practices (Associated General Contractors of America (AGC), 2003). As the process may move too quickly for competitors to accurately reassess their costs. This will have an impact on both the bidder and the owner.

- Some well-qualified bidders will not participate because they do not trust the process. In reverse auctions there will be an opportunity for contractors to re-submit their prices and therefore may encourage them to initially submit artificially high prices rather than their competitive prices. As a result, the lowest possible price may not actually be offered.

- Potter and Lovatt (2002) explored the legal obligations of the parties to an auction sale with reference to the newly defined liability for managers of auction sales where properties are sold without a reserve price. They concluded that if an auctioneer refuses to sell to the highest bidder then he would incur liability to the bidder.

- Bywell and Oppenheim (2001) discussed the Internet fraud issue. The buying, selling and transacting of money over the Internet raises important security issues. They also raised the problem of bidding under false names and addresses. They summarised that the Internet auctions are disadvantaged in comparison to traditional auctions due to the fact that the quality of the items under offer cannot be checked.

- Reverse auctions could deteriorate buyer-supplier relationships. Griffiths (2003) discussed the ability of online auctions to adversely affect relationships between suppliers and buyers. He pointed out that trust between buyers and suppliers might be affected if reverse auctions were conducted in an unethical way. For example, inviting suppliers to an auction that could never actually become suppliers due to size, quality or language barriers just to push the price down.

3.4 Summary:

E-commerce has experienced massive growth in the last few years and currently is widely being used for buying and selling various products. Many companies are using reverse auctions mainly as a means of reducing costs. However, these companies need to consider the detrimental impacts such methods can have.

In the construction industry, the use of reverse auctions as a method of purchasing and awarding contracts is a subject of current debate. The Office of Government Commerce (OGC) is encouraging the construction industry to use reverse auctions in the procurement processes. The OGC is currently revising all issues related to e-procurement such as e-contract, e-drawings and the legal problems.

The main drawback of reverse auctions is that they represent a return to the lowest price offered rather than best value. Furthermore, quality, reliability and relationship between the client and the contractor/service provider could be affected.

On the basis of what has been outlined above it is possible to conclude that although Internet reverse auctions have been introduced for procurement of construction services, however, their full implications for procurement in the construction industry remain yet to be fully appreciated.

CHAPTER FOUR

Multi-Criteria Decision Making Methods

4.1 Introduction

Multi-criteria decision making methods are techniques supporting the decision maker when faced with a problem that has a set of criteria on a set of alternatives. The adoption of multi-criteria methods helps to organise the decision-making process, determine the best alternative and rank the set of criteria under consideration. This chapter gives an introduction to the decision making process and highlights different types of formal decision-making techniques. The main characteristics of multi-attribute decision making followed by an overview of different multi criteria decision making methods are provided.

4.2 The Decision Making Process

Decision making is the process of selecting a preferred option from multiple alternatives. This option should provide the most desirable solution of the problem under consideration.

4.2.1 Overview of the Decision Making Process

The general steps for the decision making process are (Figure 4.1):

- Define the Problem: It is very important that the decision maker has a clear understanding of what it is he/she is trying to decide. A thorough list of objectives should be developed to make the decision makers aware of potential effects of their decisions.

- Gather Information: Information about the problem under consideration can be derived from many sources such as: research, results from experimentation and studies and interviews with experts and trusted bodies. In case of lack of sources, opinions and assumptions are needed.

- Develop Alternatives: It is important to identify all possible alternatives to give the decision makers a wide range of alternatives with different tradeoffs.

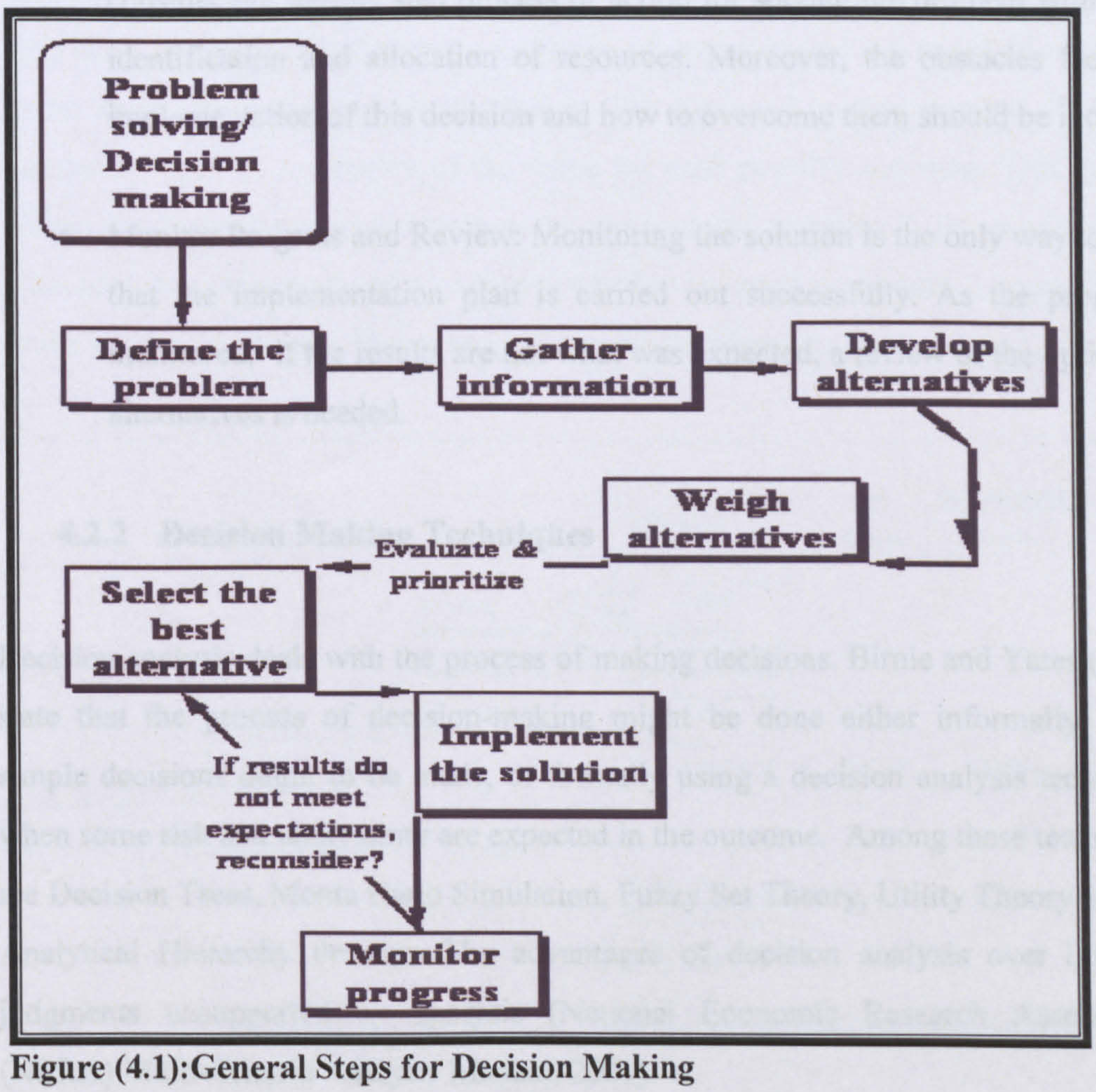


Figure (4.1):General Steps for Decision Making

- Weigh Alternatives: After listing all possible alternatives, certain measurements are identified as an indication that each objective can be met. Weights express the importance of each criterion relative to other criteria.

- Select the Best Alternative: When the decision makers are satisfied with the alternatives and analyses they choose one alternative for implementation. The selection of the "best" alternative depends on the importance the decision maker places on various objectives.

- Implement the Solution: Plans for implementation of the solution need to consider the step by step process or action for solving the problem with a clear identification and allocation of resources. Moreover, the obstacles facing the implementation of this decision and how to overcome them should be included.

- Monitor Progress and Review: Monitoring the solution is the only way to ensure that the implementation plan is carried out successfully. As the progress is monitored, if the results are not what was expected, a review of the options and alternatives is needed.

4.2.2 Decision Making Techniques

Decision analysis deals with the process of making decisions. Birnie and Yates (1991) state that the process of decision-making might be done either informally, when simple decisions ought to be made, or formally using a decision analysis technique, when some risk and uncertainty are expected in the outcome. Among these techniques are Decision Trees, Monte Carlo Simulation, Fuzzy Set Theory, Utility Theory and the Analytical Hierarchy Process. The advantages of decision analysis over informal judgments unsupported by analysis (National Economic Research Associates's (NERA) Multi-Criteria Analysis Manual, 2001):

- It is open and explicit

- The choice of objectives and criteria that any decision making group may take are open to analysis and to change if found inappropriate.
- Scores and weights, when used, are also explicit and are developed according to established techniques.
- It can provide an important means of communication, within the decision making body.

A brief description of each of these decision-making techniques is given next.

Decision Trees: a decision tree is a means of setting out problem that is characterised by a series of decisions. It shows a sequence of decisions and the expected outcomes under each possible set of circumstances. The expected monetary value (EMV) is commonly used as a measure of the value for each possible outcome. This method allows the decision-maker to structure the problem and visualize it. As an example: if a decision has to be made by a company whether to invest in product A or product B, under certain conditions, Figure (4.2) shows the decision tree.

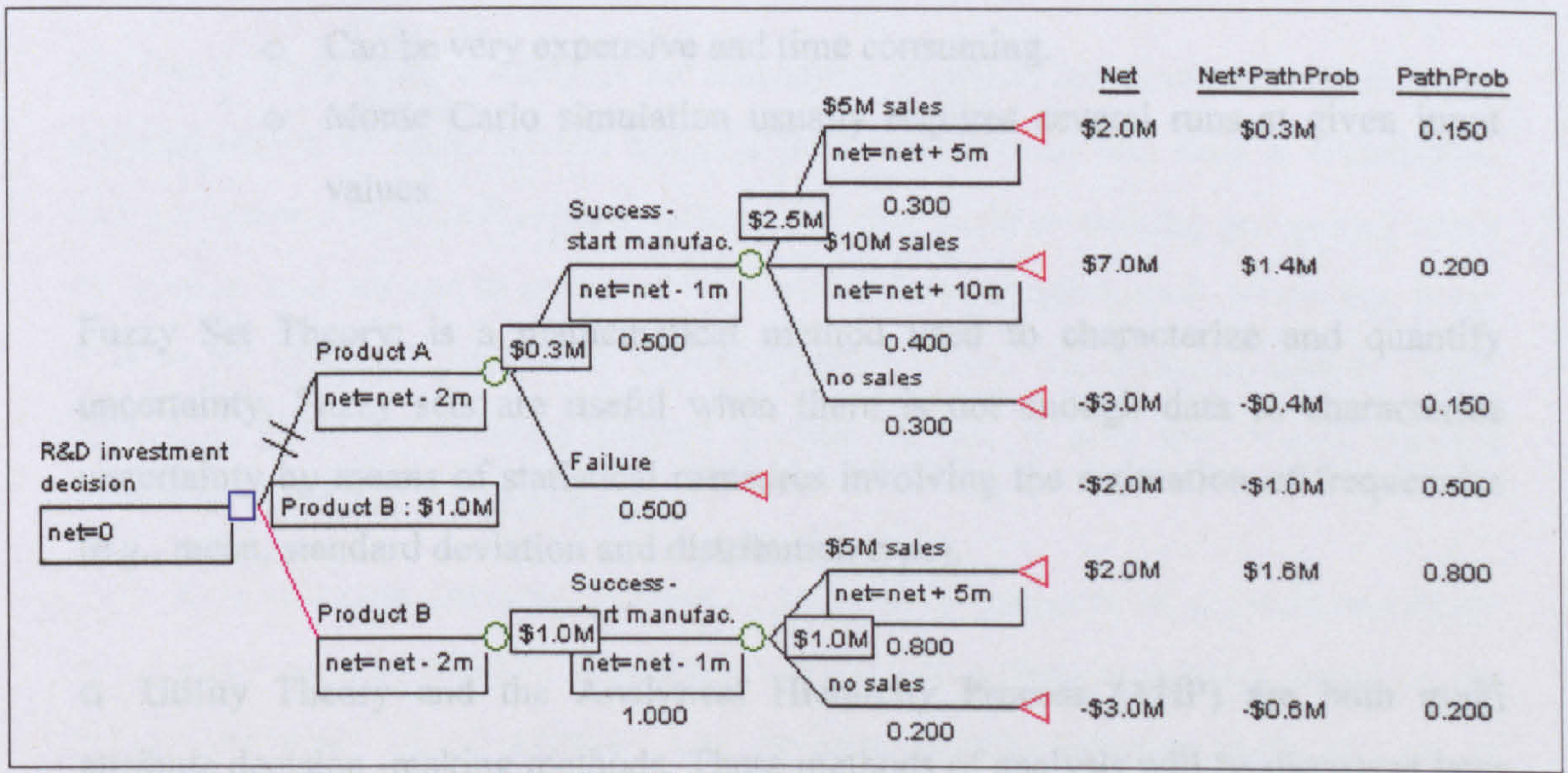


Figure (4.2): An Example of the Decision Tree

- *Advantages of Decision Trees*:
  - Easy to understand and interpret by non-technical people.
  - Can quickly express complex alternatives clearly.
- *Disadvantages of Decision Trees*:
  - Limited to one output attribute.
  - Decision trees algorithms are unstable (slight variations in the data can result in different attribute selections at each choice point within the tree.

Monte Carlo Simulation: is the most easily used form of probability analysis. It makes the assumption that parameters subject to risk and certainty can be described by probability distributions. Estimation of the optimistic, pessimistic and most likely values may be used to draw the probability distribution, as the most likely value becomes the peak of the probability distribution. This technique uses these probability distributions to generate a number of simulations.

- *Advantages of Monte Carlo Simulation*:
  - Used for complex systems.
  - Can maintain control over experimental conditions.
- *Disadvantages of Monte Carlo Simulation*:
  - Can be very expensive and time consuming.
  - Monte Carlo simulation usually requires several runs at given input values.

Fuzzy Set Theory: is a mathematical method used to characterize and quantify uncertainty. Fuzzy sets are useful when there is not enough data to characterize uncertainty by means of statistical measures involving the estimation of frequencies (e.g., mean, standard deviation and distribution type).

❑ Utility Theory and the Analytical Hierarchy Process (AHP) are both multi attribute decision -making methods. These methods of analysis will be discussed later in this chapter.

4.3 Multi-Attribute Decision Making

According to National Economic Research Associates's (NERA) Multi-Criteria Analysis Manual: " Multi criteria decision analysis is both an approach and a set of techniques, with the goal of providing an overall ordering of options, from the most preferred to the least preferred option."

Multi-criteria decision making in the presence of multiple and conflicting criteria is used to evaluate decision problems that involve multiple variables (criteria). A multi-criteria framework allows for interaction and independence among factors that enable the decision maker to arrive at the best alternative. The overall strategy within multi-criteria decisions models involves decomposition followed by aggregation. The decomposition process divides the problem into a number of smaller problems involving each of the individual criteria. This will help the decision maker to analyse the information related to each criteria and to allow for judgements to be made. The process of aggregation is where all data are brought together to present an overall coherent picture to the decision maker.

The use of multi criteria analysis for alternative selection has many advantages. The implementation of multi criteria analysis is straightforward and easy to understand. Also, the choice of objectives and criteria that any decision making group may make are open to analysis and to change if they are felt to be inappropriate. Moreover, it can provide an important means of communication within the decision making body. Finally, it gives the decision makers a clear picture of how the various concept alternatives compare with one another.

Most multi attribute decision techniques involve the concept of a Decision Matrix while others involve an ideal solution A*. A* is a hypothetical solution based on the best achievement of all criteria. The decision matrix indicates both the set of alternatives and the attributes being considered in a given problem. A decision matrix has a row corresponding to each alternative being considered and a column corresponding to each attribute being considered. In case of having m alternatives characterized by n attributes, the decision matrix X is described by a mxn matrix (see equation 1). Each element of the matrix is the score or performance rating of the row's alternative with respect to the column's attribute, and can be either expressed numerically or verbally. The matrix x_{ij} is commonly referred termed the jth attribute value for alternative i.

$$X = \begin{bmatrix} x_{11} \text{ (information about alternative 1 with respect to attribute 1)} & & x_{1n} \text{ (information about alternative 1 with respect to attribute n)} \\ & x_{ij} \text{ (information about alternative i with respect to attribute j)} & \\ x_{m1} \text{ (information about alternative m with respect to attribute 1)} & & x_{mn} \text{ (information about alternative m with respect to attribute n)} \end{bmatrix} = [x_{ij}]$$

Equation (1)

4.3.1 Key Elements in Multi-Criteria Decision Making

- **Uncertainty**

All decision making has a degree of uncertainty, ranging from predictable (deterministic) situation to an uncertain situation. Deterministic situations occur when the values of the decision variables are known with 100% certainty, which is rarely the case in construction. In uncertain situations, decision making involves the risk of making the "wrong" decision, probabilistic or stochastic techniques can be useful when uncertainty exists. These techniques are concerned with factors that cannot be estimated with certainty, such as most data associated with the construction industry. In the construction industry, decisions are to be determined by subjective probabilities as each contract is unique rather than objective probabilities. There are two approaches to the eliciting of subjective probabilities: direct and indirect. In a direct approach, the decision maker assigns a number to his opinion about the outcome in question. While, in the indirect approach, the decision maker has to answer a series of questions and from his answers, it is possible to impute the personal probability or utility.

- **Objectives**

An objective is the goal or aim that is to be achieved.

- **Criteria**

Criteria represent the decision maker's points of view along which it seems adequate to establish comparisons. There are two approaches to determining the set of criteria, reflecting the two ways of building a multi criteria decision analysis problem: a top-down and bottom-up approaches. A top-down approach, where criteria are built from the objectives which is then broken down into criteria. The bottom-up approach supports "alternative-focused thinking" where criteria are identified through a systematic elicitation process.

- **Alternatives**

The set of options the decision maker is concerned with, such as a product of any kind or action plans.

4.3.2 Multi Criteria Decision Making Analysis:

In general, the steps to construct a decision-making model using multi-attribute techniques are as shown in Figure (4.3). The process will start by identifying the overall goal and then alternative scenarios that describe the alternatives among which the decision maker is trying to choose. To assess different impacts of the scenarios and choose the best alternative, criteria identification is needed. The next step is to weigh these criteria.

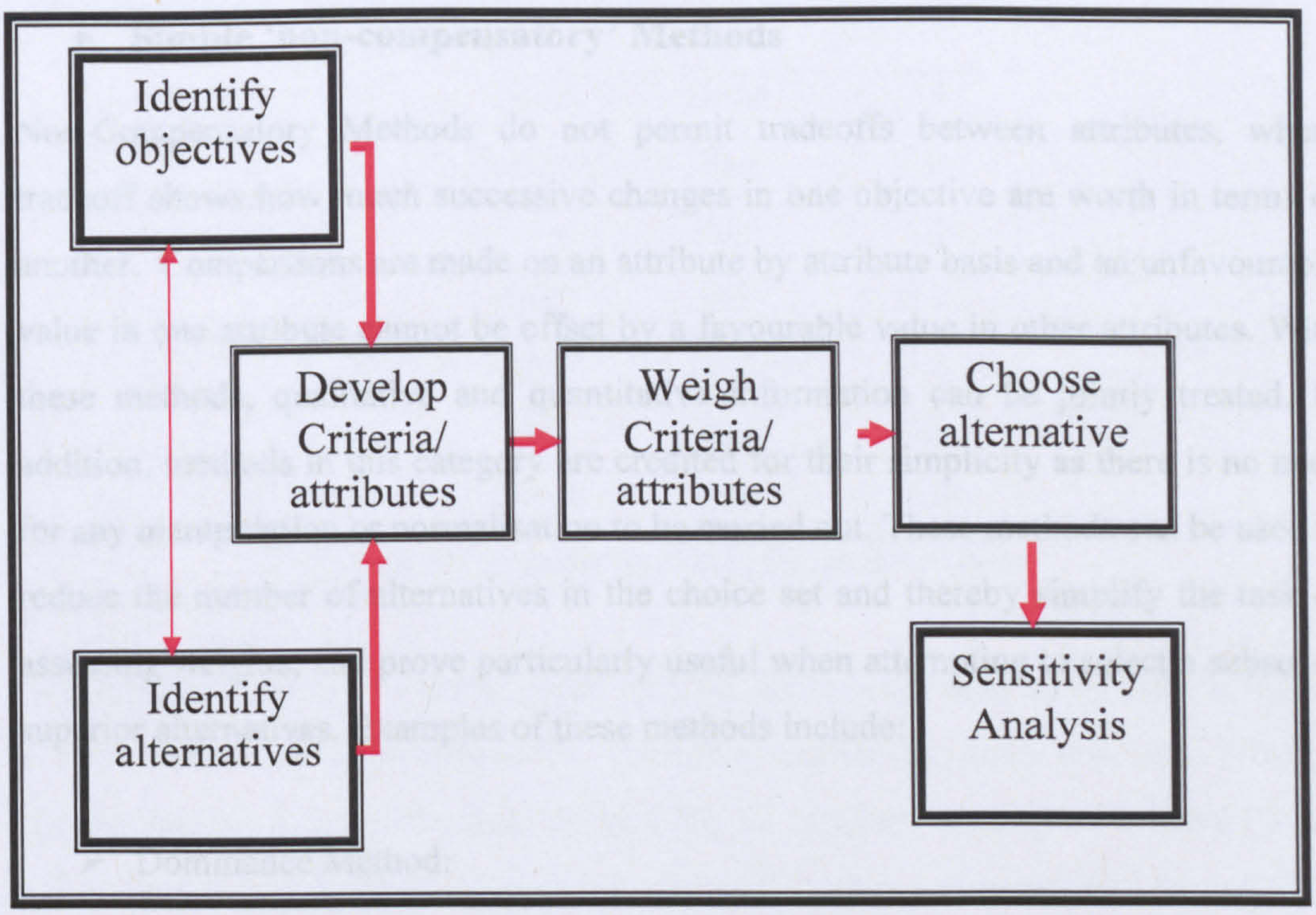


Figure (4.3): Steps for Constructing Multi-Attribute Decision Making Model

Numerous techniques have been developed to enable the decision maker to weight criteria which will be detailed in the next section. The alternative with the highest score will then be selected. Sensitivity analysis is finally carried out to investigate the sensitivity of the results to changes in the priorities of the criteria. This will be explained in Chapter Six.

4.3.3 Multi attribute Decision Making Techniques (Methods)

There are many methods available for solving Multi-Criteria Decision Making Problems. In general, there are two types of MCDM methods. One is compensatory and the other is non-compensatory.

- **Simple 'non-compensatory' Methods**

Non-Compensatory Methods do not permit tradeoffs between attributes, where tradeoff shows how much successive changes in one objective are worth in terms of another. Comparisons are made on an attribute by attribute basis and an unfavourable value in one attribute cannot be offset by a favourable value in other attributes. With these methods, qualitative and quantitative information can be jointly treated. In addition, methods in this category are credited for their simplicity as there is no need for any manipulation or normalisation to be carried out. These methods can be used to reduce the number of alternatives in the choice set and thereby simplify the task of assessing weights, and prove particularly useful when attempting to select a subset of superior alternatives. Examples of these methods include:

➢ Dominance Method:

The main objective of this method is the elimination of all dominated alternatives. An option is dominated if another option exists that performs better than it on one or more of the decision criteria and equals it on the remaining criteria. For example, if option A dominates option B, then B cannot be the single best option and as a result B may be excluded from further consideration. The following example for dominance method is extracted from Rogers (2001) to illustrate how this method can be applied. Developers wish to build a new paper mill and seven potential sites are considered. Three attributes were taken into account for the site selection: having a good supply of water and man-power (C1), a positive community attitude to water pollution (C2) and a small likelihood of union formation (C3). A four-point scale was used to measure C1 and C2 (poor, fair, good and excellent) while C3 is measured as a probability from zero to one, with preference being in favour of the lower score. Table (4.1) gives the score for the seven sites S1 to S7 on each of the three attributes.

Site	C1	C2	C3
S1	Poor	Good	0.5
S2	Excellent	Fair	1.0
S3	Poor	Poor	1.0
S4	Fair	Fair	0.1
S5	Good	Excellent	0.2
S6	Fair	Good	0.9
S7	Good	Fair	1.0

Table (4.1): Decision Matrix for the Seven Sites

When the first option S1 is compared with S2, S1 is better than S2 on criteria C2 and C3 but worse than S2 on criteria C1. Therefore, neither dominates the other. While, if the comparison is made between S3 and S1, S3 is worse than S1 on criteria C2 and C3 and equal on C1. Thus, S3 is dominated by S1. S4 is compared with S1 and S2. It is not dominated by either of them. This process is continued until S7 is reached. Three of the options, S2, S4 and S5, are non-dominated. All others are dominated: S1and S6 by S5, S7 by S2 and S5, and S3 by S4.

- Attribute-Oriented Methods:

Maximin and Maximax methods are Attribute-Oriented Methods. The maximin Method finds the weakest attribute value (min) of each alternative and then chooses the alternative with the best (max) weakest value. This is achieved by determining the worst criterion score for each option and then choosing the option with the best score on its worst criterion. This method is applicable only when attribute values are comparable with one another, either measured in the same unit or transformed to a common scale. This method is particularly useful when the decision-maker does not have any prior information regarding which criterion will have the greatest influence on overall performance. To illustrate how the Maximin method can be applied, an example has been extracted from Rogers (2001), where a local authority wishes to select a site for major regional landfill facility. Six sites were considered as options (A1 to A6), and five criteria were taken into account: road access (C1), effect on the landscape (C2), proximity to centres of population (C3), ecology (C4) and Archaeological significance (C5). A ten-point scale from 1 (worst) to 10 (best) was used. Table (4.2) shows the decision matrix for the six sites. On the basis of the maximin criteria, site A4 would be chosen.

Option	C1	C2	C3	C4	C5	Min	
A1	4	6	3	2	3	2	
A2	7	2	8	2	4	2	
A3	8	5	4	6	3	3	
A4	6	7	5	5	6	5	Max
A5	3	5	6	8	7	3	
A6	8	9	2	8	8	2	

Table (4.2): The Decision Matrix for the Six Sites (Maximin Method)

In contrast to this maximin method, the maximax method selects an alternative by its best attribute value. This is achieved by determining the best criterion score for each option and then choosing the option with the best score on its best criterion. It is also applicable when attributes are comparable.

An example of the Maximax method is extracted from Rogers (2001) where an engineering company wants to select a new chief executive. The board of directors feels that the person selected should have a 'star quality' in at least one of a set of attributes. Seven candidates were listed from A1 to A7 and five criterion were identified as: Decision-making skills (C1), profile within the profession (C2), Academic and professional record (C3), people skills (C4) and international reputation (C5). A ten-point scale from 1 (worst) to 10 (best) was used. Table (4.3) lists the best scores for each candidate. Therefore, candidate A2 would be chosen on the basis of the maximax criteria.

Option	C1	C2	C3	C4	C5	Max	
A1	3	4	6	3	2	6	
A2	8	8	2	8	9	9	Max
A3	7	4	6	5	5	7	
A4	7	2	2	8	4	7	
A5	4	6	8	2	7	8	
A6	5	7	4	5	6	7	
A7	8	7	2	8	5	8	

Table (4.3): Decision Matrix for the Seven Candidates (Maximax Method)

- Satisficing Methods:

There are two methods within this category: conjunctive and disjunctive. The conjunctive method can be undertaken by setting up a minimum standard for each attribute so the alternative selection or evaluation process is simplified to compare each attribute against a standard. For an alternative to be chosen, it must exceed this minimum value on all attributes, otherwise, the alternative will be rejected. The disjunctive method evaluates an alternative on its best attribute regardless of all other attributes. Simply, it requires that an alternative should exceed the standard for at least one attribute.

An example of this method is explained by Rogers (2001), where the decision-makers for the military want to purchase new fleet off-road vehicles. Four models were proposed A1, A2, A3 and A4. Six criteria were considered: maximum speed (km/h, C1), operating range (km, C2), maximum payload (kg, C3), purchase cost (£000, C4), reliability (four-point scale, C5) and technical specification (four-point scale, C6). The minimum standard was specified for each criterion as: C1: $\geq$ 100, C2: $\geq$ 1500, C3: $\geq$ 2000, C4: $\leq$ 60, C5: $\geq$ fair, C6: $\geq$ fair. Table (4.4) gives the decision matrix for off-road vehicles. As can be seen, A1 and A4 are acceptable as they satisfy the requirements. Taking the same example for the conjunctive method, in the case of the disjunctive method, the decision maker specifies the desirable scores for each of the six criteria as: C1: ≥ 130, C2: ≥ 2800, C3: ≥ 2200, C4: ≤ 40, C5: ≥ excellent, C6: ≥ excellent. As a result of these specifications, only A1 is acceptable.

Option	C1	C2	C3	C4	C5	C6
A1	100	1500	2000	55	Fair	Excellent
A2	125	2700	1800	65	Poor	Fair
A3	90	2000	2100	45	Good	Good
A4	110	1800	2000	50	Fair	Fair

Table (4.4): The Decision Matrix for Off-Road Vehicles (Conjunctive Method)

These methods are useful when there are many alternatives, differences between alternatives are small and time is limited.

- Sequential Elimination Methods:

There are two methods that eliminate options in a sequential way: Lexicographic and Elimination by Aspects Methods. They both start by determining the most important criterion. For the Lexicographic Method, if one option has a higher score on the chosen criterion, the most important criterion, than all other options, it is selected and the procedures stops. If there are several alternatives with the same highest value on the specified attribute, then the attribute ranked second in importance is compared across all these alternatives. Yoon and Hwang (1995) applied the Lexicographic Method to a situation where a building contractor wants to buy a number of new dumper trucks for his site operation. Four criteria were considered: list price in £ (C1), resale value in £ (C2), handling on a 10-point scale from 1(worst) to 10 (best) (C3) and acceleration in seconds for 0-60 mph (C4). Eight different dumper trucks were proposed as options, M1 to M8. The decision-maker arranged the criteria in the following order of importance: handling (C3), list price (C1), acceleration (C4) and resale value (C2). The performance matrix for the eight options is given in Table 4.5 below. As the most important criteria is C3, five options (M1, M2, M3, M4 and M7) are tied for the first position. Then the second most important criteria is the list price (C1), M1 is selected as it has the lowest price of £ 8300.

Option	C1	C2	C3	C4
M1	8300	3000	7	14.7
M2	9600	3600	7	19.1
M3	10580	3600	7	10.8
M4	13700	6000	7	13.0
M5	29850	12000	4	13.7
M6	11050	3600	4	16.2
M7	9800	3600	7	15.3
M8	27650	12000	1	13.5

Table (4.5): The Performance Matrix for Dumper Truck Options

For the Elimination by Aspects Method, evaluation proceeds with one attribute at a time, starting with attributes determined to be most important. Then, a standard is determined for the most important criterion and all alternatives with a value less than this standard-with respect to the single attribute of interest, are eliminated. The process continues with the second most important attributes then the third and so on until only one outcome remains.

- **Compensatory Methods**

Compensatory Methods permit tradeoffs between attributes. They are based on the assumption that the high performance of an alternative achieved in one or more criteria can compensate for the weak performance of the same alternative on other criteria. Compensatory methods can be classified into the following:

1. Scoring Methods:

The scoring method selects an alternative according to its score or utility. Score or utility is used to express the decision maker's preference. It transforms attribute values into a common scale such as (0,1) to allow for comparisons between different attributes. Both Simple additive weighting methods and the Analytical Hierarchy Process are scoring methods.

- Simple Additive Weightings Methods

Additive Weighting method is the simplest form of a more general decision model based on Multi-Attribute Utility Theory which was developed by Kenney and Raiffa in 1976. The main idea of Multi-Attribute Utility Theory is the formulation of a mathematical function called a multi-attribute utility function for each criterion so that the selected option for each criterion can be represented by a common scale for comparison with other criteria options. The following are the steps to develop a utility function (Dozzi, et al, 1996):

- Specify the range of interest for each criterion, upper and lower limits.
- Identify the neutral point of contribution for each criterion and the most preferred point.
- Define the utility scale.
- Develop the utility function by either straight-line or exponential function and solve for the constants of each equation. Where,
  - Straight-line equation: $u_j(y_j) = A_j y_j + B_j$
  - Exponential equation: $u_j(y_j) = A_j e^{B_j y_j} + C_j$

  Where, $u_j(y_j)$ is utility of criterion j *and* A_j, B_j and C_j are constants.

The following is an example of the simple additive weighing method extracted from Rogers (2001). Three proposed designs for a new car have been compared on the basis of five criteria: purchase cost (£), level of safety (ten-point scale), aesthetic appearance (ten-point scale), mass (kg) and reliability (%). Table 4.6 shows the raw scores for each proposal on the five criteria.

Option	Cost (£)	Safety (0-10)	Appearance (0-10)	Mass (kg)	Reliability (%)
Car 1	18000	9	8	970	95
Car 2	11000	8	4	720	80
Car 3	15000	7	6	600	88

Table (4.6): Raw Criterion Scores (Simple Additive Weighting Method)

Table (4.7) shows the normalized weights for each criterion. The criterion score are then converted to dimensionless numbers by calculating the ratio of each criterion score relative to the best score over all the available options under examination. For example, Rating (option 1) = 1100/1800 x 10 = 6.1 as shown in Table (4.7). Finally the score of each option is calculated as a product of the weight and the rating as shown in Table (4.7). Option 1 is the preferred option with the highest score.

Criterion	Weight	Option 1	Option 2	Option 3
Cost	0.25	6.10	10.0	7.30
Safety	0.20	9.00	8.00	7.00
Appearance	0.25	8.00	4.00	6.00
Mass	0.10	6.20	8.30	10.0
Reliability	0.20	10.0	8.40	9.30
Score	-	7.95	7.61	7.59

Table (4.7): Criterion Weightings & Overall Scores for the Three Options

Dozzi, S. et al, (1996) developed multi-criteria model using the utility theory method. The model was applied to the bid mark-up decision for a specific project. 21 criteria affecting the mark-up decision were used and classified into: environment factors (such as graphical factors, economic factors and historic factors), company factors (such as required rate of return and overhead recovery) and project factors (such as type, complexity and cash flow requirements). The utility functions for each bidding criteria was developed using the straight line method. The calculated utility functions for all criteria represent preferences or trade-offs between criteria and were measured on a scale so that the expected utilities of individual criteria could be combined to form a single expected utility. The use of the model was verified by including an example application of the utility theory model applied to the bid mark-up decision.

Cheung, S. and Suen, C. (2002) developed a decision making model using the Analytical Hierarchy Process (AHP) and multi attribute utility theory approach (MAUT). The model was designed to identify an appropriate dispute resolution strategy for a given dispute. A questionnaire survey was distributed among 30 professionals in dispute resolution strategies in Hong Kong construction industry. Eight criteria were selected: confidentiality, flexibility in issues, strategy and agreement, binding decisions and enforcement, overall duration, relative cost, preservation of relationships, degree of control by parties and degree of control by the neutral. Then, Expert Choice Software implementing the Analytical Hierarchy process together with MAUT was then used to analyze the criteria weightings. The model was tested by a hypothetical scenario in which three case studies were evaluated.

Chang, C. and Ive, G. (2002), employed the Multi-Attribute Utility Theory (MAUT) approach to help the client in developing a construction procurement technique. In this study, eight factors were considered to affect the client's choice of procurement system: speed, price certainty, flexibility, quality standards, complexity, risk allocation, responsibility and price competition. Three procurement options were presented as alternatives; traditional method, design and build and construction management.

Although MAUT is a well-known approach for decision-making, the main limitation of this method is the difficulty in formulating the Multi-Attribute Utility functions precisely to represent a decision-maker's view of the impact and value of a certain outcome (Skibniewski and Chao, 1992). Furthermore, Belton (1986) states that the greatest weakness of Multi-Attribute Utility Theory is its failure to incorporate systematic checks on the consistency of judgments.

- Analytic Hierarchy Process

  The Analytical Hierarchy Process was developed by Thomas Saaty in 1980. It is used to select the optimal alternative among a set of alternatives by comparing their relative performance on the criteria of interest after taking into account the decision maker's relative preference of these criteria. This method will be discussed in details in Chapter Five.

2. Compromising Methods:

The compromising methods select an alternative that is closest to the ideal solution. The ideal solution point represents a hypothetical alternative consisting of the most desirable outcomes for the evaluation criteria considered in a given decision situation. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is an example of compromising methods. In the TOPSIS technique, the chosen alternative should be as close to the ideal solution as possible, and as far from the negative-ideal solution as possible. The ideal solution is a composite of the best performance values exhibited (in the decision matrix) by any alternative for each attribute. The negative-ideal solution is the composite of the worst performance values.

Vatalis, K. and Manoliadis, O. (2002) presented a two-stage multi-criteria evaluation model for selecting the appropriate site for waste disposal. In the first stage, a Geographic Information System (GIS) digital map was used to select suitable landfill sites in Western Macedonia. The map displays residential areas, grasslands, croplands, woodlands, surface water, rivers, lakes and elevation. These proposed areas meet the condition that they are at least five miles away from rivers, lakes and residential areas. In the second stage, the criteria for determining the most appropriate site were identified. These criteria were grouped under environmental (including factors such as groundwater quality impairment and surface water quality impairment), economic land use and social value (such as the distance from human settlements, the depreciation cost and proximity to protected places) and technical operational (including the climate, the design of the site, access roads and others). The multi-criteria technique used to combine those criteria and to rank the alternatives, the proposed land fill sites, was the compromise programming.

Cha, Y. et al (2003) used TOPSIS as a multi criteria decision making method to help in the selection and evaluation of an appropriate manufacturing policy by assessing the degree of satisfaction for schedules. The degree of satisfaction of a schedule has been estimated by simulating the schedule and calculating various performance indicators. Then they used the performance indicators from simulation as criteria for the degree of satisfaction for the schedule. Seven criteria were used: average utilization of machines, minimum utilization of machines, average idleness of machines, maximum idleness of machines, throughput, total number of machine breakdown and total time of machine breakdown.

3. Concordance Methods:

The main idea of the Concordance methods is to rank a set of alternatives by means of their pair-wise comparisons in relation to the chosen criteria to determine the concordance score. The ELECTRE Method is one of the examples in this category. Several versions of ELECTRE have been developed (I through IV) based on the same concepts but operationally different. Two important concepts underline the ELECTRE method; thresholds and outranking.

An example of the concordance methods has been extracted from Rogers (2001) where five criteria were assumed j=1, 5, and the score of two options on these is shown in Table (4.8).

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Option a	4	3	4	2	4
Option b	4	4	2	2	3

Table (4.8): Option Scores on Each Criterion (Concordance Method)

The concordance scores are as follows:

On criterion 1, option a is at least as good as option b, therefore: C1 (a,b)= 1.0

On criterion 2, option a is not at least as good as option b, therefore: C2 (a,b)= 0

On criterion 3, option a is at least as good as option b, therefore: C3 (a,b)= 1.0

On criterion 4, option a is at least as good as option b, therefore: C4 (a,b)= 1.0

On criterion 5, option a is at least as good as option b, therefore: C5 (a,b)= 1.0

Then, the dominance of a or b is determined by using the relative importance weightings for the criteria as shown in Table (4.9).

Criterion	Weighting Score	Normalized Weight
1	1	0.125
2	2	0.250
3	2	0.250
4	1	0.125
5	2	0.250

Table (4.9): Criterion Weights (Concordance Method)

The overall concordance index for (a,b) is obtained by multiplying each criterion concordance score by its normalized weight.

C (a,b)= 0.125(1) + 0.25(0) + 0.25(1) + 0.125(1) + 0.25(1) = 0.75

According to concordance method, the nearer the concordance index (0.75 in this example) to one, the more certain that a outranks or dominates b. The concordance index is then calculated for each pair of options to form the concordance matrix. The result will be that option a dominates option b.

4. Evidential Reasoning Approach

The theory of evidence was first developed by Dempster in 1967 and further extended by Shafer in1976. This is why the theory is often referred to as Dempster-Shafer Theory of Evidence. The Evidential Reasoning Approach was developed in the early

1990's as a multi attribute decision making method. The ER approach uses an extended decision matrix, in which each attribute of an alternative is described by a distributed assessment using a belief structure; it describes and handles uncertainties by using the concept of degrees of belief. Degree of belief or belief degrees are subjective probabilities associated with assessment grades. It describes the confidence level of an attribute being evaluated to a grade. The belief degree could be generated from a survey or group decision-making. For example, the distributed assessment result of the quality of a car engine could be (excellent: 60%), (good: 40%), (average: 0%), (poor: 0%), (worst: 0%), which means that the quality of the car engine is assessed to be excellent with 60% of belief degree and good with 40% of belief degree. The extended matrix for M alternatives, with each alternative has N attributes is M′ N matrix; whose element X_{ij} is the distributed assessment of the i-th alternative on the j-th attributes. It is similar to a decision matrix except that each element is an array of assessment grades, not a single number or grade.

Sonmez, M. et al, (2002) utilizes the multi criteria decision making theory of evidential reasoning for a contractor pre-qualification problem. The criteria considered in this study were classified under five groups: contactor's organisation (including age, size, quality control policy and health and safety policy), financial considerations (such as ratio analysis accounts, bank reference and turnover history), management resources (consists of quality of key persons, qualification of owners and years with company), past experience (divided into the type of project completed, size of projects completed and national/local experience) and past performance (including failure of a contract, overruns: time, overruns: cost and actual quality achieved). An example of how the evidential reasoning theory can be used to assess seven contractors based on the pre-qualification criteria was also demonstrated in this paper. This paper showed the importance of the concept ' degree of belief' used in the ER approach. This is due to the fact that it is important to obtain the decision maker's true preference in a decision making problem to be able to reach a rational decision. They concluded that the ER approach is not better that any other multi criteria decision making method.

4.4 Summary

Decision making is an everyday activity which involves selecting between different alternatives. Decision making process can be made formally or informally. In this chapter, a brief description of some formal decision making techniques such as Decision Trees, Monte Carlo Simulation, Fuzzy Set Theory, Utility Theory and the Analytical Hierarchy Process was provided.

In bidding decisions the multi-attribute aspect of decision-making exists because the outcomes must be evaluated in terms of several objectives and sub-objectives. Many methods have been developed for multi-criteria decision-making. Compensatory and non-compensatory are the two types of multi-criteria decision making methods. Compensatory methods include scoring, compromising, concordance methods and evidential reasoning approach. Non-compensatory methods consists of dominance, attribute oriented, satisficing and sequential elimination methods. Each of these methods adopt different approach to try and reach a reasonable decision. A primary advantage of MCDM is the provision of a highly structured decision-making technique. Adopting these techniques develop a comprehensive analysis of complex problems by carefully identifying criteria, alternatives and recommending the best alternative.

In this research study, the focus will be on the Analytical Hierarchy Process to model the decision-making process in bidding for construction projects. It is a flexible multi-attribute decision-making method which incorporates both qualitative and quantitative factors. It treats the decision as a system and organise the decision-maker thoughts. The Analytical Hierarchy Process will be discussed in detail in chapter six.

CHAPTER Five

Qualitative and Quantitative Research Methods

5.1 Introduction

The objectives of this thesis have been identified in earlier chapters. This chapter is concerned with the methods available for implementing these objectives. Two main research approaches have been identified: qualitative and quantitative research. In qualitative research, the opinion and beliefs of people are investigated while in quantitative research; statistical methods are used to test a theory.

In this chapter, the features and methods of qualitative and quantitative research are discussed. Section (5.2) provides a definition for both research methods. In section (5.3), the features of qualitative research are identified. This is followed by a description of some of the qualitative research methods in section (5.4). Section (5.5) explores the features of the quantitative research. Section (5.6) describes different quantitative research methods. The research methods that were used in achieving the main objectives of this study are stated in section (5.7).

5.2 Definition of Qualitative and Quantitative Research

Quantitative and qualitative research can be distinguished as follows:

Quantitative research is an inquiry into an identified problem, based on testing a theory, measured with numbers, and analysed using statistical techniques. The goal of quantitative methods is to determine whether the predictive generalizations of a theory hold true.

By contrast, a study based upon a qualitative process of inquiry has the goal of understanding a social or human problem from multiple perspectives. Qualitative research is conducted in a natural setting and involves a process of building a complex picture of the phenomenon of interest. *(Source:* http://www.unr.edu/bench/chap04.pdf)

5.3 Features of Qualitative Research

The following are the main features of qualitative research (Huberman and Miles, 2002):

- Inductive: qualitative research is an inductive one as it begins by making observations, usually in order to develop a new hypothesis or contribute to new theory.
- Subjective: qualitative research more often seeks the lived experience of the participants in the research and therefore subjectively determined.
- Data obtained from the qualitative research is in the form of words, pictures or objects.
- Qualitative research usually begins with open-ended observation and analysis, most often looking for patterns and processes that explain "how and why" questions.

5.4 Qualitative Research Methods:

Methods of qualitative research include: Focus Groups, Case Studies, Participant Observation and Action Research. The principles and characteristics of qualitative research will be discussed in the next section. An evaluation of focus groups as a method of qualitative research will be provided. The key attributes of Case Studies, Participant Observation and Action Research will be discussed. Approaches to analysis of qualitative data will be assessed.

5.4.1 Focus Group Interviews

- **Key Features of Focus Groups (http://www.webcredible.co.uk)**

A focus group interview is a qualitative method of research with the primary aim of describing and understanding perceptions, interpretations, and beliefs of a select population to gain understanding of a particular issue from the perspective of the group's participants. Typically, focus group interviews involve a group of 6 to 10 people who come from similar social and cultural backgrounds or who have similar experiences or concerns. A focus group interview has several important features:

- It enables in-depth discussions and involves a relatively small number of people.
- It is focussed on a specific area of interest that allows participants to discuss the topic in greater depth.
- It is a group discussion that relies heavily on the interaction between participants, rather than a group interview. It is successful only when the participants are able to talk to each other, rather than individually answering the moderator's questions.
- Interaction is a unique feature of the focus group interview. Indeed, this characteristic distinguishes the method from individual in-depth interviews. It is based on the idea that group processes assist people to explore and clarify the points of views. Such processes tend to be less accessible in an individual interview.
- A moderator introduces the topic and assists the participants to discuss it, encouraging interaction and guiding the conversation. The moderator plays a major role in obtaining good and accurate information from the focus group method.
- The participants usually have shared social and cultural experiences (such as age, gender, ethnicity, religion, and educational background) or shared particular areas of concern.

- **Recruiting Participants to Focus Groups**

There are a number of methods for recruiting participants to focus groups. They include:

- Random telephone screening: participants are randomly selected from a telephone directory.
- Snowball: participants are asked to bring a friend to the discussion.
- Piggyback: participants suggest others who meet the characteristics for focus groups.

- Existing lists: lists of people, such as consumers of products or services are used.
- On the spot: people using a particular service are invited to participate.

- **The Moderator**

One of the key players in a focus group, who has a significant influence on the collection of rich and valid information, is the moderator. The task of the moderator is to stimulate the participants to actively engage in the discussion of the topic. The moderator also needs to be able to control the group to proceed in the direction that the focus group takes. There are a number of characteristics of a good moderator.

- A moderator needs to be sensitive to the needs of the participants.
- A moderator needs to be non-judgemental about the responses from the participants.
- A moderator needs to respect the participants.
- A moderator needs to be open minded.
- A moderator needs to have adequate knowledge about the subject.
- A moderator needs to have good interpersonal skills.
- A moderator needs to have good listening skills.
- A moderator needs to have good leadership skills.
- A moderator need to have good observation skills.
- A moderator needs to have patience and flexibility.

- **The Note Taker**

A note-taker is also essential in focus group interviews. The moderator is not able to take notes, because of the demanding nature of the task of running focus group sessions. The note-taker records the key issues emerging in the session and other factors that may be important in the analysis and interpretation of results. The note-taker writes down participants' responses as well observes and records non-verbal responses that may assist in understanding how participants feel about particular issues. Non-verbal responses include facial expressions and body gestures, which may convey feeling of approval, interest, boredom, impatience, resentment, or anger.

- **Recording Group Discussions**

Focus group discussions can be recorded as above by a note-taker. Secondly, discussions can be recorded on a tape recorder. This method is invaluable and generally recommended for all focus groups. Typically, the note-taker will not be able to record everything that is discussed, but this can be overcome with the tape recorder. The recorded discussions are then later transcribed in full for data analysis.

Participants need to be fully aware of the presence of the tape recorder and to understand that its purpose is to capture their comments as accurately as possible. The researcher also needs to obtain permission from the participants. This must be organised before the focus group is started.

- **Advantages of Focus Groups**

The use of focus groups provides a number of advantages relative to other types of research:

- Focus groups can collect data from a group of people much more quickly and at less cost than would be the case if each individual were interviewed separately. They can also be assembled on much shorter notice than would be required for a more systematic larger survey.
- Focus groups allow researchers to interact directly with respondents. This provides opportunities for clarification and probing of responses as well as follow-up questions. Respondents can qualify responses or give contingent answers to questions. In addition, researchers can observe non-verbal responses, such as gestures, smiles, and frowns, which may carry information that supplements and, on occasion, even contradicts, verbal responses.
- The open response format of focus groups provides researchers the opportunity to obtain large and rich amounts of data in the respondents' own words. Researchers

can determine deeper levels of meaning, make important connections, and identify subtle nuances in expression and meaning.

- Focus groups are very flexible. They can be used to examine a wide range of topics with a variety of individuals and in a variety of settings.
- Focus groups may be one of the few research tools available for obtaining data from children and from individuals who are not particularly literate.
- The results of focus group research are usually easy to understand. Researchers and decision makers can readily understand the verbal responses of most respondents. This is not always the case with more sophisticated survey research that employs complex statistical analysis.
- Multiple individuals can view a focus group as it is conducted, or review a video or audiotape of the group session. This provides a useful vehicle for creating a common understanding of an issue or problem. Such an understanding can be especially helpful for team building and for reducing conflict among decision makers.

- **Disadvantages of Focus Groups**

Although the focus group technique is a valuable research tool and offers a number of advantages, it does have significant limitations, many of which are simply the negative sides of advantages listed above:

- The small numbers of respondents that participate in even different focus groups and the convenience nature of most focus group recruiting practices significantly limit generalisation to larger populations. Indeed, persons who are willing to travel to a locale to participate in a 1 to 2 hours group discussion may be quite different from the population of interest.
- The interaction of respondents with one another and with the moderator has two potentially undesirable effects. First, the responses from members of the group are not independent of one another, which restrict the generalisability of results. Second, the results obtained in a focus group may be biased by a very dominant or opinionated member. More reserved group members may be hesitant to talk.

- The "live" and immediate nature of the interaction may lead a researcher or decision maker to place greater faith in the findings than is actually warranted. There is a certain credibility attached to the opinion of a live respondent that is often not present in statistical techniques.
- The open-ended nature of responses obtained in focus groups often makes summarisation and interpretation of results difficult. Statements by respondents are frequently characterised by qualifications and contingencies that make direct comparison of respondents' opinions difficult.
- A moderator, especially one who is unskilled or inexperienced, may bias results by knowingly or unknowingly providing cues about what types of responses and answers are desirable.

Although focus groups have important limitations, they are not unique to focus group research. All research tools in the social sciences have significant limitations. The key to using focus groups successfully is ensuring that their use is consistent with the objectives and purpose of the research.

5.4.2 Use of Case Studies

A case study is an empirical enquiry that investigates a contemporary phenomenon within its real life context. It is particularly relevant when the boundaries between phenomenon and context are not clearly defined.

Most qualitative research is a form of case study and some writers treat the terms "qualitative research" and "case study" as virtually identical. This is misleading as case studies often use quantitative methods as well as qualitative methods, and sometimes only use quantitative approaches (e.g. an attitude survey of employees in a single plant). We shall concentrate on qualitative methods in this section.

The issue of *generalisation* is controversial in case study research. Obviously it is hard to convincingly proclaim general truths or universal laws based on a sample of one case study. However, good case study research does not try to do this. Rather it will attempt one or more of the following:

- Explore previously unexamined territory.
- Generate theory which may later be tested by other large scale investigation.
- Test or confirm existing theories in specific contexts.

5.4.3 Participant Observation

The method of participant observation has its origins in ethnographic research studies in which anthropologists would live for prolonged periods with the peoples they were studying. It has a large literature in sociology and anthropology. For example, participant observation has been used in the study of industrial workers to identify how workers manipulate piecework systems and the reasons for doing so.

There are basically two approaches available to the participant observer (Spradley, 1980):

Explicit Researcher Role

The researcher is present each day over a period of time and is known by management and employees alike to be a researcher. Permission to observe has been negotiated openly with management and any other necessary party (such as trade unions).

Researcher as Employee

The researcher works within an organisation along with other employees, to all intents and purposes as one of them. Methodologically this role can be appropriate when the researcher needs to become fully experienced in the work and/or culture being studied. In this role researchers may find themselves isolated from their own culture for lengthy periods which can produce psychological pressure. It should be remembered that there will be physical strain on the researcher who will have to write up considerable amounts of data each night after doing a full day's work. There can also be considerable anxiety induced by the deception necessary to undertake such work. In some cases this may be increased by the risk of actual physical danger in the event of discovery. All these issues must be very carefully considered before this form of participant observation is adopted as a research method.

5.4.4 Action Research (http://www.jeanmcniff.com/booklet1)

Action research is an approach to applied social research in which the researcher and client collaborate in the development of a diagnosis of, and solution to, a problem. It has obvious applicability for management research in situations such as consultancy, and can be an attractive and viable research design for managers who are working full time and studying part time, since the researcher can use a real world problem as the basis of his/her research. Often the emphasis of action research is on the need to understand a total system in conducting the analysis, and many action research projects are in fact special kinds of single case studies (although there are examples of multiple case action research studies).

The whole range of data collection methods can be used in action research, but as with case studies we generally regard action research as a qualitative approach. The term *participative* is often used in describing certain forms of action research to distinguish cases where the researcher has a significant input in the definition of the problem from those where senior managers effectively set the agenda.

In the context of management research, *action research always involves two goals: solving the problem for the client and contributing to academic knowledge about the problem.* So the person conducting this type of research will be both a management consultant and academic researcher at the same time. As a consultant he/she must help the specific client. As a researcher, the results obtained must be presented in relation to previous research and literature, and, through his/her thesis and any related publications, distribute them to the academic community (respecting the confidentiality of your client where necessary). So although management consultants are ideally placed to become action researchers, action research is more than just consultancy. During an action research project, those involved, researcher and client, should learn from each other and develop their competence. Action research is a suitable research and consultancy strategy for change processes in business and other organisations.

Procedure to Follow in Action Research

A useful model to follow in conducting action research is as follows:

1. *Diagnosing*: identifying or defining a problem
2. *Action Planning*: considering alternative courses of action for solving the problem
3. *Action Taking*: selecting a course of action
4. *Evaluating*: studying the consequences of an action
5. *Specifying learning*: identifying general findings

The above model represents a cyclical process: Step 5 *Specifying Learning* may feed back into Step 1 *Diagnosing*.

5.5 Features of Quantitative Research

The following are the main features of quantitative research (http://www.rdinfo.org.uk/flowchart/characteristics.htm):

- Deductive: quantitative research has a deductive nature as it tests theory or hypotheses to provide evidence for or against this theory.
- Objective: as quantitative research seeks precise measurement and analysis of target concepts, e.g., uses surveys, questionnaires etc.
- Quantitative research usually begins with pre-specified objectives focused on testing preconceived outcomes.
- Data is in the form of numbers and statistics.

5.6 Quantitative Research Methods

Quantitative research methods refer to a group of methods whose main focus is on quantities i.e. numbers. Numbers will usually be the main type of data that these methods collect and then those numbers will be analysed using mathematical or statistical techniques. Major types of quantitative research methods are Experimental, Quasi-Experimental and Surveys.

5.6.1 Experimental

Experimental studies are quantitative search methods used to study a certain phenomena, mainly by examining cause and effect. Experiments usually designed to examine the influence of an independent variable (e.g. treatment) on a dependent variable. The main issue when conducting an experimental study is to control as many aspects of the situation as possible; such as participants and the environment in which the experiment is conducted. Laboratory studies are examples of this type of method.

5.6.2 Quasi-Experimental

Quasi-experimental studies are similar to experimental studies except that the researcher does not have full control over the situation in which the experiment is conducted. Quasi-Experimental methods of research are commonly applied in health related studies; where it is difficult to allocate participants to different groups due to ethical and practical reasons.

5.6.3 Surveys (http://www.writing.colostate.edu/guides/research/survey)

The most popular method of data collection used in quantitative research is the survey. The survey technique involves the collection of primary data about subjects through a questionnaire. The survey is usually conducted on a particular population to collect certain type of data. Surveys could be conducted via telephone, self-administration, or face-to-face surveys.

- Telephone surveys could be conducted by trained interviewers or by automated systems. The following are the advantages and disadvantages of telephone survey.

Advantages:

- They allow for random sampling and there tends to be less interviewer bias.
- large numbers of people can be contacted at a relatively low cost.
- easy to survey people who live in wide geographic areas.
- easy to reach some disabled people.

Disadvantages:

- respondents without a telephone or those that are ex-directory are excluded
- trained interviewers must be used.
- more easy for the respondent to be distracted than in a face to face survey.
- the language barrier will need to be addressed if the person speaks little or no English.
- telephone surveys have high refusal rates.
- cold calling can often annoy the prospective respondent.
- sample results may not be representative.

- "Self-administered surveys require the respondent to complete the questionnaire him/herself. Mail/postal surveys and computer/on line surveys are the most common ways of distributing these surveys.

    - *Mail Surveys/* postal survey: These involve sending out these surveys to respondents for them to complete. The following are the advantages and disadvantages of this type of survey.

Advantages

- large numbers of people can be contacted, either targeted or at random, at relatively low cost.
- Sensitive information can be collected as they provide anonymity for the respondent.
- sample can be statistically accurate.
- respondents can fill out the questionnaire in their own time, which may lead to more considered responses.
- Can collect data from large number of people at relatively low cost.

Disadvantages

- Surveys should be designed carefully to ensure that it meets the objectives.
- forms need to be kept short or they will put off respondents from filling them in.
- there tends to be a low response rate – sometimes as low as five per cent.
- little control over the feedback.

  - ***Computer/Online Surveys***. Surveys can also be administered by computer and the Internet. The following are the advantages and disadvantages of the computer/online surveys.

Advantages

- Complicated surveys can be completed by facilitating ' help menus' to help respondents.
- large numbers of people can be contacted at low cost.
- most software packages will do basic analysis at the touch of a button.
- easy to survey people who live over a wide geographic area.
- may encourage some hard-to-reach groups to take part.
- the respondent can fill out the questionnaire in their own time.
- data can be collected very quickly.

Disadvantages

- only respondents with internet access can fill in this type of survey.
- some potential respondents find filling out online forms daunting.
- there is little or no control over who fills in the questionnaire.
- people with poor literacy skills or with English language difficulties may not respond.

- **Face to face surveys**: where questionnaires are filled in by interviewing the respondents. The advantages and disadvantages of this method are as follows.

Advantages

- the questionnaire can often be longer than a postal survey.

- the questionnaire can be designed so that different groups of people can be interviewed.
- a higher response rate is usually achieved than with postal surveys.
- it is easier to identify the appropriate person to complete the questionnaire.

Disadvantages

- more expensive than postal surveys.
- time consuming and labour intensive.
- interviews can be done at different times of the day to ensure that all persons are questioned.
- requires trained interviewers.
- interviewers can be trained in sign language or be accompanied by an interpreter.
- may be more time consuming for the respondent.

5.7 Methodology of Data Collection

For the purpose of this study, a combination of both qualitative and quantitative methods will be used for data collection. Self administrated questionnaire survey which is a quantitative research method will be used to collect primary data. Then a case study, which is a qualitative research approach, will be employed to validate the developed models.

5.8 Summary

In this chapter, the main features of qualitative and quantitative research methods have been described. The qualitative research methods, which include focus groups, participant observation, action research and case studies, have been discussed. Then, the quantitative research methods which include experimental, quasi-experimental and surveys have been reviewed. Both research methods, qualitative and quantitative, will be combined to collect the data required for this particular study. Details of how the questionnaire was designed and the analysis of the data collected will be discussed later. Most of the developments in this study have involved application of the Analytical Hierarchy Process. The key principles that underlies this technique are discussed next.

CHAPTER SIX

Analytical Hierarchy Process

6.1 Introduction

The Analytical Hierarchy Process is a decision making tool that incorporates both qualitative and quantitative factors. It is a systematic method for comparing a list of alternatives. In this study, the Analytical Hierarchy Process (AHP) is used to model the decision-making process in bidding for construction projects. It involves building a hierarchy of decision elements and then making comparisons between each possible pair in each level (as a matrix). This gives a weighting for each element within a level of the hierarchy and also a consistency ratio which is useful for checking the consistency of the data.

In this chapter, an overview of the Analytical Hierarchy Process is introduced in section (6.2) with a description of the steps involved in constructing the AHP model. The mathematical framework underlying the eigenvector method, which is the approach used for finding the priority vector in the Analytical Hierarchy Process (AHP) is given. Section (6.3) describes how the AHP measures the reliability of judgements of the decision maker by means of a consistency check. Section (6.4) shows how group decisions can be made using the AHP. Section (6.5) provides an illustrative example of the Analytical Hierarchy Process applied to a decision making process. Finally, in section (6.6), some problematic features with the Analytical Hierarchy Process are discussed followed by a literature review of published research into applications of the AHP in section (6.7).

6.2 An Overview of the AHP

The Analytical Hierarchy Process (AHP) developed by Dr. Thomas Saaty in the 1980s, is a powerful and flexible multi-criteria decision making process that helps managers to set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. Like any good decision tool, the AHP is not designed to substitute for clear thinking by the decision-maker. It does, however, organise their thoughts and makes them more presentable to others.

The real strength of AHP, though, is that it treats the decision as a system, which is difficult for many decision-makers to do due to the number of factors involved in a complex decision. The AHP model breaks down the complex structure of the decision process to a hierarchical sequence in order to determine the relative importance of each alternative through pair-wise comparisons. Pair-wise weighting among n elements in each level leads to an approximation $a_{ij} = w_i / w_j$ which is the ratio of the weight of element i to element j. The estimated weight vector w is found by solving the following eigenvector problem:

$Aw = \lambda_{max} w$ Where, λ_{max} is the principal eigen-value of A.

and

$$A = \begin{bmatrix} w_1 / w_1 .. w_1 / w_2 .. w_1 / w_n \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ w_n / w_1 .. w_n / w_2 .. w_n / w_n \end{bmatrix}$$

The AHP has a unique feature in that it measures the quality of the input data, a measure of inconsistency, which enables decision-makers to determine judgments that need reassessment.

Basically, there are three steps for considering decision problems by AHP: Constructing hierarchies, comparative judgments and synthesis of priorities, described as follows.

6.2.1 Establishment of a Structural Hierarchy

This step allows a complex decision to be structured into a hierarchy of elements describing the problem. The objective or goal from the decision-maker's viewpoint is represented at the top level of the hierarchy. This is followed by the intermediate levels that represent the criteria and sub-criteria contributing to the decision. Finally, the lower level comprises the decision alternatives or options. As an example, consider the simple hierarchy shown in Figure (6.1) below.

According to Saaty (2000), a hierarchy can be constructed by creative thinking, recollection and using people's perspectives. He further notes that there is no limit to the number of levels in a hierarchy. If one is unable to compare the elements of a level in terms of the elements of the next higher level, one must seek an intermediate level to allow for the comparison.

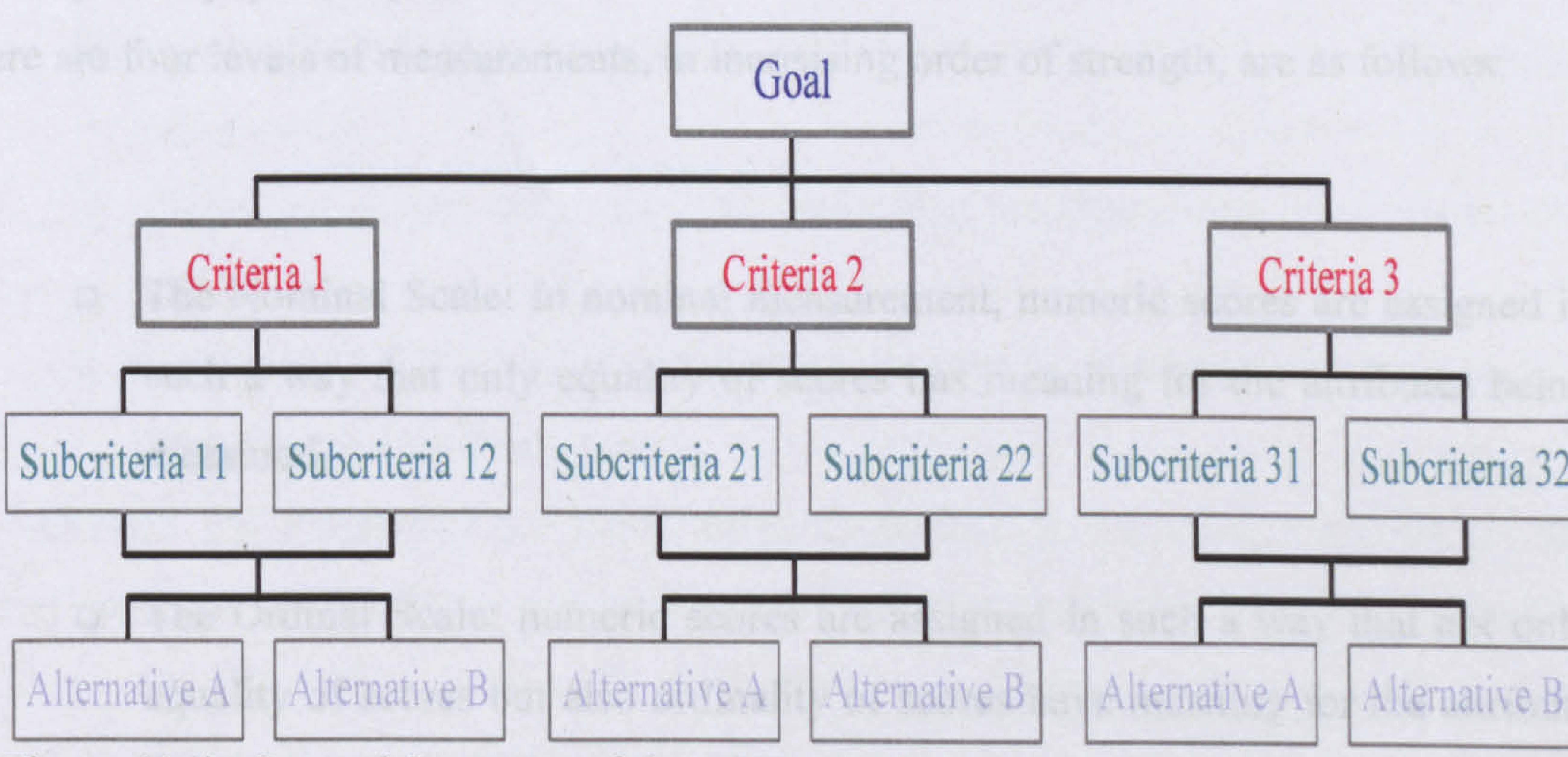


Figure (6.1): General Structure of the AHP.

Advantages of Hierarchies:

- Can be used to describe how changes in priority at upper level affect the priority of elements in lower level.
- They give a lot of information on the structure and function of a system in the lower levels.
- They are stable and flexible; stable in that small changes have small effect and flexible in that additions to a well-structured hierarchy do not disrupt the performance.

6.2.2 Establishment of Comparative Judgments

In order to determine the intensity of impact of the various components of a system, we must perform some type of measurement on a scale with units. Measurement is the assignment of numbers to objects or events in such a way that physical relationships and operations among the objects corresponds to arithmetic relationships and operations among the numbers. Not all mathematical relationships among measured values have a counterpart in physical operations.

There are four levels of measurements, in increasing order of strength, are as follows:

- The Nominal Scale: In nominal measurement, numeric scores are assigned in such a way that only equality of scores has meaning for the attributes being measured.

- The Ordinal Scale: numeric scores are assigned in such a way that not only equality of scores but also ordinality of scores have meaning for the attribute being measured. Scale assignment is by the property of "greater than," "equal to," or "less than."

- The Interval Scale: numeric scores are assigned in such a way that not only equality and ordinality of scores have meaning, but also the intervals between the scores. For example, the difference between 8 and 9 is the same as the difference between 70 and 71.

- The Ratio Scale: is the highest level where numeric scores are assigned in such a way that not only equality, ordinality and the intervals between the scores have meaning, but also ratios of scores. For example, the ratio of 2 to 1 is the same as the ratio of 8 to 4.

6.2.3 Pairwise Comparisons and Calculating the Local Priority

The ratio scale priorities produced by the AHP are dimensionless as they are based on relative pair-wise comparisons.

Once the hierarchies have been established, the next step is to find out the priority (weight) of each criterion. Therefore, elements in each level are compared pair-wise with an element in the next higher level. Typically using a nine-point scale (shown in Table (6.1), the pair-wise comparisons are done in terms of either:

- Importance: When comparing objectives with respect to their relative importance.
- Preference: When comparing the preference for alternatives with respect to an objective.
- Likelihood: When comparing uncertain events or scenarios with respect to the probability of their occurrence.

Although the judgments are made using qualitative information available on the options, the AHP allows conversion into quantitative data. There are n (n-1)/2 judgments required to develop the set of matrices in this step, where n is the number of criteria at a given hierarchy.

These pair-wise comparisons are used to derive the local priorities of the elements in one level with respect to the level above it. This is done by firstly adding the values in each column. Then, we divide each element in each column by the total of that column to obtain the normalized matrix. Finally, divide the sum of each row over the number of elements in the row.

Calculating the overall (global) priorities for the alternatives

The overall priorities are determined by means of a linear additive function, in which the local priorities for an alternative are multiplied by the importance of the corresponding criteria and summed over all criteria.

Intensity of Importance	***Definition***	***Explanation***
1	Equal Importance	Two activities contribute equally to the objective.
3	Weak Importance of one over another	Experience and judgment slightly favour one activity over another.
5	Essential or Strong Importance	Experience and judgment strongly favour one activity over another.
7	Very Strong or Demonstrated Importance	An activity is favoured very strong over another.
9	Absolute Importance	The evidence favouring one activity over another. This is the highest possible order or affirmation.
2,4,6,8	Intermediate Values	Used to represent compromises between the preferences listed above.

Table (6.1): Pair-wise comparison scale for AHP (Saaty 1980)

6.2.4 Sensitivity Analysis

Sensitivity analysis is an important aspect of an AHP problem analysis, since results are based on subjective expert assessments. Sensitivity analysis is usually carried out to investigate the sensitivity of the results to changes in the priorities of the criteria. In particular, the sensitivity analysis identifies the pair-wise comparison weights that the overall decision is most sensitive to.These weights are the ones that must be assigned with the greatest accuracy. By using an AHP software package, such as Criterium (see chapter 7) sensitivity analysis are easily performed.

6.3 Consistency of a Hierarchy

The AHP measures the reliability of judgements of the decision maker by means of a consistency Index. The consistency index (CI) is a function of the maximum eigenvalue (λ_{max})and the size of the square matrix (n). Saaty identified the CI as:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)}$$

If the decision maker is completely consistent λ_{max} should be equal to n i.e. CI would be zero. In the case of inconsistency, λ_{max} will be greater than n. The more inconsistent the decision maker is, the greater the value of λ_{max}.

As perfect consistency cannot be expected, Saaty simulated the random pairwise comparisons for different size matrices, calculating the consistency indices, and arriving at an average consistency index for random judgements for each size matix. Table (6.2) shows the value of the random consistency index (RI) for matrices of order 1 to 13 obtained by approximating random indices using a sample size of 500 (Saaty, 1980)

These values are tabled in Table (6.2) for n=3 to13.

Table (6.2): Average Random Index (RI) Based on Matrix Size (Saaty 1980)

Size of Matrix (n)	***Random Consistency Index (RI)***
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56

He then defined the consistency ratio of the consistency index (CI) for a particular set of judgments to the average consistency index for random comparisons for a matrix of the same size.

Consistency Ratio (CR) = Consistency Index (CI) / Random Index (RI)

Where

RI = reciprocal of C.I.

In general, if the consistency ratio is 0.10 or less, the inconsistency is considered to be acceptable for evaluation of the decision hierarchy (Saaty 1980).

6.3.1 Causes of Inconsistency

The most common cause of inconsistency is a clerical error. When entering one or more judgements into a computer, the wrong value, or perhaps the inverse of what was intended is entered. A second cause of inconsistency is lack of information. If one has little or no information about the factors being compared, then judgements will appear to be random and a high inconsistency ratio will result. Another cause of inconsistency is lack of concentration. This can happen if people making judgements are not really interested in the decision. A final cause of inconsistency is an "inadequate"model structure. Ideally, one would structure a complex decision in a hierarchical fashion such that factors at each level are comparable of other factors at that level. In the case of comparing several items that differed by as much as two orders of magnitude, the AHP scale will not be capable of capturing the difference since the scale ranges from 1 to 9.

6.4 Making Group Decisions Using AHP

When the analytic hierarchy process is used in a group session, brainstorming and sharing ideas will be possible.This often leads to a more complete representation and understanding of the issues than would be possible for a single decision maker. This involves structuring the problem, providing the judgments and debating the judgments.

6.4.1 Constructing the hierarchy

A good way to construct the hierarchy is to begin by brainstorming the overall focus of the problem. Several suggestions may be made, from which one is selected as most representative of the current overall concern. With the focus determined, the group defines the issues to be examined and constructs the hierarchy as richly as possible to cover the issues. Breaking down a complex issue into different levels is particularly useful for a group with widely varying perspectives. Agreement can be then reached on the higher-order and lower-order aspects of the issue through a clustering and ordering of all the concerns that members have expressed.

6.4.2 Setting priorities

Group priority setting involves bargaining and persuasion. The debate can be eliminated and individual opinion taken by questionnaire. For each pair of elements, a questionnaire asks for a judgment expressing the intensity of dominance with respect to the criterion: "Does A dominate B or does B dominate A with respect to this criterion? Indicate how strongly next to the proper alternative." (See Figure 6.2)

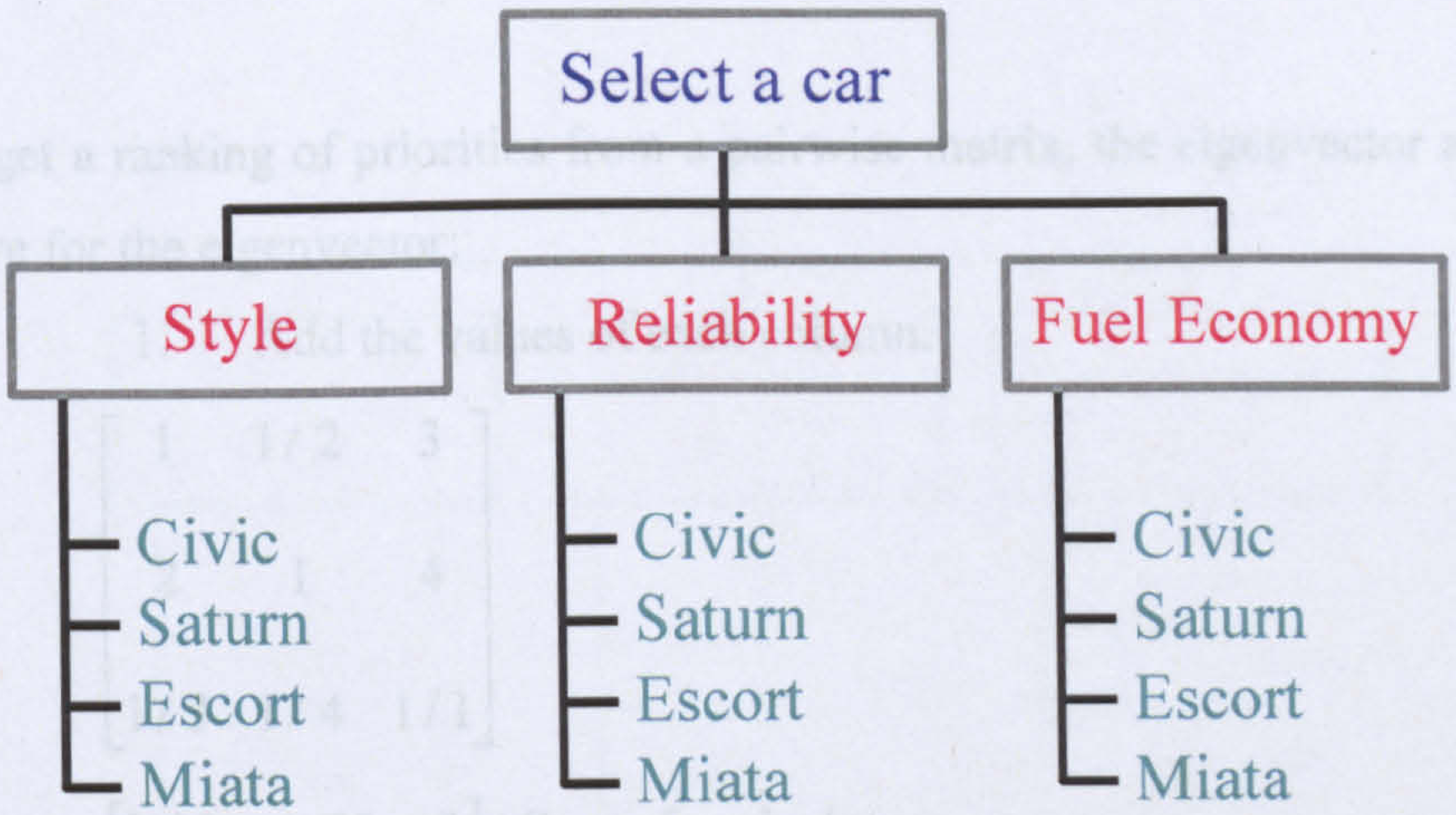
	Equal Importance	Weak	Strong	Very Strong	Absolute
	1	3	5	7	9
A over B	______	______	______	______	______
or					
B over A	______	______	______	______	______

Figure (6.2): A sample of a questionnaire question for collecting judgements.

The final step is to take all these matrices, constructed from the provided judgments, and develop a single matrix whose entries are obtained by taking the geometric mean of all the entries from the matrices. Taking the geometric mean of individual judgments is a way of to resolve a lack of consensus on values. For example, the geometric mean of 2, 3 and 7 is $\sqrt[3]{2*3*7}$, which is 3.48 (3 in the pair-wise scale).

6.5 Illustrative Example

The following example of the decision making process behind buying a new car illustrates the AHP and the mathematics associated with it. The first step is to state the goal: in our case it is to buy a new car. Then, to define the criteria in level one under the goal: style, reliability and fuel economy will be considred. Finally, to identify the alternatives: Civic Coupe, Saturn Coupe, Ford Escort and Mazda Miata. This information is then arranged in a hierarchical form as follows:



To determine the relative importance of the criteria or objectives by making judgments using the established scale below:

1 Equal 3 Moderate 5 Strong 7 Very Strong 9 Extreme

One possible outcome of a brainstorming sessions would be that:

1. Reliability against Style: 2
2. Style against Fuel Economy: 3
3. Reliability against Fuel Economy:4

$$\begin{array}{c} \\ \text{Style} \\ \text{Reliability} \\ \text{Fuel} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Style} & \text{Reliability} & \text{Fuel} \end{array} \\ \begin{bmatrix} 1 & 1/2 & 3 \\ 2 & 1 & 4 \\ 1/3 & 1/4 & 1 \end{bmatrix} \end{array}$$

The element that appears in the left-hand column is always compared with the element appearing in the top row, and the value is given to the element in the column as it is compared with the element in the row. If it is regarded less important, the judgement is a fraction. The reciprocal value is entered in the position where the second element, when it appears in the column, is compared with the first element when it appears in the row. As in comparing Reliability with the style, we enter the value 2 in the second row, first column, and enter its reciprocal 1/2 in the first row, second column.

To get a ranking of priorities from a pairwise matrix, the eigenvector approach is used. To solve for the eigenvector:

1. Add the values of each column.

$$\begin{bmatrix} 1 & 1/2 & 3 \\ 2 & 1 & 4 \\ 1/3 & 1/4 & 1/1 \end{bmatrix}$$

$$\begin{bmatrix} 3.33 & 1.75 & 8 \end{bmatrix} \textit{ Sum of each cloumn}$$

2. Then divide each entry in each column by the total of that column to obtain the normalized matrix.

$$\begin{bmatrix} 0.3 & 0.29 & 0.38 \\ 0.6 & 0.57 & 0.5 \\ 0.1 & 0.14 & 0.13 \end{bmatrix} \textit{ The normalized matrix}$$

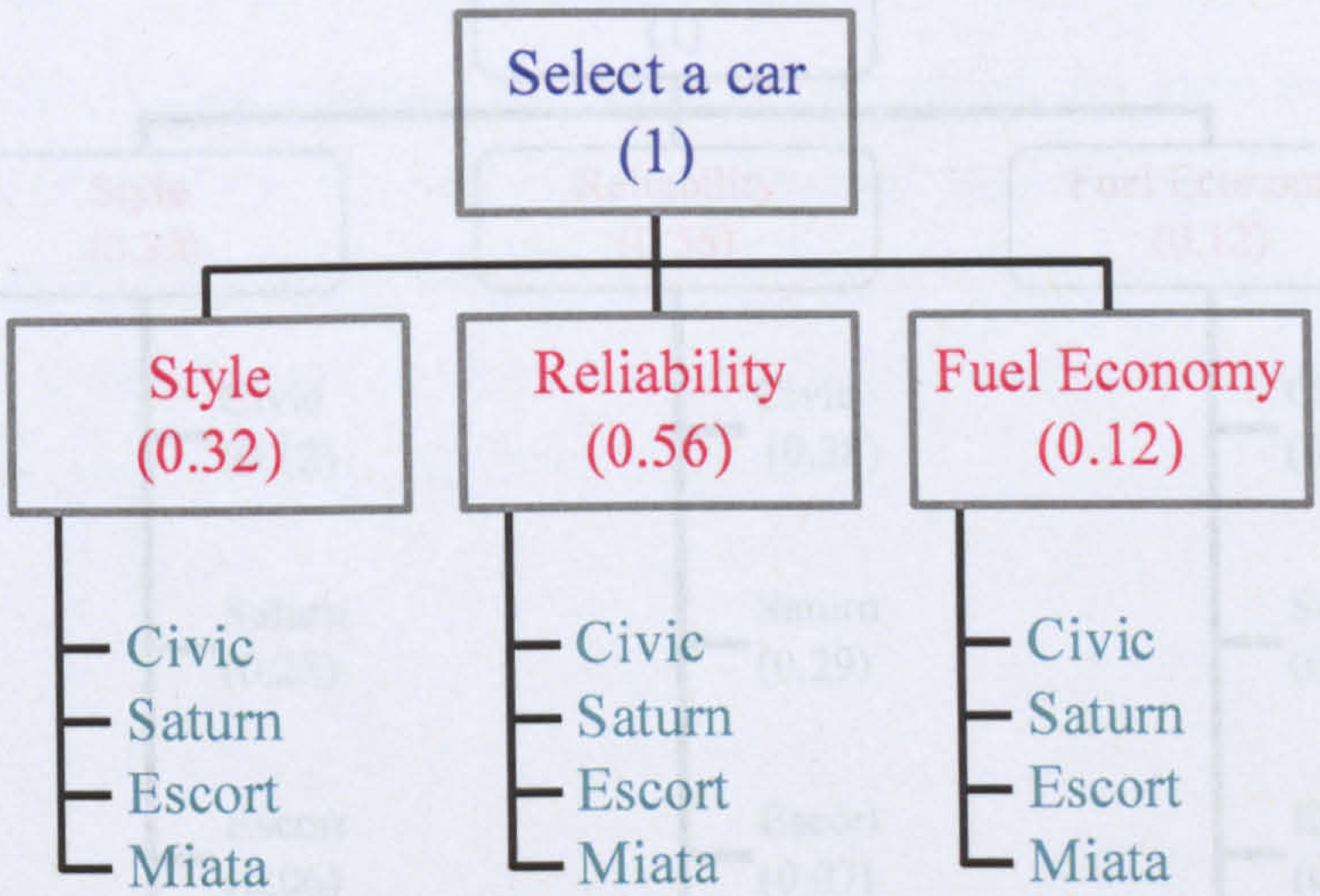
3. Finally, average over the rows by adding the values in each row of the normalized matrix and dividing the rows by the number of entries in each.

$$\begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} \textit{ Average Row Sum (The Eigenvector)}$$

The computed eigenvector provides us the relative ranking of our criteria or objectives.

$$\begin{matrix} \text{Style} \\ \text{Reliability} \\ \text{Fuel} \end{matrix} \begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} \begin{matrix} \text{The second most important criterion} \\ \text{The most important criterion} \\ \text{The least important criterion} \end{matrix}$$

The weights would be shown in the hierarchy as follows:



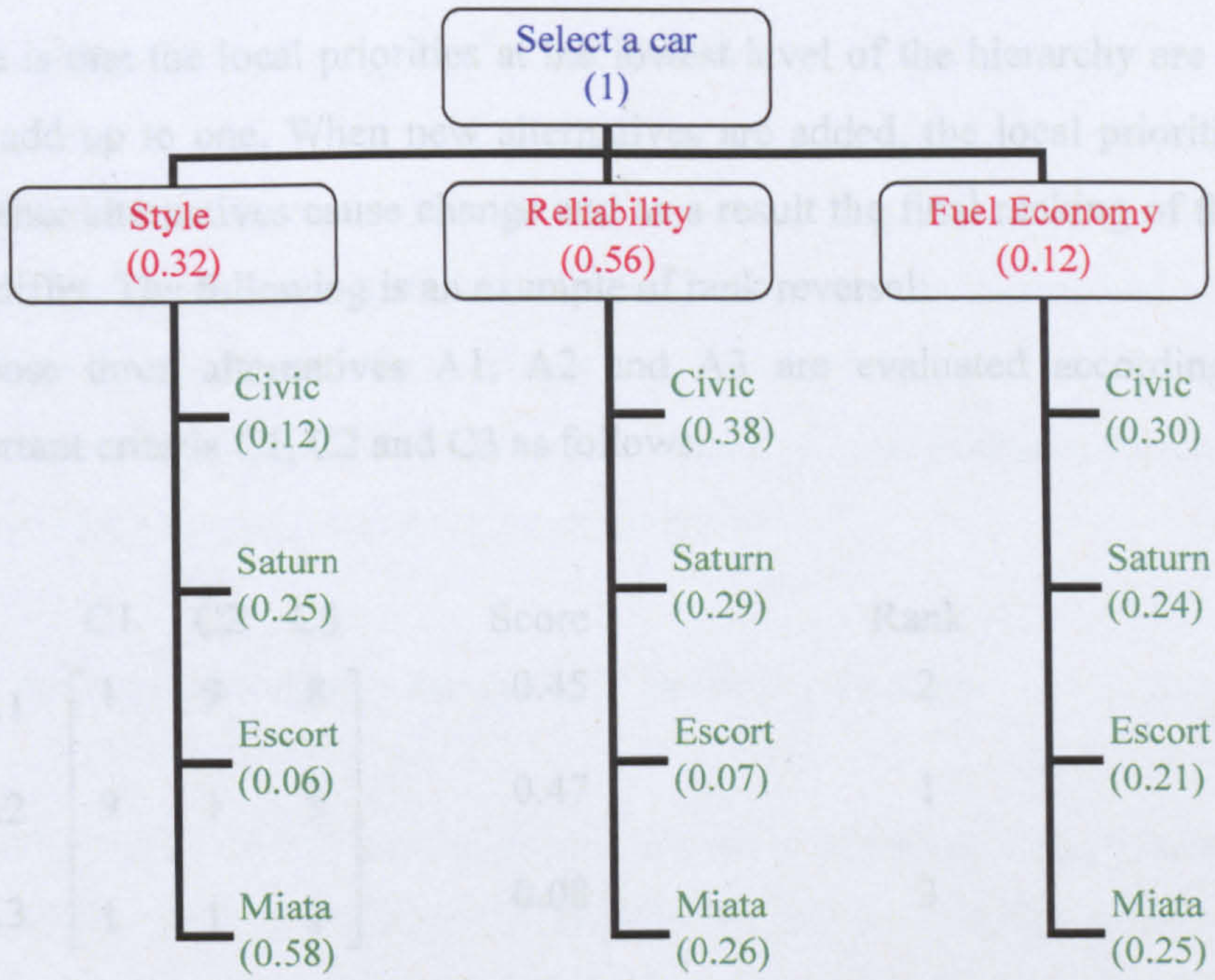
Next the same type of pairwise comparisons would be performed for each of the alternatives. For example, in terms of style, pairwise comparisons determines the preferences of each alternative over another:

	Civic	Saturn	Escort	Miata
Civic	1	1 / 4	4	1 / 6
Saturn	4	1	4	1 / 4
Escort	1 / 4	1 / 4	1	1 / 5
Miata	6	4	5	1

Following the above steps, the eigenvector would be computed to determine the relative ranking of alternatives, namely:

$$\begin{matrix} \text{Civic} \\ \text{Saturn} \\ \text{Escort} \\ \text{Miata} \end{matrix} \begin{bmatrix} 0.12 \\ 0.25 \\ 0.07 \\ 0.58 \end{bmatrix}$$

The eigenvector and ranking of alternatives for reliability and fuel economy would be accomplished the same way. The populated hierarchical tree with all weights is shown below:



To derive the solution, matrix algebra is used one more time to multiply the alternative weights by the criteria weights.

$$\begin{array}{c} \\ \text{Civic} \\ \text{Saturn} \\ \text{Escort} \\ \text{Miata} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Style} & \text{Reliabilit y} & \text{Fuel} \end{array} \\ \begin{bmatrix} 0.12 & 0.38 & 0.30 \\ 0.25 & 0.29 & 0.24 \\ 0.06 & 0.07 & 0.21 \\ 0.58 & 0.26 & 0.25 \end{bmatrix} \end{array} * \begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} \begin{array}{c} \text{Style} \\ \text{Reliability} \\ \text{Fuel} \end{array} = \begin{array}{c} \text{Civic} \\ \text{Saturn} \\ \text{Escort} \\ \text{Miata} \end{array} \begin{bmatrix} 0.29 \\ 0.27 \\ 0.08 \\ 0.36 \end{bmatrix}$$

The end results show that the Miata is the best choice for the stated criteria based on the highest ranking of 0.36.

6.6 Some Problematic Features with AHP Method

6.6.1 Rank Reversal

Rank reversal can occur when new alternatives are introduced to the hierarchy for consideration. The reason for the occurance of rank reversal in the relative measurement mode is that the local priorities at the lowest level of the hierarchy are normalized so that they add up to one. When new alternatives are added, the local priorities associated with the other alternatives cause change and as a result the final ranking of the alternatives may also differ. The following is an example of rank reversal:

Suppose three alternatives A1, A2 and A3 are evaluated according to three equally important criteria C1, C2 and C3 as follows:

	C1	C2	C3	Score	Rank
A1	1	9	8	0.45	2
A2	9	1	9	0.47	1
A3	1	1	1	0.08	3

A forth alternative is then introduced and compared with A1, A2 and A3 as follows:

	C1	C2	C3	Score	Rank
A1	1	9	8	0.37	1
A2	9	1	9	0.30	2
A3	1	1	1	0.06	4
A4	8	1	8	0.27	3

So which ranking is correct? The first or the second one? Criterium Decision Plus (CDP) addresses the rank reversal issue by providing two methods for synthesizing the results: a destributive method and an ideal method. The ideal solution represents the results of the alternative that scores perfectly for all criteria in the decision model. The ideal solution can be used as a reference point for evaluating the alternative preference.

6.6.2 The order of magnitude rating limit

Saaty (1980) states that when the difference in importance of two factors is very great meaningful comparisons cannot be made. For this reason, a using the 1-9 scale is applied in the AHP approach. When the diference in property magnitude is significantly greater than 9 (the maximum rating), attempt must be made to arrange elements in a cluster so that they do not differ by more than an order of magnitude.

6.7 Applications of the Analytical Hierarchy Process

The AHP approach has been applied to a variety of decision areas since its development. Narasimhan (1983) outlined the benefits of adopting AHP method as: it facilitates accurate judgments as it formalizes and makes systematic what is largely a subjective decision process and the results can be easily understood and therefore simplifying the process of alternative selection.

Drake (1998) presented a paper on the applications of AHP in the educational and training environment. The author and his students have applied the AHP to both 'hard' and 'soft' engineering selection problems. The three examples provided in this paper were: the selection of a condition monitoring method for a hydraulic pump, the selection of electric shock protection method and the selection of a keyboard. For the first example, four selection criteria were taken into account (signal usefulness, ease of hardware maintenance, ruggedness of the hardware and ease of mounting of sensors) and four condition monitoring methods were assessed (pump outlet pressure, vibration, pump motor current and acoustic emission). Pump outlet pressure was the most useful monitoring method and usefulness was the most important criteria as reflected by the Analytical Hierarchy Process results. The second example concerned with the selection of an electric shock protection method in a power station environment using the AHP approach. Two factors were considered, likelihood of occurrence and severity of the resultant shock, while three protection methods were proposed (foot ware, gloves and ground resistance). The result show that gloves was the most effective form of protection. The final example dealt with the selection of a keyboard, eight factors were identified to influence the decision: mounting, cost, size, ruggedness, availability, computer interface, user interface and ease of typing. Mounting, cost and size resulted in the highest weight and therefore the most important factors. The author concluded that the AHP is of great benefit when used in an education and training environment as it makes the selection process very transparent.

Lee, et al (2000) examined graduate students' preferences among a set of four learning activities commonly employed in adult educational settings using the Analytical Hierarchy Process. These four activities were lectures, in-class discussion and reflections, group based projects and individual projects. A questionnaire was designed to rate the strength of their pair-wise preferences and was given to 134 students with ages ranging from 23 to 48. The result of their study showed that adult graduate students prefer to learn by discussion and reflection as opposed to lecture and prefer individual to group projects.

Inomata, A. et al (2002) employed the AHP method to recognize important parameters that would influence the effectiveness of the web-based learning system and would characterize the difference between classroom learning and web-based learning. They identified learning environment, teacher's presentation and motivation for learning as factors affecting the learning style. The learning environment factors was divided into ease of interaction between learners, ease of interaction with the teacher, space convenience, time convenience, presence and atmosphere and richness of teaching material. Teacher's presentation consisted of the following factors: talk and tone, the way to explain teaching materials and the way to summarise teaching materials. Finally, the motivation for learning included concentration, eyestrain, ear-strain and tension and sense. Several experiments were conducted and 68 students studied themselves using web-based system. For the evaluation by the AHP, students were asked to fill in two questionnaire sheets, one was for the pair-wise comparisons between each two factors in turn and the other was to give a weight to web-based and classroom learning to each criteria. Results showed that concentration is the most important factor while ease of interaction is the least important factor.

Susilawati, et al. (2003) used the Analytical Hierarchy Process to develop a model to assess the quality of a shopping centers building in Surabaya. The required data was gathered by distributing a questionnaire survey to shopping centres' developers and tenants. The factors considered to affect the quality of the shopping centres were: access and circulation (which included circulation for person, merchandise and accessibility), facilities (such as garden, restaurants and banks), functionality (room size and structural design), building presentation (considered interior and exterior design), service and tenancy (such as lighting system, air conditioning and toilets), and management (security access, maintenance and parking management). Results show that access and circulation is the most important factor affecting the quality of shopping centers while management is the least important factor.

Dey, P. and Hariharan, S. (2005) measured the health care service performance using the Analytical Hierarchy Process. Factors affecting the performance of healthcare process in hospitals were gathered by conducting brainstorming sessions and distributing a questionnaire survey among the clinicians and managers in both India and Barbados. Three indicators of performance of healthcare in hospitals were identified: patient care sector, establishment sector and administrative sectors. Patient care sector factors included accident & emergency, operating rooms, intensive care units, out-patient clinics, general awards and physical therapy unit. Establishment sector comprised of factors such as: management of pharmacy, laboratory sciences including microbiology, patient nutrition and communication systems and library/academic activities. While, administrative sectors were classified to include human relations and personal management of staff, overall supply-chain management, financial management, clinical engineering and house keeping management and medical records management. The results show that the factor patient care ranked the first then establishment sector and finally administrative sector. The study concluded that the Analytical Hierarchy Process is a powerful tool for the measurement of the health care performance.

Abdi, M. and Labib, A. (2003) utilized the Analytical Hierarchy Process to model the decision making process for the selection of a manufacturing system. The criteria used to construct the AHP model were: responsiveness, cost, quality, inventory and operators' skill. The model was developed with three assumed alternatives: existing manufacturing system, reconfigurable manufacturing system and the hybrid manufacturing system. The resulting model indicated that the ranking of the factors was: operator's skill as the most important factor, then quality in the second place while cost in the third place, then responsiveness and finally inventory. The AHP model was then validated through a case study with a manufacturing company in Birmingham. The results revealed that the hybrid manufacturing system is the preferred alternative then the reconfigurable manufacturing system and finally the existing manufacturing system which was the dedicated manufacturing system.

Skibniewski and Choa (1992) used the AHP method tō develop a basic framework for a systematic approach to evaluation of advanced construction technologies. The model presented in their paper was based on an extended and modified cost-benefit analysis approach. In the model, operating costs, initial investment, safety problems, system reliability and system flexibility were included as cost-factors, while, strategic benefits, quality performance and schedule performance were listed under the benefit factors. A hypothetical illustrative example of the evaluation of two tower-crane alternatives, one traditional and other semi-automated, was also included. Results indicated that cost factors had the same overall weight as the benefit factors and with the semi-automated tower crane as the favoured alternative.

El-Mikawi, M. et al (1996) developed an AHP model that allows decision makers to select an optimal structural material for infrastructure repairs and construction. As a case study, this model was applied to test the use of advanced composite materials in the repair of deteriorated and damaged bridge columns in Washington. Two alternative materials were considered, either the use of composites made of carbon fibers or the use of conventional steel jackets. Performance, economic analysis, environmental aspects, codes, material availability and architectural aspects were the factors included in this study. Structural performance was found to be the most important factor and of equal importance to the economic indicators while, architectural aspects was the least important factor. The resulting AHP model recommended the selection of composite materials over the steel jackets.

Dey (2001) suggested a project management model with the application of risk management principles. Both analytical hierarchy process and decision tree analysis were used in this study. A cross-country petroleum pipeline project for constructing three pump stations in India was used as a case study. Technical risk, Financial, economical and political risk and organizational risk were among the identified factors in structuring the model. The results revealed that technical risk is the major factor among other considered factors for time and cost overrun of projects. The study concluded that the AHP is an effective means for managing a complex project and that it also can improve the team spirit and motivation.

Fong and Choi (2000) applied the AHP method to develop a model for contractor selection in order to help construction clients to identify contractors with the best potential to deliver satisfactory outcomes. Eight factors involved in contractor selection were used to form the required model: tender price, financial capability, past performance and past experience, resources, current workload, past client/contractor relationship and safety performance. They concluded their study by identifying the tender price as the most significant factor affecting the contractor selection and the validity of AHP method for this particular decision.

Al-Harbi (2001) demonstrated the AHP application on the contractor pre-qualification problem by illustrating a simplified project example. He created the AHP model using experience, financial stability, quality performance, manpower resources and current workload as factors affecting contractor pre-qualification. The AHP was implemented using the Expert Choice Software. Results from the Analytical Hierarchy model indicated that experience, financial stability and quality performance were the most important factors as they had the highest ranking weight. The study concluded that the AHP is a powerful tool for decision making.

Cheung, et al (2001) reported a study conducted in Hong Kong on the development of a procurement selection model based on multi-attribute utility theory (MAUT) and the analytical hierarchy process (AHP). Speed, flexibility, certainty, quality level, complexity, risk avoidance, price competition and responsibility were the eight selection criteria used in this study. By testing their model against 15 sample projects, they proved the reliability of the developed model.

Chan, et al (2004) reported a case study for the development of an AHP supplier selection model. Cost, delivery, flexibility, innovation, quality and service were considered as criteria for selecting the 'best' supplier for semiconductor assembly equipments. Six different company functions, which are involved in supplier selection process, were targeted through a questionnaire. The six functions were engineering, purchasing, production planning and control, production, quality and operation management. The formulated AHP model suggested that quality and delivery are the most important criteria in supplier selection problem, followed by cost, service, flexibility and then innovation respectively. This study suggested that the proposed model could reduce the time and effort in decision-making as it enables decision-makers to structure the problem systematically.

Palaneeswaran, et al (2006) developed a structured framework for materials supplier selection in the construction industry using the Analytical Hierarchy Process. The criteria affecting the supplier selection was gathered using a questionnaire survey and interviews were: to lessen costs, to achieve delivery in the right amount of time, to ensure better quality, to obtain better services and to avoid risks. The AHP model was constructed using the Expert Choice Software Package. Results from the model show that to lessen costs is the most important factor, then to receive delivery in the right time, while to avoid risk is the least important factor. The paper presented a sample of rating for the selection of steel suppliers by the construction contractors.

Khalil, (2002) discussed the selection of the most appropriate project delivery method using the Analytical Hierarchy Process. Three project delivery methods were presented in this paper: the design-bid-build method, the design-bid method and the construction management method. The factors considered in this study were grouped under three categories: project characteristics, owner's need and owner's preferences. The project characteristics include: clarity of scope, schedule, contract pricing and complexity, while owner's need considered: constructability, value engineering, contract packaging and feasibility studies, and finally owner's preferences consisted of responsibility, design control and owner's involvement after award of contract. A hypothetical example of the use of the Analytical Hierarchy process in the selection of project delivery method was illustrated. The author concluded that the resulting model is simple to use and allows the owner to consider all decision relevant factors.

Attirawong, and MacCarthy, (2002) developed an Analytical Hierarchy Process model for evaluating an overseas site selection. Factors as direct costs, indirect costs, labour characteristics, infrastructure, proximity to markets, proximity to suppliers and macro-environment were considered to affect the site selection decision. To evaluate the usability of the proposed model, it was presented to two companies with a description of how to use it. Both companies stated that the model was easy to apply and would facilitate the international location decision making process.

Rezqallah, et al (1999), determined the weights of factors influencing pavement maintenance using the Analytical Hierarchy Process. The study considered the following factors: road class, pavement condition, operating traffic, riding quality, safety condition, maintenance cost and the importance of the road section to the community. The weights needed to construct the Analytical Hierarchy Process were gathered from local people in Saudi-Arabia. Pavement condition had the highest weight of importance while maintenance cost had the lowest weight of importance. The model was then validated by real cases studies and found to be logical and efficient.

Smith, and Tighe, (2006) presented two case studies for the Analytical Hierarchy Process. The first case showed how the Analytical Hierarchy Process can be used to compare three products of 'fast track' concrete material suitable for crack repairs in the Canadian Airports. The 'fast track' referred to a material which set up very quickly and are ready for use in a short period of time. Sixteen criteria were identified to assist in selecting the suitable material. Among those factors were: mixing time, time until traffic, deicing fluid resistance, temperature range, initial set time, ease of placement, cost, degree of difficulty and crew size. The criteria with the highest ranking were the mixing time, time until traffic, temperature range and cost. In the second case the Analytical Hierarchy Process was employed to evaluate seven maintenance, rehabilitation and reconstruction strategies for asphalt pavements from the user's point of view. Nine factors were considered: ride quality, surface distress, structural adequacy, surface fiction, surface drainage, the level of noise, user delay and the life cycle cost. The most important factors were ride quality, surface distress and structural adequacy.

Tan, and Lu, (1995) used the Analytical Hierarchy Process to establish a framework to assist both project executives and project owners in managing the quality of the engineering design project. A questionnaire survey was distributed to twenty engineering companies in Taiwan to identify the criteria impacting the quality of the project design. Eight criteria were considered: qualified manpower to achieve project mission and objectives, conformance to codes and standards, conformance to owner's requirements, conformance to design processes and procedures, conformance to schedule requirements, conformance to cost requirements, completeness of and conformance to output standards and constructability. While, results form the framework revealed that there are minor disagreements between the project executives and project owners judgments, qualified manpower to achieve project mission, requirements and objectives was the most important factor from both project executives and project owners point of view. Constructability was the least important factor to the quality of the engineering design project.

Dey, (2002) analyzed the benchmarking of the project management practices in the Caribbean public sector organizations using the Analytical Hierarchy Process. Benchmarking was described as the search for the best management practice that delivers improvements, quality and efficiency. The project management success factors considered in this study were: appropriate feasibility study, adequate project plans, appropriate design and detailed engineering, availability of work, effective material procurement, good contract management, appropriate monitoring and control and effective termination. The pair-wise comparisons of factors were based on project executives' judgments. Results show that appropriate feasibility analysis, planning for implementation were the most critical factors while monitoring and termination were the least critical factors to the success of project management practices. Six alternatives were applied to the model (referred to as enablers in the paper): Management system, a process-based approach to integrating all functions of project management, effective information system, the effectiveness and flexibility of the project organization, use of the latest technology in design and detailed engineering and project control and long-term relationship among all project stakeholders. The highest rating was given to the process integration enabler.

6.8 Summary

Analytical Hierarchy process (AHP) is a simple, powerful and practical multi-attribute decision tool. It not only helps decision makers choose the best alternative, but also provides a clear rationale for the choice. The AHP has been used in a large number of applications to provide structure of the decision making process. Such applications include the use of the AHP in the educational and training environment, to assess the quality of shopping centres, to measure the health care service performance, to model the decision making process for the selection of a manufacturing system. The literature review indicates that the Analytical Hierarchy Process is an effective method for formulating decision models which are easy to use and consider all decision relevant factors.

The main strength of AHP is that it treats the decision as a system, which is difficult for many decision-makers to do due to the number of factors involved in a complex decision. Both qualitative and quantitative factors can be included in the hierarchy. Another important aspect of the AHP is the sensitivity analysis, which is carried out to investigate the sensitivity of the results to changes in the priorities of the criteria. The weaknesses of this method are the rank reversal and the order of magnitude rating limit.

Next chapter will provide an overview of different commercial software designed to implement the Analytical Hierarchy Process. In particular, four software: Criterium Decision Plus, Expert Choice, Web-HIPRE and Logical Decisions.

CHAPTER SEVEN

Determination of Weights in the AHP Models

7.1 Introduction

A number of different software packages have been developed and sucessfully utilized in the last few years for implementing multi-criteria decision making models. In particular, four commercial software were designed to implement the Analytic Hierarchy Process (AHP): Criterium Decision Plus, Expert Choice, Web-HIPRE and Logical Decisions. In this chapter, an overview of the available commercial software for implementing the Analytic Hierarchy Process (AHP) is given. This is followed by a detailed description of the Criterium Plus features.

7.2 Software Implementing the Analytical Hierarchy Process

A brief description of the Criterium Decision Plus, Expert Choice 2000, Web HIPRE and Logical Decisions Software follows next.

7.2.1 Criterium Decision Plus:

Criterium Decision Plus supports users in analysing complex decisions between alternatives and involving multiple criteria. It aids the decision-maker in consistency assigning relative importance to criteria and rating alternatives against those criteria. Two leading methodologies for multi-criteria analysis can be applied: the Analytic Hierrchy Process and Simple Multi-Attribute Rating Technique (SMART: implementing the Multi-attribute Utility Theory of decision analysis (Edwards, 1992)). Based on these methodologies, the software aids the decision maker in consistently assigning relative importance to criteria, and rating alternatives against those criteria. The interface in Criterium Decision Plus is shown in Figure (7.1).

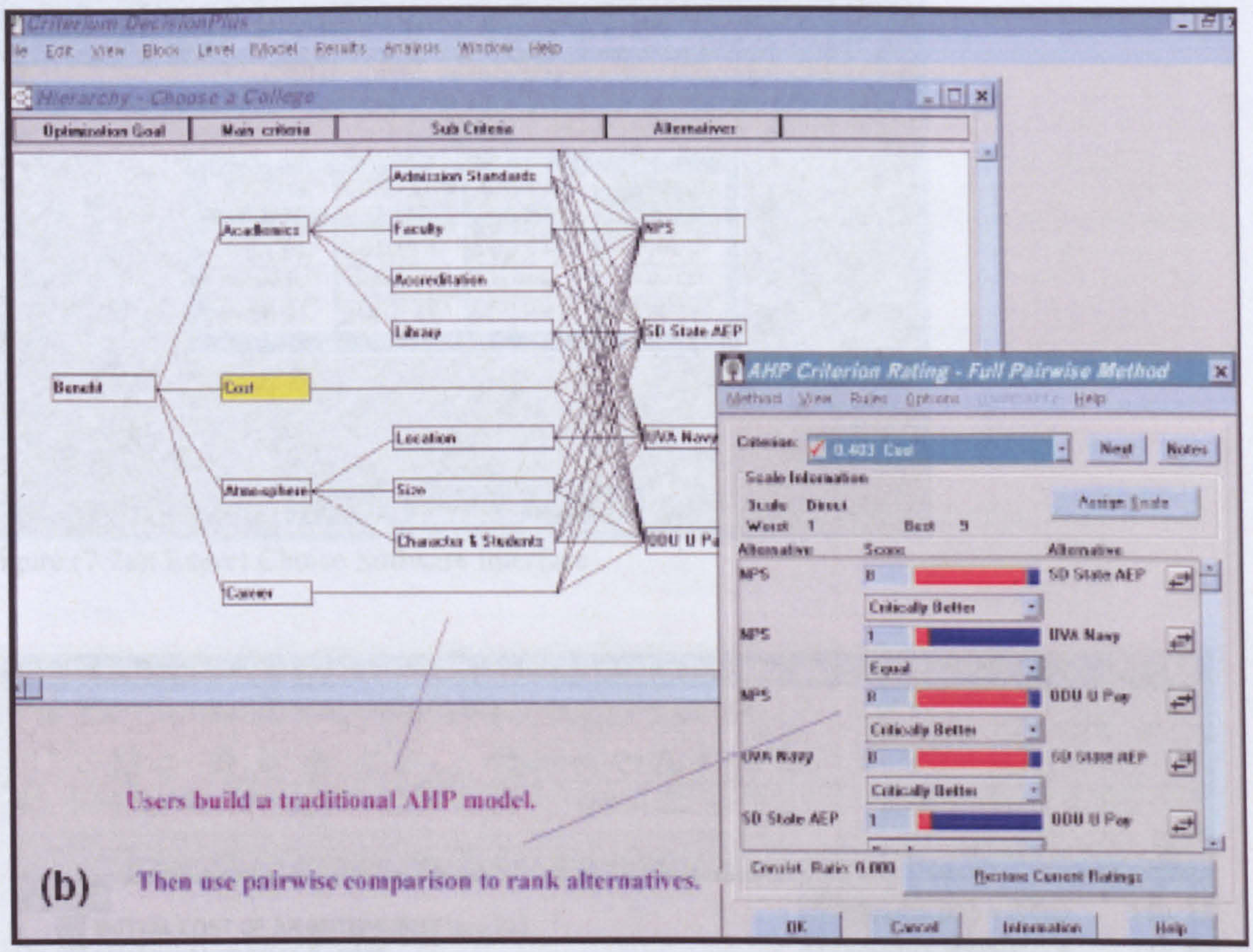


Figure (7.1): Criterium Decision Plus Interface

7.2.2 *Expert choice 2000*

Expert Choice 2000 is also a multi-criteria decision support software tool using the Analytic Hierarchy Process (AHP) decision-making methodology. It assists in defining goals, identifying the criteria and alternatives and building a decision model. The interface in Expert Choice Software is shown in Figures (7.2a) and (7.2b).

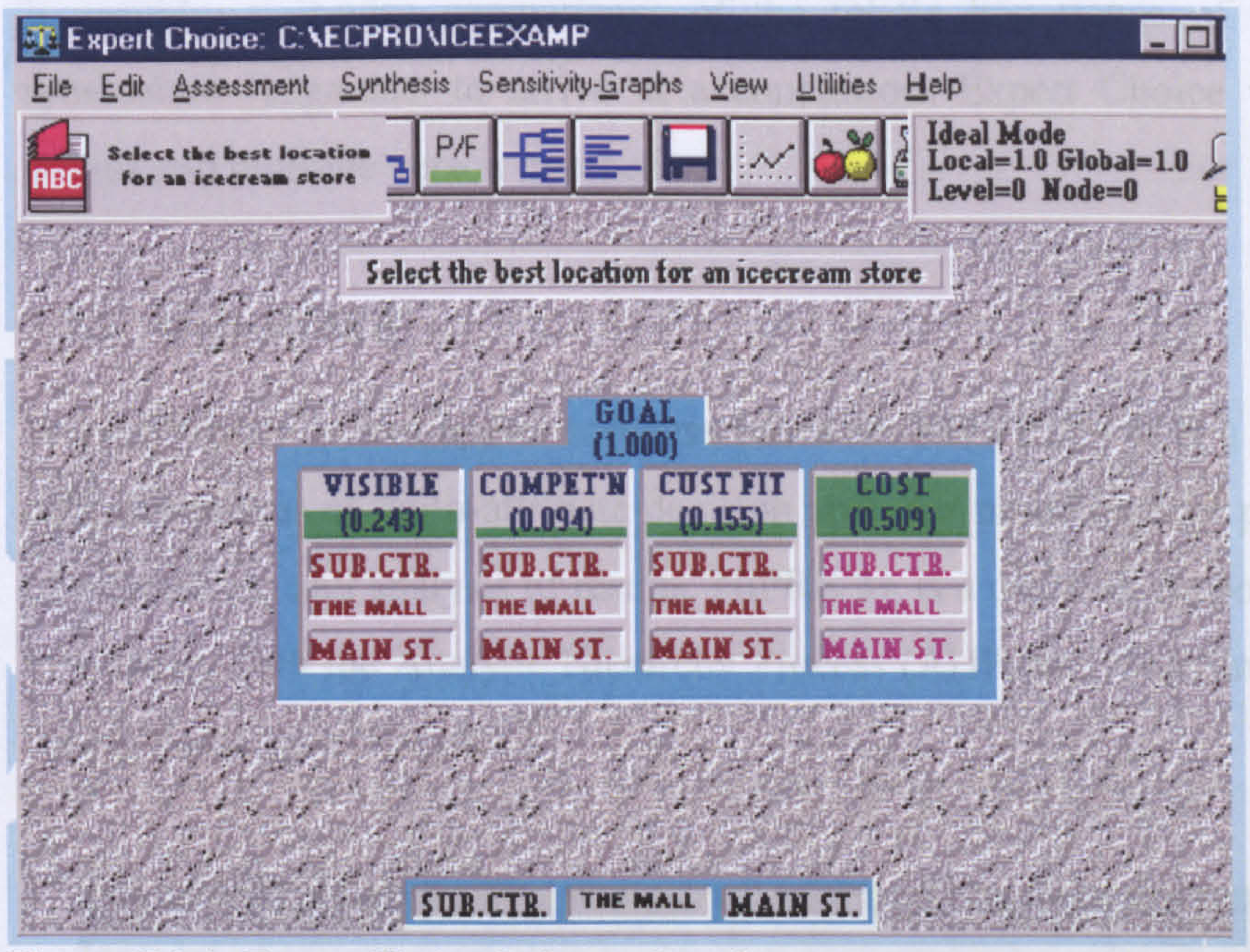


Figure (7.2a): Expert Choice Software Interface

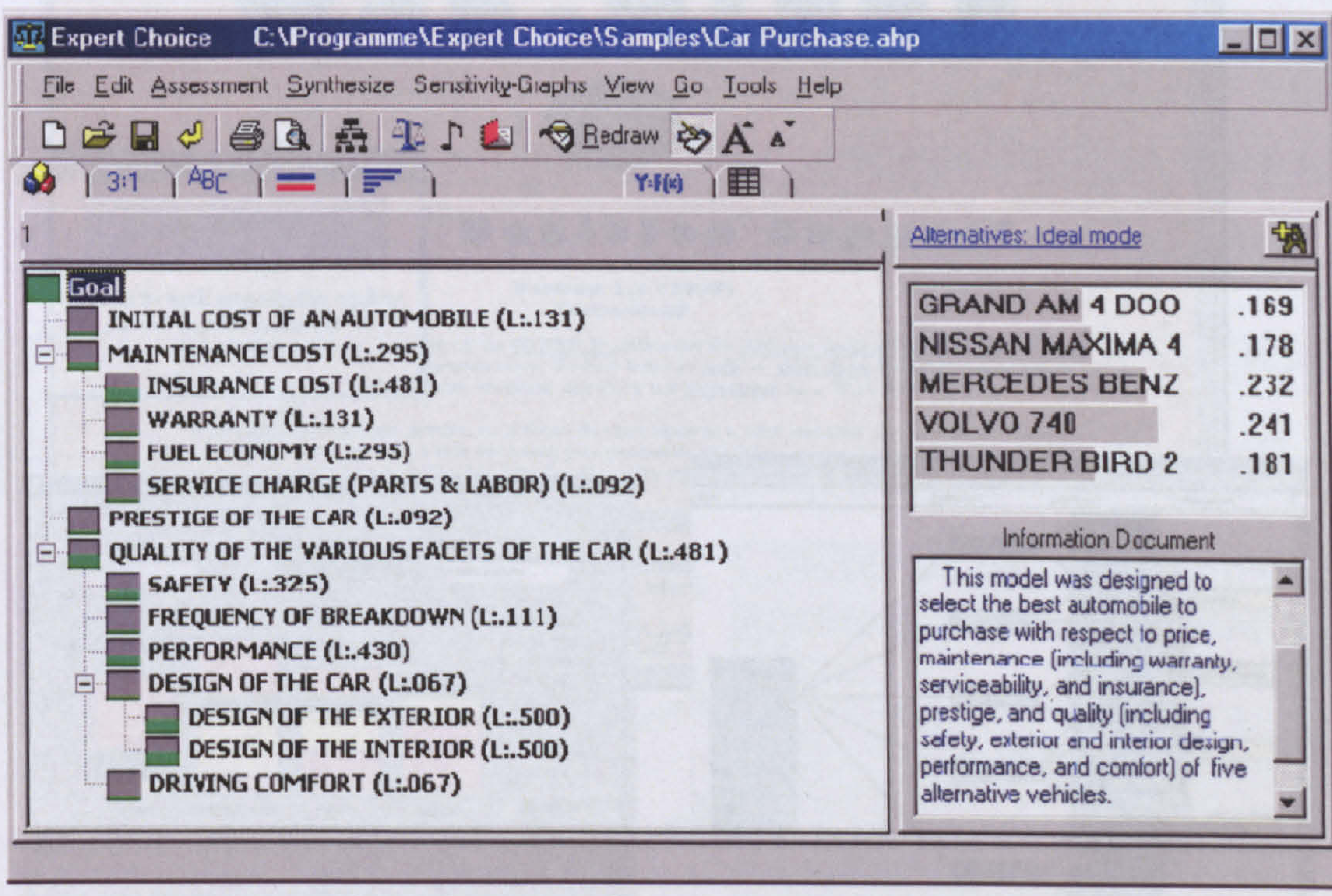


Figure (7.2b): Expert Choice Software Interface

It provides pair-wise comparisons of the relatie importance of the variables then synthesizes judgments to arrive at a conclusion. Expert Choice was developed for groups and multiple person interaction.

7.2.3 *Web-HIPRE*

Web-HIPRE is a Java-applet software based on HIPRE 3+. It is a tool for supporting different phases of multi-attribute decision analysis; modelling the problem, evaluation of alternatives and analysis of results. HIPRE 3+ is a decision support software product integrating both the Analytic Hierarchy Process (AHP) and The Simple Multi-attribute Rating Technique (SMART).

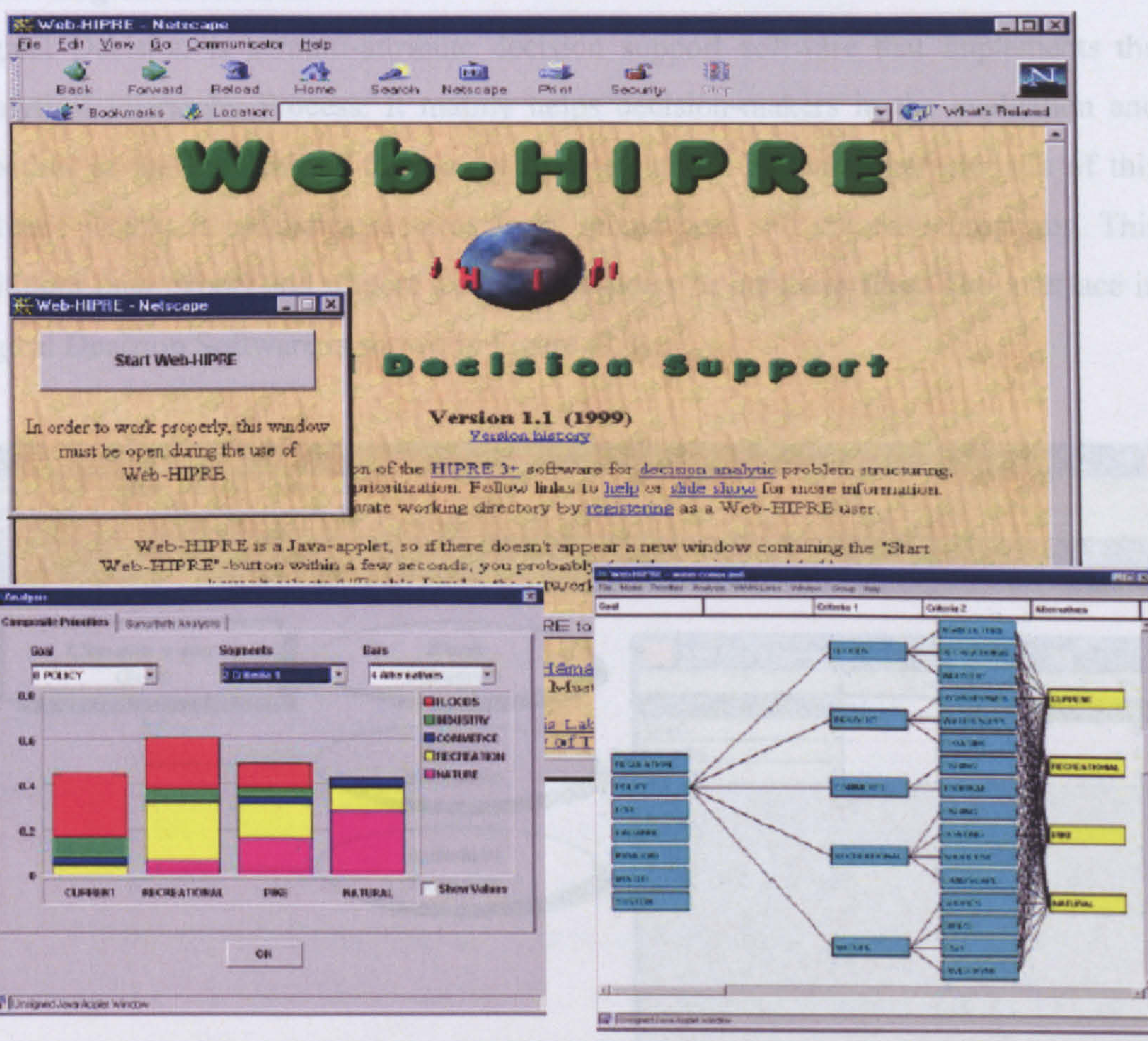


Figure (7.3): Web HIPRE Interface

Both methods can be run independently or can be combined together in one model. As Web-HIPRE is an interactive Java applet, therefore all the features of the Java-based approaches apply to it. These include, for example, the possibility to carry out interactive processes without any installations on local computers; just a Java-enabled browser needed such as Netscape or Internet Explorer. It also gives a visual and customizable graphical interface. The interface in Web-HIPRE is shown in Figure (7.3). As HIPRE 3+ is located on the Internet, it can be accessed from everywhere in the world and the results can be shared easily. Moreover, it supports individual and group decision making. The main issue with this software is that once the Web HIPRE is closed, nothing remains on local computer and the models are saved on either a public or protected directories on the server computer; this is due to Java security reasons.

7.2.4 *Logical Decisions*

Logical Decision is a multi-attribute decision support software that implements the Analytical Hierarchy Process. It mainly helps decision-makers in the evaluation and selection of the best choice from a set of alternatives. A main characteristic of this software is that it combines features from spreadsheet and database programs. This facilitates data export and import from spreadsheets or database files. The interface in Logical Decision Software is shown in Figure (7.4).

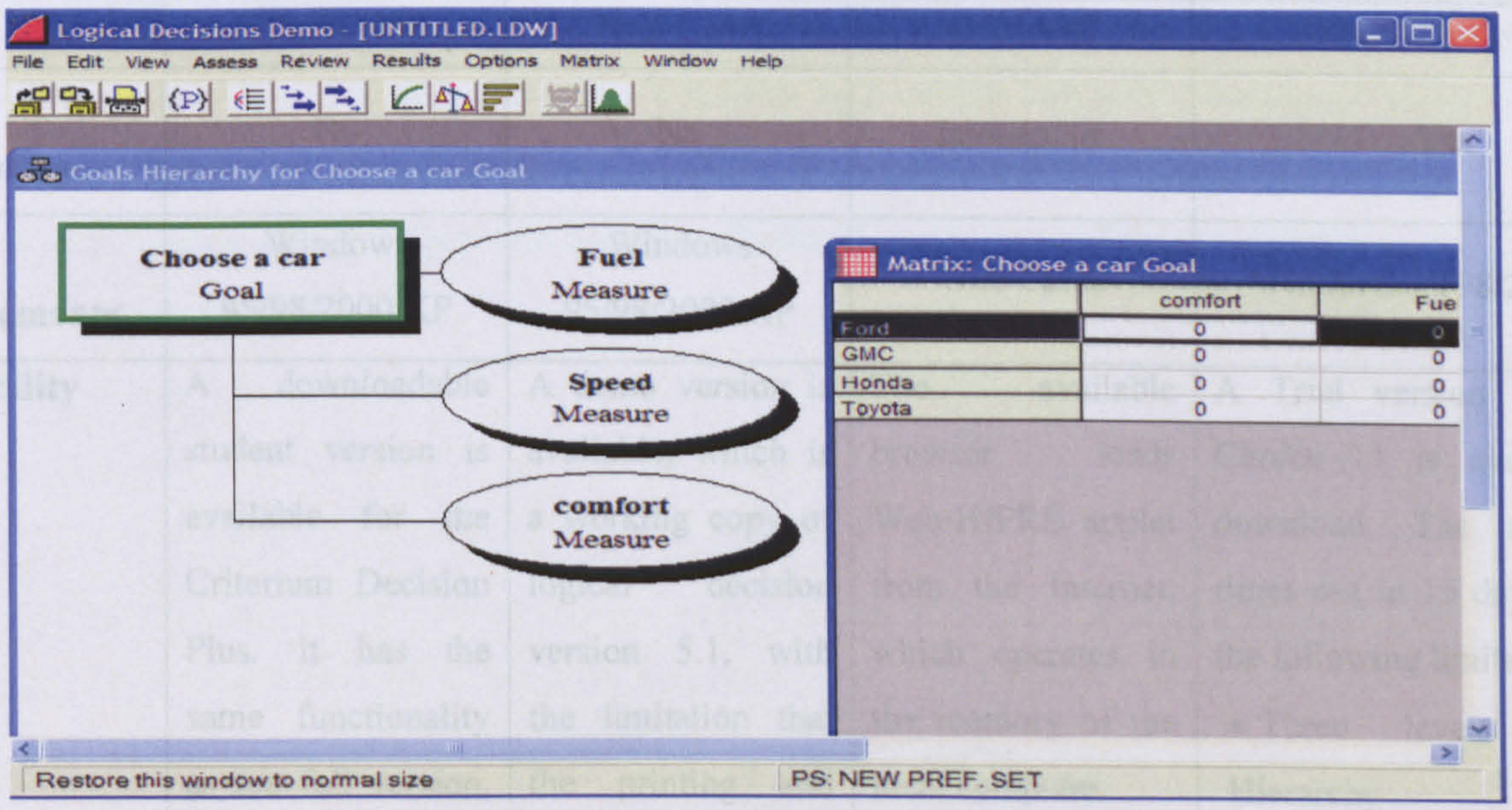


Figure (7.4): Logical Decisions Interface

7.2.5 Comparison between the Software Implementing the AHP

A comparison between the Criterium Decision Plus, Logical Decisions, Web HIPRE and Expert Choice 2000 is shown in Table (7.1).

	Criterium Decision Plus	**Logical Decisions**	**Web- HIPRE**	**Expert Choice 2000**
Functions	Structuring and analyzing complex decisions.	Modelling problems hierarchically, analyzing and ranking.	Problem Stucturing, and multi-criteria evaluation	Hierarchical defining goals and criteria and evaluating alternatives.
Problem Solving Methods	Analytical Hierarchy Process (AHP), and Simple Multi-Attribute Rating Technique (SMART)	Analytical Hierarchy Process (AHP)	Analytical Hierarchy Process (AHP), and Simple Multi-Attribute Rating Technique (SMART), and SMARTER	Analytical Hierarchy Process (AHP)
User	Single-user	Single-user	Multi-user	Single/multi-user
Web Technology	No	No	Java-applet	Yes
System Requirements	Windows 95/98/2000/XP	Windows 95/98/2000/XP	Web-based	Windows 95/98/2000/XP
Availability	A downloadable student version is available for the Criterium Decision Plus. It has the same functionality as the full version,	A demo version is available, which is a working copy of logical decision version 5.1, with the limitation that the printing and	The available browser loads Web-HIPRE applet from the Internet, which operates in the memory of the local computer.	A Trial version of Expert Choice 11 is available for download. The application times out in 15 days and has the following limitations: • Three levels in the Hierarchy

	but limits model size to 20 data blocks. The Price for the Academic License for the Criterium Decision Plus is $ 930 including shipping and handling. .	saving functions are disabled. The Price for the Academic License for the Logical Decisions 5.1 is $ 310 including shipping and handling.		• Seven objectives • Eight alternatives • Three participants • Printing disabled The License cost is £ 950(ex vat) for an Expert Choice version that takes input up to 25 decision participants in each model.
Web Sites	http://www.infoharvest.com	http://www.logicaldecisions.com	http://www.100gen.fi/English/alkusivu.htm	http://www.expertchoice.com

Table (7.1): A Comparison of CDP, Web HIPRE and Expert Choice Software

Trousdale (2001) conducted a review of decision analysis computer software programs in order to make recommendations for adopting one or more of these programs for use in public planning initiatives and decision making processes in British Columbia. Logical Decisions, Criterium Decision Plus and Expert Choice were among the reviewed software. With the help of the software developers and technicians, each software package was used for two to four hours. A summary of the technical scoring of the Decision Software Packages is shown in Table (7.2) below.

Criteria	Logical Decisions	Criterium Decision Plus	Expert Choice
Structuring Problem	**6**	**8**	**8**
Hierarchy	yes	yes	yes
Analysis	**9**	**7**	**6**
Sequential decision/decision trees	no	no	No
Probability	yes	yes	Possible
Multi-objective	yes	yes	yes
Technical	**7**	**6**	**4**
Technical Support	very good	very good	excellent
Software Reliability	Moderate	Average	Poor
Interactive Capabilities	**7**	**6**	**8**
Communication/graphics	very good	very good	very good
Group capability	very good	good	excellent
Multi-person capability	excellent	average	excellent
Ease of use	6	7	4

Table (7.2): Technical Scoring of the Decision Software Packages, Scale: 1=poor, 5=average, 10=excellent (Trousdale, 2001).

All the products help to develop a fairly realistic and complex model. All of them are designed to carry out the calculations using the AHP, provide a sensitivity analysis and offer graphical presentation of results. In this study, the relevant AHP analysis is carried out with the software package ' Criterium Decision Plus 3.0 Student Version'. The software Criterium Decision Plus (CDP) is produced by Infoharvest, Inc. to develop decision models.

With the CDP, the decision can be made more quickly than using other software and at no cost as the student free version will be used. The CDP software has been designed to allow the user/decision maker to move easily forward and backward at any stage of the decision making process. Another advantage is that CDP has a well designed graphical user interface and the goal, criteria and alternatives appear on the same page to facilitate reviewing of the hierarchy.

7.3 Creation of the Criterium Decisin Plus Model:

Creation of a decision model includes the following steps (CDP User's Guide):

1. Identify the goal (level 1).
2. Identify factors or criteria important in satisfying the goal (level 2).
3. Where appropriate, identify sub-criteria under each criterion (level 3).
4. Identify alternatives.
5. Define weights for rating sets relative to applicable criteria/subcriteria.
6. Define scores for rating set relative to alternatives.

Steps 1 through 4 form the structure or hierarchy of the decision model with steps 5 and 6 serving as quantitative and qualitative links between levels (The links are defined as weights or scores). The user has to undertake three main tasks to be able to reach a solution using the Criterium Decision Plus: Brainstorming the problem and building the model, Rating the Hierarchy and Reviewing the results. Explaination of how these steps are conducted using the Criterium Decision Plus is as follows.

7.3.1 Brainstorming and Creating the Decision Model:

Criterium Decision Plus is an interactive technique for building a model that simulate the flow of ideas and helps decision-makers organise the objectives of their decision into levels in the brainstorming session. The user has to collect preliminary decision criteria and group them graphically around a central goal while all alternatives ought to be listed in a separate column. The interface of the Brainstorming Session in Criterium Decision Plus, shown in Figure (7.5) .

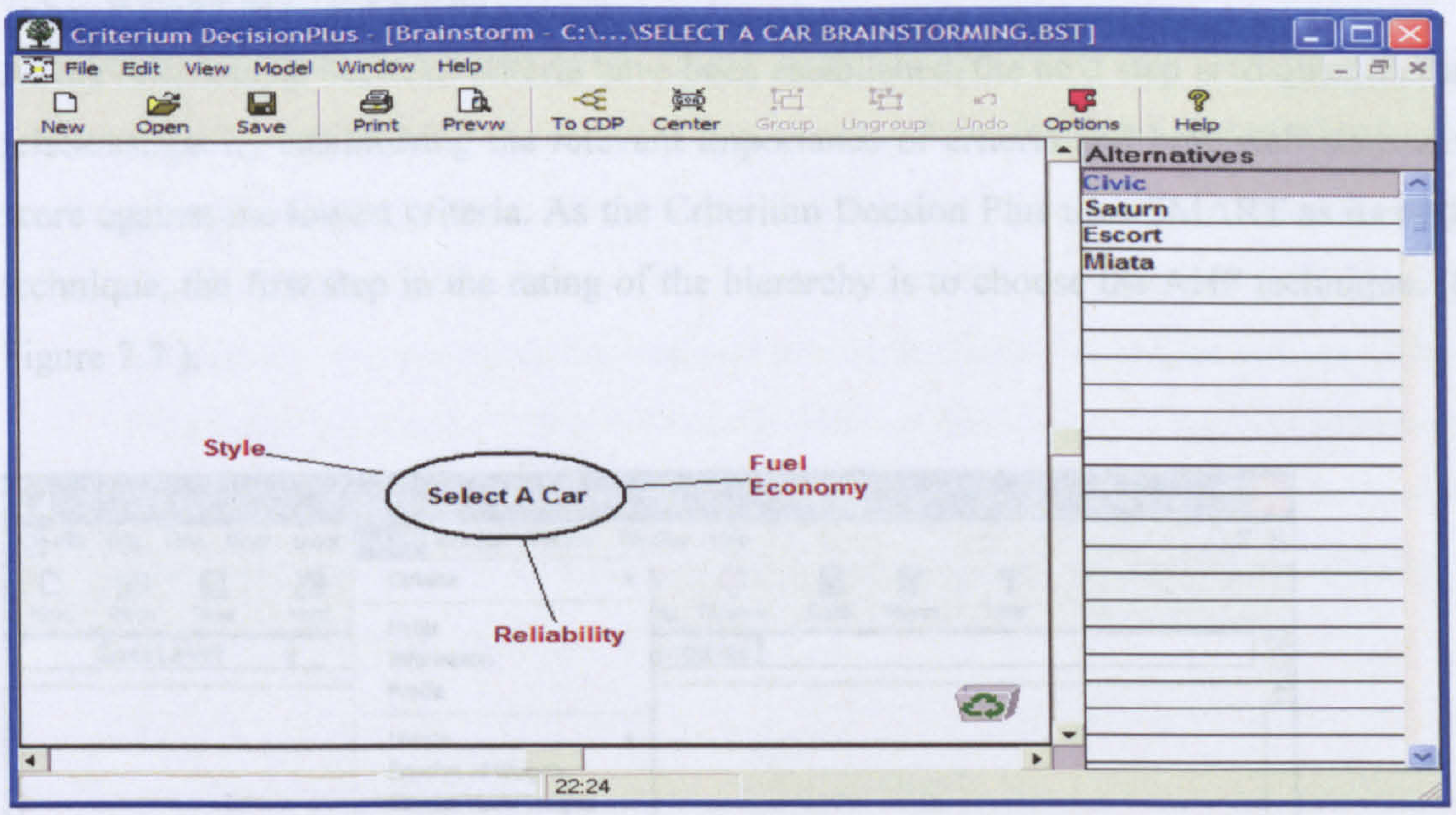


Figure (7.5): Brainstorming Window

The brainstorming session is followed by the creation of the hierarchy model. The Brainstorm model can be converted to a hierarchy model by selecting generate hierarchy from the the view menu in the brainstorm window. As can be seen in Figure (7.6), the decision model orginates at the goal, level 1, and branches off to criteria, sub-criteria and then alternatives.

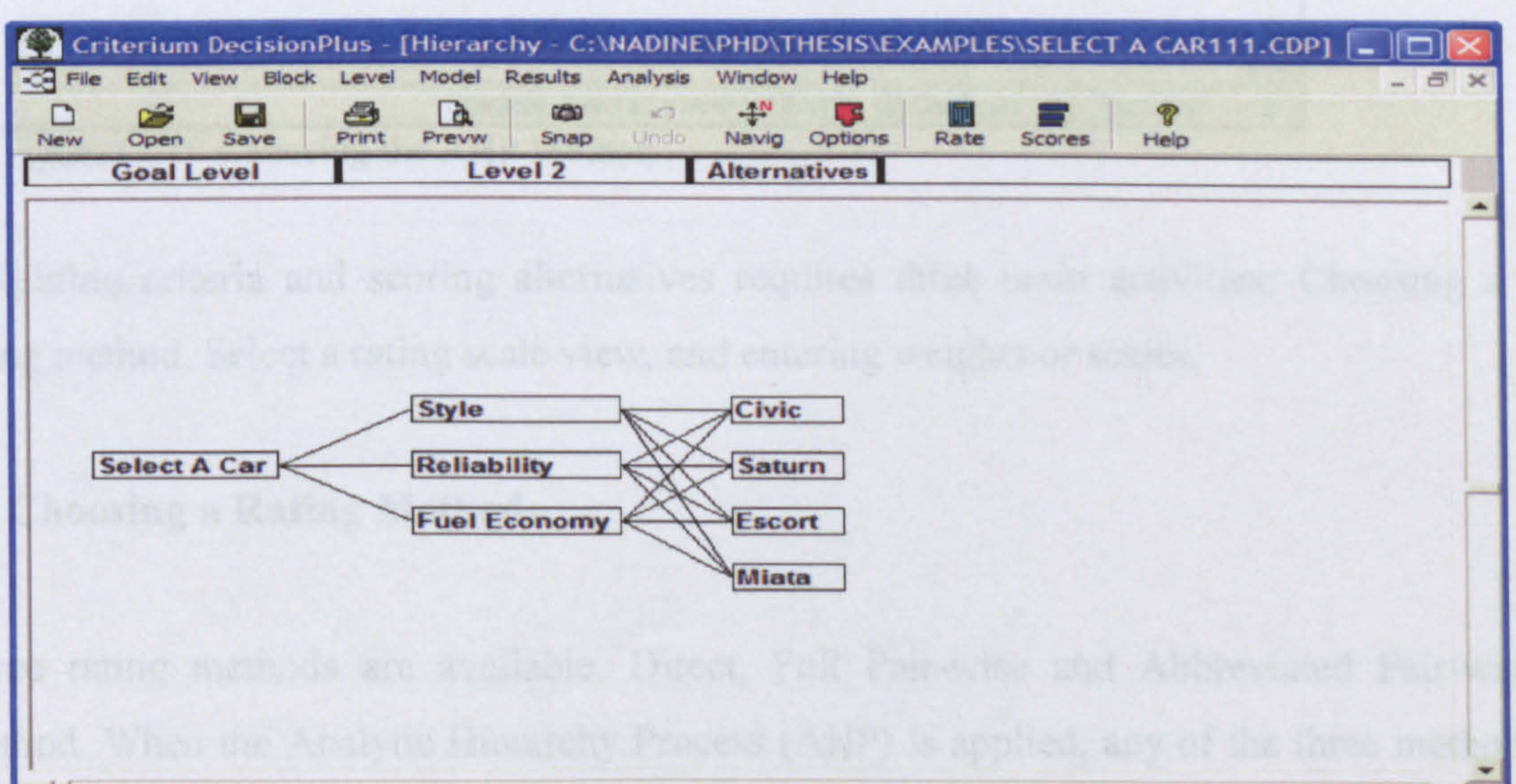


Figure (7.6): The Hierarchy Window

7.3.2 Rating the Hierarchy:

As the relationship between criteria have been established, the next step is to quantify those relationships by establishing the relevant importance of criteria and how well alternatives score against the lowest criteria. As the Criterium Decsion Plus uses SMART as its default technique, the first step in the rating of the hierarchy is to choose the AHP technique. (See Figure 7.7).

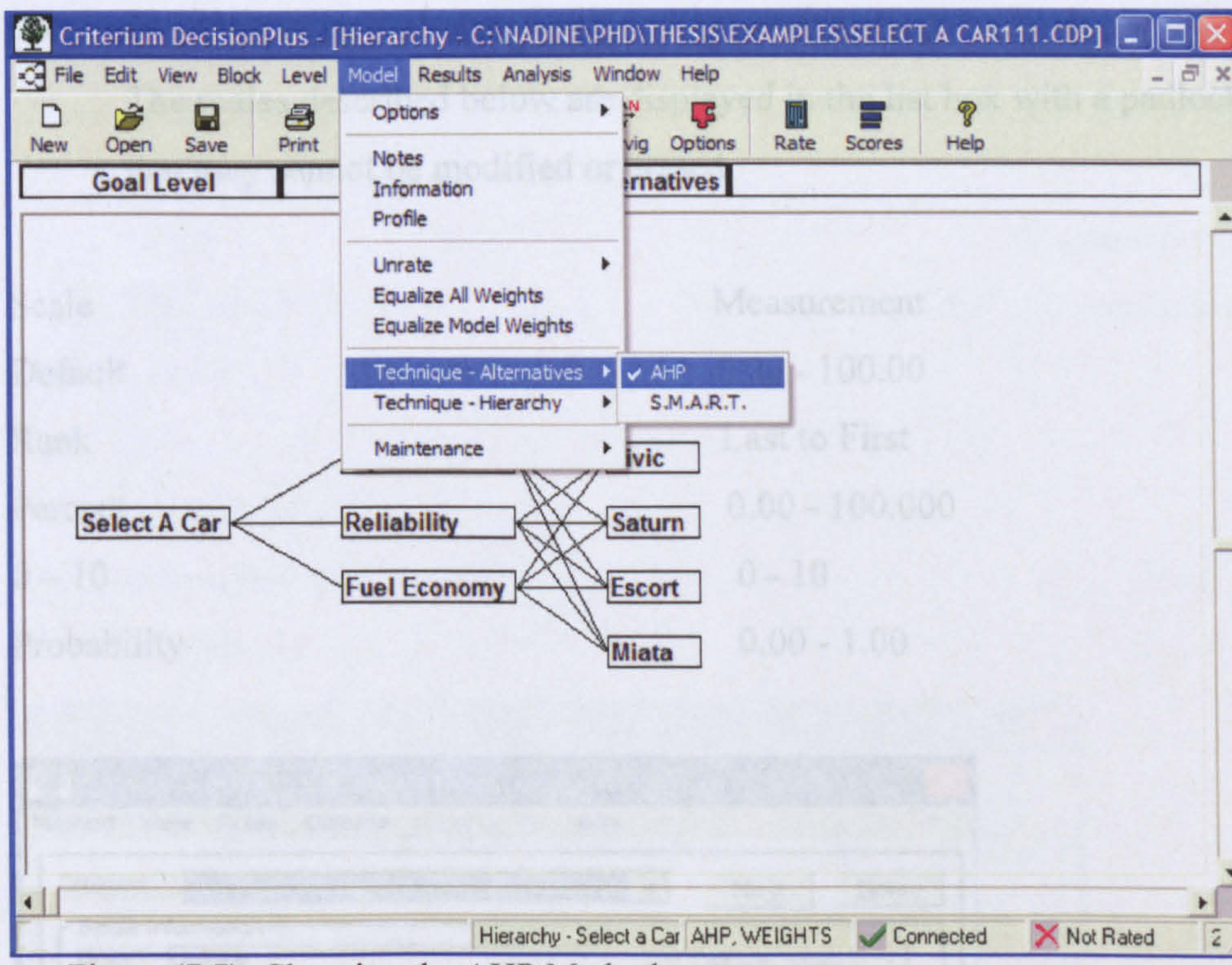


Figure (7.7): Choosing the AHP Method

Weighting criteria and scoring alternatives requires three main activities: Choosing a rating method, Select a rating scale view, and entering weights or scales.

1. Choosing a Rating Method:

Three rating methods are available, Direct, Full Pair-wise and Abbreviated Pair-wise Method. When the Analytic Hierarchy Process (AHP) is applied, any of the three methods can be used while with Simple Multi-attribute Rating Technique (SMART), only the direct method can be used at the scoring level. These three methods are described as follows:

- **Direct Method:** Direct Comparison is used to enter quantitative data about each criterion i.e. single elements are rated directly with respect to the parent element. Usually these values come from a previous analysis or from experience and detailed understanding of the decision problem. Direct Comparison is the default rating method for the Criterion Rating Window (See Figure 7.8). Five scales are provided, each with different units of measurement, from which you can choose. The scales described below are displayed in the list box with a padlock to indicate that they cannot be modified or erased.

Scale	Measurement
Default	0.00 - 100.00
Rank	Last to First
Percent	0.00 - 100.000
0 – 10	0 - 10
Probability	0.00 - 1.00

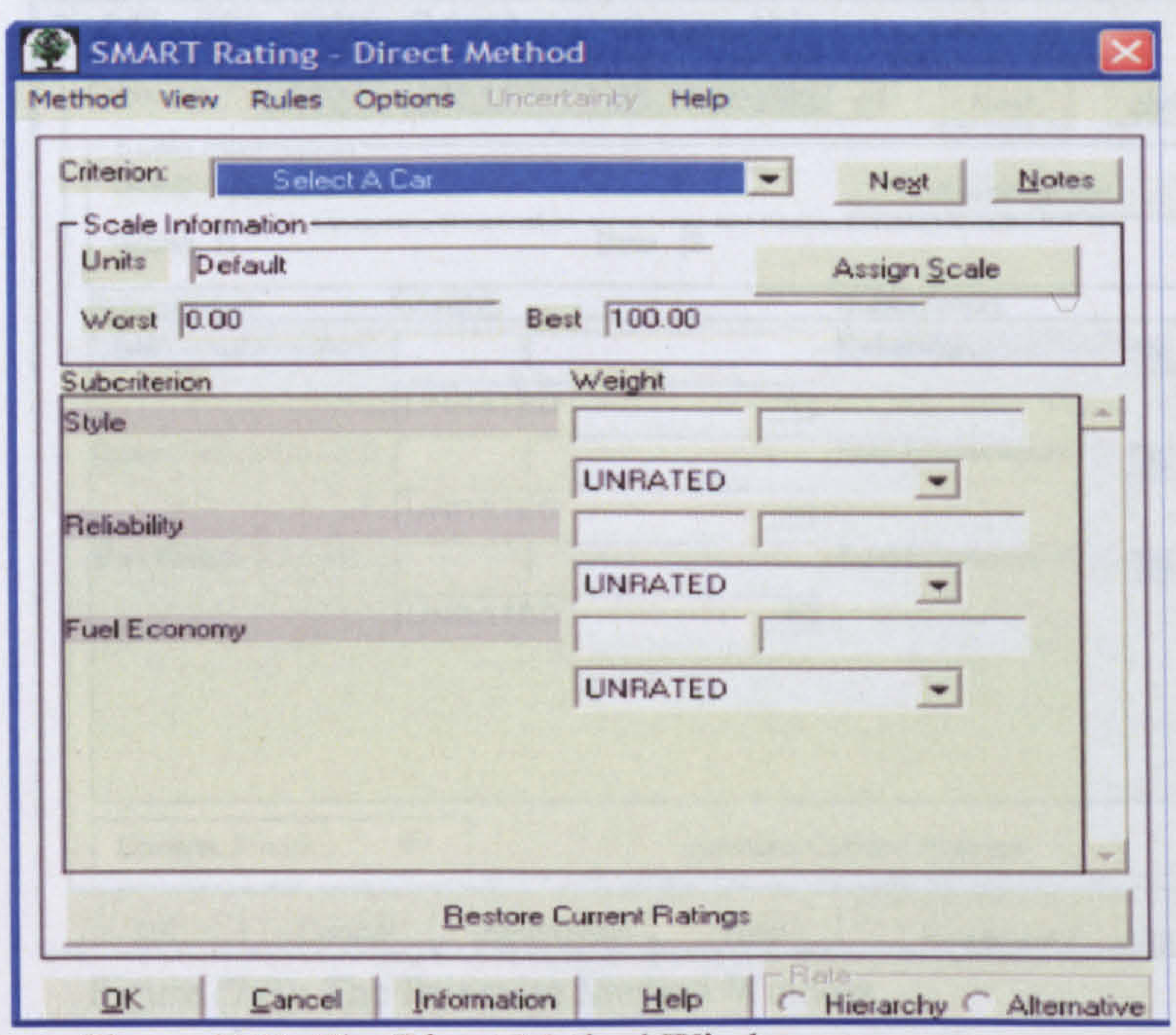


Figure (7.8): The Direct Method Window

- **Full Pair-wise Method:** Full Pair-wise Comparison means comparing in pairs. Each criterion in a rating set is compared to every other criterion in the same set (See Figure 7.9). This method is found to be useful if there is a lack in hard data about each criterion. Subjective judgment or intuition is all that needed to determine how one criterion compares to another. There are six pre-built pair-wise scales from which to choose. They are all measured in the range from +1 to +9 and their verbal and graphical equivalents. The scales listed below are displayed in the Assign Scales window list box with padlocks to indicate they cannot be modified or erased.

Scale	**Measurement**
Preference	+1 to +9 and verbal and graphical equivalents
Likelihood	
Size	
Importance	
Contribution	
Magnitude	

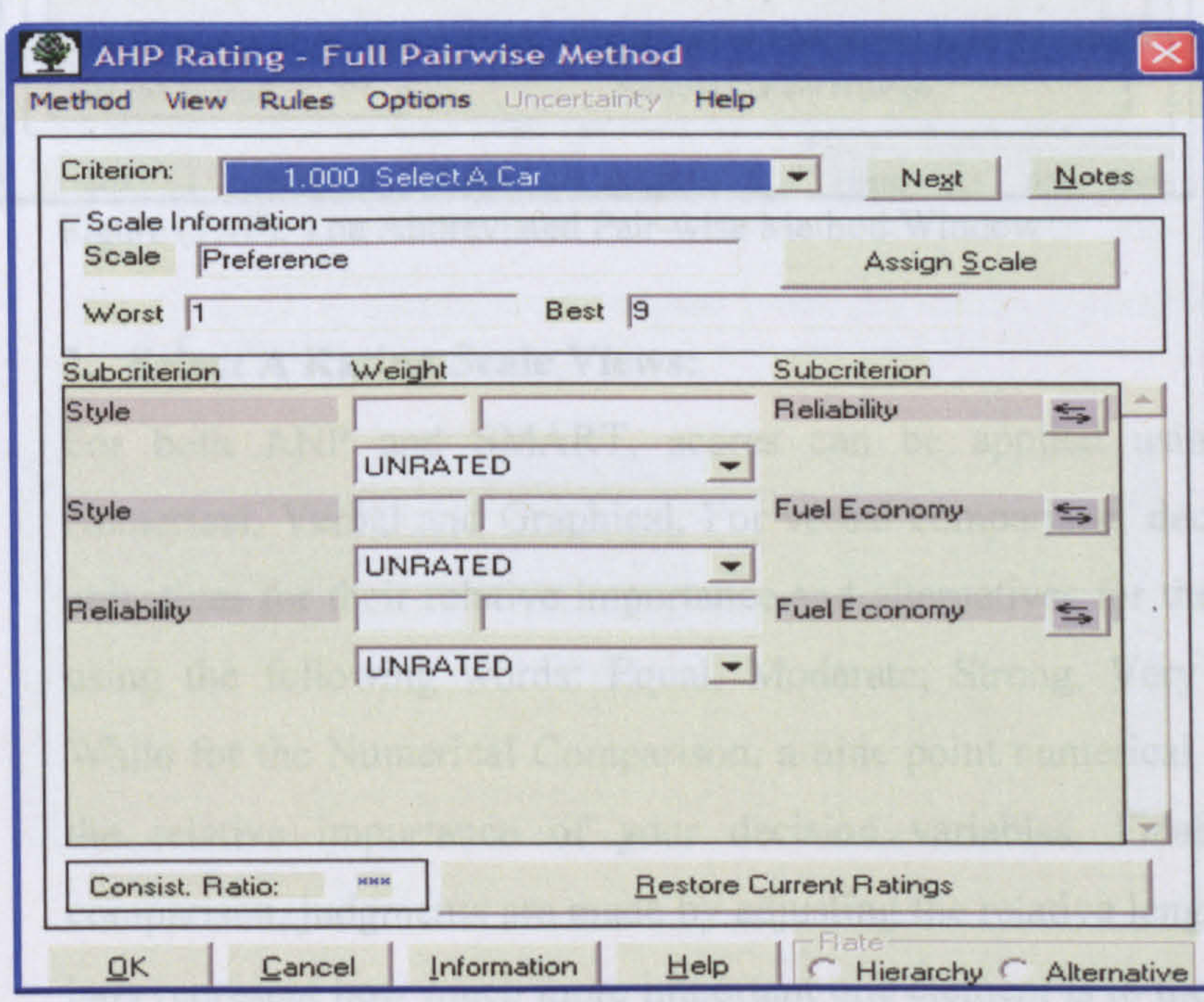


Figure (7.9): The Pair-wise Method Window

- **Abbreviated Pair-wise Method:** Abbreviated Pair-wise Comparison is similar to Full Pair-wise Comparison except that you work in smaller sets. It omits comparisons that are obvious. For example, if A is better than B, and B is better than C, then A is also better than C. The latter comparison is omitted (See Figure 7.10).

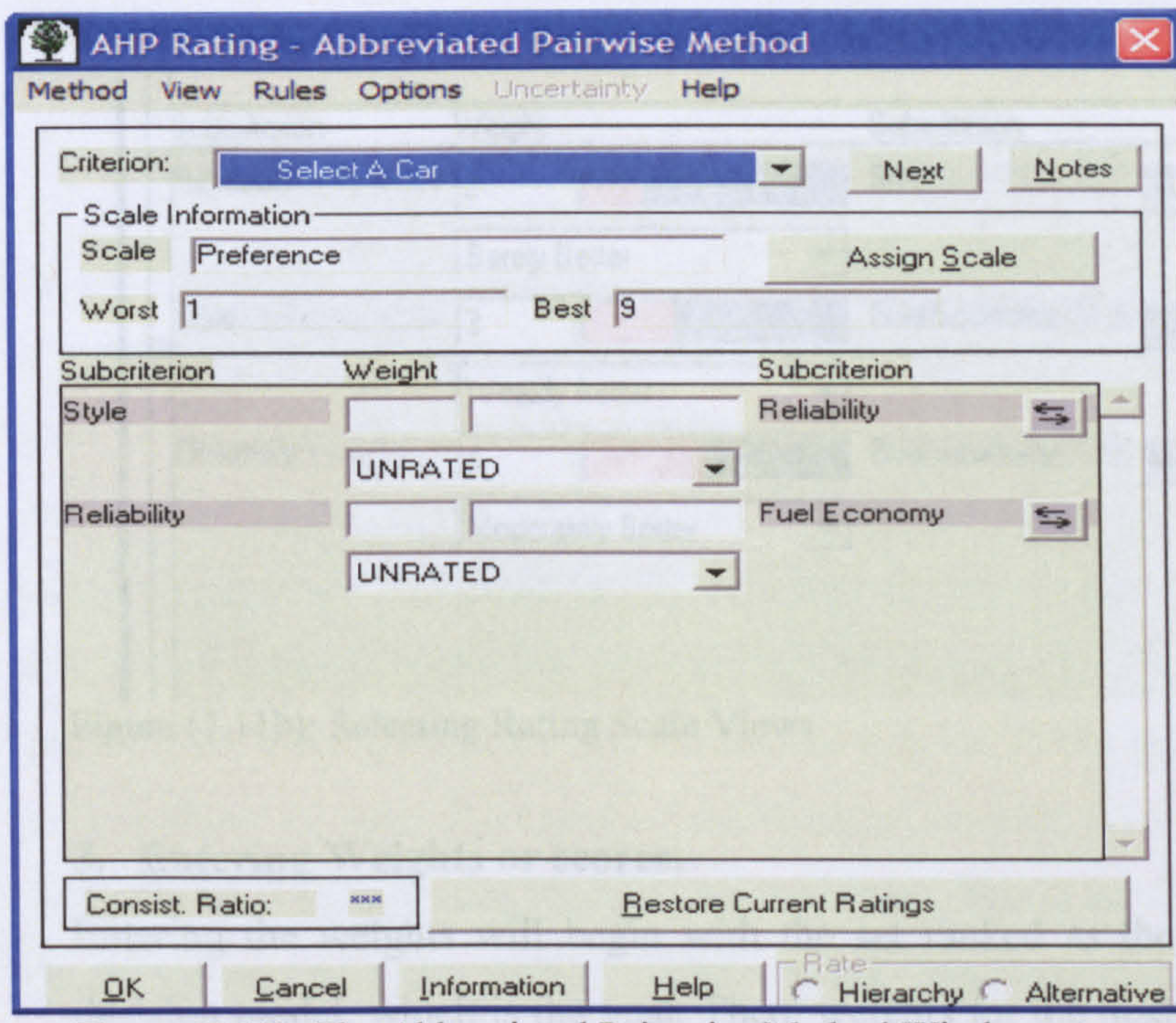


Figure (7.10): The Abbreviated Pair-wise Method Window

2. Select A Rating Scale Views:

For both AHP and SMART, scores can be applied using three scale views: Numerical, Verbal and Graphical. For verbal comparison, decision-makers compare objectives for their relative importance and alternatives for their relative preferences using the following words: Equal, Moderate, Strong, Very Strong and Extreme. While for the Numerical Comparison, a nine point numerical scale is used to define the relative importance of your decision variables. Finally, for the graphical comparison, judgments are made by adjusting the relative length of two bars until the bars represent how much more important one element is to the other. All these views appear in the Criterion Rating Window (See Figures 7.11a and 7.11b).

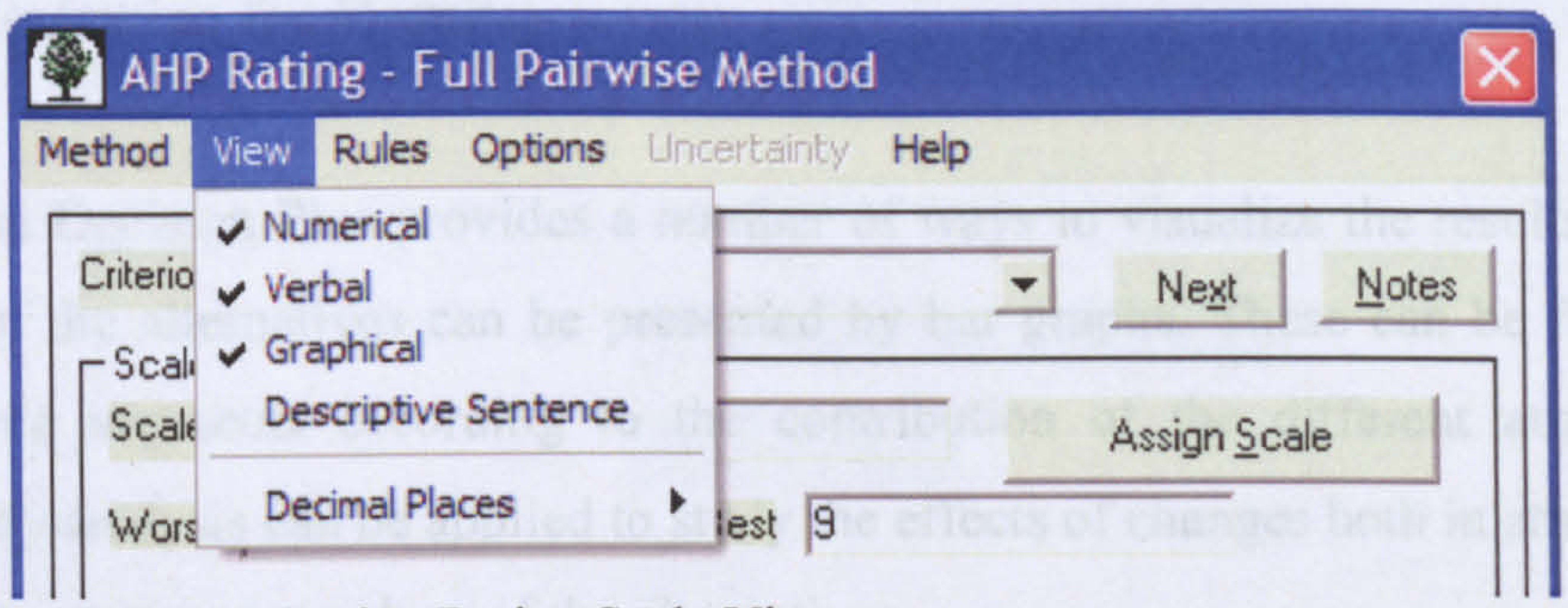


Figure (7.11a): Selecting Rating Scale Views

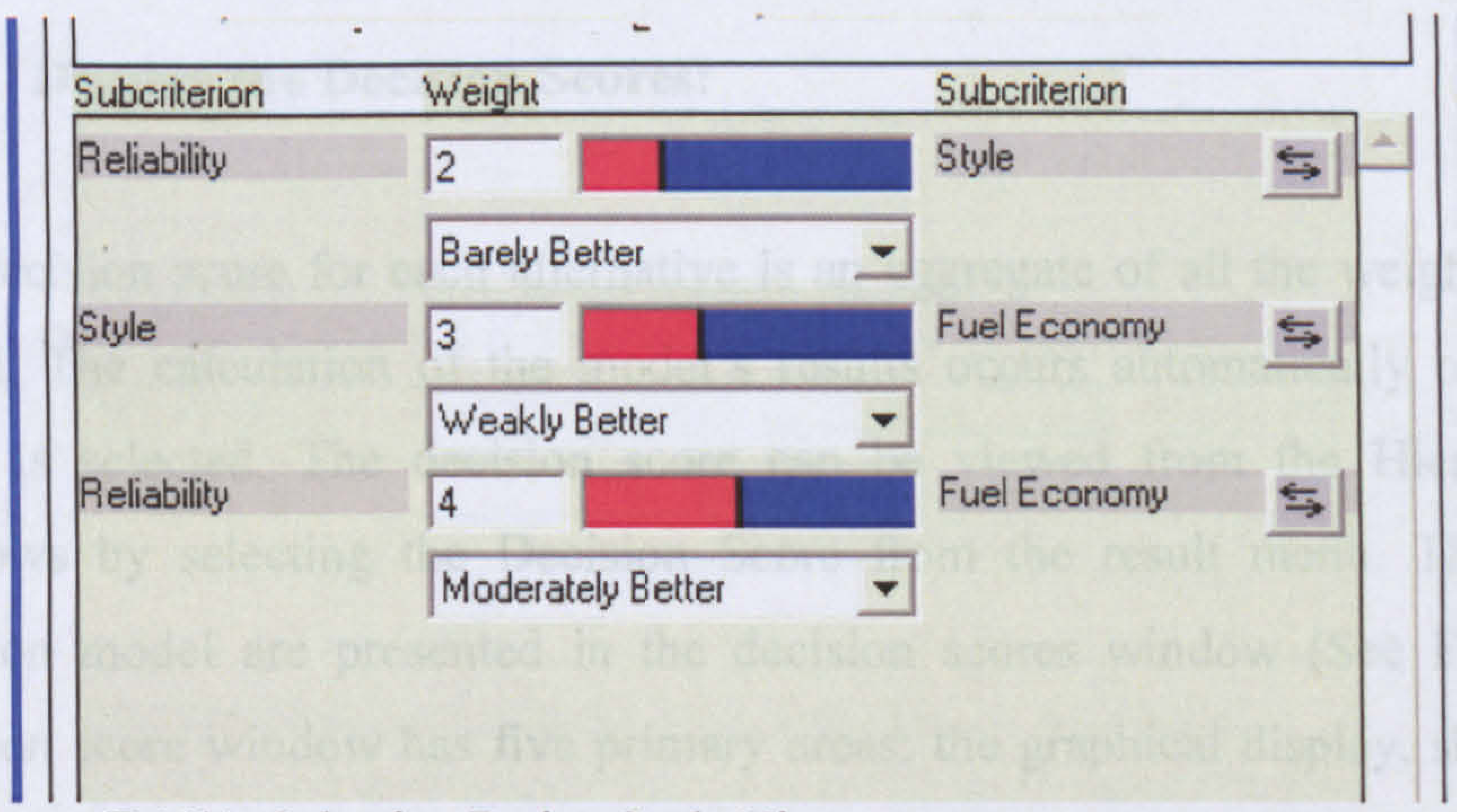


Figure (7.11b): Selecting Rating Scale Views

3. Entering Weights or scores:

Entering the weights will begin with the set ranked as the most important in the decision model, which is the goal. Then, weights for the next set are entered until all sets are rated. A message will appear when the model is completely rated as in Figure (7.12).

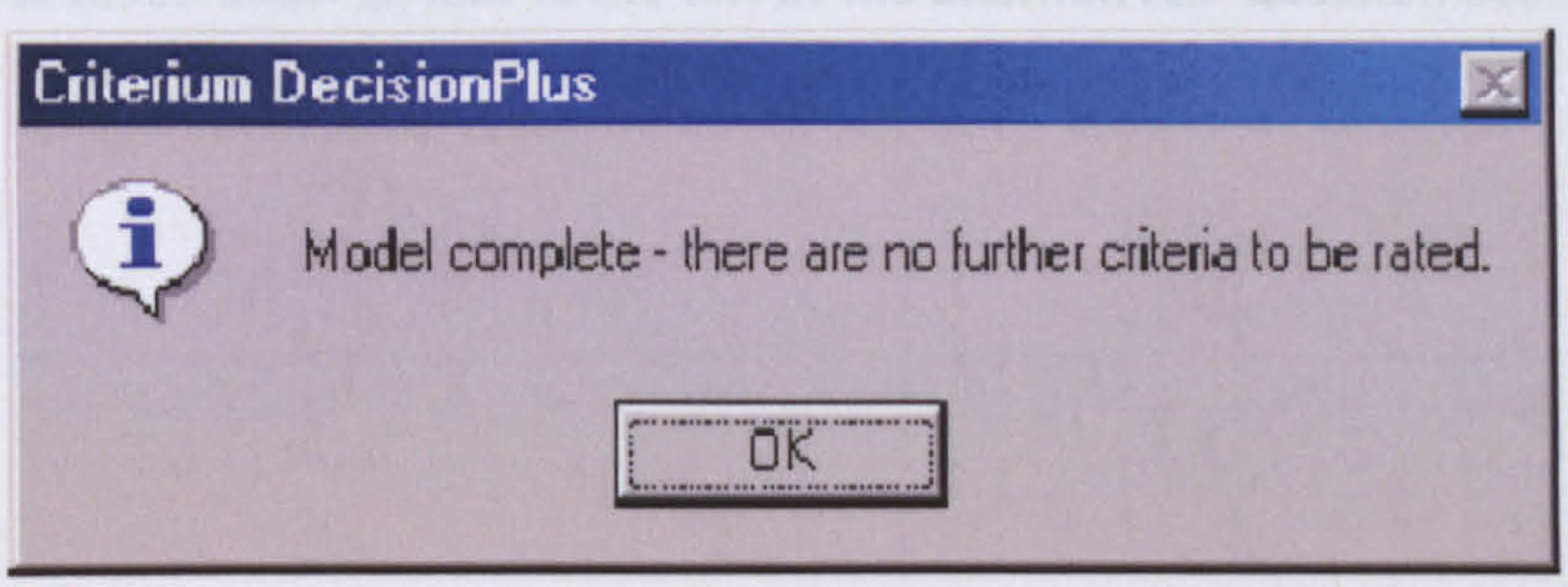


Figure (7.12): Model Complete Window

7.3.3 Reviewing the Results:

Criterium Decision Plus provides a number of ways to visualize the results. The overall values of the alternatives can be presented by bar graphs. These can be further broken down into segments according to the contribution of the different attributes. Also, sensitivity analysis can be applied to study the effects of changes both in attribute weights and in the component values of the alternatives.

- **Display the Decision Scores:**

The decision score for each alternative is an aggregate of all the weights entered in the model. The calculation of the model's results occurs automatically once the decision score is selected. The decision score can be viewed from the Hierarchy or results windows by selecting the Decision Score from the result menu. The results of the decision model are presented in the decision scores window (See Figure 7.13). The decision score window has five primary areas: the graphical display, show options, sort options, values options and the general control buttons. In the graphical display area, the decision score for each alternative of the decision model is presented as a horizontal bar chart with the decision score value shown to the left of each bar. The preferred alternative will be the one with the highest decision score. The main feature in the show options region is the ideal alternative. The sort options allow the user to arrange the alternatives in various ways. While, values options give the decision maker the choice to select which values to show in text to the left of the alternatives' decision scores bars.

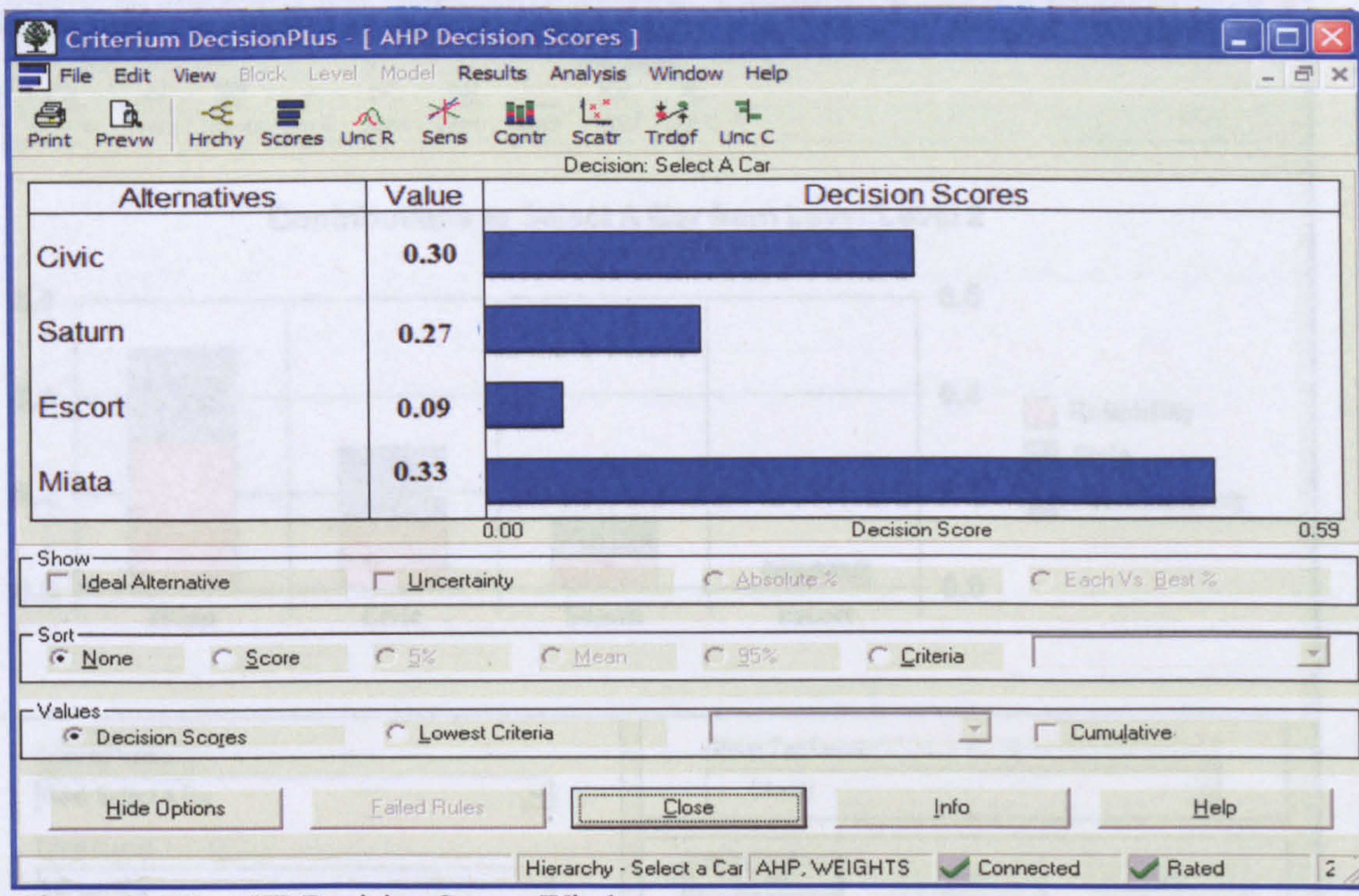


Figure (7.13): AHP Decision Scores Window

- **Contribution by Criteria and Sensitivity Analysis:**

CDP has two key built-in features that allow analysis of the weights given to the criteria and rates assigned to each alternative. The first is contribution by criteria, which presents the criteria contribute the most to the least to the score given for each alternative. This may give an indication of whether the decision is or is not a reasonable one. The contribution by criteria can be shown from the hierarchy window. The graphical presentation shows stacked histograms of the alternatives' decision scores at the target criterion, with the contribution of each criterion in the contributing level shown as a coloured band. See Figure (7.14).

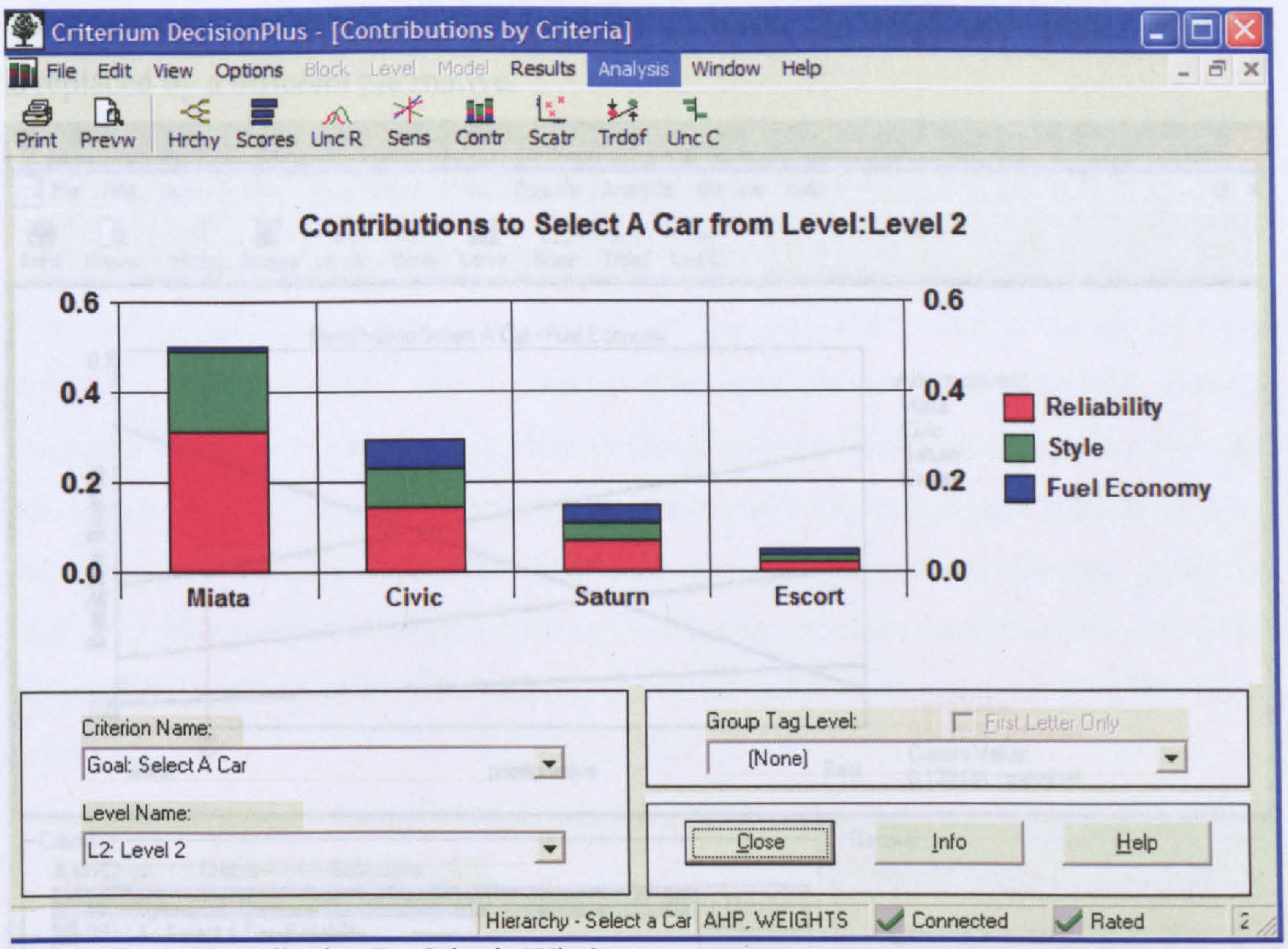


Figure (7.14): Contribution By Criteria Window

After making judgments about the relative importance of objectives, sub-objectives and alternatives, Criterium Decision Plus's powerful sensitivity graphs enable testing of the sensitivity of the decision to change in priorities. The screen shows a graphical representation of the sensitivities (See Figure 7.15).

The x-axis represents the range of values over which the most critical weight is varied (the priority value which is a function of the weight), and the y-axis represents the decision score. The horizontal lines represent the alternatives. The red cursor line and the intersection with the alternative line give the decision scores for the current set of weights which is the priority corresponding to the weight entered earlier in the Criterion Rating window for the Criterion/Sub-criterion pair. The value of that weight, in its own units, is shown to the right of the graph in parenthesis and black text. The same is repeated in red text just above. At the intersection of the red line and the alternatives lines, you see the decision score that is currently calculated for each alternative (as shown in the Decision Scores window). The importance of the sensitivity analysis is the calculation of how much the current value of the priority can change before the model's preferred alternative is replaced by a different alternative.

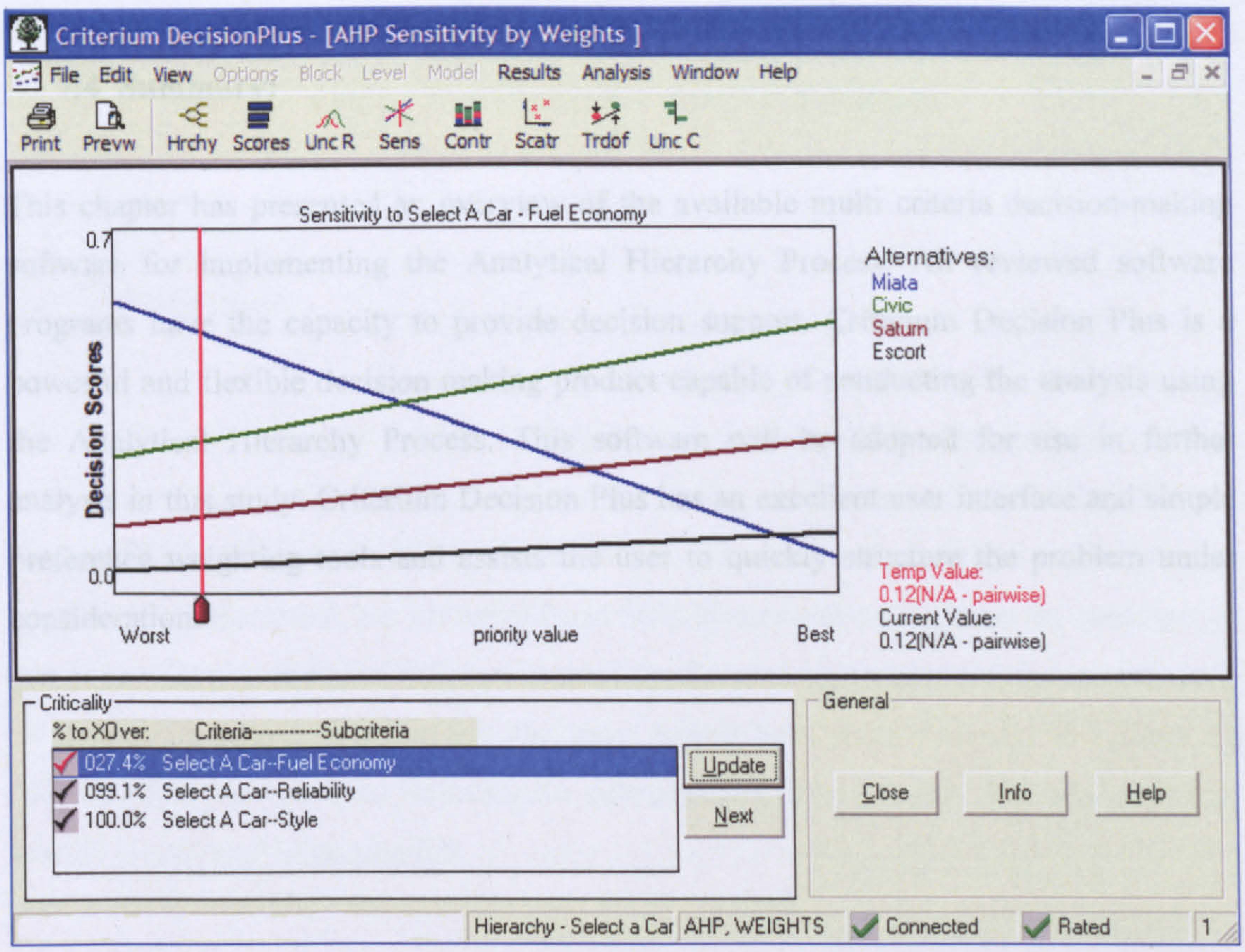


Figure (7.15): AHP Sensitivity by Weights Window

The minimum change for each priority is found and then that change as a percentage of the total priority scale is calculated. In the CDP, this percentage is referred to as the crossover percentage for a given weight. This tool calculates the most critical to least critical criterion in the model. The list box shows each weight of a sub-criterion with respect to its parent criterion in the decision model, and is identified by that Criterion/Sub-criterion pair. Beside each pair is the percentage crossover value. In the list box, the weights are shown in order of decreasing criticality of their priorities beginning with the lowest percentage (most critical) crossover point. This means that when you open the Sensitivity by Weights window, the plot you see is for the weight with the most critical priority in the model. Generally, in a sensitivity analysis, if a change of 5% or less to a particular criteria weight causes the change of the preferred alternative, the model is sensitive and it is risky to rely on the current input (InfoHarvest 1996). In such case, it is best to review and validate the initial weights.

7.4 Summary:

This chapter has presented an overview of the available multi criteria decision-making software for implementing the Analytical Hierarchy Process. All reviewed software programs have the capacity to provide decision support. Criterium Decision Plus is a powerful and flexible decision making product capable of conducting the analysis using the Analytical Hierarchy Process. This software will be adopted for use in further analysis in this study. Criterium Decision Plus has an excellent user interface and simple preference weighting tools and assists the user to quickly structure the problem under consideration.

CHAPTER EIGHT

Data Collection and Analysis

8.1 Introduction

The Analytical Hierarchy process (AHP) will be employed as a multi-criteria decision-making technique that allows many factors to be considered when making bidding decisions. The data required to construct the models were collected from top contractors in Gaza Strip. Section 8.2 is a brief of Gaza Strip history and its effect on the construction industry. Then in Section 8.3, an overview of the current state of the construction industry is given. In Section 8.4, the steps which have been followed to collect the required data were detailed including the questionnaire survey design. The analysis of the results is provided in section 8.5.

8.2 History of Gaza Strip

The Gaza Strip is a strip of land along the eastern coast of the Mediterranean Sea in the Middle East. It is bordered by Egypt from the south-west, Israel from the north and east and the Mediterranean Sea from the west. The primary language of Gazans is Arabic and it has one of the highest overall growth rates and population densities in the world; around 3750 person per square km. More than half of Gazans live in the region's urban centres, the largest of which is the City of Gaza. Other cities and towns in Gaza Strip include Khan Younis, Deir Al Balah and Rafah.

Due to its location on the Mediterranean Sea, near the crossroads of Africa, Asia, and Europe, Gaza Strip has a long history of occupation by foreign powers. In ancient times, from 1517 to 1917, Palestine was controlled by Turkey's Ottoman Empire. Then, following the defeat of Germany and Turkey in World War I, Gaza became part of the British mandate for Palestine from 1917-1948.The mandate government developed

administrative institutions, municipal services, public works and transport. It laid pipelines, expanded ports and extended railway lines.
After the armistice agreement of the Arab-Israeli War of 1948 until the 1967 war, the Gaza Strip was under the Egyptian administration. During this period, Palestinians were not allowed real control over local administration and they were totally dependent on Egypt and as a result economic development in the Gaza Strip was limited. This period witnessed a major increase of Gaza Strip population, as 70% of Palestinians living within the Israeli boundaries migrated to Gaza Strip and formed refugee camps. These camps were built and maintained by the United Nations Relief Works Administration (UNRWA). Israel did not allow them to return to their former homes or to receive compensation for their loss of property.
Then, the Gaza Strip was captured by Israel from Egypt in 1967 during the Six-Day War and occupied by Israel until 1994. During that period, the Gaza Strip became increasingly dependent on Israel for its imports (largely food, consumer goods and construction materials) and exports (mainly citrus fruit and other agricultural products).
With the inception of the Palestinian upraising (Intifada) in Gaza in 1987, the City became a major centre of political unrest and violence. Frequent military Israeli troops were sent to quell violence. High unemployment and low wages have been major problems. Moreover, as a result of the Gulf War (1991), masses of Palestinian workers in that area fled back to their families in Gaza Strip, creating a dire economic crisis and greater unemployment.
In 1994, an agreement, known as the Oslo Accord, was signed by Israel and the Palestinian Liberation Organization (PLO). Under the terms of this agreement, Israel began a phased transfer of authority in the Gaza Strip to the Palestinian National Authority (PNA). In effect, Israeli troops withdrew from the Gaza Strip, while maintaining control over Israeli settlements, and handed over the power to the PNA. The construction industry has since then witnessed noticeable expansion and activities.

8.3 An Overview of the Current Construction Industry State in Gaza Strip

Currently, the building and the construction industry is one of the leading sectors that enhance the economy in Gaza Strip. Since 1994, when the Palestinian National Authority took over power in the Gaza Strip, the construction industry witnessed major expansion and encouraged international investments. The construction sector is now employing almost 50% of the work force volume available in Gaza Strip; 20% is working in construction sites while 30% is indirectly employed in factories and other activities and services related to the construction industry. The Gaza Strip depends on Israel for nearly 90% of its imports of construction materials. Despite the fact that there are factories that are based in the Gaza Strip that can produce these building materials but they in turn rely on obtaining cement and other products from outside.

Most projects are focused on infrastructure and are financed by international bodies and organizations. These projects mostly focus on the provision of portable water, sewage disposal and road construction. Recent figures show that 45% of international grants offered to the different sectors in Gaza Strip are allocated to the construction sector. The following are the main international bodies and organizations supporting the construction industry in Gaza Strip:

- Islamic Development Bank (IDB).
- The United Nations Relief and Work Agency (UNRWA).
- World Bank (WB).
- The U.S Agency for International Development (USAID).
- United Nations Development Program (UNDP).
- The European Union (EU).
- German and Japanese Institutions.

The numbers of contractors have been also increased since 1994 and are classified according to their specialties and can be mainly divided into five categories as follows:

- Building Contractors: specialise in buildings, steel structures and building maintenance.
- Road construction Contractors: specialise in roads, concrete works and asphalt mixture.
- Water and sewer contractors: specialise in water and sewer recycling and irrigation and sewer.
- Electro-mechanics contractors: specialise in electro-mechanic maintenance, mechanical works and electrical works.

- Public works and maintenance contractors: specialise in public works and maintenance, mining, railways and wells.

8.4 Data Collection

The following are the steps that were performed to achieve the objectives of this research study:

- In order to construct the multi-criteria bidding decision models, the first step in the data collection process was the identification of the criteria/factors considered by contractors when making bidding decisions; bid/no bid and mark-up decisions. The search began with a review of all relevant material (professional journals, internet information, publications, text books and previous research papers) related to both bidding decisions. The intention was to cover all factors that influence both decisions. 55 factors were identified to affect both decisions. These factors were grouped into five categories: company characteristics, project characteristics, bidding situations, project documents and economic situations. Initially, in the light of the literature review and a consultation with two construction managers working in Gaza Strip, 20 of these factors were considered unimportant to the bidding decisions and were discarded from the list. A list of the remaining factors, 35 factors, with moderate to high importance to the bidding decisions was then presented to the two construction managers. They were asked to choose the most important factors considered when making bidding decisions. They were also asked to add any other factors considered to be important in making bidding decisions. Ten factors were selected to affect bid/no bid decisions while eleven factors were chosen to influence mark-up decision. The following are the factors considered important for bid/no bid decision:
    - Company Characteristics:
        - Experience in such projects: Number of similar projects executed and how many years of experience of executing similar projects.
        - Past profit in similar projects: Referred to the amount of profit obtained on past projects of similar type.

- Company Strength in industry: The reputation of the company, relations with banks, financial stability and certificates obtained.
- Need for work: considering the value and the number of projects the company have executed during this year with respect to the pre-set target.

- Project Characteristics:
  - Project type: Is the company classified for this type of work.
  - Contract conditions: Such as financial penalties in case of failure to perform to the terms of contracts, repairs and maintenance time.
  - Owner/client and consultant identity: This is concerned with the relationship between the Company and the Owner/ Client and Consultant.
  - Payment methods: If there is an advance payment, the currency of payments.
- Bidding Situations
  - Competition: Expected number of potential competitors bidding on this project.
- Economic Situations
  - Risk in fluctuation in material prices: If any fluctuation in material prices is expected.

While for mark-up, the following are the factors chosen:

- Company Characteristics:
  - Experience in such projects: Number of similar projects executed and how many years of experience of executing similar projects.
  - Past profit in similar projects: Referred to the amount of profit obtained on past projects of similar type.
  - Need for work: considering the value and the number of projects the company have executed during this year with respect to the pre-set target.
- Project Characteristics:
  - Project type: Is the company classified for this type of work.

- Project location: Is the project within the company work boundaries.
- Project size: Referred to the estimated project dollar volume.
- Project duration: This is the expected duration of the project.
- Contract conditions: Such as financial penalties in case of failure to perform to the terms of contracts, repairs and maintenance time.
- Owner/client and consultant identity: This is concerned with the relationship between the Company and the Owner/ Client and Consultant.

- Bidding Situations
  - Competition: Expected number of potential competitors bidding on this project.
- Economic Situation
  - Risk in fluctuation in material prices: If any fluctuation in material prices is expected.

As the use of the Analytical Hierarchy Process requires the determination of the relative importance of each of the elements in the hierarchy. Each element in a level is compared pair-wise with other elements at the same level, with respect to a criterion element at a higher level. The data required for this section was collected by way of a written structured questionnaire. It was decided to limit the sample size of 30 (large firms, which represent about 40% of the Gaza Strip construction industry population). This number of survey respondents was determined to be necessary for obtaining enough data to enable the analysis of the construction industry in Gaza Strip. The contractors were contacted first by phone to obtain their commitment and later giving them a copy of the questionnaire. The questionnaire with a covering letter was handed to the selected contracting companies in Gaza Strip. The covering letter stated the aims of the research study and a brief description of each section of the questionnaire was given (see appendix (A) for a copy of the covering letter).

8.4.1 Survey Questionnaire Design

To ensure that the questionnaire achieves the objectives of the study, suits the construction industry environment in Gaza Strip and encourages respondents to fill it in, the questionnaire was prepared in English and then translated into Arabic. Both draft versions of the survey questionnaire were then sent to two experts in the construction industry in Gaza Strip. Final versions of the survey questionnaire, in both English and Arabic languages, were then produced after taking the experts comments into account and making the necessary modifications. Contractors were given the choice of which version they prefer, the Arabic copy, the English one or both versions. The entire questionnaire extended to eight pages and was divided into four sections (See appendix A for both versions of the questionnaire). Section one of the questionnaire was an introductory section and consisted of eight general questions about the company- the classification of the company, number of years in the industry, number of full time permanent staff, the average job size executed, the average job duration, the percentage of work subcontracted on an average job, the percentage of work obtained through competitive bidding and the percentage using mathematical models to assist in bidding decisions. To make this section quick and easy to be answered, questions were of a closed ended form; where response category was provided. A few sample questions from section one of the questionnaires are given below.

<u>Section 1: Questions About Your Company:</u> *Please mark with an X where appropriate*

A- Classification of Contractor (The possibility of more than one choice)

1. Buildings ☐ 3. Electromechanical
2. Infrastructure ☐ 4. Other

B- Number of Years in Industry

1. Less than 5 ☐ 3. From 16 to 25
2. From 5 to 15 ☐ 4. More than 25

C- Number of Full Time Permanent Staff

1. Less than 10 ☐ 3. From 21 to 30
2. From 10 to 20 ☐ 4. More than 30

Section two of the survey questionnaire was based and developed using the Analytical Hierarchy Process. It was concerned with comparisons of the factors affecting the bid/no bid decision. Clear instructions of how to fill in this part of the questionnaire have been provided at the beginning of this section. Experts have been asked to make pair-wise comparisons between two factors/criterion at a time, decide which factor is more important, and then specify the degree of importance on a scale between 1 (equal importance) and 9 (absolutely more important) to the more important factor/criterion. Ten factors were considered in this section as follows:

According to the Analytical Hierarchy Process, there are n (n-1)/2 = 10(10-1)/2= 45 (i.e. 45 pair-wise comparisons) judgments required to develop the set of matrices in this step. Part of Section two are presented below in both.

<u>Section 2: Comparisons of Factors Affecting Bid / No Bid Decision</u>

For each pair of value comparisons below:

1. Tick one box of each line of the grey-highlighted section to indicate the factor that is *more important* to you.
2. Tick one box of the white section to the right to indicate how much more important that value compared to the other.
3. In case of equal importance, please tick both factors and the equally box.
4. Please note that values 2, 4, 6 and 8 are intermediate values between 1, 3, 5, 7 and 9.

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Experience in such projects	*Vs*	☐ Past profit in similar projects									
☐ Experience in such projects	*Vs*	☐ Competition									
☐ Experience in such projects	*Vs*	☐ Need for work									
☐ Experience in such projects	*Vs*	☐ Company strength in the industry									
☐ Experience in such projects	*Vs*	☐ Contract conditions									
☐ Experience in such projects	*Vs*	☐ Owner/Client/Consultan t Identity									
☐ Experience in such projects	*Vs*	☐ Project type									

Section three of the survey questionnaire was again based and developed using the Analytical Hierarchy Process. It was concerned with the comparisons of factors affecting Mark-up decision. Eleven factors were considered in this section as follows:

According to the Analytical Hierarchy Process, there are $n(n-1)/2 = 11(11-1)/2 = 55$ (i.e. 55 pair-wise comparisons) judgments required to develop the set of matrices in this step. Part of Section two are presented below.

<u>*Section 3:* ***Comparisons of Factors Affecting Mark-Up Decision***</u>

For each pair of value comparisons below:

1. Tick one box of each line of the grey-highlighted section to indicate the factor that is *more important* to you.
2. Tick one box of the white section to the right to indicate how much more important that value compared to the other.
3. In case of equal importance, please tick both factors and the equally box.
4. Please note that values 2, 4, 6 and 8 are intermediate values between 1, 3, 5, 7 and 9

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally		Weakly		Strongly		Very Strongly		Absolutely
			1	2	3	4	5	6	7	8	9
☐ Experience in such projects	*Vs*	☐ Past profit in similar projects									
☐ Experience in such projects	*Vs*	☐ Competition									
☐ Experience in such projects	*Vs*	☐ Need for work									
☐ Experience in such projects	*Vs*	☐ Contract conditions									
☐ Experience in such projects	*Vs*	☐ Owner/Client/Consultant Identity									
☐ Experience in such projects	*Vs*	☐ Project type									
☐ Experience in such projects	*Vs*	☐ Project location									
☐ Experience in such projects	*Vs*	☐ Project size									
☐ Experience in such projects	*Vs*	☐ Project duration									
☐ Experience in such projects	*Vs*	☐ Risk in fluctuation in material prices									

Section four of the questionnaire concerned with respondents view about the questionnaire. Section four is presented below.

Section 4: Your Views About this Questionnaire:		
	Too complex	About right
Did you find this questionnaire?		
How long did it take you to complete the questionnaire?		
Suggestions:		

8.5 Data Analysis and Results

This section is concerned with the analysis of the results obtained through the questionnaire survey. The questionnaires were completed by top management in the organizations, mainly directors, who usually make project selection and mark-up decisions. Eight completed copies of the questionnaire were filled in English while twenty two were Arabic versions.

8.5.1 Section One:

The following are the results obtained by analysing section one of the survey questionnaire. Mainly, the characteristics of the participating contractors are given.

- *Specialisation of the Contractors Surveyed*

To obtain the profile of the companies which participated in the survey, company specialisation details were asked for as a part of the survey questionnaire. As shown in table (8.1) and Figure (8.1), all contractors are categorised for at least two types of projects. All respondent companies are classified for building type projects. While, 97% are involved in infrastructure, 57% are involved in electromechanical projects and 17% of the respondents can carry out other works.

Table 8.1: Specialisation of the Contractors Surveyed

Specialization	No. of Respondents	Percent of Respondents
Buildings	30	100
Infrastructure	29	97
Electromechanical	17	57
Other	5	17

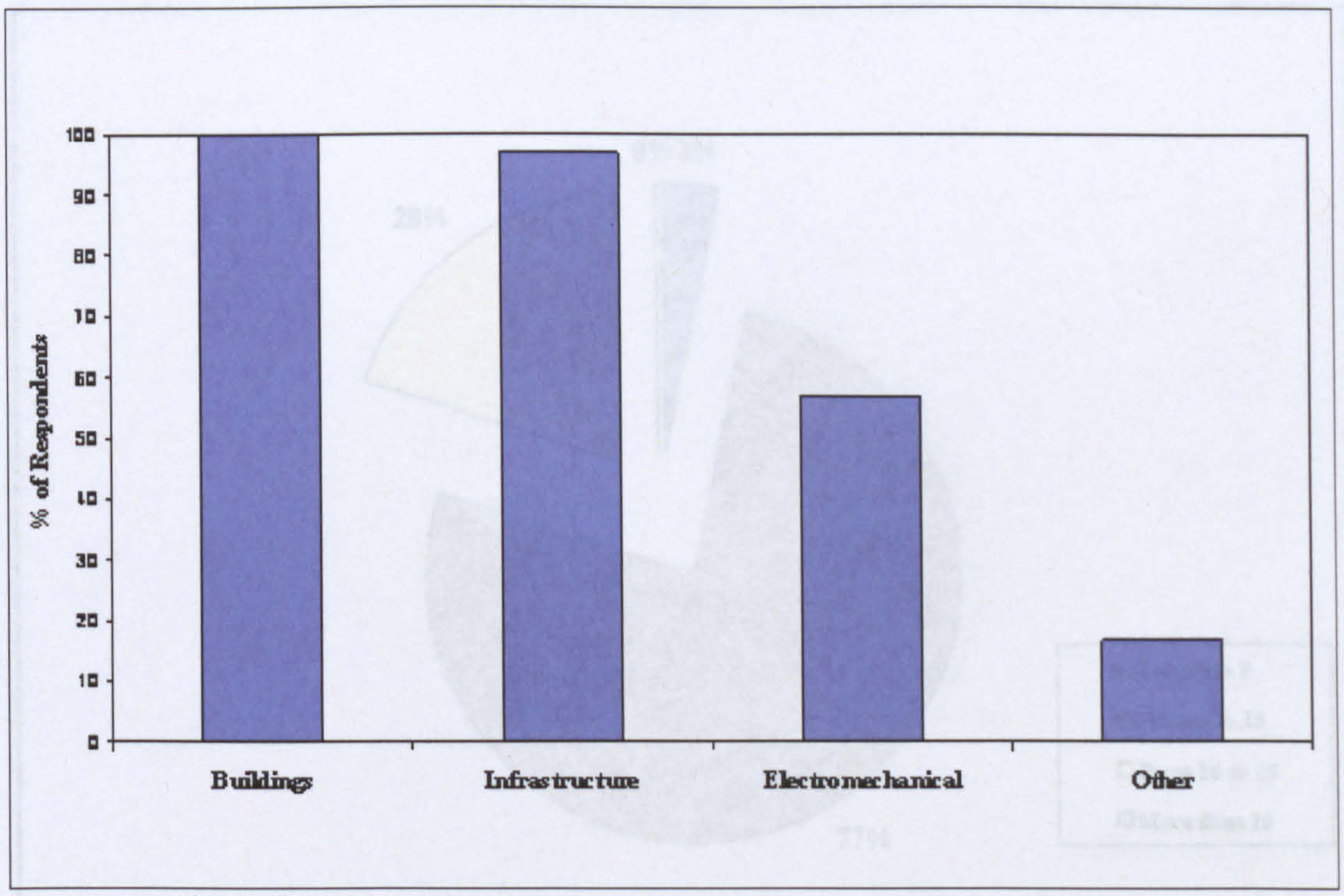


Figure (8.1): Classification of Contractors

- *Number of Years in Industry for the Contractors Surveyed*

Table (8.2) and Figure (8.2) present the number of years in industry for the surveyed contractors. The results indicate that 77% of the contractors that participated in the questionnaire survey have been in the construction industry between 5 to 15 years and 20% have been in the industry between 16 to 25 years. This indicates that the majority of companies have been established since 1994; when power was transferred to Palestinian National Authority (PNA). Only 3% (which is one contractor) of the respondents has been working for less than five years which indicates that the collected data were obtained from experienced construction contractors in the industry.

Table (8.2): No. of Years in Industry for the Contractors Surveyed

Range (Years)	No. of Respondents	Percent of Respondents
Less than 5	1	3
From 5 to 15	23	77
From 16 to 25	6	20
More than 25	0	0
Total	30	100

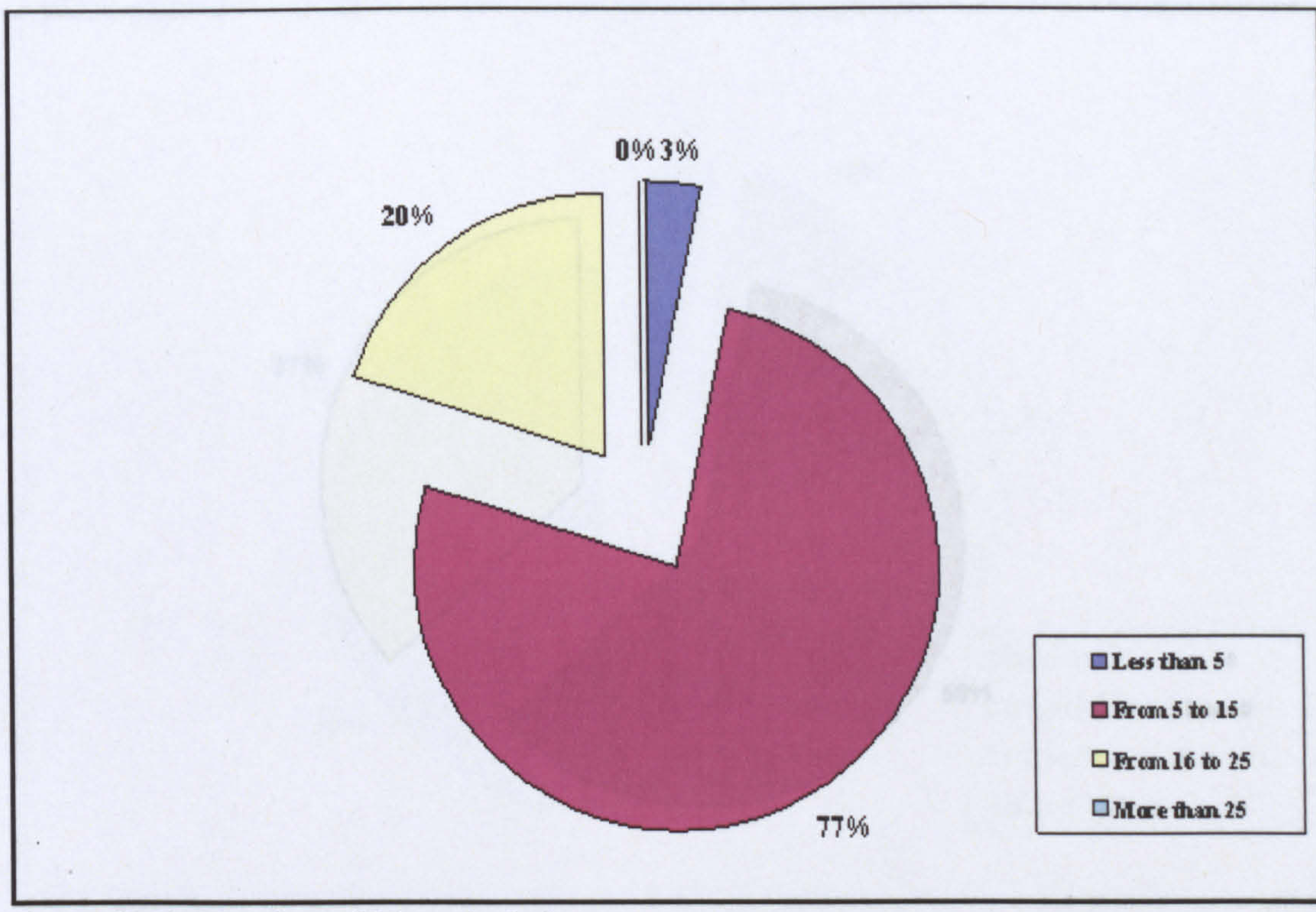


Figure (8.2): Number of Years in Industry

- *Number of Full Time Staff for the Contractors Surveyed*

Table (8.3) and Figure (8.3) show the number of full time staff for the contractors surveyed. 60 % of the companies have staff numbers in the range from 10-20, while 37% in the range from 21-30. This is quite common in Gaza Strip construction industry, as companies tend to employ temporary/part-time staff as needed for each project.

Table (8.3): No. of Full Time Staff for the Contractors Surveyed

Range	No. of Respondents	Percent of Respondents
Less than 10	1	3
From 10 to 20	18	60
From 21 to 30	11	37
More than 30	0	0
Total	30	100

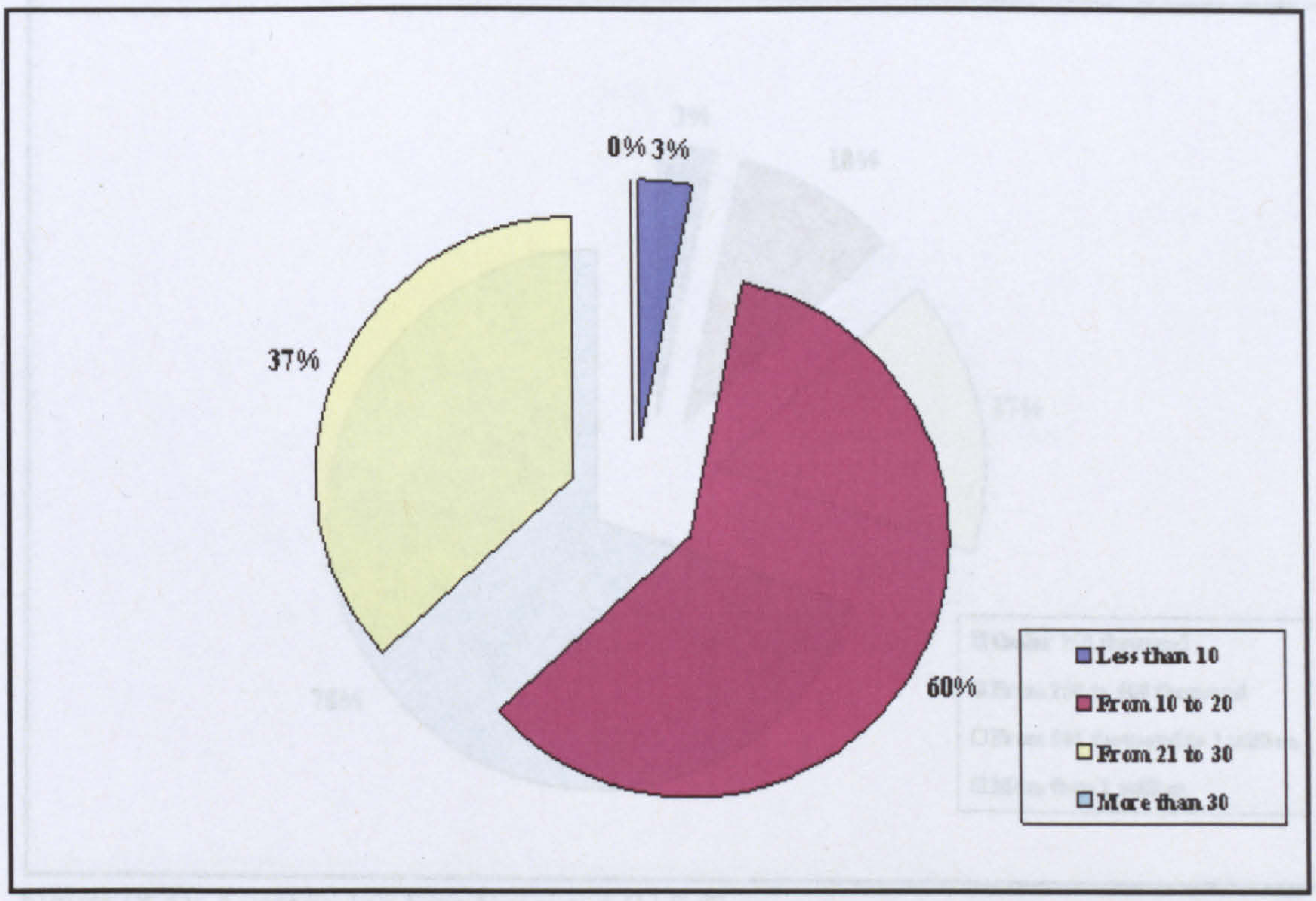


Figure (8.3): Number of Full Time Permanent Staff

- *Average Job Size Executed by the Companies Surveyed*

The average job size executed by the participating contractor is shown in Table (8.4) and Figure (8.4). 70% of the respondents have executed jobs with an average size of more than one million of U.S dollars which indicates that the majority of the surveyed contractors do execute large projects. Another 17% are between 501 thousand to one million of U.S dollars, 10% are between 250 to 500 thousand U.S dollars and only 3% under 250 thousand U.S dollars.

Table (8.4): Average Job Size Executed By the Companies Surveyed

Range (U.S $)	No. of Respondents	Percent of Respondents
Under 250 000	1	3
From 250 000 to 500 000	3	10
From 501 000 to 1000 000	5	17
More than 1000 000	21	70
Total	30	100

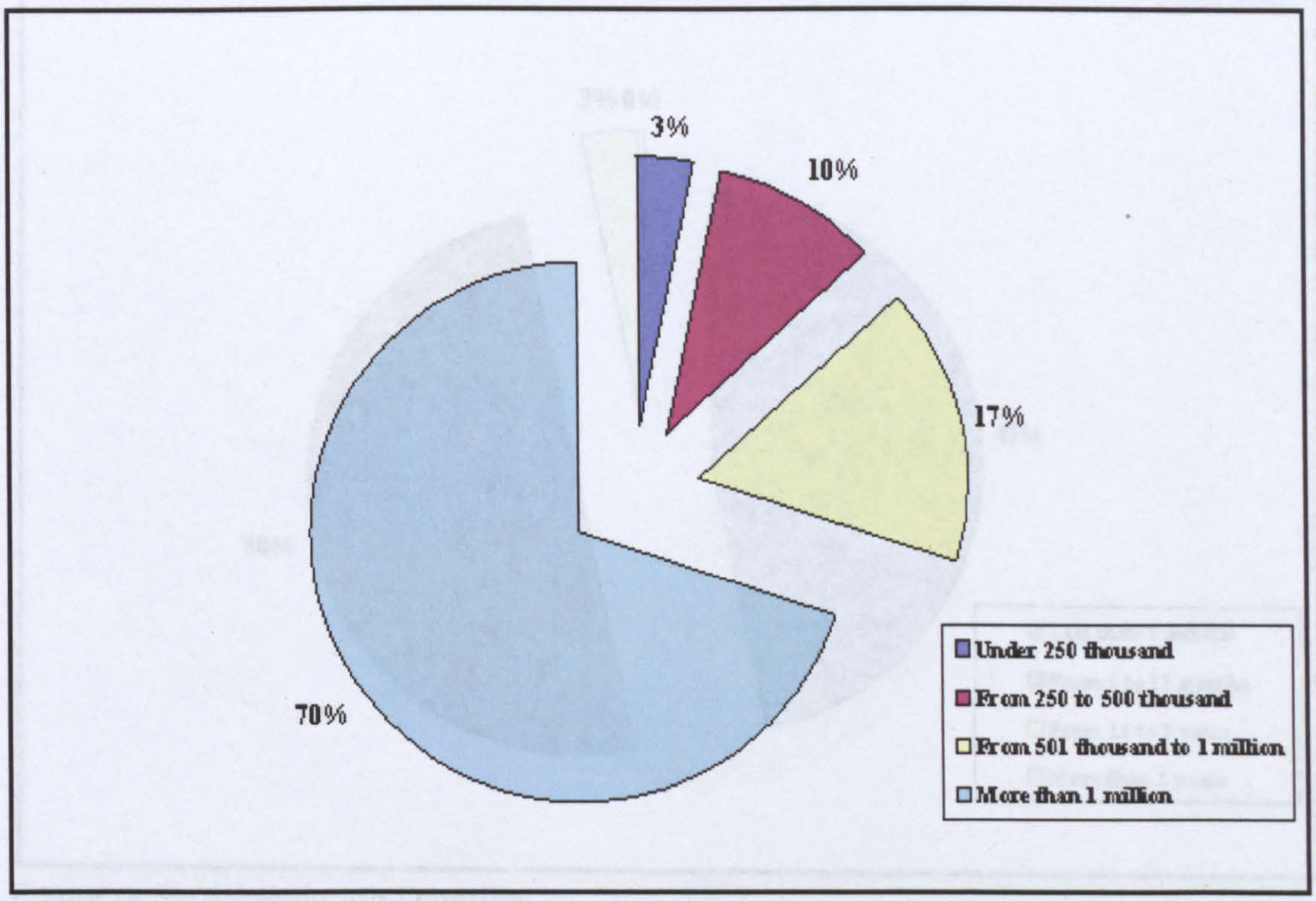


Figure (8.4): Average Job Size Executed (U.S $)

- *Average Job Duration Executed by the Companies Surveyed*

As can be seen from Table (8.5) and Figure (8.5), the job duration in Gaza Strip is relatively short as none of the respondents have job duration more than two years and only 3% (one contractor) from 13 months to 2 years. 47% of the companies surveyed have job duration less than 6 months while 50% of them from 6 to 12 months.

Table (8.5): Average Duration of Jobs Executed By the Companies Surveyed

Duration	No. of Respondents	Percent of Respondents
Less than 6 months	14	47
From 6 to 12 months	15	50
From 13 months to 2 years	1	3
More than 2 years	0	0
Total	30	100

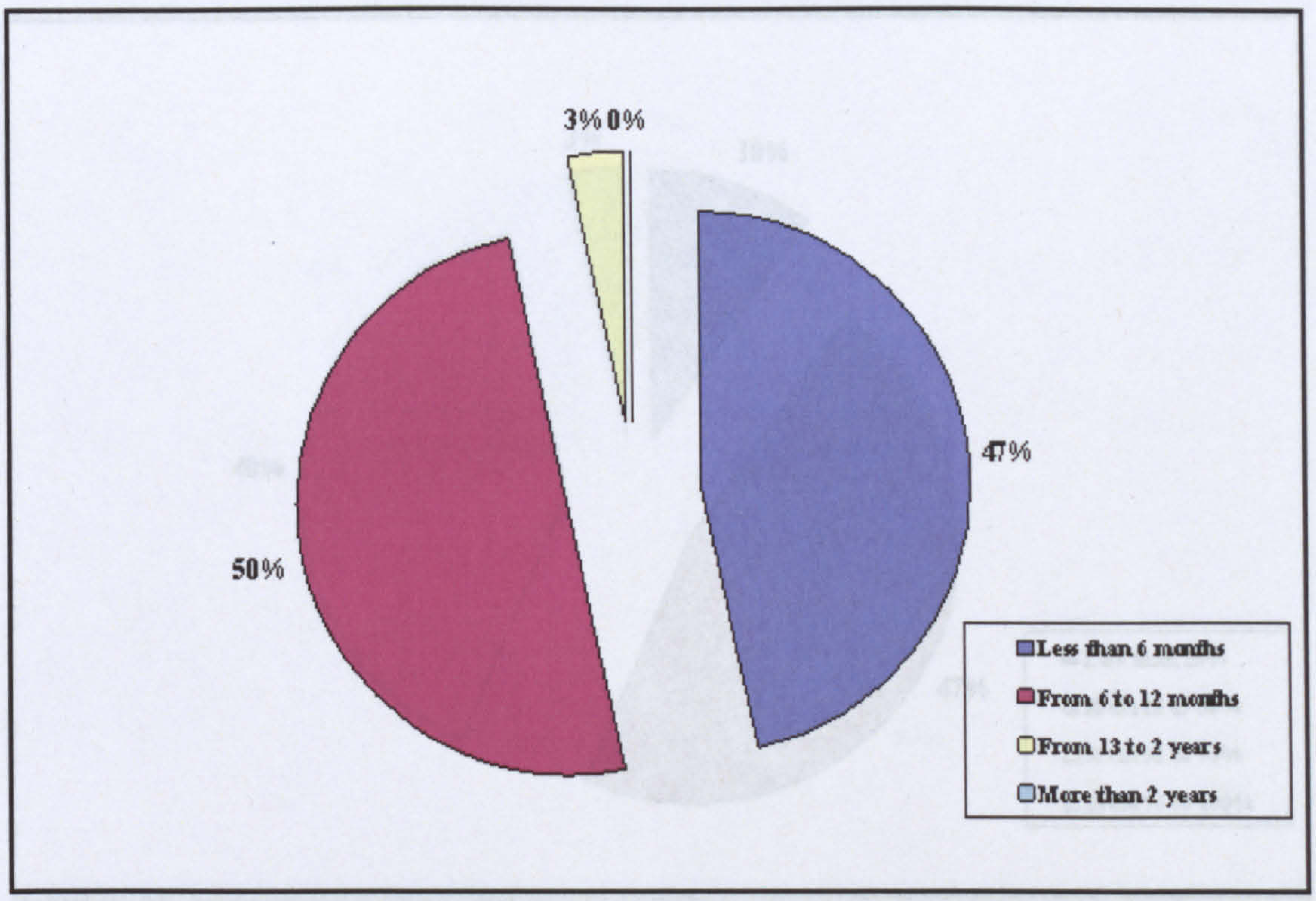


Figure (8.5): Average Job Duration

- *Details of Work Subcontracted by the Companies Surveyed*

Table (8.6) and Figure (8.6) show the percentage of work subcontracted on average job. Of the respondent companies, 47% subcontracted 25 to 50% of their works. Only 10% of them subcontracted less than 25% of their works and 40% subcontracted 51 to 75% of their works. This shows that contractors in Gaza Strip depend to a great extend on subcontracting; especially when a large number of labour is needed or when the risk exposure is high due to the nature or location of the job. They also tend to subcontract the majority of work using fixed lump-sum contracts to secure the targeted mark-up.

Table (8.6): Details of Work Subcontracted By the Companies Surveyed

Percentage of Work Subcontracted on Average Job	No. of Respondents	Percent of Respondents
Less than 25	3	10
From 25 to 50	14	47
From 51 to 75	12	40
From 76 to 100	1	3
Total	30	100

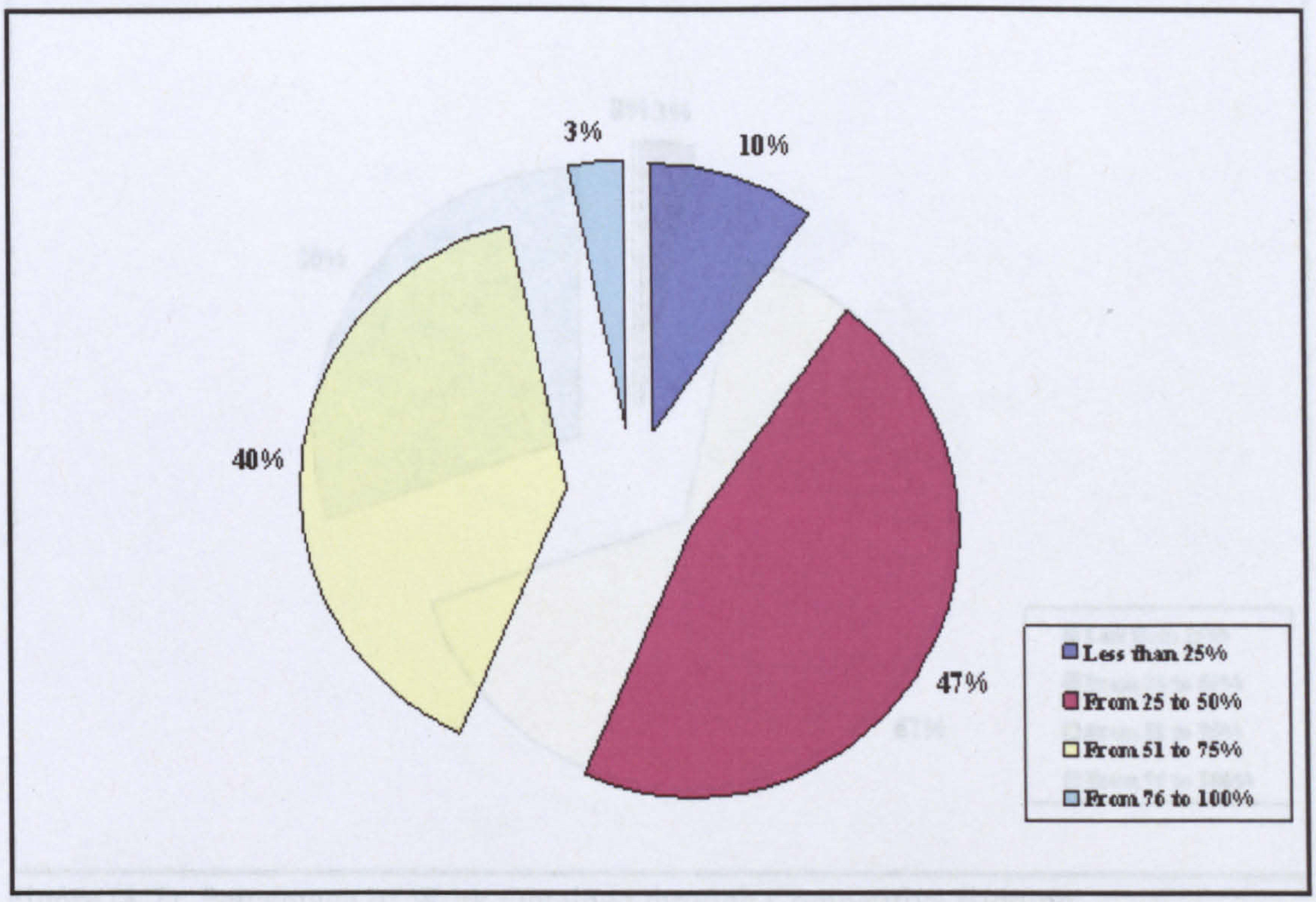


Figure (8.6): Percentage of Work Subcontracted on Average Job

- *Percentage of Work Obtained through Competitive Bidding*

Table (8.7) and Figure (8.7) show the percentage of work obtained through competitive bidding. 93.3% of the surveyed contractors secure more than 50% of their work through competitive bidding.

Table (8.7): Percentage of Work Obtained through Competitive Bidding

Percentage of Work Obtained through Competitive Bidding	No. of Respondents	Percent of Respondents
Less than 25	0	0
From 25 to 50	1	3
From 51 to 75	20	67
From 76 to 100	9	30
Total	30	100

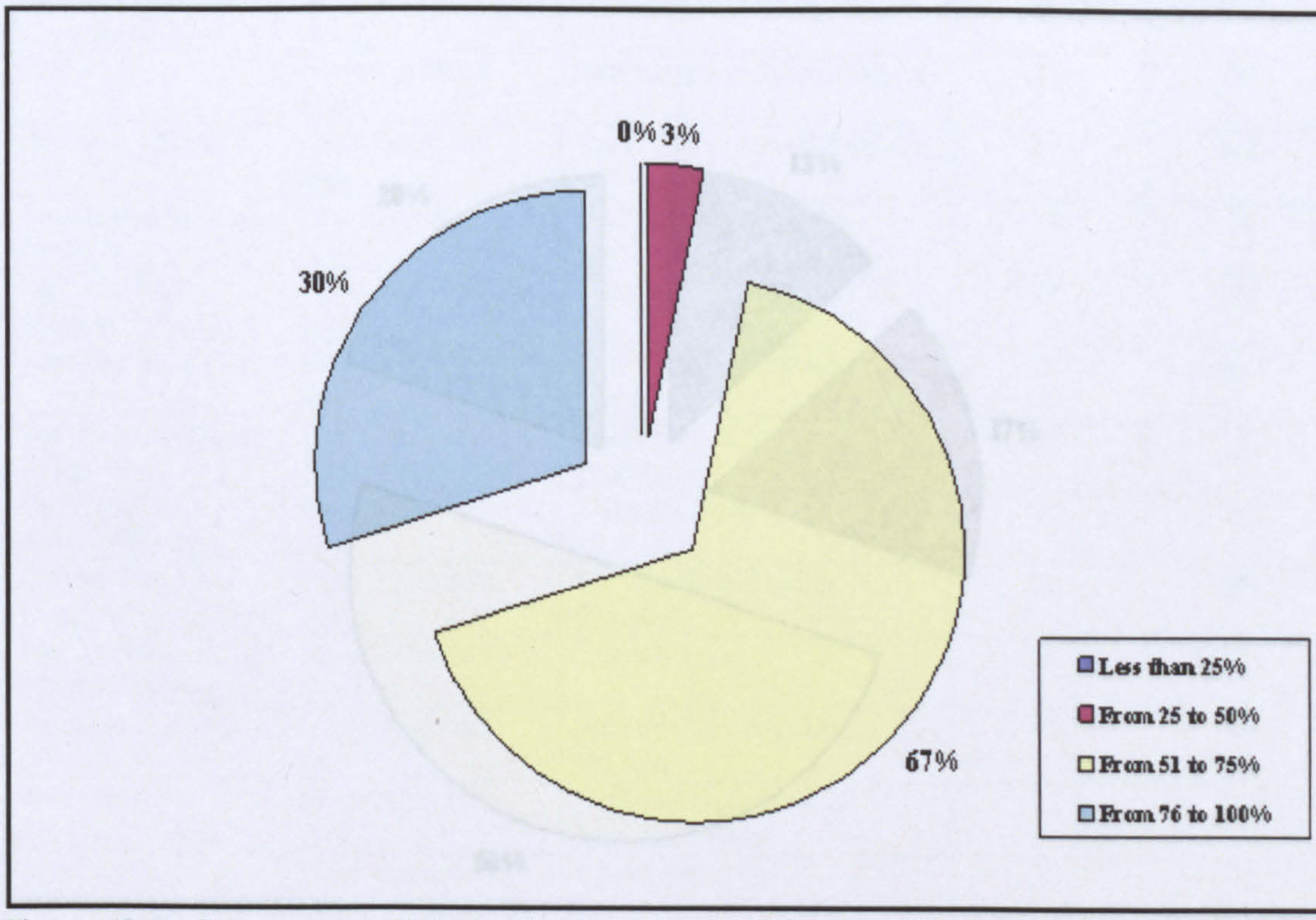


Figure (8.7): Percentage of Work Obtained through Competitive Bidding

- *Percentage of Contractors Using Mathematical Models to Assist in Bidding Decisions*

Table (8.8) and Figure (8.8) show that 20% used mathematical models to assist in bidding decisions in 76 to 100% of their works, while 50% of them in 51 to 75% of the executed projects. The results from this section emphasise the fact that the surveyed companies have the potential to use the proposed bidding decision models represented in this study.

Table (8.8): Percentage of Using Mathematical Models to Assist in Bidding Decisions

Percentage of projects on which mathematical models are used to assist in bidding decisions	No. of Respondents	Percent of Respondents
Less than 25	4	13
From 25 to 50	5	17
From 51 to 75	15	50
From 76 to 100	6	20
Total	30	100

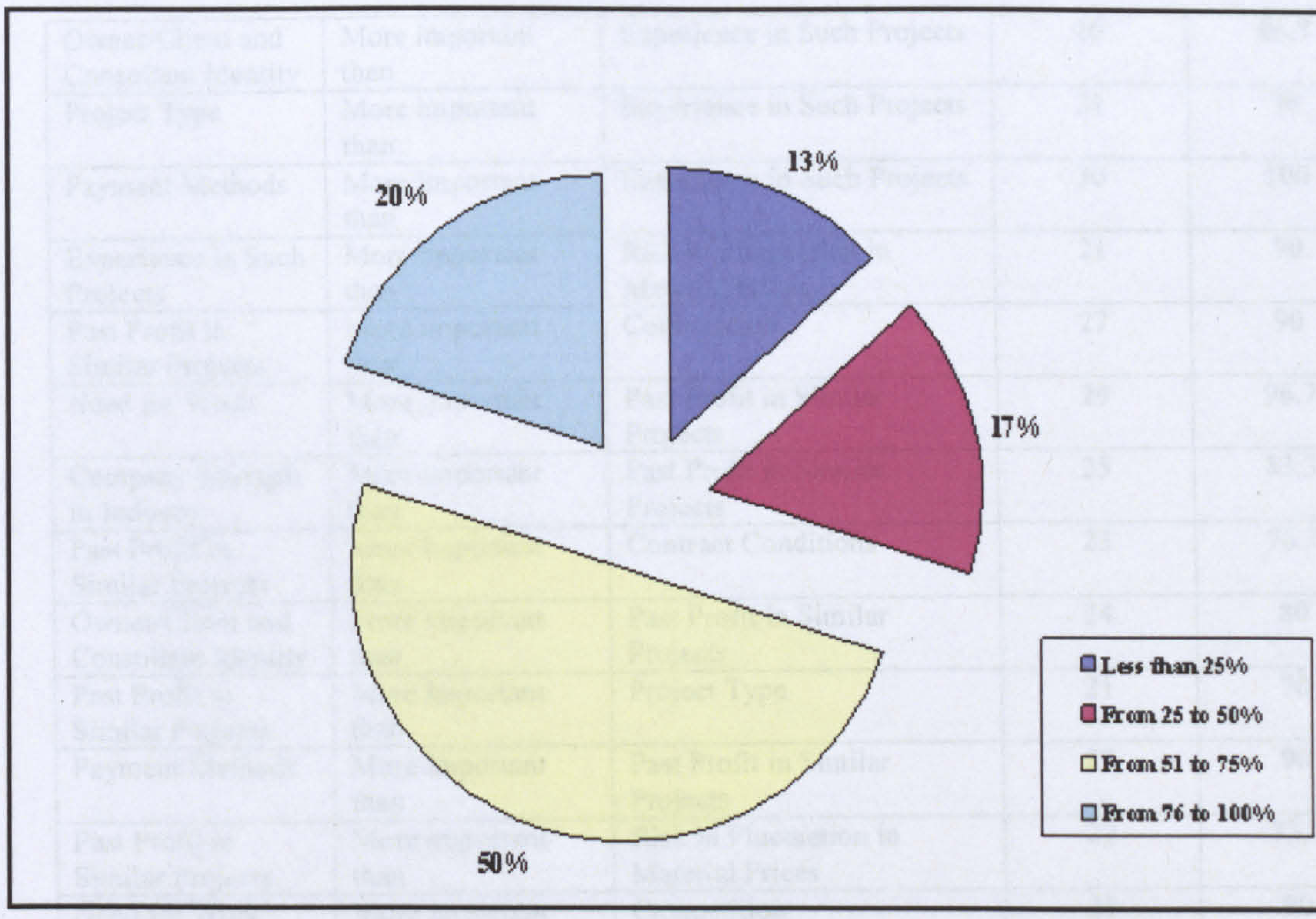


Figure (8.8): Percentage of Using Mathematical Models to Assist in Bidding Decisions

8.5.2 Sections Two and Three:

The first step in analysing sections two and three was finding out which criterion/factor is more important than others. Table (8.9) shows the results for section two for the bid/no bid decision. For example, 26 of the surveyed contractors (which are 86.7% of the respondents) decided that 'experience in such projects' is more important than 'competition'. Table (8.10) shows the results for section three for the mark-up decision. The results from these two sections will be further considered and used in Chapter nine.

Table (8.9): Results for Bid/No Bid Decision

			No. of Contractors	% of respondents
Experience in Such Projects	Equally important to	Past Profit in Similar Projects	25	83.3
Experience in Such Projects	More important than	Competition	26	86.7
Need for Work	More important than	Experience in Such Projects	29	96.7
Company Strength in Industry	More important than	Experience in Such Projects	29	96.7
Experience in Such Projects	More important than	Contract Conditions	21	70

Owner/Client and Consultant Identity	More important than	Experience in Such Projects	26	86.7
Project Type	More important than	Experience in Such Projects	21	70
Payment Methods	More important than	Experience in Such Projects	30	100
Experience in Such Projects	More important than	Risk in Fluctuation in Material Prices	21	70
Past Profit in Similar Projects	More important than	Competition	27	90
Need for Work	More important than	Past Profit in Similar Projects	29	96.7
Company Strength in Industry	More important than	Past Profit in Similar Projects	25	83.3
Past Profit in Similar Projects	More important than	Contract Conditions	23	76.7
Owner/Client and Consultant Identity	More important than	Past Profit in Similar Projects	24	80
Past Profit in Similar Projects	More important than	Project Type	21	70
Payment Methods	More important than	Past Profit in Similar Projects	27	90
Past Profit in Similar Projects	More important than	Risk in Fluctuation in Material Prices	22	73.3
Need for Work	More important than	Competition	27	90
Company Strength in Industry	More important than	Competition	28	93.3
Contract Conditions	More important than	Competition	27	90
Owner/Client and Consultant Identity	More important than	Competition	26	86.7
Project Type	More important than	Competition	30	100
Payment Methods	More important than	Competition	30	100
Competition	More important than	Risk in Fluctuation in Material Prices	22	73.3
Need for Work	More important than	Company Strength in Industry	27	90
Need for Work	More important than	Contract Conditions	26	86.7
Need for Work	More important than	Owner/Client and Consultant Identity	27	90
Need for Work	More important than	Project Type	24	80
Need for Work	More important than	Payment Methods	25	83.3
Need for Work	More important than	Risk in Fluctuation in Material Prices	24	80
Company Strength in Industry	More important than	Contract Conditions	24	80
Company Strength in Industry	More important than	Owner/Client and Consultant Identity	24	80
Company Strength	More important	Project Type	24	80

in Industry	than			
Company Strength in Industry	More important than	Payment Methods	22	73.3
Company Strength in Industry	More important than	Risk in Fluctuation in Material Prices	23	76.7
Owner/Client and Consultant Identity	More important than	Contract Conditions	27	90
Project Type	More important than	Contract Conditions	26	86.7
Payment Methods	More important than	Contract Conditions	27	90
Contract Conditions	More important than	Risk in Fluctuation in Material Prices	24	80
Owner/Client and Consultant Identity	More important than	Project Type	22	73.3
Payment Methods	More important than	Owner/Client and Consultant Identity	21	70
Owner/Client and Consultant Identity	More important than	Risk in Fluctuation in Material Prices	25	83.3
Payment Methods	More important than	Project Type	25	83.3
Project Type	More important than	Risk in Fluctuation in Material Prices	25	83.3
Payment Methods	More important than	Risk in Fluctuation in Material Prices	26	86.7

Table (8.10): Results for Mark-Up Decision

			No. of Contractors	% of respondents
Experience in Such Projects	Equally important to	Past Profit in Similar Projects	28	93.3
Project Size	More important than	Experience in Such Projects	21	70
Experience in Such Projects	More important than	Project Duration	23	76.7
Experience in Such Projects	More important than	Project Location	22	73.3
Project Type	More important than	Experience in Such Projects	21	70
Owner/Client and Consultant Identity	More important than	Experience in Such Projects	24	80
Experience in Such Projects	More important than	Competition	24	80
Need for Work	More important than	Experience in Such Projects	28	93.3
Experience in Such Projects	More important than	Contract Conditions	22	73.3
Experience in Such Projects	More important than	Risk in Fluctuation in Material Prices	25	83.3
Project Size	More important than	Past Profit in Similar Projects	21	70
Past Profit in Similar Projects	More important than	Project Duration	23	76.7
Past Profit in	More important	Project Location	24	80

Similar Projects	than			
Project Type	More important than	Past Profit in Similar Projects	21	70
Owner/Client and Consultant Identity	More important than	Past Profit in Similar Projects	22	73.3
Past Profit in Similar Projects	More important than	Competition	26	86.7
Need for Work	More important than	Past Profit in Similar Projects	29	96.7
Past Profit in Similar Projects	More important than	Contract Conditions	23	76.7
Past Profit in Similar Projects	More important than	Risk in Fluctuation in Material Prices	25	83.3
Project Size	More important than	Project Duration	28	93.3
Project Size	More important than	Project Location	27	90
Project Size	Equally important to	Project Type	25	83.3
Owner/Client and Consultant Identity	More important than	Project Size	23	76.7
Project Size	More important than	Competition	27	90
Need for Work	More important than	Project Size	27	90
Project Size	More important than	Contract Conditions	25	83.3
Project Size	More important than	Risk in Fluctuation in Material Prices	25	83.3
Project Location	Equally important to	Project Duration	21	70
Project Type	More important than	Project Duration	28	93.3
Owner/Client and Consultant Identity	More important than	Project Duration	23	76.7
Project Duration	More important than	Competition	21	70
Need for Work	More important than	Project Duration	28	93.3
Contract Conditions	More important than	Project Duration	21	70
Project Duration	More important than	Risk in Fluctuation in Material Prices	24	80
Project Type	More important than	Project Location	29	96.7
Owner/Client and Consultant Identity	More important than	Project Location	24	80
Project Location	More important than	Competition	26	86.7
Need for Work	More important than	Project Location	27	90
Contract Conditions	More important than	Project Location	21	70
Project Location	More important than	Risk in Fluctuation in Material Prices	24	80

Owner/Client and Consultant Identity	More important than	Project Type	25	83.3
Project Type	More important than	Competition	30	100
Need for Work	More important than	Project Type	26	86.7
Project Type	More important than	Contract Conditions	25	83.3
Project Type	More important than	Risk in Fluctuation in Material Prices	26	86.7
Owner/Client and Consultant Identity	More important than	Competition	27	90
Need for Work	More important than	Owner/Client and Consultant Identity	26	86.7
Owner/Client and Consultant Identity	More important than	Contract Conditions	26	86.7
Owner/Client and Consultant Identity	More important than	Risk in Fluctuation in Material Prices	25	83.3
Need for Work	More important than	Competition	27	90
Contract Conditions	More important than	Competition	25	83.3
Competition	Equally important to	Risk in Fluctuation in Material Prices	24	80
Need for Work	More important than	Contract Conditions	25	83.3
Need for Work	More important than	Risk in Fluctuation in Material Prices	27	90
Contract Conditions	More important than	Risk in Fluctuation in Material Prices	26	86.7

8.5.3 Section Four:

The results of section four show that 98% of the respondents found the questionnaire about right while only 2% found it complex. Also, of the 30 contractors that replied, the average time of questionnaire completion was 28 minutes, which is about the time suggested in the covering letter.

8.6 Summary

In this chapter, description of the steps taken to collect the required data to achieve the objectives of this research study is given. Mainly, a questionnaire survey was conducted and 30 contractors in Gaza Strip provided a response. Results of the questionnaire suggest that the construction industry in Gaza Strip is very competitive and most contractors use bidding models to assist in bidding decisions. This is a good result when compared with other studies. For example, Ahmed and Minkarah (1988) conducted a questionnaire survey on bidding in construction and concluded that only 11.1% of American contractors use mathematical models in bidding situations while Shash (1993) found out that 17.6% of UK contractors rely on mathematical bidding models.

CHAPTER NINE
Multi-Criteria Bidding Models

9.1 Introduction

Bidding is a complex process and crucial to the survival of each contractor in the construction industry. Contractors are faced with two decisions when a new project is advertised, bid/no bid and mark-up decisions. Therefore, it is essential to develop models to assist contractors in making these decisions. This chapter provides a detailed description of two AHP multi-criteria bid/no bid and mark-up models developed in sections (9.2) and (9.3) respectively. In this study, the relevant AHP analysis is carried out with a graphical software package called 'Criterium Decision Plus 3.0 Student Version'. Sections (9.2.2) and (9.3.2) present the consistency ratio check for both models. The results obtained from the two models are presented in sections (9.2.3) and (9.3.3). Finally, discussion of the results for both models is provided in sections (9.2.4) and (9.3.4).

9.2 THE BID/NO BID MODEL

Using the Criterium Decision Plus (CDP) software (A free evaluation copy can be downloaded from http://www.infoharvest.com), the development of the bid/no bid model starts with the brainstorming session. In this session, the ten selected criteria are shown graphically around the goal, which is bid/no bid decision (see Figure (9.1)).

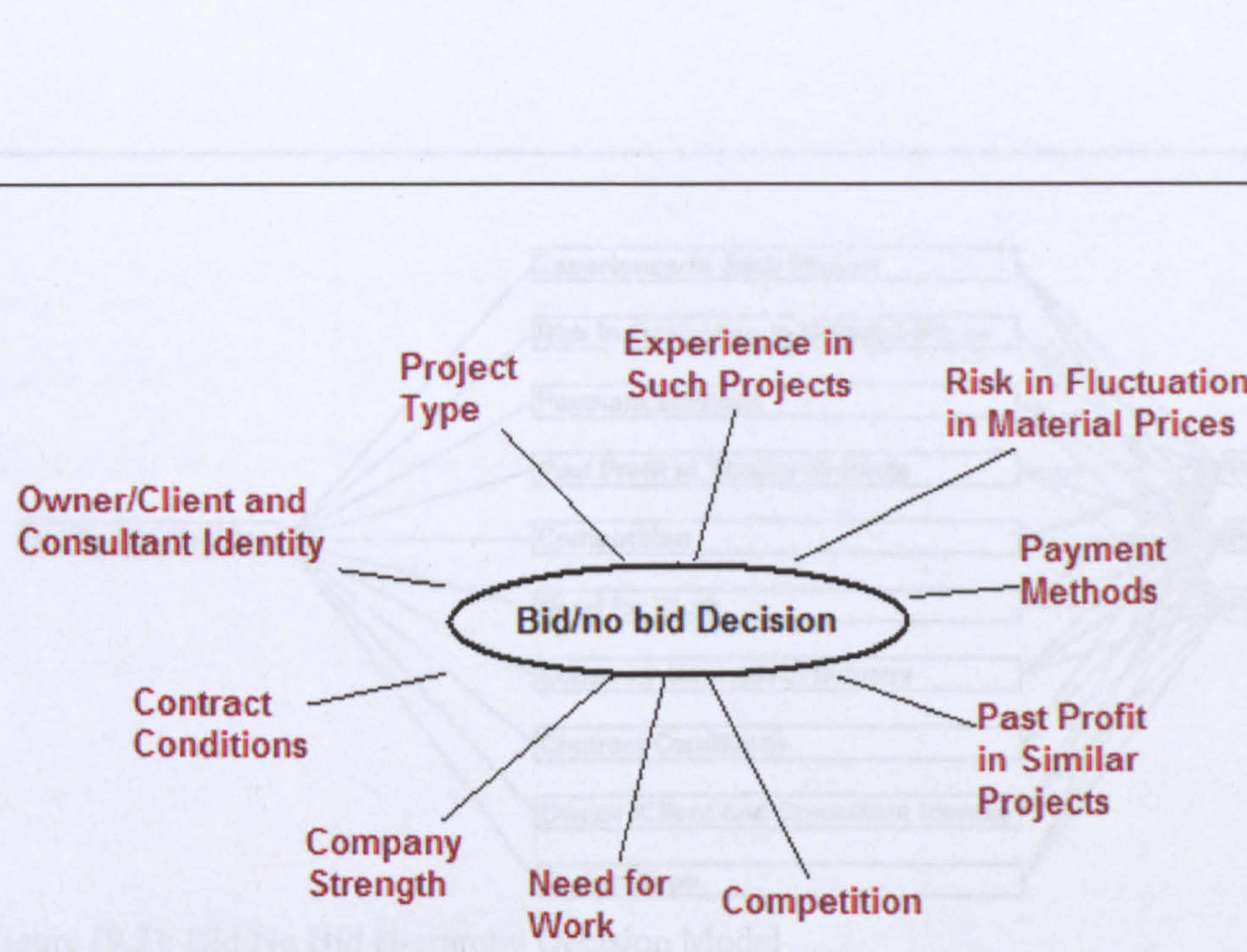


Figure (9.1): Brainstorming Session for Bid/No Bid Decision

The brainstorming session is followed by the generation of the hierarchy model. The hierarchy model is built automatically based on the brainstorming model as shown in Figure (9.2). Suppose that three projects are advertised and the contractor has to decide which project to bid for, the following is the decision hierarchy.

Level I: Generally, the overall aim/objective is presented at the first level of the hierarchy. Specifically, the overall aim of this application is 'Bid /no bid decision'.

Level II: The second level represents the factors affecting the bid/no bid decision. The ten criteria considered in this study are: experience in such projects, risk in fluctuation in material prices, payment methods, past profit in similar projects, competition, need for work, company strength in industry, contract conditions, owner/client and consultant identity and project type.

Level III: Finally, in level three of the hierarchy, the alternatives are listed as: project 1, project 2 and project 3.

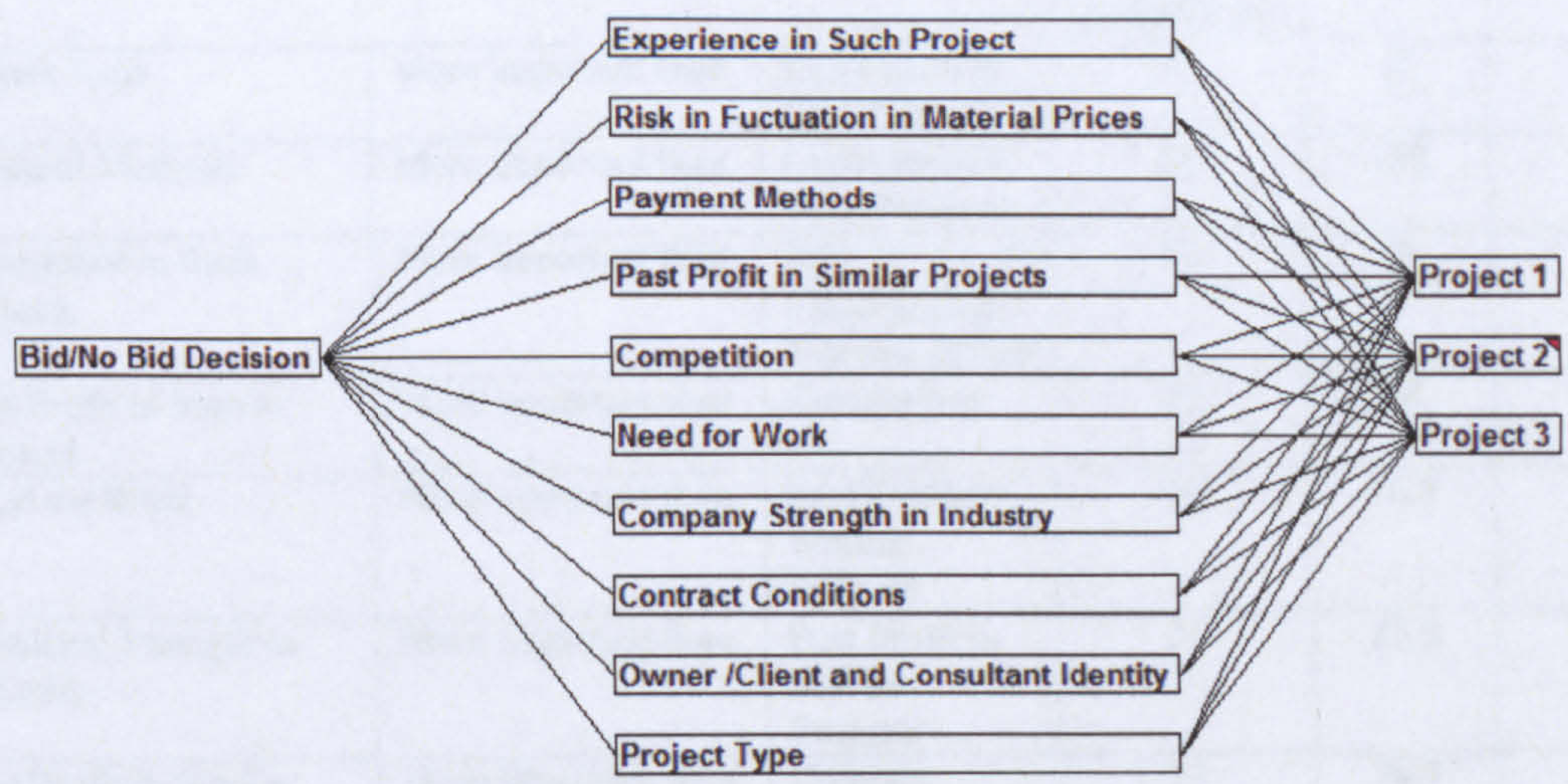


Figure (9.2): Bid/No Bid Hierarchy Decision Model

As suggested by Saaty, the geometric mean approach is used to combine the individual judgments to resolve the lack of consensus on values. For example, twenty six contractors stated in the questionnaire survey that experience in such projects is more important than competition and the judgments were: 5,5,5,5,5,2,5,3,5,5,4,5,5,5,3,5,5,5,5,5,3,5,5,4,1,4. Then, the geometric mean of these judgments is the $\sqrt[26]{5*5*5*5*5*2*5*3*5*5*4*5*5*5*3*5*5*5*5*5*3*5*5*4*1*4}$, which is 4.17 (4 in the pair-wise scale). The geometric means of the judgments obtained from the questionnaire survey for the bid/no bid decision are presented as the weight in Table (9.1).

Table (9.1): The Geometric means of the judgments for Bid / No Bid decision

			No. of Contractors	%	Weight
Experience in Such Projects	Equally important to	Past Profit in Similar Projects	25	83.3	1
Experience in Such Projects	More important than	Competition	26	86.7	4
Need for Work	More important than	Experience in Such Projects	29	96.7	7
Company Strength in Industry	More important than	Experience in Such Projects	29	96.7	5
Experience in Such Projects	More important than	Contract Conditions	21	70	4
Owner/Client and Consultant Identity	More important than	Experience in Such Projects	26	86.7	4

			No. of Contractors	%	Weight
Project Type	More important than	Experience in Such Projects	21	70	3
Payment Methods	More important than	Experience in Such Projects	30	100	4
Experience in Such Projects	More important than	Risk in Fluctuation in Material Prices	21	70	5
Past Profit in Similar Projects	More important than	Competition	27	90	4
Need for Work	More important than	Past Profit in Similar Projects	29	96.7	6
Company Strength in Industry	More important than	Past Profit in Similar Projects	25	83.3	5
Past Profit in Similar Projects	More important than	Contract Conditions	23	76.7	4
Owner/Client and Consultant Identity	More important than	Past Profit in Similar Projects	24	80	4
Past Profit in Similar Projects	More important than	Project Type	21	70	3
Payment Methods	More important than	Past Profit in Similar Projects	27	90	4
Past Profit in Similar Projects	More important than	Risk in Fluctuation in Material Prices	22	73.3	4
Need for Work	More important than	Competition	27	90	7
Company Strength in Industry	More important than	Competition	28	93.3	7
Contract Conditions	More important than	Competition	27	90	3
Owner/Client and Consultant Identity	More important than	Competition	26	86.7	6
Project Type	More important than	Competition	30	100	4
Payment Methods	More important than	Competition	30	100	6
Competition	More important than	Risk in Fluctuation in Material Prices	22	73.3	3
Need for Work	More important than	Company St. in Industry	27	90	3
Need for Work	More important than	Contract Conditions	26	86.7	6
Need for Work	More important than	Owner/Client and Consultant Identity	27	90	3
Need for Work	More important than	Project Type	24	80	5
Need for Work	More important than	Payment Methods	25	83.3	3
Need for Work	More important than	Risk in Fluctuation in Material Prices	24	80	7

			No. of Contractors	%	Weight
Company Strength in Industry	More important than	Contract Conditions	24	80	6
Company Strength in Industry	More important than	Owner/Client and Consultant Identity	24	80	3
Company Strength in Industry	More important than	Project Type	24	80	4
Company Strength in Industry	More important than	Payment Methods	22	73.3	2
Company Strength in Industry	More important than	Risk in Fluctuation in Material Prices	23	76.7	6
Owner/Client and Consultant Identity	More important than	Contract Conditions	27	90	4
Project Type	More important than	Contract Conditions	26	86.7	3
Payment Methods	More important than	Contract Conditions	27	90	5
Contract Conditions	More important than	Risk in Fluctuation in Material Prices	24	80	3
Owner/Client and Consultant Identity	More important than	Project Type	22	73.3	4
Payment Methods	More important than	Owner/Client and Consultant Identity	21	70	3
Owner/Client and Consultant Identity	More important than	Risk in Fluctuation in Material Prices	25	83.3	6
Payment Methods	More important than	Project Type	25	83.3	4
Project Type	More important than	Risk in Fluctuation in Material Prices	25	83.3	4
Payment Methods	More important than	Risk in Fluctuation in Material Prices	26	86.7	7

9.2.1 Rating the Bid/No Bid Hierarchy

In order to rate the bid/no bid hierarchy using the Criterium Decision Plus Software, the AHP technique was employed and the full pair-wise method was chosen. Factors affecting bid/no bid decision were compared for their relative importance, as shown in Table (9.2), using a nine point numerical scale starting from 1 as equally important to 9 as absolutely more important. Then, the weights listed in Table (9.1) were used as inputs for each pair of factors/criteria in turn. After all the comparisons were entered into the hierarchy, Criterium Decision Plus utilises Saaty's eigenvector method (EM) to determine the local weights.

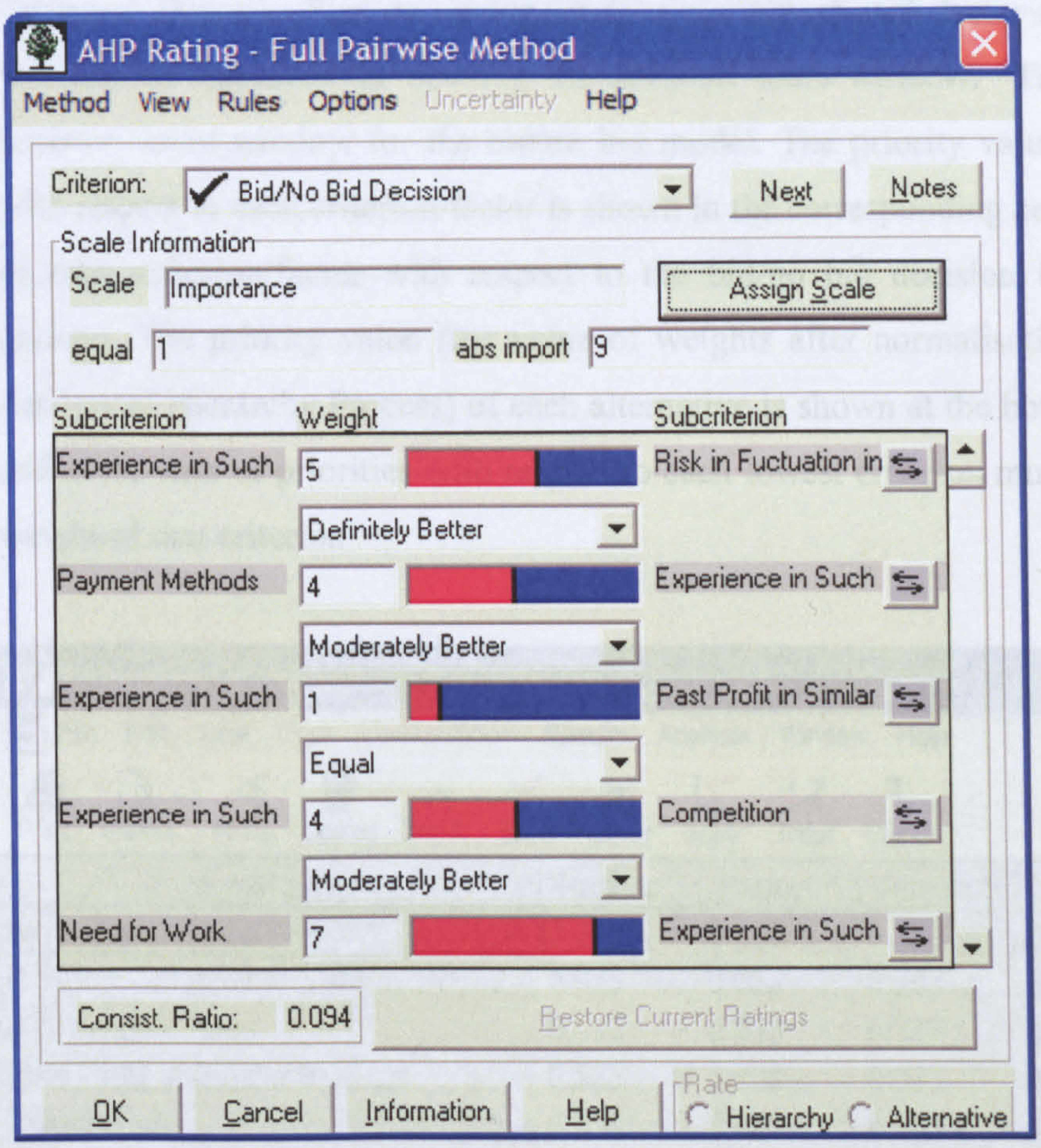


Table (9.2): Bid/No Bid Rating Window

9.2.2 Consistency of the Bid/No Bid Hierarchy

The reliability of the judgements used to develop the bid/no bid hierarchy was measured by the consistency ratio. Consistency index is an approximate mathematical indicator, of the consistency of the pair-wise comparisons. It is a function of the 'maximum eigenvalue and the size of the matrix. Criterium Decision Plus calculates the consistency ratio for the inputs automatically and usually appears at the bottom of the rating window. As shown in Table (9.2), the consistency ratio for the bid/no bid hierarchy is 0.094. As this value is less than 0.1, the consistency is considered to be acceptable for evaluation of the decision hierarchy (Saaty 1980).

9.2.3 Results of the Bid/No Bid Hierarchy

Criterium Decision Plus calculates the local weight of each factor/criteria automatically and can be displayed by opening the decision score window. Table (9.3) shows the decision score window for the bid/no bid model. The priority value of each alternative with respect to each criterion/factor is shown in the corresponding cell. The model weight of each criterion/factor with respect to the bid/no bid decision is shown in the last column. The priority value (the value of weights after normalisation; according to the Analytical Hierarchy Process) of each alternative is shown at the bottom of each column, and is the sum of priorities with respect to each lowest criterion multiplied by the model weight of that criterion.

Criterium DecisionPlus - [AHP Decision Scores]

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Lowest Level	Project 2	Project 1	Project 3	Model
Experience in Such Project	0.333	0.333	0.333	0.051
Risk in Fuctuation in Material Prices	0.333	0.333	0.333	0.017
Payment Methods	0.333	0.333	0.333	0.160
Past Profit in Similar Projects	0.333	0.333	0.333	0.064
Competition	0.333	0.333	0.333	0.021
Need for Work	0.333	0.333	0.333	0.283
Company Strength in Industry	0.333	0.333	0.333	0.196
Contract Conditions	0.333	0.333	0.333	0.030
Owner /Client and Consultant Identity	0.333	0.333	0.333	0.122
Project Type	0.333	0.333	0.333	0.058
Results	0.333	0.333	0.333	

Table (9.3): Decision Scores for Bid/No Bid Decision

The factors/criterion considered, in this study, to influence bid/no bid decision can be arranged in descending order of priority as shown in table (9.4):

Rank	Criterion	Local Weight
1	Need for Work	0.283
2	Company Strength in Industry	0.196
3	Payment Methods	0.160
4	Owner/Client and Consultant Identity	0.122
5	Past Profit in Similar Projects	0.064
6	Project Type	0.058
7	Experience in Such Projects	0.051
8	Contract Conditions	0.030
9	Competition	0.021
10	Risk in Fluctuation in Material Prices	0.017
	Total	1.00

Table (9.4): Descending order of priority for factors affecting Bid/No Bid Decision

The contribution of each factor/criteria toward the bid/no bid decision can be graphically viewed by opening the contribution by criteria window. Figure (9.3) represents the contribution of the different factors/criteria to the bid/no bid decision. For example, the red coloured shaded area of the graph corresponds to the contribution of the 'need for work' to the decision score for the three alternatives (project 1, project 2, project 3).

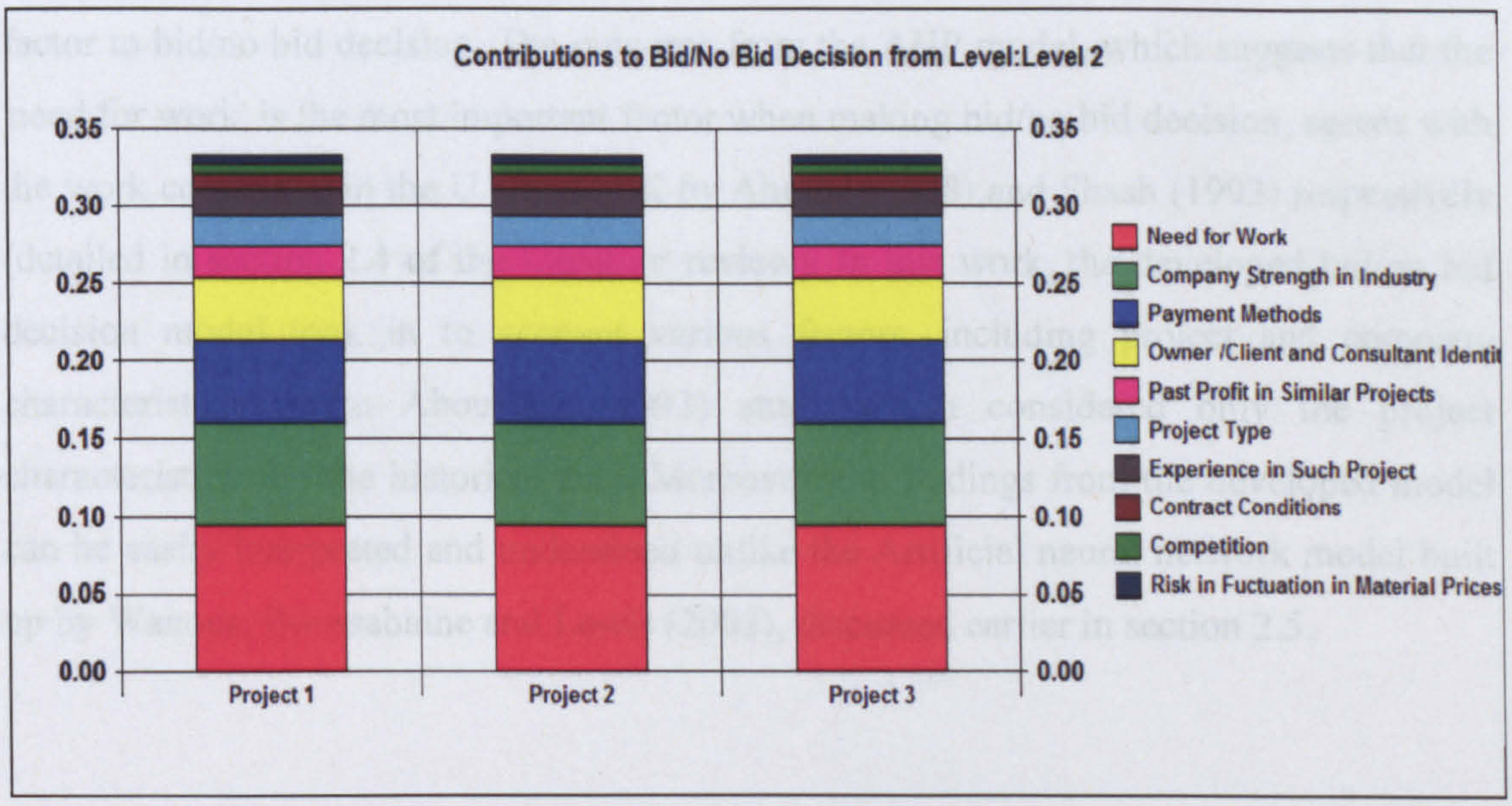


Figure (9.3): The contribution by criteria for bid/no bid decision

9.2.4 Discussion of the Results of the Bid/No Bid Hierarchy

The results indicate that company characteristics; including need for work, company strength in industry, past profit in similar projects, experience in such projects, is the most important category when making bid/no bid decision and contributed more than 59% of the total weighting. While the project characteristics; which include the payment methods, owner/ client and consultant identity, project type and contract conditions represent 37% of the total weighting. The least important two categories are the bidding situation; which include competition, and the economic situation; including risk in fluctuation in material prices. This revealed the ranking of the different categories considered in this study.

When considering each factor in turn, the need for work is found to be the most important factor among all other factors examined when making the bid/no bid decision followed by the company strength in industry, payment methods and owner/client and consultant identity, as shown in Table (9.4), with high importance. Then, past profit in similar projects, project type, experience in such projects and contract conditions with moderate importance to the bid/no bid decision. Finally, competition and risk in fluctuation in material prices with low importance to the bid/no bid decision.

Results from this study supported previous work in that profit is not the most important factor to bid/no bid decision. The outcome from the AHP model, which suggests that the 'need for work' is the most important factor when making bid/no bid decision, agrees with the work conducted in the U.S and U.K by Ahmed (1988) and Shash (1993) respectively (detailed in section 2.4 of the literature review). In this work, the developed bid/no bid decision model took in to account various factors, including project and company characteristics unlike AbouRizk (1993) study which considered only the project characteristics and the historical data. Moreover, the findings from the developed model can be easily interpreted and understood unlike the Artificial neural network model built up by Wanous, Boussabaine and Lewis (2003), discussed earlier in section 2.5.

The following is a description of the results obtained.

- *Need for Work*

  Need for work is the dominating factor on the bid/no bid decision. This study focused on large-size contractors who tend to bid for large and complex projects in order to operate at full company capacity. As the economic situation in the Gaza Strip is largely affected by the un-stable surrounding political condition, the funding of large projects is sometimes limited. This makes the 'need for work' a very important factor when making the bid/no bid decision because the work that occupies the full company capacity is not always available.

- *Company Strength in Industry*

  As shown in Table (9.4), company strength in industry is considered heavily when making the bid/no bid decision as it ranked second among the ten factors. In order to maintain a strong strength in industry, contractors aim to bid for projects which allow the company to use its full capacity as well as executing the projects to a high quality. This will maintain a good reputation for the company in industry, strengthen the relation with banks and other client organisations.

- *Payment Methods*

  The results revealed that the 'payment methods' is of high importance to bid/no bid decision. Payment methods include: the advance payment, how regular the other payments will be and the currency of the contract value. The currency used in the contract is the most influencing issue. This can be explained by the fact that contractors in Gaza Strip use local currency which is the NIS (New Israeli Shekal) to pay for almost all kinds of materials and the salaries for unskilled and skilled labour while most contracts are dealt with using either U.S dollars or Euros. The fluctuation in the U.S dollar or Euro, and the variation in the exchange rates for U.S dollars and Euro against the NIS result in a hidden profit or loss to the contractors. Contractors in Gaza Strip prefer to bid for projects in either U.S dollars or Euros.

- *Owner/Client and Consultant Identity*

  Another factor with high importance to the bid/no bid decision is the owner/client and consultant identity. Contractors do try to maintain good relationships with important and regular owners, clients and consultants. They are attracted to bid for projects were there is previous experience with the owner, client and consultant.

- *Past Profit in Similar Projects:*

  The results show that 'past profit in similar projects' has a moderate importance to the bid/no bid decision. Contractors tend to bid for projects where they have executed similar projects in the past and achieved a reasonable profit.

- *Project Type*

  Another factor with moderate importance is the project type. Large-size contractors have the required resources, staff and experience to execute most type of projects.

- *Experience in Such Projects*

  The experience in such projects is considered to have a moderate level of importance in determining the bid/no bid decision. As the contractors surveyed are large-size companies, they are classified to undertake different kinds of jobs and have experience in almost all kinds of projects.

- *Contract Conditions*

  The results show that 'contract conditions' have a moderate level of importance to bid/no bid decision. The majority of projects in Gaza Strip have realistic and acceptable contract conditions. With the exception that some projects specify the numbers of skilled and unskilled labour involved in the project and moreover specify the labour minimum rate of payment as contract conditions. Such projects aim at employing as much labour force as possible to try and reduce the unemployment rate. Contractors undertaking such projects must have a specified number of labour on site in each day of the project and have to keep records of labours' numbers and names.

- *Competition and Risk in Fluctuation in Material Prices:*

  The results revealed that 'competition' and the 'risk in fluctuation in material prices' is of low importance to the bid/no bid decision. Competition refers to the number and identities of competitors bidding for the project. In the Gaza Strip, construction materials prices depend mainly on the availability of the material. Due to constant closure of Gaza Strip boarders, construction materials are not always available. Therefore, contractors in Gaza Strip do always expect fluctuation in material prices. To avoid this risk, contractors form contracts with material suppliers to supply the required material at a specific cost.

9.3 The Mark-Up Model

Using the Criterium Decision Plus (CDP) software, the development of the mark-up model starts with the brainstorming session. In this session, the eleven selected criteria are shown graphically around the goal, which is mark-up decision (see Figure (9.4)).

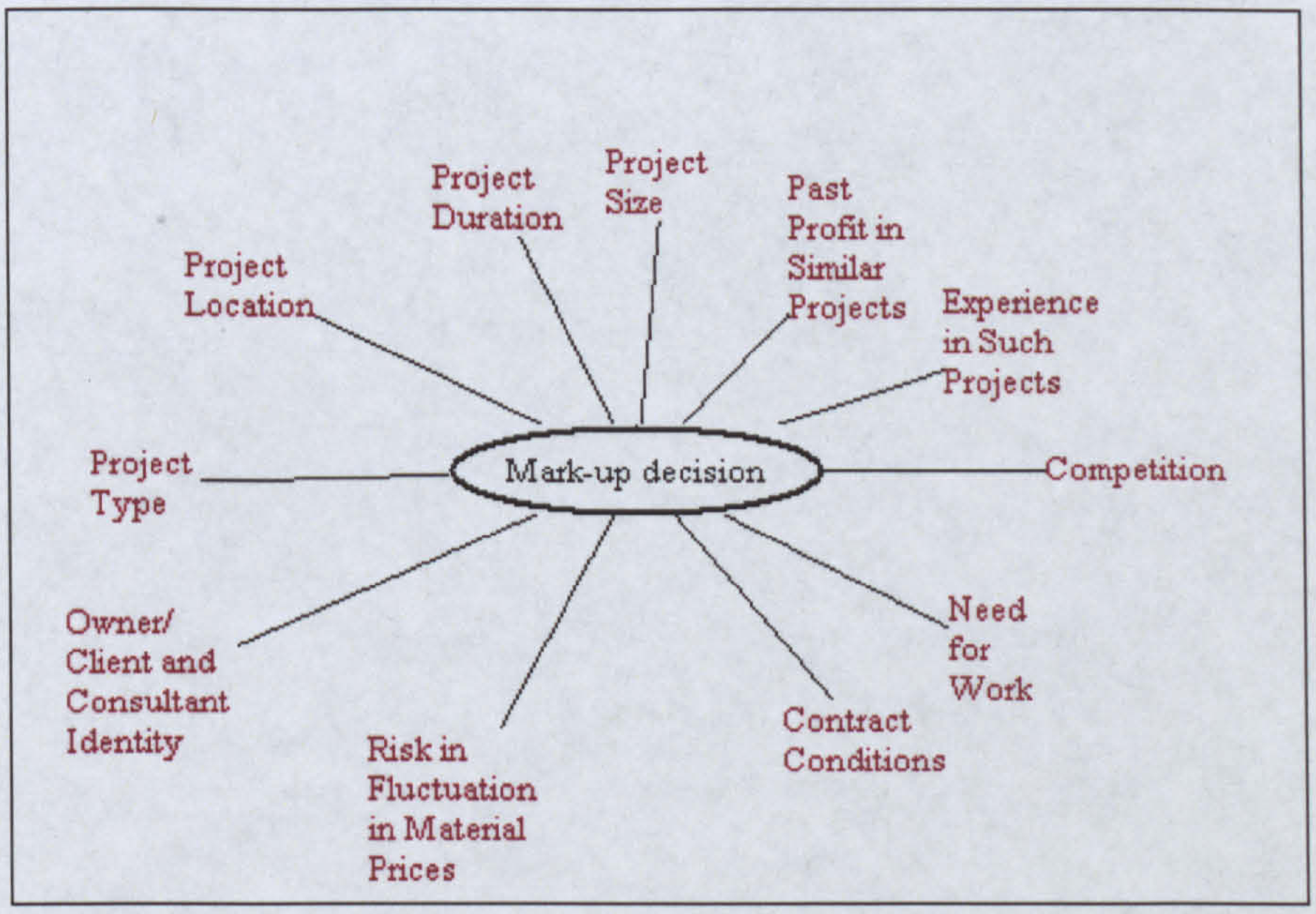


Figure (9.4): The Mark-up Hierarchy Decision Model

The brainstorming session is followed by the creation of the hierarchy model. The hierarchy model is built automatically based on the brainstorming model as shown in Figure (9.5). Suppose that the contractor has three projects to bid for and want to decide which project will give him the higher mark-up, then, the following is the decision hierarchy.

Level I: Generally, the overall aim/objective is presented at the first level of the hierarchy. Specifically, the overall aim of this application is 'Mark-Up decision'.

Level II: The second level represents the factors affecting mark-up decision. The eleven criteria considered in this study are: experience in such projects, past profit in similar projects, project size, project duration, project location, project type, owner/client and consultant identity, competition, need for work, contract conditions and risk in fluctuation in material prices.

Level III: Finally, in level three of the hierarchy, the alternatives are listed as: project 1, project 2 and project 3.

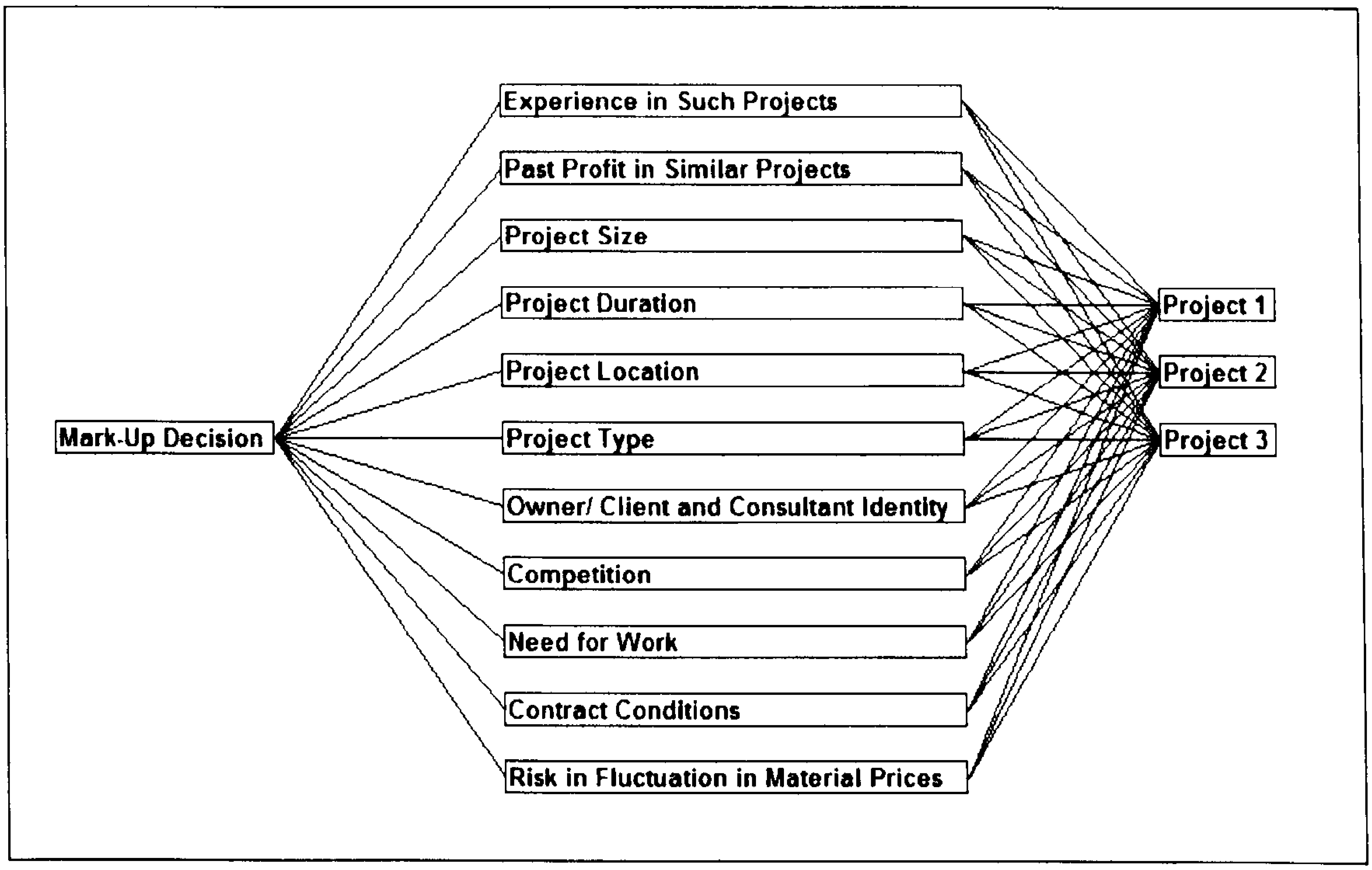


Figure (9.5): Mark-Up Hierarchy Decision Model

As suggested by Satty, the geometric mean approach is used to combine the individual pair-wise comparison matrices to resolve the lack of consensus on values. For example, twenty one contractors stated in the questionnaire survey that project size is more important than experience in such projects and the judgments were: 5,5,1,3,1,3,5,2,6,5,3,5,5,5,1,4,2,3,3,6,3. Then, the geometric mean of these judgments is the $\sqrt[21]{5*5*1*3*1*3*5*2*6*5*3*5*5*5*1*4*2*3*3*6*3}$, which is 3 in the pair-wise scale. The geometric means of the judgments obtained from the questionnaire survey for the mark-up decision are presented as the weight in Table (9.5).

Table (9.5): The Geometric means of the judgments for Mark-Up decision

			No. of Contractors	%	Weight
Experience in Such Projects	Equally important to	Past Profit in Similar Projects	28	93.3	1
Project Size	More important than	Experience in Such Projects	21	70	3
Experience in Such Projects	More important than	Project Duration	23	76.7	4
Experience in Such Projects	More important than	Project Location	22	73.3	4
Project Type	More important than	Experience in Such Projects	21	70	3
Owner/Client and Consultant Identity	More important than	Experience in Such Projects	24	80	5
Experience in Such Projects	More important than	Competition	24	80	4
Need for Work	More important than	Experience in Such Projects	28	93.3	6
Experience in Such Projects	More important than	Contract Conditions	22	73.3	4
Experience in Such Projects	More important than	Risk in Fluctuation in Material Prices	25	83.3	4
Project Size	More important than	Past Profit in Similar Projects	21	70	4
Past Profit in Similar Projects	More important than	Project Duration	23	76.7	4
Past Profit in Similar Projects	More important than	Project Location	24	80	4
Project Type	More important than	Past Profit in Similar Projects	21	70	3
Owner/Client and Consultant Identity	More important than	Past Profit in Similar Projects	22	73.3	4
Past Profit in Similar Projects	More important than	Competition	26	86.7	4
Need for Work	More important than	Past Profit in Similar Projects	29	96.7	5
Past Profit in Similar Projects	More important than	Contract Conditions	23	76.7	5
Past Profit in Similar Projects	More important than	Risk in Fluctuation in Material Prices	25	83.3	4
Project Size	More important than	Project Duration	28	93.3	4
Project Size	More important than	Project Location	27	90	4
Project Size	Equally important to	Project Type	25	83.3	1
Owner/Client and	More important	Project Size	23	76.7	5

Consultant Identity	than				
Project Size	More important than	Competition	27	90	5
Need for Work	More important than	Project Size	27	90	4
Project Size	More important than	Contract Conditions	25	83.3	4
Project Size	More important than	Risk in Fluctuation in Material Prices	25	83.3	5
Project Location	Equally important to	Project Duration	21	70	1
Project Type	More important than	Project Duration	28	93.3	4
Owner/Client and Consultant Identity	More important than	Project Duration	23	76.7	5
Project Duration	More important than	Competition	21	70	2
Need for Work	More important than	Project Duration	28	93.3	4
Contract Conditions	More important than	Project Duration	21	70	4
Project Duration	More important than	Risk in Fluctuation in Material Prices	24	80	2
Project Type	More important than	Project Location	29	96.7	4
Owner/Client and Consultant Identity	More important than	Project Location	24	80	5
Project Location	More important than	Competition	26	86.7	2
Need for Work	More important than	Project Location	27	90	5
Contract Conditions	More important than	Project Location	21	70	3
Project Location	More important than	Risk in Fluctuation in Material Prices	24	80	2
Owner/Client and Consultant Identity	More important than	Project Type	25	83.3	4
Project Type	More important than	Competition	30	100	5
Need for Work	More important than	Project Type	26	86.7	4
Project Type	More important than	Contract Conditions	25	83.3	4
Project Type	More important than	Risk in Fluctuation in Material Prices	26	86.7	5
Owner/Client and Consultant Identity	More important than	Competition	27	90	5
Need for Work	More important than	Owner/Client and Consultant Identity	26	86.7	3
Owner/Client and Consultant Identity	More important than	Contract Conditions	26	86.7	4
Owner/Client and	More important	Risk in Fluctuation	25	83.3	9

Consultant Identity	than	in Material Prices			
Need for Work	More important than	Competition	27	90	7
Contract Conditions	More important than	Competition	25	83.3	2
Competition	Equally important to	Risk in Fluctuation in Material Prices	24	80	1
Need for Work	More important than	Contract Conditions	25	83.3	6
Need for Work	More important than	Risk in Fluctuation in Material Prices	27	90	9
Contract Conditions	More important than	Risk in Fluctuation in Material Prices	26	86.7	2

9.3.1 Rating the Mark-Up Hierarchy

In order to rate the mark-up hierarchy using the Criterium Decision Plus Software, the AHP technique was employed and the full pair-wise method was chosen. Factors influencing mark-up decision were compared for their relative importance, as shown in Table (9.5), using a nine point numerical scale starting from 1 as equally important to 9 as absolutely more important. Then, the weights listed in Table (9.6) were used as inputs for each pair of factors/criteria in turn. After all the comparisons were entered into the hierarchy, Criterium Decision Plus utilises Saaty's eigenvector method (EM) to determine the local weights.

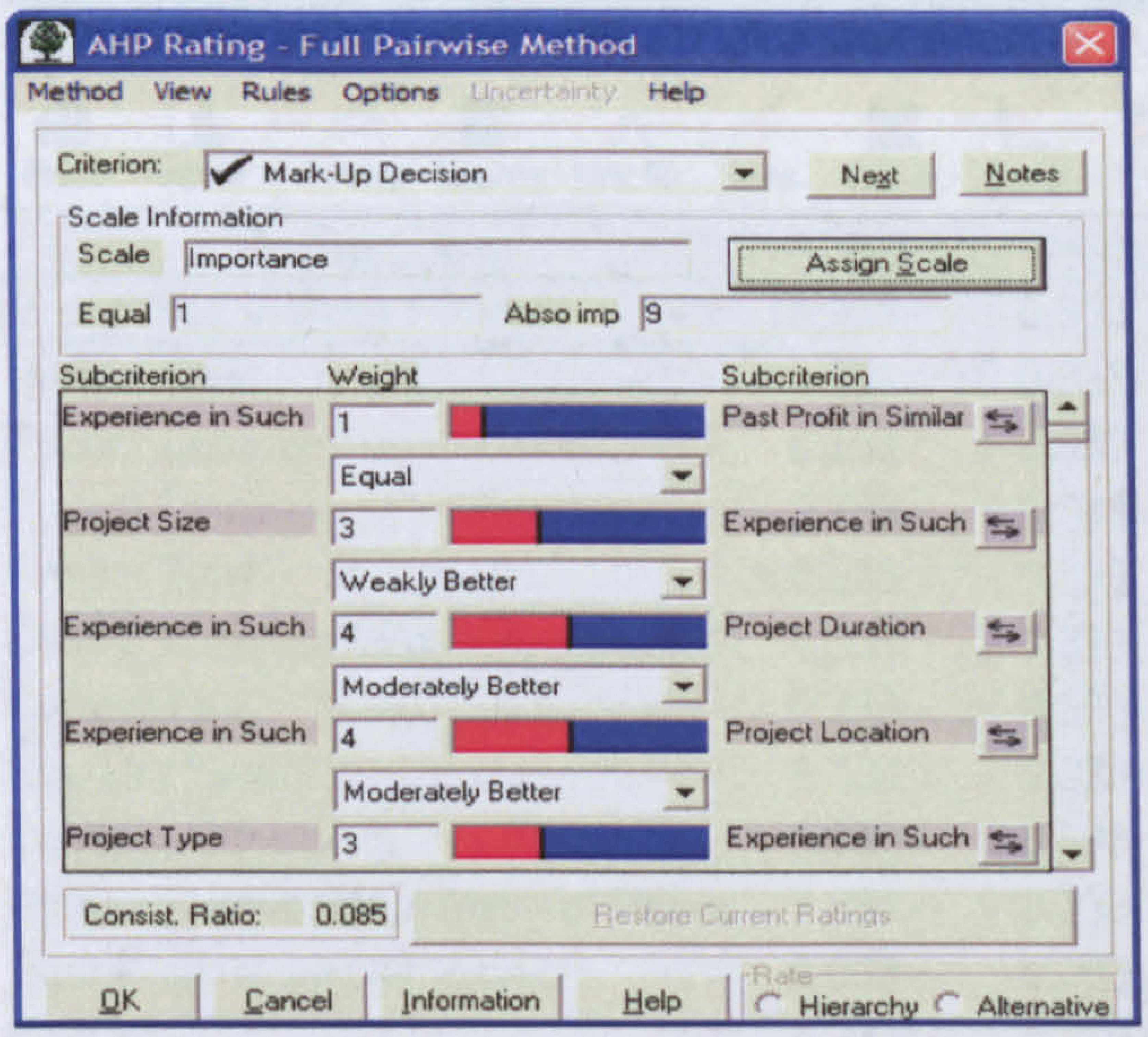


Table (9.6): Mark-Up Rating Window

9.3.2 Consistency of the Mark-Up Hierarchy

The reliability of the judgements used to develop the mark-up hierarchy was measured by the consistency ratio. As seen from Table (9.6), the consistency ratio for the mark-up hierarchy is 0.085. As this value is less than 0.1, therefore, the consistency is considered to be acceptable for the evaluation of the decision hierarchy (Saaty 1980).

9.3.3 Results of the Mark-Up Hierarchy

Criterium Decision Plus calculates the local weight of each factor/criteria automatically and can be displayed by opening the decision score window. Table (9.7) shows the decision score window for the mark-up model. The priority value of each alternative with respect to each criterion/factor is shown in the corresponding cell. The model weight of each criterion/factor with respect to the mark-up decision is shown in the last column on the left. The priority value (the value of weights after normalization; according to the Analytical Hierarchy Process) of each alternative is shown at the bottom of each column, and is the sum of priorities with respect to each lowest criterion multiplied by the model weight of that criterion.

Criterium DecisionPlus - [AHP Decision Scores]

Lowest Level	Project 1	Project 2	Project 3	Model
Experience in Such Projects	0.333	0.333	0.333	0.069
Project Size	0.333	0.333	0.333	0.116
Project Duration	0.333	0.333	0.333	0.028
Project Location	0.333	0.333	0.333	0.028
Project Type	0.333	0.333	0.333	0.110
Owner/ Client and Consultant Identity	0.333	0.333	0.333	0.218
Competition	0.333	0.333	0.333	0.020
Need for Work	0.333	0.333	0.333	0.278
Contract Conditions	0.333	0.333	0.333	0.041
Risk in Fluctuation in Material Prices	0.333	0.333	0.333	0.018
Past Profit in Similar Projects	0.333	0.333	0.333	0.073
Results	0.333	0.333	0.333	

Table (9.7): Decision Scores for Mark-Up Decision

The factors/criterion influencing mark-up decision can be arranged in descending order of priority as shown in table (9.8):

Rank	Criterion	Local Weight
1	Need for Work	0.278
2	Owner/Client and Consultant Identity	0.218
3	Project Size	0.116
4	Project Type	0.11
5	Past Profit in Similar Projects	0.073
6	Experience in Such Projects	0.069
7	Contract Conditions	0.041
8	Project Duration	0.028
9	Project Location	0.028
10	Competition	0.02
11	Risk in Fluctuation in Material Prices	0.018
	Total	1.00

Table (9.8): Descending order of priority for factors affecting Mark-Up Decision

The contribution of each factor/criteria toward the mark-up decision can be graphically viewed by opening the contribution by criteria window. Figure (9.6) represents the contribution of the different factors/criteria to the mark-up decision. For example, the red coloured shaded area of the graph corresponds to the contribution of the 'need for work' to the decision score for the three alternatives (project 1, project 2, project 3).

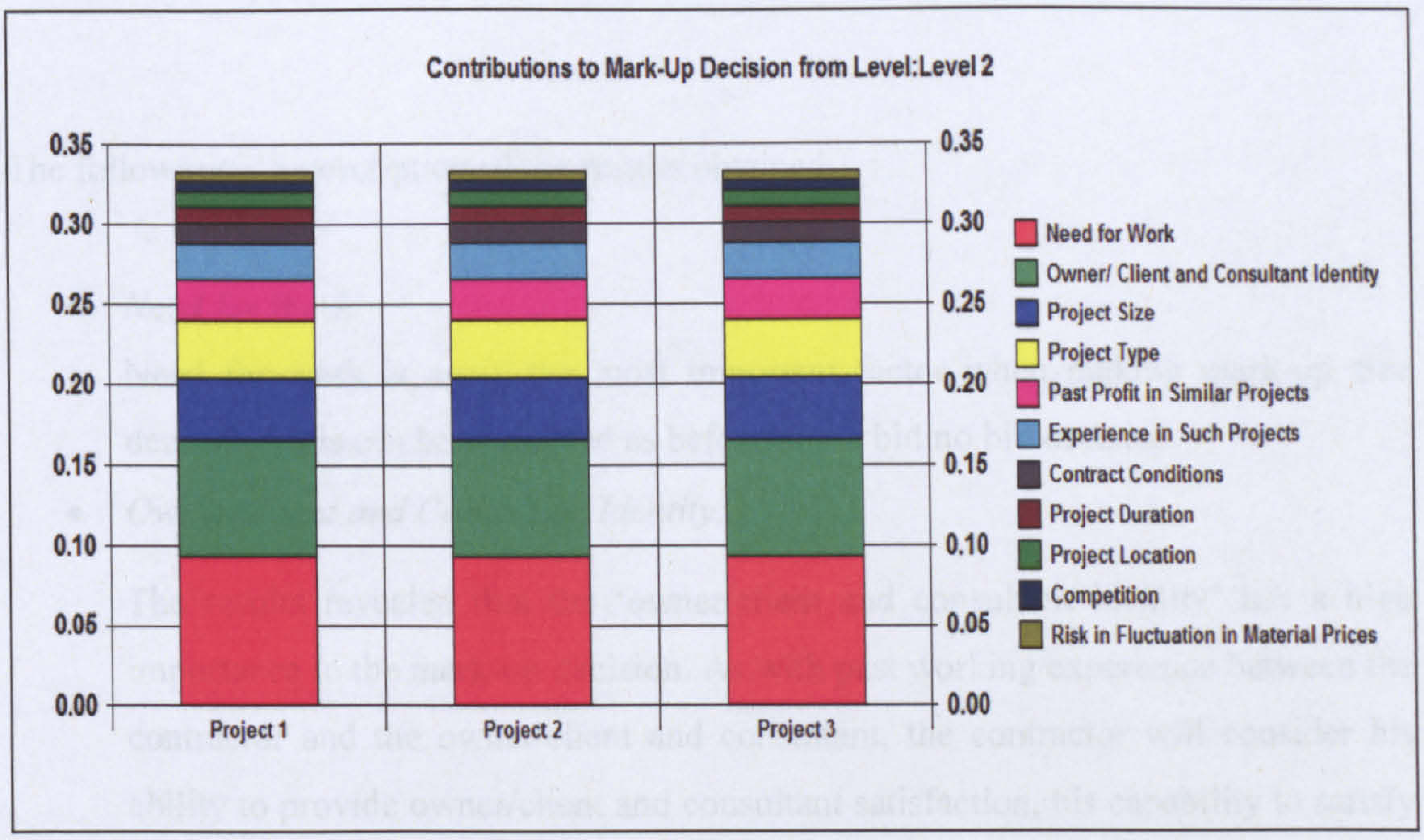


Figure (9.6): Contribution by criteria for mark-up decision

9.3.4 Discussion of the Results of the Mark-Up Hierarchy

The results show that the project characteristics which include the owner/ client and consultant identity, project size, project type, contract conditions, project duration and project location represent more than 54% of the total weighting. This makes the project characteristics the most important category for contractors when making mark-up decision. While, company characteristics including need for work, company strength in industry, past profit in similar projects, experience in such projects count for 42% of the total weighting. The least important two categories are the bidding situation; which include competition, and the economic situation; including risk in fluctuation in material prices.

The need for work, owner/client and consultant identity, project size and project type are the most important factors to be considered when making the mark-up decision representing more than 72% of the total weighting. The least important factors are the competition and the risk in fluctuation in material prices. Past profit in similar projects, experience in such projects, contract conditions, project duration and project location have moderate importance to the mark-up decision.

The following is a description of the results obtained.

- *Need for Work:*

  Need for work is again the most important factor when making mark-up size decision. This can be explained as before in the bid/no bid decision.

- *Owner/Client and Consultant Identity:*

  The results revealed that the 'owner/client and consultant identity' has a high importance to the mark-up decision. As with past working experience between the contractor and the owner/client and consultant, the contractor will consider his ability to provide owner/client and consultant satisfaction, his capability to satisfy the owner/client and consultant needs and will be aware of the ability of the client to pay on time. Moreover, if there is a good relation between the contractor and the owner/client and consultant, the delay which might be caused by the materials shortage due to boarders closure will be taken into consideration and no penalty will be imposed.

- *Project Size:*

  The results show that contractors placed great emphasis on project size when making the mark-up decision. This is due to the fact that projects with a large size will have higher mark-up margin. They will also have long duration and as a result will help to cover the company overheads for long periods and will also help the company to increase the annual business volume.

- *Project Type:*

  Contractors in Gaza Strip considered 'project type' to be important when making the mark-up decision. This is mainly because project type does affect the mark-up size. For example, electromechanical projects have higher profits due to the fact that only large contractors are classified to undertake them.

- *Past Profit in Similar Projects:*

Past profit in similar projects is considered to have moderate importance to the mark-up decision. It gives contractors an indication of the profit they may get from executing the project.

- *Experience in Such Projects:*

  The experience in such projects is considered to have moderate importance in determining the mark-up size. The same reason as stated in the bid/no bid decision.

- *Contract Conditions:*

  Another factor with moderate importance is the contract conditions. See the discussion on the bid /no bid decision.

- *Project Duration & Location:*

  Both Project duration and location have equal and moderate importance in mark-up size decision. Large contractors tend to execute long duration projects as they bid for large-size projects.

  For project location, some contractors have more than one branch office, and as a result they can manage the project easily, have good business relations with local suppliers and the cost of the resources mobilisation will be low.

- *Competition and Risk in Fluctuation in Material Prices:*

  As for the bid/ no bid decision, both factors 'competition' and 'risk in fluctuation in material prices' are of low importance to the mark-up decision.

9.4 Summary

The work described in this chapter provides a demonstration of how Saaty's Analytical Hierarchy Process (AHP), provided by the software package Criterium Decision Plus, can be used to formulate and analyse multi-criteria bidding decisions models. Models for the bid/no bid and mark-up decision were developed to assist contractors in making bidding decisions. Both models considered the most important factors influencing the choice of a project to bid for and the mark-up size. The results show the contribution of each factor to the final decision.

In the next chapter, a case study will be used to verify and validate the two Analytical Hierarchy Process models in practice.

CHAPTER TEN

Validation and Applications of the AHP Models

10.1 Introduction

The main objective of this chapter is to illustrate how bidding decisions are made using the two AHP multi-criteria bidding models developed in chapter nine through an illustrative example using real life case studies. The validation and testing of the two models were carried out using the Criterium Decision Plus Software and the Linear Programming approach.

The use of the Criterium Decision Plus Software to implement the Analytical Hierarchy Process has been discussed in earlier chapters. While for the Linear programming approach, a two-stage linear programming (LP) approach has been introduced by Chandran (2005) as a method for solving AHP problems i.e. estimating the weights for the AHP pair-wise comparison matrices. Hypothetical examples were presented in this paper and were solved using both the linear programming method, by using LINDO Software, and the Expert Choice Software. In this chapter, the linear programming approach, introduced by Chandran, will be summarized and then will be applied to a real life data. The results from the Linear Program approach will be compared with the outcome from the Criterium Decision Plus Software.

Section (10.2) provides an overview of the data collected for testing the bid/no bid and mark-up models. Followed by Section (10.3) which describes the steps involved in testing the bid/no bid model using the Criterium Decision Plus Software (CDP); as section (10.3.1) shows how to rate the bid/no bid hierarchy with the alternatives using the Criterium Decision Plus and secion (10.3.2) reviews and analyses the outputs from the Softwre. Section (10.4) describes the steps involved in testing the mark-up model using the Criterium Decision Plus Software (CDP); section (10.4.1) is concerned with rating the mark-up hierarchy while section (10.4.2) presents the outputs from the CDP software. Section (10.5) is concerened with the linear programming approach. A brief introduction to the Simplex method for solving linear programming problems is given in section (10.5.1) followed by an illustrative example of this method in section (10.5.2). Then in section (10.5.3), a description of the two-stage linear programming approach developed by chandran. Section (10.5.4) describes how the two stage linear programming approach was used to solve the pair-wise comparison matrices obtained from the real life case study for bid/ no bid decision. While, in section (10.5.5), the linear programming approach was applied to the data collected for mark-up decision. Finally in section (10.6), conclusion of this chapter is provided.

10.2 Data Collection

The data needed for conducting the validation and testing of the proposed models were collected from a Contractor operating in Gaza Strip. Twelve meetings were held with the contractor to gather the required data. The contractor was first asked to provide his general profile by completing section 1 of the questionnaire survey as shown in Table (10.1).

Section 1: Questions About Your Company: *Please mark with an X where appropriate*

A- Classification of Contractor (The possibility of more than one choice)

1. Buildings	[*]	3. Electromechanical	[*]
2. Infrastructure	[*]	4. Other	[*]

B- Number of Years in Industry

1. Less than 5	[ ]	3. From 16 to 25	[ ]
2. From 5 to 15	[*]	4. More than 25	[ ]

C- Number of Full Time Permanent Staff

1.	Less than 10	☐	3.	From 21 to 30	☐
2.	From 10 to 20	[*]	4.	More than 30	☐

D- Average Job Size executed (U.S $)

1.	Under 250 Thousand	☐	3.	From 501 Thousand to 1 Million	☐
2.	From 250 to 500 Thousand	☐	4.	More than 1 Million	[*]

E- Average Job Duration

1.	Less than 6 Months	☐	3.	From 13 Months to 2 Years	☐
2.	From 6 to 12 Months	[*]	4.	More than 2 Years	☐

F- Percentage of Work Subcontracted on Average Job

1.	Less than 25%	☐	3.	From 51 to 75%	[*]
2.	From 25 to 50%	☐	4.	From 76 to 100%	☐

G- Percentage of Work obtained through competitive bidding

1.	Less than 25%	☐	3.	From 51 to 75%	☐
2.	From 25 to 50%	☐	4.	From 76 to 100%	[*]

H- Percentage of using mathematical models to assist in bidding decisions

1.	Less than 25%	☐	3.	From 51 to 75%	[*]
2.	From 25 to 50%	☐	4.	From 76 to 100%	☐

Table (10.1): General Profile of the Contractor

It can be seen from Table (10.1), that this contractor is a good representation of the other surveyed contractors as;

- The company is specified for the three main types of projects and others as well.
- The company has been running for 5-15 years in industry which represents the 77% of the companies under study.
- It has between 10-20 permanent staff while 60% of the participated contractors have the same number of staff.

- The average job size executed in (U.S.$) is more than one million for this particular contractor while (70%) of the surveyed contractors are executing the same average job size.
- This contractor is executing projects with an average duration of 6-12 months which represents 50% of the other contractors.
- The contractor is subcontracting between 51-75% of work on average job where 40 % of the contractors filled in the questionnaire are subcontracting the same percentage.
- The contractor is obtaining the majority of his work by competitive bidding which is the main concern in our study.
- The contractor is depending heavily on mathematical models in making bidding decisions.

Three real life projects were selected as alternatives for the developed models. These projects were selected to represent different types of engineering work; as the first project is a building project while the second one is a road contract and finally the third one involves electromechanical works. The titles of the three projects are as follows:

- *Alternative one*: consists of construction of Insurance and Pension General Cooperation Building (IPGC). The main activities involved in this project were: civil, electrical, mechanical, finishing and external works.
- *Alternative two*: consists of the Rehabilitation and Reconstruction of Al-Qudus Street in Gaza. The project is mainly an infrastructure project with asphalt and pavement works.
- *Alternative three*: consists of the Construction of Jemezat Sabil Sewage Pumping Station. It involved civil, infrastructure, electromechanical and external works.

The details of the three projects are shown below in Table (10.2).

	Project No. 1	Project No. 2	Project No. 3
Project Title	Insurance & Pension General Cooperation Building (IPGC)	Rehabilitation and Reconstruction of Al-Qudus Street in Gaza	Construction of Jemezat Sabil Sewage Pumping Station
Project Location	Gaza City	Gaza City	Rafah City
Project Duration	One Year	Five Months	Six Months
Project Size	1 272 358.00 Euros	215 440.00 Euros	447 028.00 Euros
Owner Identity	(IPGC), the first time to work together	Municipality of Gaza, maintaining a good relation and worked with them for 9 projects in the past.	Municipality of Rafah, maintaining a good relation and worked with them for 2 projects in the past.
Client Identity	Ministry of Housing, the first time to work together	UNDP, maintaining a good relation and worked with them for 6 projects in the past.	Palestinian Water Authority (PWA), maintaining a good relation and worked with them on 5 projects in the past.
Consultant Identity	Ministry of Housing, the first time to work together	UNDP, maintaining a good relation and worked with them for 6 projects in the past.	Technical Engineering Consultant Company (TECC), maintaining a good relation and worked with them on 1 project in the past.
Payment Method	Advance Payment, then payment against invoices not less than 3000 Euro	Advance Payment, then payment against invoices not less than 18000 Euro	Advance Payment, then payment against invoices not less than 25000 Euro
Experience in Such Projects	Ten years of experience in such projects and two similar projects executed in the past.	Ten years of experience in such projects and Six similar projects executed in the past.	Seven years of experience in such projects and Four similar projects executed in the past.
Competition	13 Contractors were bidding but only 3 of them were potential competitors	9 Contractors were bidding but only 5 of them were potential competitors	7 Contractors were bidding and they were all potential competitors
Contract Conditions	Delay penalty: 1% for every one year, up to 10% of contract value.	Delay penalty: 1% for every one year, up to 10% of contract value.	Delay penalty: 1% for every one year, up to 10% of contract value.

	One year maintenance period.	One year maintenance period.	One year maintenance period.
Need for Work	Two similar projects have been executed in that year.	One similar project has been executed in that year.	There is a need for such project to be executed for the classification purpose.
Company Strength in Industry	Good reputation, good relations with banks, many certificated and financially stable.	Good reputation, good relations with banks, many certificated and financially stable.	Good reputation, good relations with banks, many certificated and financially stable.
Risk in Fluctuation in Material Prices	There is risk in fluctuation in material prices but the contractor has some material for this type of projects in his stores.	There is risk in fluctuation in material prices and boarders are closed.	There is risk in fluctuation in material prices and boarders are closed.
Past Profit in Similar Projects	10% or less	15% on average	More than 15%

Table (10.2): Details of the Three Projects

10.3 Validation of the Bid/ No Bid Decision Model

In this example the decision problem is to decide which project is the best option to bid for among the three projects. As shown in Figure (10.1) the model was developed using the Criterium Decision Plus Software following the steps described in previous chapters. The hierarchical model consisted of bid/ no bid decision as the goal branches off to the ten factors affecting this decision and then the three projects as alternatives.

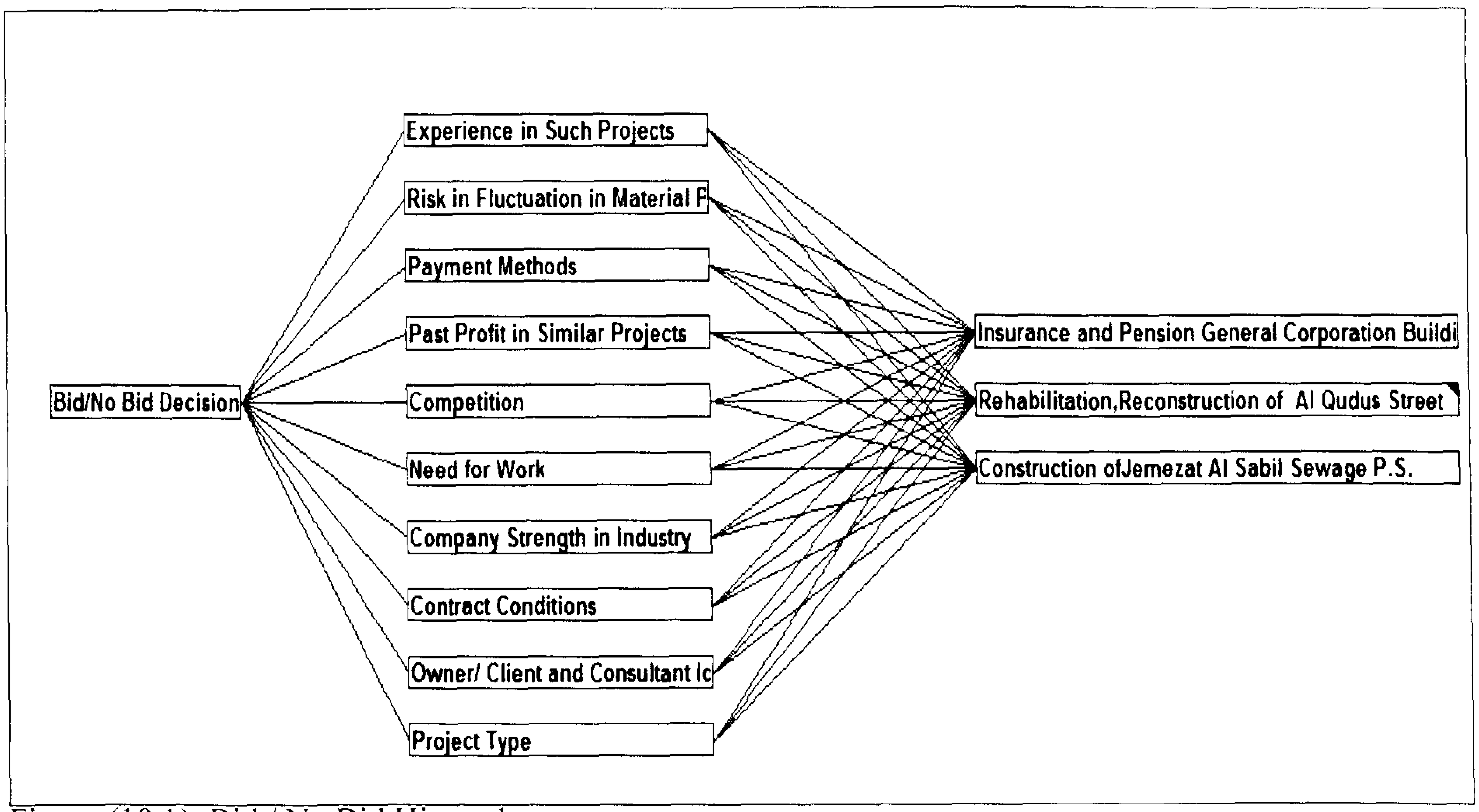


Figure (10.1): Bid / No Bid Hierarchy

10.3.1 **Rating the Hierarchy**:

The Contractor has been asked to rate the hierarchy. This has been achieved by comparing the three alternatives considered in this case study with respect to each factor in turn and then specifying the degree of importance on a scale between 1 (equal importance) and 9 (absolutely more important) to each alternative. Ten factors were considered in this section as shown in Table (10.3):

		Project No. 1	Project No. 2	Project No. 3
Project Title		Insurance & Pension General Cooperation Building (IPGC)	Rehabilitation and Reconstruction of Al- Qudus Street in Gaza	Construction of Jemezat Sabil Sewage Pumping Station
Experience in Such Projects	Bid/No Bid Decision	3	6	9
Past Profit in Similar Projects	Bid/No Bid Decision	5	7	9
Competition	Bid/No Bid Decision	4	7	9

Need for Work	Bid/No Bid Decision	6	7	9
Contract Conditions	Bid/No Bid Decision	4	4	4
Owner/Client & Consultant Identity	Bid/No Bid Decision	5	7	8
Project Type	Bid/No Bid Decision	3	4	4
Risk in Fluctuation in Material Prices	Bid/No Bid Decision	3	4	4
Company Strength in the Industry	Bid/No Bid Decision	4	5	5
Payment Methods	Bid/No Bid Decision	7	7	7

Table (10.3): Rates Provided by the Contractor for the Bid/ No Bid Hierarchy

The degree of importance provided by the contractor was then used as inputs for the Criterium Decision Plus as shown in Figure (10.2).

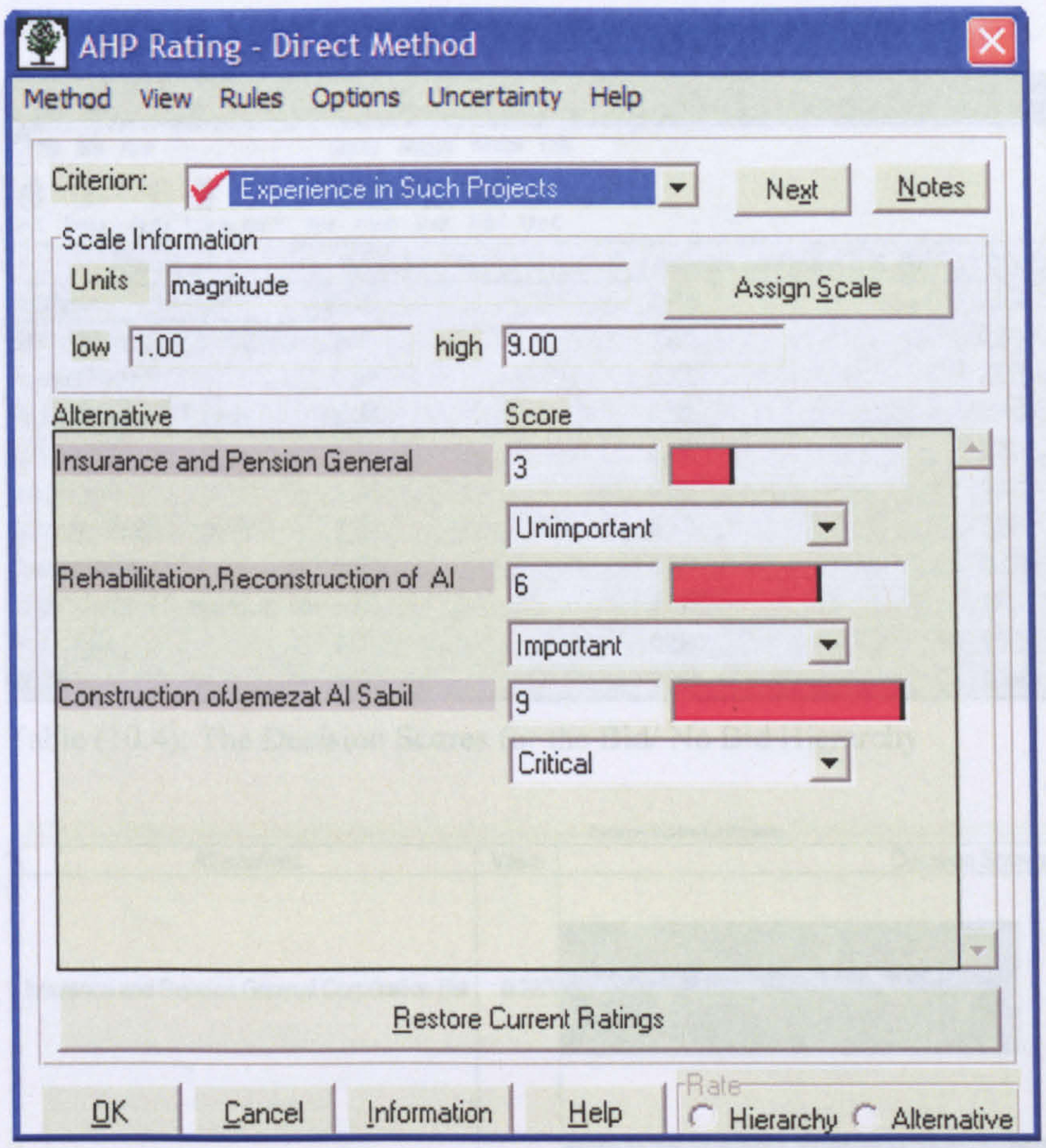


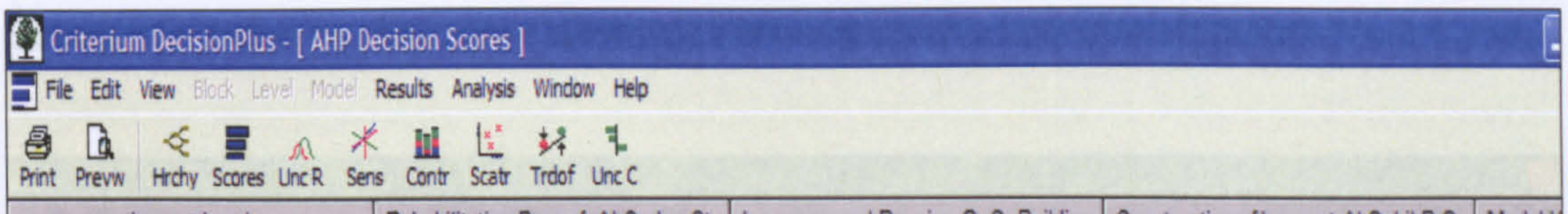
Figure (10.2): The Rating Window

10.3.2 Reviewing the Results:

The results of the developed bid/no bid model have been reviewed by displaying the decision scores, presenting the sensitivity analysis and the contribution by criteria.

- **Display the Decision Scores:**

The decision score window shown in Table (10.4) and Figure (10.3) displays the results of the bid/ no bid decision model. The results suggest that 'Construction of Jemezat Sabil Sewage Pumping Station' with a decision score of 0.397 is the most desirable/preferred option to bid for, then the Rehabilitation and Reconstruction of Al-Qudus Street project with a decision score of 0.340, and finally construction of Insurance and Pension General Cooperation Building (IPGC) alternative with a decision score of 0.263. To check the robustness and the reasonableness of the model, both sensitivity analysis and contribution by criteria are carried out next.



Lowest Level	Rehabilitation,Rec. of Al Qudus St.	Insurance and Pension G. C. Building	Construction ofJemezat Al Sabil P.S.	Model V
Experience in Such Projects	0.333	0.133	0.533	0.051
Risk in Fluctuation in Material Prices	0.375	0.250	0.375	0.017
Payment Methods	0.333	0.333	0.333	0.160
Past Profit in Similar Projects	0.333	0.222	0.444	0.064
Competition	0.353	0.176	0.471	0.021
Need for Work	0.316	0.263	0.421	0.283
Company Strength in Industry	0.364	0.273	0.364	0.196
Contract Conditions	0.333	0.333	0.333	0.030
Owner/ Client and Consultant Identity	0.353	0.235	0.412	0.122
Project Type	0.375	0.250	0.375	0.058
Results	0.340	0.263	0.397	

Table (10.4): The Decision Scores for the Bid/ No Bid Hierarchy

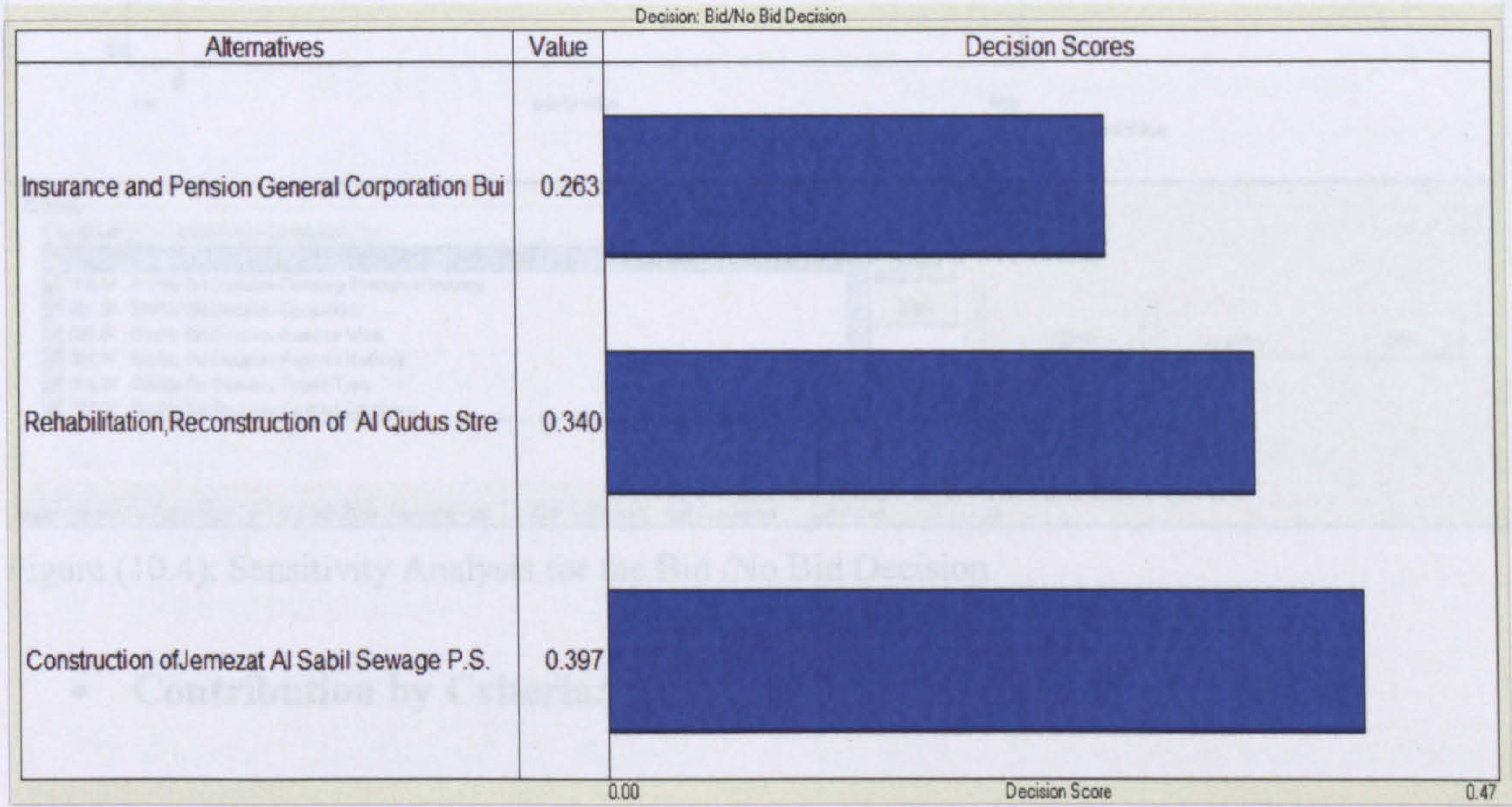


Figure (10.3): The Decision Scores for the Bid/ No Bid Hierarchy

- **Sensitivity Analysis:**

In a sensitivity analysis, if a change of 5% or less to a particular criteria weight causes the change of the preferred alternative, the model is sensitive and it is risky to rely on the current input. As shown in Figure (10.4), the 'criticality' list box lists all criteria in the order of decreasing criticality of their priorities. As shown in Figure (10.4), the factor 'Experience in Such Projects' is the most critical with a cross over percentage of 37.5%

which is very much higher than the 5% critical value and then 80.4% for Company Strength in Industry. Therefore the model is not sensitive and is acceptable.

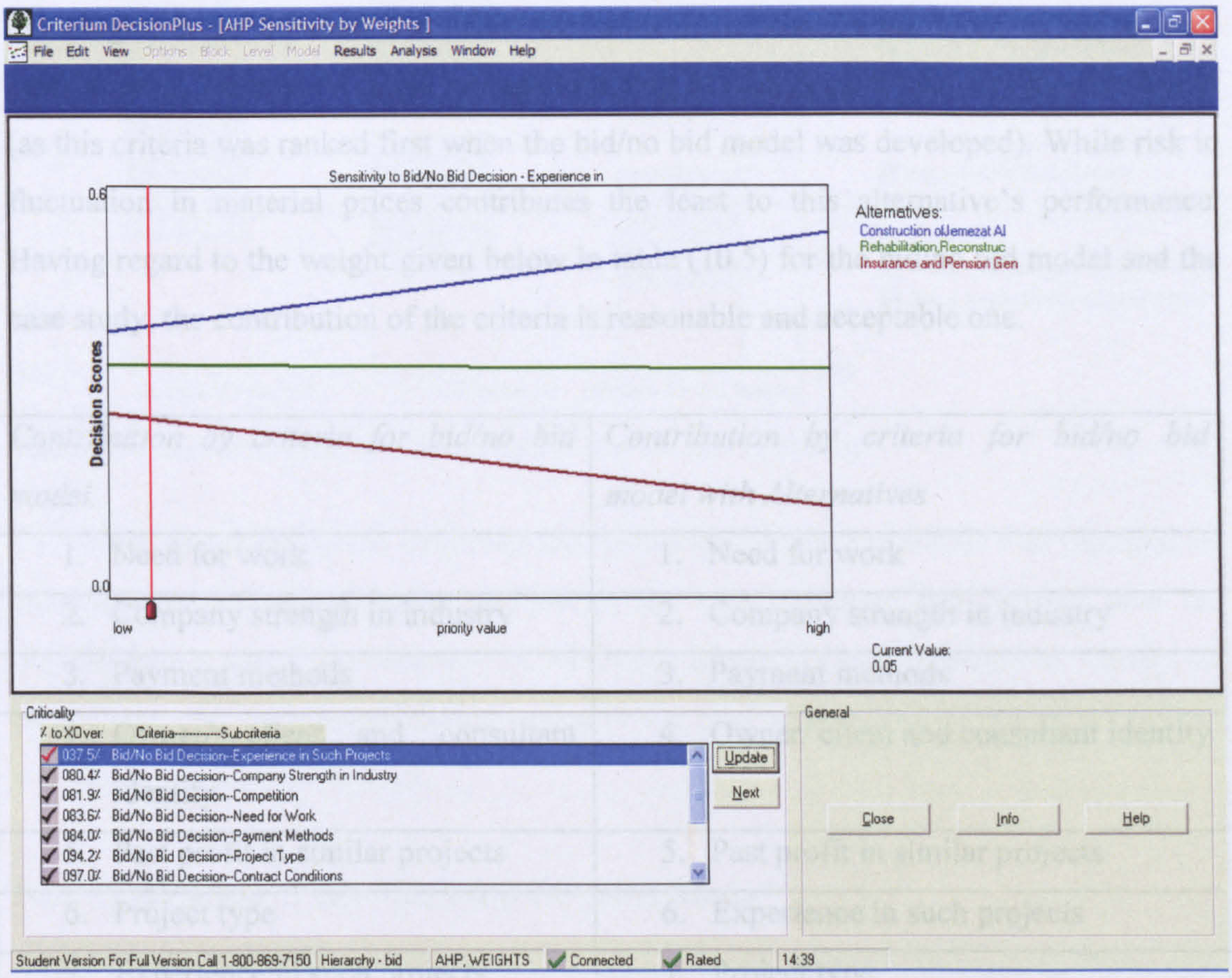


Figure (10.4): Sensitivity Analysis for the Bid /No Bid Decision

- **Contribution by Criteria:**

Contribution by criteria analyses what criteria contribute to the score given for each alternative. The criteria which have the highest contribution to the decision score of the alternatives are displayed as coloured boxes on the right hand side as shown in Figure (10.5). The stacked histogram on the left hand side shows the contribution of the criteria to the three possible projects. The height of the stacked bars shows the respective decision score of the alternatives.

The criteria have more contribution to the ranking of Jemezat Al-Sabil Sewage Pumping Station Project (the preferred alternative) than the other alternatives i.e. Jemezat Al-Sabil Sewage Pumping Station Project has the highest overall score as indicated by the overall bar height. It is apparent that need for work score contributes more to the overall preference of Jemezat Al-Sabil Sewage Pumping Station project than any other criterion (as this criteria was ranked first when the bid/no bid model was developed). While risk in fluctuation in material prices contributes the least to this alternative's performance. Having regard to the weight given below in table (10.5) for the bid/no bid model and the case study, the contribution of the criteria is reasonable and acceptable one.

Contribution by criteria for bid/no bid model	*Contribution by criteria for bid/no bid model with Alternatives*
1. Need for work	1. Need for work
2. Company strength in industry	2. Company strength in industry
3. Payment methods	3. Payment methods
4. Owner/ client and consultant identity	4. Owner/ client and consultant identity
5. Past profit in similar projects	5. Past profit in similar projects
6. Project type	6. Experience in such projects
7. Experience in such projects	7. Project type
8. Contract conditions	8. Competition
9. Competition	9. Contract conditions
10. Risk in fluctuation in material prices	10. Risk in fluctuation in material prices

Table (10.5): Contribution by Criteria for Bid/No Bid Model and for Bid/No Bid Model with Alternatives.

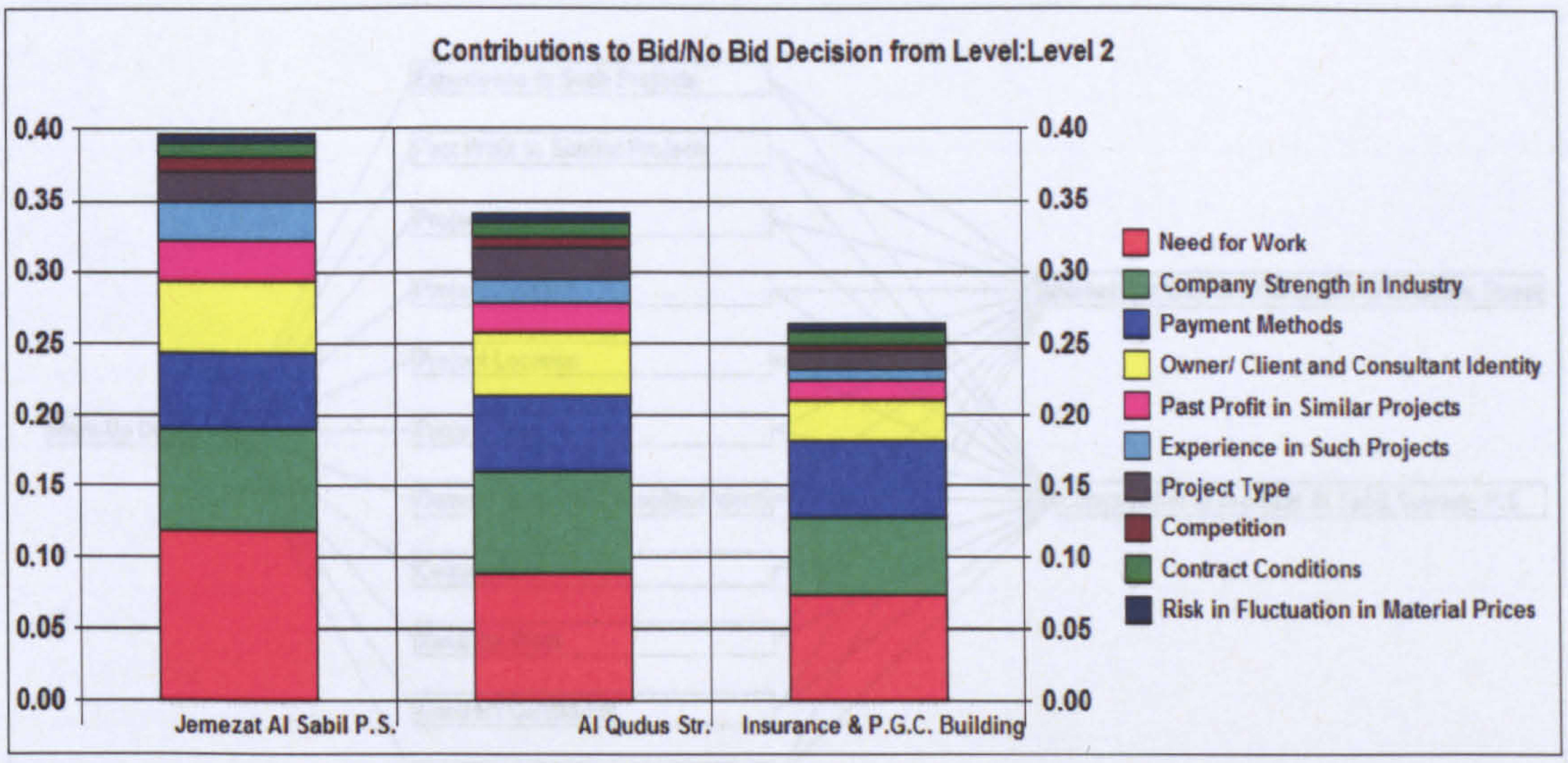


Figure (10.5): Contribution by Criteria for the Bid/ No Bid Hierarchy

The results presented by the Criterium Decision Plus Software conclude that 'Jemezat Al Sabil Sewage Pumping Station' project is the best option to bid for and then the 'Rehabilitation and Reconstruction of Al-Qudus Street in Gaza' alternative. These two alternatives will be analysed further more in the next section to find out which project will result in a higher mark-up.

10.4 Validation of the Mark-Up Decision Model

In this example the decision problem is to decide which project will result in the highest mark-up bid among the two projects; the Rehabilitation and Reconstruction of Al-Qudus Street in Gaza and the Construction of Jemezat Al Sabil Sewage Pumping Station. The decision hierarchy for the selection of the best project with the highest mark-up, based on the eleven factors identified previously and two decision alternatives is shown in Figure (10.6).

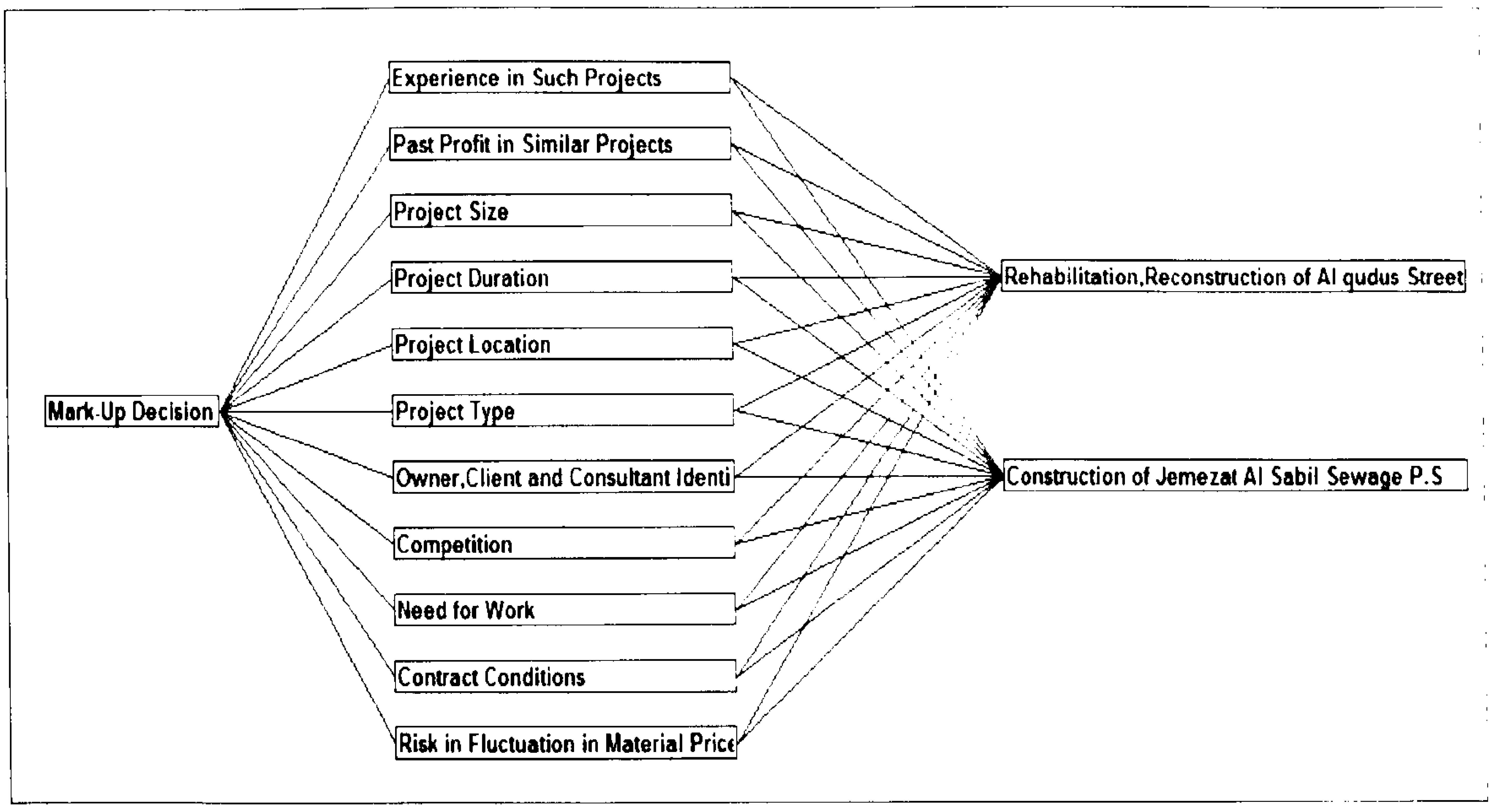


Figure (10.6): The Mark-Up Hierarchy

Rating the Hierarchy:

The Contractor has been asked to rate the hierarchy. This has been achieved by comparing the two alternatives considered in this case study with respect to each factor in turn and then specifying the degree of importance on a scale between 1 (equal importance) and 9 (absolutely more important) to each alternative. Eleven factors were considered in this section as shown in Table (10.6):

		Project No. 2	**Project No. 3**
Project Title		Rehabilitation and Reconstruction of Al-Qudus Street in Gaza	Construction of Jemezat Sabil Sewage Pumping Station
Experience in such projects	Mark-Up Decision	5	7
Past Profit in Similar Projects	Mark-Up Decision	5	7
Competition	Mark-Up Decision	5	7

Need for Work	Mark-Up Decision	4	6
Contract Conditions	Mark-Up Decision	4	4
Owner/Client & Consultant Identity	Mark-Up Decision	5	6
Project Type	Mark-Up Decision	4	5
Risk in Fluctuation in Material Prices	Mark-Up Decision	4	4
Project Location	Mark-Up Decision	4	4
Project Size	Mark-Up Decision	4	5
Project Duration	Mark-Up Decision	4	4

Table (10.6): Rates Provided by the Contractor for the Mark-Up Hierarchy

The degree of importance provided by the contractor was then used as inputs for the Criterium Decision Plus as shown in Figure (10.7).

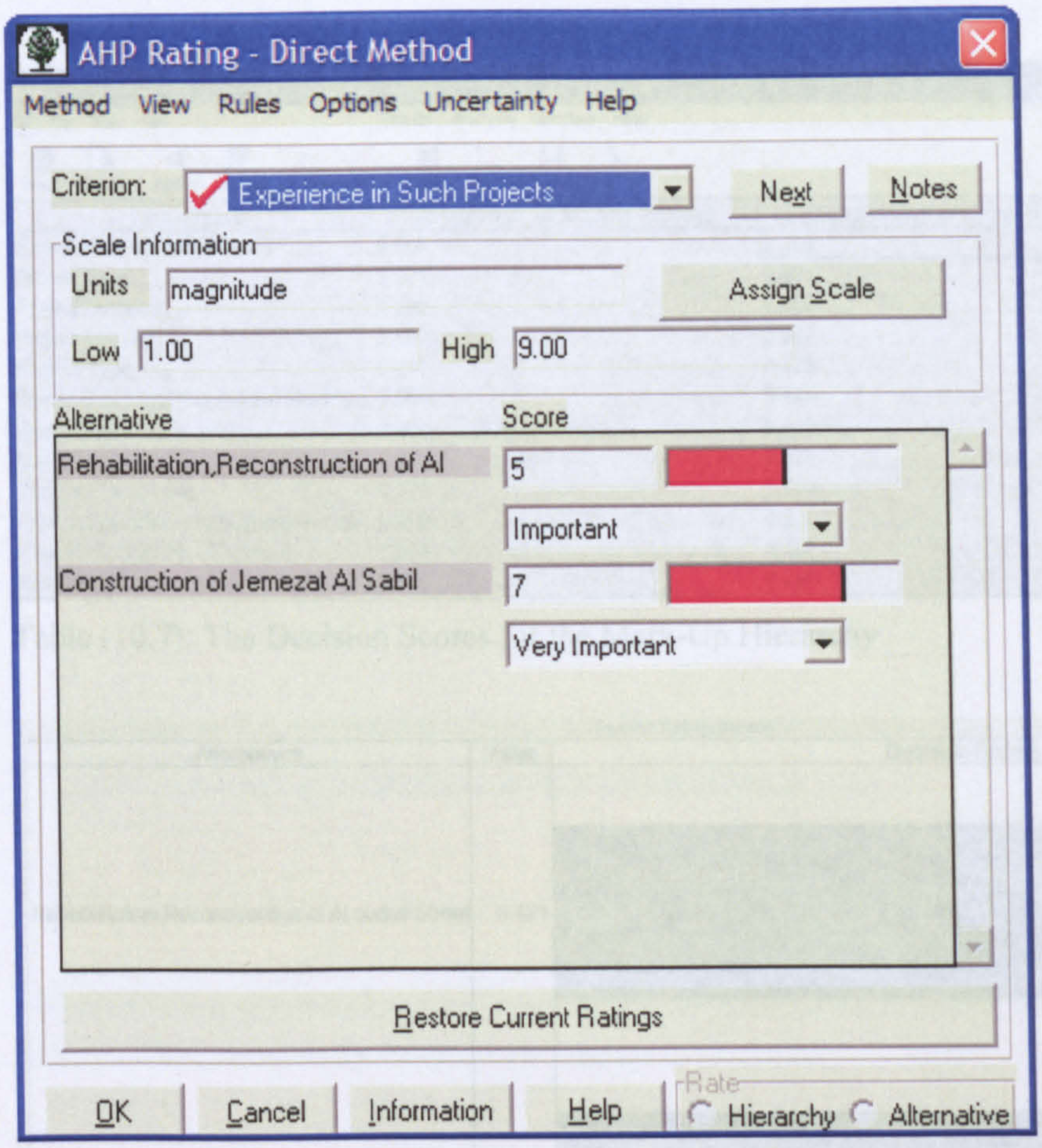


Figure (10.7): The Rating Window

Reviewing the Results:

The results of the developed mark-up model have been reviewed by displaying the decision scores, presenting the sensitivity analysis and the contribution by criteria.

- **Display the Decision Scores:**

The decision score window shown in Table (10.7) and Figure (10.8), displays the results of the mark-up decision model. The results suggest that 'Construction of Jemezat Sabil Sewage Pumping Station' with a decision score of 0.579 is the option which will give the highest mark-up value and then the Rehabilitation and Reconstruction of Al-Qudus Street project alternative with a decision score of 0.421. To check the robustness and the reasonableness of the model, both sensitivity analysis and contribution by criteria are carried out next.

Lowest Level	Construction of Jemezat Al Sabil	Rehabilitation,Reconstruction of Al qudus Street	Model
Experience in Such Projects	0.600	0.400	0.069
Project Size	0.571	0.429	0.116
Project Duration	0.500	0.500	0.028
Project Location	0.500	0.500	0.028
Project Type	0.571	0.429	0.110
Owner,Client and Consultant Identity	0.556	0.444	0.218
Competition	0.600	0.400	0.020
Need for Work	0.625	0.375	0.278
Contract Conditions	0.500	0.500	0.041
Risk in Fluctuation in Material Prices	0.500	0.500	0.018
Past Profit in Similar Projects	0.600	0.400	0.073
Results	0.579	0.421	

Table (10.7): The Decision Scores for the Mark-Up Hierarchy

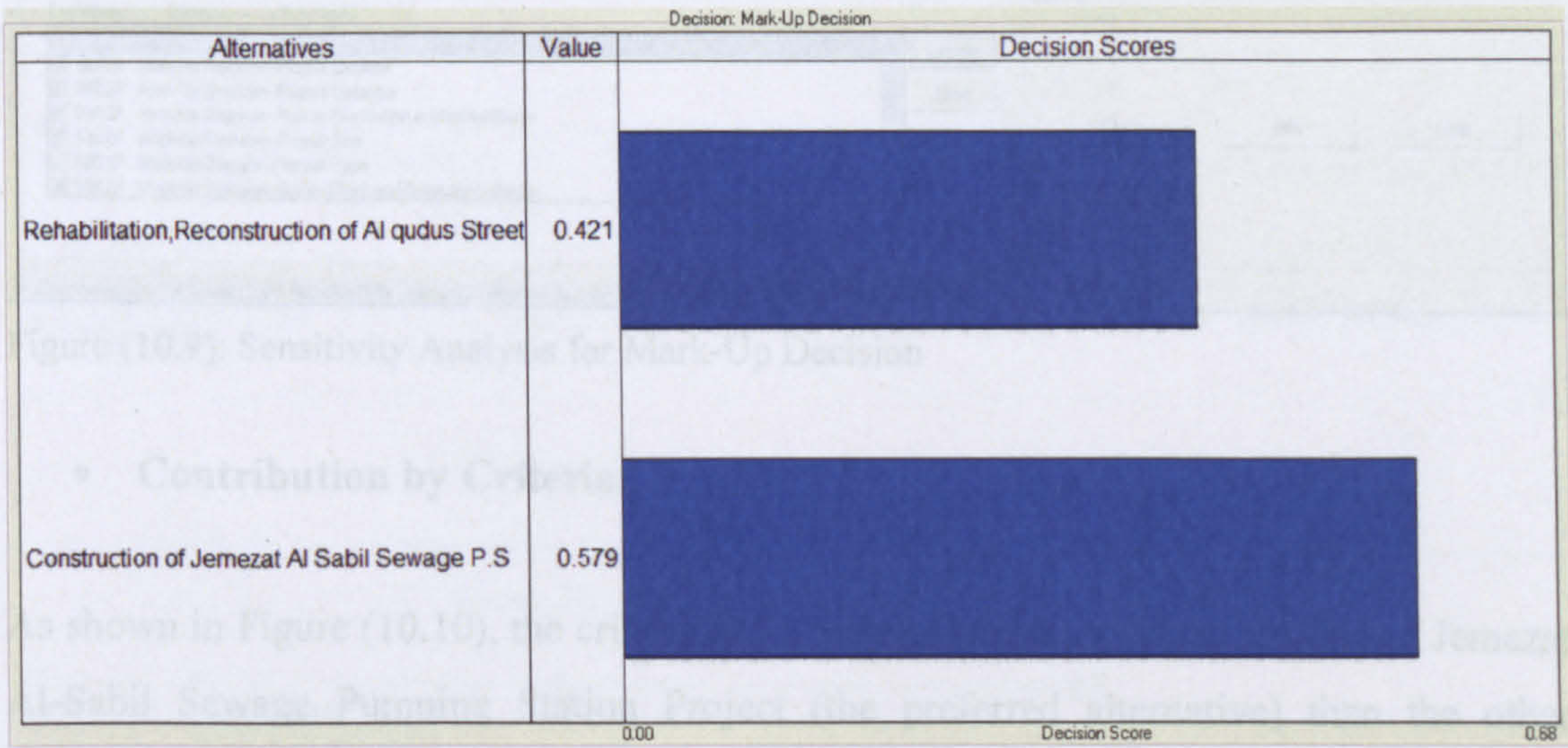


Figure (10.8): The Decision Scores for the Mark-Up Hierarchy

- **Sensitivity Analysis:**

It shows that the score of 'Contract Conditions' is the most critical. It has a cross over percentage of 95.9% and is very much higher than the 5% critical value.

As can be seen from the graph, the preferred alternative is highly insensitive to changes in the value of the critical weight. Accordingly, the model is not sensitive and is acceptable.

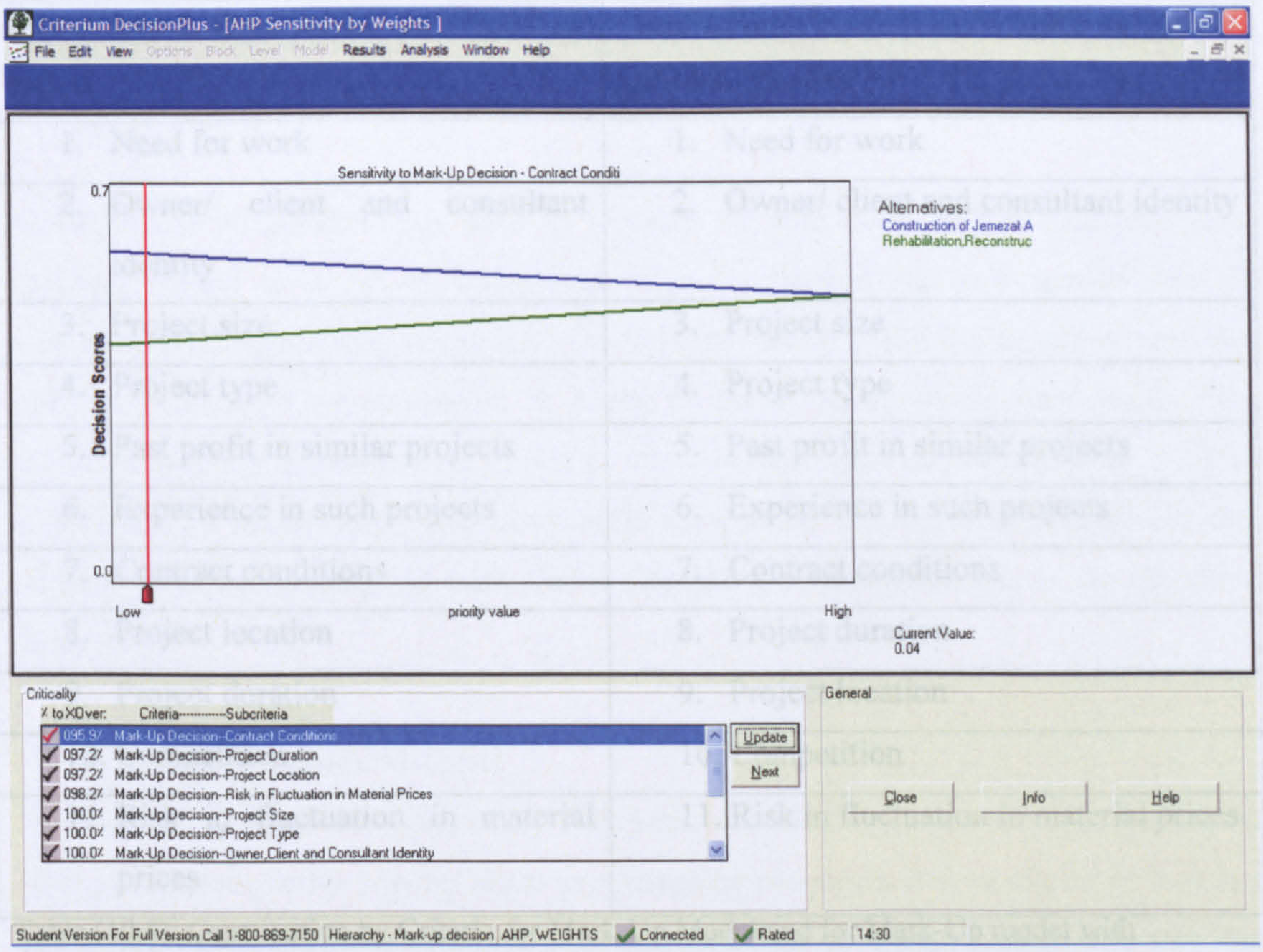


Figure (10.9): Sensitivity Analysis for Mark-Up Decision

- **Contribution by Criteria:**

As shown in Figure (10.10), the criteria have more contribution to the ranking of Jemezat Al-Sabil Sewage Pumping Station Project (the preferred alternative) than the other alternative i.e. Jemezat Al-Sabil Sewage Pumping Station Project has the highest overall score as indicated by the overall bar height. It is apparent that need for work score contributes more to the overall preference of Jemezat Al-Sabil Sewage Pumping Station project than any other criterion (as this criteria was ranked first when the mark-up model was developed). While risk in fluctuation in material prices contributes the least to this alternative's performance. Having regard to the weight given below in table (10.8) for the mark-up model and the case study, the contribution of the criteria is reasonable and acceptable one.

Contribution by criteria for mark-up model	*Contribution by criteria for mark-up model with Alternatives*
1. Need for work	1. Need for work
2. Owner/ client and consultant identity	2. Owner/ client and consultant identity
3. Project size	3. Project size
4. Project type	4. Project type
5. Past profit in similar projects	5. Past profit in similar projects
6. Experience in such projects	6. Experience in such projects
7. Contract conditions	7. Contract conditions
8. Project location	8. Project duration
9. Project duration	9. Project location
10. Competition	10. Competition
11. Risk in fluctuation in material prices	11. Risk in fluctuation in material prices

Table (10.8): Contribution by Criteria for Mark-Up Model and for Mark-Up model with Alternatives.

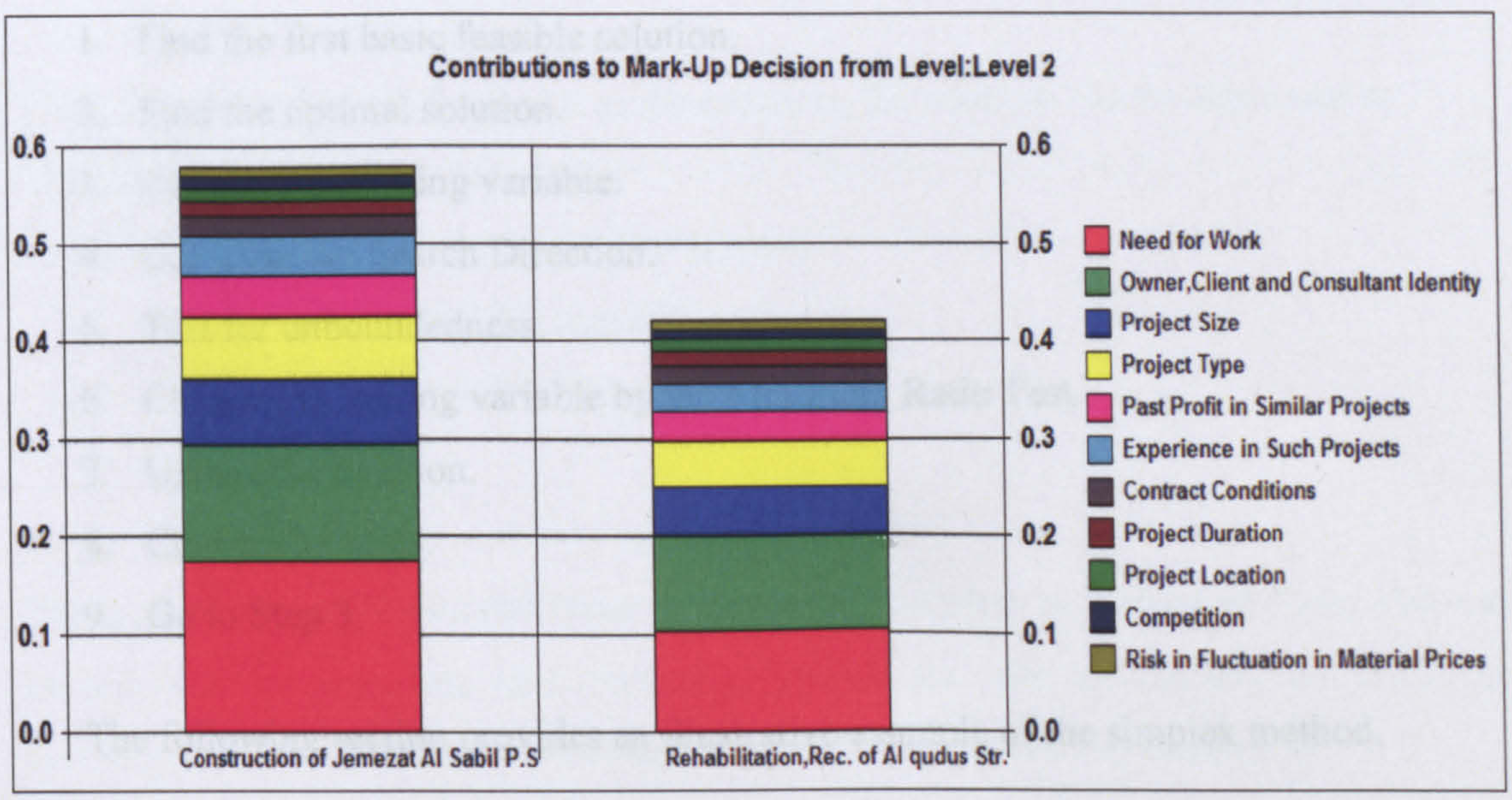


Figure (10.10): Contribution by Criteria for Mark-up Hierarchy

Linear Programming:

Mathematical programming is used to identify the maximum or the minimum of a function subject to a set of constraints. Linear programming is a special case of mathematical programming where both the function, which called the objective function, and the constraints are expressed in terms of linear equations or inequalities. The objective function is the function of one or more variables that one is interested in either maximising or minimising while constraints are a set of equalities or inequalities that describe restrictions involved with the minimization or maximization of the objective function.

10.5.1 The Simplex Method:

The simplex method was created by the American mathematician George Dantzig in 1947 as a technique for solving linear programming problems. It depends on an iterative procedure which involves moving from one solution to another in a way that the objective function value improves. The following are the steps for solving linear programming problems using the simplex method:

1. Find the first basic feasible solution.
2. Find the optimal solution.
3. Choose the entering variable.
4. Calculate the Search Direction.
5. Test for unboundedness.
6. Choose the leaving variable by the Minimum Ratio Test.
7. Update the solution.
8. Change the basis.
9. Go to Step 3.

The following section provides an illustrative example of the simplex method.

10.5.2 Illustrative example for the Simplex Method:

A small firm manufactures wooden tables, chairs and desks, and employs skilled and unskilled labour to produce these items. A table requires 1 hour of skilled labour, 2 hours of unskilled labour and 2 units of wood. The corresponding figures for chairs are 2 hours, 1 hour and 1 unit respectively, and for desks the figures are 1 hour, 3 hours and 2 units respectively. Each week 160 skilled man-hours, 120 unskilled man-hours and 100 units of wood are available. The profit contributions on tables, chairs and desks are £10, £6 and £8 respectively. Determine how much of each item should be produced each week to maximise the profit.

Solution:

Step1: To solve this problem using the simplex algorithm, the linear programming must be converted into an equivalent problem in which all constraints are equations and all variables are nonnegative.

The problem can be formulated in linear programming terms as follows:

t = number of tables produced per week

c = number of chairs produced per week

d = number of desks produced per week

Then, taking profit contribution, z, as the criterion, the problem can be expressed as:

Maximise $z = 10t + 6c + 8d$

Subject to $t + 2c + d <= 160$ (skilled labour)

$2t + c + 3d <= 120$ (unskilled labour)

$2t + c + 2d <= 100$ (wood)

$t, c, d >= 0$

The next step is to convert the linear programming problem to a standard form. This can be achieved by replacing each inequality constraints with an equality constraint by defining a slack variable s_i (s_i = non-negative slack variable for i *th* constraint).

Maximise $z = 10t + 6c + 8d$

Subject to $t + 2c + d + s_1 = 160$

$2t + c + 3d + s_2 = 120$

$2t + c + 2d + s_3 = 100$

$t, c, d, s_1, s_2, s_3 >= 0$

where: s_1 represents unused skilled man-hours, s_2 represents unused unskilled man-hours and s_3 represents unused units of wood.

Step 2: Find the first basic feasible solution. By expressing the basic variables (BVs: s1, s2, s3) and objective function in terms of the non-basic variables (NBVs: t, c, d).

$z = 10t + 6c + 8d$

$s_1 = 160 - t - 2c - d$

$s_2 = 120 - 2t - c - 3d$

$s_3 = 100 - 2t - c - 2d$

current solution : $s_1 = 160$, $s_2 = 120$, $s_3 = 100$, $t = 0$, $c = 0$, $d = 0$, $z = 0$.

Step 3: Check if the current solution is optimal. For the maximisation problem, the current solution is optimal if the coefficients of the non-basic variables in the objective function are all non-positive. Current solution is not optimal since z can be increased by increasing t, c or d from zero.

Step 4: Select t as the entering variable since it has the largest positive coefficient in the expression for z.

Step 5: from the expression for current BVs in terms of current NBVs:

s_1 decreases as t increases: $s_1 = 0$ when $t = 160$

s_2 decreases as t increases: $s_2 = 0$ when $t = 60$

s_3 decreases as t increases: $s_3 = 0$ when $t = 50$

Note that we cannot increase t beyond t = 50, since s_3 would become negative and solution would be infeasible. Hence the first variable to be forced to zero as t increases is s_3. Thus t becomes basic and s_3 becomes non- basic.

Second Iteration:

Step 2: The BVs are now t, s_1, s_2 and the NBVs are c, d, s_3. The equation for s_3 in step 2 of the first iteration determined the departing variable and is known as the pivotal equation. From this equation the new BV, t can be expressed in terms of the new set of NBVs. Hence, by substituting for t in the other equations in step 2 of the first iteration, the other BVs and the objective function can be expressed in terms of the new set of NBVs:

$t = 50 - 1/2\ s3 - 1/2\ c - d$

$s1 = 110 + 1/2\ s3 - 3/2\ c$

$s2 = 20 + s3 - d$

$z = 500 - 5s3 + c - 2d$

Current solution $t = 50$, $s_1 = 110$, $s_2 = 20$, $c = 0$, $d = 0$, $s_3 = 0$, $z = 500$.

Step 3: Current solution is not optimal since z can be improved by increasing c from zero. (Note that increasing d or s_3 will cause z to decrease).

Step 4: Select c as the entering variable – the only variable in the objective function with a positive coefficient.

Step 5: From the expressions for current BVs in terms of current NBVs:

t decreases as c increases: $t = 0$ when $c = 100$

s_1 decreases as c increases: $s_1 = 0$ when $c = 220/3$

s_2 constant as c increases.

Hence the first variable to be forced to zero as c increases is s_1, and thus c becomes basic and s_1 becomes non basic.

Third iteration:

Step 2: The BVs are now t, c, s_2 and the NBVs are d, s_1, s_3. The equation for s_1 in step2 of the second iteration is the pivotal equation. Using this equation to express the new BV, i.e. c, in terms of the new set of NBVs, and substituting for c in the other equations in step 2 of the second iteration:

$c = 220/3 - 2/3s_1 + 1/3s_3$

$t = 40/3 + 1/3s_1 - 2/3s_3 - d$

$s_2 = 20 + s_3 - d$

$z = 1720/3 - 2/3s_1 - 14/3s_3 - 2d$

Step 3: Current solution is optimal- all the coefficients of the NBVs in the objective function are non positive.

The optimal solution to this problem is therefore to produce 13.3 tables, 73.3 chairs, and no desks, yielding a profit contribution of £573.3. With this solution 20 hours of unskilled labour will be unused, and all the skilled man-hours and wood are used.

10.5.3 Linear Programming Approach for Generating a Priority Vector

Chandran, et al. (2005) developed a two stage linear program to generate the priority vector from the pair-wise comparison matrix created using the Analytical Hierarchy Process. In the first stage, the linear program was formulated to provide a consistency bound for the pair-wise comparison matrix, then, in the second stage, the consistency bound is used as an input in a linear program to obtain the priority vector.

The objective of the first stage of the linear programming method is to minimise the sum of the positive errors in the priority vector, i.e. minimise the sum of the $z_{ij's}$. This objective can be thought of as the minimization of the sum of the overestimated values, while in the original non-transferred space, it corresponds to minimising the product of the errors greater than or equal to one. When solving stage one, the results will consist of different sets of weight ratios that have the same total error. To determine which of these solutions is the optimal, stage two of the linear program is needed to select the optimal/most desired solution whose maximum error z_{max} is minimal.

LINDO will be used to optimize the Linear Program. LINDO (Linear Interactive and Discrete Optimizer) was developed by Linus Schrage in 1986. It is an interactive user-friendly computer package that can be used to solve linear programming problems. The following is stage one and two of the linear program developed by Chandran, et al. (2005).

Stage one: linear program to establish the consistency bound.

Let the equation

$w_i / w_j = a_{ij} \varepsilon_{ij}$ $\quad\quad i,j = 1, 2, \dots, n$ $\quad\quad$ ....(1)

define an error ε_{ij} in the estimate of the relative preference a_{ij}. So, if the decision maker is consistent, ln ε_{ij} will be zero when taking the natural logarithm of (9). The variables in the linear program are defined as follows:

The constants are:

n = number of rows (columns) in the square matrix A.

a_{ij} = entry for row i and column j in the matrix A.

The decision variables are:

w_i = weight of element i.

ε_{ij} = error factor in estimating a_{ij}.

In order to get the error relationship into a linear form, the following three transformed decision variables were used in this model:

$x_i = \ln(w_i)$ $\quad\quad$, $yij = \ln(\varepsilon_{ij})$, $\quad\quad$ and $z_{ij} = |y_{ij}|$

Since each error ε_{ij} assumes value around one, the corresponding $y_{ij} = \ln(\varepsilon_{ij})$ can assume either positive or negative values. As the errors are reciprocal, $y_{ij} = - y_{ji}$, by defining $z_{ij} = |y_{ij}|$, the total error in the priority vector can be captured by summing up the z_{ij} variables.

The first stage linear program is given by the following:

Minimise $\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} zij$ .... (1)

Subject to

$x_i - x_j - y_{ij} = \ln a_{ij}$, i,j = 1, 2, . . . , n; $i \neq j$ .... (2)

$z_{ij} \geq y_{ij}$, i , j = 1,2, . . . , n; i < j .... (3)

$z_{ij} \geq y_{ji}$, i , j = 1,2, . . . , n; i < j .... (4)

$x_1 = 0$ .... (5)

$z_{ij} \geq 0$, i,j = 1, 2, . . . , n .... (6)

x_i, y_{ij} unrestricted , i,j = 1, 2, . . . , n .... (7)

- Constraint (2): results from taking the natural logarithm of (9) of both sides of the error equation (equation (1): $w_i / w_j = a_{ij}\,\varepsilon_{ij}$).
- Constraints (3) and (4) represent equation zij = |yij|. As, in the comparison matrix A, if a_{ij} is overestimated (i.e. the decision maker's judgment of entry i versus entry j is greater than the true value), then a_{ji} is underestimated. Then,

  $\varepsilon_{ij} = 1/\ \varepsilon_{ji}$, i,j = 1, 2, . . . , n

  or

  $y_{ij} = -\ y_{ji}$

  Therefore, by obtaining the greater of y_{ij} and y_{ji} , constraints (3) and (4) identify for each i and j the element that is overestimated and the magnitude of error.
- Constraint (5), $x_1 = 0$, is arbitrary. This constraint is needed since an infinite number of solution can exist for this linear program (as the weights are not unique, only their ratios are), a solution where chosen with $w_1 = 1$.
- Constraint (7), x_i and y_{ij} decision variables are unrestricted since they are logarithms of positive real numbers.

<u>Second Stage: linear program to generate a priority vector</u>

Let the optimal objective function value of the first stage model be z*

The second stage linear program is given by the following:

Minimise z_{max} .... (8)

Subject to

$$\sum_{i=1}^{n-1} \sum_{j=i+1} zij = z^*$$ .... (9)

$x_i - x_j - y_{ij} - \ln a_{ij}$, i,j = 1, 2, . . . , n; i ≠ j .... (10)

$z_{ij} \geq y_{ij}$, i , j = 1,2, . . . , n; i < j .... (11)

$z_{ij} \geq y_{ji}$, i , j = 1,2, . . . , n; i < j .... (12)

$z_{max} \geq z_{ij}$, i , j = 1,2, . . . , n; i < j .... (13)

$x_1 = 0$ .... (14)

$z_{ij} \geq 0$, i,j = 1, 2, . . . , n .... (15)

x_i, y_{ij} unrestricted , i,j = 1, 2, . . . , n .... (16)

$z_{max} \geq 0$ .... (17)

- The objective function (8) minimises z_{max}.
- Constraint (9): ensures that only those solution vectors that are optimal in the first-stage linear program are feasible in the second stage model.
- Constraints (11) and (12) represent equation zij = |yij| (as in stage one).
- Constraint (13): find out the maximum value of the errors z_{max}.
- Constraint (14), $x_1 = 0$, is arbitrary (as in stage one).
- Constraint (16), x_i and y_{ij} decision variables are unrestricted since they are logarithms of positive real numbers (as in stage one).
- Constraint (17) represents the non-negativity for z_{max}.

10.5.4 Applying the Linear Programming Approach to the Bid/No Bid Decision

Bid / No Bid (Experience) First stage

To illustrate the application of the two-stage linear program, Figure (10.11) shows the comparison matrix for the data collected for the three projects in relation to the factor experience in such projects. The free version of LINDO software has been used to solve this linear programming problem.

$$\begin{bmatrix} Insurance\ \&\ P.G.C.Building & Al-QudusSt. & J.S\ Sewage\ P.S \end{bmatrix}$$

$$\begin{bmatrix} Insurance\ and\ P.G.C\ Building \\ Al\ Qudus\ Street \\ J.S\ Sewage\ Pumping\ Station \end{bmatrix} \begin{bmatrix} 1 & 0.5 & 0.333 \\ 2 & 1 & 0.667 \\ 3 & 1.5 & 1 \end{bmatrix}$$

Figure (10.11): The Comparison Matrix for the Data Collected for the Three Projects

The first stage model for the matrix in Figure (10.11) is given by the following:

```
min z12 + z13 + z23
st
x1 - x2 - y12 = -0.693
x2 - x1 - y21 = 0.693
x1 - x3 - y13 = -1.099
x3 - x1 - y31 = 1.099
x2 - x3 - y23 = -0.4054
x3 - x2 - y32 = 0.4054
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Upon running stage one of this problem, the objective function value was found to be equal to 0.0005999. This value was then used as a constraint in stage two.

The second stage model for the matrix given in Figure (10.11) is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0.0005999
x1 - x2 - y12 = -0.693
x2 - x1 - y21 = 0.693
x1 - x3 - y13 = -1.099
x3 - x1 - y31 = 1.099
x2 - x3 - y23 = -0.4054
x3 - x2 - y32 = 0.4054
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below.

```
LP OPTIMUM FOUND AT STEP      15

OBJECTIVE FUNCTION VALUE

E-030.2999753      (1

VARIABLE          VALUE
ZMAX            0.000300
Z12             0.000300
Z13             0.000300
Z23             0.000000
X1              0.000000
X2              0.693300
Y12            -0.000300
Y21             0.000300
X3              1.098700
Y13             0.000300
Y31            -0.000300
Y23             0.000000
Y32             0.000000
    ZIJ         0.000000
```

When solving the second stage of the linear program using LINDO, the value of the objective function z_{max} is 0.0002999 while, $x_1 = 0$, $x_2 = 0.6933$ and $x_3 = 1.0987$. The values obtained from LINDO (in natural logarithm space) should be transferred to normal weight space and then $x_1 = 1$, $x_2 = 2$, $x_3 = 3$. Then, by normalising the matrix, the decision scores for the three projects 'Construction of Insurance and Pension General Cooperation Building (IPGC)', 'Rehabilitation & Reconstruction of Al-Qudus Street' and 'Construction of Jemezat Al Sabil Sewage Pumping Station' is equal to (0.1667, 0.333, and 0.4999) respectively. These decision scores compare reasonably well with the results generated from the Criterium Decision Plus Software as shown in Table (10.4); the priority vector for the factor experience in such project is (0.133, 0.333, 0.533) for the three projects respectively.

Then, the matrix for each factor (with respect to the three projects) was solved using the two-stage linear program as shown in Appendix (B). The decision scores for the three projects with respect with the different factors affecting the bid/no bid decision is presented below.

By solving the matrix

$$\begin{matrix} P.P & P.T & C & R & N & C.S & C.C & P.M & E & O \end{matrix}$$

$$\begin{bmatrix} 0.238 & 0.272 & 0.2 & 0.272 & 0.272 & 0.285 & 0.333 & 0.333 & 0.166 & 0.25 \\ 0.333 & 0.363 & 0.35 & 0.363 & 0.318 & 0.357 & 0.333 & 0.333 & 0.333 & 0.35 \\ 0.428 & 0.363 & 0.449 & 0.363 & 0.409 & 0.357 & 0.333 & 0.333 & 0.5 & 0.399 \end{bmatrix} \begin{bmatrix} Insurance\ and & P.G.C & Building \\ Al\ Qudus & Street & \\ J.S\ Sewage & Pumping & Station \end{bmatrix}$$

Where;

P.P = Past Profit in similar projects, P.T= Project Type, C=Competition, R= Risk in fluctuation in material prices, N= Need for Work, C.S = Company Strength in industry, C.C = Contract Conditions, P.M= Payment Method, E=Experience in such projects, O= Owner/client and consultant identity.

By solving the above matrix, the priority vector for the three projects is

$$\begin{bmatrix} Insurance\ and & P.G.C & Building \\ Al\ Qudus & Street & \\ J.S\ Sewage & Pumping & Station \end{bmatrix} \begin{bmatrix} 0.263 \\ 0.344 \\ 0.394 \end{bmatrix}$$

Using Criterium Decision Plus Software, as shown in Table (10.4), the priority vector is as follows

$$\begin{bmatrix} Insurance\ and & P.G.C & Building \\ Al\ Qudus & Street & \\ J.S\ Sewage & Pumping & Station \end{bmatrix} \begin{bmatrix} 0.263 \\ 0.340 \\ 0.397 \end{bmatrix}$$

Both approaches, the Analytical Hierarchy Process and the Linear Programming, recommend that the Construction of Jemezat Sabil Sewage Pumping Station is the best option to bid for, then the Rehabilitation and Reconstruction of Al-Qudus Street option and finally as the last alternative the Construction of the Insurance and P.G.C. Building.

10.5.5 Applying the Linear Programming Approach to Mark-Up Decision

By applying the two-stage Linear program to the data collected for mark-up decision shown in Table (10.6), the decision scores for the three projects with respect with the different factors affecting mark-up decision is presented below (details are shown in Appendix (B)).

$$\begin{matrix} E & P.P & C & N & C.C & O & P.T & R & P.L & P.S & P.D \end{matrix}$$

$$\begin{bmatrix} 0.416 & 0.416 & 0.416 & 0.399 & 0.5 & 0.454 & 0.444 & 0.5 & 0.5 & 0.444 & 0.5 \\ 0.583 & 0.583 & 0.583 & 0.6 & 0.5 & 0.545 & 0.555 & 0.5 & 0.5 & 0.555 & 0.5 \end{bmatrix} \begin{bmatrix} Al \quad Qudus \quad Street \\ J.S \quad Sewage \quad P.S \end{bmatrix}$$

Where, E=Experience in such projects, P.P = Past Profit in similar projects, C=Competition, P.T= Project Type, R= Risk in fluctuation in material prices, N= Need for Work, P.L = Project Location, C.C = Contract Conditions, P.S = Project Size, O= Owner/client and consultant identity, P.D = Project Duration.

By solving the above matrix, the priority vector is

$$\begin{bmatrix} Al \quad Qudus \quad Street \\ J.S \quad Sewage \quad P.S \end{bmatrix} \begin{bmatrix} 0.454 \\ 0.546 \end{bmatrix}$$

Using Criterium Decision Plus Software, as shown in Table (10.7), the priority vector is as follows

$$\begin{bmatrix} Al \quad Qudus \quad Street \\ J.S \quad Sewage \quad P.S \end{bmatrix} \begin{bmatrix} 0.421 \\ 0.579 \end{bmatrix}$$

Both approaches, the Analytical Hierarchy Process and the Linear Programming, suggest that the 'Construction of Jemezat Sabil Sewage Pumping Station' project will result in a higher mark-up when compared with the 'Rehabilitation and Reconstruction of Al-Qudus Street' option.

10.6 Conclusion:

This chapter demonstrates the application of the AHP bidding models by introducing a real life case study. The Criterium Decision Plus Software and Linear Programming approach were used to solve the pair-wise comparison matrices. Results from both the CDP and the LP gave the same recommendation for bid/no bid and mark-up decisions. Moreover, the two models were reasonable, robust to rely on and not sensitive to changes.

The two-stage linear programming approach developed by Chandran el (2005) was proven to be an effective method for solving the pair-wise comparison matrices, generated using the Analytical Hierarchy Process, when applied to a real life data and compared with the outcome from the Criterium Decision Plus Software.

Bid/no bid and mark-up models can be used easily and quickly by decision makers to assist in bidding decisions even if the person is not familiar with the mathematical basis behind the Analytical Hierarchy Process. Each model takes into account the important factors affecting both decisions and there is no need to change the structure of the hierarchy whenever any of them is used i.e. they can be used repeatedly.

The benefits of using the Analytical Hierarchy Models are:

- It enables the factors that affect bidding decisions to be identified and the importance of each factor to be established.
- The hierarchical structure and value tree provide visual simplification.
- The criteria and their weights can be easily changed and this will be directly reflected into the overall results i.e. this method is flexible.
- Sensitivity analysis and the contribution by criteria allow the decision maker to check the robustness and reasonableness of the results.
- The recommended solution can be easily explained.

CHAPTER ELEVEN

Multi-Criteria Contractor Selection Models

11.1 Introduction

Contractor selection is the process of choosing the most appropriate contractor to execute the project under consideration. It is a crucial part of the construction process as it affects the progress and success of any project. Awarding construction contracts based on the bid price as the main criteria could influence the contractor's pricing. Contractors may tend to use cheaper, lower quality materials, using insufficient materials, and taking serious health and safety risks on jobs to ensure greater profits. This is why the client has to take other criteria into account when evaluating the submitted bids and not to award the contract to the lowest price only.

To consider other criteria when evaluating the submitted tenders, multi-criteria decision analysis methods can be used. This chapter compares two methods of Contractor Selection: the points method and the Analytical Hierarchy Process (using the Criterium Plus Software), which is a multi-criteria decision making method. The two methods are applied to a real life case study for Contractor Selection. The points method was recommended in the tender documents of the case study to evaluate the submitted tenders.

11.2 Brief Literature Review on Contractor Selection:

Fong and Choi (2000) developed a contractor selection model using the Analytical Hierarchy Process. Data required for this study was collected by conducting a questionnaire survey among public organisations in Hong Kong. The eight main criteria which have been considered in this paper were: tender price, financial stability, past performance, past experience, resources, current workload, past client-contractor relationship and safety performance. The results revealed that tender price is the most important factor to contractor selection followed by the financial stability then the past performance, past experience, resources, current workload, past client/contractor relationship and finally the safety performance. The model was tested by a hypothetical scenario where three contractors were evaluated.

Hatush and Skitmore (1998) presented the Utility Theory as a multi-criteria technique for contractor selection. Twenty four factors were taken into account and were categorised into six groups: the bid amount, the financial soundness, the technical ability, the management capability, the health and safety records and reputation. A hypothetical case study where five contractors are bidding for a multi-story building project was illustrated in this paper. Interviews with four leading professionals involved in contractor selection were conducted to assign utility values to different criterion in order to build the utility functions. The results showed that the bidder with the lowest price was ranked third which indicates that the other factors need to be considered when making the contractor evaluation.

Banaitiene and Banaitis (2006) analysed the issues related to the evaluation of contractors' qualification in Lithuanian companies. The required data was obtained through a questionnaire survey. Four contractor evaluation criteria were considered in this study: the bid price, legal requirements, financial criteria and technical and management criteria. The participants in the questionnaire were asked to evaluate how important each criteria for the contractor selection. The results indicated that the bid price is the most important criterion in the selection of contractor in Lithuanian and clients are selecting contractors on the basis of the tender price only.

Yawei, et al. (2005) employed an approach called the Multiple-layer Fuzzy Pattern Recognition (MFPR) to contractor selection problem. The pair-wise comparison method was used to decide relative membership degrees of qualitative criteria as well as weights of the criteria set. The feasibility of this approach was illustrated by including a case study for a channel construction project. The outcome from this paper revealed that the MFPR may assist in contractor selection decision-making process, as it can deal with different opinions in order to reach a decision.

11.3 The Case Study Background:

The proposed N8 Cashel/Mitchelstown Road Improvement Scheme in the Republic of Ireland comprises a new section of dual carriageway approximately 37Km in length. The route commences at the proposed Carrigane Junction on the existing N8 in Country Cork. After 1.5Km it crosses the Cork/Limerick boundary and continues through Limerick for 3Km. It crosses to the north side of the existing N8 at Brackbaun, close to the Limerick/Tipperary country boundary and runs on this side of the existing route for approximately 4.5 Km until it crosses to the south of the existing N8 at Glengarra. The route then continues approximately nine Km to the proposed Tincurry Junction, where again it crosses to the north of the existing N8. The route then continues north of Cahir approximately eight Km to the proposed Cloghbreedy Junction. There are no further crossings of the existing road until it connects to the Cashel Bypass some 12Km north of Cloghabreedy at Owen's and Bigg's Lot. (A copy of the letter attached to the Tender Document is presented in Appendix C)

11.4 Tender Evaluation and Submission

- Tenders were assessed on the basis of quality and price and must remain valid for 90 days. The tender must be submitted in two parts, comprising a ' Quality Submission' which should be contained in Envelope A and a ' Financial Submission' which should be contained in Envelope B. The envelopes are to be clearly marked 'A' or 'B' and the name(s) of the Tenderer(s) is to be clearly marked on the outside of each.
- Both envelopes should then be sealed in an outer envelope clearly marked ' Tender for N8 Cashel/ Mitchelstown Road Improvement'.

- Tenderers should ensure that no names, addresses, post stamps or markings indicating the identity of the Tenderer and to be marked on or affixed to the outer envelope.
- Tenders should be sent by registered post, recorded delivery (or the nearest equivalent postal service from another member state of the European Union), by courier or hand delivery in a plain sealed envelope. The outer envelope must be clearly marked as follows:

Tender for N8 Cashel/Mitchelstown Road Improvement

South Tipperary Country Council, Country Hall, Emmet Street, Clonmel, Co Tipperary to arrive not later than 4.00pm on 25th June 2004.

11.4.1 Envelope A (Quality Submission)

Envelope A shall contain statements in response to the questions contained in appendix (A). The questions have been separated into General Scheme Management, Design Phase and Construction Phase, under the headings listed below.

General Scheme Management

1. Overall Approach, Methodology and Programme
2. Innovation and Continuous Improvement Strategy
3. Public Relations
4. Risk
5. Target Cost and Activity Schedules
6. Open Book Accounting
7. Quality and Key Performance Indicators
8. Staff for the Project
9. Approach to Partnering

Design Phase

10. Estimate of Time Based Hours for Works in Design Phase
11. Environmental Impact Statement
12. Environmental Data Requirements
13. Design Development

14. Compulsory Purchase Orders
15. Oral Hearing

Construction Phase

16. Construction Issues
17. Safety and Health
18. Construction Environmental Management
19. Handover and Maintenance

Envelope A shall also contain the following:

1. Written undertakings stating the Tenderer's willingness, if awarded the contract, to accept the appointments and duties of Project Supervisor for Design Stage and Project Supervisor for Construction Stage (to include the nomination for Project Supervisor).
2. Summary of relevant insurance policies including certificates where appropriate.
3. Statement undertaking responsibilities for dealing with insurance claims or parts of such claims within the excess amount.
4. A list of the constituents of the Fee percentage (without any financial information) in the form given in Table (C1) of Appendix (C).
5. The completed Contractor's Risk Register.
6. The completed staff schedules for Design Phase, Table (C2) of Appendix (C) with hours (but not rates).

11.4.2 Envelope B (Financial Submission)

Envelope B shall contain the following:

1. The completed Letter of Tender incorporating the anti-collusion certificate and Form of undertaking (Performance Bond) and (if a joint venture) a copy of the joint venture agreement and a statement that the parties to the JV will be jointly and severally bound for performance for the contract.
2. the completed Contract Data Part 2
3. The completed Staff Rate Forms presented in Table (C3), Appendix (C).

11.4.3 Marking of the Tenders, Quality and Financial Panels

Each tender submission will be assessed by two separate panels: a Quality panel and a Financial Panel.

- *Quality Panel:*

The Quality Panel will meet prior to the Financial Panel to assess quality scores and will award marks, based on the tender criteria shown in Table (11.1), against the quality aspects stated in sub-section 11.4.1.

Table (11.1): Standard Marks for Quality Questions

	Criteria	Marks
A	Very high standard with no reservations at all about acceptability	10
B	High standard but falls just short of A	8-9
C	Good standard and requirements met but some reservations	5-7
D	Acceptance with significant reservations but not sufficient to warrant rejection	1-4
E	Fails to meet requirements	0

All Tenderers will be interviewed at their office by the Quality Panel to enable the panel to clarify any matters in connection with the Tenderer's quality submission. New information shall not be introduced by the Tenderer at the interview. Key members of staff proposed for the contract shall attend. The date, time and precise place of the interview and the numbers attending shall be agreed between the Tenderer and the project Manager at least 14 days in advance of the interview date. The interview will include inspection of documents relating to other ongoing projects to validate the quality and approach to the Tenderer.

- *Financial Panel:*

The Financial Panel will appraise the financial element of the tender independently of the Quality Panel and after the Quality Panel has completed the assessment outlined above. The financial score will be carried forward to the final tender assessment.

11.4.4 Quality Scorings:

The Quality Panel will award marks against the tender score criteria, Table (11.1). The quality threshold below which tenders will be returned to the Tenderer with Envelope B, Financial Submission, unopened is 50 marks out of the 100 available or a zero mark against any one quality section.

Weightings appropriate to the importance of each aspect will be applied to the marks awarded for each question in the quality submission.

After weighting, the highest scored tender will be allocated 100 marks. Other tenders will be allocated marks on the basis of two marks reduction for each mark lower than the highest marked tender.

The quality score for each tender will be carried forward to the final tender assessment.

11.4.5 Financial Scorings:

The financial scoring will be split into three areas for assessment:

a) Hourly Rate by staff grade for Design Phase

   The hourly rates by staff grade in the Design Phase, Table (C3) in Appendix (C), shall be completed in accordance with the instructions given and only included in the Financial Submission, Envelope B.

   These rates will be inserted into a model prepared by the Employer containing his estimate of the number of hours required for the key members of staff and other supporting staff, to produce an estimate of the design fees payable in the Design Phase.

   The Design Phase fees will be compared by allocating the lowest fee (of those achieving the minimum quality standard) 100 marks, and then allocating other design fee marks on the basis of a reduction of one mark for each percentage point increase in fees.

The hourly rates by staff grade in the Design Phase will make 20% of the overall financial assessment.

b) The Fee % for the construction Phase entered in Contract Data.

The fee % will be compared by multiplying the scheme cost estimate by each Tenderer's fee % to calculate a notional value of the fee purely for tender assessment purposes. The upper and lower fees in the range of submissions will be disregarded and average of the remaining three will be calculated. Marks will be calculated by allocating the average fee (of those achieving the minimum quality standard) 50 marks and then allocating other tendered fees on the basis of a reduction or addition of one mark for each percentage increase or decrease in fee. The lowest fee will result in the highest mark.

The constituents of the fee % entered in Table (C1) of Appendix (C) shall only form part of the quality assessment and must not be included in the Financial Submission.

The fee percentage will make up 40% of the overall financial assessment.

c) Schedule of Rates

The schedule of rates for work shall be completed in accordance with the instructions given and only included in the Financial Submission, Envelope B.

These rates will be inserted into a model prepared by the Employer containing his estimate of the principal quantities to produce an estimate of the cost of the works.

The cost of the works will be compared by allocating the lowest cost (of those achieving the minimum quality standard) 100 marks and then allocating other costs on the basis of a reduction of one mark for each percentage point increase in cost.
The schedule of rates will make up 40% of the overall financial assessment.

11.4.6 Final Tender Assessment:

The contract will be awarded to the Tenderer submitting the most economically advantageous tender in accordance with the award criteria. The individual award criteria which will be taken into account in making this assessment are: quality, which will account for 70% of the overall score and price which will account for 30% of the overall score.

Following the calculation of the weighted overall marks, the highest overall score will be compared with any other scores that lie within 5% of this score. The tender with the best financial score of those within this range will be considered for award of this contract.

11.5 Contractor Selection Using the Points Method:

Five Contractors submitted the Quality and Financial assessments. Tables (11.2, 11.3, 11.4, 11.5 and 11.6) present the quality tender assessment for tenderer A, B, C, D and E respectively.

Table (11.2): Quality Tender Assessment for Tenderer A

	Weighting	Marks Awarded	Weighted Marks
General Scheme Management			
1. Overall Approach, Methodology and Programme	7	7	49
2. Innovation and Continuous Improvement Strategy	6	6	36
3. Public Relations	5	7	35
4. Risk	6	7	42
5. Target Cost and Activity Schedules	7	6	42
6. Open Book Accounting	6	5	30
7. Quality and Key Performance Indicators	6	7	42
8. Staff for the Project	6	6	36
9. Approach to Partnering	6	6	36
Design Phase			
10. Estimate of Time Base Hours for Work in Design Phase	4	7	28
11. Environmental Impact Statement	6	7	42
12. Environmental Data Requirements	4	8	32
13. Design Development	5	9	45
14. Compulsory Purchase Orders	4	6	24

15. Oral Hearing	4	6	24
Construction Phase			
16. Construction Issues	4	5	20
17. Safety and Health	5	5	25
18. Construction Environmental Management	5	5	25
19. Handover and Maintenance	4	6	24
Totals	**100**		**637**
Weighted Mark/10 (Maximum = 100)			**63.7**
Final Quality Mark	**100**		**84.0**

Table (11.3): Quality Tender Assessment for Tenderer B

	Weighting	Marks Awarded	Weighted Marks
General Scheme Management			
1. Overall Approach, Methodology and Programme	7	7	49
2. Innovation and Continuous Improvement Strategy	6	6	36
3. Public Relations	5	7	35
4. Risk	6	7	42
5. Target Cost and Activity Schedules	7	7	49
6. Open Book Accounting	6	6	36
7. Quality and Key Performance Indicators	6	7	42
8. Staff for the Project	6	8	48
9. Approach to Partnering	6	7	42
Design Phase			
10. Estimate of Time Base Hours for Work in Design Phase	4	9	36
11. Environmental Impact Statement	6	6	36
12. Environmental Data Requirements	4	6	24
13. Design Development	5	7	35
14. Compulsory Purchase Orders	4	8	32
15. Oral Hearing	4	8	32
Construction Phase			
16. Construction Issues	4	7	28
17. Safety and Health	5	7	35
18. Construction Environmental Management	5	7	35
19. Handover and Maintenance	4	8	32
Totals	**100**		**704**
Weighted Mark/10 (Maximum = 100)			**70.4**
Final Quality Mark	**100**		**97.4**

Table (11.4): Quality Tender Assessment for Tenderer C

	Weighting	Marks Awarded	Weighted Marks
General Scheme Management			
1. Overall Approach, Methodology and Programme	7	6	42
2. Innovation and Continuous Improvement Strategy	6	8	48
3. Public Relations	5	7	35
4. Risk	6	9	54
5. Target Cost and Activity Schedules	7	6	42
6. Open Book Accounting	6	7	42
7. Quality and Key Performance Indicators	6	6	36
8. Staff for the Project	6	7	42
9. Approach to Partnering	6	5	30
Design Phase			
10. Estimate of Time Base Hours for Work in Design Phase	4	6	24
11. Environmental Impact Statement	6	7	42
12. Environmental Data Requirements	4	8	32
13. Design Development	5	8	40
14. Compulsory Purchase Orders	4	8	32
15. Oral Hearing	4	7	28
Construction Phase			
16. Construction Issues	4	6	24
17. Safety and Health	5	7	35
18. Construction Environmental Management	5	6	30
19. Handover and Maintenance	4	6	24
Totals	**100**		**682**
Weighted Mark/10 (Maximum = 100)			**68.2**
Final Quality Mark	**100**		**93.0**

Table (11.5): Quality Tender Assessment for Tenderer D

	Weighting	Marks Awarded	Weighted Marks
General Scheme Management			
1. Overall Approach, Methodology and Programme	7	8	56
2. Innovation and Continuous Improvement Strategy	6	7	42

3. Public Relations	5	9	45
4. Risk	6	6	36
5. Target Cost and Activity Schedules	7	7	49
6. Open Book Accounting	6	8	48
7. Quality and Key Performance Indicators	6	6	36
8. Staff for the Project	6	7	42
9. Approach to Partnering	6	8	48
Design Phase			
10. Estimate of Time Base Hours for Work in Design Phase	4	6	24
11. Environmental Impact Statement	6	7	42
12. Environmental Data Requirements	4	8	32
13. Design Development	5	7	35
14. Compulsory Purchase Orders	4	8	32
15. Oral Hearing	4	6	24
Construction Phase			
16. Construction Issues	4	7	28
17. Safety and Health	5	8	40
18. Construction Environmental Management	5	6	30
19. Handover and Maintenance	4	7	28
Totals	**100**		**717**
Weighted Mark/10 (Maximum = 100)			**71.7**
Final Quality Mark	**100**		**100**

Table (11.6): Quality Tender Assessment for Tenderer E

	Weighting	Marks Awarded	Weighted Marks
General Scheme Management			
1. Overall Approach, Methodology and Programme	7	7	49
2. Innovation and Continuous Improvement Strategy	6	6	36
3. Public Relations	5	6	30
4. Risk	6	7	42
5. Target Cost and Activity Schedules	7	8	56
6. Open Book Accounting	6	6	36
7. Quality and Key Performance Indicators	6	8	48
8. Staff for the Project	6	7	42
9. Approach to Partnering	6	7	42
Design Phase			
10. Estimate of Time Base Hours for	4	6	24

Work in Design Phase			
11. Environmental Impact Statement	6	7	42
12. Environmental Data Requirements	4	6	24
13. Design Development	5	8	40
14. Compulsory Purchase Orders	4	6	24
15. Oral Hearing	4	9	36
Construction Phase			
16. Construction Issues	4	7	28
17. Safety and Health	5	8	40
18. Construction Environmental Management	5	6	30
19. Handover and Maintenance	4	6	24
Totals	**100**		**693**
Weighted Mark/10 (Maximum = 100)			**69.3**
Final Quality Mark	**100**		**95.2**

The Quality assessment is followed by the Financial Assessment for the five Contractors as shown in Table (11.7)

Table (11.7): Financial Assessment (Envelope B)

Tenderer	Design Phase		Construction Phase			Schedule of Rates		Overall Financial Mark 20% x (b) + 40% x (e) + 40% x (g)	Ranking
	(a)	(b)	(c)	(d)	(e)	(f)	(g)		
	Fee (€ Million)	Mark: Design Fee	% fee from Contract Data	Fee based on current Budget Cost (€ million)	Mark: Fee	National Cost (€ Million)	Mark SoR		
A	4.543	79.6	11.0	24.2	50	150.633	90.7	72.2	3
B	5.219	61.6	10.0	22	59.1	137.789	100	76.0	2
C	4.122	90.7	8.5	18.7	72.7	171.227	75.7	77.5	1
D	4.016	93.5	12.0	26.4	40.9	177.364	71.3	63.6	4
E	3.772	100	14.0	30.8	22.7	195.644	58	52.3	5

The Quality and Financial Assessment is then combined together as shown in Table (11.8).

Table (11.8): The Overall Assessment

Tenderer	(a)	(b)	Overall Mark 70% x (a) 30% x (b)	Ranking
	Quality Mark From Table	Financial Mark from Table		
A	84.0	72.2	80.5	5
B	97.4	76.0	91.0	1
C	93.0	77.5	88.4	3
D	100.0	63.3	89.1	2
E	95.2	52.3	82.3	4

Results from Table (11.8) show that Tenderer B has the highest overall mark. Taking note of all tenderers within 5% of the overall assessment for tenderer B gives a range to consider down to 91.0 x 0.95 = 86.5. Tenderers C and D lie within that range. Tenderer C has a higher financial mark than Tenderer B; Tenderer D has a lower financial mark than Tenderer B. Therefore, Tenderer C would therefore be considered for award of contract.

11.6 Contractor Selection Using the Analytical Hierarchy Process

This section shows how the Criterium Decision Plus can be employed to assist in the Contractor Selection decision. The data from the N8 Cashel/Mitchelstown Road Improvement Scheme is used as inputs for the CDP software. The following sub-sections present the analysis carried out using the CDP.

11.6.1 Quality Assessment:

For the analysis, the Quality Assessment is divided into three main groups: the General Scheme Management, the Design Phase and the Construction Phase.

11.6.1.1 General Scheme Management:

The brainstorming session for the General Scheme Management is shown in Figure (11.1).

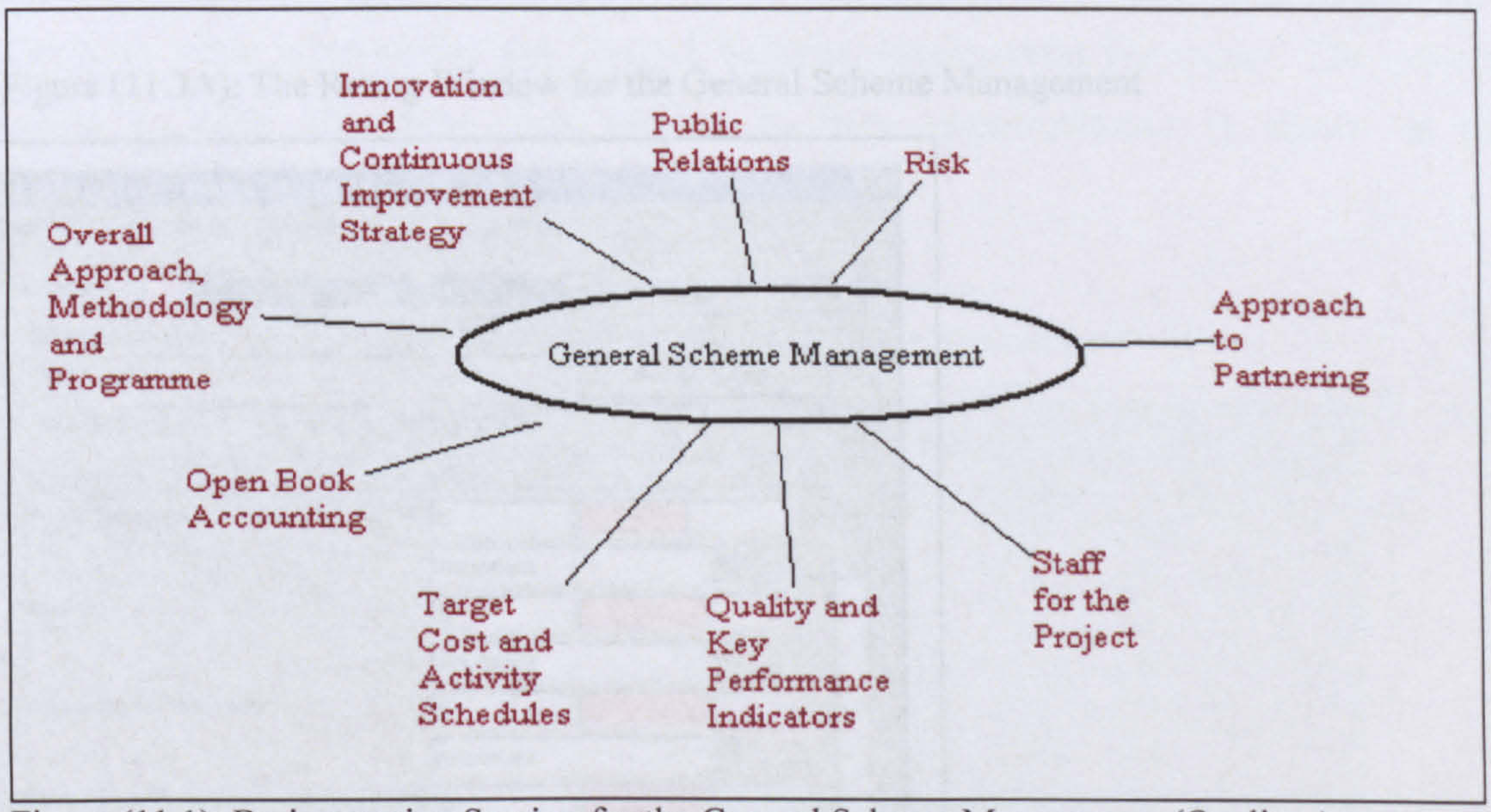


Figure (11.1): Brainstorming Session for the General Scheme Management (Quality Assessment)

The brainstorming session is followed by the generation of the General Scheme Management hierarchy. The hierarchy is built automatically based on the brainstorming session as shown in Figure (11.2).

The weights listed in Table (11.2,11.3,11.4,11.5) and (11.6) were used as inputs in the rating window shown in Table (11.3A) and (11.3B). The Criterium Decision Plus utilizes Satty's eigenvector method (EM) to determine the local weights.

Figure (11.2): The General Scheme Management Hierarchy

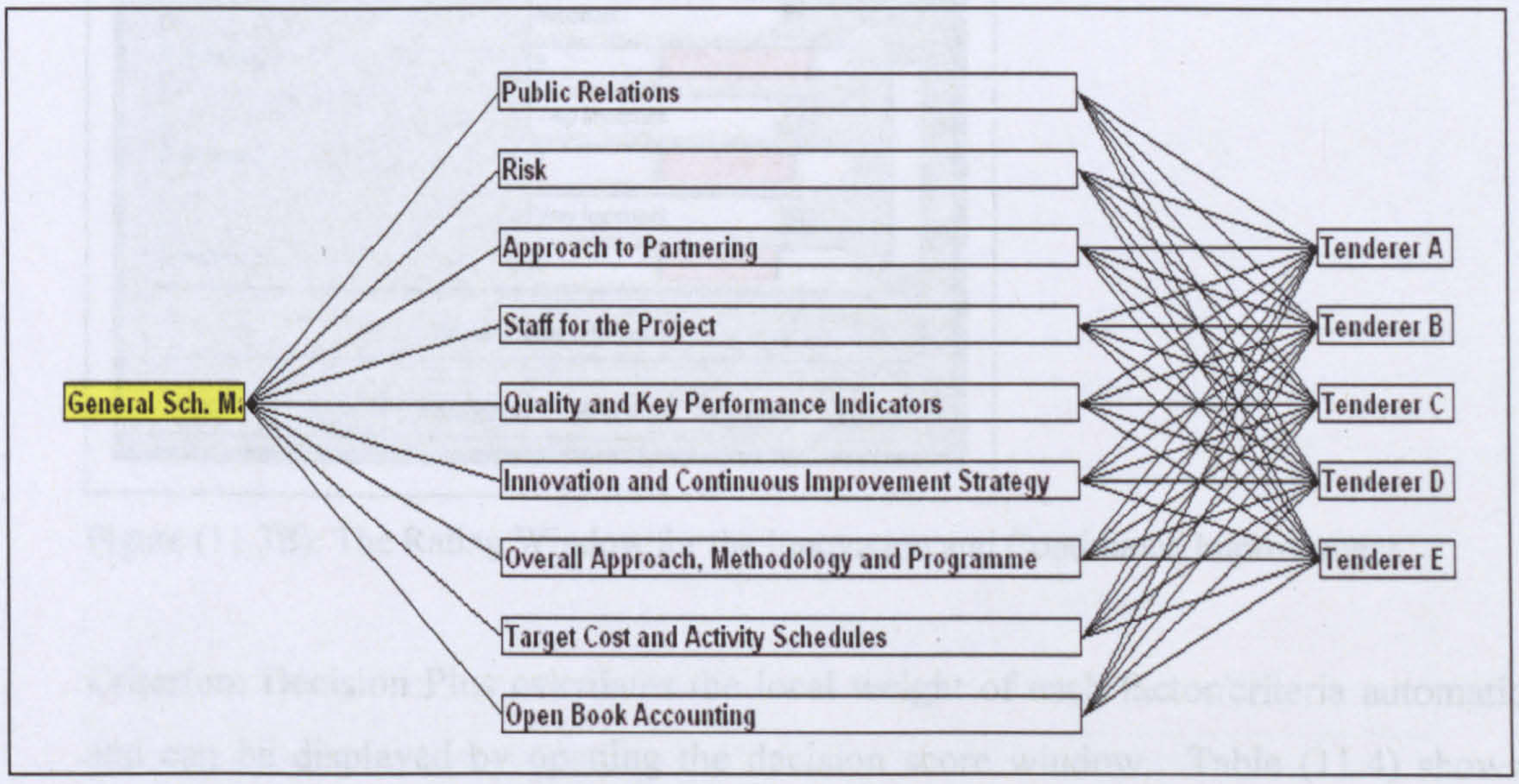
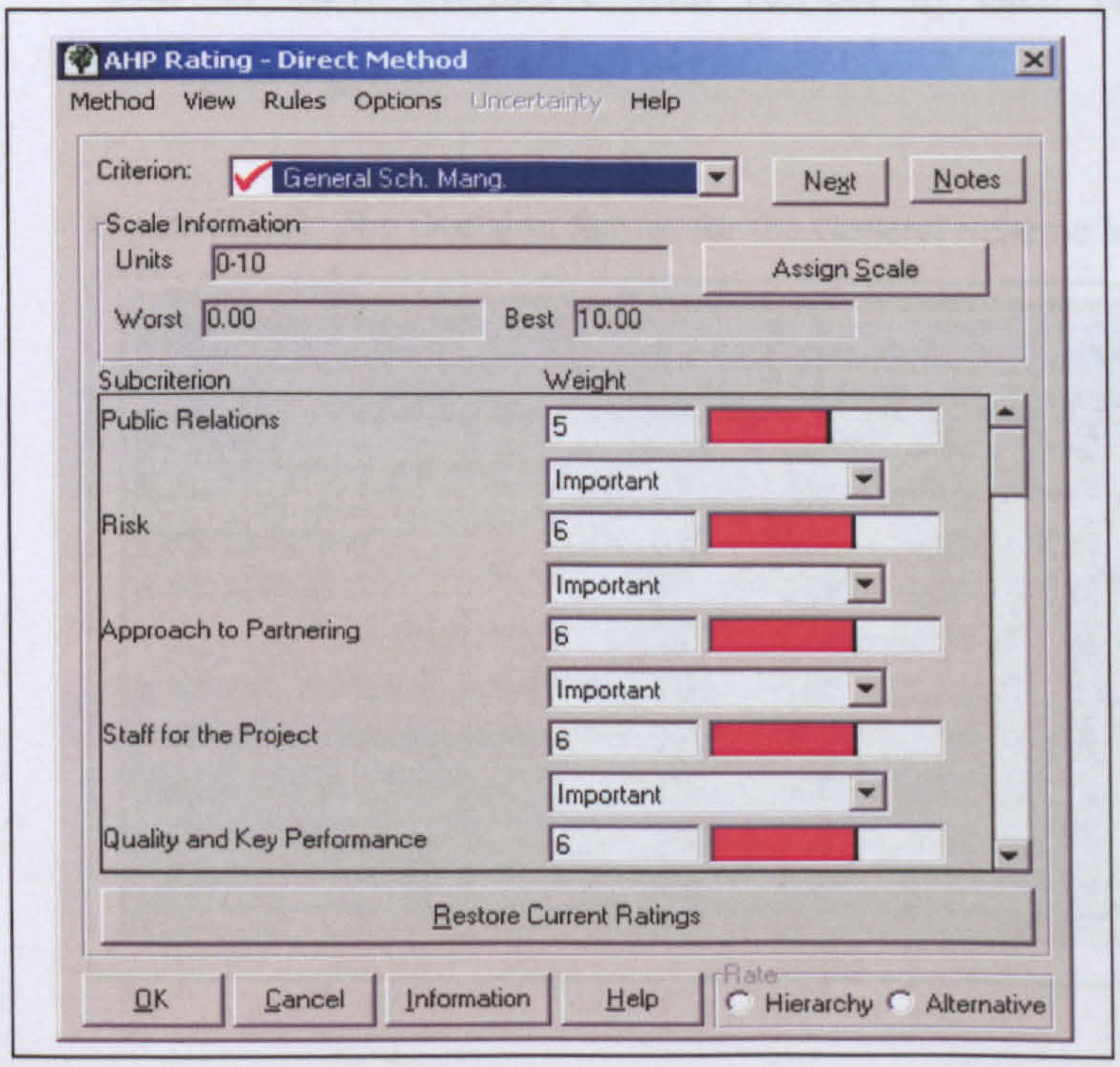


Figure (11.3A): The Rating Window for the General Scheme Management



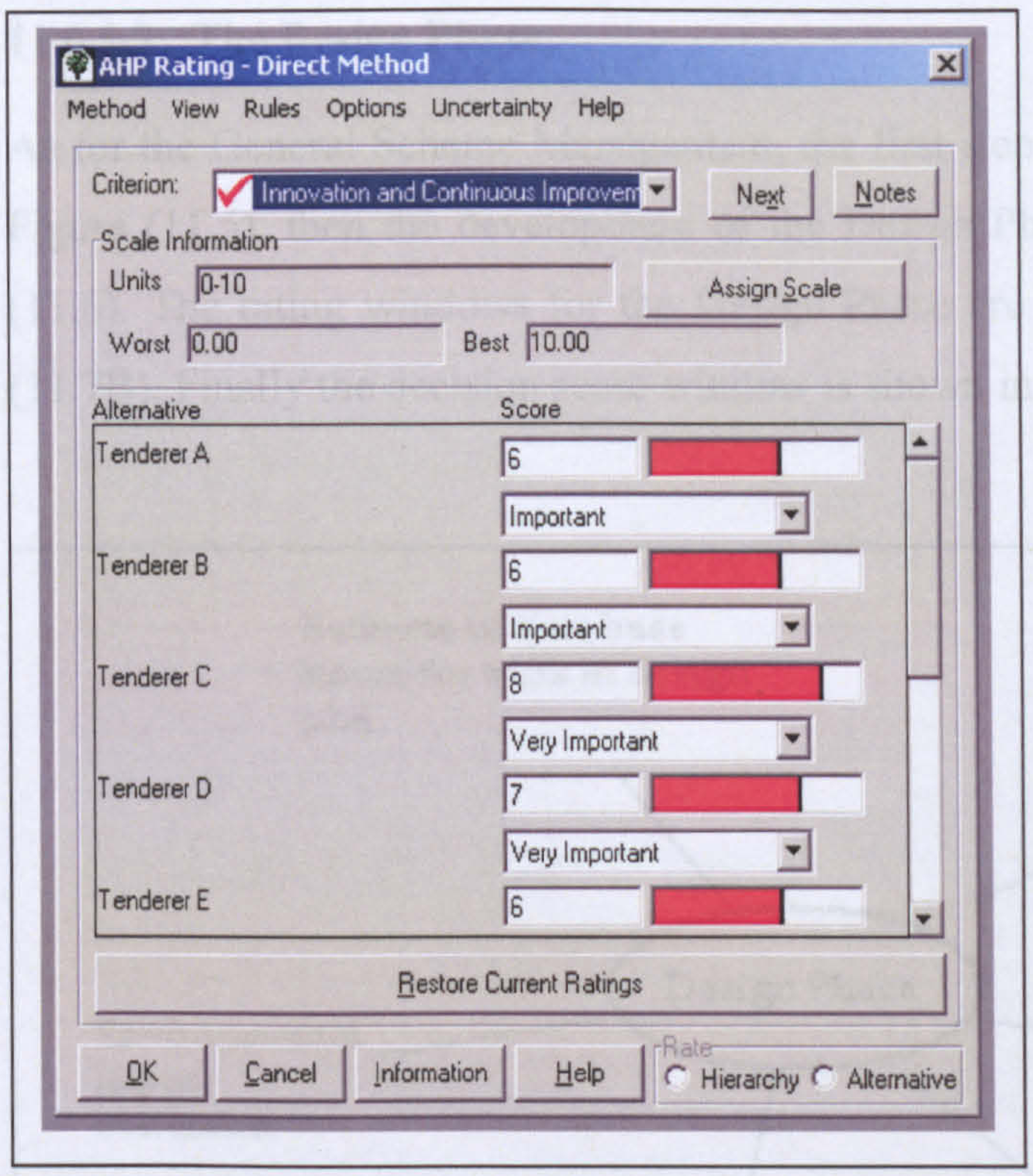


Figure (11.3B): The Rating Window for the Innovation and Continuous Improvement

Criterium Decision Plus calculates the local weight of each factor/criteria automatically and can be displayed by opening the decision score window. Table (11.4) shows the decision score window for the General Scheme Management Hierarchy. The priority value of each alternative with respect to each criterion/factor is shown in the corresponding cell.

Figure (11.4): The Decision Scores for the General Scheme Management

AHP Decision Scores

Lowest Level	Tenderer A	Tenderer B	Tenderer C	Tenderer D	Tenderer E	Model
Public Relations	0.194	0.194	0.194	0.250	0.167	0.091
Risk	0.194	0.194	0.250	0.167	0.194	0.109
Approach to Partnering	0.182	0.212	0.152	0.242	0.212	0.109
Staff for the Project	0.171	0.229	0.200	0.200	0.200	0.109
Quality and Key Performance Indicators	0.206	0.206	0.176	0.176	0.235	0.109
Innovation and Continuous Improvement Strategy	0.182	0.182	0.242	0.212	0.182	0.109
Overall Approach, Methodology and Programme	0.200	0.200	0.171	0.229	0.200	0.127
Target Cost and Activity Schedules	0.176	0.206	0.176	0.206	0.235	0.127
Open Book Accounting	0.156	0.188	0.219	0.250	0.188	0.109
Results	0.185	0.201	0.197	0.214	0.203	

11.6.1.2 The Design Phase:

As for the General Scheme Management, the first step is the brainstorming session as in Figure (11.5), then the development of the Design Phase hierarchy as shown in Figure (11.6). The rating windows for the Design Phase are presented in Figures (11.7A) and (11.7B). Finally the decision score window is shown in Figure (11.8).

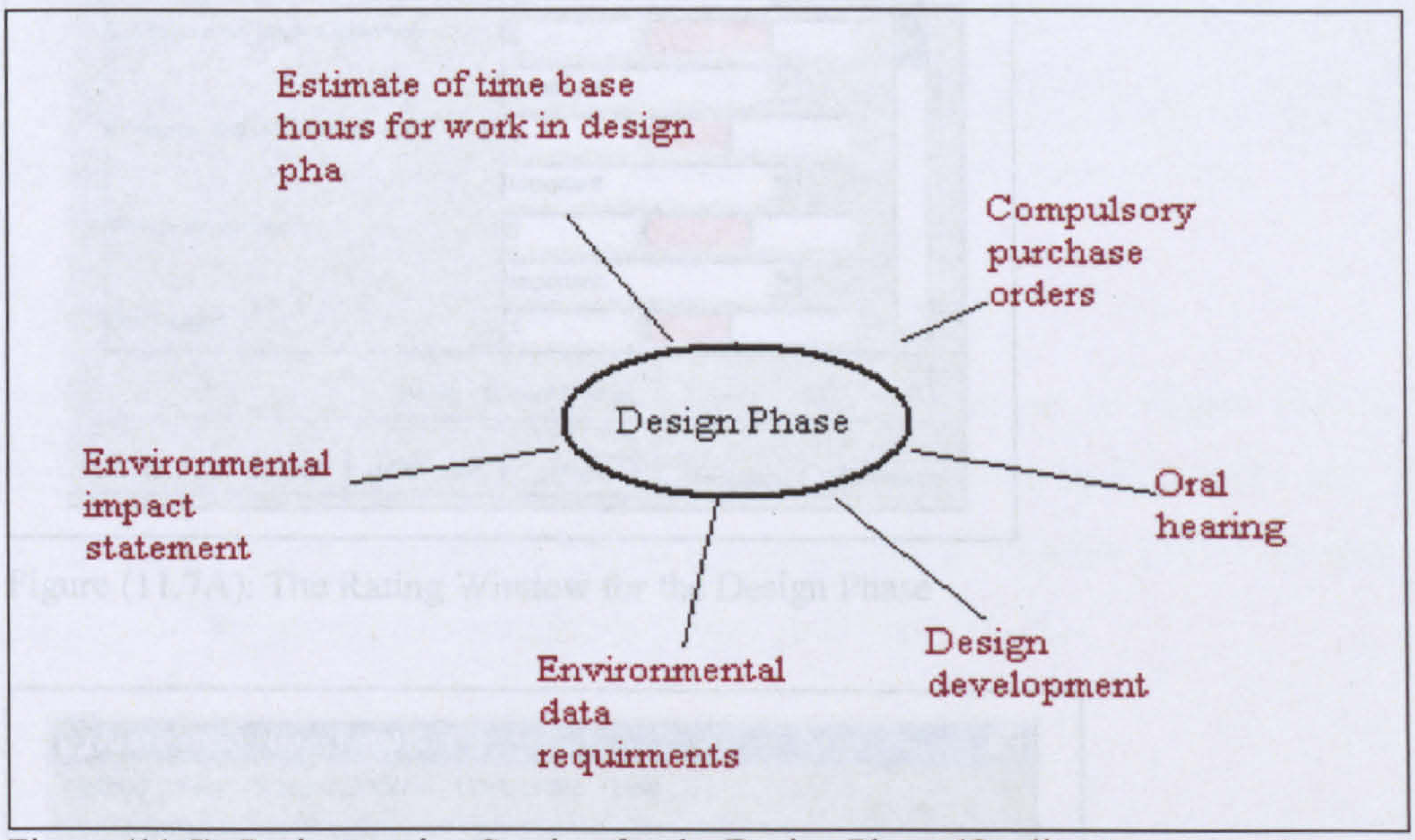


Figure (11.5): Brainstorming Session for the Design Phase (Quality Assessment)

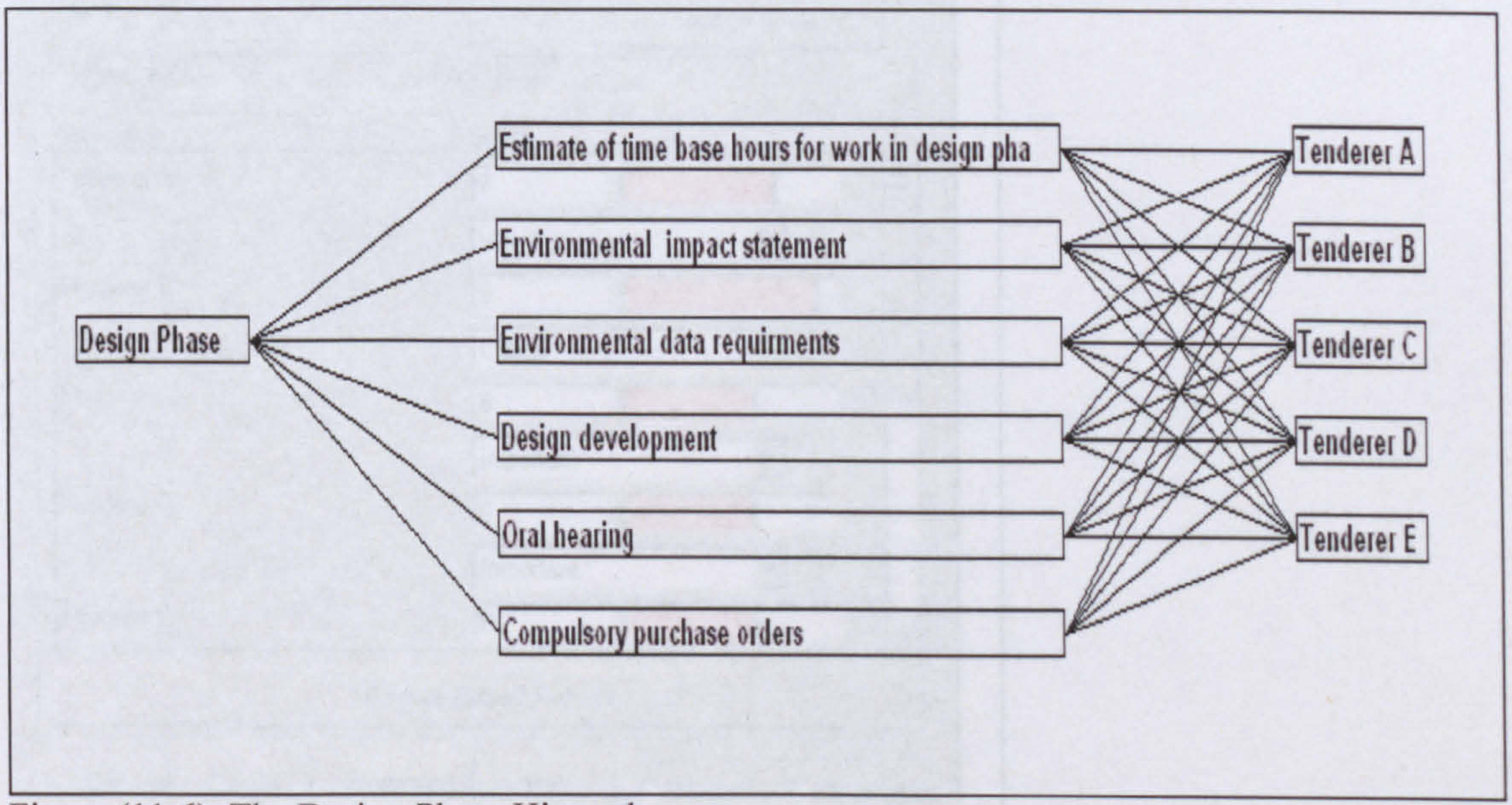


Figure (11.6): The Design Phase Hierarchy

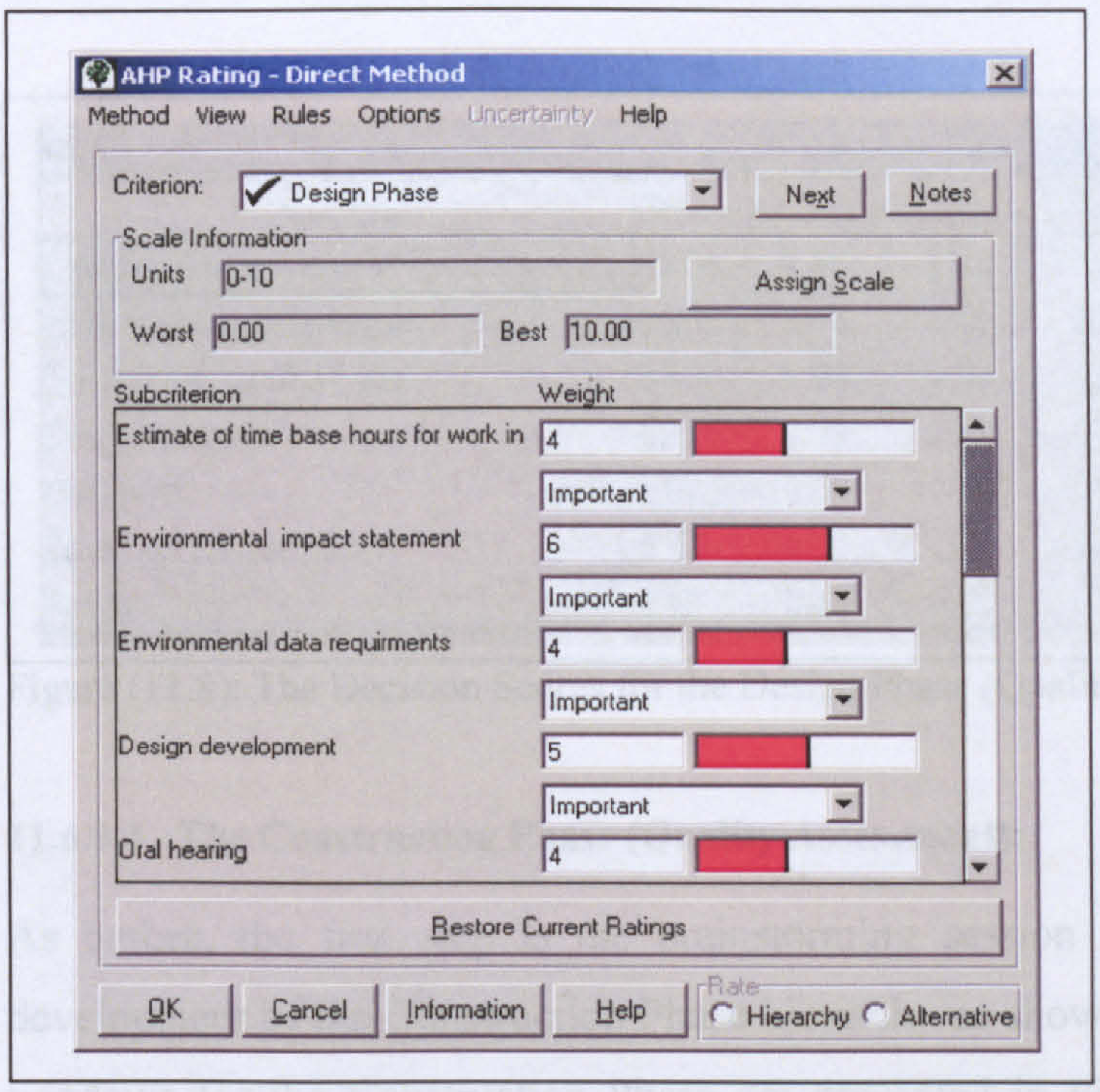


Figure (11.7A): The Rating Window for the Design Phase

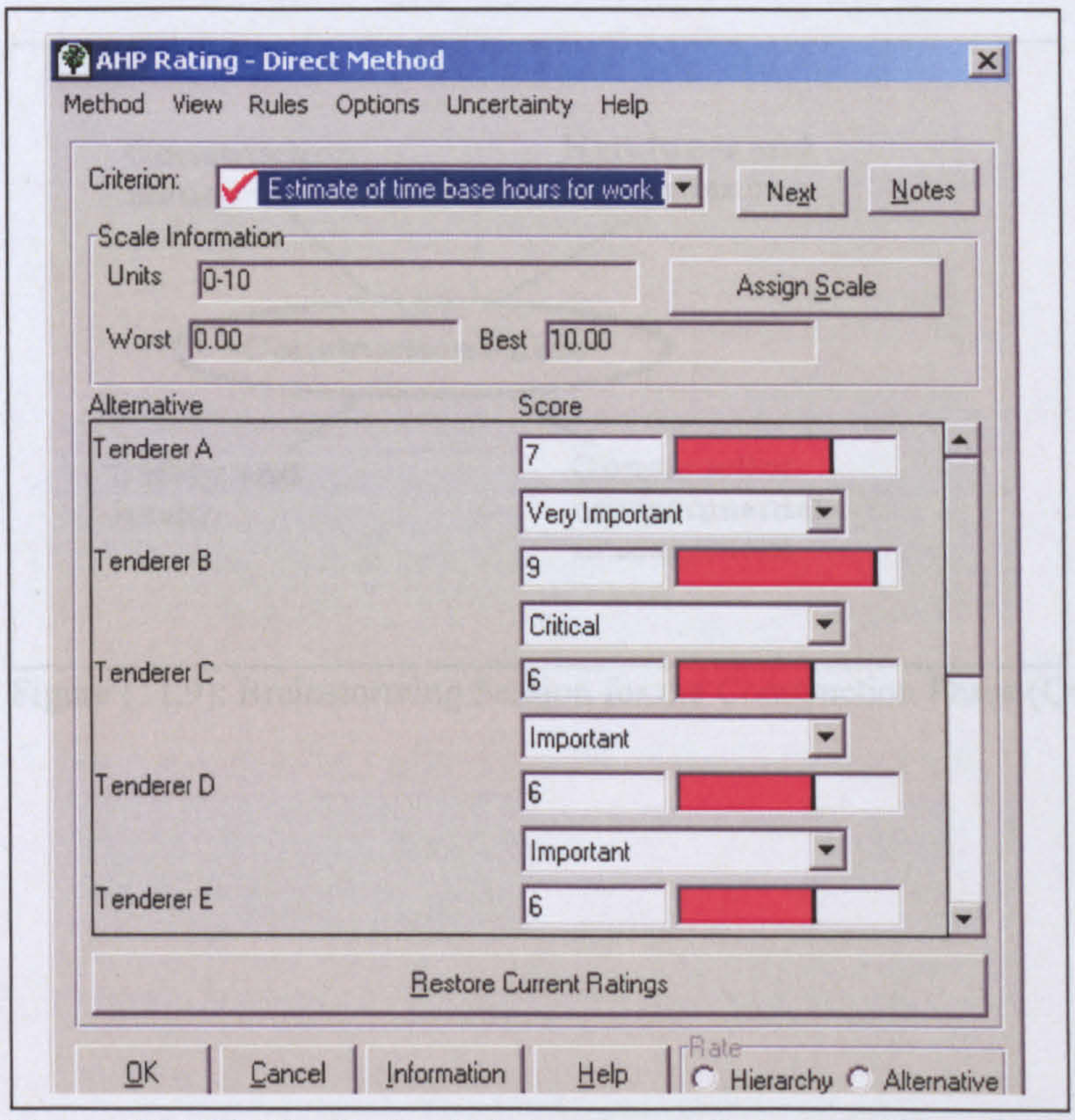
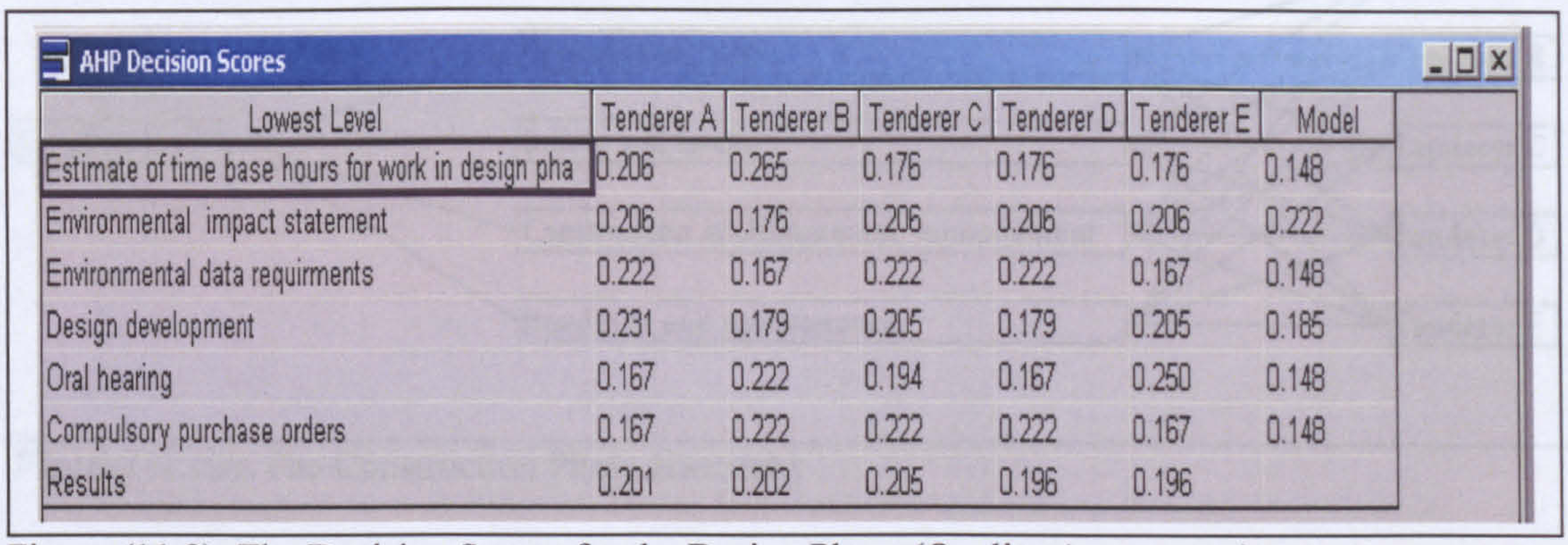


Figure (11.7B): The Rating Window for the Estimate of Time Base Hours for Work



AHP Decision Scores

Lowest Level	Tenderer A	Tenderer B	Tenderer C	Tenderer D	Tenderer E	Model
Estimate of time base hours for work in design pha	0.206	0.265	0.176	0.176	0.176	0.148
Environmental impact statement	0.206	0.176	0.206	0.206	0.206	0.222
Environmental data requirments	0.222	0.167	0.222	0.222	0.167	0.148
Design development	0.231	0.179	0.205	0.179	0.205	0.185
Oral hearing	0.167	0.222	0.194	0.167	0.250	0.148
Compulsory purchase orders	0.167	0.222	0.222	0.222	0.167	0.148
Results	0.201	0.202	0.205	0.196	0.196	

Figure (11.8): The Decision Scores for the Design Phase (Quality Assessment)

11.6.1.3 The Construction Phase (Quality Assessment):

As before, the first step is the brainstorming session as in Figure (11.9), then the development of the Construction Phase hierarchy as shown in Figure (11.10). The rating windows for the Construction Phase are presented in Figures (11.11A) and (11.11B). Finally the decision score window is shown in Figure (11.12).

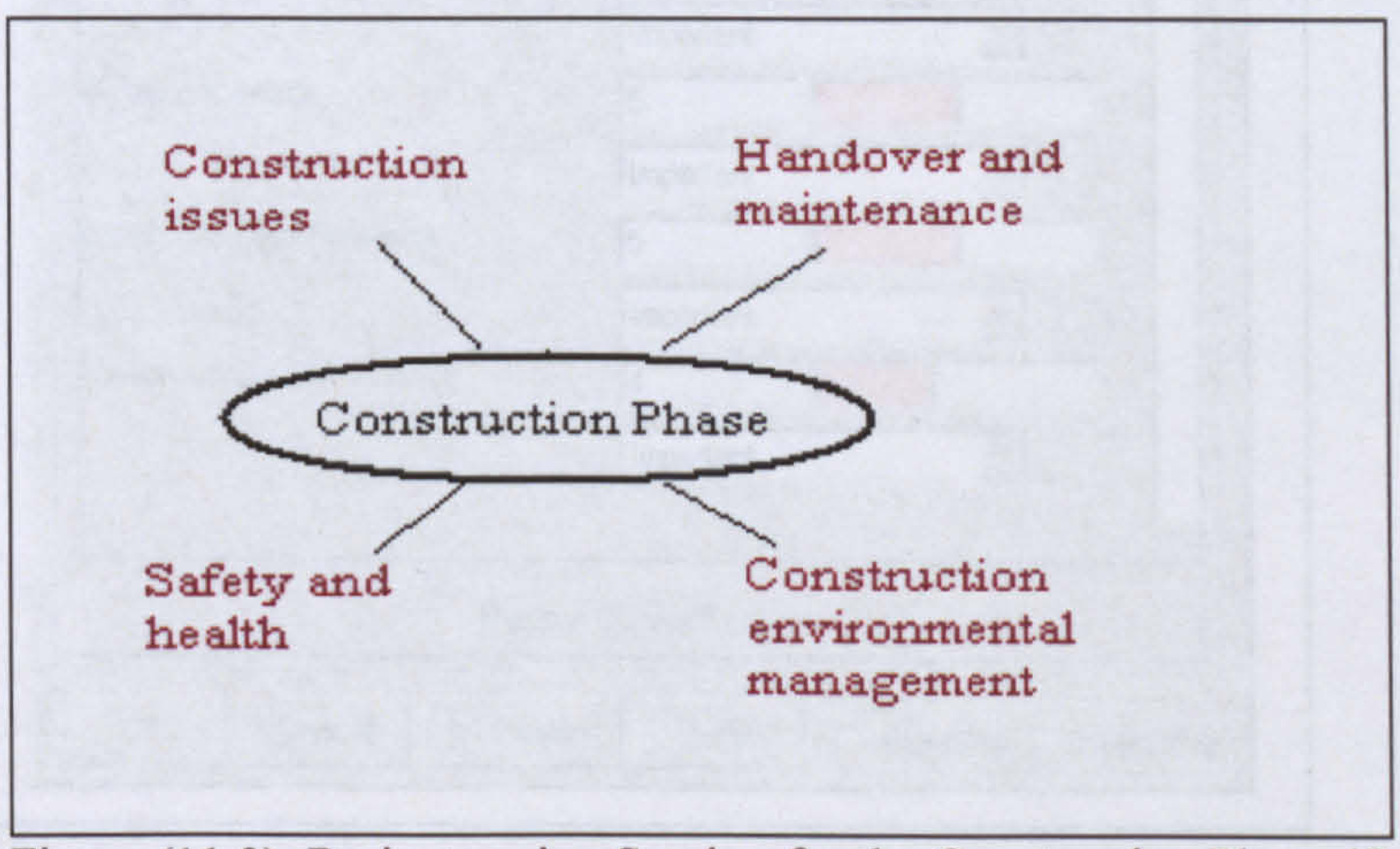


Figure (11.9): Brainstorming Session for the Construction Phase (Quality Assessment)

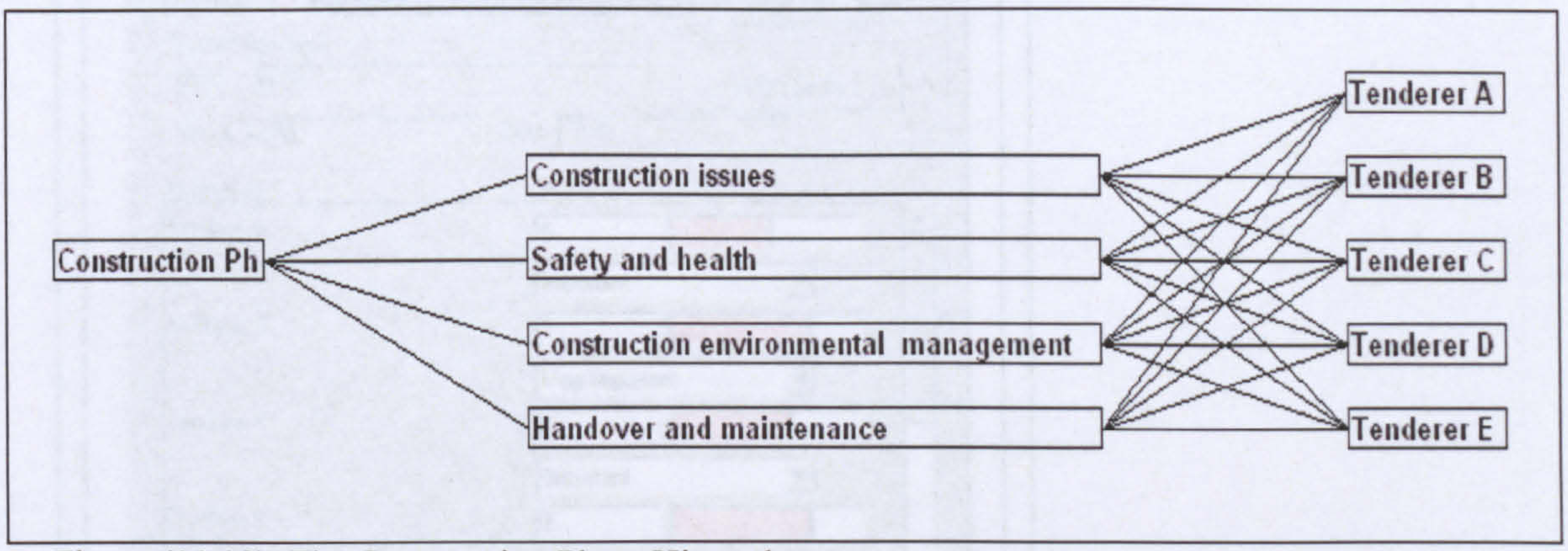


Figure (11.10): The Construction Phase Hierarchy

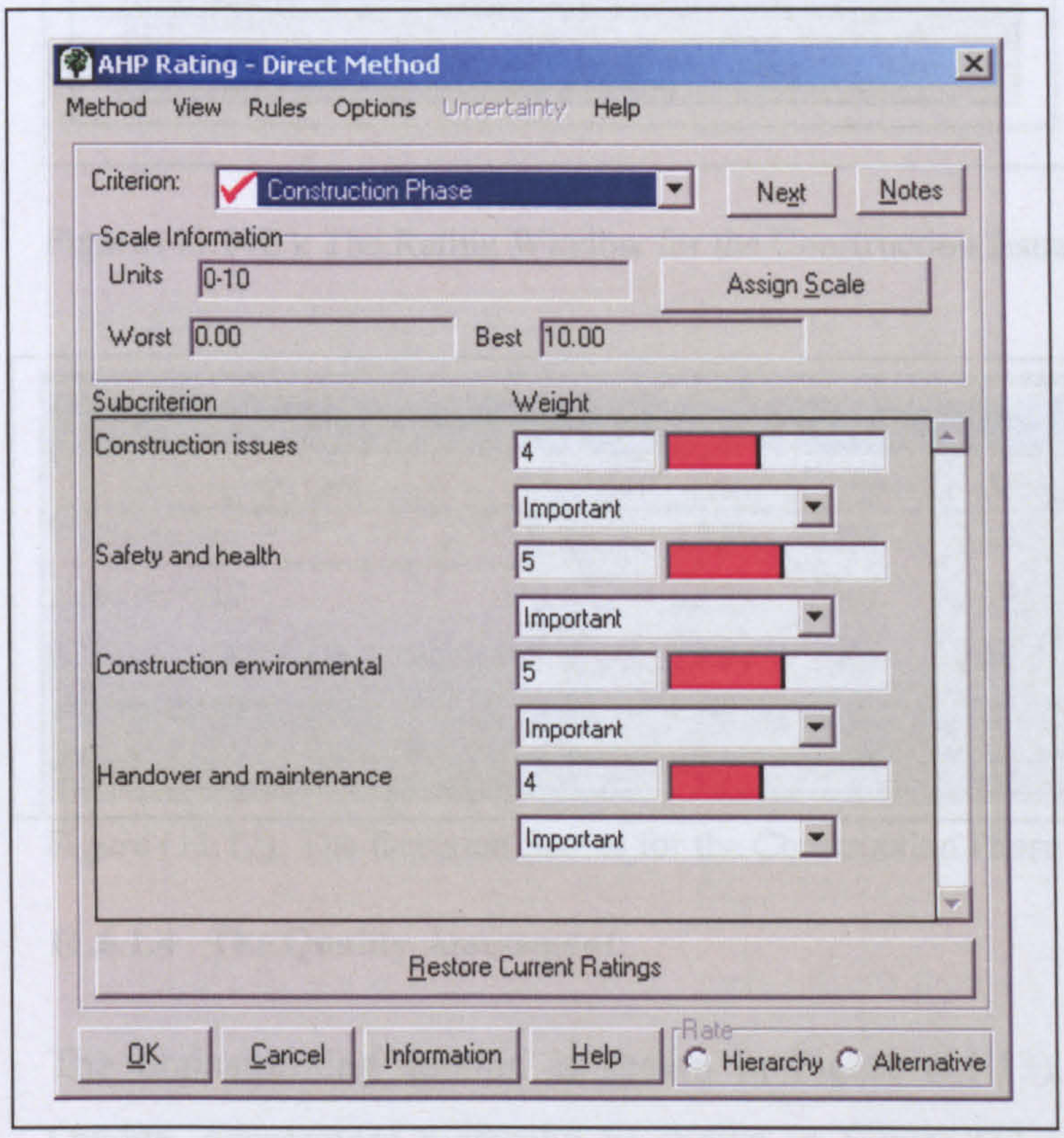


Figure (11.11A): The Rating Window for the Construction Phase

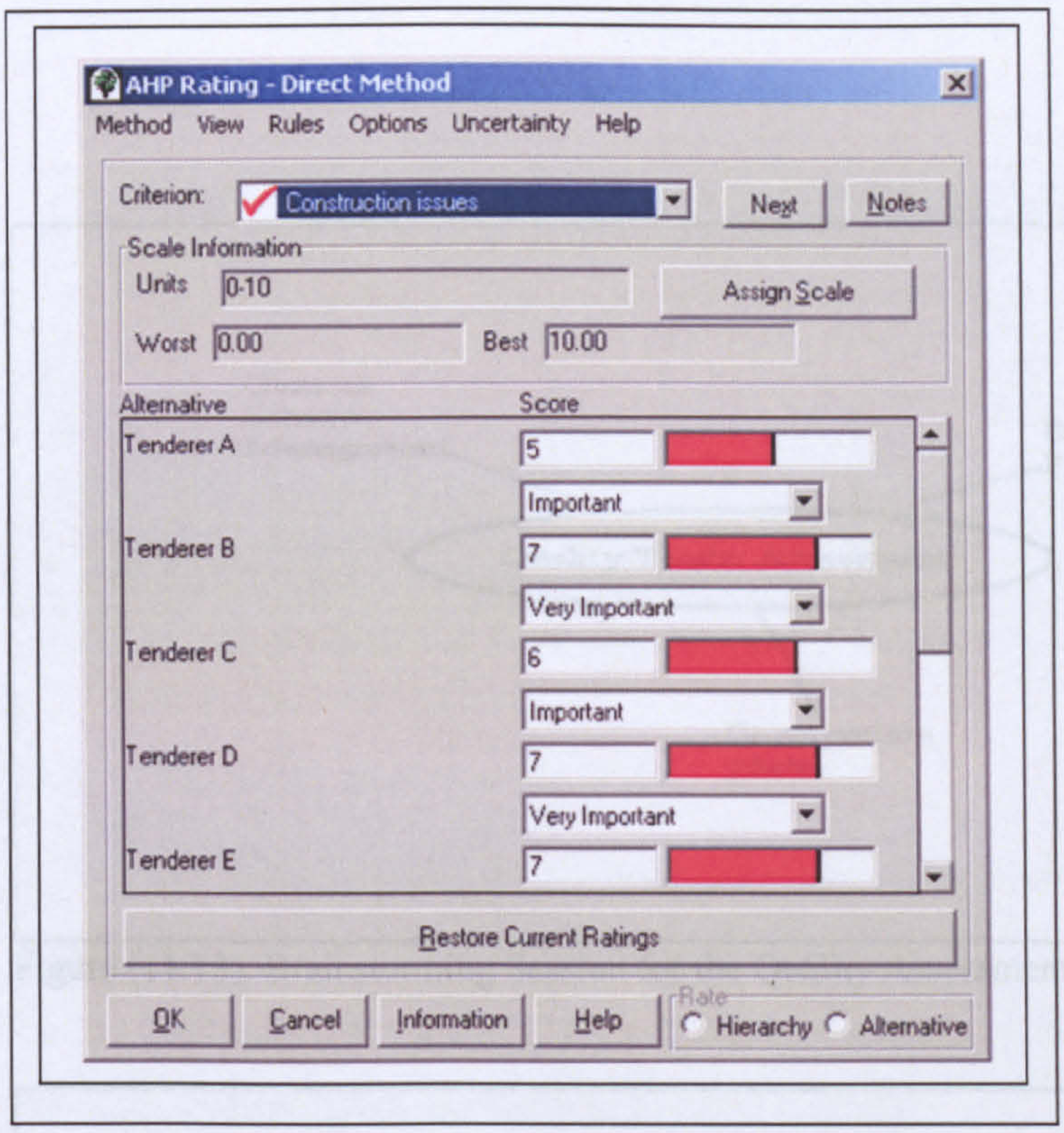


Figure (11.11B): The Rating Window for the Construction Issues

AHP Decision Scores

Lowest Level	Tenderer A	Tenderer B	Tenderer C	Tenderer D	Tenderer E	Model
Construction issues	0.156	0.219	0.188	0.219	0.219	0.222
Safety and health	0.143	0.200	0.200	0.229	0.229	0.278
Construction environmental management	0.167	0.233	0.200	0.200	0.200	0.278
Handover and maintenance	0.182	0.242	0.182	0.212	0.182	0.222
Results	0.161	0.223	0.193	0.215	0.208	

Figure (11.12): The Decision Scores for the Construction Phase

11.6.1.4 The Quality Assessment:

The brainstorming session is shown in Figure (11.13), then the development of the Quality Assessment hierarchy as shown in Figure (11.14). The rating window for the Quality Assessment is presented in Figure (11.15). Finally the decision score window is shown in Figure (11.16).

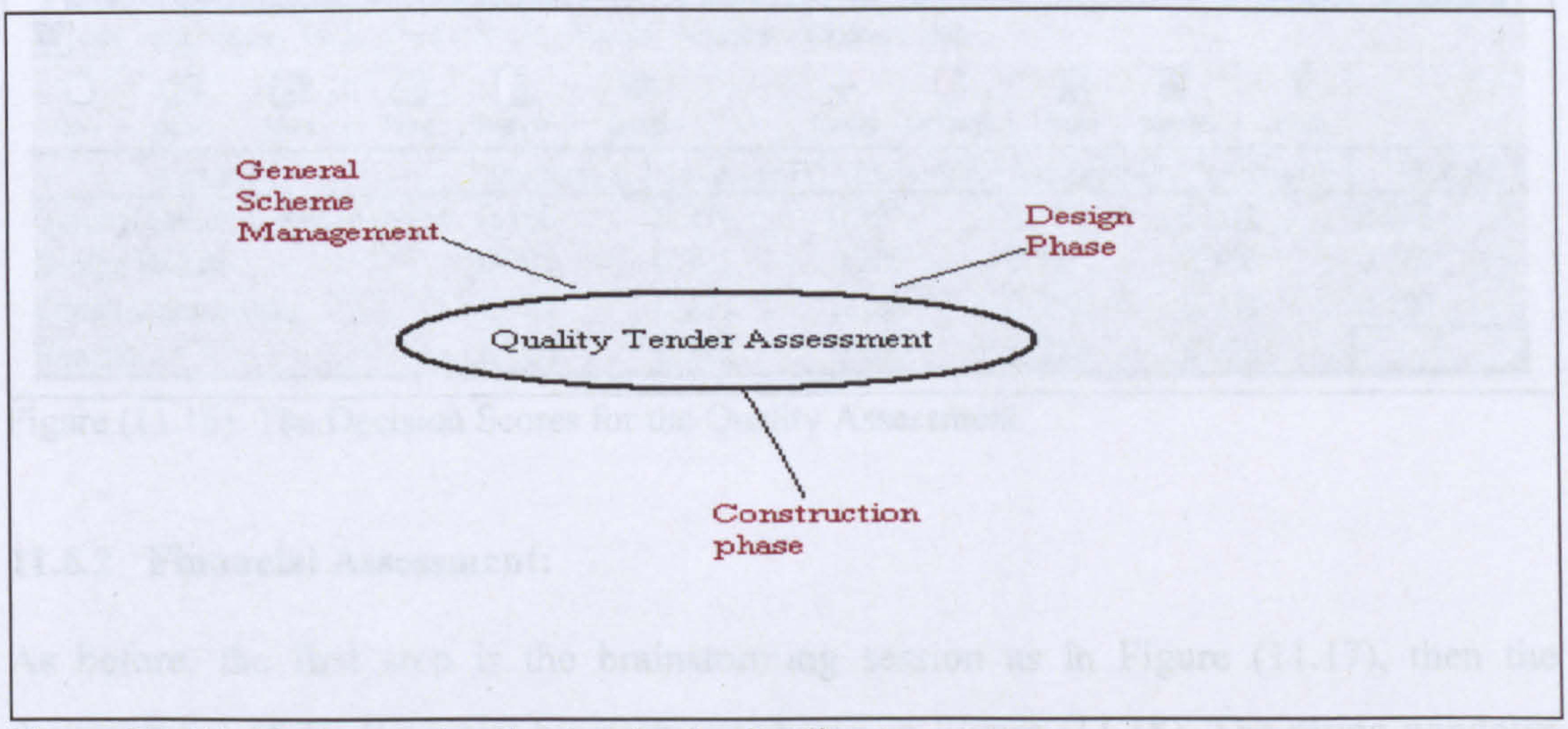


Figure (11.13): Brainstorming Session for the Quality Assessment

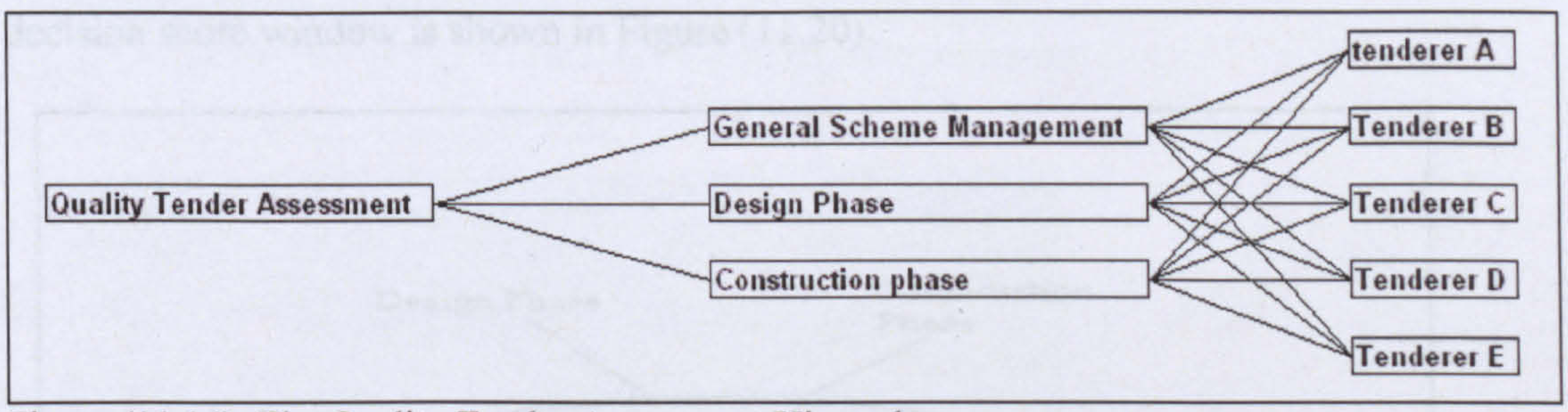


Figure (11.14): The Quality Tender Assessment Hierarchy

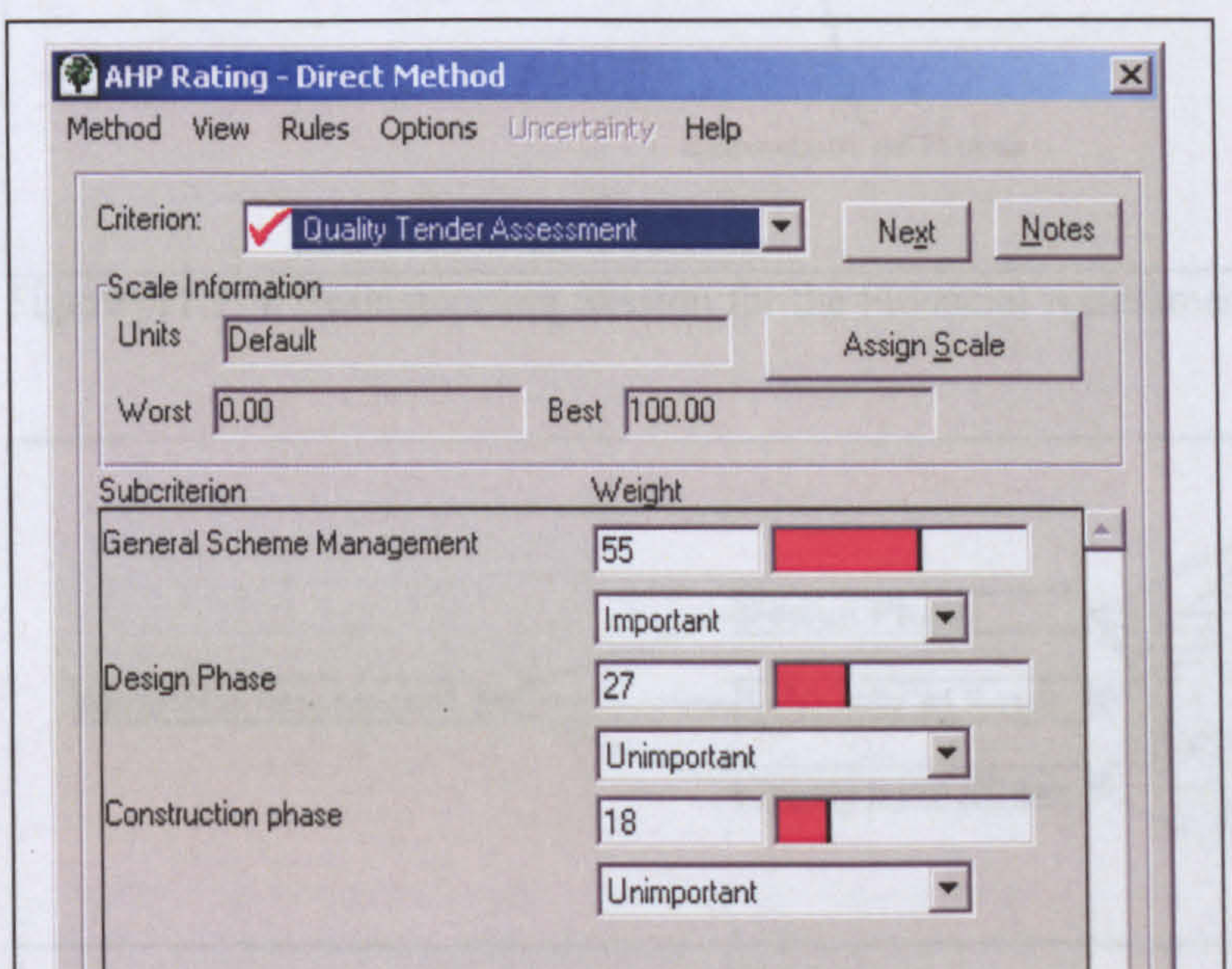


Figure (11.15): The Rating Window for the Quality Assessment

Lowest Level	tenderer A	Tenderer B	Tenderer C	Tenderer D	Tenderer E	Model
General Scheme Management	0.185	0.201	0.197	0.214	0.203	0.550
Design Phase	0.201	0.202	0.205	0.196	0.196	0.270
Construction phase	0.161	0.223	0.193	0.215	0.208	0.180
Results	0.185	0.205	0.198	0.209	0.202	

Figure (11.16): The Decision Scores for the Quality Assessment

11.6.2 Financial Assessment:

As before, the first step is the brainstorming session as in Figure (11.17), then the development of the Financial hierarchy as shown in Figure (11.18). The rating windows for the Financial assessment are presented in Figures (11.19A) and (11.19B). Finally the decision score window is shown in Figure (11.20).

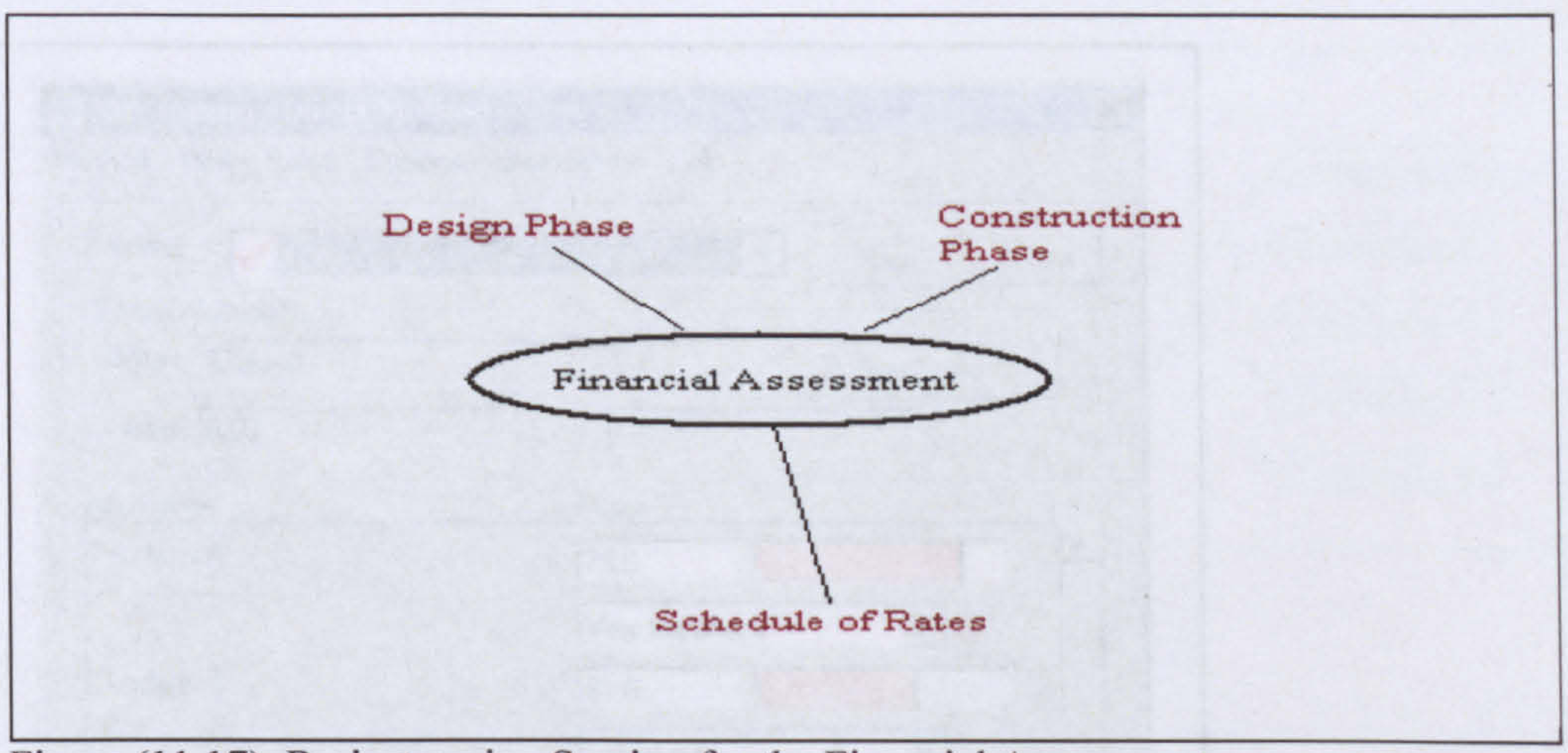


Figure (11.17): Brainstorming Session for the Financial Assessment

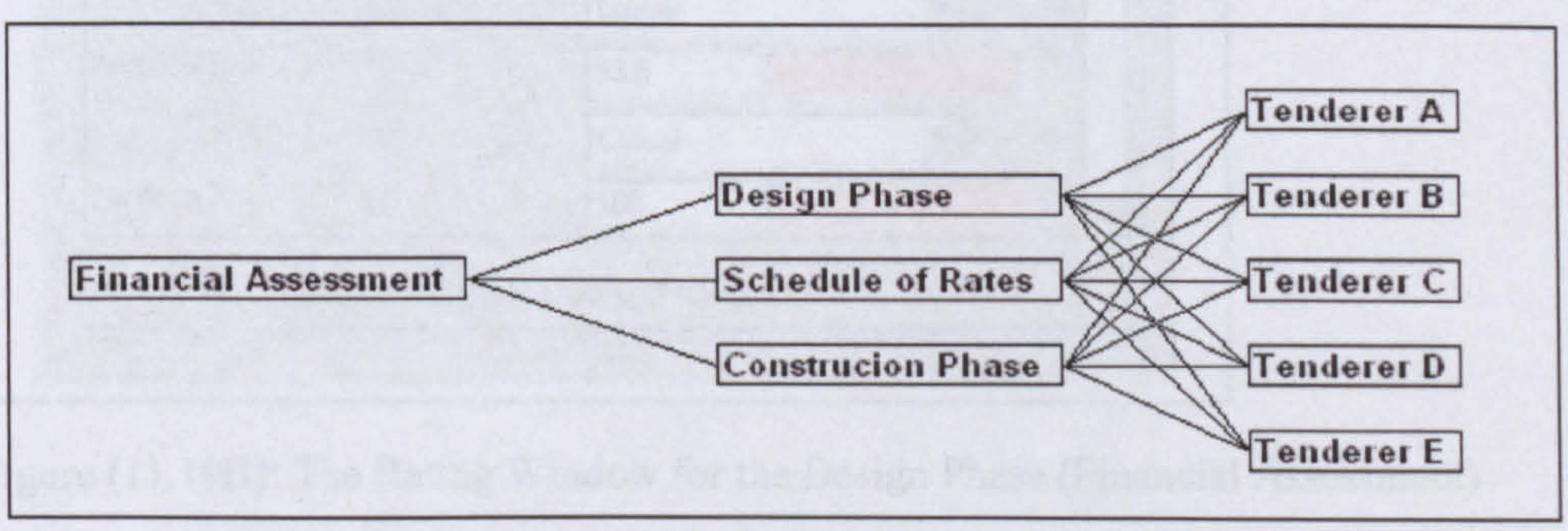


Figure (11.18): Financial Assessment Hierarchy

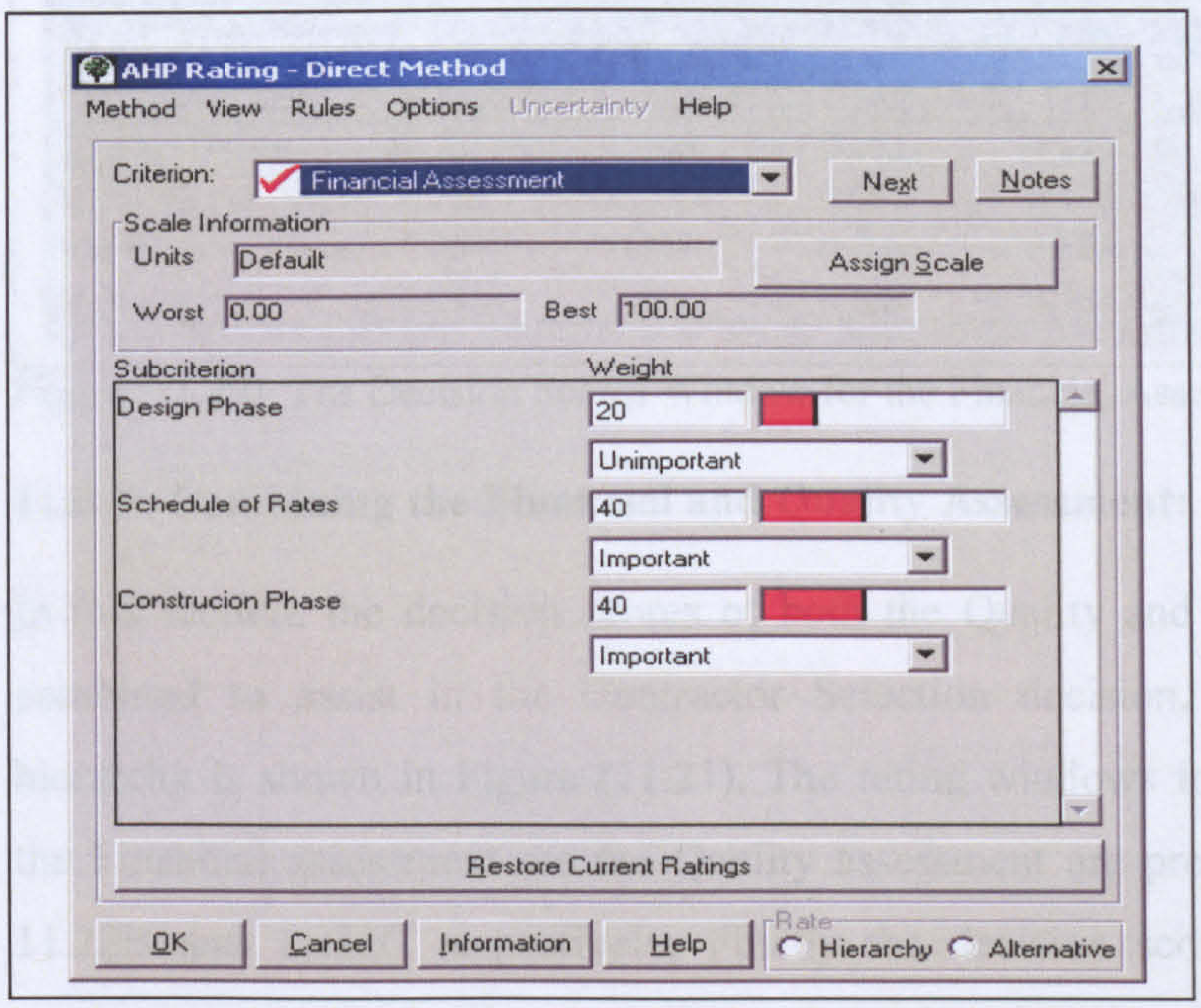


Figure (11.19A): The Rating Window for the Financial Assessment

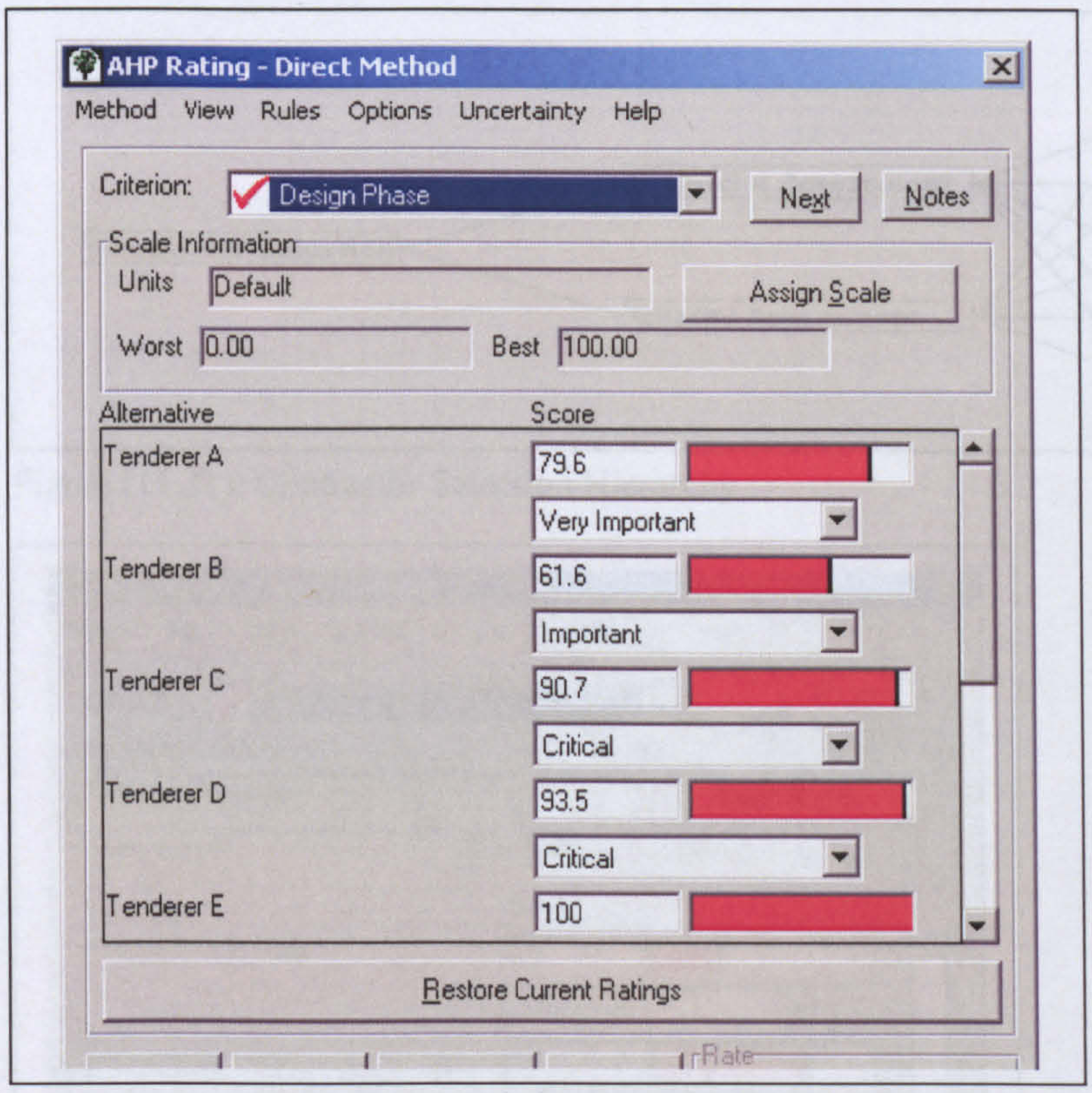


Figure (11.19B): The Rating Window for the Design Phase (Financial Assessment)

AHP Decision Scores

Lowest Level	Tenderer A	Tenderer B	Tenderer C	Tenderer D	Tenderer E	Model
Design Phase	0.187	0.145	0.213	0.220	0.235	0.200
Schedule of Rates	0.229	0.253	0.191	0.180	0.147	0.400
Construcion Phase	0.204	0.241	0.296	0.167	0.093	0.400
Results	0.211	0.226	0.238	0.183	0.143	

Figure (11.20): The Decision Scores Window for the Financial Assessment

11.6.3 Combining the Financial and Quality Assessment:

In this section, the decision scores of both the Quality and Financial Assessments are combined to assist in the Contractor Selection decision. The Contractor Selection hierarchy is shown in Figure (11.21). The rating windows for the Contractor Selection, the Financial assessment are the Quality assessment are presented in Figures (11.22A, 11.22B and 11.22C respectively. Finally the decision scores for both the Financial assessment and the Quality assessment are combined as shown in Figure (11.23).

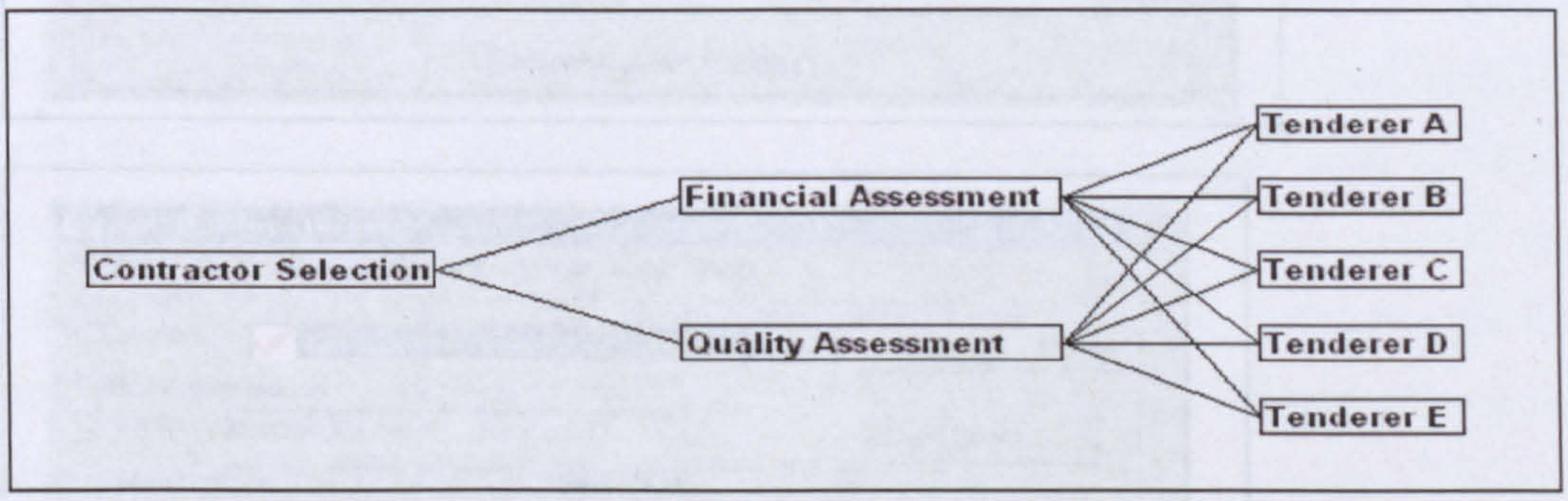


Figure (11.21): Contractor Selection Hierarchy

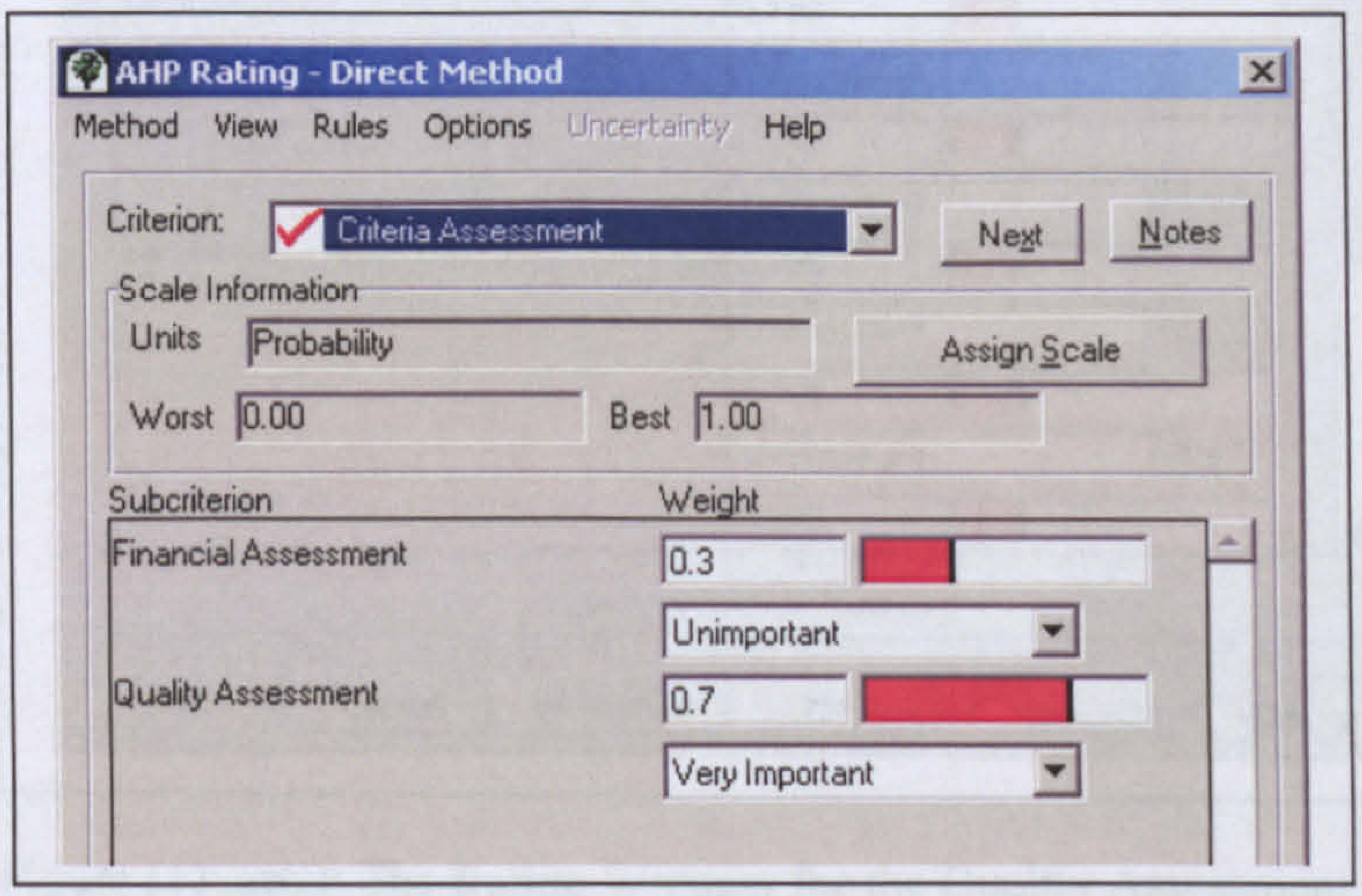
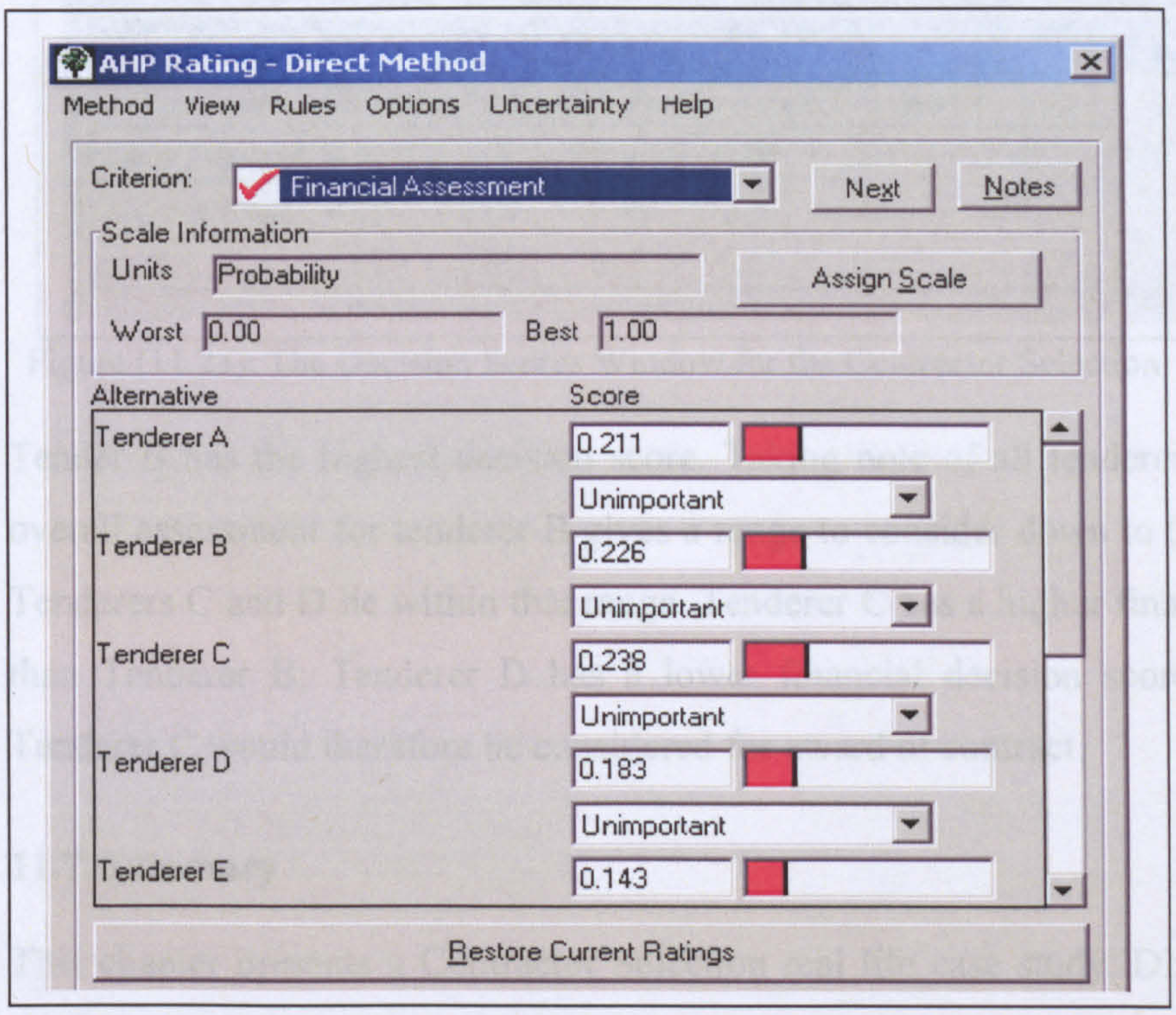


Figure (11.22A): The Rating Window for the Contractor Selection

Figure (11.22B): The Rating Window for the Financial Assessment



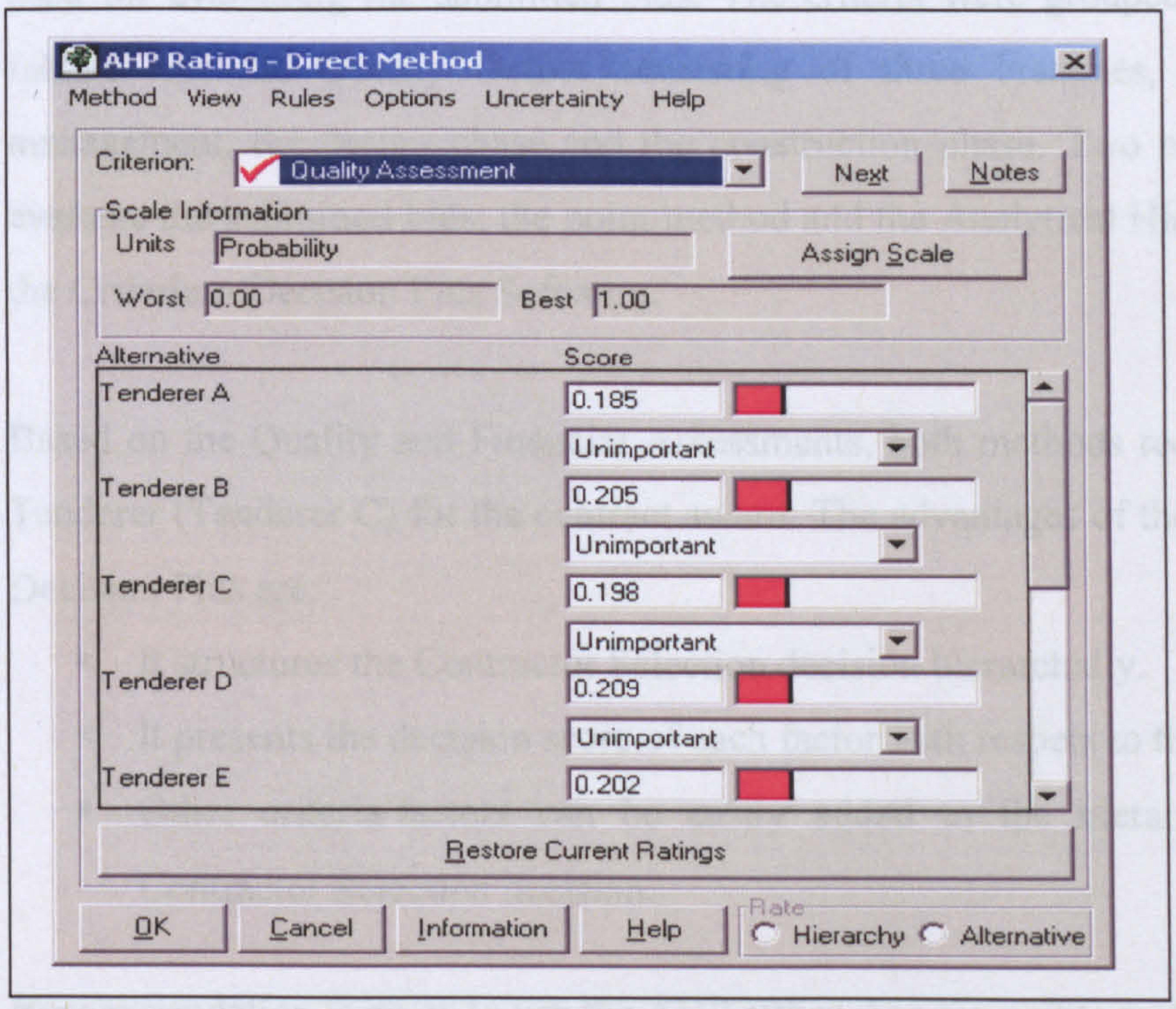


Figure (11.22C): The Rating Window for the Quality Assessment

AHP Decision Scores

Lowest Level	Tenderer A	Tenderer B	Tenderer C	Tenderer D	Tenderer E	Model
Financial Assessment	0.211	0.226	0.238	0.183	0.143	0.300
Quality Assessment	0.185	0.205	0.198	0.209	0.202	0.700
Results	0.193	0.211	0.210	0.201	0.184	

Figure (11.23): The Decision Scores Window for the Contractor Selection

Tender B has the highest decision score. Taking note of all tenderers within 5% of the overall assessment for tenderer B gives a range to consider down to 0.211 x 0.95 = 0.20. Tenderers C and D lie within that range. Tenderer C has a higher financial decision score than Tenderer B; Tenderer D has a lower financial decision score than Tenderer B. Tenderer C would therefore be considered for award of contract.

11.7 Summary

This chapter presents a Contractor Selection real life case study. Different criteria were used for evaluating the submitted bids. The criteria were grouped under the Financial factors and the Quality factors consisting of three branches, the general scheme management, the design phase and the construction phase. Two methods were used to evaluate the submitted bids; the point method and the Analytical Hierarchy Process using the Criterium Decision Plus Software.

Based on the Quality and Financial Assessments, both methods recommended the same Tenderer (Tenderer C) for the contract award. The advantages of the use of the Criterium Decision Plus are:

- It structures the Contractor Selection decision hierarchally.
- It presents the decision score of each factor with respect to the decision.
- Other criteria/factors can be easily added to the hierarchy to assist in the Contractor Selection decision.

Recommendation is given to use the AHP rather than the points method for the contractor selection process as it flexible and computer based.

One limitation of the validity of the developed model for contractor selection was the use of the student version of the Criterium Decision Plus Software. This version has a restriction on the model size, only 20 data blocks for the hierarchy, and as a result the contractor selection problem was divided to a number of sub problems and then combined at the end.

CHAPTER TWELVE

CONCLUSION AND RECOMMENDATIONS FOR FURTHER WORK

12.1 Introduction

This thesis has developed work to improve bidding decisions and the contractor selection process. A number of conclusions have been reached through the work done. This chapter presents various conclusions reached. This chapter also provides recommendations for future research.

12.2 Conclusions

1. Many studies have been conducted in different countries, including Australia, Brazil, Southeast Asia and the United States to assess the efficiency of the on-line reverse auctions. The main conclusions drawn from these studies are that the adoption of the on-line reverse auctions can result in cost savings for clients. While, the main drawback of reverse auctions is that award of the contract is mainly driven by the lowest price rather than best value or quality.

2. The results of the questionnaire survey conducted in the Gaza Strip support conclusions from previous studies that profit is not the most important factor when making the bid/no bid decision. It indicates that the need for work is the most important factor among all other factors examined when making the bid/no

bid decision. This is followed by the company strength in the industry. Payment methods and owner/client and consultant identity also have high importance. Past profit on similar projects, project type, experience in such projects and contract conditions have moderate importance in the bid/no bid decision. Finally, competition and risk of fluctuations in material prices have low importance in the bid/no bid decision.

3. The results of the survey also support earlier findings that profit is not the most important factor when making mark-up size decisions. The results revealed that the need for work, owner/client and consultant identity, project size and project type are the most important factors to be considered when making the mark-up decision. The least important factors are the competition and the risk of fluctuations in material prices. Past profit on similar projects, experience in such projects, contract conditions, project duration and project location have moderate influence on the mark-up decision.

4. The developed multi-criteria model for mark-up decision, based on the analytical hierarchy process, can be easily used by contractors in the construction industry to determine which project will result in higher mark-up. This model takes into account various factors affecting mark-up decision.

5. The sensitivity analysis and contribution by criteria proved that the developed models for Bid/no bid and Mark-up models are reliable, not sensitive, and robust.

6. The validity of the two developed AHP models was confirmed by applying the two-stage linear programming approach (LP), developed by Chandran el (2005), to real life data collected during the study. The LP approach proven to be an effective method for solving the pair-wise comparison matrices, generated using the Analytical Hierarchy Process and compared with the outcome from the

Criterium Decision Plus Software. Both approaches, the AHP and the LP, gave the same recommendations for bid/no bid and mark-up decisions.

7. The Criterium Decision Plus Software can be easily used by the decision makers even if they are not familiar with the mathematics underlying the Analytical Hierarchy Process. The Linear Programming approach is harder to implement if the decision maker does not understand the principles of Linear Programming.

8. Awarding contracts based on the price only is not an effective method as it affects the contractor's price. A number of factors need to be taken into account to make the contractor selection decision. When applying the AHP to a contractor selection decision presented by the Criterium Decision Plus, and the points method, both methods gave the same recommendation. The advantage of the Criterium Decision Plus over the points method is that it is a computer based model which can be modified by adding/ deleting factors or by changing the rates which then will be reflected automatically on the results.

12.3 Future Work

- To further work on the on-line reverse auctions. Areas such as security issues, ways to ensure the capability of the participating contractors and the tasks that should be performed by consultants and contractors to participate in an electronic auction must be explored.

- To utilise the fuzzy sets theory to quantify the uncertainty and risk involved in making bidding decisions. Then to evaluate its effectiveness in practice and furthermore compare it with the outcome from the Analytical Hierarchy Process.

- To expand the work on the mark-up decision model to assist the contractor, by further introducing a mark-up percentages to the hierarchy, as alternatives. Then, apply it to real life projects and assess the results.

- Linear Programming is an interesting field of study that has not been studied in depth and that should be more detailed in further works. The application of the linear programming in contractor selection needs to be explored. The difference between the linear programming, point's method and the Analytical Hierarchy Process when applied to the contractor selection is another area of study.

- Another method of validation which needs to be considered in the future is to encourage contractors to apply the developed AHP models in real life situations. This can be achieved by conducting training sessions and presentations to educate the industry of how to use the models.

- Further work would be constructing the contractor selection model using the full version of the Criterium Decision Plus to enable the clients to handle the contractor selection model easily.

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Appendix (A)

2nd January 2006

Napier University
School of the Built Environment
10 Colinton Road
EH10 5DT
United Kingdom

Subject: QUESTIONNAIRE SURVEY ON BIDDING IN CONSTRUCTION

Dear Contractor;

I am writing to ask for your assistance in the completion of the attached questionnaire. This survey forms part of my PhD study at the School of the Built Environment at Napier University,UK. The main aim of my research is to develop multi-criteria decision analysis models for bidding based on the Analytic Hierarchy Process.

The questionnaire is divided into four sections as follows:

- The first section consists of general questions about your company. This section is based on multiple choice questions.
- Section 2 deals with the comparisons of factors that affect bid/no bid decision. Ten factors are considered in this section: experience in such projects, past profit in similar projects, competition, need for work, company strength in the industry, contract conditions, owner/client/consultant identity, project type, payment methods and risk in fluctuation in material prices. This section requires the respondent to compare each two factors in turn with respect to their importance to bid/no bid decision. Then decide how much more important by choosing from a scale of 1 to 9.
- Section 3 deals with the comparisons of factors that affect mark-up decision. Eleven factors are considered in this section: experience in such projects, past profit in similar projects, competition, need for work, contract conditions, owner/client/consultant identity, project type, project location, project size, project duration and risk in fluctuation in material prices. Again, this section requires the respondent to compare each two factors in turn with respect to their importance to the two decisions. Then decide how much more important by choosing from a scale of 1 to 9.
- Finally, section 4 consists of questions about your view regarding the questionnaire.

It is estimated that the questionnaire will take approximately 20 minutes to complete.

Please be assured that all information provided will be treated in absolute confidence and used solely for the purpose of this research project.

Yours Sincerely

Nadine Nabeel Abu Shaaban

QUESTIONNAIRE SURVEY ON BIDDING IN CONSTRUCTION

Respondent Position: Date:

Section 1: Questions About Your Company: *Please mark with an X where appropriate*

A- Classification of Contractor (The possibility of more than one choice)

1. Buildings ☐
2. Infrastructure ☐
3. Electromechanical ☐
4. Other ☐

B- Number of Years in Industry

1. Less than 5 ☐
2. From 5 to 15 ☐
3. From 16 to 25 ☐
4. More than 25 ☐

C- Number of Full Time Permanent Staff

1. Less than 10 ☐
2. From 10 to 20 ☐
3. From 21 to 30 ☐
4. More than 30 ☐

D- Average Job Size executed (U.S $)

1. Under 250 Thousand ☐
2. From 250 to 500 Thousand ☐
3. From 501 Thousand to 1 Million ☐
4. More than 1 Million ☐

E- Average Job Duration

1. Less than 6 Months ☐
2. From 6 to 12 Months ☐
3. From 13 Months to 2 Years ☐
4. More than 2 Years ☐

F- Percentage of Work Subcontracted on Average Job

1. Less than 25% ☐
2. From 25 to 50% ☐
3. From 51 to 75% ☐
4. From 76 to 100% ☐

G- Percentage of Work obtained through competitive bidding

1. Less than 25% ☐
2. From 25 to 50% ☐
3. From 51 to 75% ☐
4. From 76 to 100% ☐

H- Percentage of using mathematical models to assist in bidding decisions

1. Less than 25% ☐
2. From 25 to 50% ☐
3. From 51 to 75% ☐
4. From 76 to 100% ☐

Section 2: Comparisons of Factors Affecting Bid / No Bid Decision

For each pair of value comparisons below:

1. Tick one box of each line of the grey-highlighted section to indicate the factor that is *more important* to you.
2. Tick one box of the white section to the right to indicate how much more important that value compared to the other.
3. In case of equal importance, please tick both factors and the equally box.
4. Please note that values 2, 4, 6 and 8 are intermediate values between 1, 3, 5, 7 and 9.

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Experience in such projects	*vs*	☐ Past profit in similar projects									
☐ Experience in such projects	*vs*	☐ Competition									
☐ Experience in such projects	*vs*	☐ Need for work									
☐ Experience in such projects	*vs*	☐ Company strength in the industry									
☐ Experience in such projects	*vs*	☐ Contract conditions									
☐ Experience in such projects	*vs*	☐ Owner/Client/Consultant Identity									
☐ Experience in such projects	*vs*	☐ Project type									
☐ Experience in such projects	*vs*	☐ Payment methods									
☐ Experience in such projects	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Past profit in similar projects	*vs*	☐ Competition									
☐ Past profit in similar projects	*vs*	☐ Need for work									
☐ Past profit in similar projects	*vs*	☐ Company strength in the industry									
☐ Past profit in similar projects	*vs*	☐ Contract conditions									
☐ Past profit in similar projects	*vs*	☐ Owner/Client/Consultant Identity									
☐ Past profit in similar projects	*vs*	☐ Project type									
☐ Past profit in similar projects	*vs*	☐ Payment methods									
☐ Past profit in similar projects	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Competition	*vs*	☐ Need for work									
☐ Competition	*vs*	☐ Company strength in the industry									
☐ Competition	*vs*	☐ Contract conditions									
☐ Competition	*vs*	☐ Owner/Client/Consultant Identity									
☐ Competition	*vs*	☐ Project type									
☐ Competition	*vs*	☐ Payment methods									
☐ Competition	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Need for work	*vs*	☐ Company strength in the industry									
☐ Need for work	*vs*	☐ Contract conditions									
☐ Need for work	*vs*	☐ Owner/Client/Consultant Identity									
☐ Need for work	*vs*	☐ Project type									
☐ Need for work	*vs*	☐ Payment methods									
☐ Need for work	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Company strength in the industry	*vs*	☐ Contract conditions									
☐ Company strength in the industry	*vs*	☐ Owner/Client/Consultant Identity									
☐ Company strength in the industry	*vs*	☐ Project type									
☐ Company strength in the industry	*vs*	☐ Payment methods									
☐ Company strength in the industry	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Contract conditions	*vs*	☐ Owner/Client/Consultant Identity									
☐ Contract conditions	*vs*	☐ Project type									
☐ Contract conditions	*vs*	☐ Payment methods									
☐ Contract conditions	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutel 9
☐ Owner/Client/Consultant Identity	*vs*	☐ Project type									
☐ Owner/Client/Consultant Identity	*vs*	☐ Payment methods									
☐ Owner/Client/Consultant Identity	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Project type	*vs*	☐ Payment methods									
☐ Project type	*vs*	☐ Risk in fluctuation in material prices									

With respect to Bid/No Bid Decision: *Which of these factors of each line are more important?*			How much more important?								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Payment methods	*vs*	☐ Risk in fluctuation in material prices									

*Section 3: **Comparisons of Factors Affecting Mark-Up Decision***

For each pair of value comparisons below:

1. Tick one box of each line of the grey-highlighted section to indicate the factor that is *more important* to you.
2. Tick one box of the white section to the right to indicate how much more important that value compared to the other.
3. In case of equal importance, please tick both factors and the equally box.
4. Please note that values 2, 4, 6 and 8 are intermediate values between 1, 3, 5, 7 and 9.

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Experience in such projects	vs	☐ Past profit in similar projects									
☐ Experience in such projects	vs	☐ Competition									
☐ Experience in such projects	vs	☐ Need for work									
☐ Experience in such projects	vs	☐ Contract conditions									
☐ Experience in such projects	vs	☐ Owner/Client/Consultant Identity									
☐ Experience in such projects	vs	☐ Project type									
☐ Experience in such projects	vs	☐ Project location									
☐ Experience in such projects	vs	☐ Project size									
☐ Experience in such projects	vs	☐ Project duration									
☐ Experience in such projects	vs	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Past profit in similar projects	vs	☐ Competition									
☐ Past profit in similar projects	vs	☐ Need for work									
☐ Past profit in similar projects	vs	☐ Contract conditions									
☐ Past profit in similar projects	vs	☐ Owner/Client/Consultant Identity									
☐ Past profit in similar projects	vs	☐ Project type									
☐ Past profit in similar projects	vs	☐ Project location									
☐ Past profit in similar projects	vs	☐ Project size									
☐ Past profit in similar projects	vs	☐ Project duration									
☐ Past profit in similar projects	vs	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutel 9
☐ Competition	*vs*	☐ Need for work									
☐ Competition	*vs*	☐ Contract conditions									
☐ Competition	*vs*	☐ Owner/Client/Consultant Identity									
☐ Competition	*vs*	☐ Project type									
☐ Competition	*vs*	☐ Project location									
☐ Competition	*vs*	☐ Project size									
☐ Competition	*vs*	☐ Project duration									
☐ Competition	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutel 9
☐ Need for work	*vs*	☐ Contract conditions									
☐ Need for work	*vs*	☐ Owner/Client/Consultant Identity									
☐ Need for work	*vs*	☐ Project type									
☐ Need for work	*vs*	☐ Project location									
☐ Need for work	*vs*	☐ Project size									
☐ Need for work	*vs*	☐ Project duration									
☐ Need for work	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutel 9
☐ Contract conditions	*vs*	☐ Owner/Client/Consultant Identity									
☐ Contract conditions	*vs*	☐ Project type									
☐ Contract conditions	*vs*	☐ Project location									
☐ Contract conditions	*vs*	☐ Project size									
☐ Contract conditions	*vs*	☐ Project duration									
☐ Contract conditions	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Owner/Client/Consultant Identity	*vs*	☐ Project type									
☐ Owner/Client/Consultant Identity	*vs*	☐ Project location									
☐ Owner/Client/Consultant Identity	*vs*	☐ Project size									
☐ Owner/Client/Consultant Identity	*vs*	☐ Project duration									
☐ Owner/Client/Consultant Identity	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Project type	*vs*	☐ Project location									
☐ Project type	*vs*	☐ Project size									
☐ Project type	*vs*	☐ Project duration									
☐ Project type	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Project location	*vs*	☐ Project size									
☐ Project location	*vs*	☐ Project duration									
☐ Project location	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutely 9
☐ Project size	*vs*	☐ Project duration									
☐ Project size	*vs*	☐ Risk in fluctuation in material prices									

With respect to Mark-up Decision: *Which of these factors of each line are more important?*			*How much more important?*								
			Equally 1	2	Weakly 3	4	Strongly 5	6	Very Strongly 7	8	Absolutel 9
☐ Project duration	*vs*	☐ Risk in fluctuation in material prices									

Section 4: Your Views About this Questionnaire:

	Too complex	About right
Did you find this questionnaire?		
How long did it take you to complete the questionnaire?		
Suggestions:		

Thank you for completing this questionnaire.

الموضوع : إستبيان عن العطاءات في مجال الإنشاءات

السيد المقاول المحترم

أرجو التكرم ببعض الوقت لتعبئة الإستبيان المرفق . وهو جزء من رسالة الدكتوراه التي سأتقدم بها إلى قسم بناء البيئة في جامعة Napier في المملكة المتحدة . رسالتي للدكتوراه تتناول تطبيقاً عملياً لأحد أساليب إتخاذ القرار المعروف بإسم " أسلوب التحليل الهرمي " وذلك بتطبيقه على بعض العوامل المتعلقة بالعطاءات .

الإستبيان مقسم إلى أربعة أجزاء كما يلي :

- **الجزء الأول** : عبارة عن أسئلة عامة عن الشركة / المقاول ويتم إختيار الإجابة من خيارات متعددة .
- **الجزء الثاني** : يضم جداول مقارنة بين العوامل المؤثرة على قرار الشركة / المقاول الدخول أو عدم الدخول في العطاء عند طرحه . عشرة عوامل تحت الإعتبار في هذا الجزء : الخبرة السابقة في مشاريع مماثلة ، الربح المحقق في مشاريع سابقة مماثلة ، المنافسة ، الحاجة إلى العمل ، وجود الشركة في سوق العمل ، شروط العقد ، هوية المالك / الممول / الإستشاري ، نوع المشروع ، طرق الدفع وخطر التذبذب في أسعار المواد . هذا الجزء يتطلب من مجيب الإستبيان أن يقارن كل عاملين على التوالي من ناحية الأهمية في دخول أو عدم دخول العطاء ومن ثم تعيين درجة أهمية العامل الذي تم إختياره على العامل الآخر عن طريق الإختيار من التدرج الموضح من 1 إلى 9 .
- **الجزء الثالث** : يضم جداول مقارنة بين العوامل المؤثرة على قرار المقاول عند تحديد نسبة الأرباح للعطاءات . تم إختيار أحد عشر عاملاً للمقارنة في هذا الجزء : الخبرة السابقة في مشاريع مماثلة ، الربح المحقق في مشاريع سابقة مماثلة ، المنافسة ، الحاجة إلى العمل ، شروط العقد ، هوية المالك / الممول / الإستشاري ، نوع المشروع ، موقع المشروع ، حجم المشروع ، مدة المشروع وخطر التذبذب في أسعار المواد . هذا الجزء يتطلب من مجيب الإستبيان أن يقارن كل عاملين على التوالي من ناحية الأهمية في تحديد نسبة الأرباح للعطاءات ومن ثم تعيين درجة أهمية العامل الذي تم إختياره على العامل الآخر عن طريق الإختيار من التدرج الموضح من 1 إلى 9 .
- **الجزء الرابع** : يشتمل على أسئلة حول رأيكم في هذا الإستبيان .

الزمن التقريبي لتعبئة هذا الإستبيان هو 20 دقيقة .

البيانات الواردة في هذا الإستبيان سيتم التعامل معها بشكل مطلق الخصوصية والكتمان وبما لا يتعدى الأهداف الأكاديمية لإتمام رسالة الدكتوراه .

ولكم جزيل الشكر
ندين نبيل أبو شعبان

إستبيان عن العطاءات في مجال الإنشاءات

منصب مجيب الإستبيان : التاريخ :

الجزء الأول : بيانات عامة عن الشركة : الرجاء وضع علامة (X) في المكان المناسب :

أ- تصنيف المقاول : (إمكانية إختيار أكثر من تصنيف)

أبنية ☐	كهروميكانيك ☐
بنية تحتية ☐	تصنيفات أخرى ☐

ب- عدد السنوات في مجال المقاولات

أقل من 5 ☐	من 16 إلى 25 ☐
من 5 إلى 15 ☐	أكثر من 25 ☐

ت- عدد الموظفين الدائمين

أقل من 10 ☐	من 21 إلى 30 ☐
من 10 إلى 20 ☐	أكثر من 30 ☐

ث- متوسط قيمة المشاريع المنفذة (دولار أمريكي)

أقل من 250 ألف ☐	من 501 ألف إلى مليون ☐
من 250 إلى 500 ألف ☐	أكثر من مليون ☐

ج- متوسط المدة الزمنية للمشروع الواحد

أقل من 6 أشهر ☐	من 13 شهر إلى سنتين ☐
من 6 إلى 12 شهر ☐	أكثر من سنتين ☐

ح- النسبة المئوية للأعمال الممنوحة لمقاولي الباطن في المشروع الواحد

أقل من 25 % ☐	من 51 إلى 75 % ☐
من 25 إلى 50 % ☐	من 76 إلى 100 % ☐

خ- النسبة المئوية للأعمال التي يتم الحصول عليها من خلال المناقصات التنافسية

أقل من 25 % ☐	من 51 إلى 75 % ☐
من 25 إلى 50 % ☐	من 76 إلى 100 % ☐

د- النسبة المئوية لإتخاذ قرار في المناقصات من خلال الإستعانة ببرامج حاسوبية متقدمة

أقل من 25 % ☐	من 51 إلى 75 % ☐
من 25 إلى 50 % ☐	من 76 إلى 100 % ☐

الجزء الثاني : مقارنة العوامل (من ناحية الأهمية) التي تؤثر على قرار المقاول الدخول أو عدم الدخول في العطاء

إرشادات :

1. لكل سطر في الجزء الرمادي (الأيمن) : الرجاء وضع علامة (✓) على العامل الأهم لقرار دخول أو عدم دخول العطاء
2. في نفس السطر ولكن في الجزء الأيسر : الرجاء تحديد درجة أهمية العامل المختار على العامل الآخر بوضع علامة (✓) على الدرجة المناسبة .
3. في حالة تساوي الأهمية للعاملين : الرجاء وضع علامة (✓) على العاملين في الجزء الرمادي وإختيار الخانة الدالة على مساواة الأهمية في الجزء الأيسر
4. لاحظ أن الدرجات 2 ، 4 ، 6 و 8 هي درجات وسطية

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ الربح المحقق في مشاريع سابقة مماثلة									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ المنافسة									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ الحاجة إلى العمل									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ وجود الشركة في سوق العمل									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ شروط العقد									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ هوية المالك / الممول / الإستشاري									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ نوع المشروع									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ طرق الدفع									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ المنافسة									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ الحاجة إلى العمل									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ وجود الشركة في سوق العمل									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ شروط العقد									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ هوية المالك / الممول / الإستشاري									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ نوع المشروع									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ طرق الدفع									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الأخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ المنافسة	مقارنة بـ	□ الحاجة إلى العمل									
□ المنافسة	مقارنة بـ	□ وجود الشركة في سوق العمل									
□ المنافسة	مقارنة بـ	□ شروط العقد									
□ المنافسة	مقارنة بـ	□ هوية المالك / الممول / الإستشاري									
□ المنافسة	مقارنة بـ	□ نوع المشروع									
□ المنافسة	مقارنة بـ	□ طرق الدفع									
□ المنافسة	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الأخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ الحاجة إلى العمل	مقارنة بـ	□ وجود الشركة في سوق العمل									
□ الحاجة إلى العمل	مقارنة بـ	□ شروط العقد									
□ الحاجة إلى العمل	مقارنة بـ	□ هوية المالك / الممول / الإستشاري									
□ الحاجة إلى العمل	مقارنة بـ	□ نوع المشروع									
□ الحاجة إلى العمل	مقارنة بـ	□ طرق الدفع									
□ الحاجة إلى العمل	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الأخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ وجود الشركة في سوق العمل	مقارنة بـ	□ شروط العقد									
□ وجود الشركة في سوق العمل	مقارنة بـ	□ هوية المالك / الممول / الإستشاري									
□ وجود الشركة في سوق العمل	مقارنة بـ	□ نوع المشروع									
□ وجود الشركة في سوق العمل	مقارنة بـ	□ طرق الدفع									
□ وجود الشركة في سوق العمل	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ شروط العقد	مقارنة بـ	□ هوية المالك / الممول / الإستشاري									
□ شروط العقد	مقارنة بـ	□ نوع المشروع									
□ شروط العقد	مقارنة بـ	□ طرق الدفع									
□ شروط العقد	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ هوية المالك / الممول / الإستشاري	مقارنة بـ	□ نوع المشروع									
□ هوية المالك / الممول / الإستشاري	مقارنة بـ	□ طرق الدفع									
□ هوية المالك / الممول / الإستشاري	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ نوع المشروع	مقارنة بـ	□ طرق الدفع									
□ نوع المشروع	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم لقرار دخول أو عدم دخول العطاء ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
□ طرق الدفع	مقارنة بـ	□ خطر التذبذب في أسعار المواد									

الجزء الثالث : مقارنة العوامل (من ناحية الأهمية) التي تؤثر على نسبة الأرباح التي يحددها المقاول للعطاءات

إرشادات :

1. لكل سطر في الجزء الرمادي (الأيمن) : الرجاء وضع علامة (✓) على العامل الأهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات
2. في نفس السطر ولكن في الجزء الأيسر : الرجاء تحديد درجة أهمية العامل المختار على العامل الآخر بوضع علامة (✓) على الدرجة المناسبة .
3. في حالة تساوي الأهمية للعاملين : الرجاء وضع علامة (✓) على العاملين في الجزء الرمادي وإختيار الخانة الدالة على مساواة الأهمية في الجزء الأيسر
4. لاحظ أن الدرجات 2 ، 4 ، 6 و 8 هي درجات وسطية

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الأخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ الربح المحقق في مشاريع سابقة مماثلة									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ المنافسة									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ الحاجة إلى العمل									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ شروط العقد									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ هوية المالك / الممول / الإستشاري									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ نوع المشروع									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ موقع المشروع									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ حجم المشروع									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ مدة المشروع									
☐ الخبرة السابقة في مشاريع مماثلة	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الأخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ المنافسة									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ الحاجة إلى العمل									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ شروط العقد									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ هوية المالك / الممول / الإستشاري									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ نوع المشروع									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ موقع المشروع									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ حجم المشروع									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ مدة المشروع									
☐ الربح المحقق في مشاريع سابقة مماثلة	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ هوية المالك / الممول / الإستشاري	مقارنة بـ	☐ نوع المشروع									
☐ هوية المالك / الممول / الإستشاري	مقارنة بـ	☐ موقع المشروع									
☐ هوية المالك / الممول / الإستشاري	مقارنة بـ	☐ حجم المشروع									
☐ هوية المالك / الممول / الإستشاري	مقارنة بـ	☐ مدة المشروع									
☐ هوية المالك / الممول / الإستشاري	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ نوع المشروع	مقارنة بـ	☐ موقع المشروع									
☐ نوع المشروع	مقارنة بـ	☐ حجم المشروع									
☐ نوع المشروع	مقارنة بـ	☐ مدة المشروع									
☐ نوع المشروع	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ موقع المشروع	مقارنة بـ	☐ حجم المشروع									
☐ موقع المشروع	مقارنة بـ	☐ مدة المشروع									
☐ موقع المشروع	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ حجم المشروع	مقارنة بـ	☐ مدة المشروع									
☐ حجم المشروع	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

لكل سطر : أي من العاملين أهم بالنسبة لقرار نسبة الأرباح التي يحددها المقاول للعطاءات ؟			ما مقدار الأهمية على العامل الآخر ؟								
			مساوي الأهمية		أهمية بسيطة		أهمية كبيرة		أهمية كبيرة جداً		أهمية مطلقة
			1	2	3	4	5	6	7	8	9
☐ مدة المشروع	مقارنة بـ	☐ خطر التذبذب في أسعار المواد									

الجزء الرابع : حول هذا الإستبيان

	معقد / صعب	ملائم / بسيط
ما رأيك في الإستبيان ؟		
ما هو الزمن الفعلي الذي إستغرقه تعبئة هذا الإستبيان ؟		
إقتراحات :		

نشكر لسيادتكم حسن تعاونكم ....

Appendix (B)

Bid/ No Bid Decision

For Past Proft in Similar Projects

```
min z12 + z13 + z23
    st
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
x1 - x3 - y13 = -0.587
x3 - x1 - y31 = 0.587
x2 - x3 - y23 = -0.251
x3 - x2 - y32 = 0.251
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0.00001

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0.00001
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
x1 - x3 - y13 = -0.587
x3 - x1 - y31 = 0.587
x2 - x3 - y23 = -0.251
x3 - x2 - y32 = 0.251
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below.

LP OPTIMUM FOUND AT STEP 15

OBJECTIVE FUNCTION VALUE

E-050.3333333

VARIABLE	VALUE
ZMAX	0.000003
Z12	0.000003
Z13	0.000003
Z23	0.000003
X1	0.000000
X2	0.336473
Y12	-0.000003
Y21	0.000003
X3	0.587783
Y13	0.000003
Y31	-0.000007
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.336473	Exp of x2	1.40
x3 =	0.587783	Exp of x3	1.79
		sum	4.19
priority vector		w1	0.238
		w2	0.333
		w3	0.428

Bid/ No Bid Decision

For Competition

```
min z12 + z13 + z23
st
x1 - x2 - y12 = -0.559
x2 - x1 - y21 = 0.559
x1 - x3 - y13 = -0.810
x3 - x1 - y31 = 0.810
x2 - x3 - y23 = -0.251
x3 - x2 - y32 = 0.251
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
    end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = -0.559
x2 - x1 - y21 = 0.559
x1 - x3 - y13 = -0.810
x3 - x1 - y31 = 0.810
x2 - x3 - y23 = -0.251
x3 - x2 - y32 = 0.251
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below.

LP OPTIMUM FOUND AT STEP 8

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.559620
Y12	0.000000
Y21	0.000000
X3	0.810930
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0.55962	Exp of x2	1.750
x3 =	0.81093	Exp of x3	2.25
		sum	5.00
priority vector		w1	0.2
		w2	0.350
		w3	0.449

Bid/ No Bid Decision

For Need for Work

```
min z12 + z13 + z23
        st
x1 - x2 - y12 = -0.154
x2 - x1 - y21 = 0.154
x1 - x3 - y13 = -0.405
x3 - x1 - y31 = 0.405
x2 - x3 - y23 = -0.251
x3 - x2 - y32 = 0.251
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0.00001

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0.00001
x1 - x2 - y12 = -0.154
x2 - x1 - y21 = 0.154
x1 - x3 - y13 = -0.405
x3 - x1 - y31 = 0.405
x2 - x3 - y23 = -0.251
x3 - x2 - y32 = 0.251
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 15

OBJECTIVE FUNCTION VALUE

E-050.3333333

VARIABLE	VALUE
ZMAX	0.000003
Z12	0.000003
Z13	0.000003
Z23	0.000003
X1	0.000000
X2	0.154153
Y12	-0.000003
Y21	0.000003
X3	0.405463
Y13	0.000003
Y31	-0.000007
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.154153	Exp of x2	1.166
x3 =	0.405463	Exp of x3	1.499
		sum	3.666
priority vector		w1	0.272
		w2	0.318
		w3	0.409

Bid/ No Bid Decision

For Project Type

```
min z12 + z13 + z23
        st
x1 - x2 - y12 = -0.287
x2 - x1 - y21 = 0.287
x1 - x3 - y13 = -0.287
x3 - x1 - y31 = 0.287
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = -0.287
x2 - x1 - y21 = 0.287
x1 - x3 - y13 = -0.287
x3 - x1 - y31 = 0.287
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 4

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.287680
Y12	0.000000
Y21	0.000000
X3	0.287680
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.28768	Exp of x2	1.333
x3 =	0.28768	Exp of x3	1.333
		sum	3.666
priority vector		w1	0.272
		w2	0.363
		w3	0.363

Bid/ No Bid Decision

For Payment Method

```
min z12 + z13 + z23
        st
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
x1 - x3 - y13 = 0
x3 - x1 - y31 = 0
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
x1 - x3 - y13 = 0
x3 - x1 - y31 = 0
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 1

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.000000
Y12	0.000000
Y21	0.000000
X3	0.000000
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0	Exp of x2	1
x3 =	0	Exp of x3	1
		sum	3
priority vector		w1	0.333
		w2	0.333
		w3	0.333

Bid/ No Bid Decision

For Contract Conditions

```
min z12 + z13 + z23
        st
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
x1 - x3 - y13 = 0
x3 - x1 - y31 = 0
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
x1 - x3 - y13 = 0
x3 - x1 - y31 = 0
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 1

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.000000
Y12	0.000000
Y21	0.000000
X3	0.000000
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0	Exp of x2	1
x3 =	0	Exp of x3	1
		sum	3
priority vector		w1	0.333
		w2	0.333
		w3	0.333

Bid/ No Bid Decision

For Risk in Fluctuation in Material Prices

```
min z12 + z13 + z23
    st
x1 - x2 - y12 = -0.287
x2 - x1 - y21 = 0.287
x1 - x3 - y13 = -0.287
x3 - x1 - y31 = 0.287
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = -0.287
x2 - x1 - y21 = 0.287
x1 - x3 - y13 = -0.287
x3 - x1 - y31 = 0.287
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 4

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.287680
Y12	0.000000
Y21	0.000000
X3	0.287680
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.28768	Exp of x2	1.333
x3 =	0.28768	Exp of x3	1.333
		sum	3.666
priority vector		w1	0.272
		w2	0.363
		w3	0.363

Bid/ No Bid Decision

For Company Strength in Industry

```
min z12 + z13 + z23
      st
x1 - x2 - y12 = -0.223
x2 - x1 - y21 = 0.223
x1 - x3 - y13 = -0.223
x3 - x1 - y31 = 0.223
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = -0.223
x2 - x1 - y21 = 0.223
x1 - x3 - y13 = -0.223
x3 - x1 - y31 = 0.223
x2 - x3 - y23 = 0
x3 - x2 - y32 = 0
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 4

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.223140
Y12	0.000000
Y21	0.000000
X3	0.223140
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.22314	Exp of x2	1.249
x3 =	0.22314	Exp of x3	1.249
		sum	3.499
priority vector		w1	0.285
		w2	0.357
		w3	0.357

Bid/ No Bid Decision

For Owner/ Client and Consultant Identity

```
min z12 + z13 + z23
st
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
x1 - x3 - y13 = -0.47
x3 - x1 - y31 = 0.47
x2 - x3 - y23 = -0.133
x3 - x2 - y32 = 0.133
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 + z13 + z23 = 0
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
x1 - x3 - y13 = -0.47
x3 - x1 - y31 = 0.47
x2 - x3 - y23 = -0.133
x3 - x2 - y32 = 0.133
z12 - y12 >= 0
z12 - y21 >= 0
z13 - y13 >= 0
z13 - y31 >= 0
z23 - y23 >= 0
z23 - y32 >= 0
zmax - z12 >= 0
zmax - z13 >= 0
zmax - z23 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 8

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.336470
Y12	0.000000
Y21	0.000000
X3	0.470000
Y13	0.000000
Y31	0.000000
Y23	0.000000
Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.33647	Exp of x2	1.399
x3 =	0.47	Exp of x3	1.599
		sum	3.999
priority vector		w1	0.250
		w2	0.35
		w3	0.399

	P.P.	P.T	Comp.	R.M.P	N.W	C.S.I	C.C	P.M	E.P	O.C.C.I	
Project 1	0.238	0.272	0.2	0.272	0.272	0.285	0.333	0.333	0.166	0.25	
Project 2	0.333	0.363	0.35	0.363	0.318	0.357	0.333	0.333	0.333	0.35	
Project 3	0.428	0.363	0.449	0.363	0.409	0.357	0.333	0.333	0.5	0.399	
Sum of each column	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	
	0.238	0.272	0.2	0.272	0.272	0.285	0.333	0.333	0.166	0.25	**2.625**
	0.333	0.363	0.35	0.363	0.318	0.357	0.333	0.333	0.333	0.35	**3.435**
	0.428	0.363	0.449	0.363	0.409	0.357	0.333	0.333	0.5	0.399	**3.938**

Where: Project 1: Insurance & Pension General Cooperation Building (IPGC), Project 2: Rehabilitation and Reconstruction of Al- Qudus Street in Gaza, Project 3: Construction of Jemezat Sabil Sewage Pumping Station.

P.P: Past Profit in Similar Projects, P.T: Project Type, Comp.: Competition, R.M.P: Risk in Fluctuation in Material Prices, N.W.: Need for Work, C.S.I: Company Strength in Industry, C.C.: Contract Conditions, P.M.: Payment Method, E.P: Experience in Such Projects, O.C.C.I: Owner, Client and Consultant Identity

Priority Vector is (2.625/10, 3.435/10, 3.938/10) = (0.262, 0.343, 0.393).

Mark-Up Decision

For Experience in Such Projects

```
min z12
st
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 = 0
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 8

OBJECTIVE FUNCTION VALUE

E+000.0000000 (1

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
Z13	0.000000
Z23	0.000000
X1	0.000000
X2	0.336470
Y12	0.000000
Y21	0.000000
X3	0.470000
Y13	0.000000
Y31	0.000000
Y23	0.000000

Y32	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.33647	Exp of x2	1.399
		sum	2.399
priority vector		w1	0.416
		w2	0.583

Mark-Up Decision

For Past Profit in Similar Projects

min z12
st
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end

Objective Function from first stage = 0

The second is given by the following:

min zmax
st
z12 = 0
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.336470
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0.33647	Exp of x2	1.399
		sum	2.399
priority vector		w1	0.416
		w2	0.583

Mark-Up Decision

For Competition

min z12
st
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end

Objective Function from first stage = 0

The second is given by the following:

min zmax
st
z12 = 0
x1 - x2 - y12 = -0.336
x2 - x1 - y21 = 0.336
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

```
LP OPTIMUM FOUND AT STEP      3
```

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.336470
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.33647	Exp of x2	1.399
		sum	2.399
priority vector		w1	0.416
		w2	0.583

Mark-Up Decision

For Need for Work

min z12
st
x1 - x2 - y12 = -0.405
x2 - x1 - y21 = 0.405
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
Objective Function from first stage = 0

The second is given by the following:
min zmax
st
z12 = 0
x1 - x2 - y12 = -0.405
x2 - x1 - y21 = 0.405
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.405470
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0.40547	Exp of x2	1.500
		sum	2.500
priority vector		w1	0.399
		w2	0.600

Mark-Up Decision

For Contract Conditions

```
min z12
st
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 = 0
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 1

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.000000
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0	Exp of x2	1
		sum	2
priority vector		w1	0.5
		w2	0.5

Mark-Up Decision

For Owner/Client and Consultant Identity

```
min z12
st
x1 - x2 - y12 = -0.182
x2 - x1 - y21 = 0.182
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
```

Objective Function from first stage = 0

The second is given by the following:

```
min zmax
st
z12 = 0
x1 - x2 - y12 = -0.182
x2 - x1 - y21 = 0.182
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end
```

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 3
OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.182320
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0.18232	Exp of x2	1.199
		sum	2.199
priority vector		w1	0.454
		w2	0.545

Mark-Up Decision

For Project Type

min z12
st
x1 - x2 - y12 = -0.223
x2 - x1 - y21 = 0.223
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
Objective Function from first stage = 0

The second is given by the following:

min zmax
st
z12 = 0
x1 - x2 - y12 = -0.223
x2 - x1 - y21 = 0.223
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.223140
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0.22314	Exp of x2	1.249
		sum	2.249
priority vector		w1	0.444
		w2	0.555

Mark-Up Decision

For Risk in Fluctuation in Material Prices

min z12
st
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
Objective Function from first stage = 0

The second is given by the following:

min zmax
st
z12 = 0
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0

zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 1
OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.000000
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0	Exp of x2	1
		sum	2
priority vector		w1	0.5
		w2	0.5

Mark-Up Decision

For Project Location

min z12
st
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end

Objective Function from first stage = 0

The second is given by the following:

min zmax
st
z12 = 0
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0

x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon r

unning the second stage is shown below
LP OPTIMUM FOUND AT STEP 1

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.000000
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0	Exp of x2	1
		sum	2
priority vector		w1	0.5
		w2	0.5

Mark-Up Decision

For Project Size

min z12
st
x1 - x2 - y12 = -0.223
x2 - x1 - y21 = 0.223
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end

Objective Function from first stage = 0

The second is given by the following:
min zmax
st
z12 = 0
x1 - x2 - y12 = -0.223
x2 - x1 - y21 = 0.223

z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE

E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.223140
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage			
x1 =	0	Exp of x1	1
x2 =	0.22314	Exp of x2	1.249
		sum	2.249
priority vector		w1	0.444
		w2	0.555

Mark-Up Decision

For Project Duration

min z12
st
x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
x1 = 0
zij >= 0
end
Objective Function from first stage = 0

The second is given by the following:

min zmax
st
z12 = 0

x1 - x2 - y12 = 0
x2 - x1 - y21 = 0
z12 - y12 >= 0
z12 - y21 >= 0
zmax - z12 >= 0
x1 = 0
zmax >= 0
zij >= 0
end

The outcome from LINDO upon running the second stage is shown below

LP OPTIMUM FOUND AT STEP 1

OBJECTIVE FUNCTION VALUE
E+000.0000000

VARIABLE	VALUE
ZMAX	0.000000
Z12	0.000000
X1	0.000000
X2	0.000000
Y12	0.000000
Y21	0.000000
ZIJ	0.000000

then from second stage

x1 =	0	Exp of x1	1
x2 =	0	Exp of x2	1
		sum	2
priority vector		w1	0.5
		w2	0.5

	P.P.	P.T	Comp.	R.M.P	N.W	C.C	E.P	O.C.C.I	P.L	P.S	P.D	
Project 2	0.416	0.444	0.416	0.5	0.399	0.5	0.416	0.454	0.5	0.444	0.5	
Project 3	0.583	0.555	0.583	0.5	0.6	0.5	0.583	0.545	0.5	0.555	0.5	
Sum of each column	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	
	0.416	0.444	0.416	0.5	0.399	0.5	0.416	0.454	0.5	0.444	0.5	**4.993**
	0.583	0.555	0.583	0.5	0.6	0.5	0.583	0.545	0.5	0.555	0.5	**6.006**

Where: Project 2: Rehabilitation and Reconstruction of Al- Qudus Street in Gaza, Project 3: Construction of Jemezat Sabil Sewage Pumping Station.

P.P: Past Profit in Similar Projects, P.T: Project Type, Comp.: Competition, R.M.P: Risk in Fluctuation in Material Prices, N.W.: Need for Work, C.C.: Contract Conditions, E.P: Experience in Such Projects, O.C.C.I: Owner, Client and Consultant Identity, P.L: Project Location, P.S: Project Size, P.D: Project Duration.

Priority Vector is (4.993/11, 6.006/11) = (0.453, 0.546).

Appendix (C)

Quality Statements
Questions to be answered and included in Envelope A, Quality Submission.

General Scheme Management

1) *Overall Approach, Methodology and Programme*

The tenderer shall provide a description of the methods he will use to achieve a defined project programme during key stages of the project. This should include the following key points:

- Design Phase A programme
- Chart(s) showing the Contractor's project programme identifying the key activities leading to the production of all project deliverables and statutory processes including allowances for comments to be made by the project manager and/or supervisor;
  - Text identifying the key challenges, risk and opportunities (environmental, engineering, Statutory Undertakers' plant and other issues) in delivering the project according to the stated programme and the methods that will be employed to manage programme risk

2) *Innovation and Continuous Improvement Strategy*

The successful tenderer will be expected to deliver continuous improvements throughout the progress of the project, through appropriate project benchmarking.

The tenderer is to provide a statement on his approach to innovation and continuous improvements and how this would be carried out during the various phases and processes of the project.

3) *Public Relations*

The Tenderer is to outline his intended approach to managing customer care and relations with the public and other affected parties throughout the statutory process and during construction. This should include but not be limited to the identification of the major issues that are expected to be encountered, how these shall be dealt with, and how the proposals will enhance all aspects of the delivery of the project.

4) Risk

The Tenderer shall submit the completed Contractor's Risk Register that shall be included in Envelope A, the Quality Submission.

In addition to the submission of the Risk Register, the tenderer is required to submit a statement to include but not limited to:

- Their understanding of the Contractor's and Employer's Risk
- Their attitude to the handling of both Risk Register
- How they propose dealing with all risks in the project and how these may be dealt with in the Risk Register

5) Target Cost and Activity Schedule

The Tenderer is required to provide a statement on his methodology for the development of the prices. The statement shall indicate how the tenderer will compile the total of the prices at various times and how these shall demonstrate the inclusion of risk allowances. This shall demonstrate how the prices will deliver the works information and are auditable, verifiable and give best value. The tenderer shall indicate how the Activity Schedule will be developed and related to the programme. The Tenderer shall indicate his understanding of the significance or otherwise of the Employer's scheme cost estimate.

The statement shall include, but not be limited to, details of:

- The development of Target Prices using tendered rates in the Schedule of Rates
- The elemental base(s) from which the prices will be developed including the proposed basis of labour and plant rate compilations and proposed resource output derivations
- Procedures for the monitoring of the prices throughout the various phases of the project

- Procedures for agreeing changes to the prices caused by compensation events or other changes
- Procedures for identifying the costs of compensation events and other changes affecting the prices and any calculation for incentives
- The conditions upon which the tenderer would propose to employ sub-contractors and the procedures that would be put in place to ensure that the sub-contractor's element of the total of the prices gives best value
- The Tenderer should comment on how and when he considers that market testing of the prices should be carried out.

6) Open Book Accounting

The tenderer is required to provide a statement regarding the operation of Open Book Accounting, this is to include:

- Who within the Tenderer's propose team will have responsibility for the accounts
- What checking/validation/review procedures are to apply
- The procedures for comparison of prices with cost for elements of work and what actions will be taken if it is established that estimates and prices do not accurately reflect the cost of the work done
- How payment applications for incurred costs will be reconciled against the state of competition and quality of work included in the application
- What procedures will be used to ensure cost is allocated against the correct task or activity and correct charging structure.
- Whether the tenderer would propose to engage sub-contractors on a cost reimbursable basis and if so what procedures will be established to ensure that such costs are auditable.

7) Quality and Key Performance Indicators

The tenderer is required to provide the following:

a) Submit a schedule of the proposed contents of the Quality Plan
b) A statement on the Control of Quality

The tenderer is to provide a statement regarding the basis, content and operation of his quality management system, including: management reviews, audits, checking, the procedures for monitoring, report and dealing with non-conformities (including defects as defined in the Contract), corrective actions and customer feedback.

c) Organisation and Management

The tenderer is to provide an organisation, management and communications statement that will be updated during the course of the project. The statement shall include the following:

- An organisational chart showing lines of communications, and number and location of key staff including support structure and their links with the project manager and supervisor, as well as links to the key stakeholders.
- A description of the individual roles of key staff within the quality management system and their location
- The job description of key staff, defining principal responsibilities and level of delegated authority, and outlining training and experience requirements.
- A description of the proposed support structure for these key staff
- Joint venture responsibility arrangements

d) A statement of the operation and quality management of the tenderer's proposed supply chain, including procedures for the selection of suppliers and sub-contractors.

e) Approach to delivery of best value. How will this be guaranteed rather than low quality/ low price and how this could be dealt with within the development of the prices and incentives.

f) The tenderer shall put forward his proposals for key performance Indicators, and how these shall be developed and measured throughout the contract.

g) Environmental Management and Sustainability

The tenderer is to indicate his approach to environmental management and how he proposes to manage and develop this throughout the progress of the project.

8) Staff for the Project

The tenderer shall provide an organisation chart for the contract showing lines of communication and location of key staff including support structure and their links with the Employer, Project Manager, Supervisor and other supply chain partners.

The tenderers shall submit a statement on role played by key staff, defining principal responsibility and level of delegated authority.

The tenderer is required to name the staff being put forward for the following posts by completing a copy of the following table which indicates the staffing required for the Design and Construction Phases.

The tenderers shall submit CVs for the staff listed below in a specified format.

Where it is intended that staff from the Design Phase continue their equivalent role in the Construction Phase restate name only against role. Where new staff would be engaged for the Construction Phase CVs are required.

Position	Design Phase	Name	CV	Const. Phase	Name	CV	As Design Phase
Key Project Staff							
Contractor's Contract Director							
Contractor's Project Manager							
Senior Estimator							
Programme Planner							
Safety and Health Co-ordinator							
Public Liaison Officer							
Design Director							
Design Project Manager							
Project Supervisor							
Environmental Co-ordinator							
Environmental Manager							
Temporary Works							

Manager							
Quality Systems Manager							

Position	Design Phase	Name	CV	Const. Phase	Name	CV	As Design Phase
Other Named Project Staff							
Landscape Architect							
Highway Team Leader							
Geotechnical Team Leader							
Structures Team Leader							
Traffic Team Leader							
Orders Specialist							
Drainage Team Leader							
Ecologist							
Archaeologist							
Noise Specialist							
Air Quality Specialist							
Water Quality Specialist							
Hydro geologist							
Soil Specialist							
Construction Highways Team Leader							
Construction Structures Team Leader							
Site Agent							
CE Clerk of Works (1)							
CE Clerk of Works (2)							
Environmental Clerk of Works							

9) Approach to Partnering

It is the intention of the Employer that the Contract is carried out in a spirit of mutual trust and co-operation. To this end the Employer proposes that there is an informal partnering arrangement established within four weeks of award of the Contract and continued through to the successful delivery of the project.

The tenderer shall put forward his proposals for partnering. These should include how the tenderer proposes to operate the project partnering with particular reference to the requirements of this scheme.

Proposals should make reference to the parties who should be part of any partnering, management of the project partnering, and performance monitoring.

Design Phase

10) Estimate of Time Based Hours for Works in the Design Phase

The tenderer shall provide an estimate of the time based hours by key staff members and support staff for all activities required to carry out the Contractor's duties in the Design Phase. The tenderer shall complete the Table (C2). These estimates of hours will be compared with the model which reflects the Employer's best estimate of the input required to carry out the Contractor's duties in the Design Phase. This Table must only be included in Envelope A, the Quality Submission.

The tenderer shall note that no pricing data for staff shall be included in the quality envelope. Pricing data for staff shall only be included in Envelope B, the Financial Submission, and this will be inserted in the Employer's model for the purpose of financial assessment.
Tenderers should provide a brief explanation of the estimate of hours provided.

11) Environmental Impact Statement

The tenderer should provide statements giving his appreciation of the issues presented by the project and his proposed methods as appropriate for outline design (indicating the level of detail required where appropriate), environmental assessment, mitigation and reporting the Environmental Impact Statement for the following:

- Water quality and drainage
- Landscape and visual impact issues
- Sites of nature conservation interest
- Protected species

- Archaeology
- Farms and landholdings
- Off site requirements such as construction compounds and spoil disposal area
- Construction techniques and environmental management
- Liaison and consultation with relevant statutory bodies and others outlining proposals for future consultation of issues raised to date.

12) Environmental Data Requirements

The tenderer should review the environmental reports listed and identify any additional baseline data or surveys that might be required and any consequent implications for the Project Programme.

13) Design Development

The tenderer shall submit a statement that will demonstrate his understanding of the following aspects of the project design development during the Design Phase. The tenderer is at liberty to add statements regarding other aspects believed to be of importance:

- The status of the design of the Preferred Route at tender
- The development of the design which is required from appointment up to the presentation of the Layout Approval Plans at a scale of 1:2500 at week 13
- The format of the Technical Working Group, how it may be used throughout the various stages of Design Phase and the benefits to be gained for the Contractor and the Employer
- The development of the design beyond week 13 to the publication of Compulsory Purchase Orders
- Development of the design from the publication of Compulsory Purchase Orders to the Oral Hearing
- How the detailed design will be taken forward after the Oral Hearing and An Bord Planeala decision prior to the start of the Construction Phase
- Comment on the traffic surveys and reports included in the tender documents, the validity of the work, any additional works that may be

necessary and how this may affect the design, and the relevance of the traffic studies of the Oral Hearing

- Comment on the geotechnical work carried out and the topographical survey and state any further survey work anticipated.
- Comment on the locations of the structures currently identified, how the designs for these will be developed, with particular regard to the structure at River Suir
- Describe how the drainage design will be taken forward, to include both the engineering and environmental aspects of this
- Comments on the socio-economic importance of Cashel/Mitchelstown Road Improvement Scheme to the region

14) Compulsory Purchase Orders

The tenderers shall submit a statement to illustrate his understanding of the statutory process involved in Compulsory Purchase Orders publication, and how this can be achieved within the required time. It shall explain the relationship between the development of the design of the works, the Compulsory Purchase Orders and the Environmental Impact Statement and state the responsibilities of the Contractor and Employer. The tenderer shall also indicate his ideas for improving the processes and timescale.

15) Oral Hearing

The tenderer shall submit a statement demonstrating their understanding of the arrangements and procedures involved in an Oral Hearing, and state their understanding of responsibilities for them. The tenderer shall state how the design can influence the duration and outcome of the Statutory Process.

Construction Phase

16) Construction Issues

The tenderer shall submit a methodology for the construction of the works. This shall include preliminary statements regarding:

- Locations for site compounds
- Site access

- Workforce to include policy for local recruitment of staff and operatives
- Supply of materials and equipment
- Proposals for site communications
- Maintenance of existing access including for pedestrians, cyclist and equestrians as well as vehicles
- Traffic management, with particular reference to the existing N8
- Other construction issues, including maintenance of existing drainage regimes, construction of the structures, earthworks including any tips, geological issues etc.

17) Safety and Health

The tenderer is required to submit the completed Safety and Health questionnaire.

- Safety and Health Questionnaire

Three separate responses are required on safety and health, one from the tenderer who will be required to take the role of Project Supervisor (Construction Stage), another from his designer and another from the organization that will be Project Supervisor (Design Stage).

Each requirement takes the form of questionnaire which must be completed in full and signed by a director of the company concerned.

1. Project Supervisor (Construction Stage) Questionnaire

   Company details

   Name and address:

   Company tel. no.:

   Company fax no.:

   - Name of person specifically responsible for safety and health within the Company and state his/her safety qualifications.
   - Does your Company have a safety and health policy? (If Yes, please enclose your Company's current policy.) How regularly is your policy reviewed, and by what method?
   - Who is responsible for the safety and health policy within your Company? (Please indicate their name and status within the Company)

- How are the policy and advice communicated to both your staff and others? How does your Company ensure these are followed by both your staff and others?
- How are risks to safety and health assessed, controlled and monitored in your Company?
- What criteria does your company use for assessing its safety and health performance and the frequency at which performance is reviewed?
- How do you assess the need for, and implementation of, corrective action?
- Has your Company gained and safety awards? If YES, please provide details.
- Has your company been prosecuted for breach(es) of any safety and health legislation in the last five years? If YES, please give details.
- Does your Company have a safety and health training policy relating to both office based and on site personnel? If YES, please provide details and training practices.
- Does your Company provide a safety and health induction course for all new staff? If Yes, please provide details.
- How does your company assess the expertise, capability and resources of organizations sub-contracted to carry out your work?
- How does you Company implement the requirements of Regulation 6 of the Regulations.
- What experience does your Company have on projects of a similar type and scale of the N8?

Certification of the project supervisor (Construction Stage) S&H Questionnaire is required as follows:

I certify that the information provided within this questionnaire is accurate. (This form should be signed by a Director of the Company who should state his/her position.)

Signature..Position..............................

For and on behalf of...

Date:..

2. Competence of Designer Questionnaire

Company details

Name and address:

Company tel. no.:

Company fax no.:

- Name of person specifically responsible for safety and health within the Company and state his/her safety qualifications of the above person.
- Does your Company have a safety and health policy? (If Yes, please enclose your Company's current policy.) How regularly is your policy reviewed, and by what method?
- Who is responsible for the safety and health policy within your Company? (Please indicate their name and status within the Company)
- How are the policy and advice communicated to both your staff and others? How does your Company ensure these are followed by both your staff and others?
- Please state how the requirements of Regulation 5 of the Regulations are implemented with your design procedures.
- The Regulations call for the production of a pre-tender Safety and Health Plan and a Safety and Health File. Please state your experience in the production of such documents.

- What system of risk assessment in design do you use and how are the findings communicated to the Project Supervisor (Design Stage) and other parties?
- Does your Company have a safety and health in design training policy relating to both offices based and on-site personnel? If YES, please provide details and training practices.
- Does your Company provide a safety and health induction course for all new staff? If YES, please provide details.
- What recent experience do you have of working in the role of designer (as related to the Regulations) on similar projects to N8 Cashel to Mitchelstown?
- What are the safety and health experience and qualifications of staff you would allocate to this project?
- What other technical support or facilities are available from within your Company?
- What specialist back up and technical facilities will you make available from outside your Company?

Certification of the Designer's S&H Questionnaire is required as follows:

I certify that the information provided within this questionnaire is accurate. (This form should be signed by a Director of the Company who should state his/her position.) Signature...Position.............................. For and on behalf of... Date:..

3. Project Supervisor (Design Stage) Questionnaire

Company details

Name and address:

Company tel. no.:

Company fax no.:

- Name of person specifically responsible for safety and health within the Company and state his/her safety qualifications of the above person.
- Does your Company have a safety and health policy? (If Yes, please enclose your Company's current policy.) How regularly is your policy reviewed, and by what method?
- Who is responsible for the safety and health policy within your Company? (Please indicate their name and status within the Company)
- How are the policy and advice communicated to both your staff and others? How does your Company ensure these are followed by both your staff and others?
- Please state how the requirements of Regulation 4 of the Regulations are implemented.
- The Regulations call for the production of a pre-tender Safety and Health Plan and a Safety and Health File. Please state your experience in the production of such documents.
- What procedures to you use for the assessment of competence and resources of designers and contractors and how are the findings communicated to the client?
- Does your Company have procedures for reporting and investigating accidents and near misses?
- Does your Company have a Project Supervisor Training Policy? Please provide training practices.
- What recent experience do you have of working in the role of Project Supervisor (Design Stage) on similar projects to N8 Cashel to Mitchelstown?
- What are the safety and health experience and qualifications of staff you would allocate to this project?
- What other technical support or facilities are available from within your Company?
- What specialist back up and technical facilities will you make available from outside your Company?

- How shall the pre-construction Safety and Health Plan be developed during the Design Phase?

Certification of the Project Supervisor (Design Stage) S&H Questionnaire is required as follows:

I certify that the information provided within this questionnaire is accurate. (This form should be signed by a Director of the Company who should state his/her position.) Signature..Position.............................. For and on behalf of.. Date:..

18) Safety and Health

The tenderer should provide an outline for the Construction Environmental Management Plan including proposals for the following:

- Construction aims and objectives
- Staff and responsibility
- Induction, training and communication
- Relevant legislation, licences and consents
- Documentation and audit
- Monitoring
- Energy and waste
- Emergency procedures
- Seasonal Constraints
- Surface and ground water protection and monitoring
- Species protection and monitoring
- Noise, vibration and dust
- Archaeology and finds
- Contaminated land

- Construction compounds

19) Handover and Maintenance

The tenderer shall submit a statement to show his understanding of the issues of completion of and handover of the road, the rectification of defects in the subsequent two years, and the interaction between their work during these two years and the work of the agent responsible for the day to day maintenance of the national road.

The tenderer shall also submit a statement setting out how they will ensure the successful establishment of the landscape, ecological and water quality measures for the scheme including completion, monitoring and handover of the environmental works and his responsibilities for the three year maintenance of this work.

The tenderer shall also put forward proposals for the completion of and handover to the Employer of all issues that are outstanding regarding the statutory processes including land purchase.

Pricing Tables

Constituent of the Fee	
1.	**Head office charges and overheads**
2.	**Insurance premiums**
3.	**Profit**
4.	
5.	
6.	
7.	
8.	

Table C1: Constituents of the Fee %. (Quality Submission, Envelope A)

Staff	**Design Phase A**	**Design Phase B**	**Design Phase C**	**Total Estimated Hours by Staff Grade**
Contractor's Contract Director				
Contractor's Project Manager				
Senior Estimator				

Programme Planner				
Safety and Health Co-ordinator				
Quality Engineer				
Public Liaison Officer				
Design Director				
Design Project Manager				
Project Supervisor				
Environmental Co-ordinator				
Landscape Architect				
Highway Team Leader				
Geotechnical Team Leader				
Structures Team Leader				
Traffic Team Leader				
Orders Specialist				
Drainage Team Leader				
Ecologist				
Archaeologist				
Noise Specialist				
Air Quality Specialist				
Water Quality Specialist				
Hydro geologist				
Soil Specialist				
Senior Engineers/ Senior Environmental Consultant				
Engineers/ Environmental Consultants				
Assistant Engineers/ Assistant Environmental Consultant				
Senior Engineering Technicians/ Senior Environmental technicians				
Engineering Technicians/ Environmental technicians				
Junior Engineering Technicians/Junior Environmental Technicians				
Total Estimated Hours by Activity				

Table C2: Time Based Hours for each Activity in Design Phase

Grade/ Position	
Brief Description of Grade/Position	
Normal Working Hours per annum	hrs

Item		€ per annum
Salary/Wages (full time equivalent for part time staff)		€
Other payments (bonus, overtime, car allowance etc.)		€
Payment in relation to employment (Employer's NI, Employer's Pension etc.)		€
Sub Total 1		€
Basic Hourly Rate (= Sub Total 1)/ normal working hours)		€
	%	
Overheads		
Hourly Rate for Time Based Work		€

Table C3: Staff Rate Form (to be enclosed in the Financial Submission, Envelope B)

South Tipperary County Council
County Hall, Clonmel, Ireland.

Telephone 052-34455
Fax 052-24355/23228
E-mail secretar@southtippcoco.ie

Comhairle Contae Thiobraid Árann Theas
Aras and Chontae, Cluain Meala, Eire.

Teileafon 052-34455
Fax 052-24355/23228

Vallis Aurea Suriensis

File Ref: 14/131(A)(C)(1)

27th April, 2004

Orig JM
Cn MJ/File

Attention: Mr Mike Jones
Ascon Balfour Beatty JV
c/o Ascon Limited
Kill
Co Kildare

RECEIVED
28 APR 2004

RE: ECI – N8 CASHEL/MITCHELSTOWN ROAD IMPROVEMENT SCHEME – TENDER DOCUMENTS

Dear Mr Jones,

Further to my letter of the 14th April, 2004, I now enclose a hard copy of the contract documents in relation to the above scheme. These are in four volumes, i.e. Volume 0,1,2 and 3. Please note that the final date for submission of these documents is **4.00 pm on Friday, 25th June, 2004**. The documents should be enclosed in a sealed envelope and marked **"Tender for ECI – N8 Cashel/Mitchelstown Road Improvement Scheme"** and addressed to **Tender Reception Office, Aras an Chontae, Emmet Street, Clonmel, Co. Tipperary.**

If you have any queries in relation to the documents, please do not hesitate to contact the undersigned at telephone number **052 – 34538 or email eva.okeeffe@southtippcoco.ie**

Yours sincerely,

Michael J. O'Malley,
Senior Engineer, Roads.

RECEIVED FOR TENDER
28 APR 2004 04013

POTENTIAL OF REVERSE AUCTIONS IN CONSTRUCTION PROCUREMENT

Sam Wamuziri and Nadine Abu-Shaaban

Construction Management Group, School of Built Environment, Merchiston Campus, Napier University, Edinburgh, EH10 5DT, UK

On-line auctions are widely used in commerce and industry to facilitate sale of goods and services. In the construction sector, use of reverse auctions is however relatively new. Reverse auctions utilise secure Internet technology to enable contractors to participate in the tendering process. This involves contractors bidding on-line against each other and progressively lowering their prices in order to win the contract. Types of auctions and how they influence bidding strategies are firstly discussed in this paper. The use of online bidding in other sectors of business is discussed. This is followed by a description of the procedure for online bidding for construction projects. The relative attractions and disadvantages of reverse auctions in construction procurement are discussed. Guidelines on the proper context for using reverse auctions in construction procurement are provided. Recommendations for further research to provide improved understanding and limitations of using reverse auctions in construction procurement are given.

Keywords: bidding, procurement, reverse auctions, e-commerce.

INTRODUCTION

On-line auctions are widely in commerce and industry to facilitate procurement of goods and services. In the construction sector, reverse auctions utilise secure Internet technology to enable contractors to participate in the tendering process. They allow contractors to bid on-line against each other by lowering their prices in an effort to win the contract. In the UK, the Office of Government Commerce is championing use of reverse auctions to improve procurement efficiency and save project costs. Use of reverse auctions in bidding for construction work is however the subject of current debate. In this paper, the different types of auctions are firstly described including their informational implications and how they influence bidder behaviour. A review of published information on use of reverse auctions in other sectors of business is provided. The procedures for using reverse auctions in construction procurement are discussed. An evaluation of the advantages and disadvantages of using reverse auctions from both clients' and contractors' perspectives is given. Guidelines for a proper context for using reverse auctions in construction procurement are given including general recommendations for further research to provide further information and improved understanding.

TYPES OF AUCTIONS

There are several types auctions for sale of items of value. Klemperer (1999) distinguishes four main types of auctions namely: English, Dutch, Sealed first price and Sealed second price auctions. In the English auction, auctioneer begins with the lowest acceptable price, usually the reserve price. The bidding then goes up until no one is willing to go above the last bid made. Whoever made the final bid gets the item at the price bid. In an English auction, no one is going to stop bidding if there is still the opportunity to buy the item at a price less than his valuation, and also no one is going to continue bidding once his last rival has stopped. English auctions therefore result in the item being sold to the highest bidder, but the actual price paid for the object will be close to the second highest valuation. From a bidders point of view, rational bidding in an English auction involves remaining in the bidding until the price reaches the bidder's own valuation. English auctions or sequential bidding is appropriate when the supply of goods is limited or if an item is unique. The seller of an item in an English auction can specify a reserve price. If the highest bid offered does not exceed the reserve price, the seller is not obliged to sell the item. He may elect to retain the item, thus releasing the highest bidder of any obligation.

In a Dutch auction, which is also known as a multiple items auction, the auctioneer begins with a high asking price that is then lowered until a participant is willing to accept the auctioneer's price. This type of auction is used to offer multiple items for sale or when it is important to auction goods quickly. Used furniture stores sometimes run a Dutch auction by reducing the price of unsold pieces by some percentage say 10 percent after regular intervals of time.

In the sealed first-price auction, all bidders simultaneously submit bids in such a way that no bidder knows the bid of any other participant until all of the bids are opened at the time of the sale. The bidder with the highest offer wins the auction. If there is a tie among the bids, the winner is chosen at random from those who made the highest bid. Rational bidding in this type of auction requires guessing the valuation of the likely next highest bidder and bidding this amount. The winning bidder earns a profit from the difference between his valuation and the next highest bid. Sealed first price auctions are widely used in awarding of construction contracts. The main difference in this case is that the contract is awarded to the lowest bidder.

The sealed second-price auction is identical to the sealed first-price auction, except that the winning bidder pays the second highest bid value rather than his own. If there is tie for the first place, the winner is chosen at random from the highest bidders. Also called a Vickrey auction, the auctioneer stands to get higher bids in this type of auction compared to other types of auctions because bidders are forced to bid their true valuations. For a bidder, bidding below one's true valuation lessens the probability of winning without altering the amount one would pay. Bidding above ones true valuation implies counting on someone else to bid your true valuation. In which case you will pay your true valuation and perhaps more and therefore not make a profit. No rational bidder would adopt this strategy.

Other types of auctions include the Japanese auction, the take-it-or-leave it auction and finally the candle auction. In a Japanese auction, the auctioneer goes up in price. Bidders have to state whether they are still in the bidding race or not and cannot re-enter once they quit. The advantage of this type of auction is the informational transparency in the valuations of the items. The take-it-or-leave it auction is perhaps the simplest type of auction. In this case, the seller writes a price on the object and prospective buyers can take or leave the item. In a candle auction, the item is awarded to the last bid before a candle goes out. In the next section, electronic reverse auctions are defined followed by an evaluation of published research into their application in procurement of goods of services.

ELECTRONIC REVERSE AUCTIONS

The first Internet auctions were set up in 1995 by auction houses such as Onsale and eBay. Many auction web sites have been established since then with the aim of helping to develop a web-based community in which buyers and sellers are brought together in an auction format to buy and sell items.

Electronic auctions are an Internet-based method of bidding for the supply of goods and services. It can be categorized as standard or reverse online auctions. In the standard online auctions, the auctioneer sets the starting bid amount and the bidders drive the price up as they compete to outbid each other. The highest bidder at the close of the auction is the winner of the auction. While in the electronic reverse auctions, the auctioneer sets the starting bid and the bidders compete in successive rounds of downward bidding for the opportunity to offer the specified product or service. It is estimated that in 2001, approximately US $ 50 billion worth of goods and services were purchased in the USA using reverse auctions (Smeltzer and Carr, 2003).

The communication mechanisms used in online auctions are primarily based on unicast technology. As the number of online auctions increases, the quality of communication between the auctioneer and the bidders become crucial. Unicast-based online auctions suffer from delays of communication between the bidders and the auctioneer. Studies by Liu, Wang and Fei (2003) using laboratory experiments have shown that the communication performance of multicast-based online auctions is significantly better than that of traditional unicast based auctions. This is mainly because multicast online auctions have much lower packet delays and higher traffic rates compared with traditional unicast-based online auctions. Although both types suffer from packet loss when the traffic is heavy, multicast technology is less sensitive to network congestion.

Massad and Tucker (2000) compare on-line auctions with traditional in-person auctions from consumers' point of view. They tested relationships between the sales of 60 collectible figurines at an in-person auction against corresponding figurines at on-line auctions conducted by e-bay. It was found that online auctions exceeded in-person auctions in both mean initial bid prices and mean final sales prices. They suggested that dealers could make a reasonable profit by purchasing goods at in-person auctions and then selling them on-line. Massad and Turker (2000) suggest that this is due to information synergies in online auctioneering at present, which should most probably close in time due to increased use of computer communications technology. These findings clearly illustrate the ability of Internet auctions to stimulate and increase effective demand of products by reaching a large number of potential customers in a short time at a low transaction cost.

Stein, Hawking and Wyld (2003) analysed use of reverse auctions in procurement. They focussed on the auction process itself and the outcomes from buyers and sellers perspectives. They concluded that reverse auctions lead to considerable savings in procurement costs typically of the order of 20 percent. Whether such savings could be sustained in the long term is a matter for further research. Their case study also found that use of reverse auctions led to replacement of the in-house procurement function and increased supplier distrust. Whilst this study revealed that both the auction vendor and the buyer gained by participating in the auction, the seller was disappointed because of the considerable input of time and effort required before he could participate. Further disappointment on the part of the seller arose from the fact that reverse auctions placed cost over other factors such as service delivery, customer support and buyer-supplier relationships in awarding the contract.

Joia and Zamot (2002) studied the efficiency, efficacy and accountability of the electronic auction system developed by the Brazilian Federal Government using a case study approach. They analysed the procurement process adopted by the Ministry of Social Security to purchase pharmaceutical products from several suppliers. They concluded that the system is efficient and that savings of approximately 30 percent in product costs for the public sector can be achieved including also a reduction in purchasing time involved. Their study however raised concerns of accountability when using the system.

Settoon and Wyld (2003) examined the potential impact of strategic implementation of reverse auctions on macroeconomic indicators and government spending in Southeast Asia. They used data from the year 2000 collected from the Asian Development Bank (ADB) and the World Bank. The data was used to assess cost savings from competitive bidding events using econometric analysis for five countries namely Indonesia, Malaysia, Philippines, Singapore and Thailand. The function areas or sectors for which savings estimates were made include:

- General public services (e.g. law and order)
- Defence
- Education
- Health
- Social Security and Welfare
- Housing and community amenities (e.g. human settlement, regional, rural and urban development).
- Economic services (e.g. agriculture, industry, utilities, transportation and communication.).

Setton and Wyld (2003) demonstrate that the use of reverse auctions could in the case of each country result in cost savings that average between US $ 468 million to US $ 1.6 billion. Such savings could be applied to reduce government deficits or increase government consumption. Such savings in efficient government procurement can help increase a country's GDP. Further analysis for the year 2000 based on the five countries in the study showed that every additional dollar spent caused GDP to rise by a government spending multiplier greater than 8.0.

In order to understand purchasers' motivations, promises, risks and conditions for reverse auctions success, Smeltzer and Carr (2003) interviewed 41 purchasing professionals in the USA. They identified cycle time reduction, and lower purchase price as promises from the buyers' perspective. From the suppliers' viewpoint, the main reasons for using reverse auctions were increased business opportunities and improved communication about the market. They suggested that the following are the main conditions necessary for reverse auctions to be successful namely:

- Specifications for the goods and services to be auctioned must be clear and comprehensive. These should include quality requirements, delivery time, location requirements, order quantities and service issues.

- The required quantities must be large enough to encourage suppliers to bid and to enable them to achieve production efficiencies.
- Appropriate supply market conditions must exist to foster competition between suppliers. Suppliers must also have spare capacity to be able to take on increased business.
- Suppliers must have skilled professional staff in order to understand and implement the purchasing procedures
- The appropriate computer and software technology must be in place.

In the UK construction industry, use of reverse auctions in bidding for construction work is a subject of current debate. Every year, private sector companies and government departments in the United Kingdom issue thousands of requests for proposals to companies seeking to secure contracts. This process is mostly paper-based with mail, faxes and agents being used to deliver important documents. The Office of Government Commerce (OGC) is championing use of reverse auctions for public sector procurement. It is estimated that savings of approximately 25 percent will be cut from procurement costs by using reverse auctions when compared with traditional paper-based tender processes. One of the areas identified for such savings is construction procurement. In the next section, we describe the online bidding process with specific reference to the guidelines developed by the UK Construction Industry Council.

ONLINE BIDDING IN CONSTRUCTION

In general, the on-line bidding process for construction contracts as identified by the Construction Industry Council, 2005) is as follows. The process starts with the client or his advisors inviting bidders to submit technical proposals to participate in the reverse auction. Drawings and specifications for the proposed contract and instructions on how to participate in the auction are availed to all potential bidders in advance of the event. The client will provide software and training as necessary. The online auction is scheduled, with a specified start and closing time, and conducted on behalf of the owner by a third party; an IT application service provider (ASP). A reserve price may be determined by the client, which is usually based on a consultant's estimate. All bidder identities are kept confidential during the reverse auction event. Once the reverse auction begins, bidders submit initial prices. The submitted prices are ranked and then communicated back to all bidders. Bidders can re-submit new lower prices as many times as they want up to the specified closing time, with the new ranking communicated back to all contractors with their new ranking. The auction process closes when no more new bids are placed and the auction time expires. All bidders are immediately notified of their final bid ranking. The auction service provider notifies the owner of the bidding results. Finally, the owner will contact the winning bidder to complete the formal award of the contract.

Online bidding for construction contracts promises increased efficiency, transparency and reduced costs and this can be seen clearly from the following advantages:

- On-line tendering can be used to standardise the procurement process.
- Bidders can be monitored.
- It increases competitiveness among tendering contractors.

- It provides an opportunity for unknown contractors to bid for work
- Comparison of bids is easy and simplified.
- There is reduction in paperwork, postage and photocopying costs.
- It facilitates simultaneous communication with multiple bidders
- Communication with bidders is easier and faster.
- Contractors have the opportunity to submit more than one bid.

Online bidding has a number of disadvantages particularly in the procurement of complex services such as those in engineering and construction projects. On-line reverse auctions have become a popular method for reducing the price of purchased goods and services. However, they expose clients to the real possibility of awarding a contract to the lowest cost bid rather than to one offering best value. In the construction sector, it can be argued that this is contrary to the partnering principles advocated for in the Egan report.

Using auctions as a method of procurement can also lead to difficulties in exercising control over specifications for the goods and services being bought. In reverse auctions, competitors have to deal with multiple rounds of bidding and as a result this may encourage imprudent bidding practices. The process may move too quickly giving competitors insufficient time to accurately reassess their costs. This will have an impact on both the bidder and the owner. If a winning bidder discovers that they are making a loss during project execution, they may resort to using low quality materials, poor workmanship and proliferation of claims.

Some well-qualified bidders may not participate in online bidding because they do not trust the process. In reverse auctions there will always be an opportunity for contractors to re-submit their prices and therefore this can encourage them to initially submit artificially high prices rather than their competitive prices. As a result the lowest possible price may not actually be offered.

Potter and Lovatt (2002) explore the legal obligations of the parties to an auction sale with reference to the newly defined liability of managers of auction sales where properties are sold without a reserve price. They studied the rules in English Law underlying the formation of auction contracts. They conclude that according to English Law, if an auctioneer refuses to sell to the highest bidder then he could incur liability to the bidder if there is no reserve price. These legal developments have implications for awarding of construction contracts in online bidding. It would appear that if factors such as experience in the industry, financial strength of the bidder, attitude to quality, safety record etc. have already been taken into account in the prequalification process and if there is no reserve price in the online bidding process, there would appear to be an obligation on the part of the client to award the contract to the lowest bidder unless there are prior explicit instructions to the contrary.

Bywell and Oppenheim (2001) discuss the issue of fraud in online auctions. The buying, selling and transacting of money over the Internet raises important security issues. They also discuss the problem of bidding under false names and addresses. In construction procurement, a fraudulent client could introduce a fictitious contractor to help drive down bid prices- a phenomenon referred to as shill bidding. Reverse auctions could also lead to deterioration in buyer-supplier relationships. Griffiths (2003) discusses the ability of online auctions to adversely affect relationships between suppliers and buyers. He points out that the trust between the buyer and supplier might be affected if the reverse auction is conducted in an unethical way. For example, inviting suppliers to an auction who never actually in the end win contracts perhaps due to size, quality or language barriers and yet their participation may help the client just to push the prices down.

A major UK client recently used reverse auctions to procure £1 billion worth of engineering consultancy work. All potential bidders however were unanimous in their condemnation of the reverse auction process. A survey reported in the New Civil Engineer of 24/31 March 2005 revealed that 87 Percent of civil engineers were against use of reverse auctions with only 10 percent in favour of their use.

Emiliani and Stec (2004) reports results of recent research to assess how aerospace parts and subcomponent suppliers specialising in producing engineered machined parts and sub-assemblies reacted to participation in online reverse auctions. Their results showed that online reverse auctions have shortcomings as far as incumbent suppliers are concerned. Key findings of the research were (Emiliani and Stec, 2004) that:

- Incumbent suppliers realised few benefits, if any, from participating in online reverse auctions
- Over 70 percent of incumbent suppliers actively seek opportunities to charge their customer higher prices as direct result of their participation in online reverse auctions when the opportunity to do so arises.
- Incumbent suppliers viewed online reverse auctions as a divisive purchasing tool that damages relationships with long time customers
- Most incumbent suppliers drop out of the bidding after one to two years
- A few suppliers responded to online reverse auctions with efforts to improve productivity by adopting lean production practices.

GUIDELINES FOR ONLINE BIDDING

The primary objective of using reverse auctions in construction procurement should be to obtain best value and not merely to lower the contract price. Most client organisations are aware that lowest tender price does not always equate to lowest final account. Several trade associations representing client and consultant organisations in Canada, USA and the UK have opposed using reverse auctions in construction procurement. Government is driving their use in the UK and as a major client for construction services, contractors and consultants cannot ignore these developments.

To make online bidding successful, clients and their professional advisors should start with a pre-qualification process. Comprehensive information regarding the project or services required should be developed and submitted to all potential bidders first. Clear pre-qualification criteria should be developed and communicated to all potential bidders to ensure parity of tendering and to provide them with the opportunity to collate information for their technical bids. Selection criteria might include experience on similar projects, health and safety record, financial stability, qualifications and experience of key personnel, etc. Bidders who meet the pre-qualification criteria should be trained on the methods to be used for reverse auctions. It is also in the best interests of the parties for the client, potential bidders the IT application service provider to sign a confidentiality agreement. The numbers of competing bidders should be disclosed and it is important that there is transparency about the bidding process including the weighting criteria and methods used to combine the financial and technical proposals before arriving at the wining bid.

If all the technical submissions have been reviewed, the only piece of information to be derived from the reverse auction is the price. Best value should be the guiding principle in awarding construction contracts and clients should emphasise this to all potential bidders. Clients should weigh the benefits of using reverse auctions and should only adopt this approach if the benefits outweigh the costs. If the client chooses reverse auctions, they should stick to the approach rather than starting with the well known sealed bid methods and only to change their mind later. Industry well known conditions of contract such ICE conditions of Contract, JCT conditions of contract or the NEC Engineering and Construction Contract should still be used and should not be amended without good reason. Any amendments to standard forms if required should only be done after taking legal and technical advice.

CONCLUSIONS

Different types of auctions used in sale of goods and awarding of contracts include the English, Dutch, Sealed first price and Vickey auctions. The key features of each type of auction are discussed in the paper. Reverse auctions are essentially Dutch auctions. They have been used widely in sale of goods although their use in construction procurement is still relatively new. Published research on use of reverse auctions for sale of goods is reviewed. There is evidence that reverse auctions have the potential to lower procurement costs but may harm client-supplier relationships. The procedures for using reverse auctions in construction procurement are given followed by a discussion of their potential advantages and disadvantages. There is concern in the construction industry that using reverse auctions goes contrary to the Egan principles. There is also the perception that because reverse auctions focus exclusively on price, best value cannot be obtained. Guidelines for using reverse auctions in construction procurement are provided. It is argued that best value can still be achieved provided other factors are taken into account in contractor selection. Such factors include contractor's attitude to quality, health and safety record, experience of similar projects and track record in the industry. Training of potential bidders about the process is essential including transparency about the entire pre-qualification and online bidding process.

Since use of reverse auctions in construction procurement is in its infancy, further research is needed if their potential benefits are to be realised. The challenges and risks associated with their use must also be appreciated. The first question that research should address is to identify the type of construction projects, products or services for which reverse auctions are suitable. The second is to assess the impact of using reverse auctions on purchasing practices in the construction supply chain. The third is to identify the savings claimed from use of these auctions and the sources of such cost savings. A further area that research should address is the impact of reverse auctions on client-contractor relationships and specifically whether they hinder or help build trust - a key ingredient in modern construction procurement practice.

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