UNIVERSITY OF SOUTHAMPTON

A DECISION SUPPORT SYSTEM FOR THE SELECTION OF THE OPTIMUM CONTRACTOR

By

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A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF ENGINEERING AND APPLIED SCIENCE

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

SOUTHAMPTON

June 2001

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE
CIVIL AND ENVIRONMENTAL ENGINEERING
FOR DOCTOR OF PHILOSOPHY

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By Ibrahim M. M. Moustafa

Awarding the tender to the lowest bidder can result in potentially serious problems, which necessitate the need for including a wide range of other criteria. This will form the basis of selection, where some of these criteria will be contractor related and others will relate to the specific characteristics of the project and the requirements of the owner. This research develops a decision support system that combines the different characteristics of the contractors with the specific conditions, requirements and objectives of the project under consideration. This research was divided into six phases.

Phase (1) literature review to identify and investigate all criteria related to the contractor selection by identifying the root causes of the problems resulting from selecting an inappropriate contractor.

Phase (2) literature review to identify an efficient and scientific method for the criteria identification and assessment for the collected criteria. The Delphi method was found to be an efficient technique to identify the criteria regarding the contractor and the Analytic Hierarchy Process (AHP) an efficient method to assess the criteria for each project on a project-by-project basis.

Phase (3) refinement and evaluation for the collected criteria by implementing the Delphi method using questionnaire and structured interviews to get the expert opinion. Three countries were surveyed namely: (i) Egypt, (ii) Kuwait and (iii) the UK.

Phase (4) researches decision support system techniques to structure the proposed contractor selection decision system (DSS). AHP was also found an efficient method to be used in structuring the DSS.

Phase (5) Structuring the logic of the contractor selection decision system. The system is divided into two processes. The first one is the contractor screening and pre-qualification process and the second process is the final selection process. A combination of the criteria that were investigated by the Delphi method with those that were assessed by the AHP is carried out to produce a short list of contractors that continues in the next stage. This combination accumulates expertise of the contract award and considers the project individuality and hence provides the required flexibility, which is a key objective of this research. An extended enhanced Knowledge-Based Expert System was developed to enable the new DSS to be used as a practical management tool.

Phase (6): verification and analysis of the contractor selection system developed. A simulated project case is used to illustrate the logic consistency, workability and flexibility. A sensitivity analysis is performed to verify the system using case studies. The analysis established that the DSS is not sensitive to a single criterion and can even tolerate the miss-judgment in single criteria due to the fact that the use of multiple criteria.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the continuing support of large number of people. I will always look up to their personal and professional standards and hope to be a similar role model for others in the future.

First, I want to thank my principal advisor Mr. *Mike Riley*. Mike, without your support, advice, criticism and patience, I would have never been able to complete this research and thesis. You taught me that it is important to establish a good starting point in order to develop a vision. Also, to be able to work towards that vision in today's world. And then, to articulate clearly the conclusions from the work in order to form a new starting point.

I wish to express my sincere gratitude and humble appreciation to Professor *Sami Fereig* for his diligence, guidance and encouragement during agonizing and frustrating days of research and writing for this dissertation. It is difficult to find the words to express my appreciation for what Prof. Sami has done for me during my study at the University of Southampton. A great thank you also goes to Mrs. Fereig for her advice and encouragement. I acknowledge Engineer Zakria Abdul-Hamid from the Kuwaiti Ministry of Housing, Contract department and Engineer Ihab Halimah from Kuwait University, contract department for their co-operation in providing me with the actual data for the two case studies, which support the system developed.

I owe special thanks to David Brown and Said El-Hajjar for being good friends and being with me when I found difficulties.

I wish to thank my wife Nabila, for her understanding, encouragement and support during these years. I wish to thank my mother, my son Ahmad and my daughter Essra'a for their patience while I was away during my study. Finally, I wish to thank God.

LIST OF CONTENTS

LIST OF TABLES V

LIST OF FIGURES VI

CHAPTER 1: INTRODUCTION 1

1.1 INTRODUCTION 1
1.2 PROBLEM STATEMENT 3
1.3 RESEARCH OBJECTIVES 3
1.4. SCOPE OF THE RESEARCH 4

CHAPTER 2: RESEARCH METHODOLOGY 7

2.1: INTRODUCTION 7
2.2 PHASE 1: INVESTIGATING ALL CRITERIA RELATED TO THE CONTRACTOR SELECTION 8
2.2.1 Contractor-related problems *8*
2.2.2 Project-Related Problems *8*
2.3 PHASE 2: RESEARCHING THE APPROPRIATE IDENTIFICATION AND ASSESSMENT TECHNIQUES FOR THE COLLECTED CRITERIA 10
2.4 PHASE 3: REFINING AND EVALUATING THE CRITERIA COLLECTED (THE DELPHI METHOD) 10
2.5 PHASE 4: RESEARCHING DECISION SUPPORT SYSTEM TECHNIQUES TO STRUCTURE THE PROPOSED CONTRACTOR SELECTION DECISION SYSTEM (DSS) 13
2.6 PHASE 5: STRUCTURING THE LOGIC OF THE DECISION SUPPORT SYSTEM 13
2.6.1 Structuring the Logic of Selection System *14*
2.6.1.1 Stage-1: Screening Process (Pre-qualification) 14
2.6.1.2 Stage-2: Final Selection Process 14
2.6.2 Structuring the Logic of a Computer-based System *15*
2.6.2.1 Step-1: Knowledge Representation and Structuring 15
2.6.2.2 Step-2: The Inference Engine 15
2.6.2.3 Step-3: Developing the input and output interface 15
2.7 PHASE 6: SYSTEM VERIFICATION AND ANALYSIS 16
2.7.1 Step-1: Verification *16*
2.7.2 Step-2: Sensitivity analysis *16*

CHAPTER 3: LITERATURE REVIEW OF THE CURRENT CONTRACTOR SELECTION SYSTEMS 17

3.1 INTRODUCTION 17
3.2 THE CHARACTERISTICS OF THE CONSTRUCTION INDUSTRY AND ITS IMPACT ON THE CONTRACTOR SELECTION 17
3.3 REVIEW OF THE CURRENT CONTRACTOR SELECTION PROCEDURES 20
3.3.1 Competitive Tendering *20*
3.3.1.1 Open Tendering 21
3.3.1.2 Selective Tendering 21
3.3.1.3 Risk Assessment in Competitive Tendering 24
3.3.1.4 Recent Innovative Selection Processes in Competitive Tendering 25
3.3.2 Negotiated Tendering *26*
3.3.3 Partnering Method *27*
3.4 CONTRACTOR SELECTION SYSTEMS NOT USING LOWEST TENDER SUM 29
3.5 PROBLEMS ARISING FROM THE USE OF CURRENT CONTRACTOR SELECTION METHODS 31

3.5.1: Contractor Related Problems ... *32*
3.5.1.1 Problems Related to Contractor's Experience record ... 34
3.5.1.2 Problems Related to Contractor's Past Performance ... 35
3.5.1.3 Problems Related to Financial Stability ... 36
3.5.1.4 Problems Related to Contractor's Current Capabilities ... 38
3.5.2 Problems Related to the Specific Project Conditions and Requirements ... *40*
3.6 PREVIOUSLY DEVELOPED SOLUTION METHODS FOR CONTRACT AWARDING PURPOSES USING MULTI-CRITERIA ... 40
3.6.1 Linear Model ... *41*
3.6.2 Linear Model Incorporating Multiple Rating ... *41*
3.6.3 Model Based on the Multi-Attribute Utility Theory ... *42*
3.7 SUMMARY AND CONCLUSIONS ... 44

CHAPTER 4: LITERATURE REVIEW OF THE CRITERIA IDENTIFICATION AND ASSESSMENT TECHNIQUES ... 45

4.1 INTRODUCTION ... 45
4.2 MULTIPLE CRITERIA ASSESSMENT TECHNIQUES ... 45
4.2.1 Ranking ... *46*
4.2.2 Rating ... *47*
4.2.3 Paired Comparison ... *47*
4.2.4 Successive Comparisons ... *49*
4.3 DELPHI METHOD ... 51
4.4 MEASUREMENT SCALE ... 55
4.4.1 Selection of Measurement Scale for the Delphi Method ... *56*
4.5 SUMMARY AND CONCLUSIONS ... 57

CHAPTER 5: CRITERIA REFINEMENT, ASSESSMENT AND EVALUATION ... 58

5.1 INTRODUCTION ... 58
5.2 CRITERIA IDENTIFICATION AND REFINEMENT ... 58
5.2.1 Identification of Knowledge Sources (Expertise) ... *58*
5.2.2 Criteria Refinement Using the Delphi Method ... *59*
5.2.3 Questionnaire Description and Design ... *61*
5.2.4 Design Of The Criteria Coding System ... *62*
5.2.5 Questionnaire Verification ... *64*
5.3 SURVEY APPROACH AND RESULTS ANALYSIS ... 65
5.3.1 Step-1: Defining Survey Population ... *65*
5.3.2 Step-2: Estimating survey sampling ... *66*
5.3.2.1 Sample Estimate and Population Value ... 68
5.3.2.2 Sample Size - Egypt's Building Construction Engineering ... 71
5.3.2.3 Sample Size- Egypt's Heavy Construction Engineering ... 71
5.3.2.4 Sample Size-Kuwait's Building Construction Engineering ... 72
5.3.2.5 Sample Size-Kuwait's Heavy Construction Engineering ... 73
5.3.2.6 Sample Size-UK's Building Construction Engineering ... 74
5.3.2.7 Sample Size-UK's Heavy Construction Engineering ... 75
5.4 RESULTS OF SURVEY ... 76
5.4.1 Heavy Construction Projects – Survey Results Analysis ... *78*
5.4.1.1 Contractor's Experience Record Decision Criteria Group (DCG1) 'Heavy Projects' ... 78
5.4.1.2 CONTRACTOR'S PAST PERFORMANCE DECISION CRITERIA GROUP (DCG2) 'Heavy Projects' ... 81
5.4.1.3 Financial Stability Decision Criteria Group (DCG3) 'Heavy Projects' ... 84
5.4.1.4 Contractor's Current Capability (DCG4) 'Heavy Projects' ... 87
5.4.1.5 Contractor's Submitted Plans for the Proposed Project (DCG5) 'Heavy Projects' ... 90
5.4.2 Building Construction Projects – Survey Results Analysis ... *92*
5.4.2.1 Contractor's Experience Record Decision Criteria Group (DCG1) 'Building Projects' ... 92

5.4.2.2 Contractor's Past Performance Decision Criteria Group (DCG2) 'Building Projects'.....94
5.4.2.3 Contractor's Financial Stability Decision Criteria Group (DCG3) 'Building Projects' ...94
5.4.2.4 Criteria Groups of Contractor Current Capabilities (DCG4) and Contractor's Submitted Plans to the proposed Project (DCG5) 'Building Projects' 97
5.5 FINAL RESULTS OF THE CRITERIA REFINEMENT....................100
5.5.1 Decision Criteria related to the Specific conditions of the Project under Consideration and the Client's Objectives 101
5.5.2 Decision Criteria related to the Contractor Qualification....................102
5.6 SUMMARY AND CONCLUSIONS....................112

CHAPTER 6: RESEARCH OF DECISION SUPPORT SYSTEMS (DSS) METHODS AND TECHNIQUES....................114

6.1 INTRODUCTION....................114
6.2 REVIEW OF DECISION SUPPORT SYSTEMS....................115
6.3 THE DECISION MAKER AND THE MULTIPLE CRITERIA APPROACH....................117
6.3.1 Decision-Making Methods Using Multiple Criteria Approach....................117
6.3.1.1 Goal Programming Technique....................119
6.3.1.2 Cluster Analysis....................120
6.3.1.3 Multi-Attribute Utility Theory (MAUT)....................121
6.4 ANALYTIC HIERARCHY PROCESS (AHP)....................122
6.4.1 Theory of the AHP....................123
6.4.2 Mathematical Foundations of the AHP....................124
6.4.3 Applications of the Analytic Hierarchy Process (AHP)....................127
6.4.3.1 Illustrative Example of using AHP....................128
6.4.4 Comparison of Multiple Criteria Solution Methods....................133
6.5 CONCEPTUAL APPROACH TO SELECT THE MOST APPROPRIATE CONTRACTOR TO SPECIFIC PROJECT....................136
6.6 COMPUTER SUPPORT TOOLS FOR DECISION SUPPORT SYSTEM DEVELOPMENT....137
6.6.1 Justification for selection of Knowledge-Based Expert System....................138
6.6.2 Knowledge in the KBES....................139
6.6.3 Knowledge Representation for KBES....................141
6.6.3.1 Rule-Based Systems....................141
6.6.3.2 Frame -Based Systems....................142
6.6.3.3 Model-Based Reasoning....................143
6.7 DEVELOPMENT SYSTEMS USING KBES....................143
6.7.1 Tools for KBES Development....................144
6.7.1.1 Computer Language....................145
6.7.1.2 Expert System Shells....................145
6.7.2 KBES Applications in Civil Engineering....................148
6.8 SUMMARY AND CONCLUSIONS....................152

CHAPTER 7: STRUCTURING THE LOGIC OF THE CONTRACTOR SELECTION DECISION SUPPORT SYSTEM (DSS)....................153

7.1 DESIGN CONCEPT OF CONTRACTOR SELECTION SYSTEM....................153
7.1.1 Knowledge Identification: Criteria Refinement....................154
7.2 STRUCTURE OF THE DECISION SUPPORT SYSTEM (DSS)....................156
7.2.1 Structure of the DSS Logic for the Contractor Selection System....................156
7.2.2 Analytical solution for the DSS of the Contractor Selection System....................159
7.2.2.1 Process 1: Contractor Screening Process - DSS Analytical Solution....................159
7.2.2.2 Process 2: Final Selection Process - DSS Analytical Solution....................164
7.2.2.3 Consistency Check....................168
7.3 STRUCTURE OF THE KNOWLEDGE-BASED EXPERT SYSTEM (KBES)....................168
7.3.1 Step 1: Knowledge Representation....................169
7.3.2 Step 2: Inference Engine....................170

7.3.2.1 Design of the Mathematical Program Using Excel 5-Visual Basic 172
7.3.2.2 Design of the Database Program 175
7.3.3 Step 3. Developing the Input and Output Interface 176
7.4 SYSTEM VERIFICATION APPROACH 177
7.5 SUMMARY AND CONCLUSIONS 179

CHAPTER 8: SELECTION SYSTEM VERIFICATION, ANALYSIS AND DISCUSSION 180

8.1 INTRODUCTION 180
8.2 SELECTION SYSTEM VERIFICATION 180
8.3 SYSTEM APPLICABILITY AND FLEXIBILITY 182
8.4 SENSITIVITY ANALYSIS 184
8.4.1 The Effect of Change in the Relative Importance of the Project Criteria on the Contractors' Rank 185
8.4.1.1 Effect of Change in the Relative Importance of Project Cost versus Project Schedule on the Contractors' Rank 188
8.4.1.2 The Effect of Change in the Relative Importance of Project Cost over Project Quality 190
8.4.1.3 The Effect of Change in the Relative Importance of Project Schedule Over Quality 192
8.4.1.4 Summary and Conclusions on the Effect of Varying One Decision Criterion to Another on the Contractors' Rank 194
8.4.2 The Effect of Varying the Relative Importance of One Decision Criterion Over More Than One Criterion (Project's Criteria) on the Contractors' Rank 195
8.4.2.1 The Effect of Varying the Relative Importance of Project Cost Over Project Schedule and Project Quality 195
8.4.2.2 The Effect of Change in the Relative weight of Project Cost (PC1) over Project Schedule (PC2), Quality (PC3), Up to Client Management Involvement (PC6) 197
8.4.2.3 The Effect of Varying the Relative Importance of Project Cost (PC1) versus Project Schedule (PC2), Quality (PC3), Up to Political Criterion (PC9) 197
8.4.2.4. Summary and Conclusions of the Effect of Varying One Criterion to More than One on the Contractors' Rank 201
8.4.3 The Effect of Varying the Relative Importance of the Contractor's Pre-Qualification Criteria With Respect To the Project Criteria on the Contractors' Rank 202
8.4.3.1 The Effect of Varying the Importance of the Contractor's Experience Record (DCG1) Over the Contractor's Past Performance (DCG2) 203
8.4.3.2 The Effect of Varying the Importance of the Contractor's Past Experience Record (DCG1) versus the Contractor's Financial Stability (DCG3) 204
8.4.3.3 The Effect of Varying the Importance of the Contractor's Past Performance (DCG2) Over the Contractor's Financial Stability (DCG3) 207
8.4.3.4 The Effect of Varying the Importance of the Contractor's Past Experience Record (DCG1) Over the Past Performance (DCG2) and Financial Stability (DCG3) 208
8.4.3.5 Summary and Conclusions for the Effect of Varying One Pre-Qualification Criterion to One or more than one 212
8.5 SUMMARY AND CONCLUSIONS 213

CHAPTER 9: DISCUSSIONS, CONCLUSIONS AND FUTURE RESEARCH 215

9.1 DISCUSSIONS OF THE RESEARCH WORK 215
9.2 CONCLUSIONS 220
9.3 ACADEMIC CONTRIBUTIONS 221
9.4 FUTURE RESEARCH 222

REFERENCES 223

BIBLIOGRAPHY 233

APPENDICES 238

LIST OF TABLES

Table 3.1: Pre-qualification and Evaluation Methods Used by UK Clients 23

Table 3.2: Comparison of Partnered and Non-Partnered Projects 28

Table 3.3: Fundamental of Financial Analysis 39

Table 4.1: Ranking of criteria- Illustrative example 46

Table 4.2: Paired Comparison Ranks – Illustrative example 48

Table 4.3: Comparisons between the Criteria Assessment Techniques 50

Table 5.1: Survey Conducted for Knowledge Acquisition and Number of Responses 66

Table 5.2: Ratio Typical Analysed by Sureties 107

Table 6.1: Scale of Relative Importance 125

Table 6.2: Random Inconsistency Index (R.I) 127

Table 6.3: Comparison between the Analytic Methods of Multiple Criteria Problem 135

Table 6.4: Expert Systems –State-of-the Art... 151

Table 7.1: Random Inconsistency Index (RI) Values 168

Table 8.1: The Relative Degree of Importance for the Criteria of Specific

Project conditions.. 181

Table 8.2: The Relative Importance of DCG1, DCG2 and DCG3 with respect to PC1 in a

Pair Comparison Form 203

LIST OF FIGURES

Figure 2.1: Summary of the Research Methodology 9

Figure 3.1.a: Number of Construction Firms in the UK 19

Figure 3.1.b: Firms Percentage Distribution by Employee Size – 1970.................. 19

Figure 3.1.c: Firms Percentage Distribution by Employee Size – 1990 19

Figure 3.2: Causes of Project Failure 33

Figure 4.1: The Delphi Process (Grubbstrom, 1988) 53

Figure 5.1: The Knowledge Acquisition Process for Tender Evaluation 60

Figure 5.2: Decision Criteria Groups in Heavy Projects, UK, Egypt and Kuwait 80

Figure 5.3: Past Performance Decision Criteria Group (DCG2) 83

Figure 5.4: Financial Stability Decision Criteria Group (DCG3) 86

Figure 5.5: Contractor's Current Capability Decision Criteria Group (DCG4) 89

Figure 5.6: Contractor's Submitted Plans Decision Criteria Group (DCG5) 91

Figure 5.7: Decision Criteria Groups in Building Projects, UK, Egypt and Kuwait 93

Figure 5.8: Past Performance Decision Criteria Group (DCG2), Bldg. 95

Figure 5.9: Financial Stability Decision Criteria Group (DCG3) Bldg. 96

Figure 5.10: Contractor's Current Capability Decision Criteria Group-(DCG4) Bldg... 98

Figure 5.11: Contractor's Submitted Plans Decision Criteria Group-(DCG5) Bldg.... 99

Figure 5.12: The Organisation of the Criteria implemented in the proposed system.... 100

Figure 5.13: Proposed Project Factors (Criteria) 102

Figure 5.14: Pre-Qualification Criteria of Contractor – Screening process 104

Figure 5.15: Criteria of Final Contractor Selection Process 109

Figure 6.1: Hierarchy of Objectives within AHP Method 123

Figure 6.2: Traditional Approach to Computer Programming 138

Figure 6.3: The Architecture of a Typical KBES 139

Figure 6.4: The Component of a more Elaborate Knowledge-Based System 142

Figure 6.5: A Simple Life Cycle Model for KBES Development (Bedford, 1992)..... 144

Figure 7.1: Formalisation and Structure Phases of the Selection Process for the Contractor Selection 155
Figure 7.2: Decision Support System (DSS) Logic for the Selection System 158
Figure 7.3: The Construction of the KBES for Contractor Selection System 177
Figure 8.1: The Contractors Ranking as Percentage of the Highest Contractor 187
Figure 8.2: The Change in the Contractor's Rank due to the change in Project Cost (PC1) Versus Project Schedule (PC2) 189
Figure 8.3: The Change in the Contractor's Rank due to the change in Project Cost (PC1) Versus Project Quality (PC3)............ 191
Figure 8.4: The Change in the Contractor's Rank due to the change in Project Schedule (PC2) Versus Project Quality (PC3)............ 193
Figure 8.5: The Change in the Contractor's Rank due to the change in Project Cost Versus Project Schedule (PC2) and Quality (PC3) 196
Figure 8.6: The Change in the Contractor's Rank due to the change in Project Cost (PC1) Versus Project Schedule (PC2) - Client Mgmt. Involve (PC6) ...199
Figure 8.7: The Change in the Contractor's Rank due to the change in Project Cost (PC1) versus Proj. Schedule (PC2) - Political Factor (PC9) 200
Figure 8.8: The Change in the Contractor's Rank due to the change in Past Experience (DCG1) vs. Past Performance (DCG2) 205
Figure 8.9: The Change in the Contractor's Rank due to the change in Past Experience (DCG1) vs. Financial Stability (DCG3) 206
Figure 8.10: The Change in the Contractor's Rank due to the change in Past Performance (DCG2) vs. Financial Stability (DCG3) 209
Figure 8.11: The Change in the Contractor's Rank due to the change in Past Experience (DCG1) vs Past Performance (DCG2) and Financial Stability (DCG3)..211

CHAPTER 1: INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

The construction industry makes a significant contribution to the economy of most countries. For example, the construction industry in the U.K. in 1993 contributed £46.3 billion, which represented 8% of Gross Domestic Product (DoE, 1994). An important characteristic of the construction industry is that the majority of its participants are small businesses. For example, the construction industry in the U.K. consists of a large number of contracting firms and design consultants. There are about 210,000 contracting firms, which range from sole traders (numbering over 100,000 firms) to large firms employing a workforce of several thousands (Roger and Allan, 1993). The existence of this large number of firms, associated with the few restrictions for their entry into the market, results in intensive competition between them. In addition they compete in a highly volatile construction industry environment, where cash flow is of overriding importance.

Every project is different in design, layout, materials, construction methods, schedule, labour requirements, weather conditions and management. In addition, the construction environment is full of uncertainty with respect to labour markets, materials, productivity, market forces, resource availability, regulatory agencies' influences, weather and geographical conditions. Given these uncertainties and associated risks, the question arises as to how the client can select the best contractor to deliver the project. These uncertainties encourage the client to delegate the risks associated with their project to the contractor. Delegation of risks to the contractor is notable in publicly funded projects because funding is limited, with any overspending being subject to public scrutiny (Crowley and Hancher, 1995). Strict guidelines are followed in publicly funded projects to avoid accusations of bias or misappropriation of public funds when awarding contracts. In addition, public clients have a legal obligation to accept the lowest tender sum obtained through competitive tendering. Contracts are still being awarded to the lowest price bid (Russell, 1990b). A similar situation also exists in the private sector, especially if the client lacks experience in pricing a construction project.

The use of the "lowest price bid" philosophy is inadequate for selecting the optimum contractor, which has a direct effect on the contractor failing in the achievement of the client's objectives. In most countries the construction industry is very competitive, and using a single criterion in awarding a contract based on the "lowest price bid" philosophy which encourages bids which could be "suicidal[1]" low or misconceived (Ashley, 1980a).

Awarding a contract on a lowest tender sum basis can result in the selection of an inappropriate contractor and the project encountering potential problems such as cost over-runs, delays and poor quality (Russell, 1991). The contractor and, occasionally, the client often adopt a confrontational "claims oriented position" as a result of this strategy. Whilst a low tender sum may seem appealing to the client at tender stage, the situation becomes very sour if the contractor is not able to complete the work satisfactorily and the client has to appoint others to complete the project as required (Murdoch and Hughes, 1996).

A more appropriate approach is to use other criteria, such as experience, performance in past projects, financial strength, etc., which should be considered simultaneously. It is important to use additional decision criteria other than the lowest cost [Herbsman (1995) Friis (1987), Ledbetter (1994), Samuelson and Levitt (1982), Hardy et al. (1981)]. However, other researchers have focused on single principal criteria in addition to the cost, to evaluate the contractor, such as duration, experience, quality of performance, project safety, or discounted cash flow, etc.

A systematic methodology to incorporate all the relevant criteria simultaneously for the selection of the best contractor would be more beneficial. In addition to such criteria, the capability of each contractor should also be evaluated based on the specific requirements of the project at hand. A formal method incorporating a range of criteria to select the most appropriate contractor for a project is proposed. The method evaluates two sets of multiple criteria, namely (i) contractor criteria (past experience, performance in recent projects, current capability to perform the project, intended plans for the execution of the proposed project and overall financial stability) and (ii) project criteria (budget constraints, duration, quality requirements, safety level). In addition, a technique is presented to facilitate the evaluation of these sets of multiple criteria, which is simple, accurate and transparent. The proposed method can also provide an explanation of why a certain contractor is accepted or rejected for a particular project, which is necessary in public projects.

A suicidal bid is a bid which, when compared with another bids, appears by virtue of its price and possibly from other bid information to be based on a different perception of work (Ashley, 1980b)

1.2 PROBLEM STATEMENT

As stated above, awarding the tender to the lowest bidder can result in potentially serious problems, which necessitate the need for including a wide range of other criteria. This will form the basis of selection, where some of these criteria will be contractor related and others will relate to the specific characteristics of the project and the requirements of the owner.

Another problem relates to the quality of the individual contractor selection, which is limited by the knowledge and experience of the decision-maker. Experience varies from one to another, and there is no guarantee of the quality of the selection process. Even with experienced and knowledgeable decision-makers, there is still no systematic procedure, which utilises multiple criteria that match the contractor's qualifications and current capabilities with the specific project's conditions, client requirements and project objectives, to choose the most appropriate contractor.

Thus there is a need for a more objective, systematic, comprehensive and transparent method, that utilises multiple criteria, which is not hindered by the limitations of a single decision-maker and single decision criteria.

This thesis will present a practical solution to these problems.

1.3 RESEARCH OBJECTIVES

The key objective of this research is to reduce the consequent risks to the client of selecting an inappropriate contractor to carry out the project under consideration. It will do this by creating a decision support system, formulated in a structured way to assist the client in selecting the most appropriate contractor. This system should be adequate to match the varied characteristics of the contractors with the specific project conditions and the client's requirements. Also, the system should allow the experiences gained from carrying out the process of the contractor selection from other projects to be included.

The specific objectives of this research are as follows:

1. To establish the selection criteria related to the contractors.

2. To establish the selection criteria related to the projects.

3. To avoid the limitations due to a single decision maker in selecting the most appropriate contractor

4. To establish a technique which can analyse the multiple decision criteria, to produce a decision which is simple, transparent and practical

5. To verify the proposed technique.

1.4. SCOPE OF THE RESEARCH

Chapter 1: Introduction

Chapter 1 provides an introduction to the impact of construction industry characteristics on the individual contractors that carry out the main portion of the work in the industry. The problem statement is described and then the research objectives are defined.

The scope of this research is then detailed.

Chapter 2: Research methodology

The approach to develop the proposed contractor selection system is described in steps in this chapter. These steps were carried out to satisfy the objectives defined in Chapter 1. The methodology includes a literature review to investigate all possible criteria that may be related to the contractor selection. Then the research carried out to determine the appropriate scientific methods to identify relevancy of the collected criteria is described. The criteria were refined by surveying the available expertise from the construction industry using appropriate methods. A review of the decision support system techniques is carried out to structure the logic of the proposed contractor selection decision system. Then the system is tested and verified for use. The final step is the research discussion, conclusions and scientific contributions.

Chapter 3: Literature Review of the Current Contractor Selection System

This chapter illustrated the general absence of a systematic approach to contractor selection and showed the decision-maker depending on a restricted knowledge base limited to personal experience and dependent on the effort made by the decision-maker. Even when a systematic approach is used, this is limited to contractor pre-qualification and was shown to be inadequate for selecting the most appropriate contractor. The survey in this chapter addressed the need of use multiple criteria in the evaluation process to select the most appropriate contractor. In addition, it showed that there is a need for using a Decision Support System (DSS) to assist the decision-maker in the contractor selection with a high degree of confidence.

Chapter 4: Literature Review of the Criteria identification and Assessment Techniques

A Literature review was carried out to identify an efficient and scientific method that can be used in identifying the significant criteria and determining their relative degree of importance within the selection system. The Delphi method was selected to identify the contractor selection criteria and a Likert scale was used to determine their relative degree of importance.

Chapter 5: Criteria Refinement and Evaluation

In this chapter, the survey of the construction industry experts via postal questionnaires and personal structured interviews, which identified the significant decision criteria, is described. 450 questionnaire forms were issued and 177 were received back. The countries surveyed were Egypt, Kuwait and the UK. The questionnaire survey results confirm the need to implement multiple decision criteria in addition to using the bid price as the criterion for contractor selection. The current evaluation system of lowest bid price, according to this survey, accounts for about 8.9% of the total decision criteria in building projects and 9.4% in heavy projects. The criteria resulting from this survey constituted the main criteria of the proposed contractor selection system.

Chapter 6: Research of Decision Support System (DSS) Techniques

This chapter researched tools and techniques that could assist in developing the most suitable contractor selection decision system. The research showed that the analytical hierarchy process (AHP) is an efficient analytical method that can be used in deciding the most appropriate contractor according to the objectives of this research (Chapter 1). In addition, AHP can be used to evaluate the criteria that are related to the project on a project-by-project basis.

Chapter 7: Structuring the Logic of the Contractor Selection Decision Support System

The structure of this process needs to be flexible enough to allow the decision-maker the opportunity of matching the contractor's qualifications and capabilities to the specific conditions and requirements for the project under consideration. In this chapter, the structure of the selection process to identify the most appropriate contractor is carried out on the basis of these findings.

The design of the proposed contractor selection system has the following phases namely (i) knowledge identification (ii) structuring the decision support system, (iii) development of the computer based system and (iv) system verification. The structure of the decision support system (DSS) for selecting the most appropriate contractor and the development of its Knowledge–Based Expert System (KBES) is detailed in this chapter.

Chapter 8: Contractor Selection System Test, Verification and Analysis

In this chapter, the proposed system was implemented based on the criteria developed (chapter 5) and the system formulated (chapter 7). A simulated project case is used to illustrate the logic consistency, workability and flexibility.

A sensitivity analysis was performed to verify the proposed system. Two case studies were used to illustrate the system's applicability, viability and sensitivity. The sensitivity of using the system developed had been investigated through studying the impact of varying the relative weights of selection criteria on the system output.

The analysis established that this system is not sensitive to a single criterion and can even tolerate the miss-judgement of a single criterion due to the fact that it utilises multiple criteria. In addition, the weight of single criterion will not dominate the output.

Chapter 9: Research Summary, Discussions and Conclusions

This chapter summaries the research, provides conclusions, described the academic contributions and suggests directions for future research.

CHAPTER 2: RESEARCH METHODOLOGY

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2.1: INTRODUCTION

Each construction project has its specific conditions and client requirements, which is a consequence of construction industry characteristics (Roger and Allan, 1993). In addition, contractors have different qualifications, capabilities and plans that can influence the project under consideration. Problems will be encountered if the contractor's qualifications, capabilities and plans do not match these project-specific conditions and client requirements. These problems arise through the absence of a structured decision making system that can avoid selection of an unsuitable contractor. By considering criteria in addition to the bid price, through the use of a structured system for selecting the most appropriate contractor, better value for money will be obtained.

In this thesis, a model selection process is developed that involves multiple criteria along with the least price. The model first identifies various criteria that affect contractor selection. Then the model performs a screening analysis to shortlist; suitable contractors based on a small number of contractor performance criteria. A detailed analysis is then performed on the selected contractors by evaluating them based on all contractor evaluation criteria and the project- specific criteria, to decide on the most appropriate contractor to select for the job.

The research methodology passes through the following six phases:

(i) Phase-1: Identifying and investigating all criteria related to the contractor selection;

(ii) Phase-2: Researching to find the most appropriate identification and assessment techniques for the collected criteria;

(iii) Phase-3: Refining and evaluating the collected criteria;

(iv) Phase-4: Researching decision support system techniques to structure the proposed contractor selection decision system (DSS)

(v) Phase-5: Structuring the logic of the contractor selection decision system

(vi) Phase-6: Verification and analysis of the contractor selection system developed.

These phases are illustrated in Figure 2.1.

2.2 PHASE 1: INVESTIGATING ALL CRITERIA RELATED TO THE CONTRACTOR SELECTION

The literature review investigated the root causes of the problems due to poor selection of contractors and identified criteria, which could be used in the selection process to avoid poor selection.

The criteria identified were divided into two categories:

2.2.1 Contractor-related problems

127 criteria were identified from the literature review are shown in the Appendix A/o. It was found convenient to group these criteria under the following headings:

- Experience record
- Past Performance level
- Financial stability
- Current Capabilities
- Submitted plans for the proposed project

2.2.2 Project-Related Problems

9 project specific criteria were identified from the literature review and include the client's requirements, cost overruns, delays, poor quality, poor safety performance, over-complexity and adverse environmental impact. The full list is given in Section 5.5.1.

The next phase was to identify which of these 136 criteria would be significant to contractor selection, and then how to assign their relative degrees of importance.

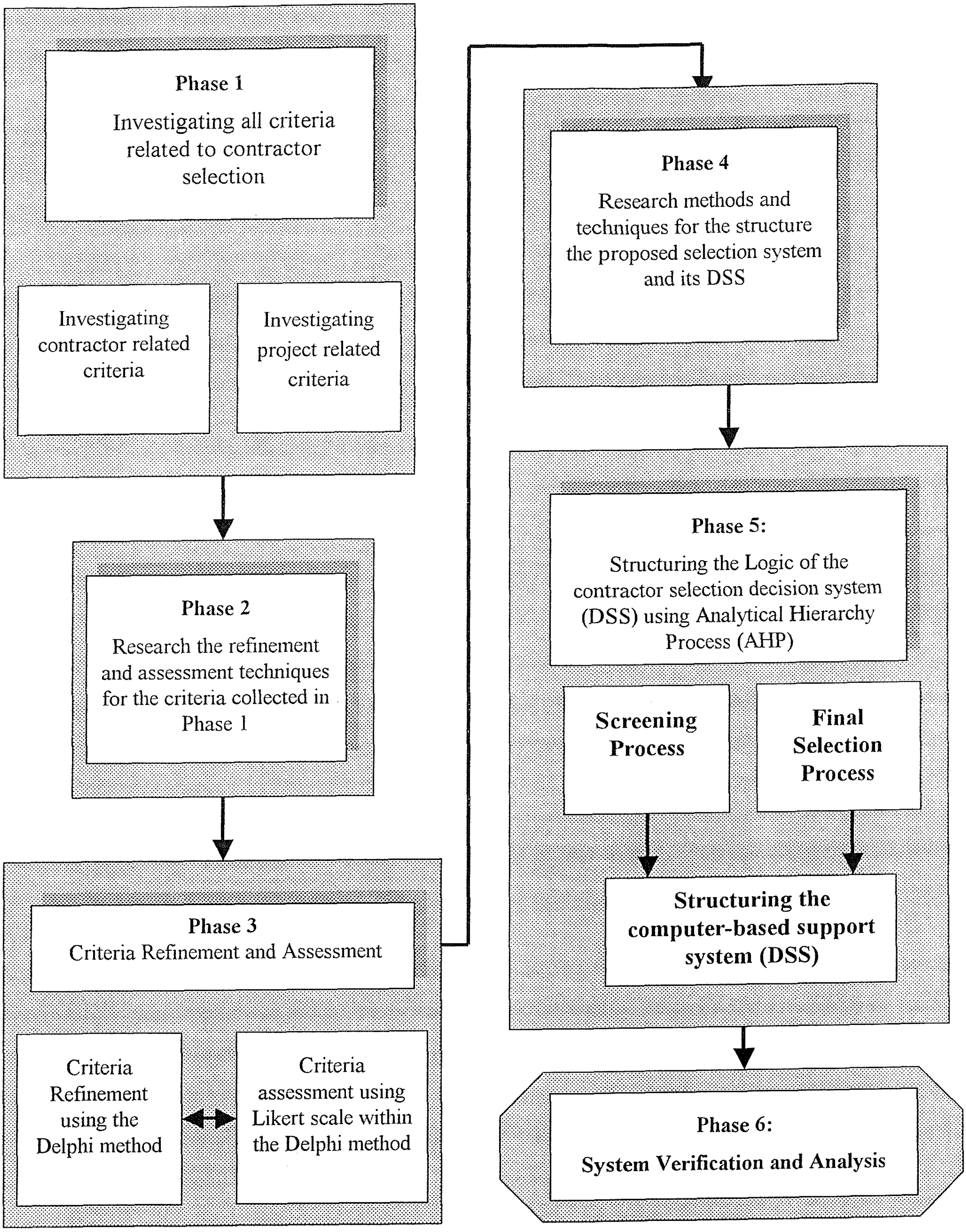

Figure 2.1: Summary of the Research Methodology

2.3 PHASE 2: RESEARCHING THE APPROPRIATE IDENTIFICATION AND ASSESSMENT TECHNIQUES FOR THE COLLECTED CRITERIA

The 127 criteria related to the contractor were divided into five groups, as indicated in phase-1. These criteria required refinement to ensure that only the significant criteria would be included and that the insignificant ones would be eliminated. Determining which criteria are significant to the contractor selection process and what their relative degrees of importance are required the input from experts. Experts in this context are defined as people with knowledge and experience of the contractor selection process. Therefore, different methods of criteria identification and evaluation were reviewed in this phase to satisfy this purpose.

The Delphi method was found to be an efficient method to carry out the refinement process of the contractor selection criteria that were collected in Phase-1. The Delphi method is defined as a systematic procedure to evoke opinions from a group of experts and then to obtain the relative importance of multiple criteria where structured information is lacking (Dalkey *et al*, 1970). Further research was undertaken to identify appropriate assessment tools that could be used within the Delphi method to help experts in determining the relative weight of the criteria identified. A five points Likert scale was used for this criteria assessment.

2.4 PHASE 3: REFINING AND EVALUATING THE CRITERIA COLLECTED (THE DELPHI METHOD)

It was considered inappropriate to use experts to generate the relative importance for the project-specific criteria since they need to be assigned by a decision-maker for the project. This gives the decision-maker the opportunity to reflect the real project conditions on project-by-project basis but at the same time provides the decision-maker with a method to help in deciding their relative importance, as a part of the decision system required. The decision-maker is defined in this research as the client or consultant who carries out the contractor selection process.

Expert persons from the construction industry were surveyed to evaluate the criteria related to the contractor, which investigated and collected in Phase-1. The evaluation process for these criteria was carried out using the Delphi method according to the research result in Phase-2, to decide only which criteria are relevant and appropriate. An expert was defined in this research as a professional from the construction industry who was involved in the contractor selection process. The number of experts required to carry out the Delphi method was established using the rule of simple size estimate for the representation of the whole population, as established by the previous investigators (Chisnall, 1988 and Margaret and Len, 1995. The survey of experts was carried out in three countries, namely Egypt, Kuwait, and the U.K.

The Delphi method was implemented as follows:

1. Postal questionnaires were issued to each expert.

2. Answers were obtained from the experts by paper-based questionnaires. The experts can include or exclude criteria to enrich the results and to add industrial relevance.

3. Statistical analysis of the mean and standard deviation of the experts' responses was carried out to create an "average" result (Appendix C, using the Statistical Package for Social Science - SPSS).

4. The "average" result was given back to the experts (through structured interviews) to ask if, in the light of the results so far, they wished to amend their answers.

5. Steps 3 and 4 were repeated using the amended results until the difference between the new and previous "average" became negligible. In this research programme, two rounds of interviews were carried out to achieve this.

The Delphi method includes 450 postal questionnaires used in the survey of experts in three countries surveyed: Egypt, Kuwait, and the UK. A sample of the initial questionnaires, which were used in Egypt and Kuwait for the implementation of the Delphi method, is given in Appendix A/o and that used in the UK is shown in Appendix A. The list of contacted addresses is given in Appendix F. Structured interviews were carried out with selected experts. 16 were interviewed in the first round carried out after the questionnaire survey and 6 were interviewed in the second round. The same form of questionnaire was used in the interviews as a basis for the validation process. These structured interviews were carried out in Egypt and Kuwait, as shown in Appendix F.

The final list of the criteria based on the above steps of the Delphi method is listed in the Tables D-1 and Table D-2 in Appendix D for heavy and building construction respectively. The description, reasons and measures of these criteria are illustrated in Tables D-3 to Table D-7 for each criteria group, which related to the contractor, as shown in Appendix D.

The expert found some of the criteria gathered in the initial list were irrelevant, and they also added some new criteria. The final list of refined criteria consists of 84 criteria, as detailed in Appendix D, which are broken down into five groups as follows:

Type of contractor criteria	**Total Number**
1. Experience Record	13
2. Past performance Level	15
3. Financial stability	17
4. Current capabilities	25
5. Submitted plans for the proposed project	14

The relevant project-specific criteria comprise 9 criteria based on the survey carried out in phase-1. The decision-maker for each project can amend the project specific criteria; this requires a structured process to identify the relative degrees of importance of the project criteria. This was considered in the research and a method that can handle the criteria refined in phase-3 to select the most appropriate contractor using a structured decision system was required.

2.5 PHASE 4: RESEARCHING DECISION SUPPORT SYSTEM TECHNIQUES TO STRUCTURE THE PROPOSED CONTRACTOR SELECTION DECISION SYSTEM (DSS)

A literature review is carried out in this phase to identify an appropriate technique that could be used to identify the relative degrees of importance for the project specific criteria. Then review which method could handle sets of evaluated criteria in deciding the most appropriate contractor to the project under consideration.

The analytical hierarchy process (AHP) was found to be an efficient method to identify the relative degrees of importance of these project criteria on a project-by-project basis, simultaneously with using the set of criteria that are related to the contractors in the evaluation process to decide the most appropriate one.

Furthermore research was carried out to investigate the most suitable computer system that could be used to develop the proposed selection decision support system (DSS). A Knowledge-Based Expert System (KBES) has the capability to combine knowledge with judgement and communicate with end-users (decision-makers) in a natural language. This made the KBES the most appropriate computer programming approach for the DSS for the contractor selection.

The structure of the proposed decision support system for the contractor selection is described in the following phase.

2.6 PHASE 5: STRUCTURING THE LOGIC OF THE DECISION SUPPORT SYSTEM

The task of this phase is to design and develop the proposed decision support system (DSS) for selecting the most appropriate contractor for the project under consideration.

The decision model proposed would utilise the contractor criteria, which were refined and evaluated as the output of Phase-3, in addition to the project criteria, which will be decided upon and ranked by the decision-maker using the AHP.

AHP was found an efficient method to also be used in the development of the proposed decision support system.

2.6.1 Structuring the Logic of Selection System

The structure of the contractor selection system was divided into two stages; a pre-qualification process and a final selection process. The purpose of this division is to reduce the time required for the selection process. Thus less data is required to submit in the first process by contractors for pre-qualification purposes. Short listed contractors submit additional data for final selection.

The selection system will utilise the AHP to rank all the contractors, given such data and utilising the criteria, which is built within the model, as follows:

2.6.1.1 Stage-1: Screening Process (Pre-qualification)

In the screening process, all the contractors will be ranked using the AHP method according to the 3 groups of contractor qualification criteria in addition to the specific project criteria, which assigned by the decision-maker on a project-by-project basis. These 3 groups out 5 groups of criteria described in Phase-3, namely: experience record, past performance level and financial stability. These groups were chosen because current capacity was found to be less significant than track record and pre planning was onerous a task at this stage.

The AHP was used to carry out the evaluation process. These short-listed contractors will only be used for further evaluation in the next stage, rather than all the -available contractors, thus saving time and energy in evaluating a large number of contractors. Only the short-listed contractors who are pre-qualified in this process will be invited to submit their project plans and prices for the project in the next stage.

2.6.1.2 Stage-2: Final Selection Process

The short-listed contractors will be subjected to a further evaluation using the remaining two groups of the contractor qualification criteria in addition to the specific project criteria. In this process, the contractors are ranked based on the following group of criteria, namely: (i) contractor's current capabilities and (ii) submitted plans for the project under consideration, along with the project-specific criteria, which have been assigned by the decision-maker for the particular project. This process also considers the evaluation results for these short-listed contractors obtained in the screening process, thus getting the benefit from the evaluation of the previous stage.

2.6.2 Structuring the Logic of a Computer-based System

A computer system was developed for the practical implementation of the proposed technique. The system facilitates the analysis of the large and complex number of criteria and creates a feedback system that can be utilised in future projects.

In this stage the computer-based system for the DSS is carried out in three steps:

2.6.2.1 Step-1: Knowledge Representation and Structuring

This step defines how the knowledge acquired from previous phases of the research can be represented and structured for incorporation as an essential part of the KBES. In this research the LEVEL5™ expert system shell was selected to create the KBES required. The representation of the knowledge acquired followed the standard representational format of this shell.

2.6.2.2 Step-2: The Inference Engine

This step investigates how the KBES can handle the DSS that was developed in this phase. It first establishes the rules from which decisions are derived, and produces reasoning for how this selection is made. Then, rules are established on the basis of the LEVEL5™ format. These rules are different from the *If-Then rules*. The problem was in the difficulty of creating the AHP rules directly within LEVEL5™. The possibility of linking LEVEL5™ with a spreadsheet like Excel gave the opportunity of analysing the AHP process using a spreadsheet (Excel™). This procedure was developed using Visual Basic within an Excel-5 Macro. The ability to link the expert system shell with database software (Paradox™) gave more flexibility in the contractors' data representation.

2.6.2.3 Step-3: Developing the input and output interface

Design of data format and knowledge that are required from the contractor as the inputs to the system was in a format that facilitated the data collection and entry for both the contractors and the project system user. These are in numerical and string formats, as described in Appendices G and H.

The procedure for using this system is described in Appendix I.

2.7 Phase 6: System Verification and Analysis

The KBES was tested to assess its reliability and consistency for identifying the optimum contractor. However, there is no theoretical method for verification of this type of new system (Mohan, 1990). Only trial and error testing, such as that often used for more traditional programmes and symbolic knowledge-based expert systems could be utilised.

The approach to system verification that was adopted was carried out in two steps, as follows:

2.7.1 Step-1: Verification

The system results were checked to make sure that they reflect the actual knowledge that can be acquired for the project under consideration and are a true representation of such data. This phase was accomplished by using a project case study of assumed data. It was based on the assumption that a given contractor would achieve equal rank for each individual criterion. The description of this case study is presented in Appendix G and its analysis is described in Section 8.2.

2.7.2 Step-2: Sensitivity analysis

This step was carried out using two real-life projects. The full description of these projects is given in Appendix H. The sensitivity analyses of these projects are described in Section 8.4. The purpose of this analysis was to study the impact of assigning the relative degrees of importance for the criteria related to the specific project conditions by the decision-maker on the contractor selection process (those criteria which the decision-maker is authorised to assign).

CHAPTER 3: LITERATURE REVIEW OF THE CURRENT CONTRACTOR SELECTION SYSTEMS

CHAPTER 3: LITERATURE REVIEW OF THE CURRENT CONTRACTOR SELECTION SYSTEMS

3.1 INTRODUCTION

This chapter investigates the basic problems that arise in typical construction project. In addition it will show how the criteria required selecting the most appropriate contractor to as specific project can be derived and formalised to avoid these problems.

The general tendency of the client is to resort to single criteria (minimum cost). This method is popular in the public sector because of the sensitivity in handling the public money and to avoid any accusation of mismanaging the public funds. This kind of selection is the underlying cause of many problems combined by the uncertainty surrounding the construction industry; create grave consequences, which are supported by considerable evidence of presence of such problems worldwide.

Different tendering systems currently in practice have been evaluated, and detailed accounts of potential problems are given. These problems show the need for a more objective and comprehensive evaluation method, which can handle the evaluation of multiple criteria.

In addition, the need to incorporate the special client requirements and specific project conditions into the evaluation process, which would add additional criteria, differ from one project to another.

The people entrusted to analyse the bids, moreover, rely on single criteria; their experience and background, which might not reflect the depth of knowledge available in the industry, limit their decisions. Furthermore, their decision is subjected to human misjudgement and subjectivity.

This situation testifies to the need for a method, which would benefit from the wide expertise of the industry and be more objective than current methods. To address this problem, a multiple criteria are investigated to provide a means of incorporating the experience of the industry is proposed in this chapter.

3.2 THE CHARACTERISTICS OF THE CONSTRUCTION INDUSTRY AND ITS IMPACT ON THE CONTRACTOR SELECTION

The construction industry holds a significant position in most economies of the world. For example, the construction industry in the UK in 1993 contributed £46.3 billion, which represented 8% of Gross Domestic Product (DoE, 1994) and similarly it is about 10 % of the Gross National Product (GNP) in the USA (Clough, 1994). In 1990, Japan's construction output was 24% of GNP (Paulson, 1990). In 1995, it was 10 % of the GNP of Italy (Pietroforte and Bon, 1995). In the Middle East, the construction industry output was 46 % of the GNP of Egypt in 1986 (AL-Waqaa'a AL-Masryia, 1986) and about 34% of the GNP for Saudi Arabia (Al Jar-Allah, 1983). In India, construction accounts for a major share of expenditure in any socio-economic development plan (Gore, 1980). Thus, increasing the efficiency of the industry by just a small percentage is critically important to the economy. This is especially important since the majority of the construction projects are commissioned by the public sector in most countries. In the UK, about 66% of the construction was carried out by the public sector in 1993 (DOE, 1994). In India, the government runs 80% of the construction industry.

The construction industry is fragmented, very sensitive to economic cycles and highly competitive due to the large number of companies and the relative ease of entry (Barrie and Paulson, 1992). For example, there are about 210,000 contracting firms in the UK (DOE, 1994) as shown in Figure 3.1.a; 500,0000 contracting companies in the USA (Barrie and Paulson, 1992) and about 400,000 in Japan, (Paulson, 1980). An important characteristic of this construction industry is that the majority of its participants are small businesses. For example, almost 50% of UK companies are sole trader, as shown in Figure 3.1.c. The existence of this large number of firms in association with the ease of entry into the market, results in intensive competition.

Each construction project goes through a series of processes of approval including regulations for planning, design, procurement and construction. Each of these processes involves a range of professional groups and trade skills. These multiple professions and trades work under a unique combination of physical, environmental, regulatory, political, economic and financial conditions pertinent to a particular project. Due to this complex and dynamic set of variables and uncertainties, risks such as project delays, cost overruns, poor quality or the environmental satisfaction that arises during the construction phase is high (Levitt and Ashley, 1980).

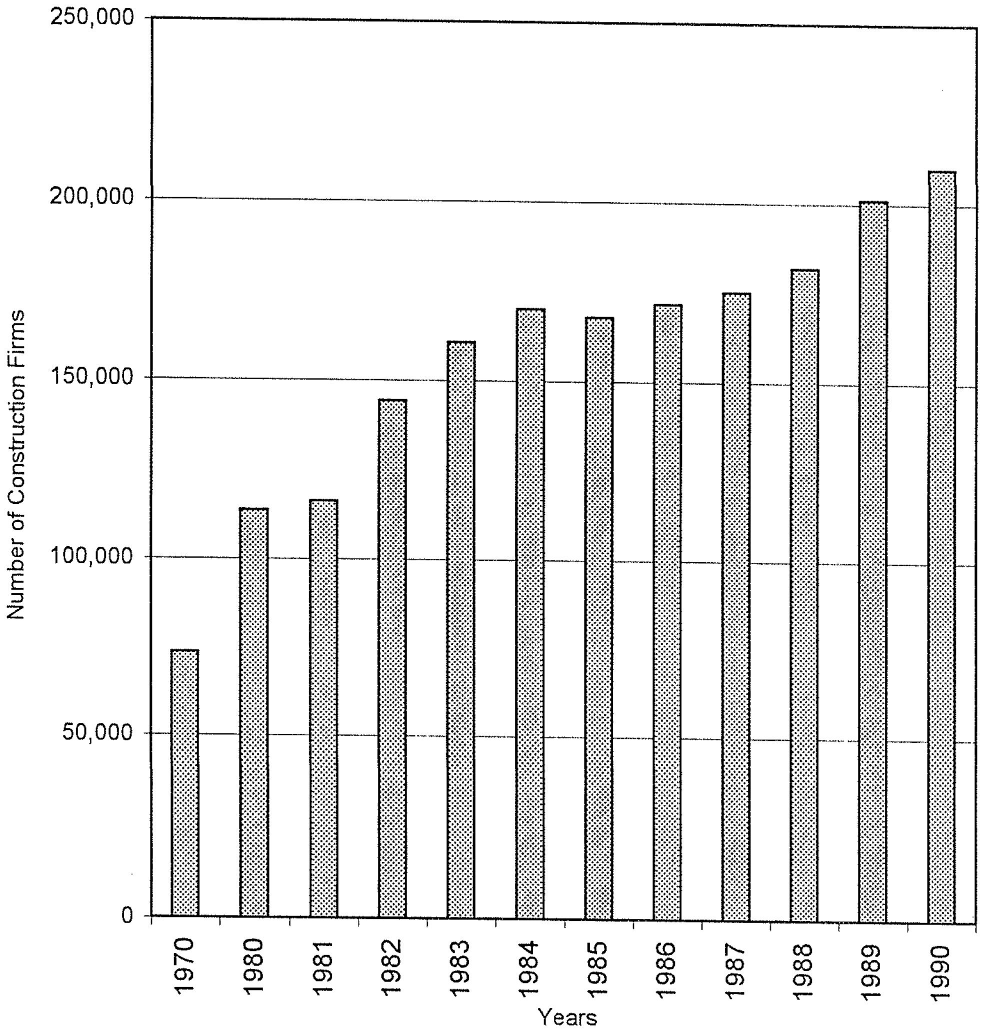

Figure 3.1.a: Number of Construction Firms in the UK*

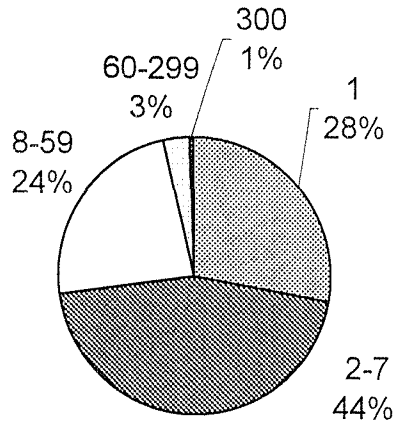

Figure 3.1.b:Firms Percentage Distribution by Number of Employee Size - 1970*

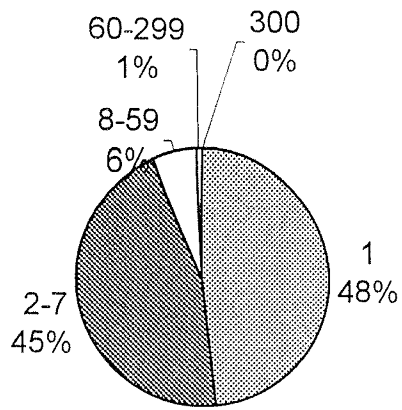

Figure 3.1.c: Firms Percentage Distribution by Number of Employee Size - 1990*

* Source: Roger et al, (1993)

Another characteristic is that construction always builds prototypes, since each project is different in design, financial aspects, layout, materials used, construction methods, time, labour requirements, weather conditions, management and the owner's willingness to share risk. In addition, the construction environment is full of uncertainties in respect of the labour markets and equipment productivity, market forces, material availability, variation in regulatory agencies' influence, and variations in weather and geographical conditions. These uncertainties lead to considerable risks in achieving the client's project objectives such as duration, cost, quality or environmental requirements. This has traditionally led to the client delegating these risks to another party in the project and in particular to the contractor; this is particularly notable in publicly funded projects (Crowley & Hancher, 1995).

Selecting an inappropriate contractor, which cannot achieve the required project's requirements or client's objectives, is a dilemma faced by the client (Ashley, 1980a).

The experience and knowledge of the person making the decision also limit the contractor selection process (Gore, 1980). Therefore, the client usually focuses on project cost as the main quantitative decision criteria. Thus, the lowest competitive tender sum philosophy is used as the base for the contractor selection. This would appear to answer the client's need for accountability and the achievement of value for money particularly in the public sector.

The following review of current selection procedures shows the contractor selection process is on the basis of the tender sum whatever its format.

3.3 REVIEW OF THE CURRENT CONTRACTOR SELECTION PROCEDURES

A range of tendering procedures has evolved in the construction industry with the main distinguishing feature being extent of the competition on winning project bid (Murdoch and Hughes, 1996). The two main procedures for tendering are (i) competitive tendering and (ii) negotiated tendering (Smith, 1991b).

3.3.1 Competitive Tendering

Competitive tendering is the most frequently used contractor selection procedure and can be divided into (i) open tendering and (ii) selective tendering.

3.3.1.1 Open Tendering

Open tendering is a procedure by which any contractor who wishes to bid for the works is permitted to submit a tender. Open tendering was the 'traditional' method until more sophisticated techniques were accepted (Russell, 1990b). The process begins by placing an advertisement (with brief details of the location, type, scale and scope of the project) in the technical press. The notification of the proposed works is advertised to all contractors, large or small and good or bad. By this method, the client supposes that it is possible to gain the biggest possible response to the advertisement, thereby achieving maximum possible competition and the lowest possible tender price. There is no reliable method to ensure the quality of the project using open tendering (Russell, 1990b).

The disadvantage of open tendering, involving a large number of contractors is the burden of time, effort and expense on the industry; more importantly, many genuine bona fide contractors refuse to bid for work. To reduce this number, the client sometimes asks for a deposit, which is returned to the contractor upon receipt of a tender (Smith, 1991b). The amount of the deposit, however, must be high enough to preclude unsuitable contractors and yet not be so high as to discourage a credible contractor. Because of the indiscriminate nature of open tendering, a contractor may be awarded a project for which they are not properly qualified, in terms of either resources or experience or the contractor that carries the work may have made a mistake in pricing the tender. The problems associated with open tendering have led to the decline of its use in recent years and the increased use of selective tendering (Murdoch and Hughes, 1996).

3.3.1.2 Selective Tendering

Selective tendering is the traditional contractor selection process in the UK. Burati *et al*, (1991) also show selective tendering has become the most frequently used method of selecting a contractor.

In selective tendering, the contractors are usually invited on the basis of their known reputation to receive the preliminary project information. A limited number of contractors, who are deemed capable of carrying the project, are invited to submit tenders. This is known as a pre-qualification process, which leads to the production of a short list of qualified contractors. The pre-qualification approach described by Merna and Smith (1990) considers decision criteria such as the contractor's financial standing and record, recent experience of completing similar work within the specified time and the structure of its company, including technical and managerial staff, workhouse and back-up facilities. Table 3.1 describes the selection methods used by a range of clients using criteria in addition to the tender sum (Merna and Smith, 1990). This table illustrates that the client considers the contractors' pre-qualifications, but it does not take into account the specific conditions of the proposed project.

Then, the selected contractors are asked to submit their tender sum. The contractor submitting the lowest tender sum is awarded the contract with the confidence that it has already met some sort of quality standard test by getting through the pre-qualification process.

The advantages of inviting a limited number of companies can be summarised as following (Jaafari and Schub, 1990):

1. Saving the cost associated with bid preparation for irresponsible contractors;

2. Encouraging competent contractors to bid with confidence that they are competing only against other bona fide contractors;

3. Saving the time and efforts of tender evaluation by reducing the number of tenders.

4. Higher probability of getting a successful project.

5. Risk of award to unsuitable contractor is reduced.

Bonds including bid, performance and payment bonds may be required in addition to the above criteria to provide a cover for particular drawbacks encountered when using this contractor selection process (Russell, 1992a).

Client	Prequalification			Number of Tenders	Bids			Evaluation		
	Origin	List of Tenders	Other		Tender Period	BoQ	Other	Pre-award Meeting	Other	Price
Dept. of Transport	Advertisement Approved list	30-40	—	4-8	Up to 12 weeks	All	—	Yes	Time	Lowest Conforming
Property Services Agency	Approved list	Varies	Competition Location Previous work	Fixed to value 4-10 6-8, varies	Up to 8 weeks	—	Tender sum	Sometimes	—	Lowest Conforming
British Waterway Board	Approved list	—	Location Previous work Distribution	Varies with price	—	All	Method Statement Program	Yes	Time	Lowest Conforming with time
British Nuclear Fuels	Records	Varies	Inter-views	4-8, varies	4 - 12 weeks	All	Method Statement Program Production Plant Scheme	Yes	Security Quality	Lowest Conforming
British, Rail	List	Large List	Previous work	4-8, varies	3 - 4 weeks	All	Program Safety	—	Time	Lowest Conforming with time
British Gas	Approved list	—	Previous work	4-8, varies	—	All	Method Statement Program	Some-times	—	Lowest Conforming
British Coal	Records	—	Location Previous work	6-8 according to value	4 - 8 weeks	All	—	Yes	Time	Lowest Conforming
British Airports Authority	Records	Varies	Previous work	4-10, varies	Up to 6 weeks	All	Method Statement Program	—	Time Safety	Lowest Conforming
Yorkshire Water Authority	Records	40-50	Competition		Up to 10 weeks	All	—	Sometimes	—	Lowest Conforming
Central Electricity Generating	Records	Varies	Project Size	4-8, varies	12 - 16 weeks	All	Method Statement Program	Sometimes	Management Safety Quality	Lowest Conforming
Council	Advertisement	Varies	Local Competition	6	4 - 13 Weeks	All	—	—	—	Lowest Conforming

Table 3-1: Pre-qualification and Evaluation Methods Used by UK Clients (Merna & Smith: 1990).

3.3.1.3 Risk Assessment in Competitive Tendering

Crowley and Hancher (1995) discuss the assessment of risks in competitive tendering. Their key finding was the significant difference between the policy makers and the practitioners on the effectiveness of competitive tendering in serving the public's interest. On one hand, policy makers believe that acquiring construction services through competitive tendering allows public agencies to gain the benefits of free competition, theoretically providing the most effective and efficient method of selecting of contractor. On the other hand, procurement the persons whom involved in the decision-making believe, based on experience, that competitive tendering is risky. The evidence is that some contractors submit claims, valid or not, almost as a matter of course.

Generally, clients will attempt to limit their exposure to risk by transferring the risk to other parties, such as insurance companies (bonds) and lending institutions but mainly to the contractor. However, the risk of increased costs due to high pricing of variation orders, poor workmanship and a propensity for claims and disputes cannot be transferred and the client always finishes up paying the bill (Al-Bahar, 1990). Doyle and DeStephanis (1990) point out that certain contractors extensively review the tender documents, noting mistakes, cataloguing ambiguities and looking for future change orders or claims (Jaselskis and Russell, 1990). These contractors can submit a low tender sum with the knowledge that, with variation orders or claims, they have a good probability of recapture the money that was initially sacrificed to win the tender.

As mentioned in section early, bonds are used to provide cover for shortages encountered in the evaluation process or, in other words, to reduce the risks on client that are encountered in the current evaluation process. But, is the use of a bond sufficient to secure project success? The question arising may take the following forms:

- Can the use of bonds ensure the reliability of the contractor to achieve a client's objectives for the proposed project?
- Can the contractor who submits the lowest price bid provide the best value for money for the client?
- Is the use of bonds to repair the damage after failure of any practical use?

Actually, bonds provide assessment of the contractor in two main areas: (i) the first one is based on the financial capacity of the contractor and its principals. (ii) The second one is the probability of business failure during construction. However, even the use of bonds will not fully compensate the client if the project's objectives are not fully achieved. For example, there are significant administrative and frustration costs involved in replacing a contractor after faults. The use of bonds cannot help to pro-actively manage a better project; they are only used as insurance after things have gone wrong.

To reduce risks associated with competitive tendering, which is based on the lowest tender sum, criteria such as time can be taken into account to select the optimum contractor as described in the following section.

3.3.1.4 Recent Innovative Selection Processes in Competitive Tendering

In the past few years, several innovative selection processes that do not rely only on the tender sum in competitive tendering have been introduced.

Herbsman (1995) describes some of the innovative approaches for the contractor selection methods introduced in highway construction projects in the United States. The main objective of these approaches is to reduce the risk of project delay, where the indirect costs to the client due to delay are not comparable to the saving in the tender sum when using the traditional system. The basic concept of this approach is to motivate and encourage the contractor to work faster, to schedule accurately and to manage the construction process better.

Herbsman *et al*, (1995) describe 3 approaches that take criteria addition to the cost criteria into account. These are:

1. Bidding on cost/time
2. Incentive/disincentive bidding
3. Bidding on cost/time combined with Incentive/disincentive

Each of these approaches considers the value of time. Using a time value method, the project duration is introduced as a very important decision criterion of evaluation. For example, in method 1 above, the basic estimating principle is similar to that used in the cost reimbursement contract. The estimator determines the value of time, which is based on a parameter defined as "unit time value". This unit time value represents the cost of delays and, in most cases, includes the client's direct costs resulting from construction delays. In the Incentive/Disincentive method the time is determined by the client and presented as part of the tender documents. If the contractor has the ability to complete the project ahead of schedule, then the contractor would have the right to a bonus (incentive fee) or if late then liquidated damages are applied (disincentive fee).

However, please note that even these approaches are based, essentially on the lowest cost, since time is converted into money equivalent.

3.3.2 Negotiated Tendering

Negotiated tendering involves negotiation agreement on the tender sum between contractor and client (Smith, 1991b). Murdoch and Hughes (1996) describe this method as a more radical approach to contract award.

The client may lose the provided benefits of the lowest tender sum that may gain in open or selected tender methods, but, what would be regarded as reasonable excess of negotiated prices over those obtained in the competition of the open tendering is a matter of opinion (Smith, 1991b). In addition, the end cost of the project to the client may not be so much higher (Riley *et al*, 1999).

Negotiated tendering may be preferable in some circumstances such as when a quick start is required a business relationship already exists between the client and the contractor (Merna and Smith, 1990). In addition, negotiated tendering may also be preferable when a contractor has specialist plant and techniques or continuation of existing contract.

There is no systematic approach or procedure that a client can use in the evaluation of negotiated tendering other than ill-structured judgement by which the client can assess risks due to the contractor's capability to complete the project successfully (Smith, 1991b). On the other hand, Murdoch and Hughes (1996) suggest the absence of the standard method for the negotiated tender provides flexibility that can be an advantage.

3.3.3 Partnering Method

Partnering is a relatively new concept in the construction industry, but it is not a new concept of doing business (Osama, 1994). Murdoch and Hughes (1996) describe partnering as an extension of the negotiated contract approach, although there is, in reality, a significant difference between partnering and negotiation. Partnering involves a completely open way of working together in a new culture based on trust and mutual respect. Partnering involves an agreement between the client and various practices to the contractor work together in a team framework for an extended period of time, on the basis of one contract or over several consecutive contracts. The advantages of working together in partnership have been strongly promoted in the Latham report (1994).

Partnering is increasingly being used in construction as an attempt to overcome the disadvantage of the traditional often adversarial, contract process. Weston and Gibson (1993) studied 139 projects (39 projects adopted client-contractor were partnered, and 100 did not) and showed that a long-term agreement through partnering allows the two parties to work more effectively and efficiently. The results showed that partnering projects had performed better, on average, than the non-partnering projects in terms of cost, schedule, change-order costs, claim costs, and value engineering savings. The comparison of these partnered and non-partnered projects is shown in Table 3.2. Five criteria that are included in Table 3.2 represent the mean values for both partnered and non-partnered projects.

Schmader and Gibson (1995) carried out another study of over 200 contracts awarded by the US Naval Facilities Engineering Command between September 1993 and May 1994 using the partnering approach. The data collected included contract award price, final completion cost, value engineering savings, claim costs, contract award date, original contract completion date, final completion date, and subjective comments pertinent to their partnering experience. Additionally, data from a similar sample of non-partnering projects was also obtained. These results indicate the benefits of using adopting partnering approach.

Mean Criterion	Partnered Project (39 Projects)	Non-Partnered Project (100 Projects)
Cost Change (%)*	11.2	9.79
Cost of Change Order (%)	11.34	9.38
Claim Cost (%)	0.04	0.57
Duration Change (% of estimated schedule)	13.54	25.93
Value Engineering – Cost Saving	17.95	4

* As a percentage of project budgets.

Table 3.2: Comparison of Partnered and non-Patterned Projects (Weston and Gibson, 1993)

In the public sector, the regulatory requirement for selection of contractors is through competition and this creates a difficulty in establishing a long-term relationship, which is essential to successful partnering.

The potential problems of partnering can be summarised as following (Hellard, 1995):

1. Partnering requires all partners to 'buy into' the concept, which is endangered if there is no true commitment. Those partners conditioned to the traditional adversarial environment may be uncomfortable with the perceived risk sharing and trust.

2. For some, changing the myopic thinking that it is necessary to win every battle, every day, at the other partner's expense, will be very difficult to change due to the difficulty in changing their culture.

3. A win/win approach is needed by all projects.

4. Not bringing in all the key players, for example, sub-contractors are at any early stage.

The following list briefly summarises the potential benefits to the client (Hellard, 1995):

- Potential reduction of claims and conflicts due to open communication
- Cost and delays reduced due to improved cost and schedule control.
- Lower administrative costs due to the elimination of the effort required recording information that might be useful in a potential claims situation.
- Open communication and early involvement of the contractor, encourages innovation and the use of value engineering.

The following list briefly summarises the potential benefits to the contractor (Hellard, 1995).

1. Reduced of costs related to potential claims and litigation, so productivity is improved.
2. Improved cost and schedule control for the project.
3. Lower risk of cost overruns and delays as a result of direct and flexible communication between partners.
4. Increased opportunity for financial success through innovative construction methods.
5. Greater profit potential by lowering overhead costs.

This means that partnering requires the client to share project risks to gain some of the benefits described above. But, there is no systematic method defined criteria of how to select the partner, which can indicate how these risks may be, reduced (Brown and Riley, 1998).

3.4 CONTRACTOR SELECTION SYSTEMS NOT USING LOWEST TENDER SUM

Competitive tendering is used in the construction industry of many countries. Hauck and Kline (1986) showed that competitive tendering has been in practice in New York since at least 1847 (bridge building-highway projects). In the UK contractor selection based on the lowest tender sum has remained relatively unchanged since the late 1940s in spite of a large number of reports and investigations, which identified the problems of using this system

(Golden *et al*, 1989).

A code of contractor selection is has proposed in the UK to achieve the best value for money by recognising the importance of quality, value and other criteria in addition to bid price (WG3, 1997).

The contractor selection method used in Japan encompasses the whole range of competitive and negotiated tendering approach used in the USA (Kakoto *et al*, 1989).

Competitive tendering is are dominated by the principle of accepting the lowest tender sum. Over the years, a few modifications to the lowest tender sum have occurred. The term "responsible contractor" and " public interest " have been added to the statutes to control the authority of awarding the public's contracts (Russell et al, 1990d). However, bid price has remained the governing factor in the selection of contractors since the 19th century in most countries.

In contrast, some countries, including Italy, Portugal, and Peru use a system in which the successful contractor is not the one submitting the lowest tender sum (Herbsman and Ellis, 1992). Herbsman and Ellis (1992), describes the philosophy behind this concept as the optimum tender is the most reasonable one, neither the highest nor the lowest, but the one judged closest to being fair. The logic for this is that the lowest tender may result from an underestimate or that the contractor is planning to rely on future claims to compensate for their low tender sum. On the other hand, the contractor with the highest tender is too inefficient tool or has high indirect costs. So, the lowest and highest tender sum are excluded (Jaafari and Schub, 1990).

One approach is that of "bracketing" which considers only those tenders that lie within a certain range above and below the engineer's estimate. In this system, the lowest tender within the range gets the award.

Countries such as Portugal and France disqualify what they call “abnormally low” bids (Russell, 1990a). They define abnormal as "any tender whose price appears so low that it may cause implementation problems".

The Peruvian tendering system is described by Jaafari and Schub, (1990), as follow:

(1) When three or more bids have been received:

- The client calculates the average of all tenders.
- All tenders that lie 10% above or below this average are eliminated.
- The average of the remaining tenders is compared with the client's project budget.
- The contract is awarded to the tender immediately below the second calculated average or to the tender closest to the client's budget whichever is the minimum.

(2) If the number of tenders received is less than three, the contracting agency may award the contract to the lowest bid or to the only contractor if this were the case.

In India, the systems for awarding contracts include:

(i) Lump Sum Contract (LSC),

(ii) Percentage Rate Contract (PRC), and

(iii) Item Rate Contract (IRC).

PRC and IRC are termed as schedule contracts or measurement contracts. The contractor is selected on the basis of the closest percentage submitted either above or below the client's estimated cost (Gore, 1980).

In conclusion, this review of the contract awarding procedures based on non lowest tender sum has shown that a wide range of countries such as Italy, Portugal, Peru and India, have realised that low tender sum does not always provide realistic best value projects.

3.5 PROBLEMS ARISING FROM THE USE OF CURRENT CONTRACTOR SELECTION METHODS

The problem that arises from the use of current contractor selection method based on the lowest tender sum is that an inappropriate contractor might be appointed which will lead to problems and failure of the project.

It is proposed that each problem have a root cause that underlies the criteria identified. It is further proposed that it is possible to carry out an assessment of these root causes during the contractor selection process and in this approach select contractors that are most likely not to lead to these problems and so lead to better value for the client. These rout causes are based on factors or criteria and it is necessary to derive all the possible criteria that are needed during the assessment of each contractor.

Russell and Jaselskis (1992b) define failure as a significant breach of the contractor's legal responsibilities to the client. Project failure can be also be defined in terms of the contractor failing to meet project objectives such as cost, schedule, or quality. Although, breach of contract is actually very rare and serious but still there is still a problem with the contractor failing to satisfy the client's total objectives. These problems can be separated in two main classes: (i) contractor related problems and (ii) project related criteria.

3.5.1: Contractor Related Problems

These problems include:

1. Project cost increase from award cost
2. Change in project duration.
3. Quality of finished product.
4. Safety achieved during construction.
5. Environmental impact.

Figure 3.2 shows the relative causes of construction project failure identified by Kangari (1988). Figure 3.2 includes five causes of project failures. The most significant cause is the economic factor, which represents about 61% of all failures. Within this factor, insufficient cash flow accounted for 74.2% of the failures in the economic factor category. Insufficient cash flow is one of the direct results of the lowest tender sum system included in competitive tendering. In addition, reduction of the down payment, late payment, under measurement and outstanding claims create serious cash flow problems (Hardy, 1981).

The highly competitive construction environment (Section 3.1) leads to a reduction in the contractor's profit and hence leads to cash-flow problems and selecting the lowest tender sum makes this profit of a minimum value (Russell, 1992b).

From Figure 3.2, other important factors are the selection of an inexperienced contractor (18% of failure) and over load (11% of failure). This may also lead to poor quality and safety problems or project delay. The two causes that have the least effect (less than 6%) are fraud and neglect and high expenses by the contractor (Kanagari, 1988).

This full list of problems that arise in traditional lowest tender sum contracts can be analysed into two types or classes and is described below.

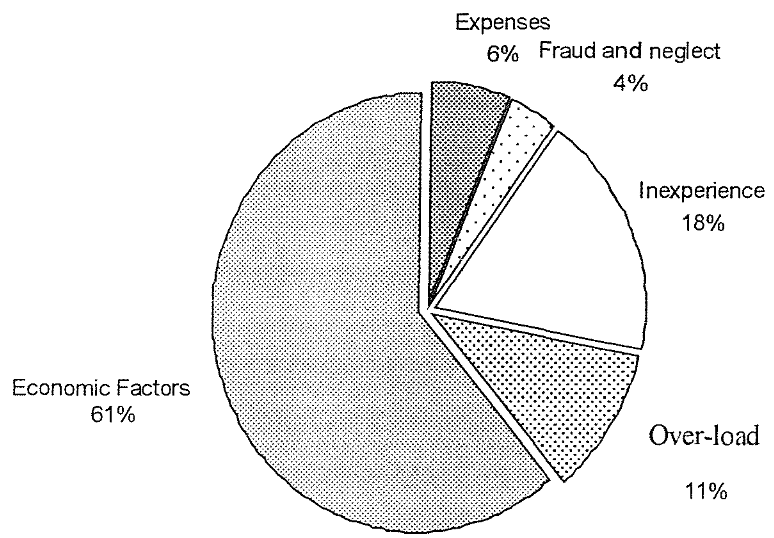

Figure 3.2: Causes of Project Failure (Kanagari, 1988)

The first type is related to the contractor qualifications and the second type is related to the specific project conditions, its requirements and objectives. The objective of this problem analysis is to derive the criteria that impact or define each of all these problems at their root. If all these criteria can be derived together with the relationship between criteria and problem, then each construction project and contractor can be assessed in terms of these criteria. The assigning of these criteria between specific project and client needs and the contractor abilities and experience can then be assessed. In this way an adequate selection system can be developed to assist in selecting the most appropriate contractor. **The most appropriate contractor is defined, in this research, as the contractor that has adequate qualifications that can match the criteria related to the specific project conditions, requirements and objectives for the project under consideration.**

Problem areas related to the contractor's qualifications can initially be grouped into four groups. These groups are suggested on the basis of the root causes, which include:

1. Contractor's experience shows how the experienced contractor is identified.
2. Contractor's past performance gives an indication of how fraud, neglect and high expenses can be avoided.
3. Contractor's financial stability shows how the cash-flow problem can be limited.
4. Contractor's current capability identifies its capability to carry the workload for both the projects in hand and the proposed project.

The details of these different problem areas are described in the following sections.

3.5.1.1 Problems Related to Contractor's Experience record

Contractors' past experience gives an indication of its construction background and depth. Inexperience appears to be a key factor in construction failure (Shuler, 1967). In the 1950s and 1960s more than half of the contractors who failed to achieve the client's project objectives had been the construction business for five years or less (Kangari, 1988). The contractors' working period in construction is considered a key criterion in identifying the success probability in achieving the client's objectives (Kangari, 1988). Several studies have tried to determine the "danger age" of a contracting company (Shuler, 1967; Kangari, 1988). These studies concluded that there were three dangerous ages; one during the first and second years due to lack of experience and a second dangerous age between the eighth and ninth years due to business expansion without sufficient experience or poor management. However, failures peak when the contractor is in its third year and the causes of this failure can frequently be traced back to poor management practices during the formative years. This step of growth problem is confirmed in the SUSTAiN report (Riley and Brown, 1998) that investigates the problem growth for small and medium sized businesses in the UK.

Attention is called to the fact that approximately 24% of contractor failures in achieving the client's objectives lie beyond the 10-years range of work in construction. This danger period occurs at about the time that the construction business begins to expand into more construction projects. Therefore, the experience of the contractor, either that recorded for its company or for contractor's employees, especially in performing similar projects, needs to be assessed. The criteria that quantify past experience need to be identified.

Contractor's experience can be defined as either relating specifically or generally to experience in project construction. The contractor's work volume, geographical and weather conditions, familiarity with local resources such as labour requirements or materials market, etc can indicate the contractor's past experience level (Hauck and Kline, 1986; Russell 1990b; Crowley and Hancher, 1995; Bubshait, 1992).

The initial set of such criteria that can be related to the contractor experience presented in Appendix A/o.

3.5.1.2 Problems Related to Contractor's Past Performance

The contractor's past performance can be defined in terms of the contractor's performance level in meeting the objectives of the previous projects either relating specifically to either similar or general construction projects.

Performance indicators provide the benchmarks necessary to show that a planned effort has achieved the desired result (Thomas *et al*, 1984). The major problems that may result from unsatisfactory performance include (Farid, 1990):

1. Extensive delays in the planned schedule,
2. Increase in the number of claims and litigation,
3. Cost over runs, and
4. Inferior quality,

Criteria are related to the contractor's performance schedule, budget, quality and safety in previous projects need to be considered in order to reduce the risk of selecting a contractor that may fail in meeting the proposed client's objectives. For example, one method of quantifying quality performance can be obtained from the consulting engineers of previous projects and any past performance records such as material test reports (Burati *et al*, 1991). In this way, the selection of quality performance will be less subjective. Another criterion considered is the contractor's attitude towards correcting faulty or incomplete work. This criterion can be considered an indicator of contractor flexibility in the previous performance and previous quality control level (Mallon and Mulligan, 1993). Safety performance is another important criterion for the contractor's performance. Unsafe conditions and accidents is usually a sign that something is wrong in the management system. Safety and co-ordination of safety program have traditionally been the responsibility of the main contractor. Smith (1991a) discussed the different safety measures and programs that can be used to develop safety benchmarks for the proposed system. The contractor's attitude towards claims and counter-claims can be considered an indicator of contractor behaviour related to litigation and disputes, and hence, contractor soundness (Russell, 1992a).

The client is always seeking a guarantee to ensure the required performance of the contractor throughout the proposed project (Ashley, 1980a). A bonding system is an attempt to achieve this. However, bonding is not a mechanism that can be used to improve a contractor's poor performance (Ashley, 1980b). The bond system does not, in itself, ensure that a contractor is qualified to perform the contract. Consequently, the bond system is necessary but is not sufficient to secure contractor performance (Russell, 1990b).

The initial set of such criteria that can be related to the contractor past performance presented in Appendix A/o.

3.5.1.3 Problems Related to Financial Stability

The contractor's financial stability should be identified to avoid such financial problems in the project cash flow. The quality of the financial statement and type of accounting method used to describe revenues earned can identify the contractor's financial stability (Smith, 1991b). The company's accountants typically carry out an in-depth revision of the contractor's financial statement, including the balance sheet and income statement. In many instances, three years of financial data are required by sureties to gain confidence in the contractor's financial stability. The analysis carried out by auditor consists of two parts:

1. A review of the quality of data presented, and
2. An analysis of the figures contained in the statement.

The opinion of a certified public accountant's (CPA) or auditor on the financial statement will be expressed in a cover letter commenting on the financial statement. The quality of the financial presentation researched by Jaselskis and Russell (1990) shows three levels of quality:

Lowest quality: A compilation-accountant provides no assurance regarding the numbers presented in a client's financial statement. No normal audit procedures were performed to verify numbers presented in the statement.

Middle quality: A review-accountant carries out enough investigation, with reasonable degrees of assurance, to confirm that no material misrepresentations exist in the reported financial information.

Highest quality: An audit-accountant applies industry-accepted audit procedures and certifies that the financial statement is presented in accordance with generally accepted accounting principles.

The type of accounting method used to prepare a contractor's financial statement is important because it indicates how income has been obtained. Income is estimated by one of the following four methods (Russell, 1992a):

(i) Cash basis-income, (ii) Straight accrual-income, (iii) Percentage of completion-income and (iv) Completed contract-income.

The percentage of completion method gives the most accurate picture of a contractor's financial position because income is recognised in proportion to cost incurred (Russell, 1992). Another classification presented by Troyin in 1991 (Russell, 1992a) to the financial performance indicators are operating factors. These factors are expressed as a percentage of sales (for example, cost of sales and executive salaries), financial ratios (for example, net sales to net working capital and net sales to net worth) and financial factors (for example, current liability to net worth, net income to net worth). The data required to develop the above parameters are sometimes considered to be confidential. To avoid this problem, Troyin developed performance indicators in his study of US contractors' performance overseas by using the available public data. Three indices are used which include commitment, presence, and gross as described by Troyin in 1991 (Russell, 1992a).

Revising the issues related to the financial statement, analysis of the data can be carried out. These include an adequate capital base, sufficient working capital, profitability, asset utilisation, overhead expenses, notes accompanying the financial statement, schedule of completed contracts and work in progress, ratio and trend analysis, credit reports, and the qualifications of the CPA preparing the statement. Table 3.3 presents an explanation of how an accountant views the various balance sheet components. Among the more significant items analysed are inventory items payable to the company owner or employees, company goodwill, slow account receivable, and cash surrender value of life insurance. Next, a review of significant financial items can be carried out. The net worth capital of a contractor is obtained. The amount of debt the contractor has in relation to equity is also important to determine the level of risk the owners of the company have assumed. A standard measure used by underwriters involves working capital (current assets and current liabilities). Physical assets are necessary to perform successful construction work. Hence, an equipment asset list of the company is an important amount of general expense related to the type and size of the company.

Without such an accurate financial picture, sound business decisions that affect the future of the company cannot be made (Russell, 1992a). Ratios can be derived from selected balance sheet and income-statement parameters are frequently used for financial analysis. These ratios can assist in extracting decision criteria related to the financial situation of the contractor and show its stability.

The description of the initial set of such criteria that related to the contractor financial stability presented in Appendix A/o.

3.5.1.4 Problems Related to Contractor's Current Capabilities

A basic pre-request for the award of most public contracts is that the prospective contractor must be "responsible" (Russell, 1992). The term responsible refers to the contractor's competence, ability and capacity. The phrase "responsible contractor" refers to more than the capacity of the contractor; it includes factors such as judgement, skill, reliability and integrity, which are important considerations in the overall determination of responsibility (Warszawski, 1982a).

Smith (1991b) discussed these capabilities that can be summarised in the following items:

- Adequate financial resources (working capital and bonding capacity) or the ability to secure such resources,
- Staff experience, organisation and technical qualifications, available personnel resources, and the ability to acquire the necessary plant and equipment for the proposed contract,
- Ability to comply with the required performance schedule, taking into accounts all existing commitments (i.e. capacity).

Resources such as management, equipment, labour, material and finances that are need to be analysed from the viewpoint of total workload can assess contractors.

The description of the initial set of such criteria that related to the contractor current capabilities presented in Appendix A/o.

As shown on financial Statement	As viewed by Accountants
(a) Current Asset[a]	
Cash	Important to get bank references--make sure cash is not pledged amounts are accurate
Accounts Receivable (A/R)	Obtain aged schedule of A/R. Look for any past due items (90 days). Underwriter may discount or eliminate A/R over 90 days old
Retainages Receivable	Underwriters will generally allow as current asset
Notes Receivable...	While an accountant may view notes as current, an underwriter will want to know who owes money and terms. If it appears that it will not be paid back in near future, or could not be readily sold--classify as 'fixed asset'
Inventory	Underwriter will want to know what inventory consists of and may classify percentage as "fixed asset".
Cash submission value life insurance Goodwill	Accountants view this as "other" asset. Underwriters classify as current Insurance asset since if needed, principal can obtain the cash on short notice while accountants may include this as asset, underwriters do not classify it as such. Goodwill is intangible asset. Underwriters deduct it from net worth
(b) Fixed Assets[b]	
Prepaid expense	It may include past due items and/or other miscellaneous receivables
Real estate	Accountants view this as current asset if held for sale. Underwriters will treat it as fixed since money is not readily obtainable. Equipment, furniture, and fixtures viewed by underwriter as fixed asset
(c) Current Liabilities	
Notes Payable, bank, other (i.e., equipment, mortgage, etc.)	If note is short term (generally due in one year or less), an underwriter will classify it as current liability. Other notes payable is reviewed. Some notes are due upon demand (term unknown) so they are classifieds current. Underwriters may charge 12 months of payments on long-term notes as CL
Accounts payable (A/P)	Try to obtain aged schedule of A/P-view terms. Trade references are helpful to determine it principal is paying bills on time. If not, is their problem? A/P are charged in full as CL
Accruals (accrued salaries accrued expenses, etc.)	Current liability since these amounts will have to be paid shortly.
Taxes payable	Underwriter will want to understand how principal pays his/her taxes. Some tax obligations may be considered long term, i.e., and completed contract--do not pay until job is complete.
(d) Long-term Liabilities	
Mortgage (due after one year)	Underwriter classifies that portion of mortgage that is not due within year as a long-term liability. Some underwriters, however, may not charge any real-estate mortgage payments as current.
Equipment loans (due after one year)	Equipment loans not due within year are long-term liabilities. Sometimes if amount is large, underwriters will question why so much equipment is being purchased. Principal may be expanding, but too much debt can lead to financial trouble.
(e) Stockholder's Equity	
Capital Surplus	Investment by owners. Earnings accumulated from operation of busines (may be a plus or minus).

[a] Those assets that are most liquid (i.e., cash or near cash) that can be used by principal.
[b] Those assets not readily convertible to cash in the normal course of business.

Table 3.3: Fundamentals of Financial Analysis (Russell, 1990a)

3.5.2 Problems Related to the Specific Project Conditions and Requirements

Since construction projects are unique, the conditions of the construction project and the client objectives and requirements lead to a need to consider each construction project on a case-by-case basis. These conditions, for example, include project complexity, environment, location, etc. The client objectives and requirements may include project budget, schedule, quality, safety, etc. Failure by the contractor in achieving one of these objectives or requirements within the specific project conditions may lead to problems such as project delay, over-budget or low quality. These problems have been defined by the author general conclusion based on the literature review in the early sections of this chapter.

The description of the initial set of such criteria that related to the contractor specific project conditions and client objectives is presented in Section 5.5.1.

In summary, Section 3.5 has carried out a survey of the problems related to a contractor and the specific project conditions. Contractor's experience, past performance, financial stability, current capabilities and submissions for the proposed project criteria constitutes the basis of the initial set of criteria that presented in Appendix A/o.

3.6 PREVIOUSLY DEVELOPED SOLUTION METHODS FOR CONTRACT AWARDING PURPOSES USING MULTI-CRITERIA

Many researchers have addressed the problems resulting from selecting an inappropriate contractor (Russell, 1992b). This research has led to changes in the contractor selection process. These changes have been introduced by considering multiple criteria for both the public and the private sectors but they have not worked, as described in the following sections. Several researchers [Brown, 1994; Hauck and Kline, 1986; Herbsman and Ellis, 1992, Riley *et al*, 1999] concluded that awarding the contract to the lowest bid, especially in the public sector, is the main reason responsible for project delays, cost overruns, low quality or high claim values. Hauck and Kline (1986); Russell and Jaselskis (1992a); Crowley and Hancher (1995); Bubshait (1992); AbouRizk *et al* (1994) carried out research on contractor selection problems. The majority of this research concentrated on determining the selection criteria for the contractor pre-qualification and some have developed models of contractor pre-qualification. These models evaluate contractors on an absolute basis using the pre-qualification approach just to determine if either the contractor is qualified or to rank the contractors. This approach did not link the contractors' pre-qualification with the specific conditions, requirements and objectives of the project under consideration, on a case-by-case basis. These models allowed only a limited flexibility in handling the dynamic and complex variables of the construction industry and client's preferences. These decision models, which determine the pre-qualification of contractors, include:

3.6.1 Linear Model

Russell (1992b) described this model. The theory of this model is based on combining decision criteria that are subjectively weighted and rated by one decision-maker, and combined into a single measure. A linear model is frequently used in the pre-qualification process and is shown in the following equation:

$$AR_j = \sum_{i=1}^{n} (w_i)\,(R_{ij})$$

Where AR_j = aggregate weighted rating of candidate j;

n = total number of decision criteria in the model;

w_i = the weight of the decision criterion i, and $\sum_{i=1}^{n} w_i = 1,\ i = 1, 2, 3, \ldots n$

R_{ij} = the rating of decision criterion i of candidate j on a specified scale (e.g., from 1.0 to 10.0)

Russell and Skibniewski (1988) describe an example application of this model. This evaluation technique is used to develop a model by which contractor pre-qualification can be determined. The model structure, decision parameters, and corresponding weights embedded within the model are based on statistically analysed questionnaire data.

3.6.2 Linear Model Incorporating Multiple Rating

A linear model incorporating multiple ratings is a method that combines decision criteria that are subjectively rated, where multiple ratings and their corresponding probabilities are possible for a given criterion. These are combined into a single measure that accounts for the impression and uncertainty associated with the process (Russell and Ahmad, 1989). This model has two differences from the linear model. The variations are represented in the subjective ratings input to the model. In the linear model, one subjective deterministic rating (by one decision-maker) for criterion is required. But in this model, multiple ratings for a criterion are possible. In the first variation each rating has an associated probability of occurrence that is assumed as normally distributed. This model is formalised by the following equation:

$$EAV_k = \sum_{j=1}^{m} (W_j)\,(EAR_{jk})$$

Where: EAV_k = the earned aggregate value for candidate k;

m = the total number of criteria in the model;

W_j = the weight of decision criterion j,

EAR_{jk} = the earned aggregate rating for criterion *j* of the candidate *k*.

The earned aggregate rating is calculated by the following equation:

$$EAR_{jk} = \sum_{i=1}^{n} (P_i)\,(R_{ijk})$$

Where: n = the total number of ratings used for a criterion; P_i = the subjective probability assigned by the decision-maker to each individual rating;

$\sum_{i=1}^{n} (P_i) = 1$ for i = 1, 2, 3... n. and R_{ijk} = the individual rating *i* for criterion j of candidate k.

The second variation of this model includes permitting a decision-maker to use three criteria ratings: optimistic, most likely, and pessimistic similar to the PERT (Project Evaluation Review Technique) scheduling technique. Russell and Ahmed (1989), using some illustrative examples, discuss the details of this method.

3.6.3 Model Based on the Multi-Attribute Utility Theory

Diekmann (1981) applied Multi-Attribute Utility theory (MAUT) to a case study in the evaluation and selection of contractors for a cost-plus type contract.

In multi-objective decision-making such as contractor evaluation and selection, a multidimensional utility function is used. One formulation of such a function is illustrated in the following equation:

$$U(x) = \pi_1 u(x_1) + \pi_2 u(x_2) + \ldots + \pi_n u(x_n)$$

Where: $U(x)$ = the multidimensional utility function.

$u(x_i)$ = the single attribute utility function of x_i;

$\pi \pi_i$ = scaling coefficient for attribute x_i.

This model permits decision-makers to quantitatively represent their preferences via utility functions, evaluate the qualitative data typically submitted by contractors, and account for risk and uncertainty in the contractors' performance. This model relies on a decision-maker's subjective and, in some cases, unstructured evaluation of qualitative data present in the evaluation process (Russell, 1992a).

Inputs necessary from a decision-maker to apply MAUT include:

- Value hierarchies - to describe in a hierarchical fashion the objectives of the owner.
- Scaling coefficient π_i - to establish the amount of importance of each criterion given the prevailing circumstances surrounding the problem.
- Utility function $u(x_i)$ - to permit the decision-maker to formalise his preferences over varying levels of values for a decision criteria.
- Probability density function $f(x_i)$ - to assess the risk and uncertainty associated with the criteria evaluated.

The expected utility of each contractor's expected performance be calculated by the following equation:

$$EU(C_k) = \sum_{i=1}^{n} \int_{\infty}^{\infty} \pi \pi_i U(X_i) f(x_i)_k \, dx$$

Where: $EU(C_k)$ = the expected utility of contractor K; π_i = the scaling function for objective (criteria) i. and $f(x_i)_k$ = the probability density function of contractor k performance regarding objective i.

As a result of the value hierarchy developed and utility theory, the expected utility for each contractor is calculated and rank-ordered for each objective as well as the aggregate expected utility. These values assist the decision-maker in formalising and documenting their evaluation process and making subsequent decisions (Diekmann, 1981).

3.7 SUMMARY AND CONCLUSIONS

The competitive characteristics of the construction industry encourage the use of the lowest tender sum in the selection of contractors.

A review of the current contractor selection method in different countries shows that competitive tendering, both open and selected, along with negotiated tendering and partnering approaches were used traditionally to select the appropriate contractor. However these methods are dominated by the principle of accepting the lowest tender sum.

Selecting the lowest tender was found to be the underlying cause of a large number of problems, such as cost over-runs, delays, poor quality, unsafe working conditions, and negative environmental impact, the use inferior quality material, poor workmanship, and resort to change orders to make profit. Thus, the current contractor selection process based on the lowest tender sum philosophy has proved to be inadequate and need to be changed

A detailed analysis of the problem areas shows that price is merely one decision factor from among a wide range of criteria that should be taken into consideration and the literature highlights the need for considering additional criteria to minimise problems. The criteria, which initially identified on the basis of these problems, are classified as follows:

(i) Criteria related to project conditions, and requirements such as the project's complexity, uniqueness, budget, schedule, required quality, safety and risk allocation; and

(ii) Criteria related to contractor's qualifications, such as contractors' experience, performance record, financial stability, current capabilities, and submitted plans to execute and manage the project.

The initial sets of criteria related to the contractor were detailed in Appendix A/o.

CHAPTER 4: LITERATURE REVIEW OF THE CRITERIA IDENTIFICATION AND ASSESSMENT TECHNIQUES

CHAPTER 4: LITERATURE REVIEW OF THE CRITERIA IDENTIFICATION AND ASSESSMENT TECHNIQUES

4.1 INTRODUCTION

The review given in Chapter 3 shows that there is a need to use multiple criteria in the contractor selection. The output of that review was the initial sets of criteria that are related to the contractor qualifications and the project specific conditions. Identification of these criteria is required to determine their relevancy and their impact on the contractor selection decision. This can be achieved by asking the expert persons from the construction industry. Therefore, there is need to find an efficient and scientific method for the criteria identification and assessment that are related to the contractor selection. In this chapter, literature review of the available techniques was carried out to satisfy this objective.

Different techniques and methods are available such as ranking, rating, paired-comparison, successive comparisons and the Delphi methods. These techniques are evaluated to select the suitable one that fit the problem in hand.

Whatever the technique or method that can be used to identify the degree of importance, the measurement scale to quantify the criteria should be assigned either in quantitative or qualitative format or measures. Different scales were reviewed discussed such as nominal scale, ordinal scale, interval scale, ration scale and Likert scale to determine which one can be used in the proposed evaluation technique.

4.2 MULTIPLE CRITERIA ASSESSMENT TECHNIQUES

Decision-making problems frequently involve multiple objectives that may be of varying importance to the decision-maker. Some objectives can be of overriding importance while some are considered less significant (Grubbstrom, 1988). The differences in the importance between basic objectives can be conceptualised in several ways (Goicoechea et al, 1992). Therefore, the appropriate tool or technique that provide the optimum solution has to be identified.

An important step before this solution identification is to define which criteria can be used to represent the objectives of any solution and to assess the relative importance or weight of these criteria. There are different methods such as ranking, rating, paired comparison, and successive comparisons, which can be used to assess these criteria. Detailed descriptions with some illustrative examples of each method are described below.

4.2.1 Ranking

In the ranking technique each expert is asked to place a numerical rank for each criterion, the most important in the situation being indicated by rank 1, the next to most important by rank 2, and so on. These raw ranks are transformed into converted ranks such that rank 1 becomes converted rank m-1 where m is the number of criteria, raw rank 2 becomes converted rank m-2 and so on up to raw rank m which becomes converted rank 0. These ranks are manipulated as follows:

$$R_k = \sum_{j=1}^{n} R_{kj}$$

Where, R_k = sum of the converted ranks across all experts for each criterion k;

R_{kj} = converted rank assigned to criterion k by expert j;

n = number of experts.

The weights are determined by, $w_k = R_k / \sum_{k=1}^{m} R_k$

Where, w_k = composite weight of criterion k across all experts;

m = the number of criteria.

This ranking method is simple and least time-consuming for the expert. For example, suppose those ten experts or decision-makers are asked to rank three criteria and the results are given in Table 4.1. The weight corresponding to each criterion is calculated as follows:

Rank Criteria	1	2	3
C1	5*	5	0
C2	3	4	3
C3	2	3	5

* Number of experts (decision-makers)

Table 4.1: Ranking of criteria- illustrative example

$$\sum_{k=1}^{3} R_k = [(5)(2) + (5)(1) + (0)] + [(3)(2) + (4)(1) + 0] + [(2)(2) + (3)(1) + 0] = 32$$

$$w_1 = [(5)(2) + (5)(1) + (0)] / \sum_{k=1}^{3} R_k = 0.47$$

$$w_2 = [(3)(2) + (4)(1) + (0)] / \sum_{k=1}^{3} R_k = 0.31$$

$$w_3 = [(2)(2) + (3)(1) + (0)] / \sum_{k=1}^{3} R_k = 0.22$$

Notice that the summation of all weight equals 1.

4.2.2 Rating

In the rating technique, the criteria are presented to each of the experts who is required to give ratings for each criterion. The rating values are usually a continuous rating from 0.0 to a higher limit of 10.0 or 100.0. More than one criterion can have the same rating. The lower limit of 0.0 indicates no importance of the objective while the higher limit refers to the value of maximum possible importance.

The weights are derived from the raw ratings in the following manner:

$$w_{kj} = P_{kj} / \sum_{k=1}^{m} P_{kj} \qquad (4.1)$$

$$w_k = \sum_{j=1}^{n} w_{kj} / \left(\sum_{j=1}^{n} \sum_{k=1}^{m} w_{kj} \right) \qquad (4.2)$$

Where, w_{kj} = weights computed for criterion k by expert j;

P_{kj} = rating by expert j to criterion k.

m = number of criteria; n = number of experts.

4.2.3 Paired Comparison

A development of the rating method is introduced by using the paired comparison method. This method is a way of converting qualitative measures into quantitative measures. All the paired comparison methods are the same in principle in the sense that every expert compares each criterion with all other criteria to indicate preference. For example, if A and B are two criteria, an expert would say whether A is more important than B or the converse or of equal importance. The number of times each criterion is chosen over the other criteria is tabulated for each expert and then added together to determine the total number of times each criterion is chosen over all other criteria.

The weights are derived using the following formula:

$$f_{kj} = \sum_{k'=1}^{m-1} f_{(k/k')j} \qquad (4.3)$$

$$w_{kj} = f_{kj} / J \qquad (4.4)$$

Where f_{kj} = frequency of choice of criterion k over all other criteria by expert j;

$f_{(k/k')j}$ = frequency of choice of criterion k over another criterion k ' by expert j;

J = total number of comparisons made,

n = number of experts and m = number of criteria;

The composite weight (w_k) can be determined using equation (4.2).

For example, consider criteria A, B, C, D and E and suppose that a pair-wise comparison has been made with the following results:

1. A > B	2. A > C	3. A > D	4. A > E	5. B < C
6. B > D	7. B < E	8. C > D	9. C < E	10. D < E

Revise the listing using the same sign yielding the new list below:

1. A > B	2. A > C	3. A > D	4. A > E	5. C > B
6. B > D	7. E > B	8. C > D	9. E > C	10. E > D

From this list, ranks are assigned and scores are given in Table 4.2.

Rank "r"	**Criterion**	**n-r***
1	A	4
2	E	3
3	C	2
4	B	1
5	D	0

* n = the number of criteria

Table 4.2: Paired Comparison Ranks - illustrative example

It must be noted that there can be inconsistencies in the decisions of the experts causing intransitivity. For example, to say that A > B, B > C and then to also say that C > A would be inconsistent, causing intransitivity of preference since the correct order of preference should be A > C. If this occurred then the expert should be asked to make the comparison again.

4.2.4 Successive Comparisons

This method is rather difficult and time consuming on the part of the experts. However, it has the merit of allowing experts to self correct their ranking. This method is very similar to rating. The procedure is as follows:

- Rank all criteria in order of preference as in the ranking method;
- Assign tentatively the value (V_1) equals 1.0 to the most important criterion, and other values (V_i) between 0 to 1 to other criteria in order of importance;
- Decide whether the criterion with the value 1.0 is more important than all other criteria combined. If it is more important, increase V_1 until it becomes greater than the sum of all subsequent V_i's. i.e., $V_1 > \sum_{i=2}^{n} V_i$

If not, adjust V_1, if necessary, so that it becomes less than the sum of all subsequent V_i's.

$$V_1 < \sum_{i=2}^{n} V_i$$

- Decide whether the second most important criterion with value V_2 is more than all lower valued criteria combined and proceed as in the above step;
- Continue until (n-1) criteria have been evaluated in this manner; where n is the number of criteria.

With the use of equation (4.1) & (4.2), the weights for the different criteria are calculated. This method is time consuming and difficult to apply for a large number of decision criteria.

Table 4.3 illustrates the results of testing the above-mentioned techniques to investigate their applicability for the multiple criteria assessment. This test was carried out using simple examples. Factors considered in this test include the time required to assess criteria, the level of relative complexity and the accuracy of the assessment process. The best technique in terms of one factor is given rank "1", the next to the best is given 2 and the worst is given rank '4".

The direct use of the techniques that are shown in Table 4.3 to give weights for the multiple criteria required in the proposed contractor selection process is not sufficient to be reliable. This is especially for the criteria related to the project-specific conditions and requirements where more consistent results and minimum assessment time are required. For the criteria related to the contractor qualifications, more accuracy and justification are required from the assessment technique. The required technique should be able to help in the assessment process for the available experience from the field. The reason behind this requirement is that once the assessment process is carried out, it can be used for other contractor selection processes.

	Technique Accuracy in Assessing Criteria	Technique Complexity Level	Time Consumed in Assessing Criteria
Ranking	4	1	1
Rating	3	2	2
Paired Comparison	2	2	3
Successive Comparison	1	4	4

Table 4.3: Comparisons between the Criteria Assessment Techniques

If the criteria "Technique accuracy in assessing criteria" has more relative importance than the other two criteria then, the "Paired Comparison" technique is most appropriate technique to be used. The accuracy of assessment level using the "Paired Comparison" technique depends on way of its implementation. Reassessing the criteria using either recheck or brainstorming concepts can increase the accuracy of assessment level. The accuracy level of the assessment process can be increased if the person who carries out this process has an acceptable experience in the field of the judgement area. The concept of the Delphi method depends on both recheck and brainstorming concepts. In addition, the Delphi method can be used to determine the relative weights of the criteria on the basis of evoking the available expertise, as will be illustrated in the following section.

4.3 DELPHI METHOD

The Delphi method is a systematic procedure to evoke expert opinion and to obtain the relative importance of multiple criteria where structured information is lacking (Dalkey *et al*, 1970). In general, the procedure consists of:

1. Obtaining from experts their answers to pre-formulated questions either by questionnaire or by some other formal method.
2. The experts can include additional criteria to enrich the results.
3. Statistical analysis of the expert's response is carried out to determine the relative weight of the criteria.
4. The questionnaire is circulated back to the experts with the "average" results so far to ask the experts if, in the light of the results so far, they wish to amend their answers.
5. Step (1) to (4) are repeated until an acceptable quality set of results has been achieved.

Thus, the accumulated experience resulting from contract awarded consequence problems of the previous construction projects as well as the relative weights of criteria can be obtained by using this method to enhance the contractor selection.

Dalkey in 1970 studied the use of this self-rating concept to improve group estimates and showed that the Delphi method leads to increased accuracy of group responses (Grubbstrom, 1988). Dalkey carried out his experimental evaluation within the University of California at Los Angeles. The experiment's conclusion was that the efficiency of the Delphi method in generating agreement increased with each iteration and feedback processes and the group responses become more accurate. It was also found that the Delphi method had the following important characteristics:

- Anonymity
- Controlled feedback
- Statistical group response.

Anonymity: *The use of questionnaires or other formal communication channels, such as e-mail, have a direct effect on the Delphi method's anonymity. By doing this, the effect of dominant individuals is reduced. The group members are not made known to each other and interaction of the group members is handled in a completely anonymous fashion. This avoids the possibility of identifying a specific opinion with a particular person. As a result, the experts can change their mind from their previous evaluation without embarrassment.*

Controlled feedback: *Issuing the questionnaires in a sequence of rounds and giving participants a summary of the statistical analysis of the results at the end of each round, is a device used to ensure objectivity. The individual or agency carrying out the experiment extracts from the questionnaires only those pieces of information that are relevant to the issue, and presents this back to the group. The primary effect of this controlled feedback is to prevent the group from taking on its own goals and objectives.*

Statistical Group Response: *The use of a statistical definition of the response is a way of reducing group pressure for conformity. The statistical analysis of the group responses ensures that the opinion of every member of the group is represented in the final response. On a single question, for instance, the group responses may be presented in terms of a median and the two quartiles. In this way each opinion within the group is taken into account in the median and the spread of opinion is shown by the size of the inter-quartile range. Within these three basic features, it is, of course, possible to have much variation.*

The rationale behind the Delphi method is the age-old adage: "Two heads are better than one" or more generally: a number of heads are better than one (Dalkey, 1970). Brockhoff (1975) in his study of the Delphi method and its future applicability found that the primary area of application had been in the physical sciences and engineering (about 26%). Brockhoff in 1975 (Shneiderman, 1988) published a comprehensive study of Delphi procedures. Figure 4.1 illustrates the Delphi process as described by Grubbstrom (1988).

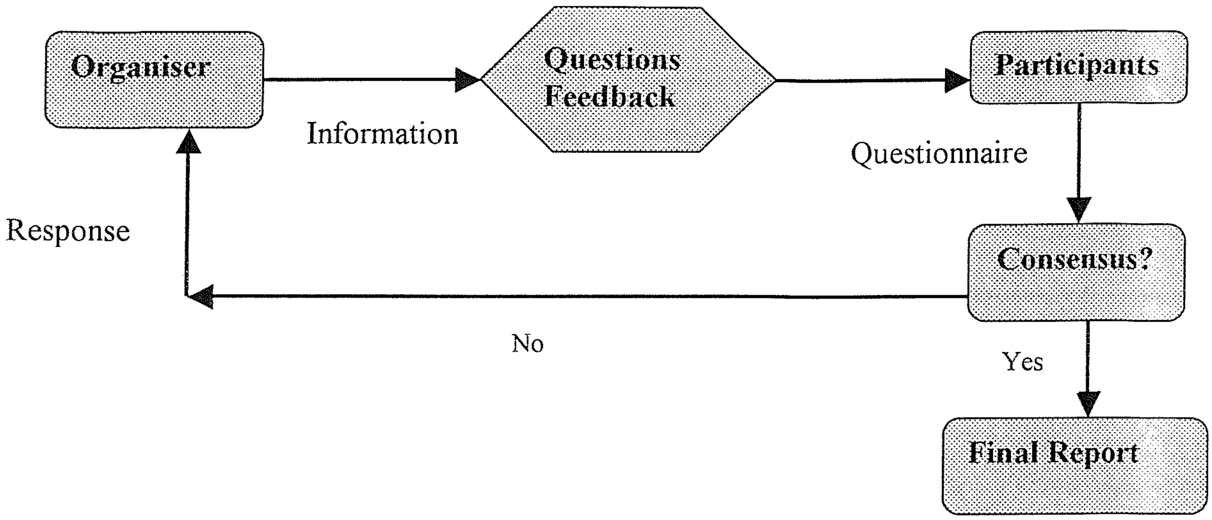

Figure 4.1: The Delphi Process (Grubbstrom, 1988)

The Delphi method can use two basic ways of questioning experts:

(1) Face-to-face contact between experts,

(2) Multi-round (iterative) processes without face-to-face contact and with controlled feedback.

The first method (1) includes the traditional "round-table discussion". In a traditional discussion, each expert receives permanent and uncontrolled feedback from all other experts in the form of their opinions as well as more general responses. A discussion may be structured to include several distinct rounds. Pankova outlines the strengths and weaknesses of round-table discussions in 1984 (Shneiderman, 1988). Generally, it is not practical to derive contractor selection criteria using this method due to the difficulty in holding this type of discussion with a large number of experts often geographically separated.

The second method is more suitable for selection of such criteria in that verification of the reliability of responses is carried out. This verification is achieved by two methods:

(1) Using cross matching questions.

(2) Holding direct interviews with the key experts to assess the reliability of their responses and to make sure that the questionnaires and the weighting system are understandable and complete.

The other advantages of the Delphi method that cannot be provided by other methods are the following (Shneiderman, 1988):

(1) All decision-makers (experts) are deeply involved in the evaluation process because the Delphi method allows them to suggest what criteria or objectives should be considered in the analysis. Therefore, the Delphi method can produce more agreement on criteria or objectives selected.

(2) Because of its anonymity, the Delphi method allows the experts to express their opinions freely and to assign numerical values to what is essentially an opinion, even though an educated one. The experts are given the opportunity to express their subjective value judgements for each criterion or objective and can be assured that their judgements will be taken into account.

One of the basic difficulties associated with forming expert judgement is how to organise the process of inquiry among the group of experts. Underestimation of this difficulty may actually invalidate the expert judgement. The low quality of the judgement collected by the inquiry technique cannot be improved by the application of sophisticated mathematical methods. The core of the problem is the organisation of the interaction among the experts in the process of inquiry. Using the verification method described above can reduce this problem. Thus, the Delphi method can be used for determining the relevance of the criteria used in the contractor selection process. The required accuracy can be obtained throughout the accumulated experience available from the completed construction projects. This can enhance the selection process. Therefore, the Delphi method is selected in the development of this contractor selection system to identify the relevant criteria and their relative degree of importance, as detailed in Chapter 5.

The ability to evaluate alternative solutions depends on criteria having an appropriate measurement scale regardless of the particular type of evaluation strategy involved. Measurement is essentially the act of quantification (the quantification used in this research may be either quantitative or qualitative). The purpose of this quantification is to investigate the relationships or the relative importance of the criteria required in the selection process. The question arising from the review described in sections 4.2 and section 4.3 is "What is the appropriate measurement scales?". The following section reviews the different measurement scales in order to identify the most appropriate scale for use in evaluating the criteria for the contract-awarding model.

4.4 MEASUREMENT SCALE

Scales are the most important method of measurement. There are four basic types of scales: (1) nominal, (2) ordinal, (3) interval and (4) ratio. The nominal scale is the weakest of the four and the ratio scale is the strongest (Bellenger and Greenberg, 1976).

Nominal Scale: This is the simplest scale of measurement, but it does not represent quantification at all; it simply classifies. In nominal scale information, for example labourers in a construction company are given numbers to serve only for the purpose of identification; they have nothing to do with the relative properties of the workers.

Ordinal Scale: This is a purely ranking scale and is the next higher order scale from nominal. One has to distinguish between elements according to a single criterion. In this scale information such as X is greater than Y or X is less than Y as well as X equals Y or X is not equal to Y are available. In this scale we measure occurrences.

Interval Scale: An interval scale, which is the 3rd higher in order of precision, has not only the properties of nominal and ordinal scales, but also adds a known interval between points on the scale. Using an interval scale one not only knows that an item is higher or lower than another, but also how much difference there is between them. A simple example is the Fahrenheit scale of temperature. The difference between 40^{O} and 80^{O} can be quantified but it is incorrect to say that 80^{O} is twice as hot as 40^{O}. The zero point of the Fahrenheit scale is defined as a reference point. Thus ratios between points cannot be computed. The scale is a continuum with no absolute zero as a benchmark (Bellenger & Greenberg, 1976).

Ratio Scale: The strongest basic scale provides an absolute zero and a constant unit of measurement. On a ratio scale, the points are ordered and spaced at equidistant intervals. Measurements of length, weight, volume, speed and height are examples of ratio scales. For example, if production volume of equipment A is 100 m^3 and equipment B is 200 m^3, then B is greater than A (ordinal), B is 100 m^3 more than A (interval), and B is twice the volume of A (ratio).

The nominal and ordinal scales are categorical or qualitative scales while the interval and ratio scales are quantitative scales of measurement. None of these scales on their own are adequate to assess the required selection criteria as required in the assessment model because of part of criteria are qualitative. A large variety of specific scaling techniques have been conceived and applied during the last three decades which may be used for both quantitative and qualitative criteria and included (1) semantic deferential, (2) Likert and (3) paired comparison, (David and Ronald, 1987).

The semantic deferential: In the semantic deferential scale, the respondents are asked to express their feeling about whatever is being assessed by recording their responses on a scale of adjectives (such as not-cold), which are paired polar opposites. Thus, this scale can be called a bipolar scale (Bellenger and Greenberg, 1976). The selection of a semantic deferential scale may introduce problems in terms of which adjective should be used. Any particular pair of adjectives may not be precisely polar opposites in some person's minds, and there will a range of several alternative adjectives from which to choose (David and Ronald, 1987).

Likert Scale: In the Likert scale, the matter of choosing opposite adjectives is avoided. Rather, it makes a statement or poses one description (or adjective) for whatever is being evaluated (David and Ronald, 1987). Respondent are asked to check one category from among several categories of answers that best represents their feeling about or belief in a statement. In general each statement has five response categories, which may be labelled strongly disagree, disagree, undecided, agree, and strongly agree. This can be reduced to three categories, for example simply disagree; undecided and agree, or seven categories providing a finer differentiation along the continuum from strongly disagree to strongly agree. One apparent advantage of the Likert scale is that the respondent needs to consider only one adjective (description) for each item, and the problem of finding an exactly opposite adjective is not required (David and Ronald, 1987). The Likert scale has the advantage over many other attitude or perception measurement techniques of being fairly simple, straightforward, and for the most part, easy for people to answer (Kaluzny and Veney, 1991). The Likert scale is a technique for measuring attitudes, beliefs, perceptions, and to a great extent, knowledge and consensus (Kaluzny and Veney, 1991). A Likert scale refers to a statement or a series of statements made in either a positive or negative manner.

4.4.1 Selection of Measurement Scale for the Delphi Method

No specified scale is defined as a part of the Delphi method. The Likert scale is selected from the range of scales detailed above in order to assess the criteria within the Delphi method for the following reasons:

1. There are a large number of criteria that need to be assessed as part of the contract award system that makes the paired comparison technique inappropriate. This also can cause fatigue for experts (respondents) and lead to bias in the results.

2. The time and effort required for carrying out the assessment using the Likert scale is relatively low, which is more appropriate for the expert.

3. It can reflect the experts' attitudes in a direct and simple way and the whole measurement process can be carried out using only one uniform set of scaling categories.

The next question is how the criteria, which can be identified and assessed by the Delphi method, can be incorporated into the selection process that is required for the contractor selection system. The following sections describe the decision analytic methods that are applicable for the proposed selection process using the multiple criteria.

4.5 SUMMARY AND CONCLUSIONS

The survey showed that the Delphi method can be utilised to identify and assess the criteria which initially collected according to the literature review of Chapter 3.

The Delphi method was selected to identify the criteria, which are related to the contractor selection for the following reasons:

i) To acquire the depth expertise available in the construction industry and utilise this for the proposed selection system to overcome the experience limitation of the decision-maker;

ii) To minimise the human subjectivity by using an objective structured decision system.

iii) To reduce the time taken in the selection process

Likert scale was selected to use in the criteria assessment within the Delphi method for the reasons indicated in this chapter.

CHAPTER 5: CRITERIA REFINMENT, ASSESSMENT AND EVALUATION

CHAPTER 5: CRITERIA REFINEMENT, ASSESSMENT AND EVALUATION

5.1 INTRODUCTION

The Delphi method was selected to identify and assess the contractor criteria as concluded in Chapter-4. The implementation of the Delphi method is described, in this chapter, in detail to show how the experience available form the construction industry can be acquired. A survey for the experts from this industry was carried out to acquire the expertise required. The approach used for this survey as a part of the Delphi method implantation includes definition of the survey population, estimation of the sample size in the countries surveyed: Egypt, Kuwait and the UK.

The findings of the survey are processed and analysed to identify the relevant criteria and to establish the relative importance of the various groups of criteria affecting the individual contractor selection.

5.2 CRITERIA IDENTIFICATION AND REFINEMENT

What are the sources of expertise and how can the criteria be acquired based on this expertise and what are the relevant criteria. This is possibly the most difficult part in the development of a contractor selection system. "Knowledge acquisition has been reported as the major bottleneck in the development of an expert system" (Bowen, 1991).

5.2.1 Identification of Knowledge Sources (Expertise)

Sources of knowledge (expertise) can be broadly sorted into two categories:

1. Expert Literature
2. Human Experts

The first source of expertise was surveyed as shown in Chapter 3 to investigate the criteria that were thought to be relevant for the contractor selection. The source of this expert literature included:

- Text books and technical reports;
- Recent research publications in journals and conferences.

The second source of expertise is private (unpublished) knowledge as against the first source, which contains public knowledge. This source is more difficult to access than the first source. Generally, in the domain of the selection process, as indicated in Figure 5.1, human experts are selected from:

- Experienced consultant engineers; or the owners of completed projects.
- Researchers interested in the contract awarding research area.

The selection criteria for human experts included the following:

1. The selected expert should have been involved in the various aspects of the contractor selection process for at least 10 years.
2. Researchers should have been involved in at least one research project related to contractor selection or construction-contractor problem areas.

This expertise was collected from three countries, namely the UK, Egypt and Kuwait. The list of these experts is given in Appendix F.

5.2.2 Criteria Refinement Using the Delphi Method

The Delphi method was selected for the criteria refinement process in the second phase of the survey, as indicated in Figure 5.1 and this was carried out using both questionnaires and interviews as described in section 5.3. This method was applied as follows:

1. Postal questionnaires were issued to each expert (450 questionnaires sent) as defined in section 5.3.1 and selected on the basis described in the survey approach in section 5.3. The experts assessed each criterion in the questionnaire by assigning a value between one and five. These ranged from (1) very important, (2) important, (3) average, (4) low and (5) very low.
2. Statistical analysis was carried out to refine these criteria with the purpose of identifying the relevant criteria and their relative degrees of importance. The basis of this statistical analysis is described in section 5.4.
3. Structured interviews (16 interviews) with key experts were conducted in first round of interviews for the purposes described later in this section. The forms of questionnaire were also used to organise these interviews.
4. Statistical analysis was carried out to refine the criteria that resulted from the first round of interviews with the purpose of identifying the relevant criteria and their

relative degrees of importance. This step was carried out as the second round of the Delphi method, as shown in Figure 5.1.

5. The refined criteria that resulted from the previous step (4) were given back to the key experts for reassessment and to assure the relevancy of the identified criteria. This step was the third round within the Delphi method. Interviews with 5 key experts in Kuwait and 1 key expert in Egypt were carried out in this step.
6. Statistical analysis was carried out to refine the criteria, which were the output of the previous step.
7. The criteria that resulted from the final statistical round are used directly in the AHP method, using their relative degrees of importance, as shown in Appendix D.

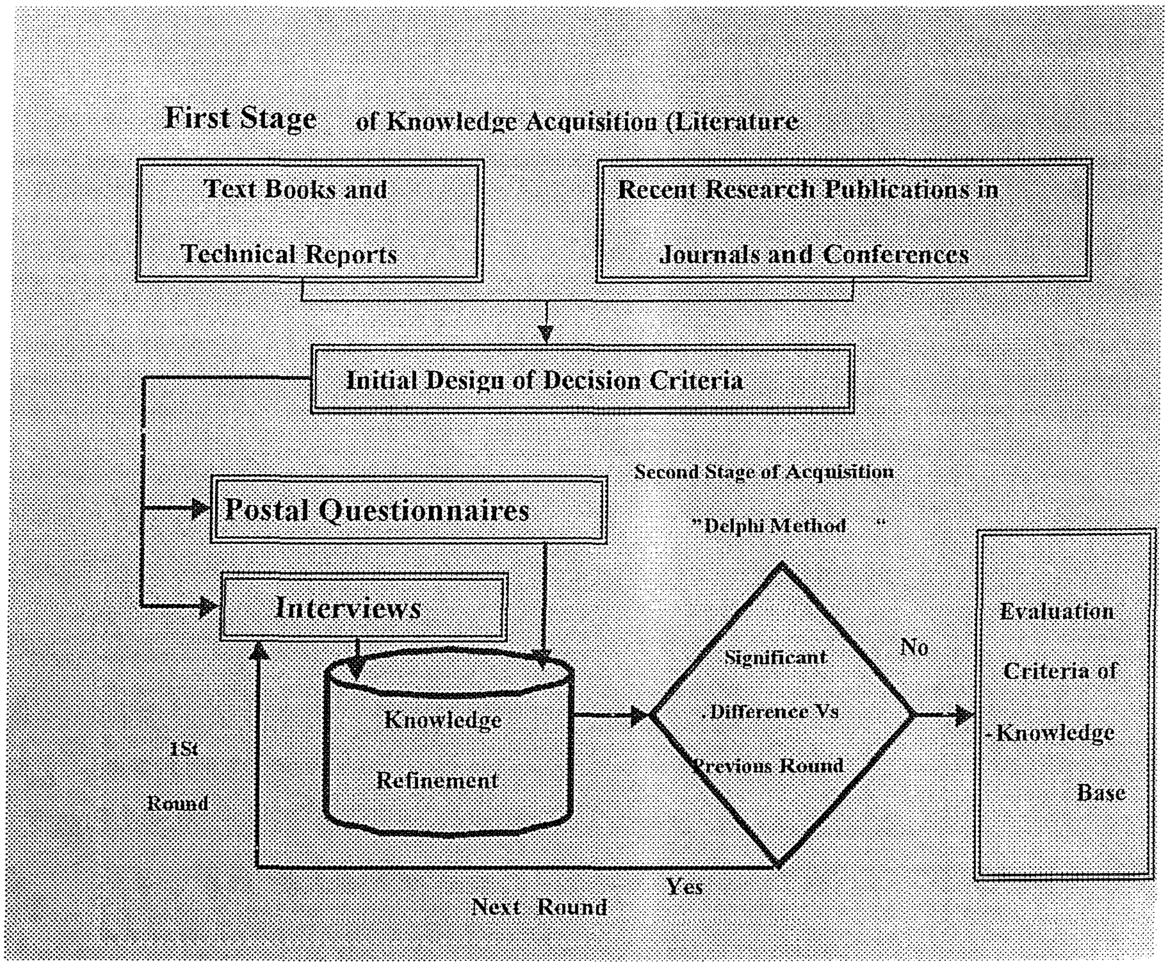

Figure 5.1: The Knowledge Acquisition Process for the Selection Criteria

The application of the Delphi method in this research was carried out using one round of questionnaire and two rounds of structured interviews for the following reasons:

- Experts willingness to give more time for extended rounds of Delphi; and
- The results acquired from step (2) that applied to Egypt and Kuwait were used as the first round for the UK knowledge acquisition. The results of criteria identification from this round had unrecognised difference to those acquired from Egypt and Kuwait as illustrated in Section 5.4 and Appendix B.

5.2.3 Questionnaire Description and Design

The knowledge (in the form of closed questions /answers only) acquired from the experts should not be limited to the questionnaire responses; it should be flexible and open to receive additional knowledge reflecting the experts' experiences by allowing them to add more criteria to the lists. Generally, the questionnaire forms may take one of three formats (Bellenger and Greenberg, 1976):

(1) Structured,

(2) Semi-structured, and

(3) Unstructured.

The semi-structured form was selected since it can generate additional criteria from experts whereas the first and last formats cannot do this. A measurement scale is assigned, as with the structured method, in order to avoid the problem of using different scales as used in the structured format. The criteria involved in this semi-structured questionnaire are listed in Appendix A/o and Appendix A.

The criteria selected were categorised into five groups. The first group (DCG1) measures the contractor experience record. The second group (DCG2) evaluates the contractor past performance level throughout previous projects. The third (DCG3) assesses the financial stability of the contractor. The fourth group is to measure the contractors' current capabilities of contractors (DCG4) and the contractors' plans to execute the proposed project (DCG5).

Each criteria group includes sub-criteria groups and the sub-criteria groups may include more than division levels of criteria, as detailed in Appendix A/o and Appendix D. Experts can add more criteria based on their experience.

The main design feature of the questionnaire is described as follows:

i. The first page of the questionnaire survey form includes a brief introduction explaining the survey's purposes. A brief description of the questionnaire objectives is given as an approach to formalise a list of the most relevant criteria, which can be used to develop a new selection method and hence overcome the problems inherited by the current system.

ii. The questions were structured in five criteria groups for clarity.

iii. The second page lists the five main groups in order to determine the relative importance between the groups using both a descriptive and numerical scale based on the Likert scale (section 4.4).

iv. From the first phase of the survey, the full list is given in appendix A/o, decision criteria were identified as possibly having an effect on contractor selection. The criteria belonging to each group were described in the remaining pages separately.

v. The questionnaire forms were printed in three colours, blue for experts in heavy construction (public), yellow for non-residential building projects and green for private engineering consultants.

Generally, the questionnaires were designed to be as simple as possible as shown in Appendix A/o and Appendix A.

The details of the survey procedure, basic analysis and results of these questionnaires as a final step of the Delphi method are described in the following sections.

5.2.4 Design Of The Criteria Coding System

The hierarchy of criteria consists of three levels under each criteria group. The proposed coding system for the criteria, which are related to the contractors, was designed to reflect their hierarchy as follows:

- The first four digits in the code represent the criteria group as follows:
  - **DCG1** is the code of the first criteria group "Contractor's Experience

Record".

- **DCG2** is the code of the second criteria group "Contractor's Past Performance".
- **DCG3** is the code of the third criteria group "Contractor's Financial Stability".
- **DCG4** is the code of the fourth criteria group "Contractor's Current Capabilities".
- **DCG5** is the code of the fifth criteria group "Contractor's Submitted Plans to the Proposed Project".

- The criteria in the first hierarchy level are represented by two digits where the number of criteria in this level is more than 9 criteria and less than 20. For example, the criterion "Financial performance" is the fifth criterion within the first hierarchy level under the criteria group 3, and then its code is (DCG3.05).
- The criteria in the second and third hierarchy level are represented by one digit each where the number of criteria in each level is less than 9 criteria. For example, the criterion "Liquidity ratios (solvency ratios)" is the first criterion in the second hierarchy level under fifth criterion within the first hierarchy level under the criteria group 3, and then its code is (DCG3.05.1). Also, the criterion "Current ratio" is the first criterion in the third hierarchy level under the first criterion in the second hierarchy level which under the fifth criterion within the first hierarchy level under the criteria group 3, and then its code is (DCG3.05.1.1).
- The period (.) is used as a separator between each hierarchy level.

This coding system is used for the criteria included in the original list (before the implementation of the Delphi method) and the final list of criteria.

The code of criteria in the original list will be included in the final list of criteria either they are considered as decision criteria or not. The criteria that considered as decision criteria are described in the final list and their final relative degree of importance are also recorded. The code of criteria, which was excluded as decision criteria in the final list, is mentioned, described as "Low rate criterion (Excluded one)" and given "0.00%" relative degree of importance.

5.2.5 Questionnaire Verification

A structured interview programme was used as part of the knowledge acquisition process in order to verify the credibility of questionnaire design and the reliability of responses. Previous research (of the engineering knowledge process) has shown that personal interviews, rather than pure questionnaires, are the most effective method of knowledge acquisition (Kartam, 1994). The use of interviews with the proposed system supports this finding especially where questions were returned with incomplete assessment or comment and particularly those related to the contractor's financial stability and financial ratios. The interviews clarified the situation in which these questions were presented on the basis of an accountancy format that was not familiar to the majority of experts used.

The limitations of using questionnaires to investigate the contractor selection criteria can be summarised as follows:

- Some questions were misinterpreted.
- The return rate of questionnaires was relatively low.
- The questionnaire did not have the flexibility of interviews.
- A general understanding of the thesis problem domain was required in order to acquire meaningful answers.

Generally, the questionnaires were carried out before the interviews because questionnaires do have some benefits:

1. It was easier to gain contributions from a wider number and range of experts who would not have otherwise been approached for interview (177 questionnaire responses versus 22 interviews).
2. The questionnaire was less personal and there is no requirement to make an appointment with the expert.
3. The questionnaire approach provided a means of maximising the expertise sources.

Section 5.3 describes the survey conducted to apply the Delphi method for knowledge acquisition purposes. This description includes the expert selection (survey sampling), the basis of statistical analysis following this survey and finally the statistical analysis results, which represent the final round.

5.3 SURVEY APPROACH AND RESULTS ANALYSIS

The approach of this survey was carried out in two steps:

Step-1: Defining survey population.

Step-2: Estimating the survey sample size

5.3.1 Step-1: Defining Survey Population

Defining the population of the survey is the first step in the survey of experts for knowledge acquisition purpose, as described in Section 5.3.2. It was conducted using both postal questionnaires and structured interviews as indicated in Section 5.2.2.

This survey was carried out in Kuwait, Egypt and the United Kingdom. These three countries were surveyed for the following reasons:

- The author had the opportunity to collect knowledge from experts in these countries. The author is an Egyptian working in Kuwait and is familiar with the construction industry in these countries.
- Egypt and Kuwait are representative of the Middle East construction industry where Egypt represents the non-oil countries and Kuwait represents the oil countries.

The questionnaire was posted to client representatives, advisors or consulting firms, in both heavy and building construction, who satisfied the expert selection criteria mentioned in Section 5.3, either in both the heavy and building construction. These experts are working in both building projects and heavy construction in the United Kingdom, Egypt and Kuwait. The experts were working in architectural engineering firm (A/E) whom involved directly in contractor selection, preparing or alternatively providing construction management services. The list of experts contacted is provided in Appendix F.

The number of experts contacted by either questionnaire or interview within the rounds of the Delphi method is shown in Table 5.1. However, some problems were encountered during this survey, including the appointments for interviews with the experts.

Reasons for not returning the questionnaire include:

- Experts' willingness to give their knowledge free, as a matter of confidentiality and private asset, was not easily available.
- Insufficient time to complete the questions;

5.3.2 Step-2: Estimating survey sampling

The objective of this section is to identify the sample size of experts required to represent the total population. There are many references that describe the sampling process, techniques and selection methods, including market research references (Bellenger and Greenberg, 1976; David and Ronald, 1987 and Margaret and Len, 1995). Survey sampling methods are statistical methods for collecting knowledge and making inferences about the characteristics of defined populations. The term "population" is used broadly to designate a group to be studied. Sampling has two main functions: (1) to describe a total population on the basis of an examination of only a small part of it and (2) to be certain that results obtained from an experiment reflect its true effect. The objective of this section is to apply the principles of sampling to ensure the validity of this survey.

		Posted Questionnaires		Reply to the Questionnaires		Interviews	
	Country	**Building**	**Heavy**	**Building**	**Heavy**	**Building**	**Heavy**
1st Round of the Delphi method	**Egypt**	110	70	45	32	-	-
	Kuwait	60	60	32	30		
	UK	80	70	23	15		
2nd Round of the Delphi method	**Egypt**					3	3
	Kuwait					3	7
	UK					-	-
3rd Round of the Delphi method	**Egypt**	-	-	-	-	1	-
	Kuwait	-	-	-	-	3	2
	UK	-	-	-	-	-	-

Table 5.1: Survey Conducted for Knowledge Acquisition and the Number of Responses

Sampling Technique: refers to the way in which the desired numbers of elements are selected from the population. The two basic approaches are probability sampling and non-probability sampling. With a probability sample, each element in the population has a known probability of being selected for the sample. The probability samples are usually preferred over the non-probability approach (Bellenger and Greenberg, 1976). The probability samples include different types of sampling strategies such as (1) simple random sampling, (2) stratified sampling, and (3) cluster sampling.

Simple Random Sampling: is a procedure for drawing a sample of n units from a population in such a way that each and every subset consisting of n distinct units has the same probability of being selected. In a population of size N there are possible samples of size n without replacement. This means that every possible subset of n units from the population is given the same chance of being selected. Although simple random sampling is conceptually straightforward, it has two major problems: precision and bias (David and Ronald, 1987). In a simple random sample, there is a small probability that the sample selected could consist of the most extreme members of the population because every possible sampling has an opportunity to be included. The second major problem of simple random sampling is the difficulty of obtaining a complete and accurate sample. A stratified sampling method is an alternative method adopted to reduce the degree to which the results of sampling will be inaccurate.

Stratified Sampling: refers to a population that consists of non-overlapping sub-populations, that is, strata, such that every unit in the population may be identified uniquely with a single stratum. In essence, a sample survey of a stratified population can be thought of as a collection of independent surveys conducted within each stratum. A stratified sample is designed specifically to increase the precision and hence the probable accuracy of sample sizes (David and Ronald, 1987). A strategy that may be used to increase the probability of the sample population and target population being the same and which has certain advantages over either simple random or stratified sampling is the use of cluster sampling.

Cluster Sampling is a technique whereby the sample is drawn in two or more stages. At the first stage the total population to be sampled is drawn and divided into several clusters on the basis of some meaningful variable such as work type or geographical area. These clusters are mutually exclusive. Cluster sampling has the disadvantage that responses within one organisation (cluster) are likely to be more dissimilar than those responses in another organisation (cluster) (Harrison, 1989). This may reflect a significant variation between clusters. Although similarity of responses within particular strata is an advantage for stratified sampling, it is a disadvantage for cluster sampling because all clusters are not represented. In consequence, most cluster sample-based estimates of population parameters are likely to be less precise than stratified sample estimates and are frequently less precise than simple random sampling.

The essential difference between cluster sampling and stratified sampling comes down to whether or not all the subgroups are represented in the sample. If at least one element is selected from every subgroup, then the subgroups are treated as strata and methods on stratified sampling apply. If some, but not all, of the subgroups are selected into the sample, then the subgroups are treated as a cluster (Harrison, 1989).

5.3.2.1 Sample Estimate and Population Value

Whatever the technique used for probability sampling, understanding the relationship between the population distribution and the sampling distribution is important to an understanding of how statistics can be used to make inferences about a parameter value result (David and Ronald, 1987). This importance can be defined by indicating how closely the sample statistics are distributed around the population mean. If the sample size is sufficiently large, the sampling distribution approximates the normal distribution whether or not the population is normally distributed. Statisticians generally agree that a sample size of 30 or more is usually adequate to produce a normal distribution (David and Ronald, 1987).

'*We do not expect our sample estimate to be exactly the same as the population value*' (Margaret and Len, 1995). Therefore, allowance for possible error should be given.

The size of allowance depends on (Margaret and Len, 1995):

- The size of the sample in relation to the variability in the population where the subject of the survey is concerned (if attitudes were uniform throughout the population, the responses of one individual would suffice).
- The size of the sample.
- The confidence levels that are chosen to work with.

Variability in population is measured by the standard deviation. The confidence level is determined by time and cost of precision, the higher level of confidence is out of proportion to the benefit received. In normal distribution figures, there is a 68% chance that a sample selected at random will have a mean that lies within +/- 68% standard deviations of the population mean. Also, there is a 95% chance that the sample mean will lay within +/- 2 standard deviations of the population mean (David and Ronald, 1987).

In any survey of human attitudes there are possible sources of error other than those, which can be statistically measured (Margaret and Len, 1995). As a rule of thumb, the confidence level applied varies from 5 to 10 percent when the sample includes more than 5 percent of the population (David and Ronald, 1987).

Sample size is determined according to the selected method of sampling. As mentioned above, there are different ways of selecting samples. The formulas that can be used to determine sample size of different sampling methods are fully discussed in many handbooks of statistical methods for engineers and scientists as indicated in section 5.3.2.

The **notation** used in the basic statistics of sampling is as follows:

Population values		**Sample estimates**	
Number of items	N	Number of items	n
Mean	μ or X	Mean	x
Standard deviation	σ or S	Standard deviation	s
Proportion	π or P	Proportion	p
		Standard error of the mean	s_X
		Standard error of the proportion	s_p

Sampling Formulae:

$$\text{Standard deviation} = \sqrt{\frac{1}{n} * \sum (X - x)^2} \qquad (5.1)$$

$$\text{Standard error of the mean} = \frac{s}{n} \text{ applies variables} \qquad (5.2)$$

Standard error of the proportion applies attributes (5.3)

$$s_p = \sqrt{\frac{p(1-p)}{n}} \text{ or } \sqrt{\frac{p(100-p)}{n}} \ (\%) \text{ or } \sqrt{\frac{pq}{n}}$$

Where q is the proportion without the attribute.

If p is the percentage or proportion with the attribute and **q** the percentage or proportion without, the standard error is calculated as follow: $s_p = \sqrt{\frac{pq}{n}}$ often written as above.

The above formulae suggests that, in order to estimate sample size, the following figures need to be determined:

1. The standard deviation anticipated for individual variables (question response) 's'
2. The proportion/ percentage likely to hold each attribute (p).
3. The number of standard errors required by the confidence level (Z)
4. Action standards set by decision-maker, the acceptable error (E).

Z is usual to work at 95 percent confidence level, i.e. according to standard deviation tables it sets limits of +/- 1.96 (or 2) standard errors around the sample estimate and the range of acceptable error (E) can be +/- 2 % (Margaret and Len, 1995). Harrison (1989) showed that a 95% confidence interval to contain the mean for a normal population is often used in the engineering field.

Then, the formula for estimating sample size is:

1. For variables using the standard error of the mean:

$$n = \frac{(s^2 * Z^2)}{E^2} \tag{5.4}$$

2. For attributes using the standard error of the proportion:

$$n = \frac{(p * q * Z^2)}{E^2} \tag{5.5}$$

If the population size is finite and known (N), the following formula can be used (David and Ronald, 1987):

$$n = \frac{p * q}{\frac{E^2}{Z^2} + \frac{p * q}{N}} \tag{5.6}$$

The accepted error range around a sample can be estimated based on equation (5.6) as follows:

$$E = \sqrt{Z^2 * p * q * (1/n - 1/N)} \tag{5.7}$$

The sample size for questionnaire responses from each country is determined as described in the following sections.

5.3.2.2 Sample Size - Egypt's Building Construction Engineering

There are about 400 consulting offices and agencies (public and private) involved in building construction in Egypt. Applying equation (5.6) to estimate the appropriate sample size as follows:

N is 400, nothing is known about the probable percentage of replies, so p is set at 50%.

Assuming the range of acceptable error (E) is +/- 5 %, which is normally considered an acceptable range of error around the sample estimate.

If the desired confidence level is 95%, then from Standard Tables, Z = +/- 1.96.

$$q = 1.0 - 0.5 = 0.5$$

$$n = \frac{p*q}{\frac{E^2}{Z^2} + \frac{p*q}{N}} = \frac{0.5*0.5}{\frac{0.05^2}{1.96^2} + \frac{0.5*0.5}{400}} = 196.$$

Applying equation (5.6) to assess the appropriateness of the sample size estimated to represent this population:

The estimated sample size (number of selected experts): n = 110. The error range:

$E = \sqrt{Z^2 * p * q * (1/n - 1/N)} = \sqrt{1.96^2 * 0.5 * 0.5 * (1/110 - 1/400)} = 7.96$ %, which is considered an acceptable range of error around the sample estimate according to the basic rules of thumb mentioned above (E can be from 5% to 10%).

The expert response number was 45, which represents about 40.9% of the posted questionnaires (generally, 25% responses are acceptable).

5.3.2.3 Sample Size- Egypt's Heavy Construction Engineering

There are about 250 consulting offices in the public (about thirty organisations involved in heavy construction of the public sector) and private sectors involved in heavy construction engineering.

Applying equation (5.6) to estimate the appropriate sample size as follows:

N is 250; nothing is known about the probable percentage of replies, so p is set at 50%. Assuming the range of acceptable error (E) is +/- 5 %, which is considered an acceptable range of error around the sample estimate.

If the desired Confidence Level is 95%, then from Standard Tables, Z = +/- 1.96.

$$q = 1.0 - 0.5 = 0.5$$

$$n = \frac{p*q}{\frac{E^2}{Z^2}+\frac{p*q}{N}} = \frac{0.5*0.5}{\frac{0.05^2}{1.96^2}+\frac{0.5*0.5}{250}} = 152.$$

Applying equation (5.6) to assess the appropriateness of the sample size estimated to represent this population:

The estimated sample size (number of selected experts): n = 70,

The population size: N = 250

The error range: $E = \sqrt{Z^2 * p * q * (1/n - 1/N)} = \sqrt{1.96^2 * 0.5 * 0.5 * (1/70 - 1/250)} = 9.94\ \%$,

which is still considered an acceptable range of error around the sample estimate according to the basic rules of thumb mentioned above (E can be from 5% to 10%).

The expert response number was 32, which represents about 45.7% of the posted questionnaires.

5.3.2.4 Sample Size-Kuwait's Building Construction Engineering

The total number of consultants' offices in Kuwait working in building construction (public and private) is about 110 consultants; at least two experts are included in each office, therefore, the sample size is estimated equal to 220.

Applying equation (5.6) to estimate the appropriate sample size as follows:

N is 220, nothing is known about the probable percentage of reply, so p is set at 50%.

Assuming the range of acceptable error (E) is +/- 5 %, which is considered an acceptable range of error around the sample estimate.

If the desired confidence level is 95%, then from Standard Tables, Z = +/- 1.96.

$$q = 1.0 - 0.5 = 0.5$$

$$n = \frac{p*q}{\frac{E^2}{Z^2}+\frac{p*q}{N}} = \frac{0.5*0.5}{\frac{0.05^2}{1.96^2}+\frac{0.5*0.5}{220}} = 140.$$

Applying equation (5.6) to assess the appropriateness of the sample size estimated as representative of this population:

The estimated sample size (number of selected experts): n = 60,

The population size: N = 220

The error range: $E = \sqrt{1.96^2 * 0.5 * 0.5 * (1/60 - 1/220)} =$ 10.79 %, which is considered slightly out of the acceptable range of error around the sample estimate according to the basic rules of thumb mentioned above (E can be from 5% to 10%), and hence few questionnaires needed to be posted to increase the confidence level.

The expert response number was 32, which represents about 53.3% of the posted questionnaires.

5.3.2.5 Sample Size-Kuwait's Heavy Construction Engineering

There are about 85 consultant offices working in the heavy construction area in Kuwait; at least two experts are included in each office, therefore, the sample size is estimated equal to 170.

Applying equation (5.6) to estimate the appropriate sample size as follows:

N is 170, nothing is known about the probable percentage of replies, so p is set at 50%.

Assuming the range of acceptable error (E) is +/- 5 %, which is considered an acceptable range of error around the sample estimate.

If the desired confidence level is 95%, then from Standard Tables, Z = +/- 1.96.

$$q = 1.0 - 0.5 = 0.5$$

$$n = \frac{0.5 * 0.5}{\frac{0.05^2}{1.96^2} + \frac{0.5 * 0.5}{170}} = 118.$$

Applying equation (5.6) to assess the appropriateness of the sample size estimated as representative of this population:

The estimated sample size (number of selected experts): n = 60,

The population size: N = 170

The error range: $E = \sqrt{1.96^2 * 0.5 * 0.5 * (1/60 - 1/170)} = 10.18\ \%$, which is considered slightly out of the acceptable range of error around the sample estimate (E can be from 5% to 10%), and hence few questionnaires needed to be posted to increase the confidence level.

The expert response number was 30, which represents about 50.0% of the posted questionnaires.

5.3.2.6 Sample Size-UK's Building Construction Engineering

There are more than 700 (N) consultants' offices and agencies (public and private) involved in building construction in the UK.

Applying equation (5.6) to estimate the appropriate sample size as follows:

N is 700; nothing is known about the probable percentage of replies, so p is set at 50%.

Assuming the range of acceptable error (E) is +/- 5 %, which is considered an acceptable range of error around the sample estimate.

If the desired confidence level is 95%, then from Standard Tables, Z = +/- 1.96.

$$q = 1.0 - 0.5 = 0.5$$

$$n = \frac{0.5 * 0.5}{\frac{0.05^2}{1.96^2} + \frac{0.5 * 0.5}{500}} = 217$$

Applying equation (5.6) to assess the appropriateness of the sample size estimated as representative of this population:

The estimated sample size (number of selected experts): n = 80.

The population size: N = 500

The error range: E = $\sqrt{1.96^2 * 0.5 * 0.5 * (\frac{1}{80} - \frac{1}{500})}$ = 10.0 %, which is considered an acceptable range of error around the sample estimate (E can be from 5% to 10%).

The expert response number was 23, which represents about 28.8% of the posted questionnaires.

5.3.2.7 Sample Size-UK's Heavy Construction Engineering

Public sector organisations involved in heavy construction in the UK are about 400 consulting offices working in the public and private sectors.

Applying equation (5.6) to estimate the appropriate sample size as follows:

N is 400, nothing is known about the probable percentage of reply, so p is set at 50%.

Assuming the range of acceptable error (E) is +/- 5 %, which is considered an acceptable range of error around the sample estimate.

If the desired confidence level is 95%, then from Standard Tables, Z = +/- 1.96,

$$q = 1.0 - 0.5 = 0.5$$

$$n = \frac{0.5 * 0.5}{\frac{0.05^2}{1.96^2} + \frac{0.5 * 0.5}{400}} = 195.$$

Applying equation (5.6) to assess the appropriateness of the sample size estimated as representative of this population:

The estimated sample size (number of selected experts): n = 70,

The population size: N = 400

The error range: E = $\sqrt{1.96^2 * 0.5 * 0.5 * (\frac{1}{70} - \frac{1}{400})}$ = 10.60 %, which is considered an acceptable range of error around the sample estimate (E can be from 5% to 10%).

The expert response number was 15.

To assess its appropriateness as representative to the population, E is estimated as follows:

Based on the values of confidence level, Z and N those used in the above. Then applying equation (5.7), the error range: E = $\sqrt{1.96^2 * 0.5 * 0.5 * (1/15 - 1/400)}$ = 24.82 %, which is considered significantly out of the acceptable range of error around the sample estimate (E can be from 5% to 10%), and hence more questionnaires needed to be posted again to increase the confidence level.

Actually, whatever the size of sample used, carrying out interviews helps to minimise and verify the questionnaire and to be more confident of the results as described in section 5.2.3. These interviews were sixteen in the first round of application of the Delphi method and six interviews in the second round as shown in Table 5.1.

Generally, the results of survey and the number of reply to the questionnaire is convenient to demonstrate the concept of this research but it may not fully confident in the commercial level, where more survey is needed.

5.4 RESULTS OF SURVEY

Once the knowledge was acquired, either from the questionnaires or interviews, the results for each group were tabulated and statistically analysed. The requirements of the statistical analysis can be summarised as follows:

- Central tendency of responses,
- Variability,
- Test of significance,
- Correlation.

In selecting statistical analysis techniques, a scale is often taken to reflect the quality of data (knowledge) as discussed by Bellenger and Greenberg (1976). They concluded for the interval and ratio scales that:

1. Mean can be used to measure the central tendency when the interval scale is used, while the geometric mean can be used for ratio scales.
2. Standard deviation can be used to measure the variability when the interval scale is used, while coefficient of variation is used in the ratio scales.
3. "T-test" can be used for testing the significance of interval scales, and Chi-test for the ratio scale.
4. Factor analysis can be used as a measure of correlation or association.

All these statistical analysis requirements can be carried out using different types of software such as SPSS for Windows© or ANSYS using the VAX© computer. This statistical analysis of the questionnaire response results was carried out using the SPSS for Windows© (Version 6 -1994).

The results obtained include:

- The mean, standard deviation, and correlation (alpha) for each criterion in all group for the surveyed countries separately.
- The criteria were accepted if the experts' questions responses satisfied the following conditions:
    1. Experts'' responses' mean value was equal to or more than the average defined in the Likert scale.
    2. Experts'' responses' standard deviation was within the defined range (+/-1).
    3. The correlation of question response recorded was 50% using the factor analysis (alpha) scale.

Samples of this statistical analysis are shown in Appendix C. Results of the statistical analysis of the responses obtained by the implementation of the Delphi method are described in the following two sections. These responses for the criteria, based on questionnaires detailed in Appendices A/o and A, were separated into heavy and building construction for the three surveyed countries and described in sections 5.4.1 and 5.4.2 respectively.

5.4.1 Heavy Construction Projects – Survey Results Analysis

The degree of relative importance for each criteria group (DCG) with respect to the other decision criteria groups is varies to some extent from one country to another and also within each country in this survey. Contractor's past performance criteria group (DCG2) was recorded as having the highest degree of importance in the UK while it was recorded the fourth highest degree of importance in both Egypt and Kuwait. Contractor's experience record criteria group (DCG1) recorded a similar degree of importance (fifth order) in both Egypt and Kuwait, while it was recorded the fourth degree of importance in the UK, as illustrated in Figure 5.2.a.

The relative degree of importance recorded in the contractor's current capabilities (DCG4) group varies from one country to another. DCG4 was recorded the highest degree within screening and final selection processes in Egypt and Kuwait, while it recorded the lowest degree of importance in the UK (87.13%). DCG4 criteria group, which is related to contractor's plans submittals to the project under consideration, was recorded the second level of importance in the three countries of survey, UK (93.45%), Egypt (94.35%) and Kuwait (95.03%) as depicted in Figure 5.2.a. These results indicate that the tender sum was not recorded the highest priority as it was expected from the expert responses as a main decision to select the contractor, which was actually used in the current contract award system. Producing an average weight for the criteria resulting from the three countries may be misleading due to the variance in the expert responses that resulted mainly from the significant difference in the construction industries of these countries.

5.4.1.1 Contractor's Experience Record Decision Criteria Group (DCG1) 'Heavy Projects'

Contractor's experience record decision criteria group (DCG1) was recorded the lowest degree of importance in both Egypt (83.87%) and Kuwait (86.54%) while it was recorded the second lowest degree in the UK (90.29%). This result can be interpreted using the comments received from the interviews and some questionnaires as follows: The contractor experience criteria group is not strong enough to decide the appropriateness of a contractor to the project under consideration. The major reason given relating to the measures used for this group did not relate directly to the contractor performance degree of importance in the previous projects. This group included 17 criteria in its second level, as indicated in Figure 5.2.b. The most important criterion within these 17 criteria varied between the countries surveyed to another. The criterion "the previous work volume in similar projects with same owner (DCG1.12)" has the highest degree of importance within DCG1 in the UK. The interpretation of this importance for the criterion DCG1.12 within this group (DCG1) supports the reason to consider this criterion as an indirect measure for past performance.

The criteria "the number of years working in S.Ps. [Similar Projects] (DCG1.01)" and "Average annual work volume of S.Ps.-last 3 years (DCG1.07)" have the highest degree of importance within DCG1 in both Egypt and Kuwait respectively, as shown in Figure 5.2.b. The main reasons given relating to this result were:

1. The Kuwaiti contract award system classifies contractors based on the monetary value of their previous projects.
2. The number of years working in similar projects is the most important measure of the contractor experience within Egyptian construction.

Some criteria have a similar degree of importance in all three countries (UK, Egypt and Kuwait). Five decision criteria out of the seventeen criteria (about 30%) within DCG1 are close in these three countries. The criterion (DCG1.01) has a degree of importance more than 92.5% in all surveyed countries. The criterion (DCG1.12) has more than 85%. The criterion of "the previous work volume in similar geographical conditions and S.Ps. (DCG1.16)" has a degree of importance more than 80%. The criteria "maximum project delivery rate within last 3-years (DCG1.03)" and the "previous work volume in C.Ps. [construction projects] with the same owner (DCG1.13)" had more than 75% degree of importance.

There are also some criteria that can be categorised in a similar degree of importance in the UK and Egypt, in the UK and Kuwait or Egypt and Kuwait. The degree of importance for six criteria is close in both the UK and Egypt, five criteria in both the UK and Kuwait and ten criteria in both Egypt and Kuwait, as indicated in Figure 5.2.b. This can be interpreted as a common requirement in the contractor experience. Four criteria were excluded from these seventeen on the basis of exclusion factors mentioned above.

The statistical analysis carried out refined the 17 criteria from the initial identification to 13 criteria. The relative weights of these 13 criteria were calculated after excluding four criteria of low rate. The criteria codes were not changed in order to avoid any confusion of recoding the final 13, rather than 17, criteria used in the model: the codes remain as listed in appendix D.

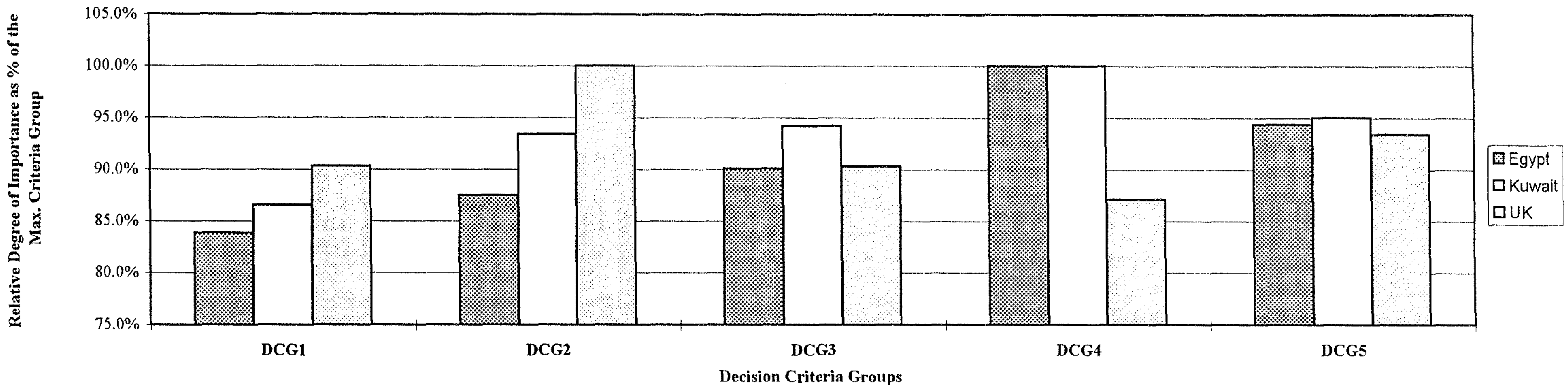

Figure 5.2.a: Relative Importance of Decision Criteria Groups for Heavy Projects at the UK, Egypt and Kuwait

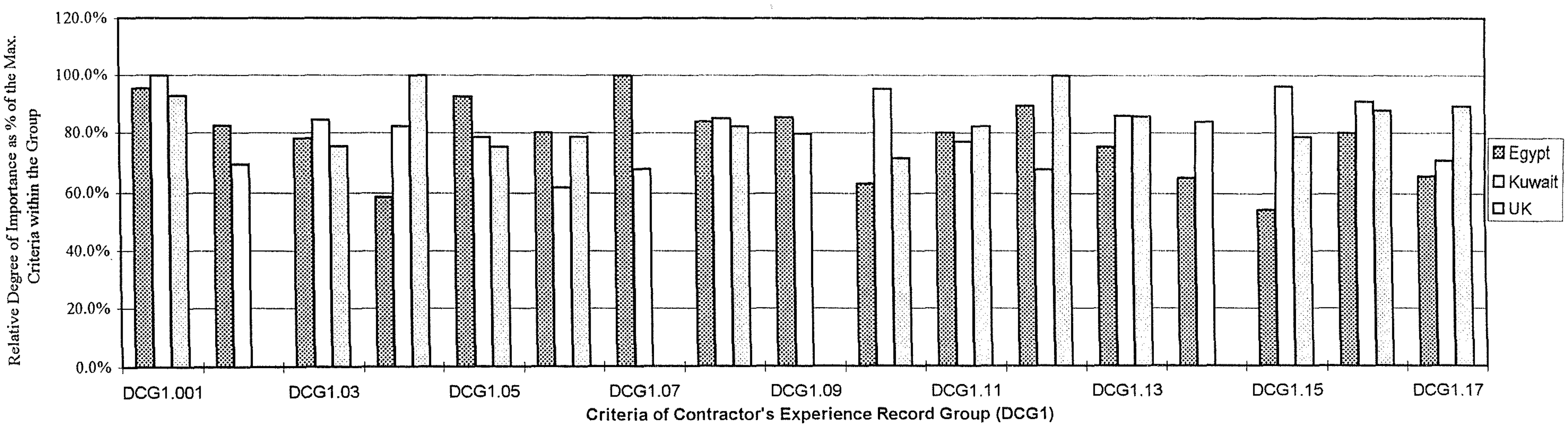

Figure 5.2.b: Relative Importance of Criteria within Contractor's Expaerience Record Decision Groups for Heavy Projects (initial Design)

5.4.1.2 CONTRACTOR'S PAST PERFORMANCE DECISION CRITERIA GROUP (DCG2) 'Heavy Projects'

Contractor's past performance criteria group (DCG2) contributed the highest degree of importance within screening and tendering phases in the UK (100%), while it contributed the second lowest degree in both Egypt (87.5%) and Kuwait (93.37%).

This result reflects the general attitude of experts in the UK looking to maximise the project quality objective, while it reflects the attitude of experts in Egypt and Kuwait of that depending on the more qualitative judgement gives the chance for a bias or personal judgements. This comment was received from the group generally for any qualitative judgement in both Egypt and Kuwait.

DCG2 has six criteria in the first hierarchy level, twelve criteria on the second level and four criteria on the third level within the decision criteria hierarchy as indicated in Figure 5.3.a. The criterion "Meeting project quality of completed similar projects (DCG2.03)" recorded the highest degree of relative importance within the first hierarchy level of DCG2 in both the UK and Egypt, while it recorded the third highest degree (~90.1%) in Kuwait. The "technical competence level in construction in the last 3 years (DCG2.04)" criterion recorded the lowest degree of relative importance in both Kuwait (~78%) and Egypt (~85%), while it recorded the third degree of importance (~86.1%) within the first hierarchy level of DCG2 in the UK. This variance can be interpreted as the difference in dependency on construction technology in these countries.

The criterion "Contractor reputation (DCG2.05)" was considered the most important decision criterion within the first hierarchy level of (DCG2) in Kuwait (100%), while it recorded the second degree of importance (98.3%) in Egypt. It recorded the lowest degree of relative importance (~72%) in the UK, as shown in Figure 5.3.a. This variance can be interpreted as a social difference in these countries.

The criterion "Meeting project schedule last 5 years (DCG2.01)" was recorded more than 85% in the three countries surveyed. DCG2.01 has two criteria in its second hierarchy level, "Project delay (DCG2.01.1)" and "Source of project delay (DCG2.01.2)". The criterion (DCG2.01.1) had a recorded degree of importance higher than DCG2.01.2 in the UK while the criterion (DCG2.01.2) had a recorded level of importance higher than (DCG2.01.1) in both Egypt and Kuwait, but generally they were below average.

The criterion "Meeting project quality of completed S.Ps. last 5 years" (DCG2.03)" has four criteria in its second hierarchy level, "Approved quality control plans and quality assurance of completed S.Ps. (DCG2.03.1)", "Test results of completed S.Ps. (DCG2.03.2)", "The contractor has previous projects with current owner (DCG2.03.4)" and the fourth criterion (DCG2.03.3) which was excluded due to its low rate. The criterion (DCG2.03.4) is considered the most important criterion within the second hierarchy level of the criterion (DCG2.03) in both the UK and Egypt, as indicated in Figure 5.3.b. While it has the third degree of importance out of the four criteria within the criterion (DCG2.03) in Kuwait, the criterion "The quality control meeting frequency (DCG2.03.3)" has been recorded a degree of importance below the average in the UK. It has the lowest degree of importance within the criterion (DCG2.03) in both Egypt and Kuwait.

The criterion "Willingness to correcting fault attitude in similar projects (DCG2.04.1)" has a degree of importance higher than the criterion "Safety record Last 3 years (DCG2.04.2)" within the second hierarchy level of criterion (DCG2.04) in both the UK and Egypt. But in Kuwait the degree of importance of (DCG2.04.2) was higher than the criterion (DCG2.04.1). The criterion (DCG2.04.1) has two criteria in the third hierarchy level of DCG2.04, "The work volume of repeated works (DCG2.04.1.1)" and " The cost of repeated works (DCG2.04.1.2)" which recorded low rate as decision criteria and then they were excluded.

The criterion (DCG2.04.2) has two criteria in the third hierarchy level of DCG2.04, "The availability of a safety system (DCG2.04.2.1)" and "Meeting frequency for safety (DCG2.04.2.2)". The criterion (DCG2.04.2.1) was considered more important than the criterion (DCG2.04.2.2) in Egypt, while it was considered less important than the criterion (DCG2.04.2.2) in Kuwait, as indicated in Figure 5.3.c. These two criteria recorded low rate as decision criteria then they were excluded.

The criterion (DCG2.05) has four criteria in the second hierarchy level of DCG2. The most important criterion within this second hierarchy level of DCG2.05 is the criterion "Contractor reputation at previous owners (DCG2.05.1)" in the three surveyed countries, as indicated in Figure 5.3.b. The criterion "Contractor reputation at previous suppliers (DCG2.05.2)" has the second level of importance within (DCG2.05) in both the UK (~81.9%) and Kuwait (~92.5%), while it has the fourth level of importance within (DCG2.05) in Egypt.

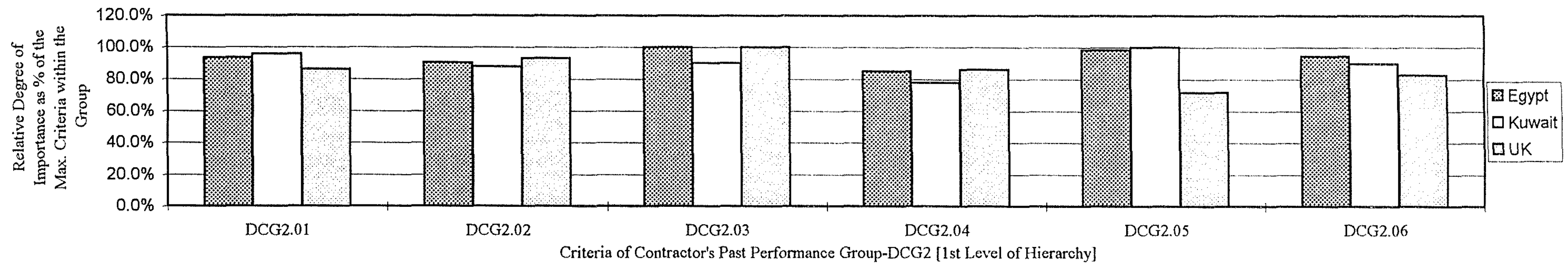

Figure 5.3.a:Relative Importance of Criteria within Contractor's Past Performance Decision Groups for Heavy Projects (initial Design)

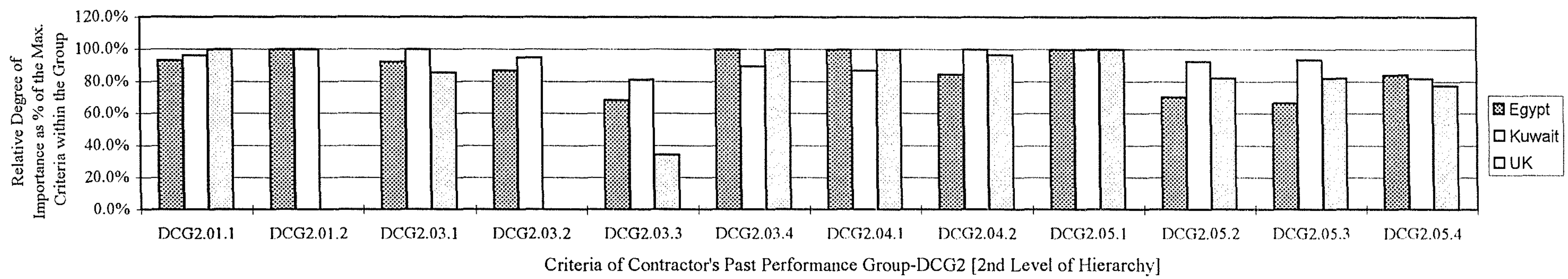

Figure 5.3.b: Relative Importance of Criteria within Contractor's Past Performance Decision Groups for Heavy Projects (initial Design)

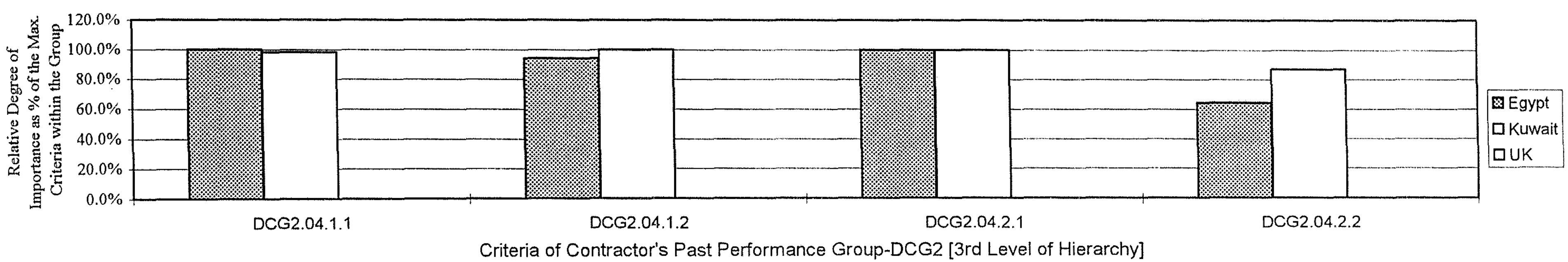

Figure 5.3.c: Relative Importance of Criteria within Contractor's Past Performance Decision Groups for Heavy Projects (initial Design)

The criterion "Average value of claims as a percent of past projects (DCG2.06)" recorded the fourth level of importance within DCG2 in its first hierarchy level in both the UK (~82.6%) and Kuwait (~89.7%), while it has the third importance level in Egypt (~94.6%). This low level of importance can be interpreted as a result of the difficulty to assess the reasons for these claims due to confidentiality.

5.4.1.3 Financial Stability Decision Criteria Group (DCG3) 'Heavy Projects'

The third decision criteria group is the financial stability group (DCG3), and it was also recorded the third degree of importance within pre-tender and tender phases in all three countries surveyed. It was about 90.3% in the UK, about 90.12% in Egypt and about 94.2% in Kuwait, as shown in Figure 5.2.a. This was interpreted, according to the expert responses received from the interviews, generally as the unfamiliarity of experts with financial aspects who had engineering backgrounds that were oriented to the technical project management aspects.

This decision group has six criteria in the first hierarchy level of DCG3, twenty criteria in the second hierarchy level of DCG3 and five criteria in the third hierarchy level of DCG3.

The criterion "Bonding capacity (DCG3.01)" has the highest degree of importance in Kuwait (100%) and the second degree within (DCG3) in Egypt (~99.3%), while it has the lowest degree in the UK (~86.1%), as indicated in Figure 5.4.a. The criterion "Financial policy (DCG3.02)" has the highest degree of importance within (DCG3) in Egypt (100%), the second highest degree within (DCG3) in the UK (~93.2%) and the third highest degree within (DCG3) in Kuwait (86.12%).

The criterion "Credit level (DCG3.03)" has the highest degree within (DCG3) in the UK (100%), while the (DCG3.03) criterion has the lowest degree within (DCG3) in Egypt (73.24%) and the third highest level of importance within (DCG3) in Kuwait. The "Financial statement reliability (DCG3.04)" and " Financial performance (DCG3.05)" have the fourth and fifth highest degrees of importance respectively within (DCG3). This in both the UK (~86.1% & 82.6%) and Egypt (~94.8% & ~89.6%), while they have the second and last degrees respectively within (DCG3) in Kuwait (~96.9% & ~70%), as indicated in Figure 5.4.a.

Within the second hierarchy of DCG3, the criterion "Performance bonds (DCG3.01.2)" within criterion (DCG3.01) and the criterion "Status of the audited financial statement (DCG3.04.1)" within criterion (DCG3.04) have the highest degrees of importance in the UK and Egypt. The criterion "Credit value (DCG3.03.2)" within criterion (DCG3.03) has the highest degree of importance in both the UK and Kuwait, while it has the second degree of importance in Egypt (~67%). The criterion "Leverage ratios (DCG3.05.2)" has the highest degree of importance in both Egypt and Kuwait. The criterion "Liquidity ratios (solvency ratios) (DCG3.05.1)" has the highest degree of importance in the UK, as indicated in Figure 5.4.b. The criterion "Source of finance (DCG3.02.1)" has the highest degree of importance in the UK, the second degree in Egypt (96.9%) and the third degree in Kuwait (87%).

In the third hierarchy level of the financial stability criteria group (DCG3) there are five criteria, as indicated in Figure 5.3.c. The criteria "Return to equity (DCG3.05.1.2)" in Kuwait and "Total liabilities / Tangible net worth (DCG3.05.2.1)" have the highest degree of importance in Egypt and the UK. The criterion "Hard debt /Tangible net worth (DCG3.05.2.2)" has the second degree in both the UK and Kuwait while it has the highest degree in Egypt.

The criteria groups of the final contractor selection that include the contractor's current capabilities (DCG4) and the contractor's submissions to the project under consideration (DCG5) are described in the following two sections.

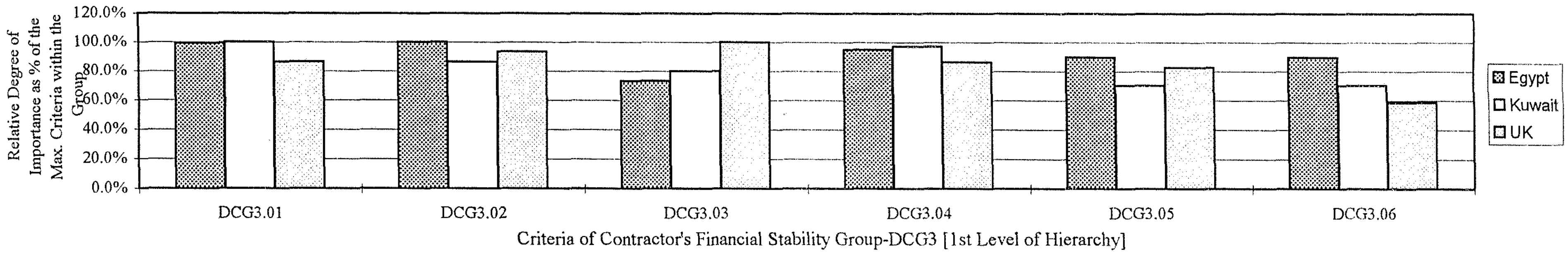

Figure 5.4.a:Relative Importance of Criteria within Contractor's Financial Stability Decision Groups for Heavy Projects (initial Design)

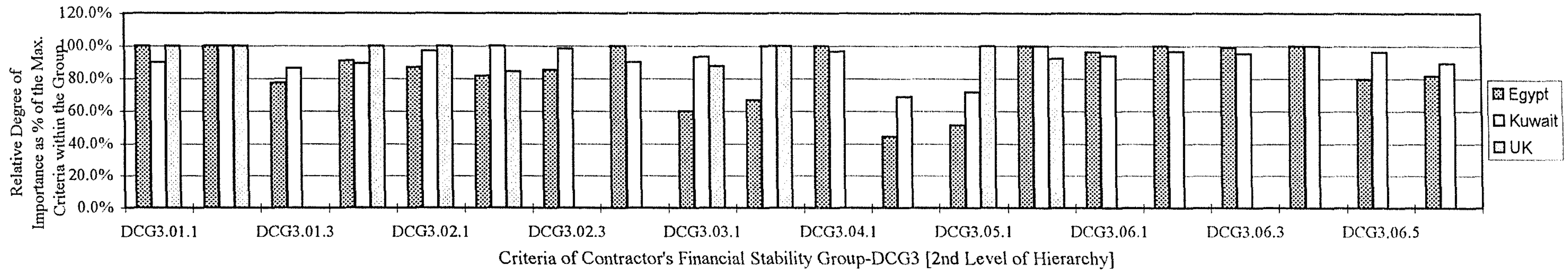

Figure 5.4.b: Relative Importance of Criteria within Contractor's Financial Stability Decision Groups for Heavy Projects (initial Design)

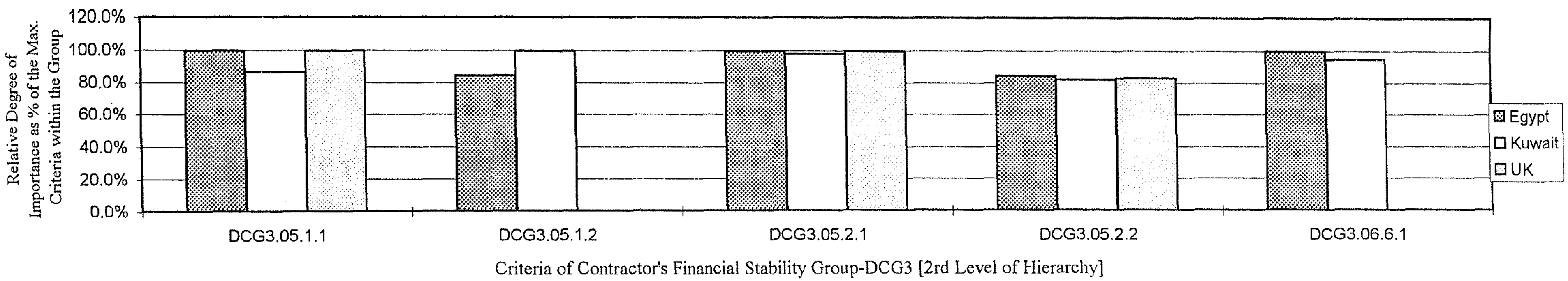

Figure 5.4.c: Relative Importance of Criteria within Contractor's Financial Stability Decision Groups for Heavy Projects (initial Design)

5.4.1.4 *Contractor's Current Capability* (DCG4) *'Heavy Projects'*

Contractor's current capability criteria group (DCG4) has four decision criteria in its first hierarchy level as shown in Figure 5.5.a. The degrees of relative importance for these four criteria are similar in Egypt and Kuwait while they varied in the UK. The criterion "Contractor's Management capabilities (DCG4.01)" has the highest degree of importance in both Egypt and Kuwait, while it has the second degree in the UK (~96.6%). The criterion "Equipment availability (DCG4.02)" has the highest degree within DCG4 in the UK, while it has the lowest degree within DCG4 in both Egypt (~81.7%) and Kuwait (~ 77.7%).

The criterion "Manpower resources availability (DCG4.03)" has recorded the lowest degree of importance within DCG4 in the UK (~82.9%) while it has the second lowest degree in both Egypt (~86.1%) and Kuwait (~ 85.0%). The fourth criterion in the DCG4 is "Contractor's capacity to carry out the work (DCG4.04)" has the second highest degree in both Egypt (~95.2%) and Kuwait (~91.1%), while it has the third highest degree within DCG4 in the UK (~89.6%), as shown in Figure 5.5.a.

The number of decision criteria included in the second hierarchy level of the DCG4 is seventeen. There are four criteria within the second hierarchy level under criterion (DCG4.01). The criterion "Management organisation structure (DCG4.01.1)" has the highest degree of importance within (DCG4.01) in both Egypt and Kuwait, while it has the third degree in the UK (~88%). But the criterion "Subcontracting work value (DCG4.01.4)" has the highest degree of importance in the UK and the second and third degrees in Egypt and Kuwait respectively.

The criterion "Number of labour from each craft type (DCG4.03.2)" has the highest degree within (DCG4.03) in both Egypt and Kuwait, while it has the second degree in the UK (~91.6%). The criterion "Quantity of the available Equipment (DCG4.02.4)" has the highest degree in the UK and the second degree in Egypt and Kuwait respectively. The criterion DCG4.04 has 6 criteria. The criterion "Subcontractor's work type (DCG4.04.2)" has the highest degree of importance in both Egypt and Kuwait while it was below the average in the UK (~41.2%) within its criteria group. But the criterion "Contractor's current capacity to carry out an additional work (DCG4.04.5)" has the highest degree in the UK and the sixth and fourth degree of importance in Egypt and Kuwait respectively, as indicated in Figure 5.5.b.

The criteria in the third hierarchy level of DCG4 were nineteen. There are about 31.5% of these criteria that have degrees of importance above the average in the UK. The criterion "Percentage complete of current projects (DCG4.04.6.1)" out of 5-criteria within the third hierarchy level of (DCG4.04.6) has the highest degree of importance in both Egypt and Kuwait while it was below the average in the UK (43.0%). The criterion "Number of years working in S.Ps. (DCG4.01.2.5)" has the highest degree of importance in the UK and the third degree in both Kuwait (~91.8%) and Egypt (~68.4%). The criterion "Current capacity to carry an additional construction work (DCG4.04.6.2)" within the third hierarchy level of (DCG4.04.6) has the highest degree of importance in the three surveyed countries. The criterion " Subcontractor work volume (DCG4.04.1)" has the highest degree of importance in both the UK and Egypt within the third hierarchy level of (DCG4.04), while it has the fourth degree in Kuwait (~62.8%).

The criterion "Planning and control technique (DCG4.01.3.1)" out of 3-criteria within the third hierarchy level of (DCG4.01.3) has the highest degree of importance in the three surveyed countries, as indicated in Figure 5.5.c.

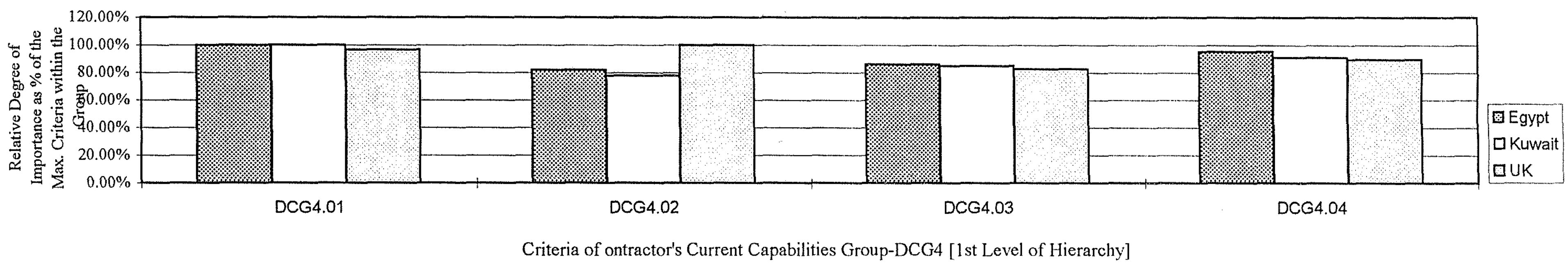

Figure 5.5.a:Relative Importance of Criteria within Contractor's Current Capabilities Decision Groups for Heavy Projects (initial Design)

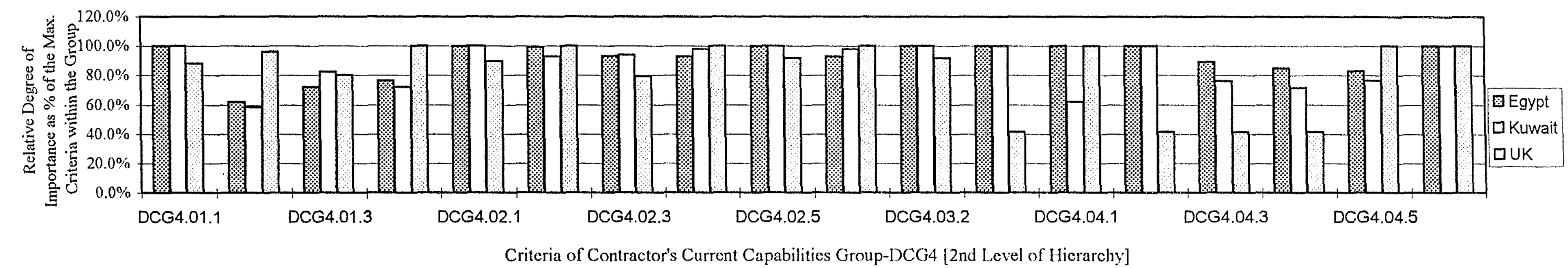

Figure 5.5.b: Relative Importance of Criteria within Contractor's Current Capabilities Decision Groups for Heavy Projects (initial Design)

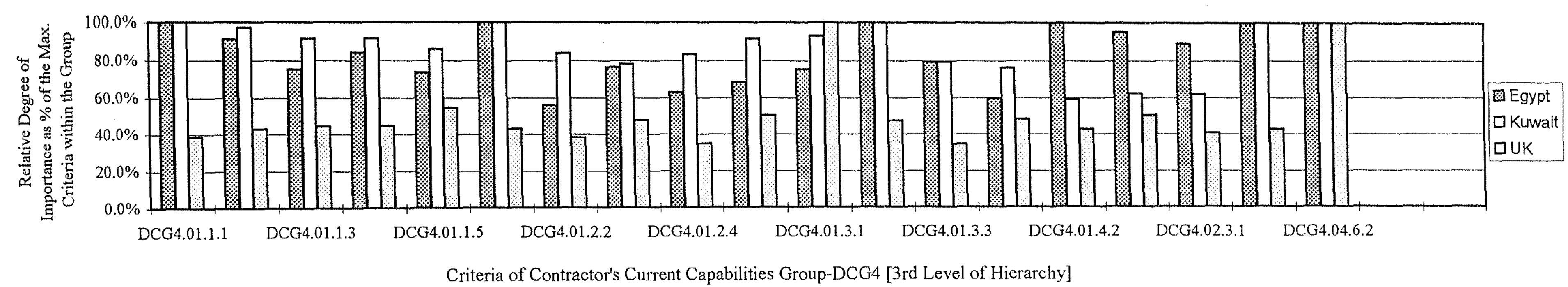

Figure 5.5.c: Relative Importance of Criteria within Contractor's Current Capabilities Decision Groups for Heavy Projects (initial Design)

5.4.1.5 *Contractor's Submitted Plans for the Proposed Project (DCG5) 'Heavy Projects'*

The Contractor's submitted plans for the proposed project (DCG5) have three decision criteria in the first hierarchy level as shown in Figure 5.6.a. The degrees of relative importance for these three criteria are similar in Egypt and Kuwait while there is slight variance in the UK. The criterion "Total bid amount (DCG5.01)" has the highest degree of importance within DCG5 in both the UK and Egypt while it has the second degree in Kuwait (97.0%).

The criterion "Job statement of proposed project (DCG5.02)" has the highest degree of importance within DCG5 in Kuwait, while it has the second degree in both the UK (~88.7%) and Egypt (~95.9%). The comment received on this criterion was the difficulty that may be encountered in its assessment where it was considered a matter of qualitative judgement that depends, to a great extent, on the experience level of the decision-maker. This comment was made as a general comment on all qualitative criteria within this group.

The criterion "Applied management planning techniques (DCG5.03)" has the third degree of importance in the three surveyed countries as shown in Figure 5.6.a.

The second hierarchy level of the DCG5 has thirteen criteria. The criterion "Total bid amount (DCG5.01.1)" was more important than the criterion "Cash-out schedule (DCG5.01.2)" within the (DCG5.01) criterion in the three surveyed countries, as shown in Figure 5.5.b. The criterion "Construction method statement (DCG5.02.1)" has the highest degree of importance within the second level of hierarchy of criterion (DCG5.02) in all surveyed countries. The third criterion (DCG5.03) in the first hierarchy level of (DCG5) has eight criteria. The most important criterion changed from one country to another. The criterion "Payment schedule (DCG5.03.1)" has the highest importance in Egypt, while the criterion "Quality assurance and quality control plan (DCG5.03.5)" has the highest importance in Kuwait and "Safety plan (DCG5.03.6)" has the highest importance in the UK, as shown in Figure 5.6.b.

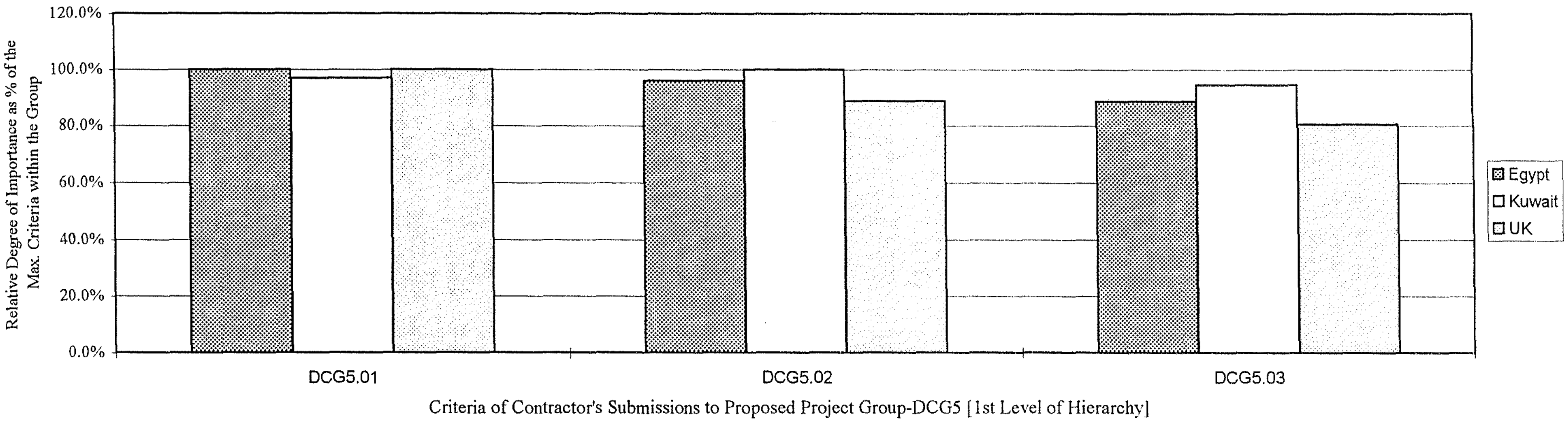

Figure 5.6.a: Relative Weights of the Criteria within Contractor's Submitted Plans to Proposed Project for Heavy Construction Pavy Projects (initial Design)

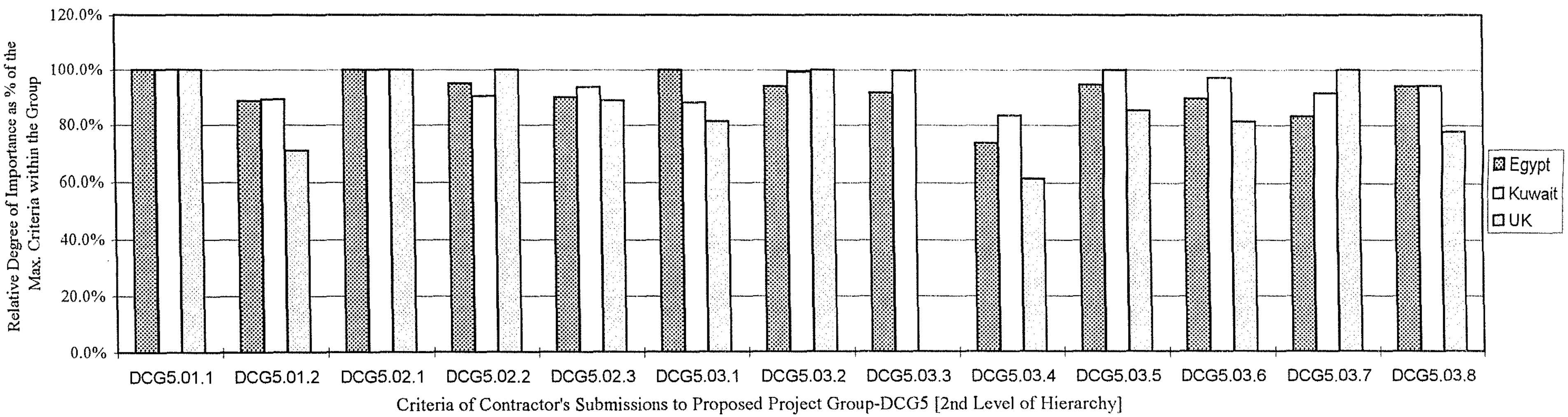

Figure 5.6.b: Relative Weights of the Criteria within Contractor's Submitted Plans to Proposed Project for Heavy Construction Projects [2nd Level of Hierarchy] (Initial Design)

5.4.2 Building Construction Projects – Survey Results Analysis

Criteria groups of building construction are shown in Figures 5.7 to Figure 5.11. In general, there was no significant difference in the comment received from the experts' responses with respect to the building projects except those related to resource management. The experts' responses were directed to maximising the importance of manpower resource management over equipment management.

The first three criteria groups of building construction recorded relative degrees of importance similar to those in heavy construction in both Egypt and Kuwait. Criteria group DCG3 has the highest importance within the five decision criteria groups in building instead of the third degree in heavy projects in the UK, as indicated in Figures 5.2.a and Figure 5.7.a.

Contractor's past performance level criteria group (DCG2) has the same degree of importance in the UK for both building and heavy projects. The experience record decision criteria group (DCG1) recorded the lowest importance in building projects instead of fourth degree received for heavy projects in the UK.

5.4.2.1 Contractor's Experience Record Decision Criteria Group (DCG1) 'Building Projects'

Contractor's experience record decision criteria group (DCG1) recorded the lowest degree of importance within both screening and final selection processes in the three surveyed countries, Egypt (84%) and Kuwait (88%), while it recorded the degree before the lowest in the UK (90%), as indicated in Figure 5.7.a. These degrees of relative importance are approximately similar to those obtained in heavy projects. The relative degree of importance of the second hierarchy level within DCG1 in building projects is similar to that obtained in heavy projects, as indicated in Figure 5.7.b and Figure 5.2.b respectively.

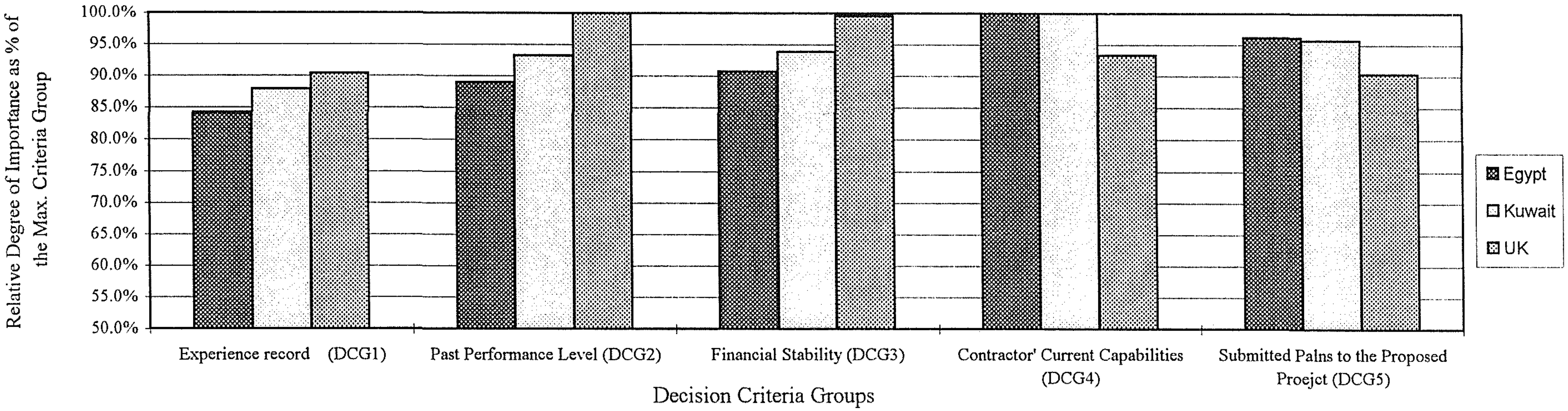

Figure 5.7.a: Relative Weights of the Decision Criteria Groups for Building Construction Projects in the UK, Egypt and Kuwait

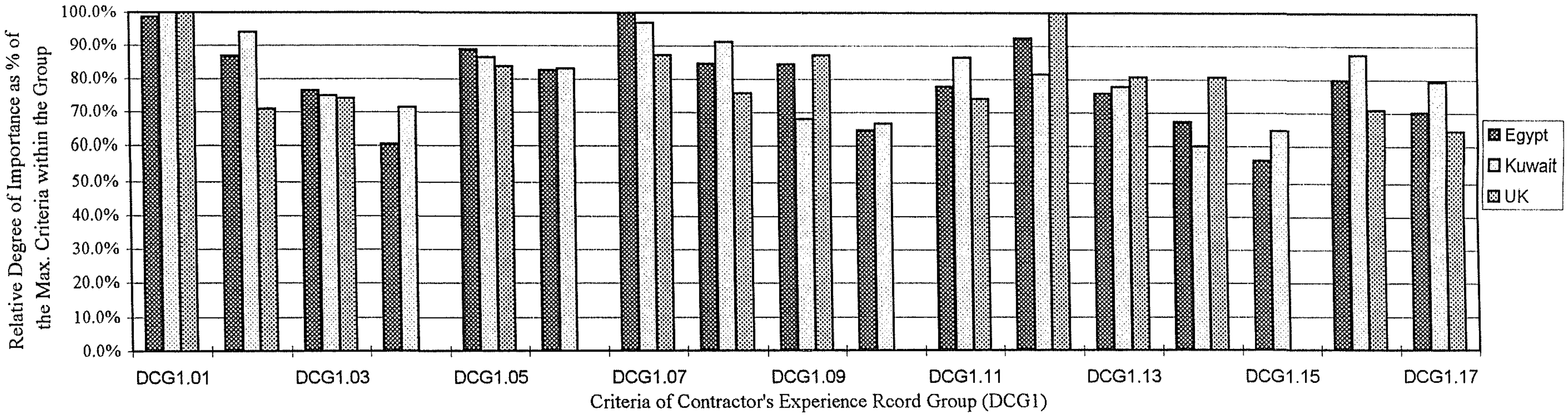

Figure 5.7.b: Relative Weights of the Criteria within Contractor's Expaerience Rcord Decision Groups for Building Projects (Initial Design)

5.4.2.2 Contractor's Past Performance Decision Criteria Group (DCG2) 'Building Projects'

Contractor's past performance decision criteria group (DCG2) recorded the highest degree of importance within both screening and final selection processes in the UK (100%), while it recorded the second lowest one in both Egypt (89%) and Kuwait (93%). These results are similar to those obtained in the heavy projects in the three surveyed countries, as indicated in Figures 5.2.a and 5.7.a.

The similarity in results for the first, second and third hierarchy levels of DCG2 criteria for both building and heavy projects in both Egypt and Kuwait are shown in Figures 5.3 and 5.8. It was remarkable in the UK, where DCG2.02 has the highest importance instead of the second in the UK heavy projects. In addition, the relative degree of importance for the criterion DCG2.04 is changed from the fourth in the UK heavy projects to the second in building projects. The criterion DCG2.06 degree is moved from second lowest to the lowest degree of importance in the UK building projects.

5.4.2.3 Contractor's Financial Stability Decision Criteria Group (DCG3) 'Building Projects'

The similarity in results for both building and heavy projects in both Egypt and Kuwait to the first, second and third hierarchy levels of DCG3 criteria is also continued with a very limited change as shown in Figures 5.4 and 5.9. It was remarkable in the UK, where the criterion DCG3.01 moved from the lowest importance in the UK heavy projects to the second out of the six criteria included in the second hierarchy level of DCG3 in the UK building projects, as shown in Figure 5.9.a. In addition, the criterion DCG3.04 moved from the second degree of importance in heavy projects to the second lowest in the UK building projects.

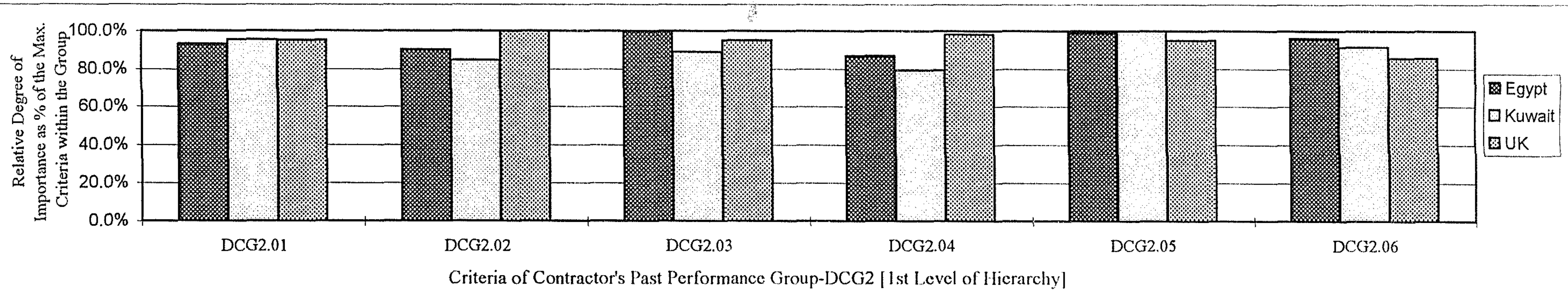

Figure 5.8.a: Relative Weights of the Criteria within Contractor's Past Performance Decision Groups for Building Projects (Initial Design)

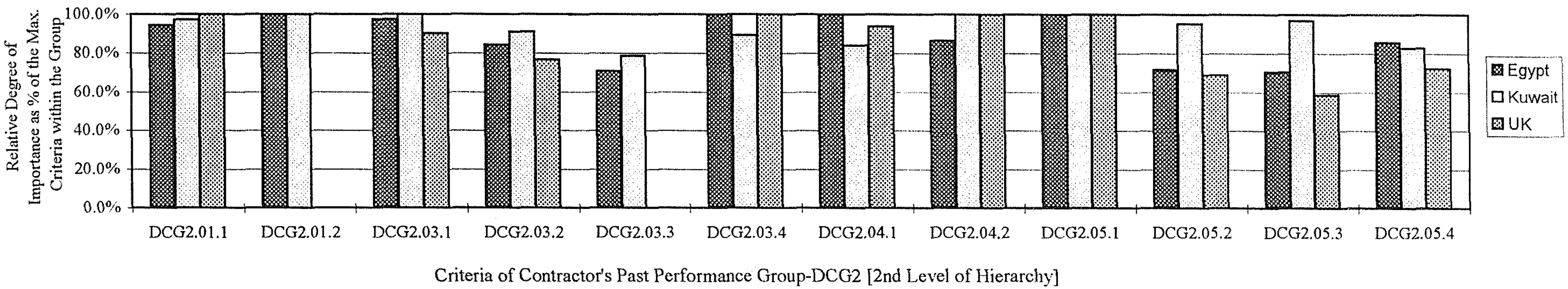

Figure 5.8.b: Relative Weights of the Criteria within Contractor's Past Performance Decision Groups for Building Projects (Initial Design)

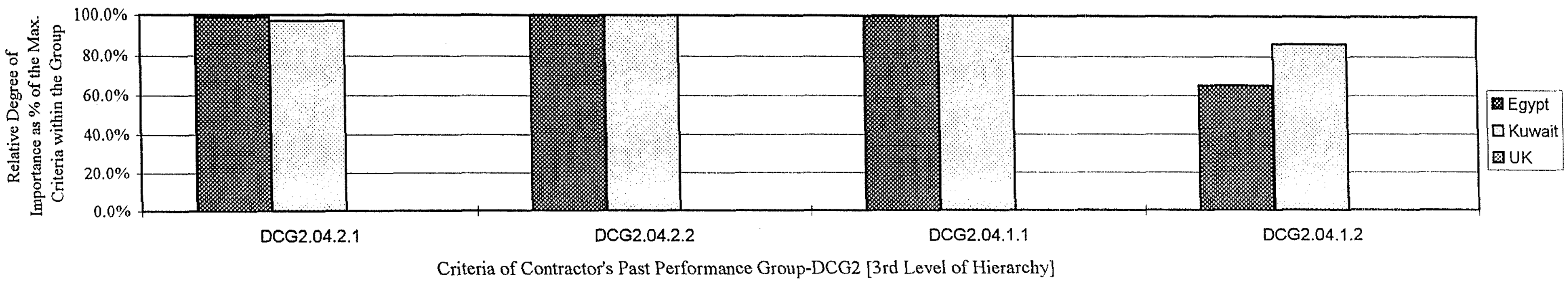

Figure 5.8.c: Relative Weights of the Criteria within Contractor's Past Performance Decision Groups for Building Projects (Initial Design)

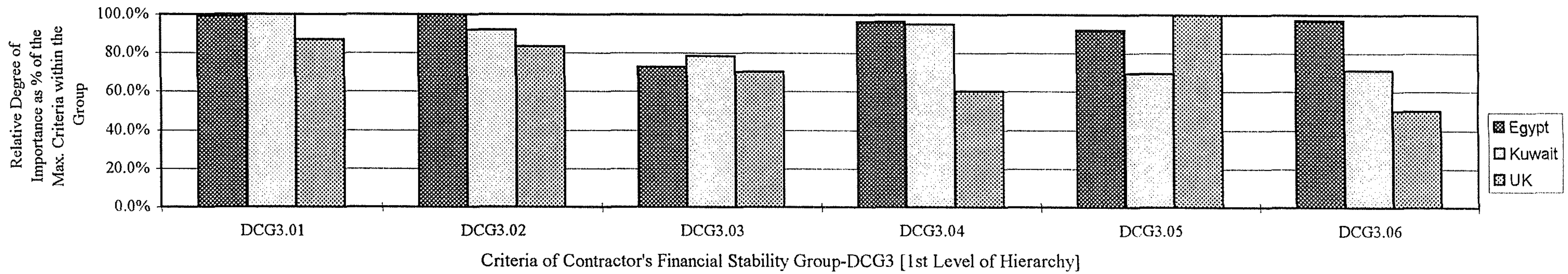

Figure 5.9.a: Relative Weights of the Criteria within Contractor's Financial Stability Group for Building Projects (Initial Design)

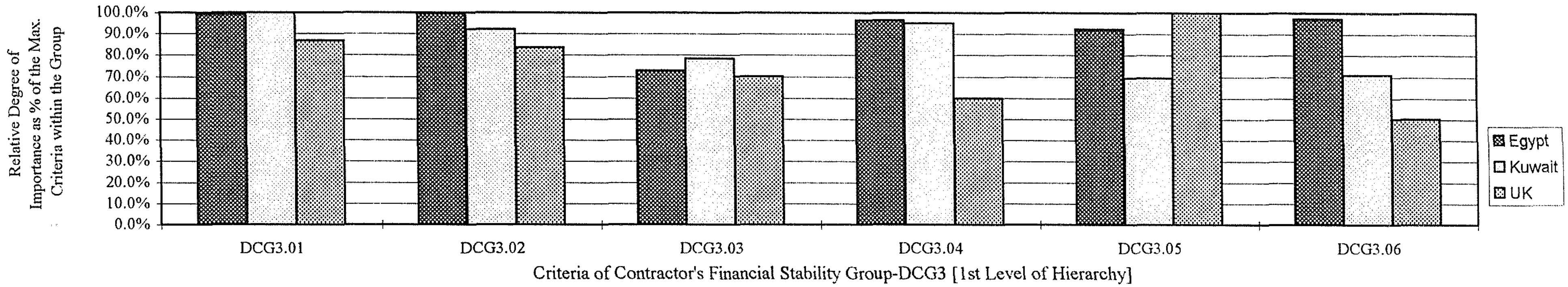

Figure 5.9.a: Relative Weights of the Criteria within Financial Stability Group for Building Projects (Initial Design)

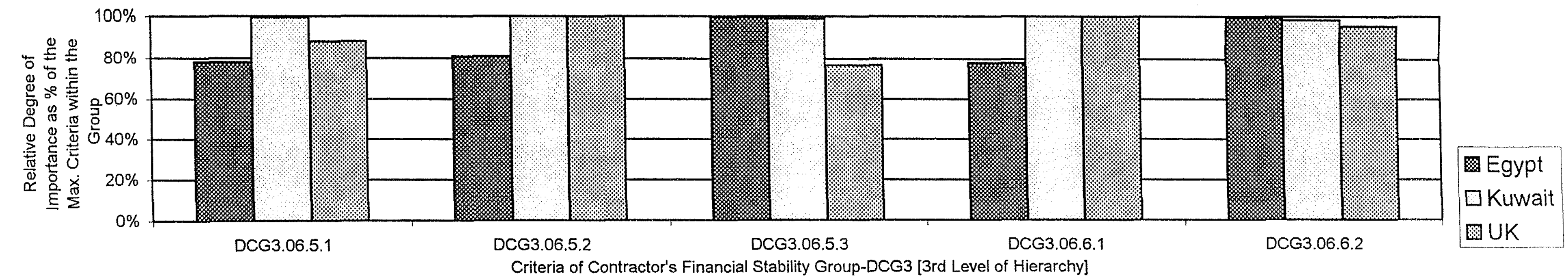

Figure 5.9.c: Relative Weights of the Criteria within Financial Stability Group for Building Projects (Initial Design)

5.4.2.4 Criteria Groups of Contractor Current Capabilities (DCG4) and Contractor's Submitted Plans to the proposed Project (DCG5) 'Building Projects'

The degree of relative importance for DCG4 in building projects is similar to that in heavy projects for both Egypt and Kuwait. Its degree moved from the lowest in the UK heavy projects, to third in building projects, as indicated in Figures 5.2.a and 5.7.a. The results for building and heavy projects in the three surveyed countries in the first, second and third hierarchy levels of DCG4 criteria are totally changed, as indicated in Figures 5.5 and 5.10. The degree of importance of criterion DCG4.01 was changed from the highest in heavy projects to the lowest degree in building projects for both Egypt and Kuwait and from the second degree to the third in the UK. The similarity in results for both building and heavy projects in the three surveyed countries to the first, second and third hierarchy levels of (DCG4) criteria is continued with a very limited change as indicated in Figures 5.5 and 5.10.

In the second hierarchy level of this decision criteria group (DCG5), the main change in the degree of importance was carried out in the criteria DCG5.03.3 and DCG5.03.4. The degree of importance for the criterion "Equipment schedule (DCG5.03.3)" was moved from the fourth in heavy projects to the second lowest in building. The criterion "Manpower schedule (DCG5.03.4)" moved from the lowest in heavy to the third in building projects in the three surveyed countries, as indicated in Figures 5.6.b and 5.11.b.

The relative weights of the criteria based on the statistical analysis and excluding criteria of a grade less than the mean of the group or weak correlation was less than 50%. The relative weight of each criterion within its decision criteria group and its relative weight to the total decision criteria groups are indicated in Table D.1 and Table D.2 of Appendix D for heavy and building construction respectively.

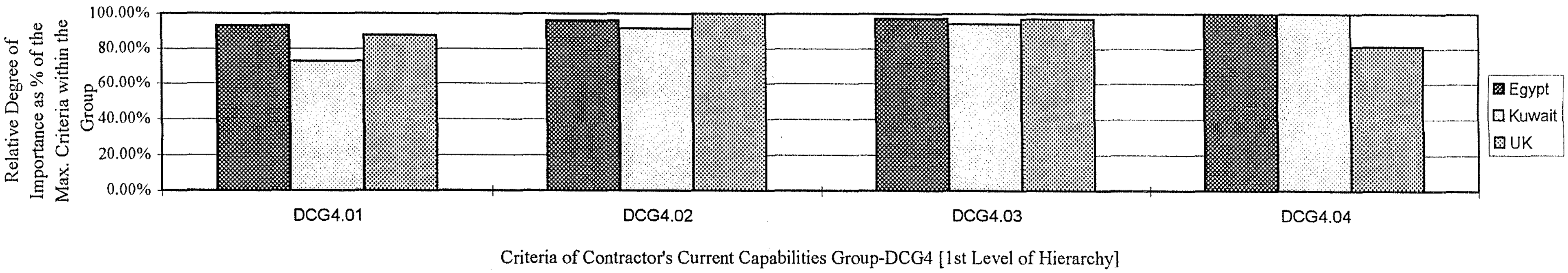

Figure 5.10.a: Relative Weights of the Criteria within Contractor's Current Capabilities Groups for Building Projects (Initial Design)

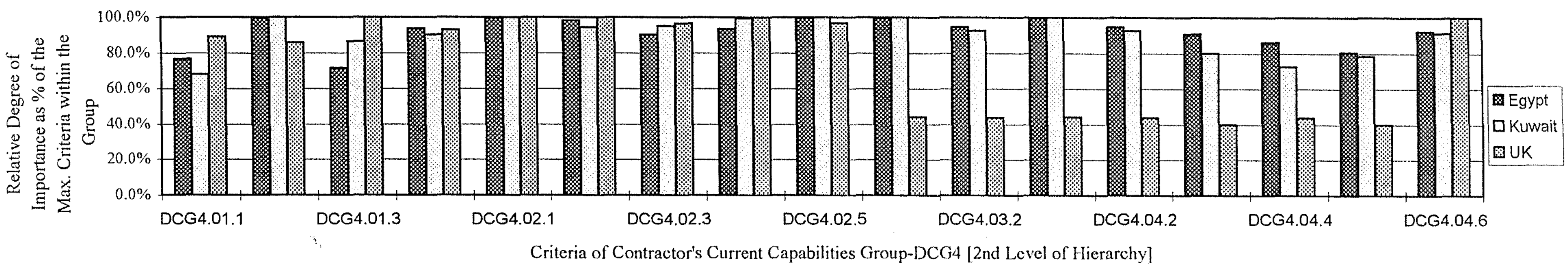

Figure 5.10.b: Relative Weights of the Criteria within Contractor's Current Capabilities Groups for Building Projects (Initial Design)

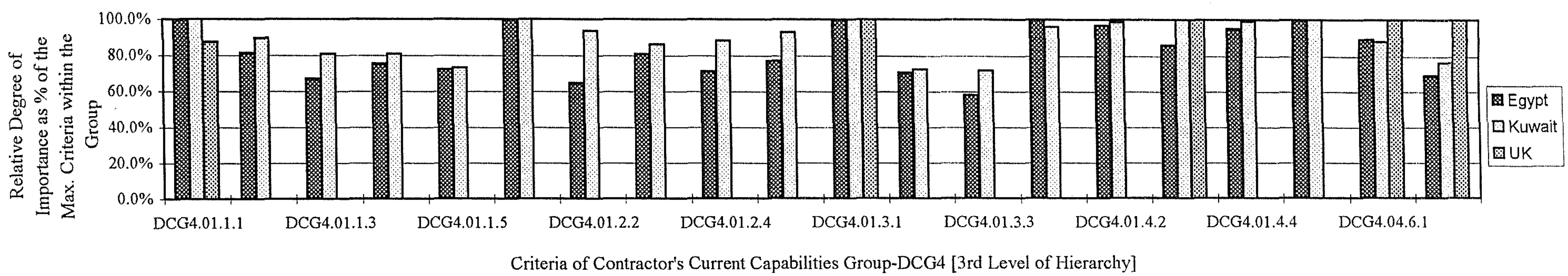

Figure 5.10.c: Relative Weights of the Criteria within Contractor's Current Capabilities Groups for Building Projects (Initial Design)

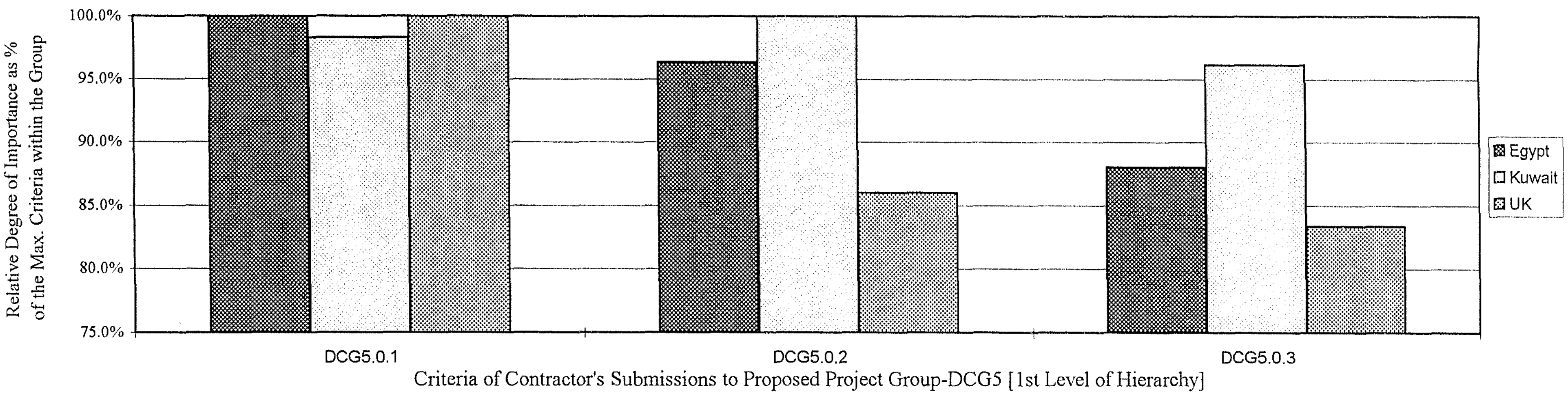

Figure 5.11.a: Relative Weights of the Criteria within Contractor's Submitted Plans to Proposed Project for Building Construction Projects [1st Level of Hierarchy] (Initial Design)

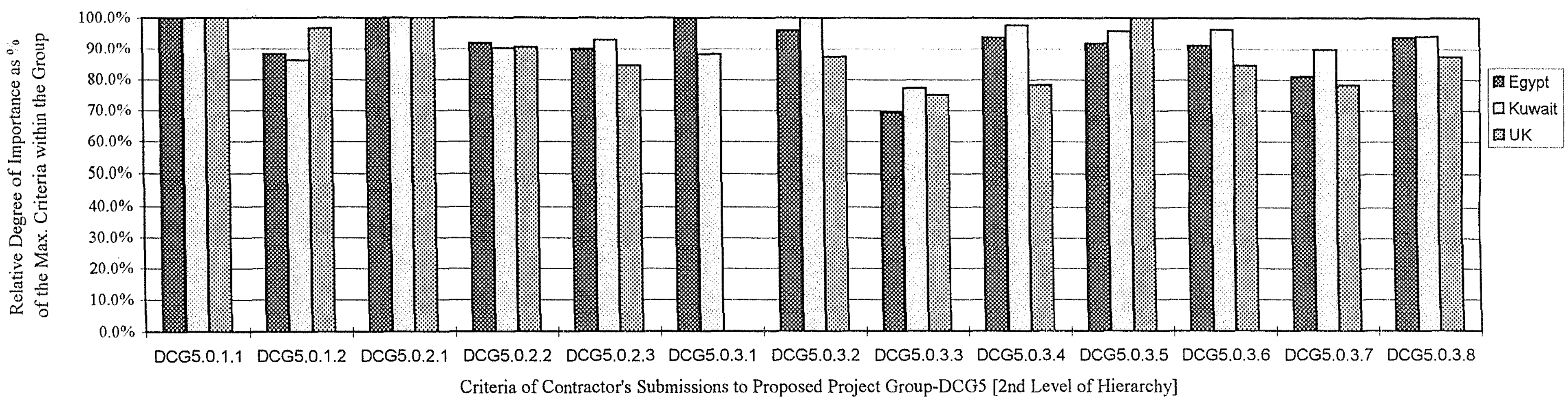

Figure 5.11.b: Relative Weights of the Criteria within Contractor's Submitted Plans to Proposed Project for Building Construction Projects [2nd Level of Hierarchy] (Initial Design)

5.5 FINAL RESULTS OF THE CRITERIA REFINEMENT

The organisation of refined criteria, which was identified on the basis of the survey carried out in Chapter 3 are shown in Figure 5.12. The hierarchies of each refined group of criteria are illustrated in Figure 5.13, Figure 5.14 and Figure 5.15. The contractor criteria were grouped into two figures. The first three groups of the contractors' criteria are shown in Figure 5.14, and included contractor's experiences record, contractor's past performance and financial stability groups of criteria. The fourth and fifth groups of the contractors' criteria are shown in Figure 5.15, and include the contractor's current capabilities and the contractor's specific submission to the proposed project.

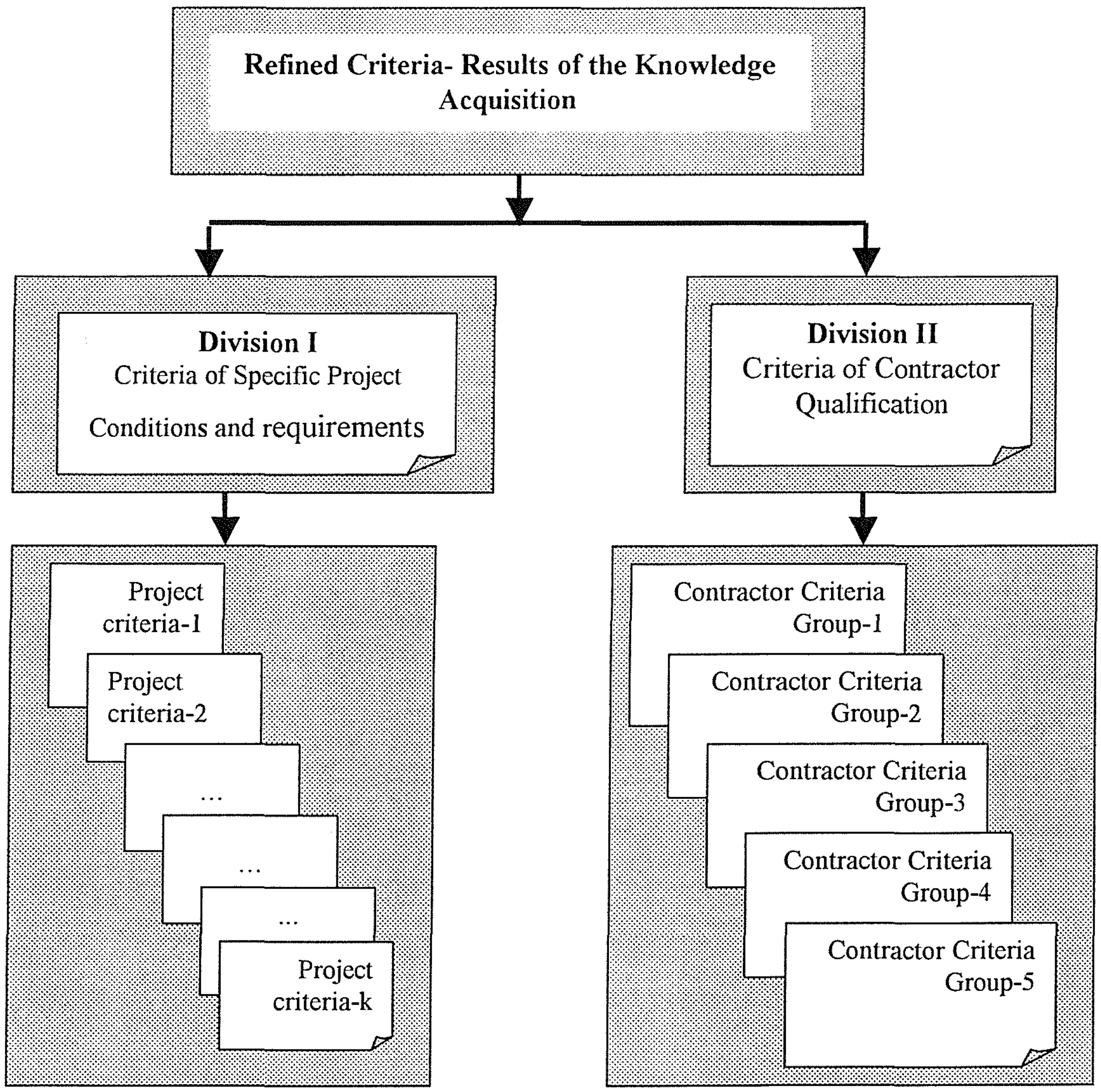

Figure 5.12: The organisation of the criteria implemented in the proposed selection system

5.5.1 Decision Criteria related to the Specific conditions of the Project under Consideration and the Client's Objectives

From the literature review in Chapter 3, there are many project conditions that need to be considered during the evaluation process, and the key criteria are identified as follows:

1- Project budget,
2- Project schedule,
3- Quality requirements,
4- Project complexity (Uniqueness),
5- Project design change,
6- Client management involvement,
7- Client risk share,
8- Safety requirements,
9- Political factors.

These were the criteria within Division I as indicated in Figure 5.12, which are called the specific project conditions to clearly distinguish them from those criteria that related to contractors. Of course, the specific project conditions are not limited to these criteria. All these criteria were included in this survey just to determine their relevancy by the expert and to determine which criteria need to be included in the contractor selection process. This means additional criteria can be considered during the contractor selection. Some additional criteria may include the client requirements. Clients are different and each will have their own views, requirements and business situations. These differences may affect the selection process, such as client's financial, technical, organisational and managerial capabilities and hence impact on their preferences. Therefore, a list of additional criteria that are based on the client's characteristics and requirements and can be taken into account during the contractor selection include:

1- Client's financial capability,
2- Client's technical competence,
3- Client's organisation structure,
4- Previous dealings with a contractor.

Criteria that are related to the project were presented to the decision-maker within the proposed decision system of the contractor selection, without defining their relative importance. This to give the decision-maker the opportunity to reflect the real project conditions on project-by-project basis but at the same time provide the decision-maker with the method that help in deciding their relative importance, as a part of the decision system required. This gives more flexibility to the decision-maker to adapt the model to cope with the specific conditions of the proposed project and client's preferences.

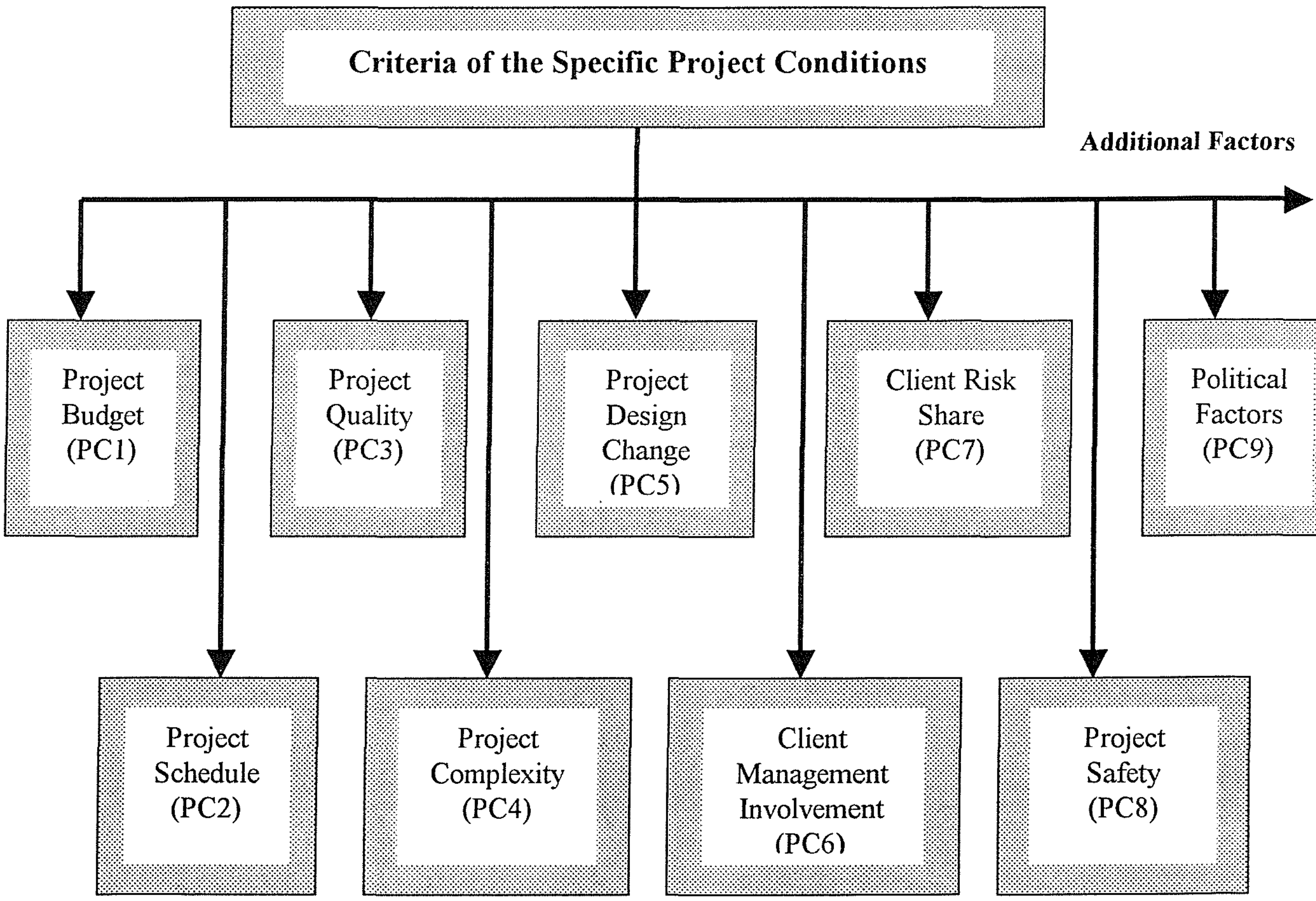

Figure 5.13: Criteria of Specific Project Conditions and Client Requirements

5.5.2 Decision Criteria related to the Contractor Qualification

Criteria that are related to contractor qualification included five groups of criteria. The first three of criteria groups are shown in Figure 5.14 that included three criteria groups as follows:

1. Criteria related to contractor's experience record,

2. Criteria related to contractor's past performance level, and
3. Criteria related to contractor's financial stability of the contractors.

Each decision criteria group has its own sub-criteria divided into different hierarchy levels, as shown in Figure 5.14. The purpose of this division is to introduce the flexibility of decision-making by allowing the decision-maker to decide the level of detail can go through. This decision depends on the following:

1. The knowledge and time available for selection of the most appropriate contractor.
2. The level of confidence required in the results; higher confidence requires a higher level of detail.

The description of each decision criteria group, its purposes and measures are detailed in Appendix D and described in the following sections.

Group 1. Decision Criteria Related to Contractor's Experience Record

This criteria group represents the record of the contractor's experience and is designated by the code 'DCG1'. The letters 'DCG' indicate that this is a decision 'D' criteria 'C' group 'G' and the number '1' describe this group as the first group of criteria within the screening process.

In general, the experience record criteria measure the levels of expertise offered by the contractors. These criteria are designed to encompass a broad range of experiences, as illustrated in Figure 5.14 (S.Ps. and C.Ps. mean that similar projects and construction projects respectively as indicated in both Figures 5.14 and 5.15).

For example, the criteria of this group include the time and volume of work of similar and dissimilar (in construction generally) projects, such as:

- The project delivery rate achieved;
- The average volume of work in the last three years in similar projects (S.Ps.).
- The total work volume of construction projects in the last 10 years in both S.Ps. and C.Ps. (construction projects).
- The contractor's experience of handling and willingness to accept project risks, which is indicated by the work volume carried out for each type of contract within the last 10 years.
- The contractor's experience of dealing with similar geographical and weather conditions, especially in S.Ps.

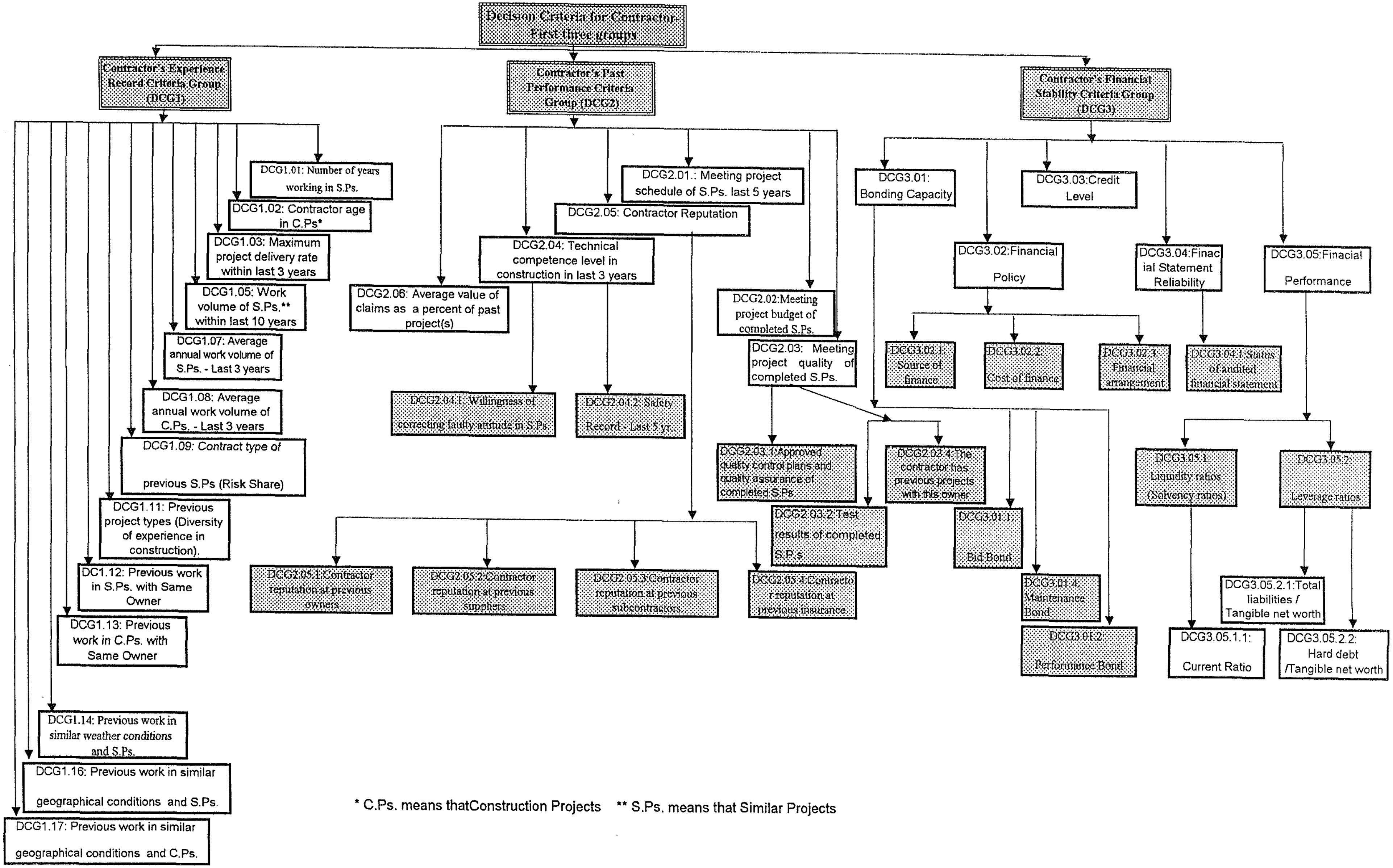

Figure 5.14: Decision Criteria of Screening Process

Considering the experience record of the contractors is not sufficient to give a full indication for their performance level, where the experience mentions what their work have, not how it was performed. The actual performance level achieved needs to be investigated to provide an indication of future performance on the proposed project (Hauk and Kline, 1986; Russell 1992; Jaselskis, 1992; Crowley and Hancher, 1995; Bubshait, 1996). The contractor's past performance criteria is described in the following section.

Group 2: Decision Criteria Related to Contractor's Past Performance

The past performance level decision criteria group has the code 'DCG2'. This criteria group measures the level of performance in the volume of work, which was carried out as past experience. This DCG2 has six major criteria as indicated in Figure 5.14. Review of the problems raised from the past performance shows that the majority of problems are related to the project delays, cost overruns, quality, safety and the contractor attitude toward claims. Generally, the major criteria included in this group are:

- The contractor's ability to meet the defined objectives such as project schedule, budget and quality of previously completed projects and in particular, similar projects.
- The contractor's reputation with previous clients, suppliers, subcontractors and insurance companies.
- The contractor's level of technical competence.
- The contractor's attitude towards claims.

Disappointments in performance are difficult to compensate for if the contractor is responsible. This may have resulted in extensive project delays, cost overruns, very serious problems in the quality and safety plus claims and litigation. Therefore, this decision group measures past performance level of a contractor in previous projects that were similar or dissimilar. These objectives are related to project budget, time schedule, safety and quality and claim attitude.

The contractor's reputation with previous projects' owners, suppliers, subcontractors and insurance companies help to indicate whether a contractor has adequate capability to carry out the proposed project and to meet its objectives. In addition, the contractor's attitude towards claims in previous projects gives an indication for the contractor behaviour and agreement to the owner and towards litigation and disputed solution.

If the contractor's experience and performance from previous projects are suitable the question next arising is that of the contractor's financial situation, and its current capabilities. The following sections highlight the consequences of this question with the purpose of identifying the appropriate criteria for the proposed contractor selection system.

Group 3: Decision Criteria Related to Contractor's Financial Stability

The contractor's financial stability decision criteria group has the code 'DCG3'. The purpose of this decision criteria group is to assess the stability of a contractor and its capacity to meet its financial obligations in both the short term (current projects) and the long term (for the project under consideration).

This decision group has five major criteria, which include, as indicated in Figure 5.14:

1. Bonding capacity;
2. Financial policy;
3. Credit Level;
4. Financial statement reliability;
5. Financial performance ratios.

The first criterion of bonding capacity will indicate if the contractor has adequate financial resources or is able to secure such financial requirements from independent financial institutions. This criterion has three sub-criteria that include bid bond, performance bond, and maintenance bond. For the owner, bid bond measures contractor's credibility and confirms that the contractor is serious. Maintenance bond confirms that the contractor returns to the project to correct faults occurring in the maintenance period.

The financial policy of a contractor is very important if the contractor is financing the proposed project. In the Middle Eastern countries' projects, especially in non-Gulf countries, overseas contractors are generally competing using this form of project financing. Evaluating the financial policy of a contractor assesses adequacies of financial resources and ability to secure such resources.

The source of finance and loan arrangements determines the financial policy of the contractor and hence, the costs of finance. The project owner can determine which one is the most appropriate to its financial conditions.

A credit level criterion can track the contractor's payment record to its creditors, such as suppliers and subcontractors. It shows the financial obligations and strengths. The quality of its financial statement as a main source of financial data is a very important criterion. The accountant method applied determines to a great extent its reliability. The audited account is the most reliable quality of statement.

The fifth major criterion is the contractor's financial performance ratios. This criterion has four sub-criteria. The grade of performance based on the financial ratios determines the strength of the financial stability of a contractor. Liquidity ratios measure the adequacy of current assets to cover current liabilities. The quick ratio and current ratio are the main sub-criteria of liquidity ratios. Leverage ratios measure the amount of debt pressure in general, short and long term. Financial ratio descriptions, definitions and limits stated in Table 5.2 can be utilised in the development of the financial ratios by which the financial assessment of the contractor can be identified for the proposed system, as detailed in Table D.5 of Appendix D

Ratio name	**Definition**	**Ratio Range**
	(a) Liquidity	
Quick ratio	Total quick assets (cash and marketable securities) Divided by current liabilities	>1.0
Current ratio	Total allowable current assets divided by total Current liabilities	> 1.2 times
Collection period	Annual sales revenue divided by accounts receivable and multiplied by 365 days	<60 days
	(b) Operations	
Net profit/tangible net worth	Take net profit (before taxes) as percentage of the owners' investment	>15%
Net profit/total assets	Net profits (before taxes) divided by total assets	> 1%
Net sales/tangible net worth	Measures relative activity of invested capital	10-15
Net sales/working capital	Net sales divided by current assets minus current Liabilities	5-30
	(c) Leverage	
General and administrative expenses/tangible net worth	General and administrative expenses divided by owners' investment	<60%
Fixed assets/tangible net worth	Long-term assets (i.e., land, buildings, and equipment) divided by owners' investment	10-40%
Total liability/tangible net worth	Measures amount of debt pressure	1:1 - 3:1
Hard debt/tangible net worth	Measures amount of both short-term and long-term debt pressure	1:1-2:1

Table 5.2: Ratios Typically Analysed by Sureties (Russell, 1990)

The fourth and fifth groups of contractor criteria are shown in Figure 5.15 that included two criteria groups as follows:

1. Contractor's Current Capabilities,

2. Contractor's Submission to the project under consideration.

Group 4: Criteria Related to Contractor's Current Capabilities

This decision criteria group represents the current capabilities of the contractor and is designated by the code 'DCG4'. The main purpose of this criteria group is to assess the contractor's current capabilities to help determine the adequacy of being able to carry out the project under consideration. Different current capabilities need be checked to ensure the required performance efficiency on site includes:

1. Field staff must be adequate,
2. There must be a sufficient number of managers to execute necessary tasks,
3. The project manager and superintendents must have adequate experience and support staff to perform the work efficiently.
4. Plant and Equipment: Reviewing the amount, availability, and adequacy of the construction plant and equipment, maintenance and repair capabilities are relevant in assessing the ability of the contractor to respond in the event of mechanical difficulties.
5. Labour: Construction work is labour intensive, thus, the availability of labour in the geographic area where work has been obtained or is desired should be investigated.
6. Material: The material necessary to construct a facility must be available. The risk of price escalation should be assessed and incorporated within the contractor's estimation process.
7. Subcontracting works: A prospective contractor may be required to demonstrate affirmatively its responsibility towards its proposed subcontractors and project personnel.
8. Contractor capacity to perform any additional work.
9. Contractor attitude to safety and health regulations and requirements.

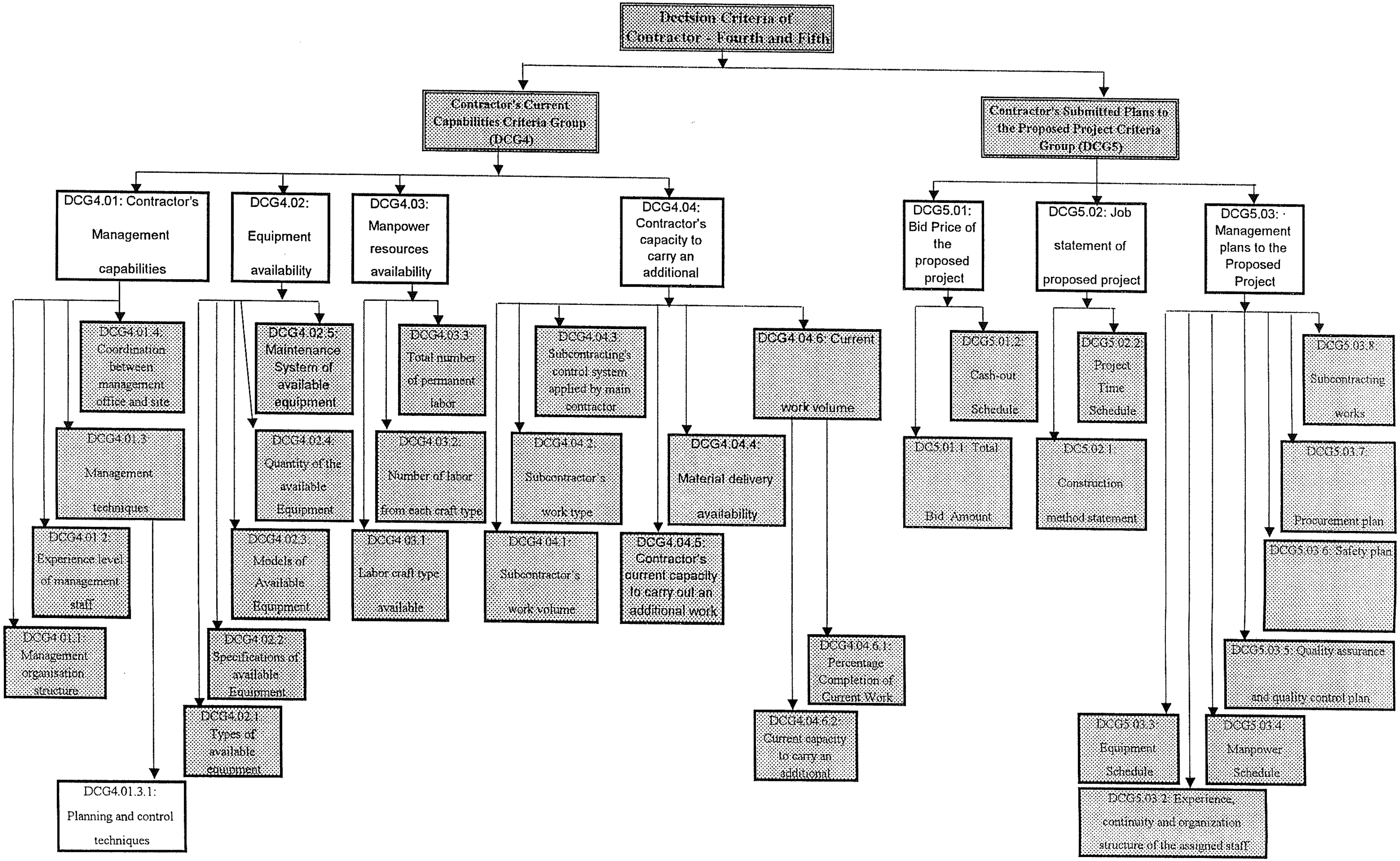

Figure 5.15: Decision Criteria of Final Contractor Selection Process

Management decisions impact the contractor's profitability. Consequently, a contractor's management ability in both the office and the field is important. The important management criteria can be summarised by the following seven items (Neufville and King, 1991):

1. The experience of its personnel and the work previously completed by the contractor need to be considered when evaluating a contractor's ability to administer activities related to its operations, to produce a realistic estimate, and control field operations at the current and anticipated level of activity.
2. The measures used to establish the quality of the contractor management include the efficiency of processing paper work such as pay requisitions, invoices, variation orders, quality, cost accounting records, understanding of financial matters including cash flow, importance of cost documentation, and business planning (Arditi and Gutierrez, 1991).
3. Company philosophies and procedures impact the level of efficiency that is achieved by a firm. Crucial elements to the total process are the estimating procedures and job-cost monitoring systems. Criteria posed relate to the estimating process and include (i) who is involved and what is their background and (ii) previous success in pricing products, etc. Criteria pertaining to job-cost monitoring include who in the field is responsible for collection of cost data and how is the cost information and project status communicated to the head office.
4. The company's position on subcontracting, including the amount of work subcontracted and the procedures used to ensure the subcontractor's qualifications.
5. The organisational structure of the construction company. Review of the company's organisation chart depicting management positions, titles, responsibilities and relationships with other positions. An evaluation of each individual's qualifications is made to assess skills and experience. Analyse all key employees by determining their responsibility level and past experience. With this information, judgement is made as to whether or not the company has the adequate technical expertise (company management, estimating and field management) necessary to compete.
6. The contractor's capacity is also analysed by what the contractor has done historically, as an indication of its capability to undertake the proposed work volume and type.

6. The use of project control procedures (For example, cost, schedule, quality, and safety) by field staff is vital management tools to assess and subsequently enhance field performance.

Group 5: Criteria Related to Contractor's Submitted Plans for the Proposed Project

Plans submitted by the contractor to accomplish the proposed project are the fifth group of the contractor's criteria. The main purpose of this group of criteria is to assess the plans submitted by a contractor for carrying out the proposed project. These plans have three major criteria, as illustrated in Figure 5.15, as follows:

- Bid Price of the proposed project
- Job statement of proposed project
- Management plans to the Proposed Project

Bid price includes information on the total bid amount on the basis of bill of quantity (BoQ) and the contractor's cash flow. Therefore, the suitability of the project cost arrangements to the client's project budget can be evaluated. The job statements include a construction method statement and the management and planning techniques to be used. Project management plans include, for example, project schedule, resources, quality control, safety and staff organisation plans. The resource management plans encompass the equipment, manpower and the material delivery plans. The last criterion is the percentage and type of work, which will be sub-contracted, in the proposed project.

The final lists of contractor's criteria are shown in Appendix D. The final statistical results as the knowledge acquisition part of the KBES developed was based on the survey carried out in Egypt in this thesis for illustration purpose. But this KBES can be easily adapted to the other countries by modifying the relative degree of importance for each criteria group.

5.6 SUMMARY AND CONCLUSIONS

A literature review was carried to identify the major groups of factors affecting the contractor selection process. A postal questionnaire was designed based on the literature review to identify the specific factors affecting the contractor selection process. A postal survey was carried out in UK, Egypt and Kuwait using the designed questionnaires.

Statistical information about the number of consultants operating in UK, Egypt and Kuwait were reviewed and a sample size of 450 consultants, divided into heavy construction (200 no) and building construction (250 no) were selected and contacted using postal mail. Selecting experts from these countries enable the representation of a wide range of expertise. A total of 177 replies were obtained and were statistically analysis based on the Delphi method using SPSS™ and a refined set of factors affecting contractor selection were generated. This refined set is further verified by a set of experts from these countries using 22-structured interview in two rounds, as indicated in Table 5.1.

A review of the results obtained from the survey confirmed the need to implement multiple decision criteria for the selection of the optimum contractor, in addition to using bid price. The results indicated that more than 65% of the criteria, out of the total number of criteria considered in the initial design, were relevant. The current evaluation system of lowest bid price, according to this survey, accounts for only 8.91% of the total decision criteria in building projects and accounts about 9.38% in heavy projects.

The survey revealed that the five contractor selection criteria groups selected are relevant. In general, the criteria relating to the contractor's current capabilities recorded the highest relative degree of importance within both building projects (20.90%) and heavy construction projects (20.72%). The criteria related to submitted plans recorded the second highest relative degree of importance within heavy projects (20.52%), while it was the third highest (20.11%) within building projects.

The relative importance of the decision criteria relating to building and heavy construction is detailed in Appendix D.

Criteria that are related to the project were presented to the decision-maker that involved in the contractor selection, without defining their relative importance. This to give the decision-maker the opportunity to reflect the real project conditions on project-by-project basis but at the same time provide the decision-maker with the method that help in deciding their relative importance, as a part of the decision system required. Therefore, research to find efficient method(s) to carry out the assessment of the project criteria and incorporate the all criteria to select the most appropriate contractor are discussed in the following chapter.

CHAPTER 6: RESEARCH OF DECISION SUPPORT SYSTEMS (DSS) METHODS AND TECHNIQUES

CHAPTER 6: RESEARCH OF DECISION SUPPORT SYSTEMS (DSS) METHODS AND TECHNIQUES

6.1 INTRODUCTION

The quality of the individual contractor selection is limited by the knowledge and experience of the decision-maker, as indicated in Chapter 1. Experience varies from one to another, and there is no guarantee of the quality of the selection process. Even with experienced and knowledgeable decision-makers, there is still no systematic procedure, which utilises multiple criteria (collected and refined in Chapter 5) that match the contractor's qualifications and current capabilities with the specific project's conditions, requirements and objectives, to choose the most appropriate contractor. Thus there is a need for a more objective, systematic, comprehensive and transparent method, that utilises multiple criteria, which is not hindered by the limitations of a single decision-maker and single decision criteria.

Different multiple criteria solution methods have the capability to handle criteria of quantitative and/or qualitative measures. These techniques include goal programming (GP), cluster analysis, multiple attribute utility theory (MAUT) and analytical Hierarchy process (AHP). Examples are presented for each of these methods. All these solutions are discussed and evaluated using rules specifically tailored for the research objectives. The method selected will form the basis of the Decision Support System (DSS).

The presence of affordable powerful computer facilities and the availability of inexpensive generic computer software would make it possible to build a powerful computer based decision support system which can be widely accessible to decision-makers. The development of a computer based decision support system is discussed, which led to the selection of a knowledge-based expert system (KBES) to evaluate the outputs generated by the Delphi method and AHP used to find the optimum contractor. The development issues such as selection of KBES, knowledge representation, building rules, and user interface are discussed.

6.2 REVIEW OF DECISION SUPPORT SYSTEMS

Decision making has been defined as a mechanism of going through a structured process of certain steps, each time a choice must be made between two or more competing alternatives (Davis, 1988). Scott-Morton (1971) first articulated the concepts involved in the decision support system (DSS) in the early 1970s under the term *management decision systems*. He defined such systems as *"interactive computer-based systems, which help decision makers utilise data and models to solve unstructured problems"*. Another classical definition of DSS, provided by Keen and Scott-Morton (1978), is as follows: *"Decision support systems couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions. It is a computer-based support system for management decision makers who deal with semi-structured problems"*. However, there is no universally accepted definition of DSS (Efraim Turban, 1988).

The foregoing definitions indicate the four major characteristics of DSS (Efraim Turban, 1988):

- DSSs incorporate both data and models.
- They are designed to *assist* managers in their decision process in *semi-structured* (or *unstructured*) tasks.
- They support, rather than replace, managerial judgement.
- The objective of DSSs is to improve the *effectiveness* of the decision, rather than the *efficiency* with which decisions are being made.

Most decisions are made without any awareness that the human mental process is actually going through the following procedure (Ahmed, 1995):

- Identification of available alternative solutions to the problem.
- Examination of the factors influencing each alternative solution.
- Evaluation of the alternative solutions with respect to some objective, criteria or requirement.
- Comparison and ranking of the possible outcomes.
- Selection of the most appropriate alternative.

A decision support system (DSS) is developed to help decision-makers analyse the ramifications of a complex problem in order to optimise the choice from all the feasible alternative solutions. Decision support has become a valuable asset to virtually every management function and at all levels of the decision process (Ahmad, 1995). The successful areas of decision support application have been surveyed and categorised into three groups of decision types: operational, tactical and strategic (Davis, 1988).

Operational Decisions

Decision Support Systems (DSSs) have been used to support operational decisions in areas such as: material distribution, personnel or task assignments, production scheduling, workload and personnel scheduling. Generally, operational decisions mainly deal with the administration of day-to-day affairs.

Tactical Decisions

DSSs have been used to answer tactical questions in areas such as: determining staffing requirements and recruitment polices, projecting the expected workload and resource requirements, and performing financial planning and analysis. Generally, tactical decisions deal with the best methods for satisfying short-term objectives.

Strategic Decisions

DSSs have been used to support strategic decisions in such areas as: establishing long range staffing requirements, selecting plant locations and layouts, evaluating long term capital expenditures and evaluating strategic organisational issues. Generally, strategic decisions deal with alternative strategies for satisfying long term goals. Issues that take a significant time to take effect or that require an extended time for implementation are also successful areas for strategic decisions (Ahmad, 1995).

To define the most appropriate decision support system for contractor selection leads to a search for the most appropriate analytical tools or techniques that the DSS would use. These tools or techniques should satisfy the objectives of this research as described in Section 1.3. Different decision systems for the contractor evaluation are investigated in the following sections to illustrate their appropriateness to the problem in hand.

6.3 THE DECISION MAKER AND THE MULTIPLE CRITERIA APPROACH

It is often true that no contractor will exist that can better satisfy all criteria (Russell, 1990). Thus, a decision-maker, responsible for selecting the optimum contractor is faced with the problem of how to trade off one criterion against another within the selection process. These trade-off issues need a decision support system to help in the selection of the optimum contractor with a high degree of confidence for the reasons discussed in the following sections.

Evidence exists that past decision-making research painted a bleak picture of the abilities of the decision-maker (human professional expert) to make the best decisions based only on the amount of information and knowledge of the decision-makers. This picture was based on the assumption that decision-makers should use all relevant information to make the best decision (Ebbesen and Konecni, 1975). One reason found for the limited use of relevant information was that the decision-maker was often influenced by irrelevant information. For example, in geotechnical investigation, the analysis of soil formation, irrelevant materials such as soil pocket might influence the observation. The decision-maker decides how the soil elements may be represented on the basis of the personnel experience and information (Gaeth and Shanteau, 1984). Similar findings have been reported in studies of nurses, where the decision of diagnosing the patient case depends on the information and knowledge available that, this may related to the patient's age, (Shanteau, *et al* 1991). With this research, it was found that decision-making, across many different domains, was often inaccurate, unreliable and biased if it depended only on the direct human decision (Kahneman, 1982 and Wright, 1990). The main reasons behind this are that humans are not able to consider all the information and knowledge relating to the conditions of the problem being addressed.

Therefore, the uses of an organised system could help in overcoming such given limitation. Thus a decision support system is needed to carry out the contractor selection process. The conceptual approach for this selection process is discussed in the following Section.

6.3.1 Decision-Making Methods Using Multiple Criteria Approach

There are several types of decision-making methods using a multiple criteria approach. Adulbhan and Tabucanon in 1980 (Ahmad, 1995) classified these methods into three main categories on the basis of how the initial multiple criteria are transformed into a mathematically manageable format. Hwang *et al* (1980), on the other hand, proposed a different classification according to the stage at which the analysis needs information from the decision-maker. The classification based on the information flow is either bottom-up or top-down.

Bottom-up Information Flow: If information flows from analysis process to decision-making (bottom-up), it will contain results about a set of feasible alternatives without nominating a particular alternative to be prioritised. Techniques using such an approach are called 'Generating Techniques'.

Top-Down Information Flow: Information flowing from the decision-making to the analysis process (top-down) occurs when decision-makers explicitly articulate preferences so that a best-compromise solution may be identified. Methods using such an approach are called 'Techniques that Incorporate Preferences'.

Multiple Criteria Decision-Making, MCDM, methods can be placed into the following categories:

- Multiple Criteria Mathematical Programming.
- Multiple Criteria Discrete Alternatives
- Multi-attribute Utility Theory

Usually these categories involve one decision-maker, or possibly a group; the group consisting of members who all have similar objectives. Generally, there are different multiple criteria solution methods that have the capability to deal with criteria of quantitative and/or qualitative measures. These techniques include:

1. Goal Programming (GP),
2. Cluster Analysis,
3. Multiple-Attribute Utility Theory (MAUT), and
4. Analytic Hierarchy Process (AHP).

Whatever the classification of the multiple criteria decision-making methods, the decision analytic method required for selection of the most appropriate contractor should have the following characteristics:

1- It must handle both quantitative and qualitative criteria.
2- It must permit flexibility in varying the number of criteria depending on individual project conditions.
3- Be capable of determining the relative weight of additional criteria, to reflect the project individuality.
4- Be able to handle criteria that has pre-defined relative weights, which are related to the contractor qualification and irrespective of the specific requirements of the project under consideration.
5- Be able to carry out the selection process at different levels of details. This provides the opportunity to reduce the time and cost of the selection process using a low level of detail.

In the following section, a discussion of the different decision-making methods and a comparison are presented to determine which of them will be the most appropriate to use in this research.

6.3.1.1 Goal Programming Technique

Goal Programming (GP) is a method that requires regular information for multiple objective decision-makings. In GP, deviation variables (from goals) with assigned priorities and weights are minimised rather than optimising the objectives function directly, as in linear programming (LP). Assumptions in LP, such as adaptively, homogeneity, and linearity must also be met in GP, except unidimensionality. GP allows conflicting goals to be specified and still yield an acceptable solution. Grubbstrom (1988) indicates the main difference between Goal Programming (GP) and Linear Programming (LP), as being:

1. The GP technique has multiple objectives to be achieved as closely as possible to the optimum solution, while LP has a single objective to be optimised.
2. The LP problem can be unbounded while the GP problem cannot be unbounded. This situation occurs because the overall objective of GP is to minimise the summation of positive deviations.
3. An in-feasible solution may be obtained in the LP problem. Since a priority structure is introduced in GP, an in-feasible solution does not occur.

This method is not adequate for the process of select the optimum contractor since mathematical programming is basically a static optimisation problem but the construction environment is dynamic. For example, the major problem of LP, even if it provides an optimal solution, is that only one objective is considered (Reza, 1988). In addition, the major problem of GP is that the decision-maker must initially specify the goals and their priorities and it is not an easy task to change them if they are assigned. Another problem of GP is the lack of a systematic approach in the setting of priorities and the trade-off between objectives. This shortcoming is more evident when both quantitative and qualitative factors need to be considered. In addition, it is not an easy task to define the objective function and its constraints within varied conditions, requirements and objectives, which is the situation in construction projects (Russell, 1991).

Methods having the ability to handle both quantitative and qualitative criteria are described in the following sections.

6.3.1.2 Cluster Analysis

Cluster Analysis is a frequently used exploratory procedure that attempts to find natural groupings or clusters of items. This technique is useful in providing means to assess data validity, possible hypotheses, and strategic marketing approaches according to Tomonaga and Matsuzawa in 1992 (Birks, 1993). Duran and Odell (1974) discuss the aspects of Cluster Analysis. The main aspect of the cluster analysis is usually to determine a partitioning that optimally satisfies some objectives. These objectives may be given in terms of a functional relation that reflects the levels of desirability of the various partitions or groupings. This functional relation is often called an objective function. In general, the value of the objective function and the number of groups desired should be considered. There are different types of objective functions that can be defined and formulated in a unified and general manner (Duran and Odell, 1974).

The applicability of this method in the contractor selection process is not efficient. This is mainly due to the difficulty in formalising the objective function from time and cost point of views. Even when it is formalised, it has a very limited flexibility to reflect the project individuality. Multi-Attribute Utility Theory can also handle both quantitative and qualitative criteria similar to the cluster analysis as described in the following section.

6.3.1.3 Multi-Attribute Utility Theory (MAUT)

Multi-Attribute Utility Theory (MAUT) is defined as the method of assessing and fitting of utility functions and probabilities for attributes (criteria or objectives). Thus, utility functions are used to assess and rank alternatives.

Fishburn in1964 (from Goicoechea *et al*, 1992) published a study that explored multi-criteria models using utility theory. Keeney and Raiffa (1976) discussed the details of the utility theory and proved its applicability in the evaluation and selection of the optimum alternative.

The utility function method converts the multi-objective optimisation problem into a single objective problem in the following form:

$$\text{Maximise } Z = F\,[f_1(x), f_2(x) \ldots f_k(x)]$$

$$\text{Subject to } g_i(x) <= 0, \text{ and } i = 1,2 \ldots m \quad , x >= 0$$

Where Z is the objective function and F is the utility function of the multiple objectives, representing the decision-maker's preferences. $g_i(x)$ is a function of constraint and k is the number of objectives and m is the number of constraint functions. If F is properly determined, the solutions obtained will ensure the decision-maker's satisfaction, but it is extremely difficult to determine F (Grubbstrom, 1988).

A possible solution based on a decision-making model in either cluster analysis or utility theory necessitates the establishment of utility functions representing the decision-makers' values for different criteria or objectives. Often in a given decision-making situation, the utility functions are difficult to formulate or adequately represent in a general decision-making process, especially with many criteria (Kenny and Raffia, 1976). Further, the use of these methods requires extensive effort to collect information to identify their coefficients, especially when the number of criteria is frequently varied. This is often a costly, time-consuming process because the tender evaluation decision-making model based on the utility theory necessitates the establishment of utility functions representing the decision-maker's value scales for each criteria or objective. The inflexibility of this approach causes difficulty in adapting to change in either the attributes (objectives or criteria) or the utilities of the model (Skibniewski - Chao, 1992).

The following section describes another method that has the capability to handle the multiple criteria decision-making case.

6.4 ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) is a theory of measurement concerned with deriving priorities from paired comparisons of homogeneous elements with respect to a common criterion or attribute (Saaty, 1994). AHP may be thought of as a multi-attribute utility theory (MAUT) approach. It was introduced by Thomas Saaty (1980) to provide a simple multiple-criteria analytic method for evaluating alternatives solutions (Goicoechea, 1992). AHP helps in identifying priorities on the basis of the decision-maker's knowledge and experience of each problem. AHP takes into consideration judgements based on people's feeling and emotions as well as their thoughts (Saaty, 1994). The strength of AHP lies in its ability to structure a complex, multi-person, multi-criteria problem hierarchically and then to investigate each level separately, combining the results as the analysis progresses. The philosophy behind AHP can be briefly described as follows (Golden et al, 1989):

Analytic: AHP uses numbers. Mathematics is used to understand and/or describe the choice to others. In this sense of the word all methods that seek to describe a decision are analytic if they use mathematical reasoning.

Hierarchy: AHP structures the decision problem in levels which correspond to one's understanding of the situation: goals, criteria, sub-criteria, and alternatives. By breaking the problem into hierarchy levels, the decision-maker can focus on smaller sets of decisions, as indicated in Figure 6.1. The top level of Figure 6.1 reflects the overall objective: the most appropriate alternative. Criteria on which the focus is dependent are listed at intermediate levels, while the lowest level includes the alternatives. An element in a higher level is said to be a governing element for those elements at the lower level. The decision criteria have two levels (higher level) and all criteria are linked by all alternatives (lowest level) where each alternative is compared with the others with respect to each criterion. Harker (1989) discussed detailed examples, which describe how complex problems can be analysed in a hierarchy.

Process: Decisions, which are truly important, cannot be made in a single meeting; one cannot expect AHP to counteract this basic human tendency. People need time to think about a decision, gather information and negotiate if it is a group decision (Goicoechea, 1992).

6.4.1 Theory of the AHP

AHP is based on a set of axioms, which were first stated by Saaty and are described in the paper by Harker and Vargas (1987). Saaty (1980) provides a good introduction to the method and its theoretical underpinning (Saaty, 1988). Generally, AHP has been defined as a theory of measurement with a capacity to handle both quantitative and non-qualitative sets of criteria. *AHP allows the user to establish criteria for decision-making in a hierarchical manner and analyses the complex decision problem by incorporating the user's knowledge-based preference* (Hassell et al, 1992). The hierarchy is arranged in a descending order from the overall focus to criteria, sub-criteria and alternative solutions, as shown in Figure 6.1.

The following basic set of axioms provides the theoretical basis on which the method is founded.

Axiom 1: *Given any two alternatives 'i' and 'j' out of the set of alternatives A, the decision maker is able to provide a pair-wise comparison a_{ij} of these alternatives under any criterion c from the set of criteria C on a ratio scale which is reciprocal; This means,*

$$a_{ji} = 1/a_{ij} \quad \text{for all } i, j \text{ belong to A}$$

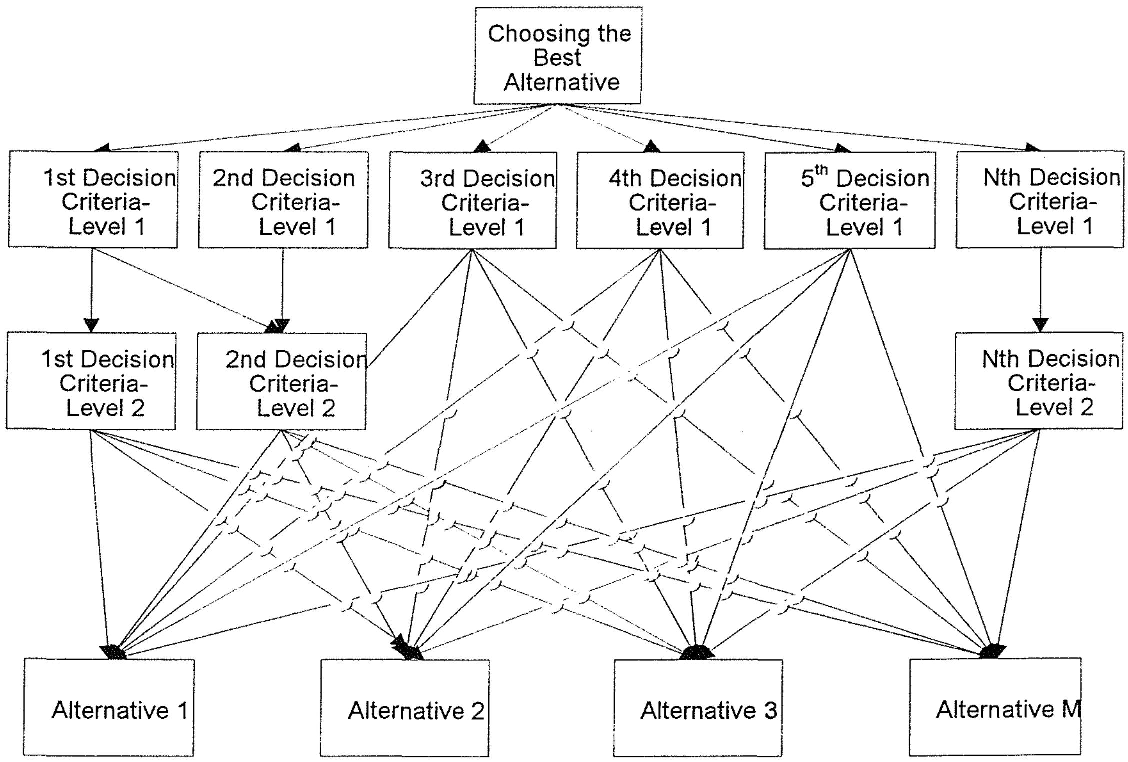

Figure 6.1: Hierarchy of objectives within AHP Method

Thus, if a decision-maker is able to say something is three times more important than something else, then he should agree that the reciprocal property holds.

Axiom 2: *When comparing any two alternatives (i) and (j) belong to set A, the decision-maker never judges one to be infinitely better than another under any criterion "c" belongs to "C".* This means that:

$$a_{ij} \neq 0 \quad \text{for all i, j belong to A}$$

The assumption of this axiom says that infinite preferences are not allowed. In this situation, there is really no choice since the other alternatives will not matter at all. In this situation, one really doesn't need a decision tool, the answer being known from that criterion.

Axiom 3: *The decision problem can be formulated as a hierarchy.*

Axiom 4: *All criteria and alternatives that have an impact on the given decision problem are represented in the hierarchy. That is, all the decision-maker's intuition must be represented (or excluded) in the structure in terms of criteria and alternatives.*

Thus, the above axioms are used to describe the two basic tasks in AHP: formulating and solving the problem as a hierarchy (3 and 4), and eliciting judgements in the form of pair-wise comparisons (1 and 2). Such judgements represent an articulation of the trade-off among the conflicting criteria and are often highly subjective in nature.

6.4.2 Mathematical Foundations of the AHP

The basic mathematical concepts used in the AHP will be summarised as follows:

(a) Assuming the elements (criteria) C_1, C_2, ...Cn of some level in a hierarchy and denoting their normalised unknown priority weights by w_1, w_2...w_n, respectively. The value of w_i reflects the degree of importance of C_i with respect to C_i's.

(b) The first major task in the AHP involves the estimation of the weights (w_i's) of the set of objects (criteria C_i or alternatives) to derive pair-wise comparisons between the n elements. These pair-wise comparisons are structured into an n-by-n reciprocal and positive matrix $A = (a_{ij})$, which is called the judgement matrix. Thus, given the matrix:

$$A = \begin{array}{c} \\ C_1 \\ C_2 \\ . \\ . \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & & \cdots & . \\ . & & \cdots & . \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}$$

Where $a_{ij} = 1/a_{ji}$ for all i, j = 1,2, ..,n.

Elements of matrix A are derived using the scale described in Table 6.1. There are $n\,(n-1)/2$ judgements required to develop an n-by-n judgement matrix, since reciprocals are automatically assigned in each pair-wise comparison. Noting that by using ratio scales, the estimated weights w = (w_1, w_2...w_n) are only unique up to multiplication by a positive constant; this means that w is equivalent to cw where c>o.

Thus, w can be normalised so that it sums to 1 or 100 for convenience. If the judgement were perfectly consistent, this means that $a_{ik}a_{kj} = a_{ij}$ for all i, j,k = 1,2, ..,n.

Intensity of Importance	**Definition**	**Explanation**
1	Equal importance of both elements.	Two elements contribute equally to the property
3	Weak importance of one element over another.	Experience and judgement slightly favour one element over another.
5	Essential or strong importance of one element over another.	Experience and strongly favour one element over another.
7	Demonstrated importance of one element over another.	An element is judgement strongly favoured and its dominance is demonstrated in practice.
9	Absolute importance of one element over another.	The evidence favouring one element over Another is of the highest possible order of confirmation.
2,4,6,8	Intermediate values between two adjacent judgements	
Reciprocals	If activity i have one of the proceeding numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

Table 6.1: Scale of Relative Importance [This table is reproduced from Saaty (1980)].

In this case, simply normalise any column j of A to yield the final weights:

$w_i = a_{ij} / (\sum_{k=1}^{n} a_{kj})$ for all i = 1,2, ..,n.

(c) However, errors in judgement are frequently made, and therefore the final result using the column normalisation would depend on which column was chosen. Saaty's method computes w as the principle right eigenvector[1] (proper vector or characteristic vector) of the matrix A. Computing a vector of unknown weights or priorities w = (w_1, $w_2 \ldots w_n$) for these objectives from the judgement matrix A using the following equation:

$w_i = (\sum_{j=1}^{n} a_{ij} w_j) / \lambda_{max}$ for all i, j, k = 1, 2, ..., n.

This eigenvector method can be interpreted as being a simple averaging process by which the final weights w are taken to be the average of all possible ways of comparing the alternatives (Harker, 1989).

In practice, the decision-maker is only estimating the "true" elements of A by assessing them as values from Table 6.1, so the perfectly consistent case represented by the equation $a_{ij} = a_{ik} a_{kj}$ (for all i, j, k = 1,2...n) is not likely to occur. Therefore, as an approximation, the elements of A can be thought to satisfy the relationship $a_{ij} = w_I / w_j + e_{ij}$, where e_{ij} is the error term representing the decision-maker's inconsistency in judgement when comparing factor i to factor j. Thus, it is not expected that a_{ij} to $a_{ik} a_{kj}$ is equal throughout. The eigenvector method also yields a measure for consistency. As shown by Saaty (1988), λ_{max} is always greater than or equal to n for positive, reciprocal matrices, and is equal to n if and only if A is a consistent matrix, where n is the matrix size (Saaty, 1988). Thus, λ_{max} - n provides a measure by size of the matrix.

Saaty defines this measure as the consistency index (CI) as: CI = $(\lambda_{max} - n)/(n-1)$.

This consistency index is incorporated as measuring the reliability of the results of AHP. Saaty (1988) compared the CI to the index derived from a completely arbitrary matrix whose entries are randomly chosen. Through simulation, Saaty has obtained the results shown in Table 6.2, where n represents the dimension of the particular matrix and RI denotes the random index computed from the average of the CI for a large sample of random matrices.

---

1 Let $A = n \times n$ matrix. The real number λ is called the eigenvalue (proper value) of A if there exist a nonzero vector w such that $Aw = \lambda w$. Every nonzero vector w satisfying this equation is called eigenvector of A associated with the eigenvalue λ.

The values of R.I, as shown in Table 6.2, increase when the size of matrix (n) is increased. For example the RI is zero when *n* is one i.e. the matrix has one element and RI is 0.9 when n is equal to 4.0. Saaty (1988) introduced the consistency ratio (CR) as a reliability measure for the AHP results. Using the values of n and C.I, the consistency ratio

(CR) is defined as the ratio of the CI to the RI. Thus CR is a measure by the following equation:

$$C.R = C.I / R.I$$

Matrix Size (n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R. I.	0.00	0.00	0.58	0.90	.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 6.2: Random Inconsistency Index (R. I.)

Experience suggests that the CR should be less than 0.1 if one is to be fully confident of the results[1] (Shtub *et al,* 1994).

Larger values of C.R require the decision-maker to revise their judgement to make sure that the AHP assumptions and scale reduce the inconsistencies encountered (Harker, 1989). Golden *et al* (1989) discussed and demonstrated an alternate measure of consistency of entries in a pair wise comparison matrix and the hierarchy as a whole in their paper and introduced a modification to C.R value (Golden *et al,* 1989).

6.4.3 Applications of the Analytic Hierarchy Process (AHP)

Since its introduction in mid of 1970s, the Analytic Hierarchy Process (AHP) has been applied to many types of decision problems. Applications can be found in such diverse fields as portfolio selection, transportation planning, manufacturing systems design, and artificial intelligence (Saaty, 1988). There are more than 150 published papers that use AHP to model diverse problems such as conflict analysis, urban planning and space exploration (Golden *et al,* 1989). The majority of these applications introduced analytical solutions for the problems that involved both quantitative and qualitative criteria, which is similar to the selection process that is the objective of this thesis.

1 There is a certain amount of subjectivity in this assertion, much like that associated with interpreting the coefficient of determination in regression analysis (Shtub, *et al,* 1994).

6.4.3.1 Illustrative Example of using AHP

Consider the case of having to evaluate several alternatives for installation of a sewer pipeline in a residential area (AbouRizk *et al*, 1994). Sewer improvements had been needed for years, but had been resisted by property owners due to the disruption factor associated with open-cut trenching.

A number of new techniques have been introduced that offer the advantage of minimum disruption and that are said to cost effective in deep cuts. To analyse the problem according to the model described above, the solution will be as follows:

For simplicity, the micro-tunnelling technique and the open-cut technique are considered as the only alternatives. The micro-tunnelling technique uses a remotely guided excavation machine and causes minimum disruption because no open cut is required. The market price of such equipment is approximately £600,000. The equipment being able to operate at fairly deep locations minimises the possibility of breaking the existing utility lines. No workers are required to accompany the machine, so safety problems are also kept to a minimum. A relatively sophisticated technology associated with this machine means that the initial stages of the project could be characterised by an intense learning process. As a consequence, production could be lower than its manufacturers' estimates.

The machine could install approximately ten to fifteen sections of pipe per day according to Isely in 1987 (AbouRizk, 1994).

If the open-cut technique is considered as the first alternative and the second is the micro-tunnelling technique, the criteria to be used are the following: -

1. Effect of alternative technology on cost of the project (C1).
2. Total time required completing the job (C2).
3. Retention of a competitive advantage in the market (C3).
4. Level of environmental disruption associated with the considered technique (C4).

The risk factors involved include the following:

1. Size of the initial investment associated with each alternative technology of (F1).
2. Possibility of causing damage to the existing utility line (F2).
3. Degree of defective work associated with each technology (F3).
4. Chance of breakdown of equipment (F4).

The relative importance of the criteria estimated on the evaluator judgement as described in the following Table:

Criteria	Evaluator judgement
C1	C1 has a weak importance of over C2 and has essential importance over C3 and C4.
C2	C2 has a weak importance of over C3 and has equal importance with C4.
C3	C3 has a weak importance of over C4

This table can be converted into the following matrix.

$$[C] = \begin{array}{c} \\ C_1 \\ C_2 \\ C3 \\ C4 \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C3 & C4 \end{array} \\ \left[\begin{array}{cccc} 1 & 2 & 4 & 4 \\ 0.5 & 1.0 & 2.0 & 1.0 \\ 0.25 & 0.50 & 1.00 & 2.00 \\ 0.25 & 1.0 & 0.50 & 1.0 \end{array} \right] \end{array} \qquad (1.a)$$

Eigenvector

$$[C_w] = \begin{array}{c} C_1 \\ C_2 \\ C3 \\ C4 \end{array} \left[\begin{array}{c} 0.4963 \\ 0.2168 \\ 0.1555 \\ 0.1314 \end{array} \right] \qquad (1.b)$$

Largest eigenvalue = 4.1855

The eigenvector (1.b) gives the relative importance of the criteria compared to each other. The relative weight matrix (1.b) indicates that cost (C1) is more important than time (C2), [strong = 2], and is much more important than competitive advantage and disruptions (C3 & C4), [very strong = 4], as described in Table 6.1.

The impact of risk factors on cost, time, competitive advantage and disruption to the environment are, respectively:

With respect to cost

$$\begin{array}{c} \\ F_1 \\ F_2 \\ F3 \\ F4 \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & F3 & F4 \end{array} \\ \left[\begin{array}{cccc} 1 & 4.00 & 4.00 & 4.00 \\ 0.25 & 1.00 & 2.00 & 2.00 \\ 0.25 & 0.50 & 1.00 & 1.00 \\ 0.25 & 0.50 & 1.00 & 1.00 \end{array} \right] \end{array}$$

Normalised Eigenvector

$$[C_1] = \begin{matrix} F_1 \\ F_2 \\ F3 \\ F4 \end{matrix} \begin{bmatrix} 0.5665 \\ 0.1993 \\ 0.1171 \\ 0.1171 \end{bmatrix} \quad (2.a)$$

Largest eigenvalue = 4.0606

With respect to time

	F_1	F_2	$F3$	$F4$
F_1	1	0.25	0.25	0.25
F_2	4.00	1.00	2.00	2.00
$F3$	4.00	0.50	1.00	1.00
$F4$	4.00	0.50	1.00	1.00

Normalised Eigenvector

$$[C_2] = \begin{matrix} F_1 \\ F_2 \\ F3 \\ F4 \end{matrix} \begin{bmatrix} 0.0755 \\ 0.4251 \\ 0.2497 \\ 0.2497 \end{bmatrix} \quad (2.b)$$

Largest eigenvalue = 4.06067

With respect to competitive advantage

With respect to time

	F_1	F_2	$F3$	$F4$
F_1	1	0.25	0.25	0.50
F_2	2.00	1.00	4.00	4.00
$F3$	4.00	0.25	1.00	4.00
$F4$	2.00	0.25	0.25	1.00

Normalised Eigenvector

$$[C_3] = \begin{matrix} F_1 \\ F_2 \\ F3 \\ F4 \end{matrix} \begin{bmatrix} 0.1055 \\ 0.5004 \\ 0.2804 \\ 0.1137 \end{bmatrix} \quad (2.c)$$

Largest eigenvalue = 4.5731

With respect to disruption

	F_1	F_2	$F3$	$F4$
F_1	1	0.25	0.50	0.50
F_2	4.00	1.00	4.00	4.00
$F3$	2.00	0.25	1.00	4.00
$F4$	2.00	0.25	0.50	1.00

Normalised Eigenvector

$$[C_4] = \begin{bmatrix} 0.0993 \\ 0.5617 \\ 0.1986 \\ 0.1404 \end{bmatrix} \begin{matrix} F_1 \\ F_2 \\ F3 \\ F4 \end{matrix} \qquad (2.d)$$

Largest eigenvalue = 4.1213

The eigenvector corresponding to the largest eigenvalue of each of these matrices become columns of the combined criteria and risk matrix.

[S] = (3.a)

	C_1	C_2	$C3$	$C4$
F_1	0.5665	0.0755	0.1055	0.0993
F_2	0.1993	0.4251	0.5004	0.5617
F_3	0.1171	0.2497	0.2804	0.1986
F_4	0.1171	0.2497	0.1137	0.1404

The multiplication of matrix [S] and [C_w] gives the relative weights of criteria and risk factors together. The matrix of phase 3 is:

$$[S]\,[C_w] = \begin{bmatrix} 0.3270 \\ 0.3427 \\ 0.1819 \\ 0.1484 \end{bmatrix} \qquad (3.b)$$

The comparison should be made according to the same criteria of judgement to select the best alternative. The weights given to each risk factor in each alternative technology must be the same, since the objectives should not change for each technology. Therefore, the risk factor weights F_i obtained previously are used for both technology alternatives.

Both alternatives are compared to each other depending on their importance regarding each risk factor. Comparing micro tunnelling (MT) to open-cut (OC) with regard to size of initial investment (F1), micro tunnelling should have a higher weight. The weights obtained by pair-wise comparison of alternatives per risk factor show this. These weights are 1 and 4 for micro tunnelling (MT) and open-cut (OC) respectively, as can be seen in (4.a). The same analogy is applied to other risk factors while formulating matrices as shown in (4b-d).

$$\begin{array}{c|cc} & MT & OC \\ \hline MT & 1.00 & 4.00 \\ OC & 0.25 & 1.00 \end{array} \qquad [AR_1] = \begin{array}{c} \\ MT \\ OC \end{array}\begin{bmatrix} \text{Eigenvector} \\ 0.8 \\ 0.2 \end{bmatrix} \tag{4.a}$$

Largest eigenvalue = 2.0

$$\begin{array}{c|cc} & MT & OC \\ \hline MT & 1.00 & 0.25 \\ OC & 4.00 & 1.00 \end{array} \qquad [AR_2] = \begin{array}{c} \\ MT \\ OC \end{array}\begin{bmatrix} \text{Eigenvector} \\ 0.2 \\ 0.8 \end{bmatrix} \tag{4.b}$$

Largest eigenvalue = 2.0

$$\begin{array}{c|cc} & MT & OC \\ \hline MT & 1.00 & 2.00 \\ OC & 0.50 & 1.00 \end{array} \qquad [AR_2] = \begin{array}{c} \\ MT \\ OC \end{array}\begin{bmatrix} \text{Eigenvector} \\ 0.667 \\ 0.333 \end{bmatrix} \tag{4.c}$$

Largest eigenvalue = 2.0

$$\begin{array}{c|cc} & MT & OC \\ \hline MT & 1.00 & 1.00 \\ OC & 1.00 & 1.00 \end{array} \qquad [AR_2] = \begin{array}{c} \\ MT \\ OC \end{array}\begin{bmatrix} \text{Eigenvector} \\ 0.5 \\ 0.5 \end{bmatrix} \tag{4.d}$$

Largest eigenvalue = 2.0

The matrices referred to in (4) are aggregated to form the following matrix:

$$\begin{array}{c} \\ MT \\ OC \end{array} \begin{array}{c} \begin{array}{cccc} F1 & F2 & F3 & F4 \end{array} \\ \begin{bmatrix} 0.8 & 0.2 & 0.667 & 0.5 \\ 0.2 & 0.8 & 0.333 & 0.5 \end{bmatrix} \end{array} \quad (5)$$

At this stage, the matrix given by (5) is multiplied with the matrix given by (3.b) resulting in final weights per alternative.

$$[AR][S][C_w] = \begin{bmatrix} 0.8 & 0.2 & 0.667 & 0.5 \\ 0.2 & 0.8 & 0.333 & 0.5 \end{bmatrix} * \begin{bmatrix} 0.3270 \\ 0.3427 \\ 0.1819 \\ 0.1484 \end{bmatrix} = \begin{array}{c} MC \\ OC \end{array} \begin{bmatrix} 0.5256 \\ 0.4744 \end{bmatrix} \quad (6)$$

Since the score of alternative 1 (micro tunnelling) is larger than that of alternative 2 (open-cut), more risk is associated with the first alternative. The major factors contributing to risk in this alternative as resulted from equation (3.b) are the initial investment and defective workmanship. This analysis was for the purpose of illustrating how to use the AHP in the process of selecting the optimum alternative technology as introduced by AbouRizk *et al* (1994).

The following section investigates the difference between the analytic methods mentioned above (3.6.1 to 3.6.4), to identify the most appropriate one to use in developing the DSS for the process of selecting the optimum contractor.

6.4.4 Comparison of Multiple Criteria Solution Methods

Table 6.3 shows the comparison between the multiple criteria solution methods that have been described in the previous sections. The comparison was carried out on the basis of the characteristics or criteria that each method potentially satisfies the criteria in Table 6.3 are described as follows:

1- Handling quantitative criteria characteristic, is expressed:

- **Yes** means the method is capable of handling quantitative criteria. or
- **No** means the method has no capability to handle quantitative criteria

2- Handling qualitative criteria characteristic is expressed as:

- **Yes** means the method is capable of handling qualitative criteria. or

- **No** means the method has no capability to handle qualitative criteria

3- Flexibility of varying the number of criteria depending on the individuality of project conditions is expressed as:

- **High** means there is no need for a complex method to add or delete any criteria. It has a simple formulation and requires little experience, effort and time to carry out. or
- **Medium** means this method needs relatively more time and effort to formulate. or
- **Low** means this method is complex in its formulation and requires more experience, effort and time.

4- Capability of determining the relative weight of new criteria is expressed as:-

- **Yes** means there is a capability to determine the relative weight. or
- **No** means there is no capability to determine the relative weight.

5- Handling criteria which have pre-defined relative weights is expressed as:-

- **Yes** means there is a capability to handle the pre-defined relative weight. or
- **No** means there is no capability to handle the pre-defined relative weight.

6- Possibility of evaluating alternatives using a varying number of criteria at different levels of detail is expressed as:-

- **High** means it is possible with relatively minimum time and mathematical effort to produce different levels of evaluation. or
- **Medium** means it is possible with a relatively high time and average mathematical effort to produce different levels of selection. or
- **Low** means it is possible with a relatively long-time and high mathematical effort to produce different levels of selection.

The comparison of these different analytic methods indicates that AHP can handle the multi-criteria problem more effectively than other methods, as shown in Table 6.3. Thus AHP is considered the most appropriate method, which can be used in the development of the selection process for selecting the optimum contractor model as described in Chapter-7.

The advantage of AHP is the capability to handle criteria either that assessed by the AHP or any other assessment technique to evaluate alternatives. But the problem of using the AHP directly to assess the contractor selection criteria has two aspects. The first problem aspect is that the assessment level of criteria depends mainly on the level of experience and knowledge of the decision-maker, which may affect on the decision quality. The second problem aspect is that the time required making pair-comparison for all criteria by experts is not available and cannot easily collect. Therefore, the contractor criteria were assessed by the experts form the construction industry using the Delphi method, as described in Chapter 5. These contractor criteria are incorporated directly in the AHP to select the most appropriate contractor alternative. This incorporation reduces the time required to assess the contractor criteria and introduce the quality required by evoking the experts' opinions using the Delphi method.

	Handling Quantitative Criteria	Handling Qualitative Criteria	Flexibility of Adding Criteria	Capability to Give Weight for Criteria	Handling Criteria of Pre-defined Weights	Evaluating Alternatives Using Varying No. of Criteria
Goal Programming (GP)	Yes	No	Medium	No	Yes	Medium
Cluster Analysis	Yes	Yes	Low	No	Yes	Low
Multiple-attribute utility theory (MAUT)	Yes	Yes	Low	No	Yes	Low
Analytic hierarchy process (AHP)	Yes	Yes	High	Yes	Yes	Yes

Table 6.3: Comparison between the Analytic Methods for the Multiple Criteria Problem

The AHP is used to assess the project criteria to represent realistically the specific project conditions, requirements and objectives on a project-by-project basis.

Once the analytical method has been identified, research for a suitable computer based system is required to enhance the DSS development as described in the following section 6.8.

6.5 CONCEPTUAL APPROACH TO SELECT THE MOST APPROPRIATE CONTRACTOR TO SPECIFIC PROJECT

The process of selecting the optimum contractor has to meet the special requirements to satisfy the objectives of this research. These requirements direct the research towards methods that have the capability to handle decision criteria that are assessed by the experts in addition to handling decision criteria to be assessed for each project on a case-by case basis. AHP can be used to assess the required criteria and incorporating these assessed criteria to assess the optimum contractor (alternative solution).

This section describes the conceptual approach for selecting the most appropriate contractor to carry out the project under consideration. The approach to the selection process of the traditional system needs to be developed into a properly structured or adequate way to reduce the risks associated with the selection of an inappropriate contractor for the reasons illustrated in Section 2.6.1. Therefore, the conceptual approach of the selection process of selecting the most appropriate contractor is divided into two main processes, each using a different formalisation and structure to include:

Part 1: Screening Process

The objective of the first selection process is to select contractors who are the most suitable to carry out the work in terms of matching the contractor's qualifications with the project's specific conditions, requirements, and the client's objectives. The qualification requirement encompasses the contractor's experiences and performances in the preceding projects in addition to the contractor's financial position. This selection process can be considered as the screening process or pre-qualification process, which uses a qualitative and quantitative judgement and assessment of all contractors who wish to tender, and then reduces their numbers down to a select few. The output of this process is a short list of the most appropriate contractor to the project under consideration.

Short listed contractors submit their current resources, capabilities and plans for the project under consideration to get into the second part of selection process.

This division will reduce the time and effort required in evaluating or preparing the data by the client or contractors respectively.

Part 2: Final Selection Process

The objective of this selection process is also to match the current capabilities of the qualified contractors and their plans to the proposed project with the project specific conditions and requirements and the client's objectives.

The criteria previously obtained from the previous chapter are used in the development of the proposed selection system to identify the most appropriate contractor.

The optimum contractor does not necessarily mean the best contractor in terms of its qualifications, but it means the contractor whose qualifications match the project- specific conditions, requirements or the client's objectives. Thus, the required technique or tool should have the capability to select this optimum contractor.

The criteria that will be implemented in the system proposed are related to contractor's qualification and the project-specific conditions, requirements and objectives. The criteria related to the project-specific conditions, requirements or the client's objective is assessed for each project on a case-by-case basis using the AHP

The purpose of this conceptual approach is to give a chance for the person who makes the selection decision- to reflect the real project conditions, requirements or the client's objective in the selection process as described in the following chapter.

6.6 COMPUTER SUPPORT TOOLS FOR DECISION SUPPORT SYSTEM DEVELOPMENT

The development of the current generation of fast computers has enhanced the process of decision support because of their ability to handle structured (programmable) decision problems in a short time. Computers can also solve ill-structured and complex problems using the "Knowledge-Based Expert System" technique (Ahmad, 1995).

A knowledge-based expert system (KBES) is a computer program that provides "answers" to non-trivial problems that typically require human expertise for their solution. Typically, these systems utilise knowledge and lines of reasoning similar to that of the human expert when carrying out the same task. A good standard definition of KBES is the following: Knowledge-based expert systems are interactive computer programs incorporating judgement, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice about a variety of tasks (Kostem and Maher, 1986).

6.6.1 Justification for selection of Knowledge-Based Expert System

The main difference between the traditional approach to systems development and the approach brought by a knowledge-based expert system (KBES) is the organisation of the knowledge. In a conventional algorithmic system, the knowledge is locked within the procedural control. As a result, during the development of an algorithmic, a significant proportion of the program development time is spent designing the procedural control structure as indicated in Figure 6.2, in order that the right problem can be solved at the right time (Bedford, 1992).

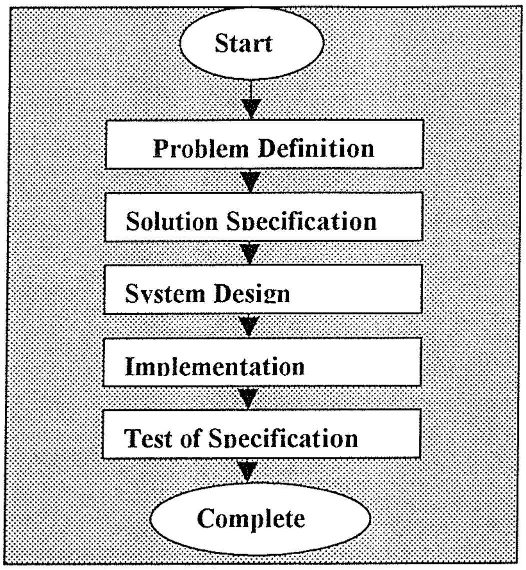

Figure 6.2: Traditional Approach to Computer Programming

A KBES normally has an architecture where knowledge about the problem domain (in the knowledge base) is separated from knowledge about how to solve the problem (in the inference engine), or knowledge about how to interact with the user (in the user interface). The classical simple structure of the KBES is illustrated in Figure 6.3. The components of a more elaborate a KBES are illustrated in Figure 6.4.

The architecture of KBES has the following advantages:

- The different types of knowledge constitute separate entities within the system, which makes the domain of knowledge more explicit and accessible (Basri and Stentiford, 1994).
- The KBES developer (programmer) spends a greater proportion of the development time acquiring and representing the knowledge rather than organising and proceduralsing it (Bedford, 1992).

- Unlike procedural control programming, the control in expert systems is guided by the available knowledge. For example, it is often possible to remove knowledge from the knowledge base and still be able to arrive at a 'solution'. This would almost not be possible with an algorithmic system (Bedford, 1992).

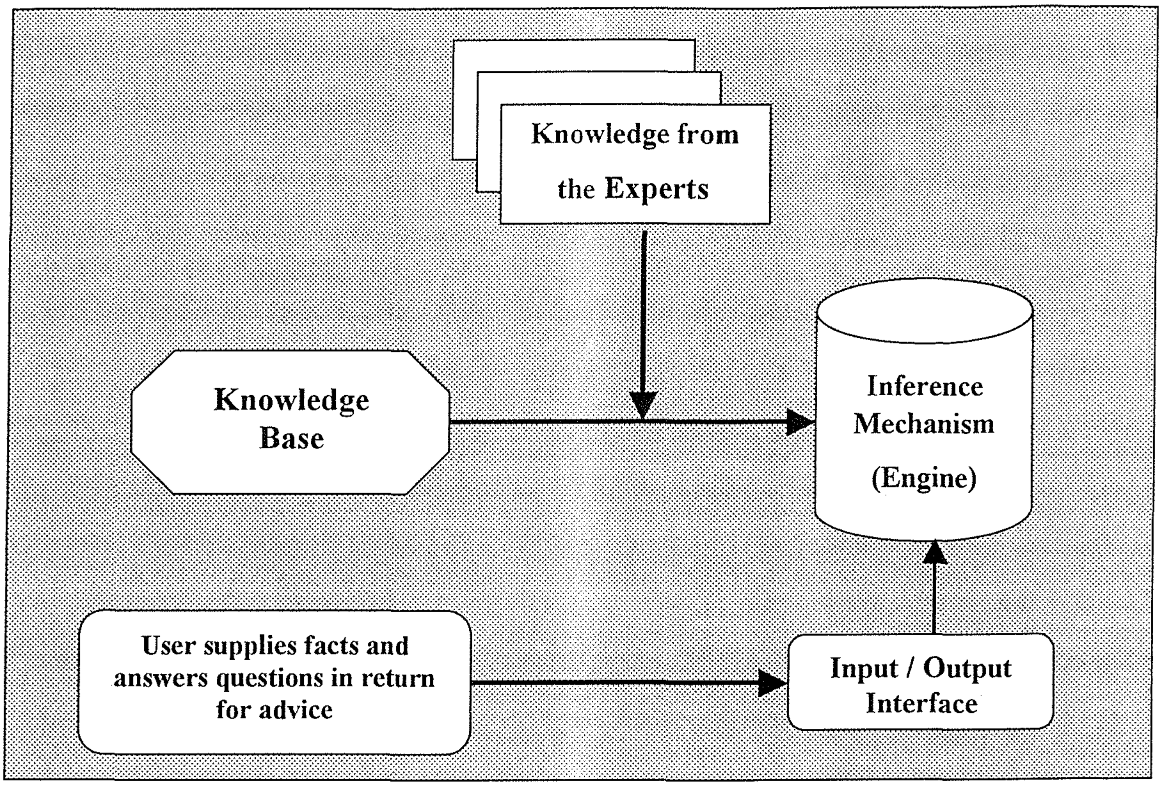

Figure 6.3: The Architecture of a Typical KBES (Hart, 1986)

The questions to be asked are what is knowledge, how can it be represented and how can the KBES be developed and what are the tools for KBES development that can assist in contractor selection system? The answers to these questions are described in the following sections.

6.6.2 Knowledge in the KBES

What is knowledge and how it is represented in the human mind are problems that have been addressed by philosophers and cognitive psychologists without coming to any generally accepted conclusions (Bedford, 1992). Generally, in the domain of Artificial Intelligence (AI), four forms of knowledge are usually recognised:

1. Declarative knowledge,
2. Procedural knowledge,

3. Generic or common sense knowledge and
4. Heuristic knowledge.

Declarative knowledge refers to factual information about describable entities that are usually static. For example, the following definition *a flat slabs* is *a type of structural system* is a declarative statement. In the human mind, this type of knowledge has the facility to be organised by categorisation, e.g. the above definition is an example of a concrete roofing system that is generally used when a relatively large space is required.

Procedural knowledge refers to knowledge about how to perform various cognitive activities and has a fundamentally different problem-solving organisation.

Generic knowledge can be defined as the knowledge an individual collects about the world and how it works, e.g. inadequate rest reduces labour productivity, make backup copies of a file, do not rely on the hard disk storage.

Heuristic knowledge is that knowledge that is not gained from books or external sources but is built up by an individual from past experiences, thereby giving an intuitive sense of what is the right solution or approach. This form of knowledge is dynamic in the sense that it is continually being updated with increased experience in a task and considerably more elusive to acquire than declarative knowledge.

Also within the AI domain, there is another classification to knowledge into:

1. Surface knowledge
2. Deep knowledge

Surface knowledge is defined as being the domain-specific heuristics that are typically gained by word of mouth or experience e.g. knowledge of British Standard Codes of Practice. Deep knowledge is defined as that which provides a theoretical underpinning to domain and is typically acquired through education and detailed individual study, e.g. a theoretical understanding about the behaviour of material under stress (Bedford, 1992).

It is usually the volume of surface knowledge that distinguishes the expert from the novice (Bedford, 1992). For a specific problem, surface knowledge incorporates both domain dependent facts and heuristics. They can lead to direct problem solution, but as they are usually related to specific situations they are not guaranteed to succeed.

Little research has been carried out regarding studies of knowledge or the knowledge environment in construction. Howard (1989) discussed the range of data and knowledge whose elements have to be captured in an engineered system. This knowledge ranged from very specific defined details (basic data) to very abstract, common principles (general knowledge). He suggested that project data be accumulated from those initial design decisions that linked elements of basic data, design data, project specification, domain knowledge and general knowledge to explain the design. Jain *et al* (1990) classified the knowledge required for structural engineering as system, behaviour, performance, product, and concept and strategy knowledge. Once knowledge is defined, the question arises as to how it can be represented. The following section describes how the knowledge can be represented.

6.6.3 Knowledge Representation for KBES

Knowledge representation is the process of structuring knowledge about a problem in a way that makes the problem easier to solve. Figure 6.4 illustrates that the knowledge base is a fundamental part of a KBES. Actually, the system of knowledge representation depends mainly on the tools that can be used for the KBES. It is recognised that one key to the rapid development of a system is the selection of an appropriate means of knowledge representation. Boose (1989), Boose and Gaines (1990) and Forsythe (1989) describe various researches that investigated knowledge representation schemes and languages, which assist knowledge acquisition and knowledge maintenance. These systems are based on rule interpretation, facts organised into frames or model-based reasoning as described below.

6.6.3.1 Rule-Based Systems

Rule based systems are the principle form of knowledge representation employed in most KBES. In these systems, knowledge representation is in the form of:

(If) condition => (Then) action.

This statement consists of a number of premises or antecedents (If) and one or more conclusions or consequences (Then). Rule-based systems are most appropriate when:

- The underlying knowledge was already organised as rules or in a table format.
- The required structures were predominantly categorised.
- There was not a great deal of context dependency.

This kind of situation would be characterised by screening or a policy implementation type problem in which the appropriate strategy for each situation is well documented (Howard, 1990).

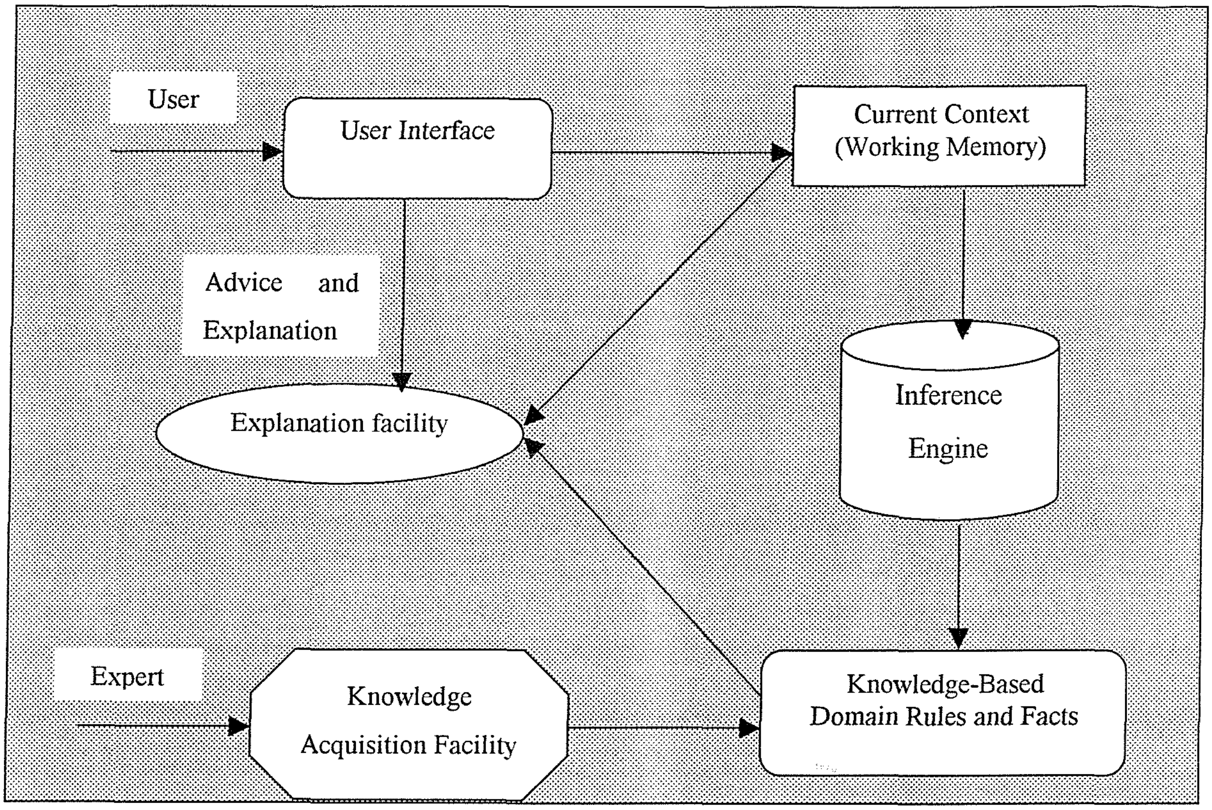

Figure 6.4: The Components of a more Elaborate Knowledge-Based Expert System [KBES] (Maher, 1987)

6.6.3.2 Frame -Based Systems

Frame-based systems consist of structured sets of facts organised around objects. These facts typically consist of attribute-object-value; e.g., the attributes (slots) of the frame PERSON could be date-of-birth, father, mother, occupation, marital status, number-of-children, nationality and age. For a particular person, Ahmad Ibrahim, these slots might have slot values '4.12.1996', 'Ibrahim Mahmoud', 'Nabila', 'Egyptian', etc.

Symbolic reasoning in frame-based systems had no necessary features but were usually based on procedural attachments that manage mechanisms such as the assignment of default values to slots.

Frame-based systems are most appropriate when:

- The underlying knowledge is descriptive consisting predominantly of facts;

- There is a mixture of probabilistic and categorical classification required;
- There is a large amount of context dependence;
- There are potentially many simultaneous outcomes to be considered.

This approach to knowledge representation would therefore be applicable to large diagnostic problems where the technique was most frequently employed in large KBES applications (Lenat and Guha, 1990).

6.6.3.3 Model-Based Reasoning

Model-based reasoning is an approach in knowledge representation for an engineering system that is intuitive and efficient to implement and which permits multiple kinds of reasoning about the system. This employs the representation and reasoning techniques already discussed, including rules, frames and another one which is object-oriented programming.

Model-based reasoning represents an emerging methodology for extending the reach of KBES techniques from classification problems, such as diagnosis, to problems that involve the formation of solutions from primitive elements e.g. design and planning. Model-based reasoning has emerged as useful for solving problems in diverse application areas (Kunz *et al*, 1989 and Scarl, 1989).

6.7 DEVELOPMENT SYSTEMS USING KBES

The development of conventional systems typically follows a methodology associated with a life cycle model of knowledge engineering, which includes the following stages (Bedford, 1992):

1. Requirement analysis: by deriving desired properties and capabilities.
2. Requirement specification: statement of functions and constraints.
3. Design: by producing solutions to satisfy the specification.
4. Implementation: by realising the design in a programming language.
5. Validation: by checking; the system fulfils its requirements.
6. Verification: by checking that the end product of the first four stages matches its input.
7. Operation: installation on the intended environment.

This life cycle for developing KBES is recognised as having a number of deficiencies particularly with respect to producing large complex systems. The reasons for this deficiency is that the life cycle above does not address issues stemming from the separation of knowledge representation and reasoning strategies in KBES. A simple life cycle model for knowledge engineering is illustrated in Figure 6.5.

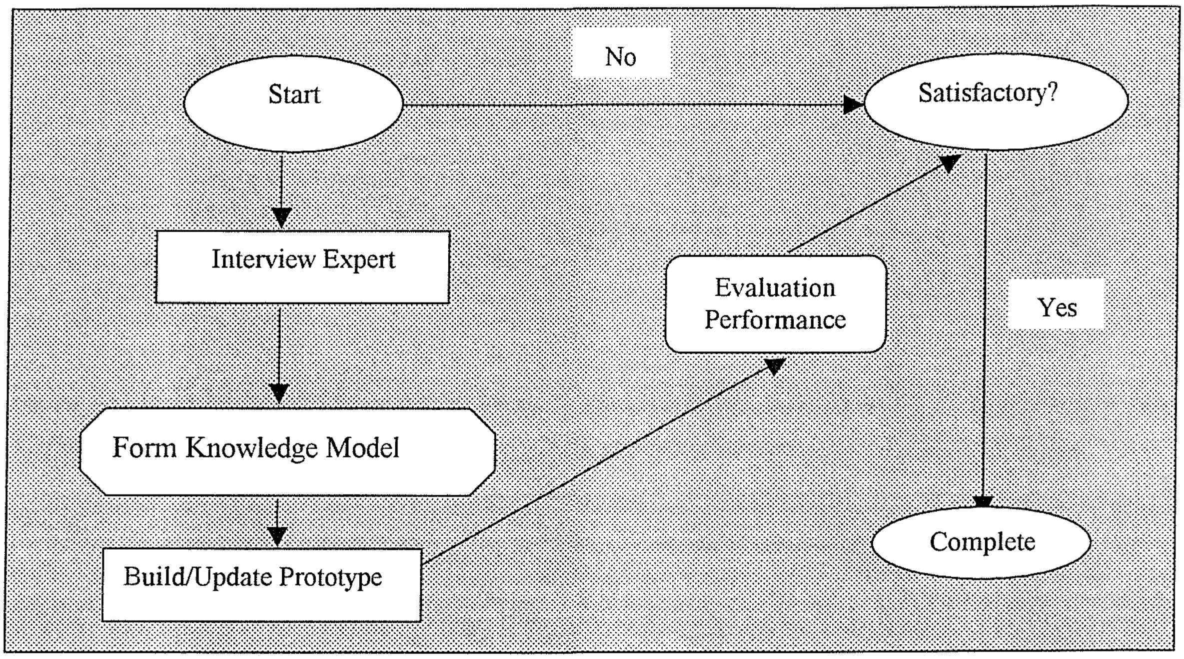

Figure 6.5: A Simple Life Cycle Model for KBES Development (Bedford, 1992)

Typically a knowledge-based expert system (KBES) is developed over several iterations before the system is complete. One manifestation of this approach is that it becomes increasingly more difficult to manage complexity in large systems (Bedford, 1992). It is for these reasons that formal methodologies are being adopted for complex systems in conventional software development. It is concluded that whilst formal methodologies for KBES development are an important part of current AI research, the current state-of-the-art provides little research for developing complex systems at present.

6.7.1 Tools for KBES Development

Two main classes of tools are actively used for KBES development and these are:

1. Computer Language for KBES;
2. Expert System Shells.

6.7.1.1 Computer Language

The development of expert systems and expert system tools has been carried out using a wide range of computer languages. For language implemented prototype systems, however, a high level AI language is usually preferred, such as LISP, PROLOG or TURBO PROLOG and, to a lesser extent object-oriented environment such as SCHEME and SMALLTALK.

LISP is a procedural language derived from the mathematical theory of recursive functions. The language provides a powerful medium for the implementation of symbolic data structures and was the first language to be used seriously for KBES development. The syntactic elements of the language are primarily atoms and lists. *PROLOG* is the most common example of a range of languages based on first-order clause logic (It is a clause that contains at most one conclusion). This language can be used for either declarative or procedural representation. Knowledge is symbolically represented in logical facts and clauses (Bedford, 1992).

A common feature of complex knowledge-based systems implemented in a high level language is their apparently inefficient operation when compared to conventional systems. Knowledge-based systems make heavy use of computer memory and, as a result, such systems can result in memory overflow but this problem can be overcome by the new versions of recent computers. Established software languages that developed in higher languages such as PROLOG and LISP, much of the control is perceived to emanate from the systems knowledge. In systems developed in conventional languages, the high-level control algorithms have to be implemented. As a consequence, for commercial systems there is a trend to develop prototypes in a higher level language before implementation of the run time system in conventional language. For conventional languages such as FORTRAN, which is generally adopted for Engineering Systems, the restrictions on usable data (knowledge) types, such as a step for runtime system particularly complex

6.7.1.2 Expert System Shells

An expert system shell is an expert system that retains knowledge about how to reason with a particular knowledge representation and about communicating with the user, (Bedford, 1992).

A growing number of commercially available shells exist. Between them, they provide tools for the development of a wide variety of problem types. The advantage of using such a tool is that the knowledge representation and control mechanism is provided and the knowledge engineer can concentrate on acquiring and organising the domain knowledge. A major disadvantage of shells is that they are typically inflexible, placing restrictions on:

- The form of knowledge representation available,
- The size of the knowledge base, and
- The way in which the knowledge is manipulated.

The expert system shells that have recently become available include EXSYS version-5 (1994), Level-5 Object (1995) and NExpert Object (1995). Some of them, such as Level-5 and NExpert shells, have introduced a significant level of flexibility in knowledge representation by using additional forms to the if-then rules by the previous systems. The description of these shells is presented below.

EXSYS Shell: The program uses IF-THEN-ELSE type rules. A rule is made up of a list of IF conditions (Normal English sentences or algebraic expressions) and lists of THEN and ELSE conditions (more sentences) or statements about the probability of a particular choice being the appropriate solution to the problem. If the program determines that all IF conditions in a rule are true, it adds the rules THEN conditions are true; otherwise if they are false; the ELSE conditions are added to what is known. The EXSYS editor, runtime and utility programs are written in C programming language. Expert systems developed with EXSYS Professional function the same way on Microsoft Windows, VAX/VMS Motif, Macintosh, SUN-Open Look and OS/2 Presentation Manager computers. The available version is number 5.0 (1994).

LEVEL5 OBJECT: This expert system shell includes the following integrated array of tools:

- True objects providing the object-oriented programming.
- Graphical User Interface (GUI) development editors, forms and display builders, and control over all aspects of the user interfaces.
- Complex logic capabilities, business rules triggers, agendas, procedural and non-procedural modules.

- Robust and seamless database access, SQL, object-oriented databases, and client/ server architectures.
- A set of integrated debugging tools, including stepping, breakpoints, traces, and reasoning.

NExpert Object: NExpert Object rules include IF-THEN-ELSE as well as Frame rules such as classes, subclasses, objects and sub-objects which give more knowledge representation facilities that can be obtained similar to Level-5 Object. In addition, it provides the object-oriented programming facilities. NExpert provides the graphical user interface (GUI) facility as Level-5 Object.

These three shells were tested to determine the most appropriate one to the tender evaluation knowledge-based system. A prototype evaluation model program, which included a limited number of facts and rules, was implemented for this purpose. These facts and rules were related to the contractors past experience as a part of the contractor pre-qualification. The results of this test indicated that the Level-5 Object expert system shell is the most appropriate one for the following reasons:

- EXSYS expert system shell rules are IF-THEN-ELSE type rules. These type of rules have a limited flexibility to build the required rules for the tender evaluation system proposed. An enormous number of rules are required to compensate for this inflexibility problem. Hence, this shell is excluded from the development of the required KBES of tender evaluation.

- NExpert Object expert system shell rules are more flexible than EXSYS, where rules other than IF-THEN-ELSE can be built such as when changed.

- Level-5 Object expert system shell rules have a similar flexibility to the NExpert but it is easier to learn and less expensive than NExpert; as well, the link with other software, such as the electronic spreadsheet and database is easier.

Therefore, Level-5 selected to incorporate in the design of the required KBES for contractor selection system as described in Chapter 7.

6.7.2 KBES Applications in Civil Engineering

Expert systems have a special appeal to the construction profession because of their characteristic of combining factual knowledge with judgement. An additional advantage is that communication with their users is in a natural language (Mohan, 1990). Expert systems have been receiving broad attention in construction literature. The use of Knowledge-Based Expert Systems (KBES) within engineering has spread rapidly from research laboratories to commercial applications. This technology allows the representation of certain problems using a computer and, as a result, to provide computer-based solutions of certain problems that previously could not have been readily automated, such as design, selection of construction facilities or methods, Allen (1992). Many construction decisions, such as safety management, labour relations, decision to bid, tender evaluation and risk management are qualitative and subjective in nature and need a heuristic approach (Allen, 1992).

Mohan (1990) in his paper discussed the characteristics of the state-of-the-art expert systems researchers and expert systems-developing institutions. His paper listed 37 expert-system applications in the field of construction management and engineering. The majority of the expert systems shells developed so far on microcomputer uses a rule-based knowledge-representation scheme and is implemented using commercial expert-systems shells.

Table 6.4 summarises the different expert systems shells developed in construction up to 1990, detailing the input-data requirements, system output, knowledge structure, control strategy, and software used in the building of each of the expert systems, address of system building organisation, and the name of the key contact. These expert systems are considered at an early stage for the development of KBES. IBM, PC expert system developed at Stanford (Calif., USA) related to contractor qualification. Five systems are related to project planning and scheduling. Five systems that are related to project cost estimate and another five systems are related to methods of construction. Four systems are related to project evaluation. Construction contract, project feasibility, quality and evaluation, each one has a developed expert system developed.

Most of the expert-systems development work is being carried out in academic institutions. For example, about 60% expert systems out of the expert systems listed in Table 6.4 are affiliated with universities; eight with research institutions and only seven are involved with industry. It is estimated that about 40% of the expert systems have extracted knowledge from human experts and the remaining 60% from books and journals. The hardware used in producing 24 out of the 37 expert systems listed were developed on the IBM PC class of microcomputers and 10 were developed on LISP machines such as TI Explorer or the Xerox 1100 series (1990). Various types of software have been used in expert-systems development. In the commercial expert systems shells, the more popular were DECIDING FACTOR, INSIGHT 2+, M-1, EXSYS, PERSONAL CONSULTATION PLUS, and SAVOIR (1990). Several expert system shells available recently are more developed than those mentioned earlier, such as EXSYS version 4, Level-5 Object and NExpert.

The successful areas of expert systems applications in engineering have been surveyed and can be categorised into the following engineering areas:

1. Engineering Design
2. Project Management
3. Construction Management and methods
4. Constructability Evaluation.

***Engineering Design*:** this area includes different design disciplines such as different structural concrete elements, foundation and steel.

***Project Management*:** Several kinds of expert systems can be built in this area. This includes choice of a project-delivery strategy; selection of a contract type design checking and management of design changes, construction contract formulation, and project-financing options. In addition, expert systems are used in consultant (A/E) and construction management (CM) selection, pre-qualification of contractors, bidding strategies, evaluating progress payments, evaluating claims, management of risks, evaluating the quality of a constructed component or facility, formulation of general conditions, and formulation of technical specifications.

Construction Management: This includes, for example, design of construction methods, choice of construction methods; man machine trade-off; choice of transportation mode for the movement of materials, personnel, and equipment; selection of optimum sizes, configurations, and methods of jointing of various components in modular construction; and deep-excavation problems. In addition to concrete mixing and placement where subsystems include mix design to meet performance standards for a variable set of site conditions and materials; choice of construction materials; choice of a placement method; configuration of crushing, batting, and design of form-work.

Constructability Evaluation: Some important issues include analysis of the Constructability of designs, choice of construction materials, selection of the best design function cost combination, bid packaging, choice between prefabricated and in-situ construction, and feedback into the design process. Early work in this direction applied to project management can be seen in Dym and Levitt (1991).

Kartam (1990) and Wright and Fergus (1990) also demonstrate the use of artificial intelligence (AI) tools to automate construction. The details of these expert systems in the engineering area are included in the attached reference list. This list includes Ahmad (1995); Allen (1992); Dym and Levitt (1991); Ludvigsen and Ignizio (1990); Mohan (1990); Amirkhanian and Baker (1992); Ibbs and Crandall (1982); Diekmann and Kim (1992); Sanvido (1992); Chan and Paitoon (1995) and others.

These development of KBES systems give a remarkable indication on the possibility of using them in the process of selecting the optimum contractor, as described in Chapter 7.

Expert Area	Expert System	Systems Input	Systems Output	Knowledge Structure	Expert System Tools
(a) Operational Expert System					
Value Engineering	HI-Cost	Preliminary Design Alternative	Cost Estimate based on preliminary design	Rule-Based	PSRL, LISP and C languages
Management	KNOW-HOW SAFEQUAL HOWSAFE	Risk, Safety-management and Personnel procedures respectively	Risk reduction, Pre-qualification of contractors and Safety rating of contractors	Rule-Based	PROLOG and Deciding Factor
Construction	WELDING ADVISOR and PUMP PRO	Type of material and Welding procedure	Estimate of welding, its procedure and special equipment	Rule-Based	LOTUS 1-2-3, EXSYS Shell and MAIDS-AI Language
(b) Operational Prototype					
Management	CGS-DSC	Claims & Site conditions	Contractor chances	Rule-Based	Personal Consultant Plus
Construction	Brickwork –MASON Expert	Design of Cladding – Duration & Crew Estimate	Design quality, best solution and construction duration & productivity	Hierarchical, Rule-Based	OPSS, MUFL
(C) Developmental Expert Systems					
Design	Site Layout and Ready Mix Concrete	Available space, type of structure and equipment	Site plan, Appropriate concrete technique and mix design	Rule-Based	Blackboard Architecture & INSIGHT+
Management	Project Mgmt. System, Time estimate, Risk identification	Time & cost monitoring data and project data	Project evaluation, time estimate and Identification of risk on the project	Rule-Based	LISP, AI Language, INSIGHT+ and TI Explorer

Table 6.4: Expert Systems –State-of-the Art (Mohan, 1990)

6.8 SUMMARY AND CONCLUSIONS

The survey showed that the methods, which can be utilised to meet the objectives of this research, are as follows:

The Analytical Hierarchy process (AHP)

i) AHP is flexible and provide a systematic method to rank multiple criteria, which are quantitative or qualitative in nature, and

ii) AHP can also use previously ranked criteria, along with new criteria to rank different alternatives

The analytical hierarchy process (AHP) was found to be the most appropriate method of ranking project related criteria to reflect the project unique features as required in this research. AHP was also found to be the most appropriate method to perform contractor ranking based on the previously established contractor criteria combined with project criteria.

Level 5, a commercially used KBES was selected for the development of the computer decision support system.

The structure of the proposed decision support system will be formulated in chapter 7.

Since the need to consider multiple criteria in the contractor selection has been established, a review of different multiple criteria techniques was undertaken, such as linear modelling, linear modelling incorporating multiple rating, and model based on multi-attribute theory.

These methods, however, are not suitable for the problem under consideration for various reasons outlined in this chapter.

Given such limitations, a conceptual approach is proposed in two stages: (i) pre-qualification and screening process; and (ii) a selection process, which is discussed in the following chapters.

CHAPTER 7: STRUCTURING THE LOGIC OF THE CONTRACTOR SELECTION DECISION SUPPORT SYSTEM (DSS)

CHAPTER 7: STRUCTURING THE LOGIC OF THE CONTRACTOR SELECTION DECISION SUPPORT SYSTEM (DSS)

Chapter 3 illustrated the general absence of a systematic approach to contractor selection and showed the decision-maker depending on a restricted knowledge-base limited to personal experience and dependent on the effort made by the decision-maker. Even when a systematic approach is used, this is limited to contractor pre-qualification and was shown to be inadequate for selecting the optimum contractor. Chapter 6 researched tools and techniques that could assist in developing the most suitable contractor selection process. The structure of this process needs to be flexible enough to allow the decision-maker the opportunity of matching the contractor's qualifications and capabilities to the specific conditions and requirements for the project under consideration. In this chapter, the structure of the selection process to identify of the optimum contractor is developed on the basis of these findings. To ensure generic application the process is based on around two quite different construction work tasks- namely heavy civil construction and building projects.

The design concept of the proposed contractor selection system has the following 3 phases: (i) knowledge acquisition (ii) structuring the logic of the decision support system and (iii) development of the computer based system. The system is then verified.

7.1 DESIGN CONCEPT OF CONTRACTOR SELECTION SYSTEM

The design concept of the contractor selection system is summarised in three stages, as shown in Figure 7.1 as follows:

The ***first stage*** of knowledge identification has two steps, as described in Figure 7.1:

Step-1: Implementation of the contractor criteria (as detailed in Chapter-5).

Step-2: Identification and assessment of project criteria (using AHP on a project-by-project basis).

The ***second stage*** is to structure the Decision Support System (DSS) that incorporates the refined criteria in a systematic approach. This phase divides into two steps:

Step-1: Screening process (using the ***Delphi*** method and ***AHP***).

Step-2: Final contractor selection process (using the ***Delphi*** method and *AHP*).

Figure 7.1 shows the Delphi method and AHP implementation in the selection system.

The ***third stage*** is directed to the structure of the Knowledge-Based Expert System (*KBES*) and has three interrelated steps:

Step-1: Knowledge Representation and Structuring: This area describes how to represent and structure the knowledge that is acquired from the first phase. In addition, how this knowledge can be incorporated in this KBES.

Step-2: Inference Engine: This area describes how the KBES can handle the DSS approach. Establishing rules that can derive decisions and produce reasoning for how this selection carries out the process.

Step-3: Developing the input and output interface (user interface).

Then the system is verified to ensure its reliability and to provide the correct contractor selection. The following sections describe the details of these system phases.

7.1.1 Knowledge Identification: Criteria Refinement

Knowledge acquisition was carried out as detailed in Chapter 5, in which all the criteria those required to the contractor selection process were defined in Appendix D.

It was inappropriate to use experts to generate the relative importance for the project-specific criteria since they need to be assigned by the decision-maker. This to give the decision-maker the opportunity to reflect the real project conditions on project-by-project basis but at the same time provide the decision-maker with the method that help in deciding their relative importance, as a part of the decision system proposed. A list of 9 criteria was defined in Chapter 5 for this purpose to be implemented in the selection decision system.

Expert persons from the construction industry evaluated the contractor criteria. The survey of experts was carried out in three countries, namely Egypt, Kuwait, and the U.K. This was carried out using the Delphi method to identify and to refine the significant criteria. The lists of these criteria refined are shown in Appendix D.

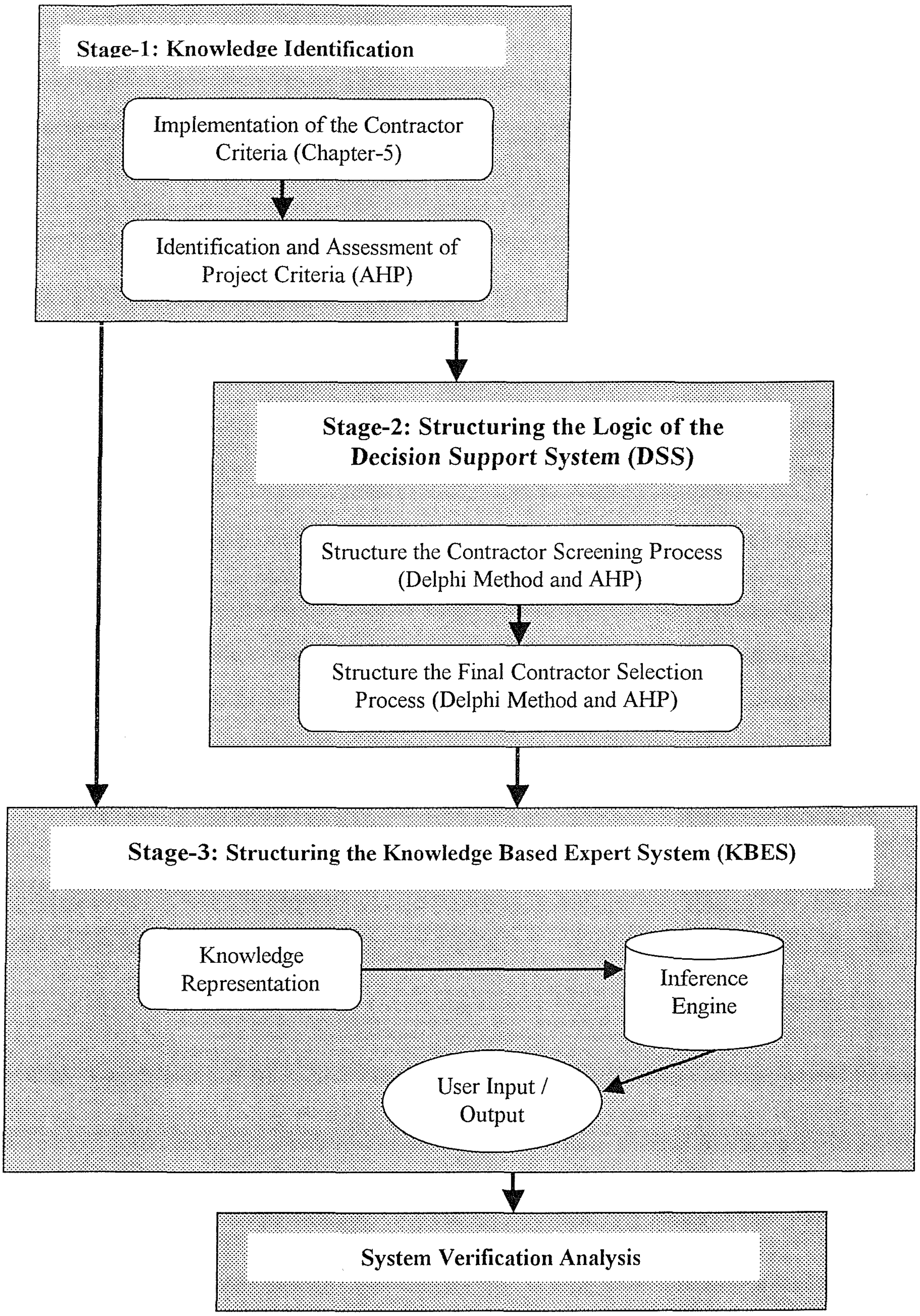

Figure 7.1: Formalisation and Structure Stages of the Process of the Contractor Selection

7.2 STRUCTURE OF THE DECISION SUPPORT SYSTEM (DSS)

The decision support system, DSS, is designed to support the whole contractor selection process. It starts with the contractors screening and finishes when the optimum contractor has been appointed and contract signed.

It was illustrated in Section 6.3 that there is a need to establish a decision support system (DSS) to reduce the problem of the decision-maker using insufficient experience, information and knowledge during the selection process. There are several multi-criteria analytic methods that can be used as the basis for the DSS, as described in Section 6.3.1. Comparison between these methods led to combining both the Delphi Method with the Analytical Hierarchy Process (AHP) to produce a flexible DSS, (Section 6.4.4).

This "Combined" approach is used for the following reasons:

1. The Delphi method allows the accumulated experience from previous projects to be acquired to enhance the quality of the contractor selection decision. This experience is not available for each project decision-makers on a case-by-case basis.

2. The criteria assessed by the Delphi method can be used directly by the AHP.

3. The AHP produces an evaluation for the criteria. This process is needed to evaluate the importance of the criteria, which are related to the specific project conditions and are required for each project case-by-case.

Research to create the DSS has two processes:

1. Structure the DSS for the contractor screening and pre-qualification, and

2. Structure the DSS for the final contractor selection.

The details of these structures are described in the following sections.

7.2.1 Structure of the DSS Logic for the Contractor Selection System

The hierarchy of the decision support system (DSS) developed for the contractor selection system is illustrated in Figure 7.2, which is based on Figure 2.1.

The main design aspects of this hierarchy are described as follows:

1. The DSS has two selection processes: (i) Screening process and (ii) Final selection process.

2. In the screening process, the predefined criteria collected from the use of the Delphi method (CC_i, i = 1,2… n) are reassessed by AHP with respect to the different criteria related to specific project conditions (project criteria PC_j; j = 1,2… m) for all eligible contractors (Alternatives, AT_r; r = 1,2…k). Where, 'n' is the number of pre-qualification criteria; 'm' is the number of project condition criteria and 'k' is the number of contractors. Three contractor criteria groups are included in this process (i) contractor's experience [DCG1] (ii) past performance record [DCG2] (iii) financial stability [DCG3], as described in section 7.2.2.

3. The output of this screening process is a short list of top contractors. This short list represents the most appropriate contractors and they are allowed to continue to the second selection process (for illustration purposes Figure 7.2 shows r=3 meaning that three contractors move onto the second process).

4. This reduced number of contractors then progress to the final contractor selection process and the same basic process is repeated, but the criteria related to the contractors are the current capabilities of the contractors [DCG4] and their submissions to the proposed project [DCG5] as described in section 7.2.2.

5. The most appropriate contractor from this evaluation is the one with the highest relative weight.

The analytical solution for this DSS approach is described in the following section.

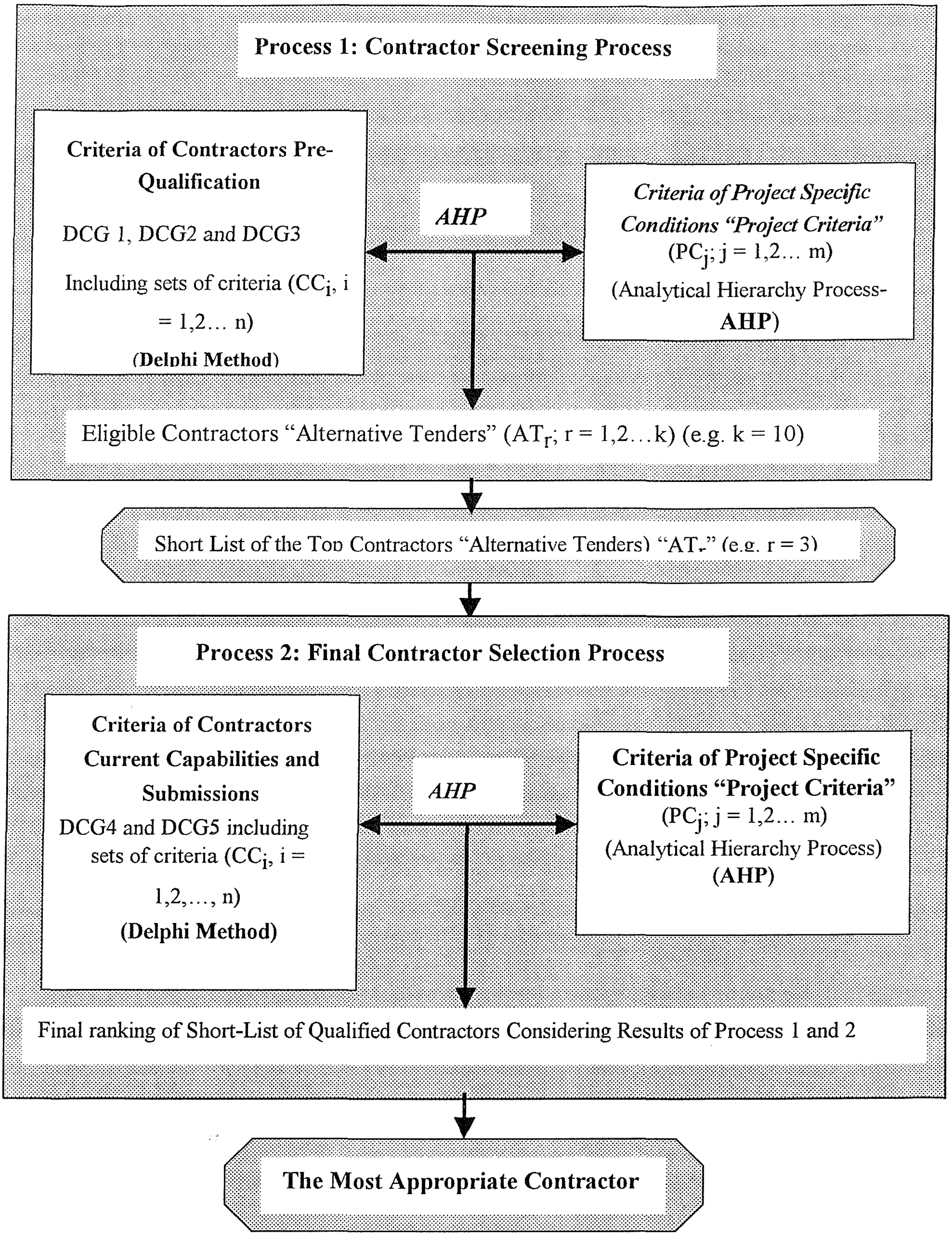

Figure 7.2: Decision Support System (DSS) Logic for the Contractor Selection

7.2.2 Analytical solution for the DSS of the Contractor Selection System

The decision support system (DSS) consists of two major processes, as indicated in Figure 7.2 (i) screening process and (ii) the final selection process. The reason for this division is mainly to reduce the time and effort of the selection process for both client and contracting company. At the same time, the contractors, which are deemed unsuitable for the proposed project, do not have to waste resources in the preparation of any documents related to the project specific. Therefore, the five groups of the contractor decision criteria are divided into two parts on the basis of the structure of the DSS developed. The first part includes three decision criteria groups namely (i) contractor's experience (ii) past performance record, and (iii) financial past performance. The refined list of criteria included in these groups of contractor criteria and their relative degree of importance is shown in Table D.1 and Table D.2 of Appendix D for heavy and building construction respectively.

The contractor's experience record group is "DCG1". The description, purposes and measures of these criteria that are related to the contractors experience record criteria are detailed in Table D.3 of Appendix D.

The contractor's past performance is "DCG2". The description, purposes and measures of these criteria that are related to the contractors past performance level criteria are detailed in Table D.4 of Appendix D.

The contractor's financial stability group is "DCG3". The description, purposes and measures of these criteria that are related to the contractors past performance level criteria are detailed in Table D.4 of Appendix D.

The analytical solution used for this DSS is carried out in two processes based on these two selection processes are described in the following two sub-sections.

7.2.2.1 Process 1: Contractor Screening Process - DSS Analytical Solution

The analysis solution starts by using the relative weight of pre-defined criteria "CC_i" (DCG1, DCG2 and DCG3), which resulted from the Delphi method, as described in Section 5.5.2. It then defines the project criteria "PC_j" and identifies the alternative tenders "AT_r" by the decision-maker by setting their relative degree of importance.

The mathematical solution for the evaluation model includes the following seven basic steps:

Step 1: The weights of criteria related to the contractor's qualification (CC_i) are taken directly from the end results of the Delphi method (detailed in Appendix D). A weight vector related to the criteria (CC_{iw}) is constructed directly in the following form (equation 7.1):

$$[CC_{iw}] = \begin{bmatrix} CC_{1w} \\ CC_{2w} \\ CC_{3w} \\ . \\ CC_{nw} \end{bmatrix} \qquad (7.1)$$

This vector consists of the set of weights for each criterion, reflecting its relative degree of importance to others and its matrix size is [n x 1], where 'n' is the number of criteria. For example, CC_{1w} represents the relative weight of the first criterion and CC_{nw} represents the relative weight of the last criterion within the contractor's qualification criteria.

Step 2: The decision criteria related to the client's preferences and the specific conditions of the proposed project are PRE-determined by the decision-maker (Client or Consultant). The relative weights of these decisions Project Criteria (PC_j) are determined by solving a matrix using the AHP method. The result of weight assignment for each pair of Project Criteria [PC_j] is presented in matrix form as shown in (equation 7.2).

$$[PC_j] = \begin{array}{c} \\ PC_1 \\ PC_2 \\ PC_3 \\ . \\ PC_m \end{array} \begin{array}{c} \begin{array}{ccccc} PC_1 & PC_2 & PC_3 & \ldots\ldots & PC_m \end{array} \\ \begin{bmatrix} 1 & PC_{12} & PC_{13} & \ldots\ldots & PC_{1m} \\ 1/PC_{12} & 1 & PC_{23} & \ldots\ldots & PC_{2m} \\ 1/PC_{13} & 1/PC_{23} & 1 & \ldots\ldots & \\ . & . & . & \ldots\ldots & . \\ 1/PC_{1m} & 1/PC_{2m} & 1/PC_{3m} & \ldots\ldots & 1 \end{bmatrix} \end{array} \qquad (7.2)$$

The weight vector related to the project criteria $[PC_{jw}]$ can be estimated by calculating the eigenvector corresponding to the maximum eigenvalue of the matrix. This vector consists of the set of weights for each project criterion reflecting its importance relative to others as indicated in (equation 7.3).

$$[PC_{jw}] = \begin{bmatrix} PC_{1w} \\ PC_{2w} \\ PC_{3w} \\ \cdot \\ PC_{mw} \end{bmatrix} \qquad (7.3)$$

This vector consists of the set of weights for each criterion, reflecting its relative degree of importance to others and its matrix size is [m x 1], where 'm' is the number of project criteria. For example, PC_{1w} represents the relative weight of the first criterion and PC_{mw} represent the relative weight of the last criterion within the project conditions criteria.

Step 3: Assess the impact of project criteria (PC_j) on contractor criteria (CC_i) using matrices of AHP to produce another vector matrix $[CC_{i\,w}.\ PC_j]$ as follows:

The relative weights of the contractor criteria $[CC_i]$ are reassessed with respect to each project criterion (PC_j) by solving the equations 7.4 up to 7.9. The decision criteria matrices $[CC_i.\ CC_i]_{PC1}$, $[CC_i.\ CC_i]_{PC2}$ ... $[CC_i.\ CC_i]_{PCm}$ can then be established as follows.

$$[CC_i.\ CC_i]_{PC1} \quad \begin{array}{c} \\ CC_1 \\ CC_2 \\ CC_3 \\ \cdot \\ CC_n \end{array} \begin{array}{c} \begin{array}{cccccc} CC_1 & CC_2 & CC_3 & \ldots\ldots & CC_n \end{array} \\ \begin{bmatrix} 1 & CC_{12w} & CC_{13w} & \ldots\ldots & CC_{1nw} \\ 1/CC_{12w} & 1 & PC_{23} & \ldots\ldots & CC_{2nw} \\ 1/CC_{13w} & 1/CC_{23w} & 1 & \ldots\ldots & \\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot \\ 1/CC_{1nw} & 1/CC_{2nw} & 1/CC_{3m} & \ldots\ldots & 1 \end{bmatrix} \end{array} \quad \text{for criterion 'P } C_1\text{'} \qquad (7.4)$$

.

.

$$[CC_i . CC_j]_{PCm} \quad \begin{matrix} & CC_1 & CC_2 & CC_3 & \cdots & CC_n \\ CC_1 & 1 & CC_{12w} & CC_{13w} & \cdots & CC_{1nw} \\ CC_2 & 1/CC_{12w} & 1 & PC_{23} & \cdots & CC_{2nw} \\ CC_3 & 1/CC_{13w} & 1/CC_{23w} & 1 & \cdots & \\ . & . & . & . & \cdots & . \\ CC_n & 1/CC_{1nw} & 1/CC_{2nw} & 1/CC_{3m} & \cdots & 1 \end{matrix} \quad \text{for criterion 'P } C_m\text{'} \qquad (7.5)$$

The eigenvector corresponding to the largest eigenvalue for matrix (equation 7.4) up to the last one (equation 7.5) would be as follows:

$$[CC_{iw}]_{PC1} = \begin{bmatrix} CC_{11w} \\ CC_{21w} \\ CC_{31w} \\ . \\ CC_{n1w} \end{bmatrix} \quad (PC_1) \qquad (7.6)$$

....

$$[CC_{iw}]_{PCm} = \begin{bmatrix} CC_{1mw} \\ CC_{2mw} \\ CC_{3mw} \\ . \\ CC_{nmw} \end{bmatrix} \quad (PC_m) \qquad (7.7)$$

iii. The components of the vector corresponding to the maximum eigenvalue of the matrix become the weights. The resulting matrix is shown in (equation 7.8)

$$[CC_{iw}][PC_m] = \begin{bmatrix} PC_1 & PC_2 & PC_3 & \cdots & PC_m \\ CC_{11w} & CC_{12w} & CC_{13w} & \cdots & CC_{1mw} \\ CC_{21w} & CC_{22w} & CC_{23w} & \cdots & CC_{2mw} \\ CC_{31w} & CC_{32w} & CC_{33w} & \cdots & CC_{3mw} \\ . & . & . & \cdots & . \\ CC_{n1w} & CC_{n2w} & CC_{n3w} & \cdots & CC_{nmw} \end{bmatrix} \qquad (7.8)$$

Then the eigenvector equation (7.9), which combines the decision criteria related to the contractor's pre-qualification, pre-tender phase (screening phase) and that related to the proposed project, is compared with the project criteria weight, equation 7.3, to produce the new relative weight of contractor criteria '$CC_{i\,sw}$' by solving equation (4.9).

$$[CC_n\, PC_m].\,[PC_w] = [n.m].\,[m.1] = \begin{bmatrix} CC_{1w} \\ CC_{2w} \\ CC_{3w} \\ . \\ CC_{nw} \end{bmatrix} = [CC_{is\,w}] = [n\,.\,1] \qquad (7.9)$$

Step 4: Alternative contractors (AT_r) are evaluated with respect to decision criteria resulting from the equation (7.1) by assessing its impact on the contractors. Therefore, the relative weight for each contractor with respect to each criterion can be obtained. The matrices, $[AT_{rw}]_{CC_1}$, $[AT_{rw}]_{CC_2}$... $[AT_{rw}]_{CC_n}$ are formed. The maximum eigenvalue for each matrix is taken to produce the eigenvector matrices for each matrix formed to be as follows:

$$[AT_{rw}]_{CC_1} = \overset{CC_1}{\begin{bmatrix} AT_{11} \\ AT_{21} \\ AT_{31} \\ . \\ AT_{k1} \end{bmatrix}} \qquad (7.10)$$

$$[AT_{rw}]_{CC_2} = \overset{CC_2}{\begin{bmatrix} AT_{12} \\ AT_{22} \\ AT_{32} \\ . \\ AT_{k2} \end{bmatrix}} \qquad (7.11)$$

.

.

.

$$[AT_{rw}]_{CC_n} = \begin{bmatrix} CC_n \\ AT_{1n} \\ AT_{2n} \\ AT_{3n} \\ . \\ AT_{kn} \end{bmatrix} \tag{7.12}$$

Then, the matrix $[AT_{rw}.\ CC_i]$ of size 'k . n', which resulted from equations (7.10) to (7.12), is multiplied in the eigenvector matrix which represents the adjusted relative weight of the contractor's pre-qualification criteria '$CC_{i\ sw}$' (equation 7.9) to obtain the ranking of the alternative contractors $[AT_{rsw}]$ as follows:

$$[AT_{rsw}] = [AT_{k}.\ CC_{n}].\ [CC_{i\ sw}] \tag{7.13}$$

A short-list of the top three contractors (AT_S), where s =3 for illustration purposes, can be obtained from the last step. This list of 'AT_S' is invited to submit their tenders to be evaluated in the second part of the evaluation system, as will be described in the following section.

7.2.2.2 Process 2: Final Selection Process - DSS Analytical Solution

The criteria related to the contractors in the tender evaluation process (DCG4 and DCG5), that can also be represented by 'CCfi', are integrated with the criteria related to the specific conditions of the proposed project 'PC_j'. The most appropriate tenders submitted by the short list of contractors can be determined using a procedure that is used, in essence, in the same way as that of the pre-tender evaluation process:

Step 5: Assess the impact of project criteria (PC_j) on contractor criteria (CC_{fi}) matrices to produce another vector matrix $[CC_{fi\ w}.\ PC_j]$ as follows:

i. The relative weights of the decision criteria $[CC_{fi}]$ are reassessed with respect to each project criterion (PC_j) by solving the equations 7.14 to 7.19. The decision criteria matrices $[CC_{fi}.\ CC_{fi}]_{PC1}$, $[CC_{fi}.\ CC_{fi}]_{PC2}$ ... $[CC_{fi}.\ CC_{fi}]_{PCm}$ can then be established as follows:

$$[CC_{fi} . CC_i]_{PC1} = \begin{array}{c|cccccc|} & CC_1 & CC_2 & CC_3 & ..... & CC_n \\ CC_1 & 1 & CC_{12w} & CC_{13w} & ..... & CC_{1nw} \\ CC_2 & 1/CC_{12w} & 1 & PC_{23} & ..... & CC_{2nw} \\ CC_3 & 1/CC_{13w} & 1/CC_{23w} & 1 & ..... & \\ . & . & . & . & ..... & . \\ CC_n & 1/CC_{1nw} & 1/CC_{2nw} & 1/CC_{3m} & ..... & 1 \end{array} \text{ for criterion 'P } C_1\text{'} \quad (7.14)$$

.

.

.

$$[CC_{fi} . CC_i]_{PCm} = \begin{array}{c|cccccc|} & CC_1 & CC_2 & CC_3 & ..... & CC_n \\ CC_1 & 1 & CC_{12w} & CC_{13w} & ..... & CC_{1nw} \\ CC_2 & 1/CC_{12w} & 1 & PC_{23} & ..... & CC_{2nw} \\ CC_3 & 1/CC_{13w} & 1/CC_{23w} & 1 & ..... & \\ . & . & . & . & ..... & . \\ CC_n & 1/CC_{1nw} & 1/CC_{2nw} & 1/CC_{3m} & ..... & 1 \end{array} \text{ for criterion 'P } C_m\text{'} \quad (7.15)$$

ii. The eigenvector corresponding to the largest eigenvalue for equation (7.14) up to equation (7.15) would be as follows:

$$[CC_{ifw}]_{PC1} = \begin{array}{c} PC_1 \\ \begin{bmatrix} CC_{11w} \\ CC_{21w} \\ CC_{31w} \\ . \\ CC_{n1w} \end{bmatrix} \end{array} \quad (7.16)$$

.

.

$$[CC_{ifw}]_{PC_m} = \begin{array}{c} PC_m \\ \begin{bmatrix} CC_{1mw} \\ CC_{2mw} \\ CC_{3mw} \\ . \\ CC_{nmw} \end{bmatrix} \end{array} \quad (7.17)$$

C: The components of the vector corresponding to the maximum eigenvalue of the matrix become the weights. The resulting matrix is shown in (equation 7.18)

$$[CC_{fiw} . PC_m] = \begin{array}{c} \\ \end{array}\begin{bmatrix} \overset{PC_1}{CC_{11w}} & \overset{PC_2}{CC_{12w}} & \overset{PC_3}{CC_{13w}} & \overset{.....}{.....} & \overset{PC_m}{CC_{1mw}} \\ CC_{21w} & CC_{22w} & CC_{23w} & ..... & CC_{2mw} \\ . & . & . & ..... & . \\ CC_{n1w} & CC_{n2w} & CC_{n3w} & ..... & CC_{nmw} \end{bmatrix} = [n . m] \qquad (7.18)$$

Then the eigenvector matrix (7.19), which combines the decision criteria related to the tender evaluation phase (final phase) and that related to the proposed project is compared with the project criteria weight, equation 7.3, to produce the new relative weight of contractor criteria '$CC_{i f w}$'.

$$[CC_{f...} . PC\_]. [PC_w] = [n . m]. [m.1] \begin{bmatrix} CC_{f1w} \\ CC_{f2w} \\ CC_{f2w} \\ . \\ CC_{fnw} \end{bmatrix} = [CC_{ifw}] = [n . 1] \qquad (7.19)$$

Step 6: Alternative contractors (AT_r) are evaluated with respect to decision criteria resulting from the equation (7.1) by assessing its impact on the contractors' tenders. Therefore, the relative weight for each alternative tender with respect to each criterion can be obtained. $[AT_{rw}]_{CC_1}$, $[AT_{rw}]_{CC_2}$... $[AT_{rw}]_{CC_n}$ are formed. The maximum eigenvalue for each matrix is taken to produce the eigenvector matrices for each matrix formed to be as follows:

$$[AT_{rw}]_{CC_1} = \begin{bmatrix} \overset{CC_1}{AT_{11}} \\ AT_{21} \\ AT_{31} \\ . \\ AT_{k1} \end{bmatrix} \qquad (7.20)$$

$$[AT_{rw}]_{CC_2} = \begin{bmatrix} AT_{12} \\ AT_{22} \\ AT_{32} \\ . \\ AT_{k2} \end{bmatrix}^{CC_2} \qquad (7.21)$$

.
.
.

$$[AT_{rw}]_{CC_n} = \begin{bmatrix} AT_{1n} \\ AT_{2n} \\ AT_{3n} \\ . \\ AT_{kn} \end{bmatrix}^{CC_n} \qquad (7.22)$$

Then, the matrix $[AT_{rw}.\ CC_{fi}]$ of size 'k . n', which resulted from equations (7.20) to (7.22), is multiplied in the eigenvector matrix which represents the adjusted relative weight of the contractor's pre-qualification criteria 'CC_{ifw}' (equation 7.19) to obtain the ranking of the alternative contractor $[AT_{rfw}]$ as follows:

$$[AT_{rfw}] = [AT_{k}.\ CC_{n}].\ [CC_{i\,fw}] \qquad (7.23)$$

Step 7: This step is the last step in this analysis procedure. In this step, the top of the short-list, which resulted in process 1, can be obtained by summing up the two equations (7.13) and (7.23) of steps 4 and 6. Using these equations (7.13) and (7.23), the final scores are given by

$$\underset{r\times 1}{[AT_{w}]} = \underset{r\times 1}{[AT_{rsw}]} + \underset{r\times 1}{[AT_{rfw}]} \qquad (7.14)$$

The values of AT_{wr}, r =1, 2, 3, ... k are then used as the final scores providing the basis of comparison of the various tender alternatives, k is taken to be equal to three for illustration purpose in this system.

7.2.2.3 Consistency Check

According to Saaty, (1980), the consistency of response of a comparison matrix is measured by consistency ratio (CR), as described in Chapter 6.

$$CR = CI / RI \quad (7.25)$$

$$CI = (\lambda_{max} - n) / (n-1) \quad (7.26)$$

Where: CI = Consistency Index

n = dimension of a particular matrix

λ_{max} = largest eigenvalue

RI = the random index computed from the average of CI for a large sample of random matrices.

Experience suggests (according to Shtub et al 1994), that CR should be less than 0.1 if one is to be fully confident of the results. Therefore, if the CI value for the matrix is more than 0.1 or 10%, the result is fewer confidants and re-assessment is required.

Matrix (n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R. I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 7.1: Random Inconsistency Index (RI) values, Saaty (1980)

7.3 STRUCTURE OF THE KNOWLEDGE-BASED EXPERT SYSTEM (KBES)

Chapter 6 illustrated the need for creating a knowledge-based expert system to facilitate the use of the DSS developed for the contractor selection system. This process involves three steps as described in section 6.2 and illustrated in Figure 7.1:

Step 1. Knowledge Representation and Structuring: This area describes how the knowledge acquired from the first phase of knowledge acquisition can be represented and structured for incorporation as an essential part of this KBES.

Step 2. Inference Engine: This area describes how the KBES can handle the DSS approach. Establishing the rules that derive decisions and produce reasoning for this selection is how it carries out the process.

Step 3. Developing the input and output interface.

7.3.1 Step 1: Knowledge Representation

The types, the sources and the acquisition of knowledge are indicated in section 7.1.1. How the knowledge can be represented is described in detail in this section, and it is concluded that knowledge can be represented in different forms depending on the KBES tools used.

In this research the LEVEL5 expert system shell is selected for the reasons described in Section 6.7.1.2. Thus, the representation of the knowledge acquired was followed the standard representation format of this shell. Knowledge was represented in a class; instance and attribute format according to the LEVEL-5 syntax (format) as illustrated below:

CLASS Syntax:

CLASS <class name> [properties]

[WITH <attribute name> <attribute type>]

A class defines the general properties and structure of a group of objects in the evaluation system (Class is similar to Frame as defined in Section 6.6.3.2). For example, a contractor can have the ***class** employee*, which is used to organise all employees in the company. Attributes are part of the class definition. They describe the object's important characteristics. For example, the **attributes** name, age, department, and so on can describe the class employee. Classes and their attributes can be created in the ***Objects Editor*** of the LEVEL 5 expert system shell.

A class remains an empty structure or template until specific values are added to it. In order to add this data, one must create occurrences of the class. An occurrence of a class is called an ***instance***. For example, *employee 1* is an *instance* of the *class employee*. These instances contain the structure of the class to which they belong, but they also add values. For example, the instance employee 1 could have ***Ahmad Ibrahim*** and ***20*** as the values of the *attributes name* and *age*.

An instance can be created: Either through an instance declaration in the Objects Editor or PRL source file (LEVEL5 Language), or via the ***MAKE*** command. In addition, if a value is set at the class level and no instance exists, LEVEL5 OBJECT will make one automatically to hold that value.

Classes, attributes, and instances can be compared to the parts of a database. A class is similar to the database structure, attributes are similar to database fields, and instances are similar to database records. Unlike databases, however, classes can contain behaviour that defines how to obtain an attribute's value or how to react when a specific value is reached. In LEVEL5 OBJECT, behaviour is defined by creating demons, rules, methods, and facets.

When exported to a PRL source file, a class declaration begins with the reserved word CLASS followed by the class name. Different class declarations can contain the same attribute names. Therefore, in subsequent attributes, one must reference the class name as well as the attribute name to uniquely specify the attribute. The preferred syntax is

attribute *name* OF class *name*

For example, '*name* OF *employee*' clarifies that the attribute name belongs to the class employee. One can also use the syntax

class *name*.attribute *name*

Example:

```
CLASS employee
  WITH name STRING
  WITH age NUMERIC
  WITH department STRING
  WITH full time SIMPLE
    INIT TRUE
```

7.3.2 Step 2: Inference Engine

Establishing rules that can derive decisions and produce reasoning for this selection on the basis of the LEVEL 5 KBES format carries out this stage. These rules are different than the *If-Then rules* as described by the following example.

This example describes the rules of how the KBES loads the first criteria group (DCG1) of the past experience on the first level of evaluation (as it was written in the *Object Editor* of the Rule Talk part of LEVEL 5) as follows:

Load DCG1 1st level Of action data

```
WHEN CHANGED
 BEGIN
  V11: = 0
  FORGET DCG L1 List
  FIND DCG L1
   WHERE DCG Code OF DCG L1 = DCG Code OF Screening DCGs
```

```
    WHEN FOUND
      V11: = Instance Number OF Screening DCGs
      MAKE DCG L1 List
        WITH DCG Code: = DCG Code OF DCG L1
        WITH DCG1 Code: = DCG1 Code OF DCG L1
        WITH DCG Name: = DCG Name OF DCG L1
        WITH Description: = Description OF DCG L1
        WITH Current Instance Number: = Instance Number OF DCG L1
   FIND END
!
! Position to the First item in DCG Level 1 List
!
   FIND DCG L1 List
    LIMIT 1
    WHERE Instance Number OF DCG L1 = V11
    FIND END
  END
```

In this example, the rule asked LEVEL-5 to make the instance value of the attribute *V11* (criteria weight) empty before carrying out the next step. To specify the weight of each criterion in this first evaluation level of DCG1, this step clears any values that may exist to make sure it will receive the new values assigned. This step is *'FORGET DCG L1 List'*. Then, the rules asks LEVEL-5 to carry out a search for the criteria of the first evaluation level included in the SDCG1 group by using the rule *'FIND DCG L1'* using certain conditions. It uses *WHERE* and *WHEN* to specify the required conditions for this search. When the conditions are fulfilled, this rule as LEVEL-5 to assign the appropriate values according to the instances defined within this KBES. Then the results of this search can be available for the rules.

The details of these rules of the KBES for contractor selection system are included in the disk attached in this thesis.

The problems encountered during the establishment of rules using the LEVEL-5 expert system shell are that its rules are not adequate to handle the analytical solution of the DSS developed using the AHP as described in section 6.4.4 or to handle the contractor data directly. Fortunately, LEVEL-5 has the capability to link with different types of other software such as Excel or Lotus spreadsheets and any database software that can produce a file with the extension (.dbf). Therefore, the visual basic of Excel 5 (Spreadsheet Windows© application) was selected to develop a mathematical solution for the AHP approach, described in section 6.4.3 and Paradox (Database software, version 5 as Windows© application) to develop the required database files (Section 7.4.2.2).

7.3.2.1 Design of the Mathematical Program Using Excel 5-Visual Basic

The mathematical model for the AHP technique was designed using Visual Basic written through an Excel Macro for the following reasons:

- The mathematics of the model is based on the solution of matrices that can be written easily using basic language.
- Visual basic program can be written using the Excel Macro.
- The Level-5 Object (KBES) can be linked with Excel for data transfer easily.

The following program is an example of how the AHP mathematical solution approach is written using the Visual Basic of Excel 5.

```
'
' Macro3 Macro
' Macro recorded 5/7/95 by Ibrahim M. M. Moustafa
'

Sub Macro3 ()
  Dim a (12, 12), u (12), w (12), v (12), ev (12), x (12, 12), y (12, 12)
  Dim cc (12, 12), b (12, 12), bb (12, 12), aa(12, 12)
  n = 12 'no of equations
  Let n = n - 1
  'Initialisation
  For i = 0 To n
  u(i) = 0
  v(i) = 0
  w(i) = 0
  ev(i) = 0
  For j = 0 To n
  a(i, j) = 0
  Next j
  Next i
  'Input data
  Active Sheets = "Sheet1"
  For i = 0 To n
  For j = 0 To n
  a(i, j) = Cells(i + 2, j + 1)
  aa(i, j) = a(i, j)
  Next j
  Next i
  'Iteration
210:
For r = 0 To n - 2
Let w(r) = 0
Let p = 0
For i = r + 1 To n
p = p + (a(i, r)) ^ 2
Next i
240
Let S = Sqr (p)
If a(r + 1, r) < 0 Then
Let S = -S
```

```
End If
If S = 0 Then
GoTo 430
End If
Let w(r + 1) = Sqr ((1 + a(r + 1, r) / S) / 2)
For i = r + 2 To n
Let w(i) = a(i, r) / 2 / S / w(r + 1)
Next i
Let T = 0
For i = 0 To n
Let p = 0
Let Q = 0
For j = r + 1 To n
Let p = p + a(i, j) * w(j)
Let Q = Q + a(j, i) * w(j)
Next j
Let u(i) = p
Let v(i) = Q
Let T = T + p * w(i)
Next i
For i = 0 To n
For j = r To n
Let a(i, j) = a(i, j) - 2 * w(i) * v(j) - 2 * w(j) * u(i) + 4 * T * w(i) * w(j)
Next j
Next i
430:
Next r
Let r = 0
Let d = 0
'Shift
510:
Let d = d + a(n, n)
For i = 0 To n
Let a(i, i) = a(i, i) - a(n, n)
Next i
' qr factorisation
Let r = r + 1
Let Q = 0
For i = 0 To n - 1
630:
If a(i, i) = 0 Then
Let T = 2 * Atn(1): GoTo 650
End If
Let T = Atn (a(i + 1, i) / a(i, i))
650:
Let c = Cos (T)
Let S = Sin (T)
Let u(i) = c
Let v(i) = S
For j = i To n
Let p = a(i, j)
Let a(i, j) = c * p + S * a(i + 1, j)
Let a(i + 1, j) = -S * p + c * a(i + 1, j)
Next j
```

```
Let w(i) = 0
If Abs (T) > 0.000001 Then Let w(i) = 1
If i = 0 Then GoTo 760:
Let Q = Q + w(i) * w(i - 1)
760:
Next i
' Find product RQ
For j = 0 To n - 1
Let c = u(j)
Let S = v(j)
For i = 0 To j + 1
Let p = a(i, j)
Let a(i, j) = c * p + S * a(i, j + 1)
Let a(i, j + 1) = -S * p + c * a(i, j + 1)
Next i
Next j
'Print matrix
'  Cells(2, 13) = r
'  For i = 0 To n
'  For j = 0 To n
'  If j > i - 2 Then
'  Cells (i + 2, j + 14).Value = a(i, j)
'  End If
'  Next j
'  Next i
  If Q > 0 Then GoTo 510:
     'Print results
For i = 0 To n
If w(i) = 1 Then GoTo 1100:
ev(i) = a(i, i) + d: GoTo 1170:
1100:
p = (a(i, i) + a(i + 1, i + 1)) / 2
Q = a(i, i) * a(i + 1, i + 1) - a(i, i + 1) * a(i + 1, i)
r = p * p - Q
S = Sqr(Abs(r))
p = p + d
If r >= 0 Then
ev(i) = p + S
ev(i) = p - S
End If
i = i + 1
1170:
Next i
'Output results
For i = 0 To n
Cells (i + 2, 14) = ev(i)
Next i
Lamba = Cells (2, 14)
For i = 0 To n
For j = 0 To n
If i = j Then
cc(i, j) = Lamba
Else
cc(i, j) = 0
```

```
End If
Next j
Next i
For i = 0 To n
For j = 0 To n
b(i, j) = cc(i, j) - aa(i, j)
Next j
Next i
  For k = 0 To n - 1
  For i = k To n
  For j = 0 To n
  bb(i, j) = b(i, j) / b(k, k)
  If i > k Then
  bb(i, j) = (b(i, k) * bb(k, j)) - b(i, j)
  End If
  Next j
  Next i
  For xx = 0 To n
  For yy = 0 To n
  b(xx, yy) = bb(xx, yy)
  Next yy
  Next xx
  Next k
  For i = 0 To n
  For j = 0 To n
  Cells (i + 39, j + 2) = bb(i, j)
  Next j
  Next I
```

This program is one of 32 programs that have been designed to solve the different matrices of the AHP approach. These matrices calculate the maximum eigenvalue of a matrix, which is used to develop the eigenvector matrix where, given the relative weight of criteria or contractors, can be calculated.

7.3.2.2 Design of the Database Program

The required data from the contractors was designed using the Paradox program. The required data was divided into five files: (1) past experience data file, (2) past performance data file, (3) financial stability file, (4) contractor current capabilities file and (5) the submitted plans for the proposed project file.

The data required for the specific project conditions are designed to be direct input data within LEVEL-5 where its data is small compared with that required for the contractor. But, it can also develop using the database in a similar way to that related to the contractors.

7.3.3 Step 3. Developing the Input and Output Interface

The required knowledge and data input to the system should have the same format to that used in the database files or, in other words, if the data is required in a numerical or a string format, it should be collected with the same format.

Data requested from the different contractors, which take the format described in Appendix E, are detailed in the Appendices G and H for the 10 contractors given in the project case study.

The procedure of using this KBES of the contract award evaluation system is described in Appendix I.

The construction (mechanism) of the evaluation system using the KBES is illustrated in Figure 7.3. However, there are some constraints in the use of this system that can be described as follows:

(1) Data Availability,

(2) Data Reliability,

(3) Time Constraints,

(4) Cost Constraints.

(1) Data Availability: The accuracy of the system results depends on the availability of data. This might take a long time and great effort if a client uses the system for the first time. The same client reduces this time and effort with repeated use.

(2) Data Reliability: The developed model requires some degree of reliability of the input data. This reliability relates to the availability and sources of such data. There has to be some degree of confidence in the results of the system, depending on the degree in confidence of the input data.

(3) Time constraints: The owner, who is often pressed for time, cannot afford to wait a long period before making a decision. Although time is required to collect and validate contractors' data, a time limit is usually set, and a balance between the value of timely decisions and time delays has to be made.

(4) Cost constraints: Acquiring data and information costs money, and the decision maker needs a balance between the amount of money spent on acquiring data against the savings earned by making an optimum decision. This is even more so in the Middle East and in developing countries, where data is not usually available and acquiring information and data costs much more money than in industrialised countries.

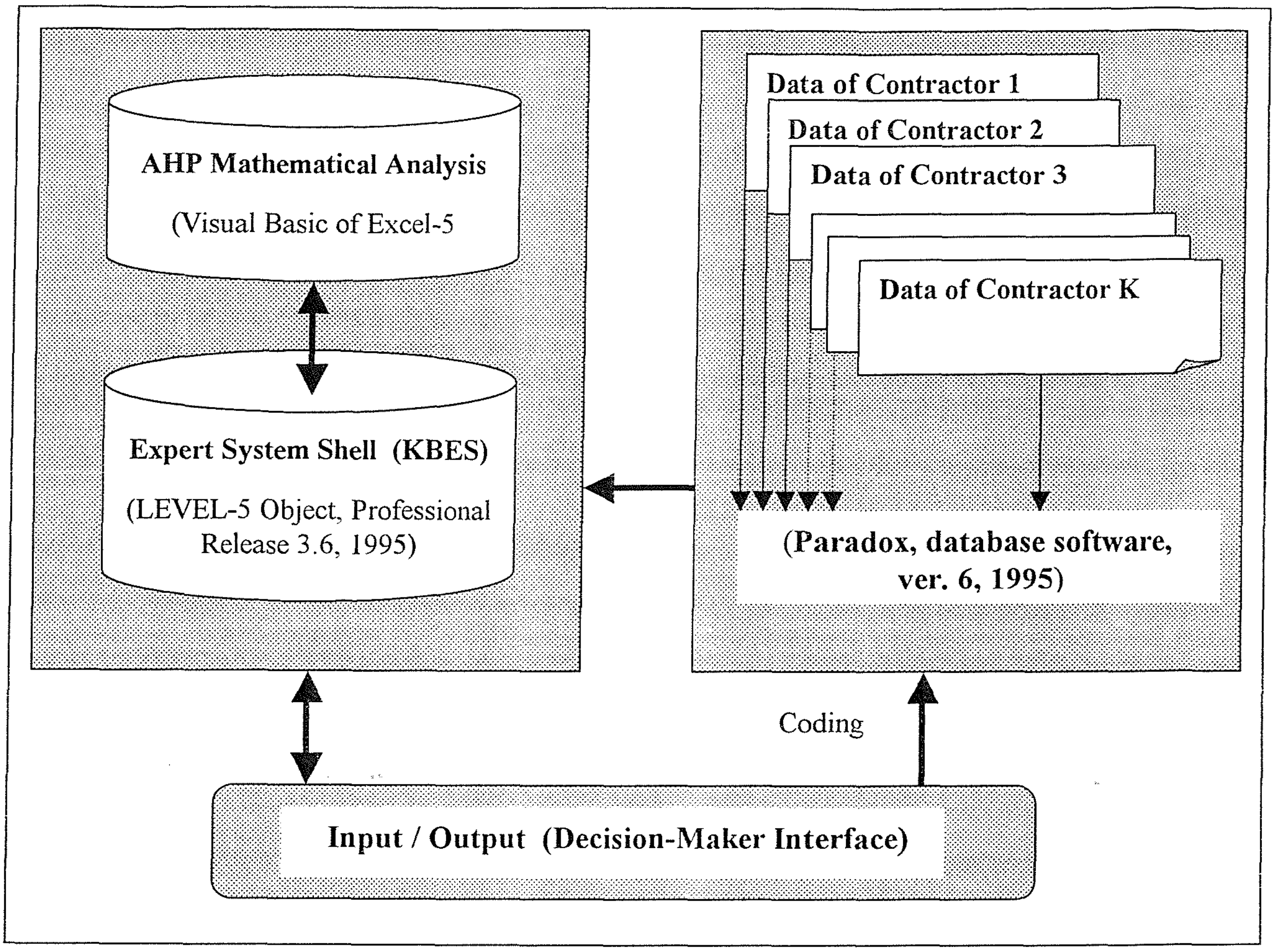

Figure 7.3: The Construction of the KBES for Contractor Selection System.

7.4 SYSTEM VERIFICATION APPROACH

The objective of system verification is to evaluate the validity and consistency of results that can be provided by this descriptive system. However, there is no theoretical method for verification for this type of new system. Only trial and error testing, such as that often used for more traditional programs and symbolic knowledge-based expert systems can be utilised (Maren 1990). This approach to system verification has been adopted and developed in two steps as follows:

Step-1: Verifies that the system results reflect the actual knowledge that can be acquired for the project under consideration and are a true representation of such data. This phase was accomplished by simulating its use in a test project case. In this project case it was assumed that the criteria of a contractor was such that the weight of any criterion belonging to this contractor compared with the other contractors, was similar to the weight of other criteria of the same contractor compared with the other contractor. This means that the rank of any contractor can be recognised directly by inspection without using the selection system; there are no trade-off problems. Thus, this test project can be used to determine if the output from the tender evaluation system reflects the input data. The description of this project is presented in Appendix G and its analysis is described in Chapter 8.

Step-2: Sensitivity analysis

As in every system development, it is necessary to validate the performance of the system in the tender evaluation process before it can be used to provide solutions in real-life applications. This validation phase is carried out using two real life project cases. The full description of these projects is detailed in Appendix H. The sensitivity analyses of real projects are described in Chapter 8. The purpose of this analysis is to:

- Study the effect of changing one decision criterion of the specific project conditions with respect to another one or more decision criteria to make the change in relative importance of the contractor criteria on the ranking result of the contractor either in the pre-tender or tender selection processes.

- Study the effect of changing one decision criterion of the specific project conditions with respect to one or more criteria, together with the change of the relative importance of contractor criteria on the ranking result of the contractor in both the pre-tender or tender selection processes.

The end result of this analysis is to identify the limits in the accuracy that the decision-maker assigns the relative degree of importance for the criteria related to the specific project conditions (which the decision-maker is authorised to assign), as described in Chapter 8.

7.5 SUMMARY AND CONCLUSIONS

Based on the literature study and the survey of industry experts using Delphi, a group of criteria were identified and classified into two classes; namely (i) contractor qualifications criteria which includes five groups of criteria and (ii) project criteria.

The identified contractor selection criteria groups are (i) experience record, (ii) past performance level, (iii) financial stability, (iv) current capabilities (v) submitted plans to execute and manage the project. The project criteria relate to the specific project conditions and client requirements, which vary according to the project nature.

Structuring the decision support system for contractor selection goes through two main processes, namely: (i) a screening and pre-qualification process (ii) a selection process. In the screening process, the first three groups of contractor criteria identified and evaluated using the Delphi method are combined with the project criteria evaluated by the AHP to produce a ranked list of contractors.

In the selection process, the top ranked contractors were further evaluated using the two additional groups of contractor criteria and the project criteria using AHP to select the most appropriate contractor. In fact, the selection process takes into consideration the results of the previous screening process thus the contractor getting the benefit from the evaluation of previous stage.

An integrated computer based System to implement the discussed contractor selection method is developed using the capabilities of an expert system shell, a spread sheet program and database. The rules required for processing the criteria evaluated by Delphi and AHP be handled using the Level 5 KBES. The required contractor data was stored in the Paradox database program and the analytical data processing was carried out using Excel spreadsheet. The components of this system are integrated in the form of a computer based decision support system to make it easy for the use of decision-maker to use.

The system is applied and verified by using a sample contractor selection problem and the implementation issues, the advantages, and the limitations of the system were discussed in Chapter 8.

CHAPTER 8: SELECTION SYSTEM VERIFICATION, ANALYSIS AND DISCUSSION

CHAPTER 8: SELECTION SYSTEM VERIFICATION, ANALYSIS AND DISCUSSION

8.1 INTRODUCTION

The purpose of this chapter is to describe the verification process of the contractor selection system. The system is verified for the following:

1. Logic consistency, workability and flexibility.
2. Applicability and viability of the results.
3. The sensitivity of changes in the relative degrees of importance for the criteria provided by the system user (the decision-maker).

A simulated project case is used to illustrate the logic consistency, workability and flexibility. Two case studies are used to illustrate the system's applicability and viability. The sensitivity of the system been investigated through studying the impact of varying the relative weights of selecting important criteria of the proposed system outcome.

8.2 SELECTION SYSTEM VERIFICATION

The simulated project case that is described in this section satisfies the following assumptions:

1. The specific project criteria are assumed similar to those collected from a real project case and are shown in Table 8.1.

2. There are 10 contractors in the contractor screening process.

3. Data for each contractor is assumed such that a given contractor would achieve equal rank for each individual criterion. This assumption should make a clear-cut difference in the ranking of the contractors without the application of the selection system. The data that are assumed for contractor number five considers this contractor as the most appropriate one to carry out this simulated project.

4. A short list of the top three contractors is the end result of the pre-tender phase and they are allowed to continue to the full tender phase.

5. Data for each contractor from this short list is assumed by the same condition of the third assumption.

6. The winning contractor is the one that recorded the highest relative weights resulting from both the pre-tender and tender phases.

The contractor's data for this simulated project case is shown in Appendix G. The pair-wise comparison of the criteria for the specific project conditions is shown in Table 8.1. The purpose of this simulated project case is to verify the logic consistency and workability of the system. The logic of the evaluation system and its workability can be accepted if the end result of the system is matched with the assumptions mentioned above. The contractor data were assumed such that the contractor number five out of ten contractor had thee highest rank in all criteria, i.e., the most appropriate contractor selected as the end result of using the selection system developed should be the contractor number 5. The final results of the ten contractors' rankings in the pre-tender phase using the evaluation system are shown in Figure 8.1.a. These results of ranking illustrate that contractor number 5 records the highest rank order. This result matches with the third assumption mentioned above, which confirms the consistency of system logic and workability.

Project Factors	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12
Cost (PC1)	1	0.75	0.70	0.85	0.90	1.50	4.00	2.00	0.60	9.00	9.00	9.00
Time (PC2)	1.333	1	0.90	1.30	1.20	2.00	5.30	2.70	0.85	9.00	9.00	9.00
Quality (PC3)	1.429	1.111	1	1.20	1.25	2.10	5.70	2.90	0.90	9.00	9.00	9.00
Complexity (PC4)	1.176	0.769	0.833	1	1.10	1.80	4.70	2.40	0.80	9.00	9.00	9.00
Design Change Sensitivity (PC5)	1.111	0.833	0.80	0.909	1	1.70	4.40	2.20	0.70	9.00	9.00	9.00
Client Management Involvement (PC6)	0.667	0.500	0.476	0.556	0.588	1	2.70	1.30	0.40	9.00	9.00	9.00
Client Risk Share Willingness (PC7)	0.250	0.189	0.175	0.213	0.227	0.370	1	0.50	0.20	9.00	9.00	9.00
Project Uniqueness (PF8)	0.500	0.370	0.345	0.417	0.455	0.769	2.000	1	0.30	9.00	9.00	9.00
Political Conditions (PC9)	1.667	1.176	1.111	1.250	1.429	2.500	5.000	3.333	1	9.00	9.00	9.00
Additional Factor-1 (PF10)	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1	9.00	9.00
Additional Factor-2 (PC11)	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1	9.00
Additional Factor-3 (PC12)	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	1

Table 8.1: The Relative Degrees of Importance for the Criteria of Specific Project Conditions

8.3 SYSTEM APPLICABILITY AND FLEXIBILITY

Two real projects were investigated to test the applicability and flexibility of the evaluation system. These project cases were:

1. New buildings for the College of Engineering and Petroleum of Kuwait University, at a new location on the Arabian Gulf, Kuwait City, Kuwait.
2. Al-Zall Commercial Mall, Al-Mubarakiah, Kuwait City Centre.

Project Case 1 - University Buildings, is the construction of 19 new buildings for the College of Engineering as follows:

1. Four similar major three-storey buildings for lecturers and staff offices,
2. Twelve two-storey laboratory buildings for the five departments of the college,
3. One library building,
4. One workshop building, and
5. One administration building.

These buildings are located in a part of the old university site at Shuwaikh, and required the demolition of seven old buildings as part of the project.

The Ministry of Public Works (MPW) owns the project and Kuwait University operates it with funding from the Kuwaiti government. The total budget for this project is about KD35 million, which is equivalent to about £70 million.

The pair-wise comparison of the criteria for the specific project conditions is shown in Table 8.1. The relative degrees of importance for these criteria in Table 8.1 are estimated on the basis of the client representative's (decision-maker's) personal knowledge, as it was used in section 8.2.

Project Case 2 - Commercial Building (Al-Zall Mall) consists of one main building which has a car park of three levels (two levels in the basement) and five commercial and business storeys. The Ministry of Al-Awqaf owns the project and its budget is about KD10 million (about £ 20 million). The criteria of the specific conditions for this project were different from the first project in the degrees of importance of the project cost, time and quality criteria. The cost criterion weighted 20% higher than quality and was equivalent to the time criterion due to the location of the project in a congested area (city centre). In addition, there was no direct involvement of the client in the project management or sharing in risk (a lump-sum contract was used). Data related to the construction companies and their past experience, past performance, financial stability, current capabilities and submitted plans for both projects are detailed in Appendix H.

Two personal interviews with the decision-makers who were involved in the evaluation process of awarding the contract for two real-life projects were carried out to demonstrate the system's viability and test its applicability based on their observations and comments.

Some limitations were encountered in collecting complete data for the real projects due to a lack of project documents required or the limited time and information that can be obtained from the consultants. In addition, some data are considered secret. All missing data are assumed by values based on the discussions with the two decision makers and their knowledge and experience.

This process of testing the applicability and viability of the evaluation system was carried out as follows:

1. Data of the two projects were collected with the help of these two decision-makers and the end results were formatted as described in Appendix H.
2. Data entry to the KBES was carried out and then checked in the presence of the decision-makers.
3. The running process for the KBES evaluation system was described in a way similar to that illustrated in Appendix I.
4. The results of the running were discussed and illustrated below for both real projects.

In Project Case 1, the selected contractor using the evaluation system was ranked third in the *actual* evaluation process. In Project Case 2, the selected contractor using the system developed was ranked second in the *actual* selection process.

The summary of comments made during the discussions based on the test of this system for the two real projects is:

- The comment by the decision-maker on the third rank of contractor in list of Project Case 1 that was selected by the system as the most appropriate contractor was "... *The contractor selected by the system in my actual judgement should be awarded the contract, but the political game has the upper hand...*"

- The comment by the decision-maker on the second rank of contractor in the list of Project Case 2 that was selected by the system as the most appropriate contractor was, ".... *The contractor selected by the system is more appropriate to the project in my judgement. This is on the basis of the contractor's experience in carrying out similar projects, current workload, and management staff. But the decision-making committee saw that the contractor that was actually selected satisfies the Kuwaiti contractor classification law, which is based on the work volume experience record and the lowest tender sum. ...*".

- Generally, this system is applicable and flexible enough to select the appropriate contractor such that data in the form of knowledge acquisition is introduced in a simpler language and more specific measures. In particular, these measures were used in the evaluation of contractor-submitted plans to the proposed project, which may give the chance for biased judgement in the absence of well-defined measures. These measures need more expert suggestions.

In general these comments gave a good indication of the applicability and flexibility of the evaluation system, especially since there is no real decision support system available except the dependency on the governmental classification for contractors based on their work volume and the lowest tender sum.

8.4 SENSITIVITY ANALYSIS

On the basis of the contractor selection system design, the decision-maker is responsible for assigning the relative importance of the criteria for the specific project conditions, in addition to assigning the relative importance of the contractor's criteria with respect to these criteria of the specific project conditions. Therefore, the objective of this section is to assess the range of sensitivity of assigning the relative importance for the criteria provided by the decision-maker. This sensitivity analysis is divided into two sections: 8.4.1 and 8.4.2.

In Section 8.4.1, a sensitivity analysis is carried out to study the impact of varying the relative weight of one or more criteria related to the specific project conditions (project criteria) on the ranking of contractors in the pre-tender phase, for illustration purposes.

In Section 8.4.2, a sensitivity analysis is carried out to study the impact of varying the relative importance of one or more criteria related to the contractor pre-qualification with respect to the criteria related to the specific project conditions on the ranking of contractors in the pre-tender phase.

This sensitivity analysis was carried out using the simulated project that is described in Section 8.2 and one of the two real projects that is described in Section 8.3 (The College of Engineering of Kuwait University) for the following reasons: -

1. The simulated project represents a non trade-off case from the contractor side. In other words, the variation in the relative importance for criteria that is related to the contractor's pre-qualification with respect to that related to the specific project conditions should have no effect on the contractor ranking. The objective of this test is to verify the logic consistency, workability and flexibility of the evaluation system in addition to its range of sensitivity.
2. The real construction project represents a trade-off situation. In other words, the variation in the relative importance for the criteria that are related to the contractor's qualification with respect to that related to the specific project conditions should have an effect on the contractor ranking. Thus, the objective of this test is to study the effect of varying criteria either related to the specific project conditions or the contractor's pre-qualification on the ranking of contractors. This test should give an indication of the relative importance limits that can be assigned to these criteria by the decision-maker on the ranking of the contractors.

8.4.1 The Effect of Change in the Relative Importance of the Project Criteria on the Contractors' Rank

In this section the analysis is carried out to study the effect of change in the relative degree of importance for the criteria of the specific project conditions (project criteria) on the contractors' rank by varying one criterion against one or more than one criterion within the project criteria. This analysis is carried out within the pre-tender process for illustration purposes. In particular, the concept of application in the pre-tender and tender processes is similar.

Twelve criteria are considered as the criteria related to the specific project conditions. The first nine decision criteria are those defined in Figure 5.13. The last three criteria have been left to be defined by the decision-maker giving the flexibility of adding other criteria specifically relevant to the actual project conditions.

Three decision project criteria were selected for illustration purposes to study the effect of changing the degree of importance for each criterion with respect to another criterion on the ranking of the contractor. The decision criteria selected were:

1. Project Cost (PC1),
2. Project Schedule (PC2) and
3. Project Quality (PC3).

The relative degrees of importance for these three decision criteria are based on the values given in Table 8.1 and they are used for both project cases.

The results of the contractors' rank from both the simulated and real construction project based on the previous knowledge of Sections: 8.2 and 8.3, and which are illustrated in Figure 8.1.a or b, are used as a reference (benchmark).

Figure 8.1a or b shows the rank of the ten contractors who participated in the pre-tender phase. Its vertical axis represents the relative weights of these contractors, which were estimated as a percent of the highest contractor who was graded by 100%. The corresponding ranking of the contractors in the simulated project (project case-1) is shown in Figure 8.1.a and indicates that Contractor CC5 records the highest rank (100%) while Contractor CC10 recorded the lowest rank. In the second and third rank, there are only two contractors (CC4 and CC6) that recorded a close result of relative weight.

There is a difference between the third and fourth rank order that means no further evaluation is needed to distinguish between contractors (second or third evaluation level is based on the hierarchy of criteria as indicated in Section 5.5). The corresponding ranking of the contractors in the real construction project (Project Case 2) is shown in Figure 8.1.b.

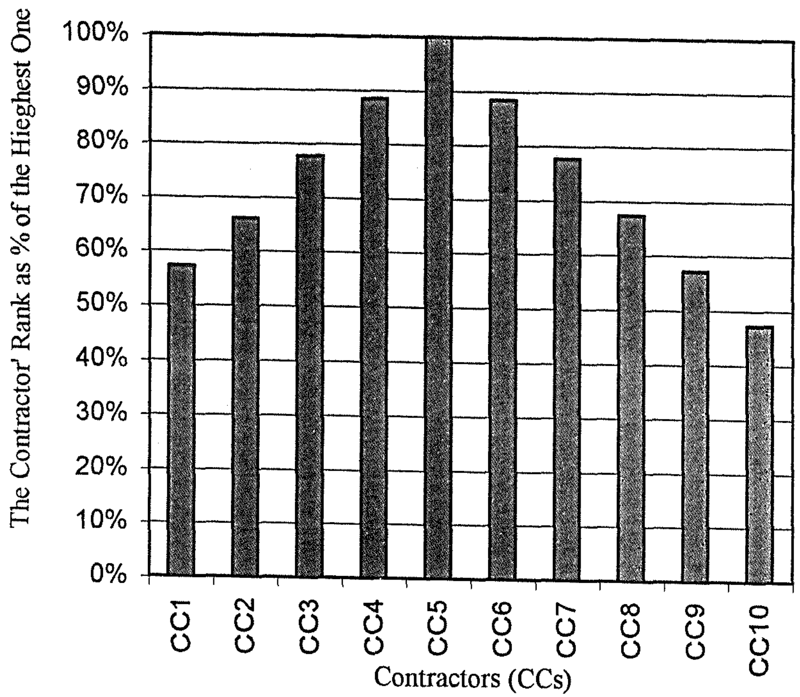

Figure 8.1.a: The Contractors Ranking as % of the Highest Contractor - Proj. Case-1

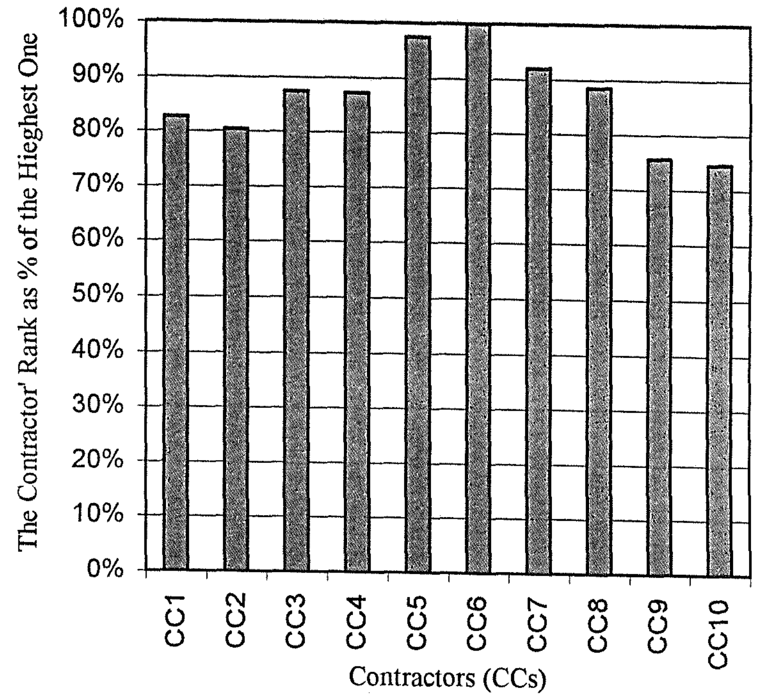

Figure 8.1.b: The Contractors Ranking as % of the Highest Contractor - Proj. Case-2

In Project Case 2 there are two contractors (CC3 and CC4) in the fourth ranking. If the short list of contractors, as an output of the screening process is four contractors, a further evaluation using the next level of criteria hierarchy should be carried out to distinguish more precisely between the rankings of contractors.

8.4.1.1 Effect of Change in the Relative Importance of Project Cost versus Project Schedule on the Contractors' Rank

As mentioned in section 8.4, the decision-maker is responsible for assigning the relative weights for the project criteria. The consistency of these relative weights can be measured by the consistency ratio (C.R.) defined by the AHP method, which is limited by a 10% value. Therefore, the change in the contractor's ranking due to changes in the relative importance of the project cost over schedule is carried out by getting a consistency ratio (C.R.) of value equal to 10% for the project criteria. The corresponding rank of contractors, which was recorded as a percent of the highest one (100%) is shown in Figure 8.2.a for Project Case 1 and Figure 8.3.a for Project Case 2. This rank is recorded for the different increases in the relative importance of the project cost over schedule. The increase importance of project cost over schedule continues until a consistency ratio (C.R.) of value equal to 10% is achieved for the project criteria. The vertical axes of these figures represent the relative weights of contractors with respect to the highest contractor, which is graded by 100%. The horizontal axes represent the rate of change in the relative importance of one criterion, such as cost, over another one such as schedule. It shows that PC1 varies from equal to PC2 to being 40 times more important.

For example, Figure 8.2.a, **Project Case 1**, shows that the rank order for the contractors remains unchanged when the relative degree of importance for criterion project cost is varied over the criterion project schedule up to a CR value of over 10%. It shows that the relative weights for the contractors have no change. This means that whatever change in the relative importance of project criteria, the rank of contractors' remains without change in case of the non-trade-off situation as indicted in the assumption of Project Case 1, Section 8.2.

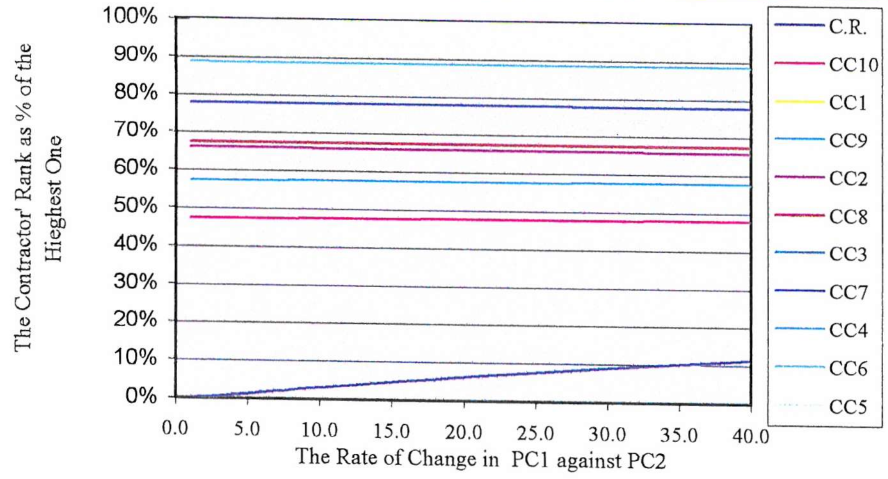

Figure 8.2.a: The Change in the Contractors' Rank due to the Change in the Proj. Cost (PC1) vs Proj. Schedule (PC2) [Case1]

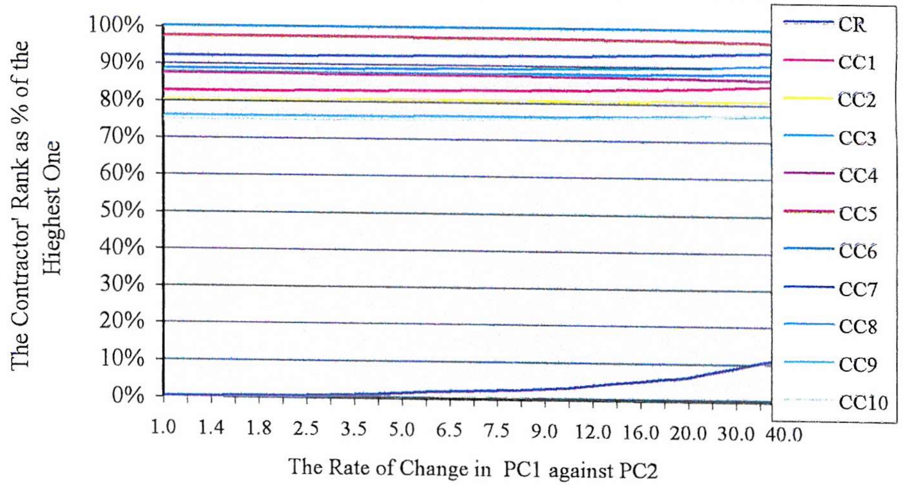

Figure 8.2.c:The Change in the Contractors' Rank due to the Change in the Proj. Cost (PC1) vs Proj. Schedule (PC2) [Case2]

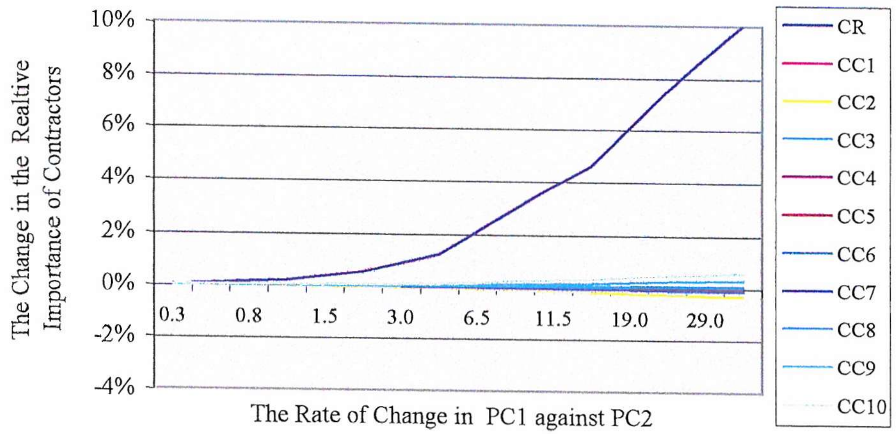

Figure 8.2.b: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs Proj. Schedule (PC2) [Case-1]

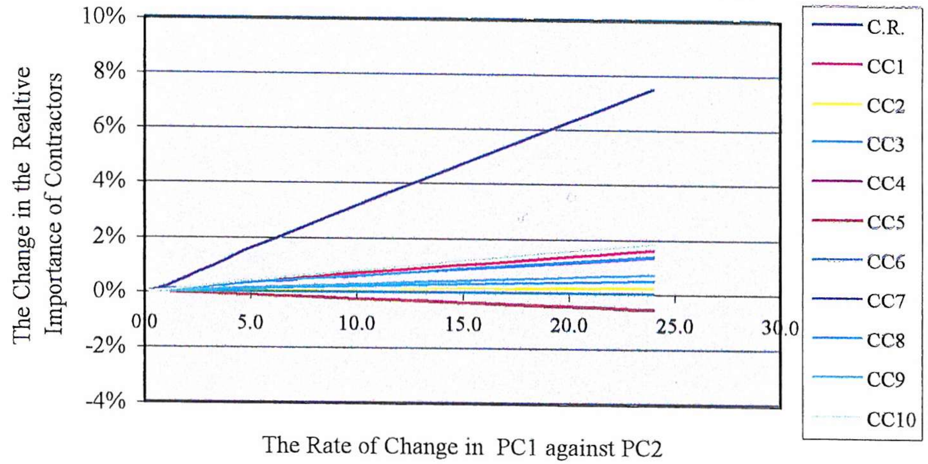

Figure 8.2.d: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs Proj. Schedule (PC2) [Case-2]

Figure 8.2.c, **Project Case 2,** shows the first change in the contractors' rank recorded when the value of project cost (PC1) is increased by 24 times the reference value (value indicated in Table 8.1) against the project schedule (PC2). The consistency ratio (CR) recorded at this change has the value of 7.5%. The contractors' rank changed for the value of CR less than 7.5%. Then, the rank of contractors proceeds without change up to the consistency ratio (C.R.) more than 10% (the maximum acceptable value as indicated in Chapter 6). The change in the contractors' ranks due to the change in the relative importance of PC1 against PC2 up to a CR of 10% value is indicated in Figure 8.2.d.

8.4.1.2 The Effect of Change in the Relative Importance of Project Cost over Project Quality

The effect of change in the project cost decision criterion (PC1) over project quality decision criterion (PC3) on the ranking of the contractors (CCs) for both project cases is presented in the following section with results presented in Figs 8.3.a and 8.3.c.

Figure 8.3.a, **Project Case 1**, shows the ranking order for the contractors' remains unchanged until the CR reaches a value of more than 10%. The relative weights of all contractors remain approximately constant. Very small changes in the relative weight of contractors of less than 0.1% occurs at 10% CR without affecting the contractors ranking. This change in the relative weight of contractors was due to some exchangeable levels in the relative degree of importance of data related to the cost, schedule and quality.

Figure 8.3.c, **Project Case 2,** shows the first change in the contractors ranking when the value of project cost (PC1) increased by 24 times the reference value (value indicated in Table 8.1) over the project quality (PC3). The consistency ratio (CR) recorded at this change has the value of about 6.2%. Then, the ranking of contractors proceeds without change until the consistency ratio (C.R.) has become more than 10% (the maximum acceptable value as indicated in Chapter 6) as indicated in Figure 8.3.b. The changes in the contractors' ranks due to changes in the relative importance PC1 over PC3 up to a CR of 10% value are indicated in Figure 8.3.d.

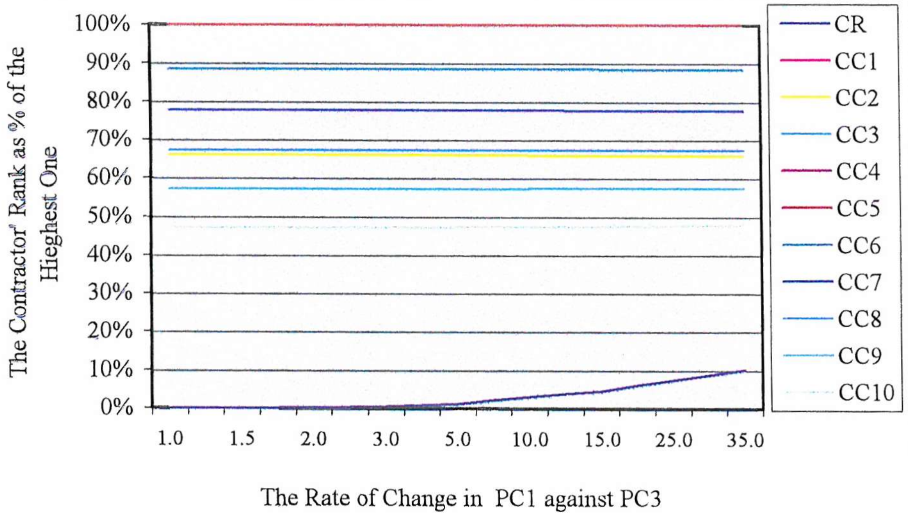

Figure 8.3.a:The Change in the Contractors' Rank due to the Change in the Proj. Cost (PC1) vs Proj. Quality (PC3) [Case-1]

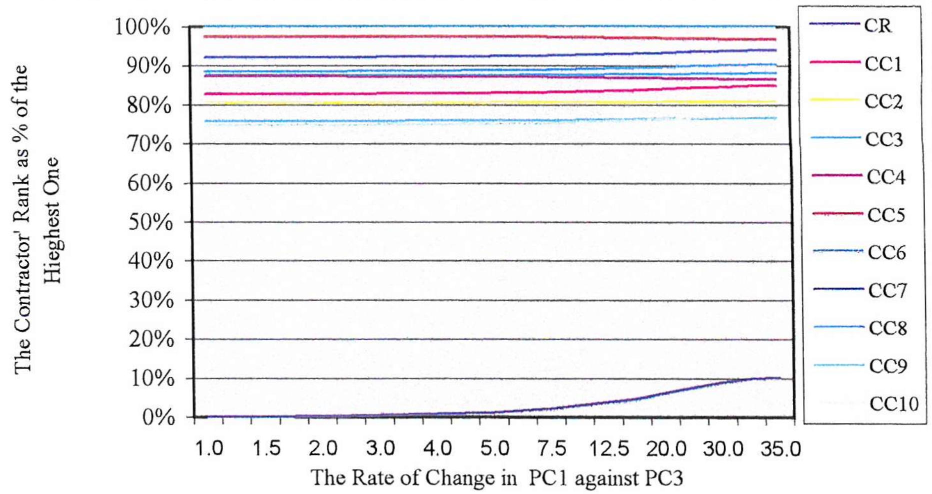

Figure 8.3.c: The Change in the Contractors' Rank due to the Change in the Proj. Cost (PC1) vs Proj. Quality (PC3) [Case2]

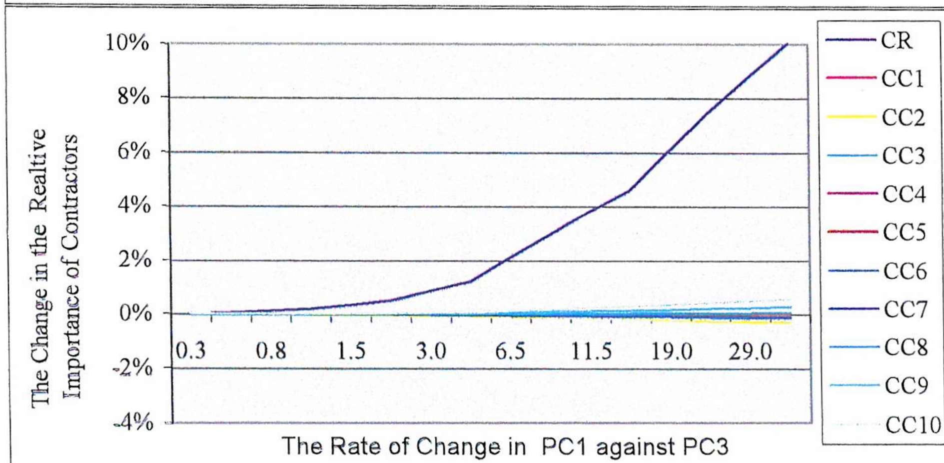

Figure 8.3.b: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs Proj. Quality (PC3) [Case-1]

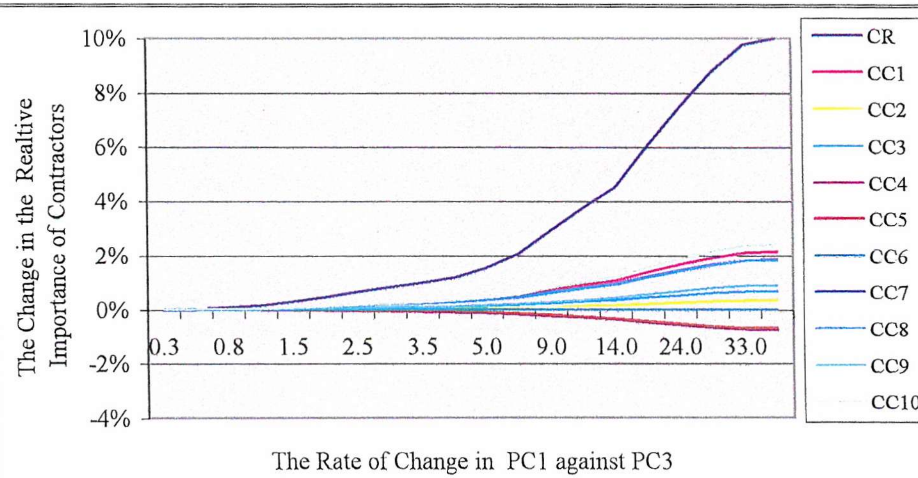

Figure 8.3.d: The Change in the Contractors Rank due to the Change in the Proj. Cost (PC1) vs Proj. Quality (PC3) [Case2]

8.4.1.3 The Effect of Change in the Relative Importance of Project Schedule Over Quality

The third analysis investigates the effect of changing in the relative importance of the project schedule (PC2) over quality (PC3).

Figure 8.4.a, **Project Case 1**, shows the rank change between contractors resulting from the change of PC2 against PC3. The research is similar to that in the previous two analysis sections. The ranking remains unchanged up to a CR value of more than 10%. Figure 8.4.b shows the change in the relative importance and ranking of contractors, due to the increase in PC2 versus PC3 up to the 10% of consistency ratio (C.R.) in Project Case 1.

Figure 8.4.c, **Project Case 2,** shows the first change in the contractors ranking when the value of project schedule (PC2) increased by 26.5 times the reference value (value indicated in Table 8.1) against the project quality (PC3).

The consistency ratio (CR) recorded at this change has the value of about 8.16%. The ranking of contractors proceeds without change up until the consistency ratio (C.R.) has become more than 10%. The changes in the relative weight of contractors due to a change in PC2 against PC3 up to a CR of greater than 10% value are shown in Figure 8.4.d.

A very limited change in the contractors' ranks at the later stage of CR value is recorded as indicated in Figure 8.4.c. This limited change in the contractors' ranks has a corresponding limited change in the relative weight of contractors, less than 2% at CR 10%, as shown in Figure 8.4.d.

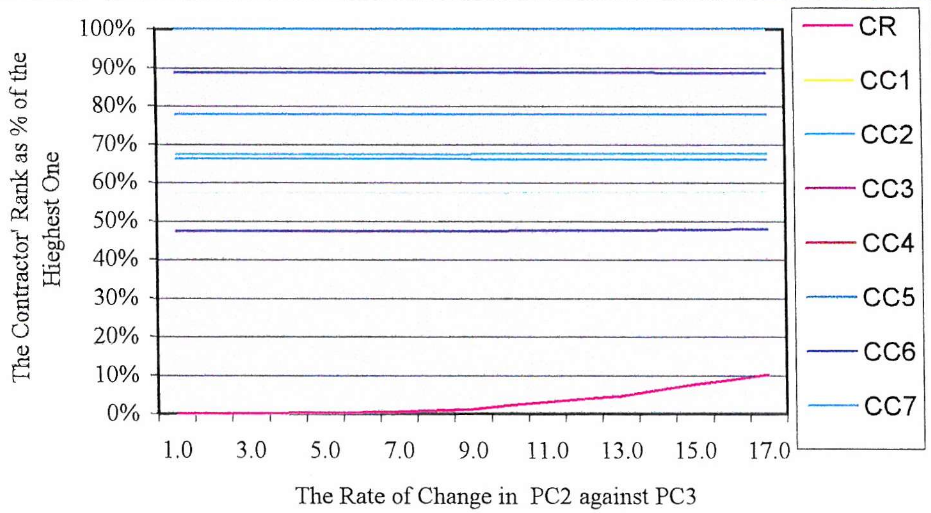

Figure 8.4.a: The Change in the Contractors' Rank due to the Change in the Proj. Schedule (PC2) vs Proj. Quality (PC3)[Case-1]

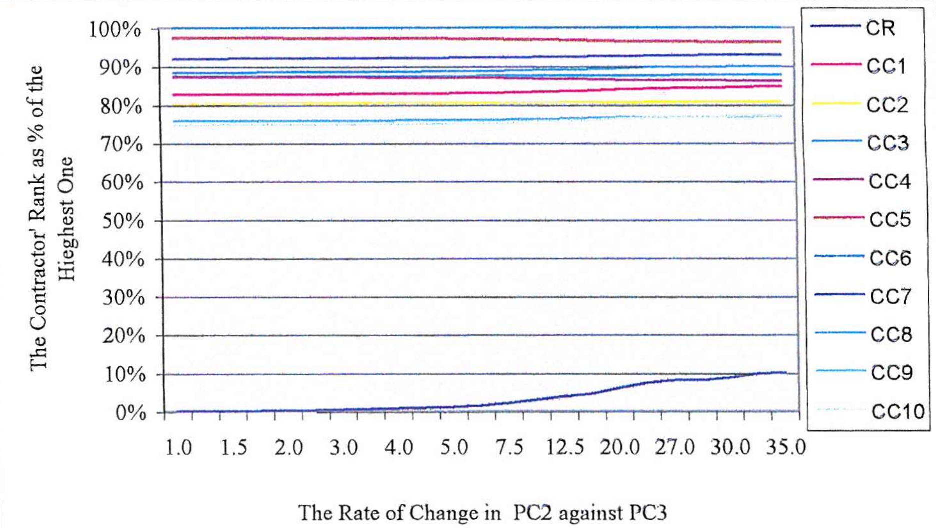

Figure 8.4.c: The Change in the Contractors' Rank due to the Change in the Proj. Schedule (PC2) vs Proj. Quality (PC3)[Case-2]

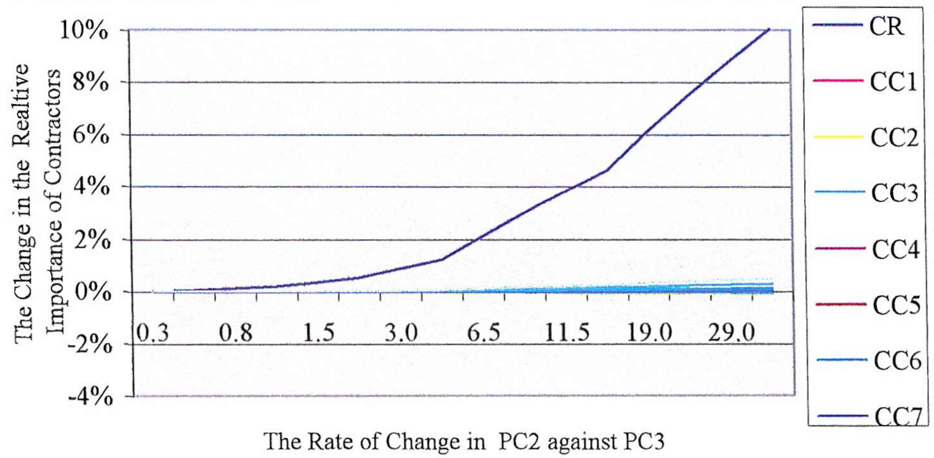

Figure 8.4.b: The Change in the Contractors Relative the Relative due to the Change in the Proj. Schedule (PC2) vs Proj. Quality (PC3) [Case-1]

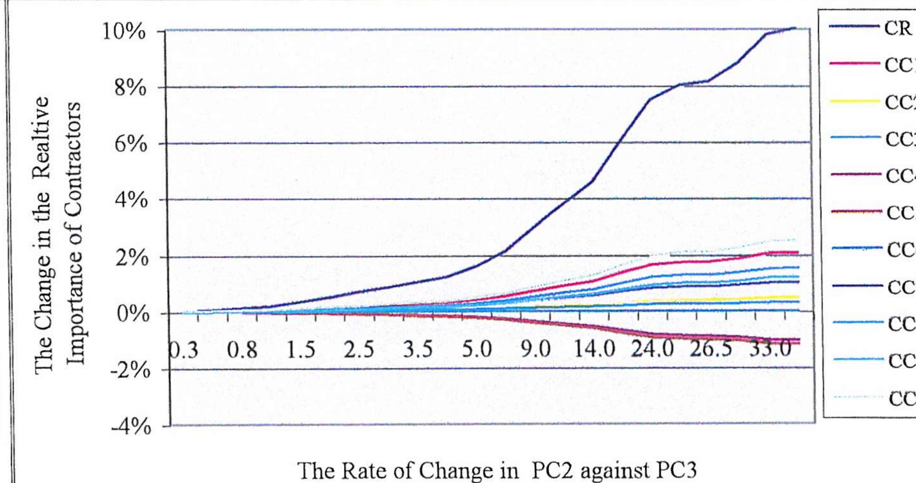

Figure 8.4.d: The Change in the Contractors Relative Importance due to the Change in the Proj. Schedule (PC2) vs Proj. Quality (PC3) [Case-2]

8.4.1.4 Summary and Conclusions on the Effect of Varying One Decision Criterion to Another on the Contractors' Rank

The above analysis shows that when there is a difference in the relative importance for the contractors with a non-trade-off situation (Project Case 1), there is no change in ranking the contractors, whatever the change between one criterion and another. When the contractors have a different level in their relative importance with trade-off situation (Project Case 2), their ranking is affected by the change in one decision criterion with respect to another. This effect on the contractor's ranking is, however, limited. For example, the change in the contractors ranking occurred due to more than 20 times of increase in the relative importance of the project cost against either schedule or quality, at a C.R. value of more than 6%.

The above analysis indicates that the variation in one decision criterion has a limited effect on the relative weight of the contractors in a trade-off situation (the actual situation) and on their ranking. This leads to the conclusion that using multiple decision criteria in the evaluation process reduces the effect of biasing to one criterion in the evaluation process.

8.4.2 The Effect of Varying the Relative Importance of One Decision Criterion Over More Than One Criterion (Project's Criteria) on the Contractors' Rank

The effect of varying one decision criterion to another single criterion has been investigated in the previous Section 8.4.1. The effect of varying the relative importance of a single criterion against more than a single criterion on the contractors ranking is analysed in this section. The two project cases, which are investigated in Section 8.4.1, are used in the following sections for illustration purposes. Any criterion within the specific project criteria such as project cost (PC1) is taken as a single criterion against the other criteria within the specific project criteria. The relative degree of importance for project cost (PC1) against the other criteria shown in Table 8.1 will be used as a reference for any further changes in both Project Case 1 and Project Case 2.

8.4.2.1 The Effect of Varying the Relative Importance of Project Cost Over Project Schedule and Project Quality

Figure 8.5.a, **Project Case 1**, shows the change in the contractors rank resulting from increasing the relative weight of the project cost (PC1) over the project schedule (PC2) and project quality (PC3). The research is similar to that in previous analysis sections. The ranking remains unchanged up to a CR value of more than 10%. Figure 8.5.b shows the change in the relative importance resulting from the increase in PC1 over PC2 and PC3 up to a consistency ratio (CR) of value more than 10%. This change was very small (less than 0.1% at CR >10%). The reasons for this result are mainly due to the assumption of a non-trade-off situation of the contractor data in Project Case 1.

Figure 8.5.c, **Project Case 2,** shows the first change in the contractors ranking when the relative importance of project cost (PC1) increased by 12 times over the project schedule (PC2) and project quality (PC3). The consistency ratio (CR) recorded at this change has the value of about 7%. It is noted that the change in the contractors ranking occurred at a value of increase in the relative importance for PC1 over PC2 and PC3 less than that recorded in sections 8.4.1.1 and 8.4.1.2. This mainly resulted from changing one criterion against two criteria instead of a single criterion. A limited change in the contractors ranking at the later stage of CR value is recorded as indicated in Figure 8.5.c. This limited change in the contractors ranking has a corresponding limited change in the relative weight of contractors, less than 3% at CR 10%, as shown in Figure 8.5.d.

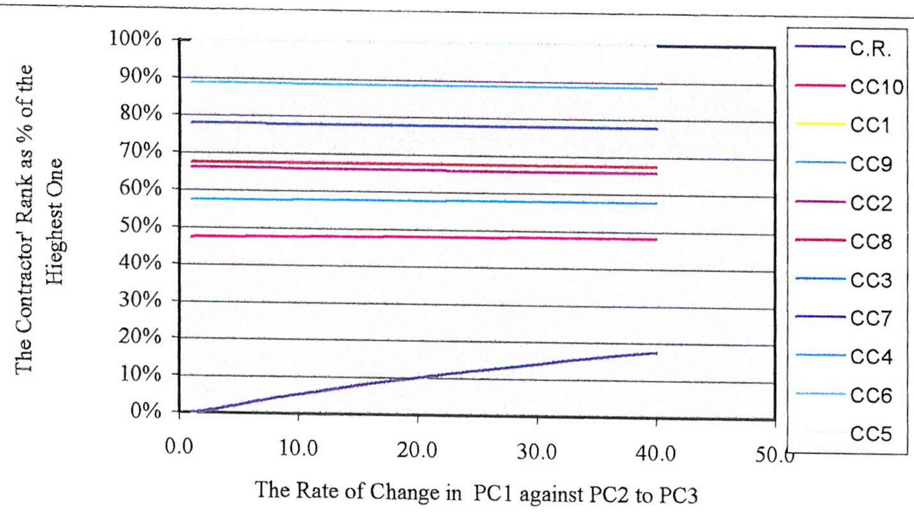

Figure 8.5.a: The Change in the Contractors' Rank due to the Change in Proj. Cost (PC1) vs Proj. Schedule (PC2) Proj.Quality (PC3)[Case-1]

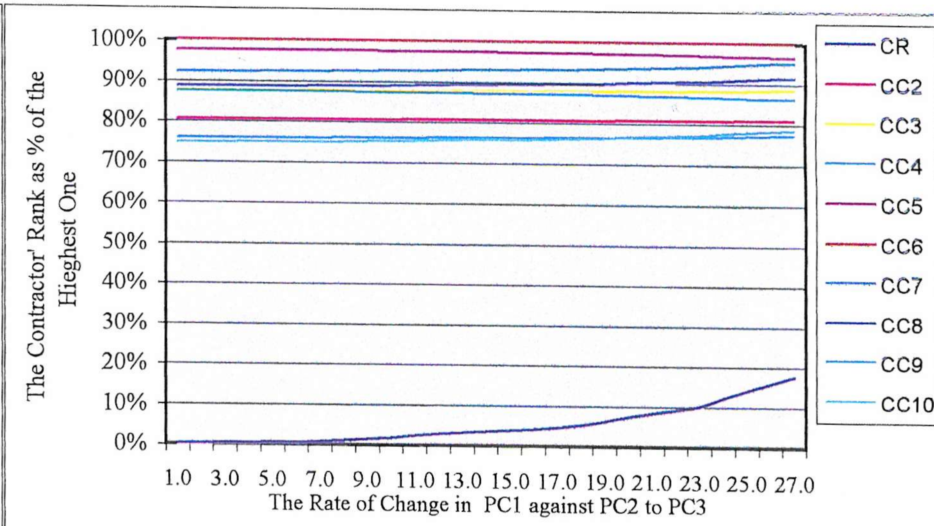

Figure 8.5.c: The Change in the Contractors' Rank due to the Change in Proj. Cost (PC1) vs Proj. Schedule (PC2) Proj.Quality (PC3) [Case-2]

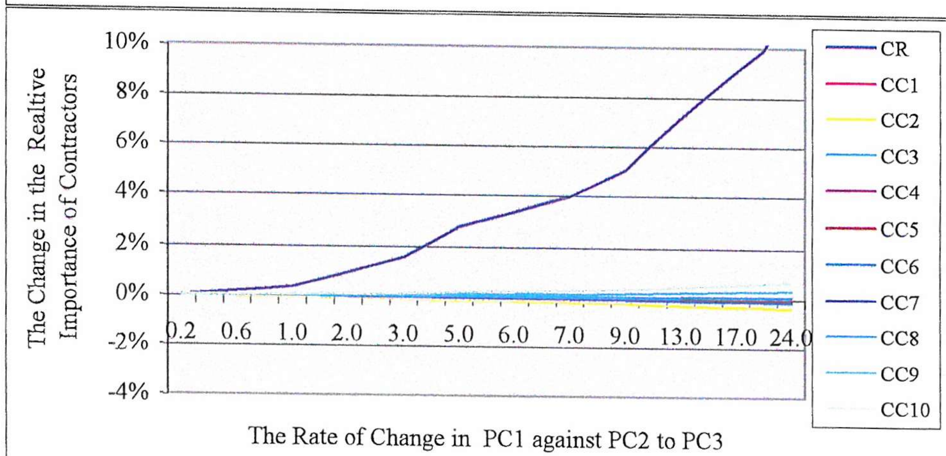

Figure 8.5.b: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs Proj. Schedule (PC2) Proj.Quality (PC3) [Case-1]

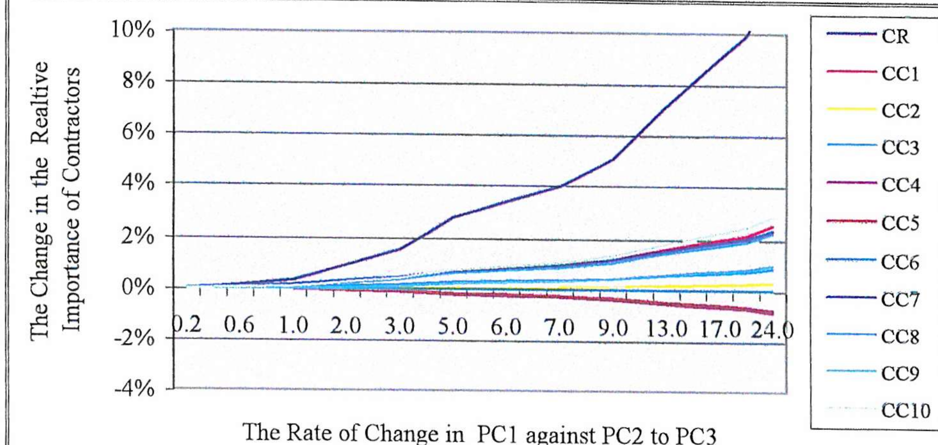

Figure 8.5.d: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs Proj. Schedule (PC2) Proj.Quality (PC3) [Case-2]

8.4.2.2 The Effect of Change in the Relative weight of Project Cost (PC1) over Project Schedule (PC2), Quality (PC3), Up to Client Management Involvement (PC6)

Figure 8.6.a, **Project Case 1**, shows the change in the contractors ranking resulting from increasing the relative weight of the project cost (PC1) over the project schedule (PC2), quality (PC3), complexity (PC4), design change sensitivity (PC5) and client management involvement (PC6). The research shows are similar to those in previous analysis sections. The ranking remains unchanged up to a CR value of more than 10%.

Figure 8.6.b shows the change in the relative importance resulting from the increase in PC1 over PC2 and PC3 up to a consistency ratio (CR) of value more than 10%. This change was very small (less than 1% at CR >10%). The reasons for this result are mainly due to the assumption of a non-trade-off situation of the contractor data in Project Case 1. This step is an additional verification to the logic consistency workability and flexibility of the evaluation system.

Figure 8.6.c, **Project Case 2,** shows the first change in the contractors' ranking when the relative importance of project cost (PC1) increased by 2.5 times over PC2, PC3, PC4, PC5 and PC6. The consistency ratio (CR) recorded at this change has the value of about 3%. It is noted that the change in the contractors ranking occurred at a value of increase for PC1 over PC2 up to PC6 less than that recorded in Section 8.4.2.1, where Contractor 9 (CC9) exchanged its rank with CC10 from the ninth rank to the tenth rank. This mainly resulted from the change of one criterion against six criteria instead of two criteria. The change in the contractors' rank has a corresponding change in the relative weight of contractors, less than 4% at CR 10%, as shown in Figure 8.6.d.

The second change in the contractors ranking occurred when the relative importance of PC1 versus PC2 up to PC6 increased by 10 times more than the reference values at CR ~= 10.0 %, where Contractor 1 (CC1) moved one rank step higher from seventh to sixth ranking to take the place of CC4.

8.4.2.3 The Effect of Varying the Relative Importance of Project Cost (PC1) versus Project Schedule (PC2), Quality (PC3), Up to Political Criterion (PC9)

The effect of changing the project cost criterion (PC1) against criteria of the specific project conditions (from PC2 up to PC 9) on the ranking of the contractors in Project Case 1 and Project Case 2 is presented in this section.

Figure 8.7.a, **Project Case 1**, shows the rank change between contractors resulting from the change of project cost (PC1) against the other nine criteria of project conditions. These criteria include project schedule (PC2), quality (PC3), complexity (PC4), design change sensitivity (PC5), client management involvement (PC6), client risk share willingness (PC7), project uniqueness (PC8) and political conditions (PC9). The research shows are similar to those in previous analysis sections. The ranking remains unchanged up to a CR value of more than 10%. Figure 8.7.b shows the change in the relative importance resulting from the increase in PC1 against PC2 up to PC9. This change is recorded up to a C.R of value more than 10%. This change was very small (less than 1% at CR>10%). This step is an additional verification to the logic consistency workability of the evaluation system where the system output matches its input data (assumptions of Project Case 1).

Figure 8.7.c, **Project Case 2,** shows the first change in the contractors' rank when the value of project cost (PC1) increased by 1.7 times against PC2, PC3, PC4, PC5, PC6, PC7, PC8 and PC9. The consistency ratio (CR) recorded at this change has the value of about 1.10-%. It is noted that the change in the contractors' rank occurred at a value of increase for the PC1 against PC2 up to PC9 less than that recorded in Section 8.4.2.2, where Contractor 10 (CC10) exchanges its rank with CC9 from the ninth rank to the tenth rank order. This is mainly the result of changing one criterion against nine criteria instead of six criteria. The second change in the contractors' rank was when the relative importance of PC1 versus PC2 up to PC9 increased by 4.5 times more than the reference values at CR ~= 2.5%, where Contractor 1 (CC1) moved one step higher from seventh to sixth rank order to take the place of CC4. CC7 exchanged its rank from third to second to take the rank of CC5 due to the increase in PC1 versus PC2 up to PC9 by 7.5 times over their reference values at C.R. value ~= 5.5%. Another change in the ranking of CC10 occurred when the relative importance of PC1 versus PC2-9 increased to be 12.0 times over their reference values at CR ~= 8.5%, where CC10 moved to eighth rank at the same time that CC2 moved one rank less to be in ninth rank and exchanged its rank with CC10. The last change in the contractors' rank before the C.R. values reached 10% was in CC1 and CC3, where CC1's ranking changed from sixth rank to fifth to take the place of CC5 due to the increase in the relative importance of PC1 versus PC2- PC9 by 13.5 times over their reference values at CR ~= 9.75%, as shown in Figure 8.7.c. The change in the contractors' rank order has a corresponding change in the relative weight of contractors, less than 4% at CR 10%, as shown in Figure 8.7.d.

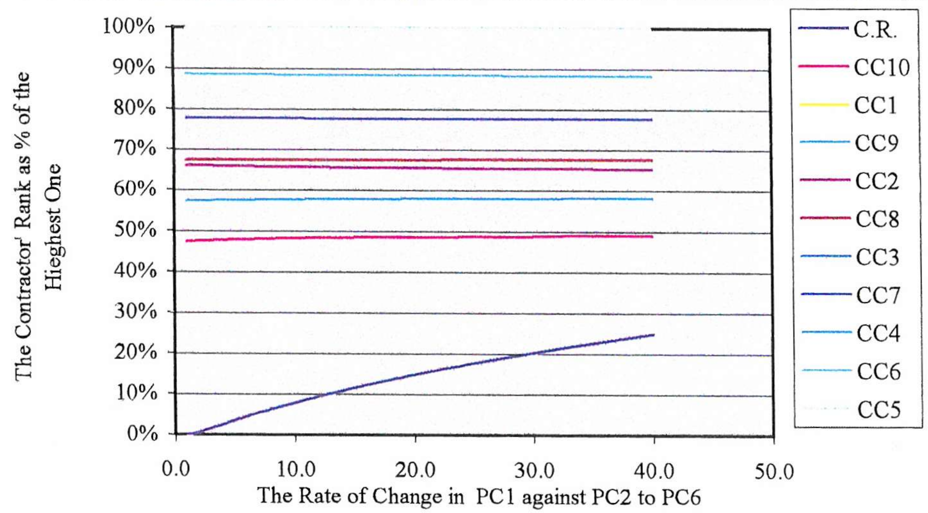

Figure 8.6.a: The Change in the Contractors' Rank due to the Change in Proj. Cost (PC1) vs Proj. Schedule (PC2) to (PC6) [Case-1]

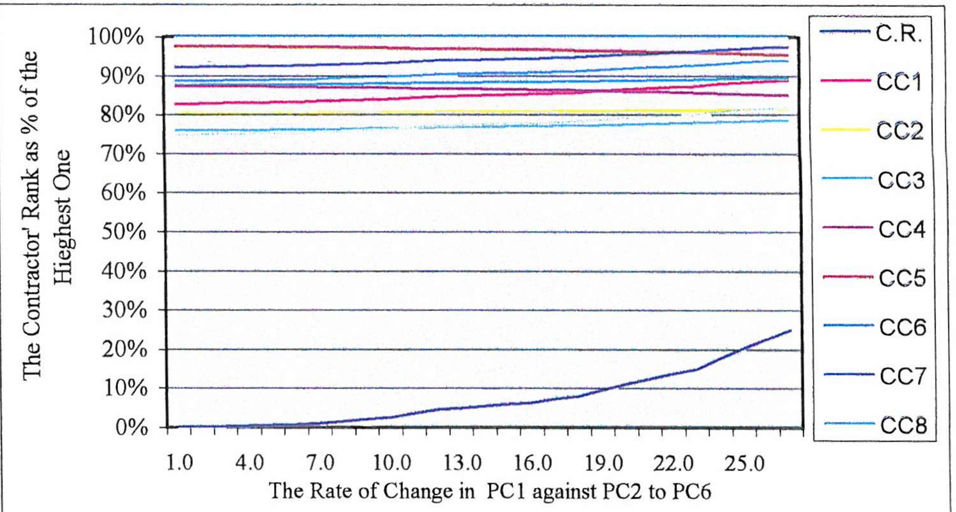

Figure 8.6.c: The Change in the Contractors' Rank due to the Change in Proj. Cost (PC1) vs Proj. Schedule (PC2) to (PC6) [Case-2]

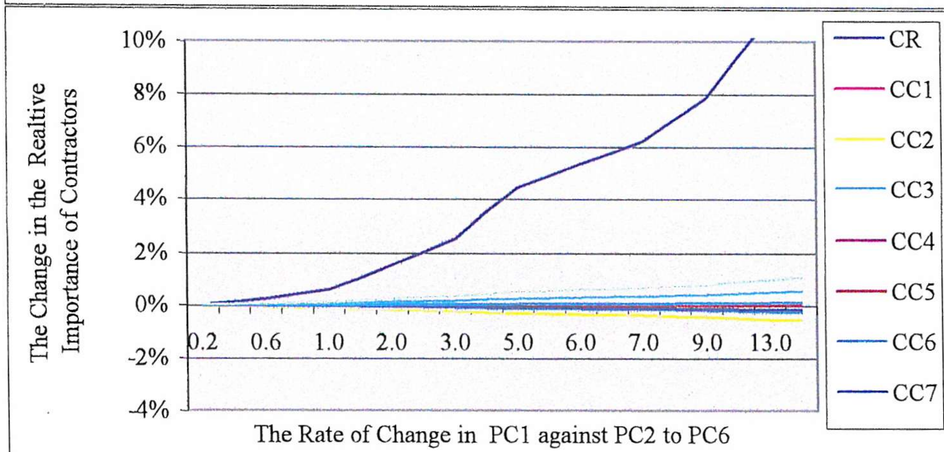

Figure 8.6.b: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs (PC2) - (PC6) [Case-1]

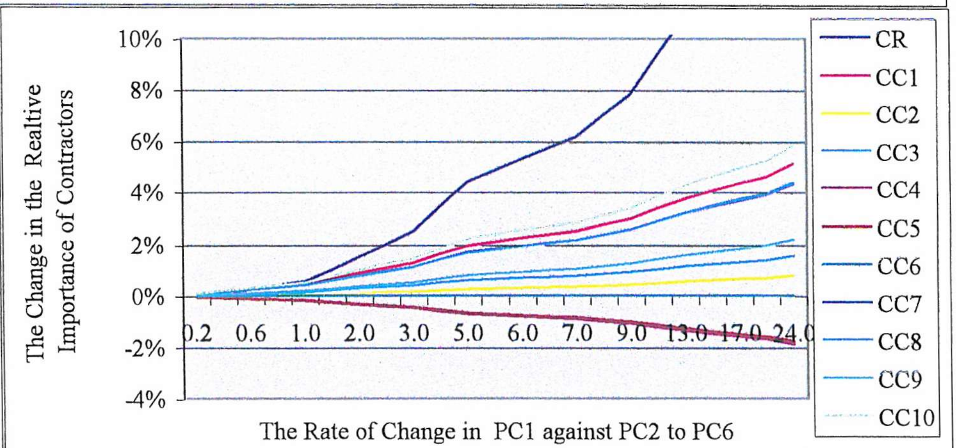

Figure 8.6.d: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs (PC2) - (PC6) [Case-2]

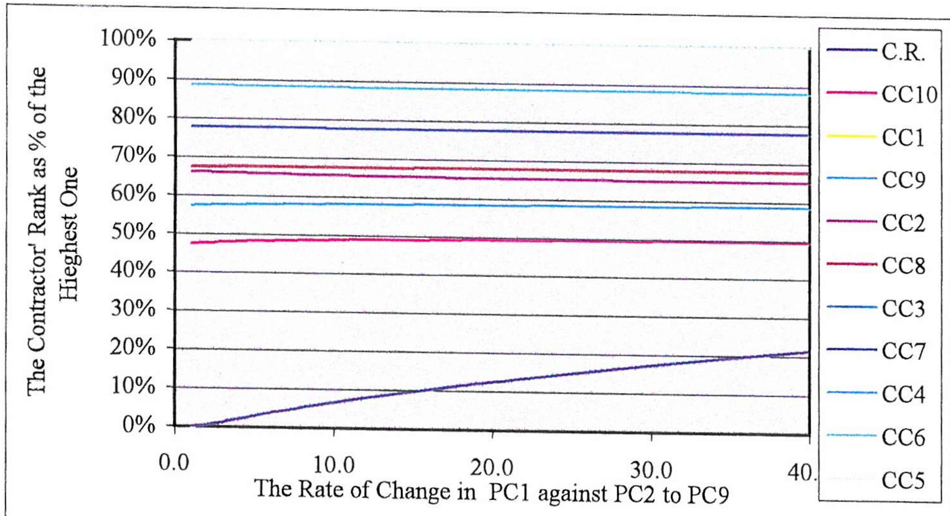

Figure 8.7.a: The Change in the Contractors' Rank due to the Change in Proj. Cost (PC1) vs Proj. Schedule (PC2) to (PC9) [Case-1]

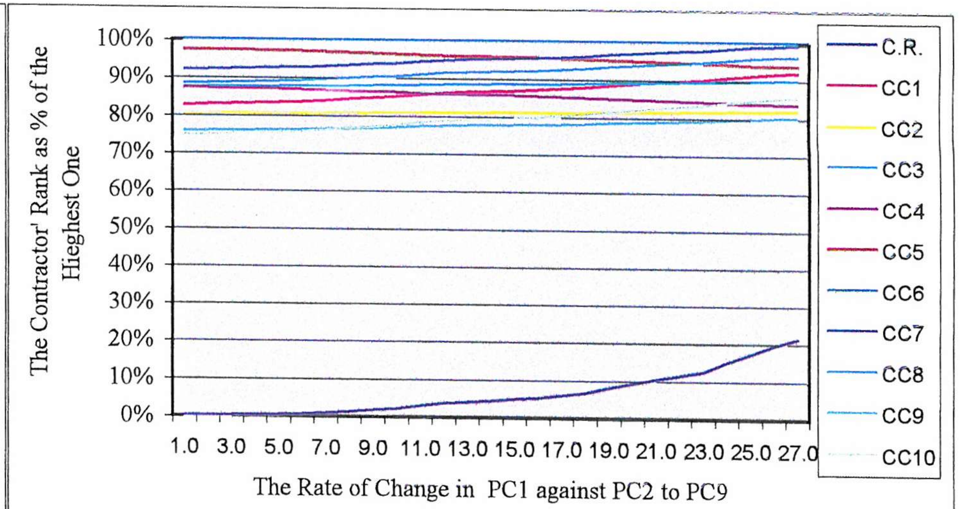

Figure 8.7.c: The Change in the Contractors' Rank due to the Change in Proj. Cost (PC1) vs Proj. Schedule (PC2) to (PC9) [Case-2]

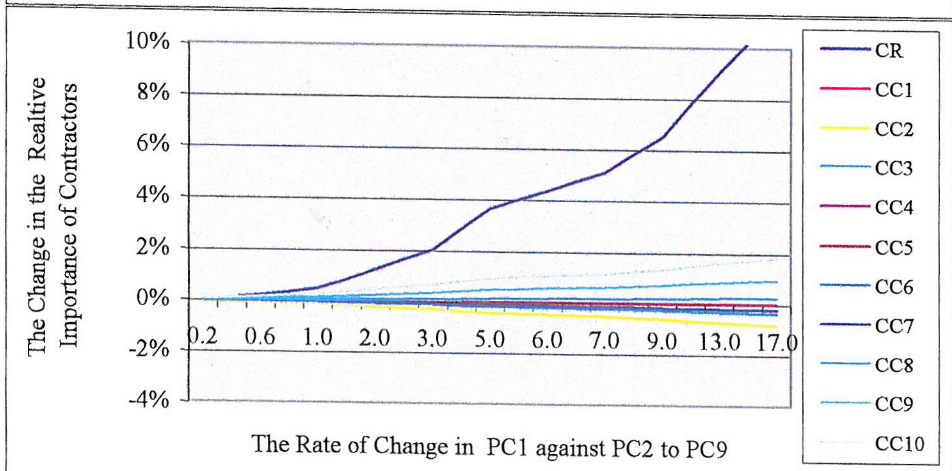

Figure 8.7.b: The Change in the Relative Importance of Contractors due to the Change in the Proj. Cost (PC1) vs (PC2) - (PC9) [Case-1]

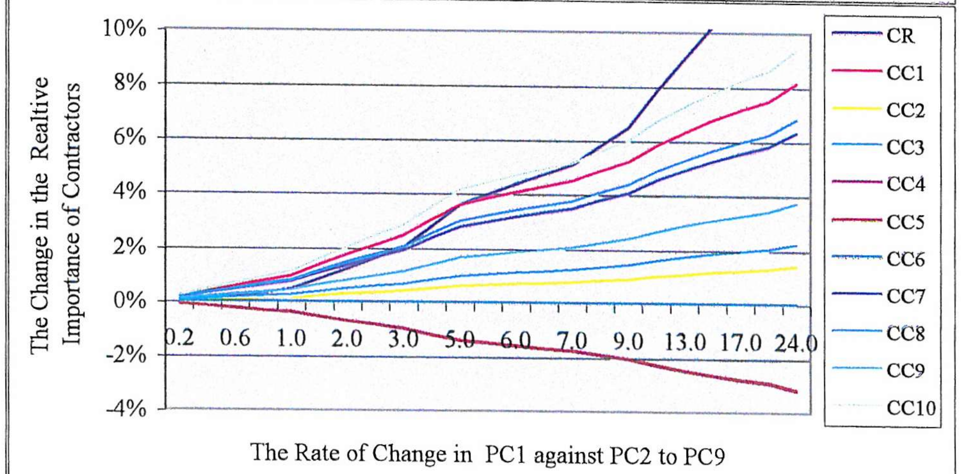

Figure 8.7.d: The Change in the Relative Importance of CCs due to the Change in the Proj. Cost (PC1) vs (PC2) - (PC9) [Case-2]

8.4.2.4. Summary and Conclusions of the Effect of Varying One Criterion to More than One on the Contractors' Rank

The above analysis illustrates that when there is a difference in the relative importance of the contractors with a non trade-off situation (Project Case 1) there is no change in rank recorded for the contractors. This situation was obtained whatever the change occurring in one criterion against either one or more than one criterion. When the contractors have a different level in their relative importance with a trade-off situation (Project Case 2), their ranking is more affected by the change in a single criterion with respect to more than one criterion. This effect on contractors' rank was increased by increasing the number of criteria that varied against a single criterion as indicated in the previous sections. The first change in the rank of contractors was attained when, for example, PC1 increased against PC2 or PC3 by 20 times at CR ~=7.2%, while the first change in the rank of contractors was attained when the relative degree of importance of PC1 was increased versus PC2 and PC3 by 12 times at CR ~= 7.0%. When PC1 importance increased against PC2 up to PC6 by 2.5 times at CR 3.0%, the first change in the CCs ranking occurred, as indicated in Section 8.4.2.2.

The above analysis indicates that any variation in a single criterion against another single criterion has a very limited effect on the relative weight of the contractors and on their ranking. This effect increased by increasing the number of criteria to be varied against a single criterion. This leads to the conclusion that, again, depending on multiple decision criteria in the evaluation process reduces the effect of biasing to one criterion in the evaluation process.

It was noted that there is a significant effect in the change of the rank of contractors when PC1 increased against six criteria, as shown in Section 8.4.2.2, more than that which occurred when PC1 increased against nine criteria, as shown in Section 8.4.2.3. The main reason for this significant change in the rank of contractors' results from the difference in the relative importance of project schedule (PC2), quality (PC3) and complexity (PC4) compared with that of PC5, PC6, PC7 and PC8. PC1 has a relative degree of importance less than PC2, PC3 and PC4, while it was more important than the other criteria. Therefore, the change in the relative importance of PC1 against PC2-4 is more effective in the rank of contractors than the change in PC1 against PC5-8.

8.4.3 The Effect of Varying the Relative Importance of the Contractor's Pre-Qualification Criteria With Respect To the Project Criteria on the Contractors' Rank

The analysis in this section is continued to the second part of the criteria, which the decision-maker is also responsible for assigning their relative importance with respect to the criteria of the specific project conditions (project criteria). These criteria include the contractor's pre-qualification criteria (in the pre-tender phase).

The analysis is carried out to investigate the effect of changing the relative importance of these pre-qualification criteria, with respect to project criteria on the ranking of the contractors in two main aspects:

1. The change in a single criterion relative to another.
2. The change in a single criterion relative to more than one.

The main concept behind the design of the selection system is its flexibility to reflect the specific project conditions together with the accumulated experience when evaluating contractor pre-qualification. Hence, the effect of change in the relative degree of importance of the contractor' pre-qualification criteria (past experience, past performance and financial stability with respect to the project criteria, shown in Figure 5.14) will be analysed in the following sections.

Within the pre-tender phase of the selection system, three decision criteria are related to the contractor's pre-qualification in their first hierarchy level, as shown in Figure 5.15. The relative degree of importance for these three criteria were determined according to the analysis carried out in Chapter 5, based on expert judgement. These decision criteria are related to:

1. Contractor's experience record (DCG1),
2. Contractor's past performance (DCG2), and
3. Contractor's financial stability (DCG3).

The relative degree of importance of these three decision criteria will be taken as a reference in the further changes for both project cases. The relative degree of importance to the three contractors' pre-qualification criteria with respect to the project cost (PC1) is shown in Table 8.2. The relative importance of these three pre-qualification criteria with respect to the project criteria (PC2, PC3, etc.) is described in Appendices H and I. The corresponding relative weights for the contractors (CCs) and their ranking are shown in Figure 8.1.a for Project Case 1 and Figure 8.1.b for Project Case 2.

	DCG1	DCG2	DCG3
Contractor's past experience (**DCG1**)	1*	1.5	0.5
Contractor's past performance (**DCG2**)	0.667	1	0.333
Contractor's financial stability (**DCG3**)	2.0	3.0	1

* Values assigned by the decision-maker

Table 8.2: The Relative Importance of DCG1, DCG2 and DCG3 with respect to PC1 in a Paired Comparison Form

8.4.3.1 The Effect of Varying the Importance of the Contractor's Experience Record (DCG1) Over the Contractor's Past Performance (DCG2)

Figure 8.8.a, **Project Case 1**, shows a change in the rank of the contractors due to the change in the contractors' past experience (DCG1) over the contractors' past performance (DCG2). This change occurred along with the change in the importance of project cost (PC1), schedule (PC2), quality (PC3), complexity (PC4), design change sensitivity (PC5), client management involvement (PC6), client risk share willingness (PC7), project uniqueness (PC8) and the political condition (PC9). The research results are similar to those in previous analysis sections. The ranking remains unchanged up to a CR value of more than 10%. Figure 8.8.b shows the change in the relative importance resulting from the increase in DCG1 against DCG2 with respect to PC1 up to PC9. This change is recorded up to a consistency ratio (C.R) of more than 10%. This change was very small (less than 1% at CR >10%). This step is also an additional verification of the logic consistency workability of the system where the system output matches its input (Project Case 1 assumptions).

Figure 8.8.c, **Project Case 2,** shows a change in the rank of the contractors due to the change in the contractor's past experience (DCG1) over the contractor's past performance (DCG2) with respect to project cost (PC1) up to the political condition (PC9). The first change recorded in the contractors' rank was recorded when the value of DCG1 increased over DCG2 by 4.5 times their reference value, as shown in Table 8.2, at consistency ratio

(CR) ~= 2.5%. The rank of contractors continued without change up to the point where DCG1 was increased by 10 times DCG2 at the consistency ratio (C.R.) about 7%. Then, the rank of the contractors proceeded without change up to the point where CR had become 10%. The change recorded in the contractors' rank due to varying the relative importance of DCG1 over DCG2 with respect to PC1 up to PC9 is shown in Figure 8.8.d.

8.4.3.2 The Effect of Varying the Importance of the Contractor's Past Experience Record (DCG1) versus the Contractor's Financial Stability (DCG3)

Figure 8.9.a, **Project Case 1**, shows a change in the rank of the contractors due to the change in the contractor's past experience record (DCG1) against the contractor's financial stability (DCG3). The change is with respect to project cost (PC1), schedule (PC2) quality (PC3), complexity (PC4), design change sensitivity (PC5), client management involvement (PC6), client risk share willingness (PC7), project uniqueness (PC8) and the political condition (PC9).

The contractors' rank remains unchanged up to a CR value of more than 10%. Figure 8.9.b shows the change in the relative importance resulting from the increase in DCG1 over DCG2 with respect to PC1 up to PC9. The change in the relative importance of contractors has no effect on their rank order, where a very small change was recorded (less than 1% at CR >10%). This step is also an additional verification of the logic consistency workability of the evaluation system where the system output matches its input data (assumptions of Project Case 1).

Figure 8.9.c, **Project Case 2,** shows a change in the contractors ranking due to the change in the contractor's past experience record (DCG1) against the contractor's financial stability (DCG3) with respect to project cost (PC1) up to the political condition (PC9).

The first change recorded in the contractors ranking was recorded when the value of DCG1 increased over DCG3 by 3.6 times their reference value, as shown in Table 8.2, at consistency ratio (CR) ~= 2.4%, where Contractor 4 (CC4) moved from sixth to fifth rank instead of CC3. The ranking of contractors changed again when the relative degree of importance for DCG1 was increased by 5.3 times DCG3 at the consistency ratio (C.R.) about 3.8%, where CC4 moved another step up to take the fourth rank instead of CC8.

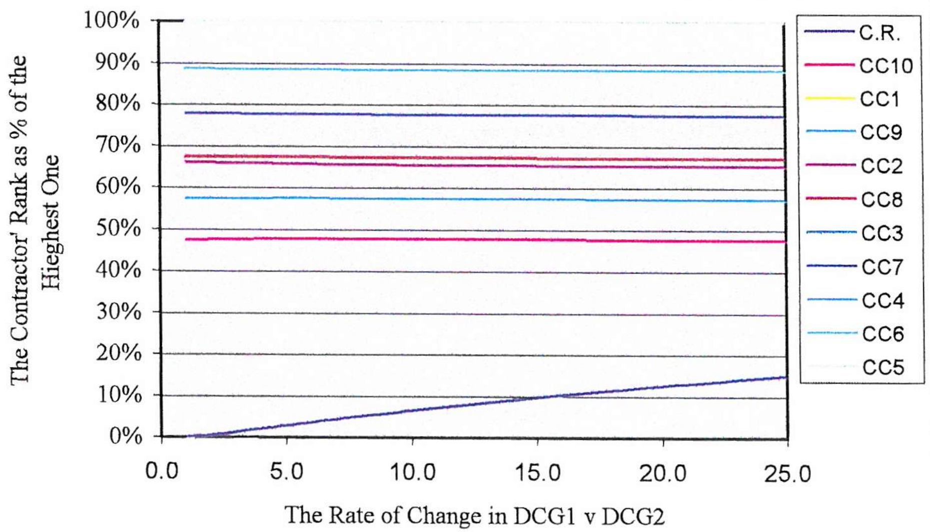

Figure 8.8.a: The Change in the Contractors' Rank due to the Change in the DCG1v DCG2 [Case-1]

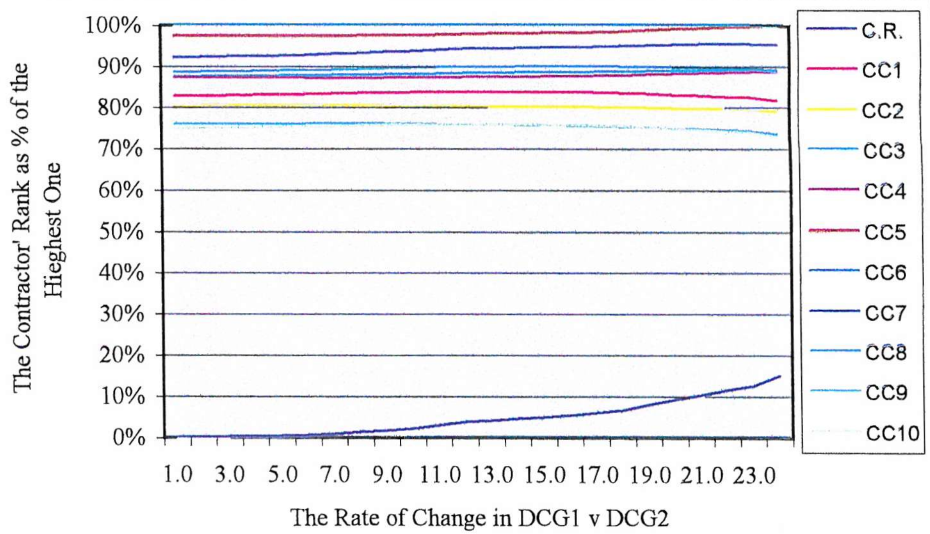

Figure 8.8.c: The Change in the Contractors' Rank due to the Change in the DCG1v DCG2 [Case-2]

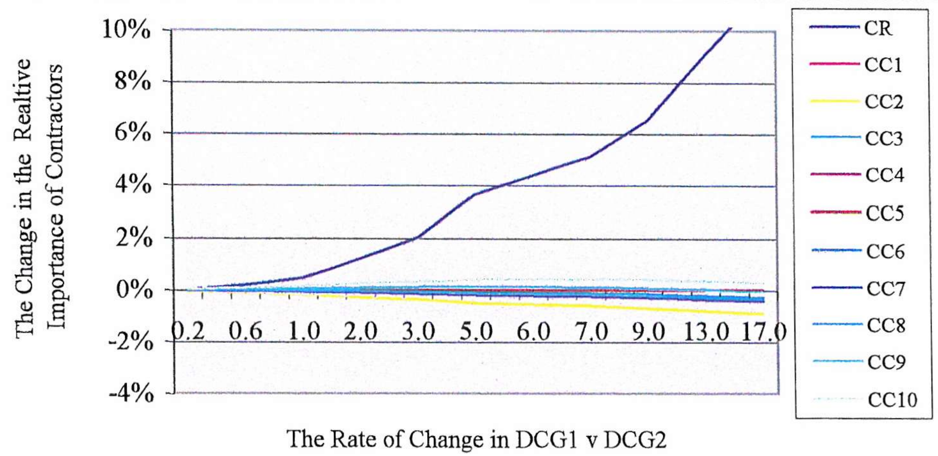

Figure 8.8.b: The Change in the Relative Importance of Contractors (CCs) due to the Change in the DCG1v DCG2[Case-1]

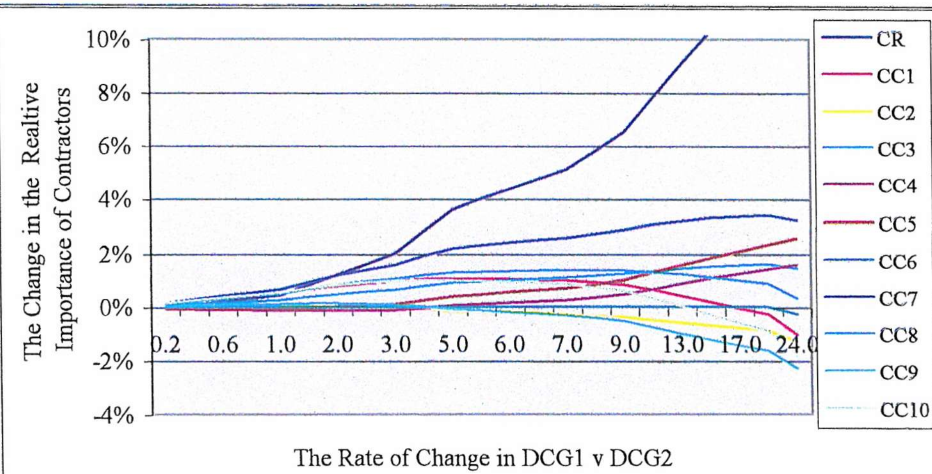

Figure 8.8.d: The Change in the Relative Importance of Contractors (CCs) due to the Change in the DCG1v DCG2[Case-2]

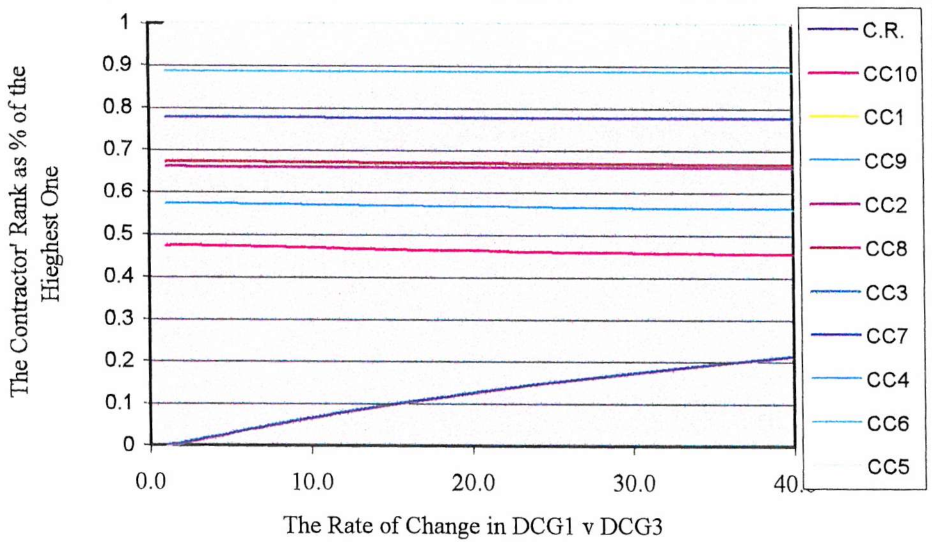

Figure 8.9.a: The Change in the Contractors' Rank due to the Change in the DCG1v DCG3 [Case-1]

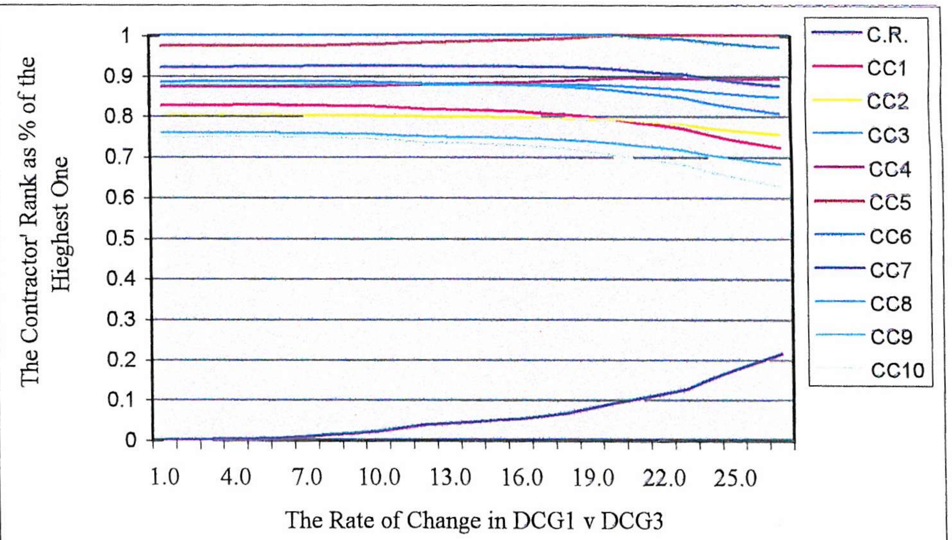

Figure 8.9.c: The Change in the Contractors' Rank due to the Change in the DCG1v DCG3 w.r.t. PC1-PC9 [Case-2]

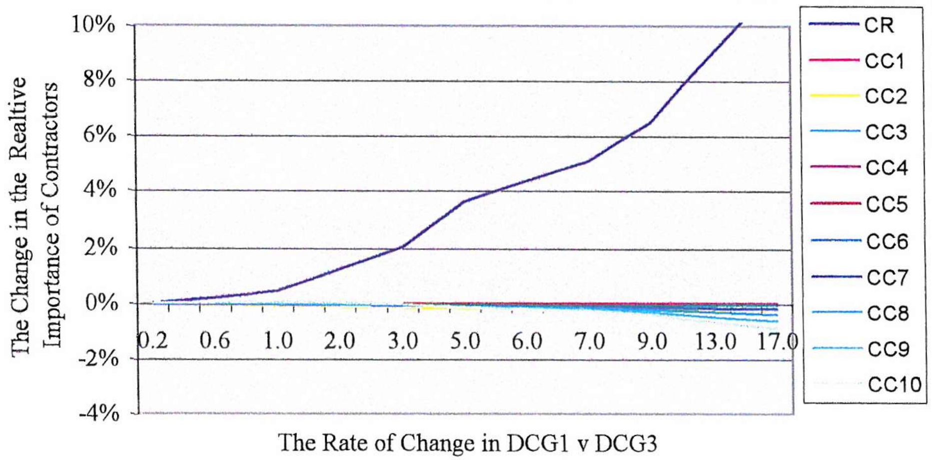

Figure 8.9.b: The Change in the Relative Importance of Contractors (CCs) due to the Change in the DCG1v DCG3[Case-1]

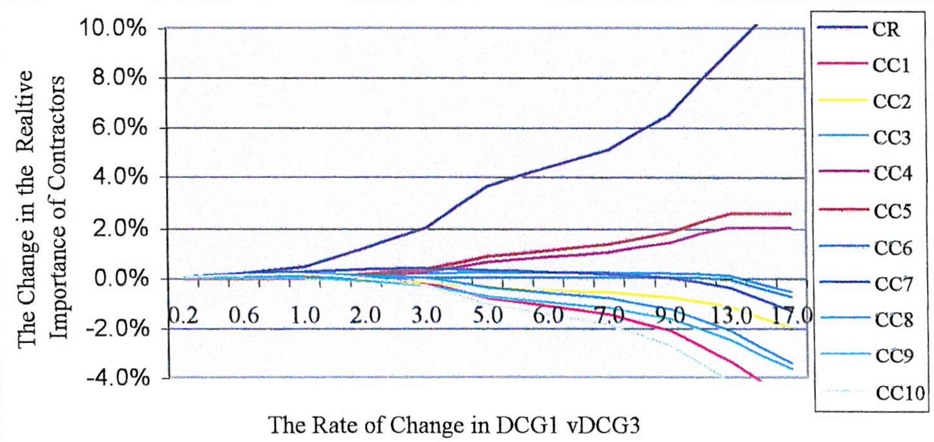

Figure 8.9.d: The Change in the Relative Importance of Contractors (CCs) due to the Change in the DCG1v DCG3[Case-2]

The last change was recorded before the CR value had become 10% when DCG1 increased by 12 times over DCG2 at CR 8.8%. In that change, CC5 takes the first rank instead of CC6 and CC2 takes the seventh rank instead of CC1. Then, the ranking of the contractors proceeds without change up to the point where CR had become 10%.

The change recorded in the contractors ranking due to varying the relative importance of DCG1 against DCG2 with respect to PC1 up to PC9 is shown in Figure 8.9.d.

It is noted that the first change in the contractors ranking occurred at a value of increase for DCG1 against DCG3 less than that for DCG1 against DCG2. The main reasons for this change in the contractors ranking resulting from the high degree of importance for DCG3 compared with DCG1 and DCG2 are shown in Table 8.2, where DCG3 is more important than DCG1 by 2 times and more than DCG2 by 3 times. This means that the decision-maker has the flexibility in assigning a different relative degree of importance to the project criteria and, hence, reflecting the actual project conditions in deciding the contractors' rank.

8.4.3.3 The Effect of Varying the Importance of the Contractor's Past Performance (DCG2) Over the Contractor's Financial Stability (DCG3)

The third comparison between criteria DCG2 and DCG3 is presented to verify the results obtained in the previous two comparisons as indicated in the above two sections.

Figure 8.10.a, **Project Case 1**, shows the change in the ranking of the contractors due to the change in the contractor's past performance (DCG2) over the contractor's financial stability (DCG3). This change is with respect to project cost (PC1), schedule (PC2), quality (PC3), complexity (PC4), design change sensitivity (PC5), client management involvement (PC6), client risk share willingness (PC7), project uniqueness (PC8) and the political condition (PC9). The contractors' ranking remains unchanged up to a CR value of more than 10%. Figure 8.10.b shows the change in the relative importance resulting from the increase in DCG2 over DCG3 with respect to PC1 up to PC9. The change in the relative weight of contractors has no effect on their rank, where a very small change was recorded (less than 1% at CR >10%). This step is also an additional verification of the logic consistency workability of the selection system where the system output matches its input data (assumptions of Project Case 1).

Figure 8.10.c, **Project Case 2,** shows the change in the contractors' rank due to changing the contractors' past performance (DCG2) over the contractors' financial stability (DCG3) with respect to project cost (PC1) up to the political condition (PC9).

The first change recorded in the contractors ranking was recorded when the value of DCG2 increased over DCG3 by 4.75 times their reference value, as shown in Table 8.2, at consistency ratio (CR) ~= 2.7%, where Contractor 10 (CC10) moved from tenth to ninth rank to take the place of CC9. The rank of contractors changed again when the relative degree of importance for DCG2 was increased by 8.5 times DCG3 at the consistency ratio (C.R.) about 6.3%, where CC1 moved one step up to take sixth rank instead of CC4. Then, the ranking of the contractors proceeded without change up to the point where CR had become 10%. The change recorded in the relative weight of the CCs due to varying the relative degree of importance of DCG1 over DCG2 with increasing PC1 up to PC9 is indicated in Figure 8.10.d.

8.4.3.4 The Effect of Varying the Importance of the Contractor's Past Experience Record (DCG1) Over the Past Performance (DCG2) and Financial Stability (DCG3)

The effect of varying one decision criterion to another one has been studied in the previous Sections: 8.4.3.1, 8.4.3.2 and 8.4.3.3. The effect of varying the relative degree of importance for a single pre-qualification criterion over more than one with respect to project cost (PC1) up to political criterion (PC9) on the rank of the contractors is analysed in this section. This decision criterion is the contractors' past experience record (DCG1) over the contractors' past performance (DCG2) and the contractors' financial stability (DCG3) criteria, with a relative degree of importance, as shown in Table 8.2.

Figure 8.11.a, **Project Case 1**, shows the change in the rank of the contractors due to the change in the contractors' past performance (DCG2) over the contractors' financial stability (DCG3) with respect to project cost (PC1) up to the political criterion (PC9). The contractors' rank order remains unchanged up to a CR value of more than 10%. The relative degree of importance among contractors changed less than 2.0% at CR >10%, as shown in Figure 8.11.b. Figure 8.11.c, **Project Case 2,** shows the change in the contractors ranking due to changing the contractors' past experience record (DCG1) over the contractors' past performance (DCG2) and the contractors' financial stability (DCG3) with respect to project cost (PC1) up to the political condition (PC9).

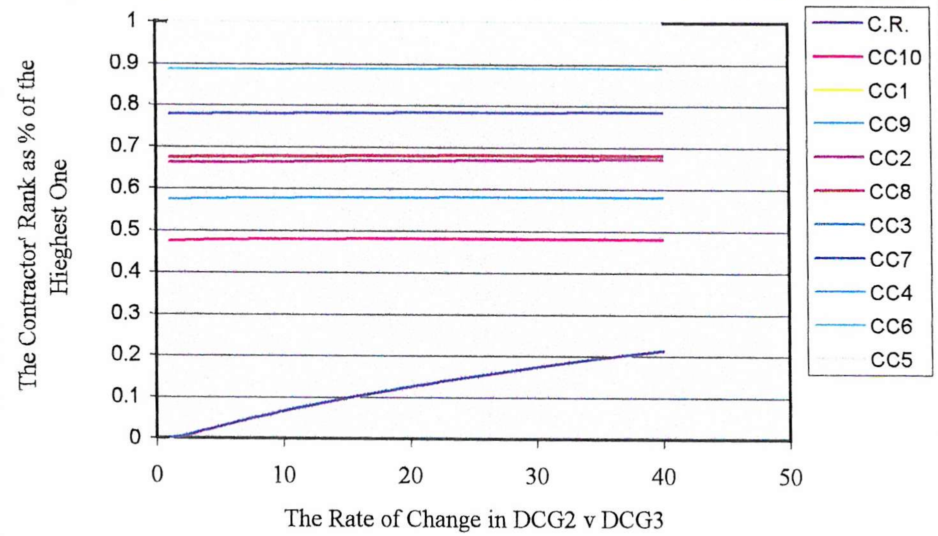

Figure 8.10.a: The Change in the Contractors' Rank due to the Change in the DCG2 v DCG3 [Case-1]

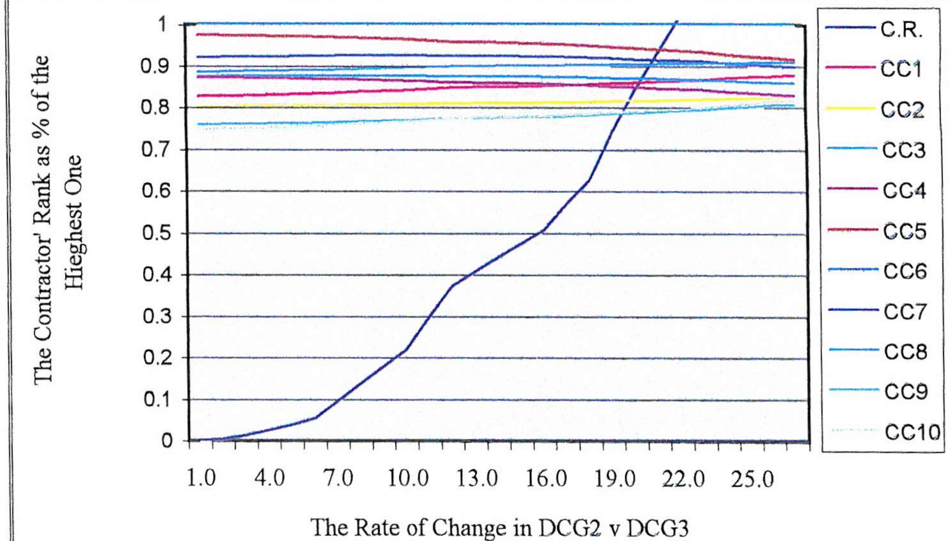

Figure 8.10.c: The Change in the Contractors' Rank due to the Change in the DCG2v DCG3 [Case-2]

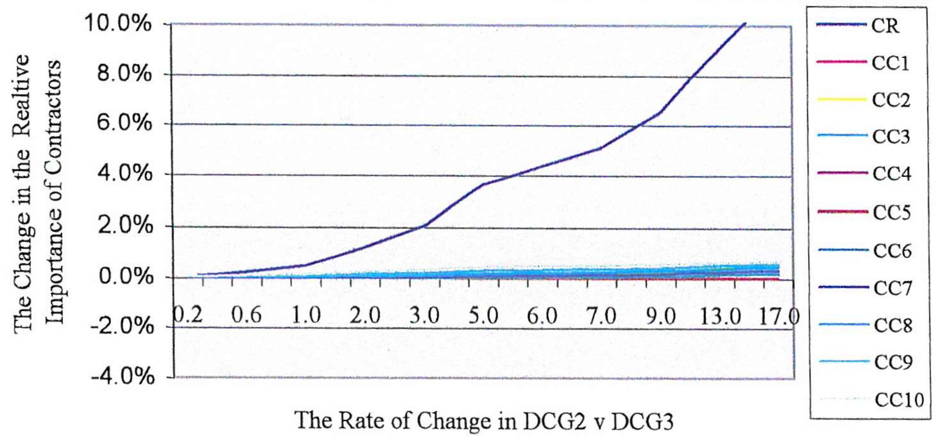

Figure 8.10.b: The Change in the Relative Importance of Contractors (CCs) due to the Change in the DCG2v DCG3[Case-1]

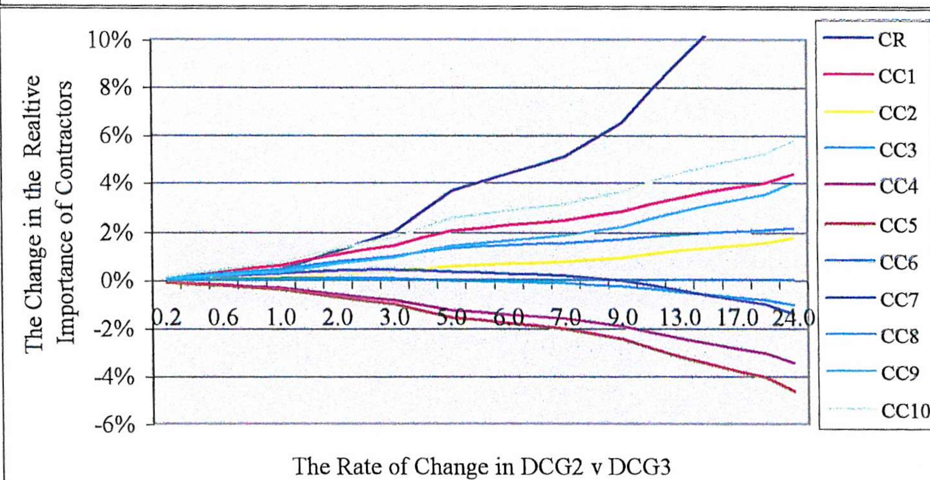

Figure 8.10.d: The Change in the Relative Importance of Contractors due to the ChaChange in the DCG2 v DCG3 [Case2]

The first change in the contractors' rank was recorded when the value of DCG1 increased over DCG2 and DCG3 by 0.9 times more than their reference value and at a consistency ratio (CR) ~= 0.4%, where Contractor 4 (CC4) moved from sixth to fifth rank instead of CC3. The rank of contractors changed when the relative degree of importance for DCG1 was increased over DCG2 and DCG3 by 1.7 at the consistency ratio (CR) about 1.15%, where CC4 moved one-step up to take fourth rank instead of CC8. The ranking of contractors changed again when the relative degree of importance for DCG1 was increased over DCG2 and DCG3 by 4.5 times at the consistency ratio (CR) about 3.25%. In this change, CC5 takes first rank instead of CC6, and CC2 moved one step up to take seventh rank instead of CC1. CC4 moved again one step to take third rank instead of CC7 when DCG1 was increased over DCG2 and DCG3 by 8.6 times at a consistency ratio (CR) about 6.3%. Then, the rank order of the contractors proceeded without change up to the point where CR had become 10%. The change recorded in the relative weight of the CCs due to varying the relative degree of importance of DCG1 over DCG2 with increasing PC1 up to PC9 is indicated in Figure 8.11.d.

It is noted, on the basis of the previous analysis, which the contractors' ranking is highly affected by the change in a single pre-qualification criterion over more than one pre-qualification criterion, with respect to the project criteria. This large effect resulted from considering only three pre-qualification criteria (first hierarchy level of the pre-qualification criteria) in the previous analysis. If the number of criteria considered in the selection process is increased (e.g., as in the case of the second hierarchy level), the effect on the contractors' ranking will be less than the case of discussed in Section 8.4.3. The analysis using the project criteria, where nine criteria were considered, illustrates how the change in the contractors' ranking recorded less change by varying the relative importance of project criteria compared with the pre-qualification criteria.

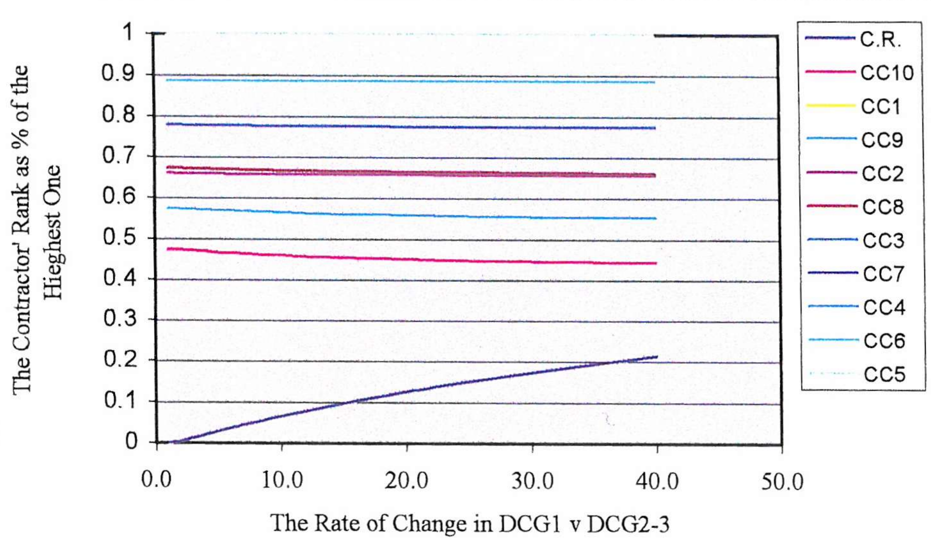

Figure 8.11.a: The Change in the Contractors' Rank due to the Change in the DCG1v DCG2-3 [Case-1]

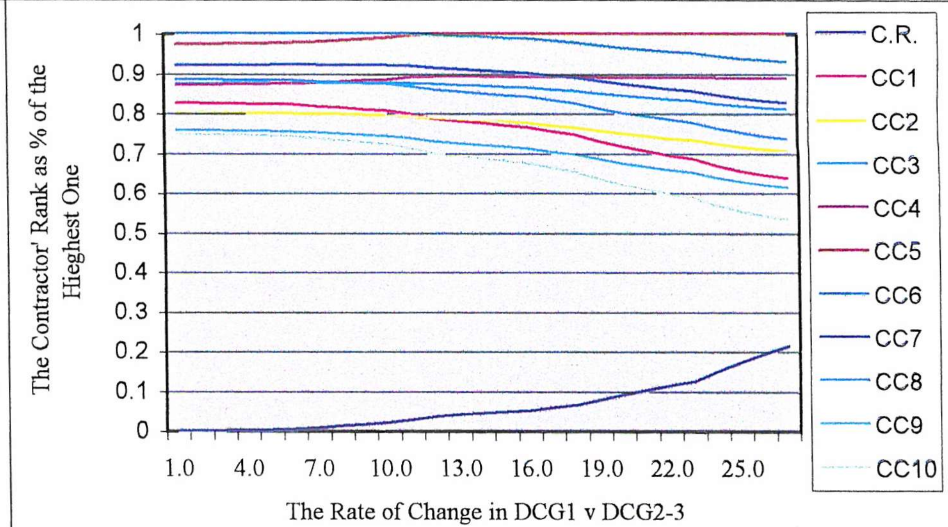

Figure 8.11.c: The Change in the Contractors' Rank due to the Change in the DCG1v DCG2-3 [Case-2]

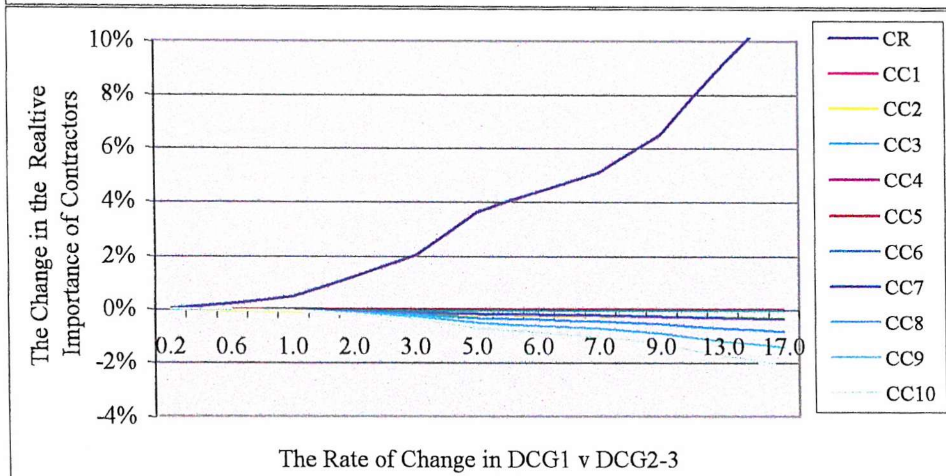

Figure 8.11.b: The Change in the Relative Importance of Contractors due to the Change in the DCG1v DCG2-3 [Case1]

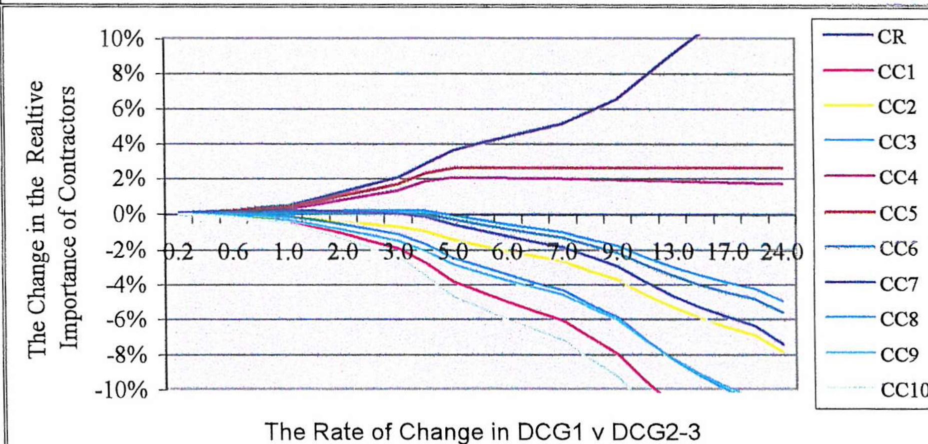

Figure 8.11.d: The Change in the Relative Importance of Contractors due to the Change in the DCG1v DCG2-3 [Case-2]

8.4.3.5 Summary and Conclusions for the Effect of Varying One Pre-Qualification Criterion to One or more than one

The above analysis illustrates that when there is a difference in the relative importance of the contractors with a non trade-off situation (Project Case 1) there is no rank variation recorded for the contractors. This situation was obtained whatever the change occurred in one criterion against either one or more than one criterion. When the contractors (CCs) have a different level in their relative importance with a trade-off situation (Project Case 2), the contractors' ranking is more affected by the change in a single pre-qualification criterion against another with respect to project criteria. This situation is more remarkable if the change occurred in a single criterion of importance higher than another single one within the pre-qualification criteria. This effect on the contractors' ranking was increased or decreased depending on the relative degree of importance of a single pre-qualification criterion against another one with respect to project criteria. For example, Contractor 4 (CC4) was affected positively by varying DCG1 versus DCG3 at CR ~= 2.5% while the effect was negative when DCG2 increased over DCG3 at CR ~= 6.3%. This means that the decision-maker has the flexibility of assigning a different relative degree of importance to the project criteria and, hence, reflecting the actual project conditions in deciding the contractors' rank order. This effect on the contractors' ranking increased when the number of criteria that varied against a single criterion was increased as indicated in section 8.4.3.4. The first change in the contractors' ranking was attained when DCG1 increased versus DCG2 or DCG3 by 3.5 times at CR ~=2.5%. The first change in the contractors' ranking was attained when the relative degree of importance of DCG1 was increased versus DCG2 and DCG3 by 0.9 times at CR ~= 0.4%.

The above analysis indicates that any variation in one decision criterion has a very limited effect on the relative weight of the CCs and their ranking. This effect is increased when the number of criteria that are varied against one or more than one criterion is increased. This leads to the conclusion that, again, depending on multiple decision criteria in the evaluation process reduces the effect of biasing to one criterion in the selection process.

8.5 SUMMARY AND CONCLUSIONS

The DSS was tested for logical consistency, workability and flexibility by using a simulated project. The simulated case gave the first contractor the highest rank in all criteria, while the second contractor was given the second rank in all criteria (lower than the first) followed by the other contractors ranked down to the contractor no. 10. This data was fed to the DSS, which produced the same anticipated outcome. This happened after a series of trials and debugging of the system until it was running smoothly with no hitches.

The implementation of the DSS using two case studies was carried out to test its applicability and viability. In the first case study, the proposed DSS ranked the contractor awarded that project third out of ten contractors. While, in the second case, the contractor awarded project ranked second out of ten contractors. The contractors in both projects were selected on lowest bid price basis.

During this test was carried out in co-operation with the engineers who actually studied and awarded these projects and they found that the DSS was valuable tool with no difficulties.

Studying the sensitivity of the DSS, the relative weights of various criteria were changed within a range established by the Analytical Hierarchy Process (AHP). Different computer runs were performed, to study the impact of these changes on the outcome of contractor selection process. It was found that, due to the dependency of large number of criteria, the outcomes have low sensitivity due to the limited change in the relative degree of importance of a single criterion against one or more than one criterion.

The most significant outcome of this sensitivity is as follows. The change in the contractors' ranking occurred only due to 20 times increase in the relative importance of the project cost against either schedule or quality, (This gave a C.R. value of more than 6%, which should be less than or equal to 10% on the basis of normally accepted AHP limits).

The ranking of contractors has a significant effect when more than one criteria was varied against a single criterion. For example, the first change in the rank of contractors was attained when criterion "project budget" increased against criterion "project schedule" **or** "project quality" by 20 times at CR ~=7.2%. The first change in the rank of contractors was attained when the relative degree of importance of "project budget" criterion was increased versus "project schedule" **and** "project quality" by 12 times at CR ~= 7.0%. When "project budget" importance increased against "project schedule" up to the six criterion "client management involvement" by 2.5 times at CR 3.0%, the first change in the ranking of contractors occurred

This established that this system is not sensitive to a single criterion and can even tolerate the mis-judgement in single criteria due to the fact that the use of multiple criteria. The weight of single criterion will not dominate the outcome.

CHAPTER 9: DISCUSSIONS, CONCLUSIONS AND FUTURE RESEARCH

CHAPTER 9: DISCUSSIONS, CONCLUSIONS AND FUTURE RESEARCH

This chapter discusses the research study and its conclusions and provides recommendations for further research. In this chapter, four major sections are organised as follows: Section 9.1 includes discussions of the research work to identify the optimum contractor. Section 9.2 illustrates the conclusions of the research. Section 9.3 introduces the academic contributions of this research. Finally, Section 9.4 suggests directions for future research.

9.1 DISCUSSIONS OF THE RESEARCH WORK

This research work has described the development of a decision support system (DSS) for contractor selection based on the multiple criteria approach. A knowledge-based expert system was formalised and structured to facilitate the use of the DSS. The main aspects of this system include:

1. Collecting the experience from the contractor selection process used in previous projects to incorporate in the proposed contractor selection system. This aspect introduces more confident decision criteria and can reduce time and cost involved in the selection process.

2. The DSS is flexible to assess new criteria, which is needed to represent the project specific conditions and client's objectives. These types of criteria should be assessed for each project on a case-by-case basis. At the same time, these criteria can be incorporated with the criteria that were acquired on the experience basis from the previous projects, the criteria of the contractor pre-qualifications and capabilities.

3. The use of a systematic approach (the DSS) can reduce the possibility of using insufficient information by the decision-maker.

4. Structuring a KBES allows the decision-maker to organise the decision process and reduce the time required for the selection process. In addition, it provides a standard system, which can reduce the possibility of biased decisions.

Therefore, the structured approach of the contractor selection system was carried out in following major phases:

Phase-1: Identifying and investigating all criteria related to the contractor selection;

Phase-2: Researching to find the most appropriate identification and assessment techniques for the collected criteria;

Phase-3: Refining and evaluating the collected criteria;

Phase-4: Researching decision support system techniques to structure the proposed contractor selection decision system (DSS)

Phase-5: Structuring the logic of the contractor selection decision system

Phase-6: Verification and analysis of the contractor selection system developed.

The Delphi method and the AHP were used to develop the contractor selection method. The use of the Delphi method enhances the quality of decision while AHP helps to process the criteria assessed by the Delphi method, along with other criteria to decide the optimum alternative solution (the optimum contractor).

A review of the different computer support systems had been carried out and a knowledge-based expert system (KBES) was selected to implement the DSS. Different popular, commercially available KBES tools (shells) were evaluated and LEVEL5-Object was selected, as illustrated in Chapter 6.

The main design aspects of the decision support system (DSS) for selecting the optimum contractor and the incorporation of a KBES as a computer support system, as illustrated in Chapter 6, include:

1. Dividing the criteria of the selection process into: (i) a contractor screening process (pre-qualification process), and (ii) a final selection process.

2. The screening process involved matching the contractor's qualification criteria with the criteria related to the project under consideration to produce a short list of qualified contractors. The DSS used a combination of the Delphi method and the AHP at this process.

3. The final selection process involved matching the contractor's current capabilities and submitted plans criteria with the criteria related to the project under consideration. The DSS used the AHP at this process

4. Developing the KBES, which facilitated the use of the DSS.

The expert system shell of KBES, LEVEL5-Object, is linked with a mathematical optimisation model (Excel 5) and a database programme (Paradox) constitutes the DSS.

Relevant and significant decision criteria were identified using a survey approach, as described in Chapter 5. This survey was carried out using the Delphi method. Postal questionnaire and structured interview conducted the survey. 450 questionnaires were posted out and 177 were answered. The questionnaire survey results confirm the need to implement multiple decision criteria in addition to the bid price.

The results indicated that more than 65% of criteria, out of the number of criteria considered in the initial design, were relevant. The current evaluation system of lowest bid price, according to this survey, accounts for only 8.91% of the total decision criteria in building projects and 9.38% in heavy projects. The survey revealed that the five decision criteria groups, which were selected as a basis for the proposed selection system, are relevant and had the degrees of importance detailed in Appendix D.

Generally, in the three surveyed countries, the criteria related to contractors' current capabilities group (DCG4) recorded the highest relative degree of importance within both building projects (20.90%) and heavy projects (20.72%). The criteria that related to submitted plans group (DCG5) recorded the second highest relative degree of importance within heavy projects (20.52%), while it was the third highest (20.11%) within building projects.

The verification and analysis of the contractor selection system are described in Chapter 8. The developed system was tested for logic consistency, workability and flexibility by using a simulated project. The simulated case gave the first contractor the highest rank in all criteria, while the second contractor was given the second rank in all criteria (lower than the first) followed by the other contractors ranked down to the contractor no. 10. This data was fed to the model and the model produced the same anticipated outcome. This happened after several trials and debugging of the system until it was running smoothly with no hitches.

The implementation of the system using two case studies was carried out to test its applicability and viability. In the first case study, the proposed system ranked the contractor awarded that project third out of ten contractors. While, in the second case, the contractor awarded project ranked second out of ten contractors. The contractors in both projects were selected on lowest bid price basis.

During this test, which was carried out in co-operation with engineers whom actually study and awarded these projects, they found that the system can be a valuable tool and they can use the system with no difficulties. Their general comments gave a good indication of the applicability and flexibility of the evaluation system, especially when there is no real decision support system available except the dependency on the governmental classification for the contractors based on their work volume and the lowest tender sum. These comments also concluded that more research is needed to identify well-defined measures for the criteria, which can assess the contractor submissions to the project under consideration, particularly those needed for decision-makers' judgement, which is limited to their experience and effort.

Studying the sensitivity of the system, the relative weights of various criteria were changed within a range established by the Analytical Hierarchy Process (AHP). Different computer runs were performed, in studying the impact of these changes on the outcome of contractor selection process. It has been found that due to the dependency of large number of criteria, the outcome have low sensitivity due to the limited change in the relative degree of importance of a single criterion against one or more than one criterion.

The most significant outcome of this sensitivity is as follows. The change in the contractors' ranking occurred due to more than 20 times of increase in the relative importance of the project cost against either schedule or quality, at a C.R. value of more than 6% (C.R. should be less than or equal to 10% on the basis of AHP limits).

The ranking of contractors has a significant effect when the number of criteria that varied against a single criterion was increased. For example, the first change in the rank of contractors was attained when criterion “project budget” increased against criterion “project schedule” **or** “project quality” by 20 times at CR ~=7.2%. The first change in the rank of contractors was attained when the relative degree of importance of “project budget” criterion was increased versus “project schedule” **and** “project quality” by 12 times at CR ~= 7.0%. When “project budget” importance increased against “project schedule” up to the six criterion “client management involvement” by 2.5 times at CR 3.0%, the first change in the ranking of contractors occurred

This established that this system is not sensitive to a single criterion and can even tolerate the mis-judgement in single criteria due to the fact that the use of multiple criteria. The weight of single criterion will not dominate the outcome.

Finally, the contract awarding process that is based on price alone, whatever its format has been, is shown to be insufficient to select the most appropriate contractor. In addition, considering the contractors' pre-qualification criteria to create a short list of qualified contractors is not sufficient.

Selecting a qualified contractor does not necessarily mean that this contractor should have the highest pre-qualification in general, but it is that contractor who is the closest and most appropriate to the specific conditions of the proposed project. Using this evaluation system, project owner can define its own criteria according to the specific project conditions in addition to the criteria defined by the experts from the field to evaluate the contractors.

9.2 CONCLUSIONS

1. Multiple criteria (which include contractor pre-qualifications, current capabilities, project specific conditions and client objectives) should be used in the contractor evaluation process in addition to the lowest tender sum.
2. The appropriate contractor is not necessarily the contractor who have the highest qualification in general, but who is the closest and most appropriate to the specific conditions, requirements and objectives of the project under consideration.
3. A contractor selection process that is based on price alone, whatever its format, is insufficient in selecting the most appropriate contractor.
4. The results of the survey indicated that more than 65% of the criteria, considered in the initial criteria design, were relevant and hence support the use of multiple criteria in contractor selection..
5. According to the survey, the to relative degree of importance of "total tender sum" was only 8.91% and 9.38% according to experts form building and heavy projects respectively.
6. The use of a decision support system (DSS) can reduce the risk resulting from the limitation of individual experience and knowledge in setting criteria weights and priorities, and thus increasing the fairness possibilities,
7. The use of a computer support system organises the complex evaluation process, which can reduce the complexity and minimise the time of data handling.
8. The Delphi Method was efficient to evoke experts' opinions and thus helped to identify the relevant criteria that relate to the contractor's pre-qualifications.
9. The Analytical Hierarchy Process (AHP) was powerful in evaluating and a large set of multiple criteria and comparing contractor alternatives.
10. The use of the computer support system facilitates easy and accurate processing of complex data, reduces the time of data handling, and creates a feedback system that can be utilised in future contract awarding.
11. A Knowledge-Based Expert System (KBES) was found to be an efficient tool for developing the proposed contractor selection system.

9.3 ACADEMIC CONTRIBUTIONS

The main academic contributions of this study include:

1. Creating a standard methodology for contractor selection, which formulates the evaluation process for clients and assists in eliminating bias, thus achieving fairness for all parties involved. This reduces the workload, time and cost, as well as increasing the efficiency of the evaluation process for awarding contracts.
2. Confirming the requirement to use multiple criteria (as shown from a survey conducted in the U.K., Egypt and Kuwait) in the process of selecting the most appropriate contractor, thus reducing the risk incurred by using the lowest tender criterion.
3. Research has achieved a full list of criteria that are associated with the contractor selection decision. The research also found the criteria that are considered significant and relevant, by construction experts, to this selection process.
4. Creating a method for combining two different analytical techniques, namely the analytical hierarchy process (AHP) and the Delphi method, which produced a flexible system where the criteria identified and assessed using the Delphi method, are utilised by the AHP to assess various contractor selection criteria.
5. Benchmarking a methodology that allows the experience and knowledge of previous projects to be easily used for contractor selection, and producing metrics for an individual contractor's continuous improvement.
6. Providing a benchmark that will aid the construction industry, where the contractors know that criteria other than price will be considered in the selection process. In the U.K. domestic market this supports the proposals from Latham and Egan for a move towards reducing the claims-orientated approach. Hence, the client can obtain a more realistic assessment of the cost of their project.
7. The idea of creating a standard database for contractors which can shorten the time and cost of data collection for contractors in the future.
8. The DSS developed for the contractor selection can be used to support the selection of consultants, project managers, construction managers, management contractors, and the selection of subcontractors (by the main contractor). Identifying the proper selection criteria for each case can do this.

9.4 FUTURE RESEARCH

The process of the contractor selection proposed in this research can be extended to other civil engineering selection problems. One of the primary directions of this research work is to apply the knowledge found in this study to extend its domain to include the different construction work types. The process of transforming construction expertise from human experts to a formalised language offers an opportunity to accumulate and further articulate this knowledge.

Thus, future development of a construction-related knowledge-based system application should not be limited to solving problems for a narrow domain. They should also look into the potential benefits that may accrue from the further articulation of this formalised construction experience. Other artificial intelligence techniques may be considered in this regard.

The major future research areas resulting from this research are:

1. Developing the evaluation system for the contractor selection process using a Web site, which can make knowledge acquisition more beneficial and thus enrich the quality of the contractor selection decision.

2. Researching more specific quantitative measures for evaluating plans submitted by the contractor, which are now evaluated based on the direct judgement of the decision-maker, who may have limited experience.

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APPENDICES

Appendices

Appendices Content

A/o: Sample of Blank Questionnaire Form Used in Egypt and Kuwait

A: Sample of Blank Questionnaire Form Used in the UK

B: Statistical Results of Questionnaire Survey on the Basis of SPSS Program

C: Sample of Statistical Analysis to Identify Decision Criteria

D: The Relative Weights of the Decision Criteria for Heavy and Building Construction

E: Blank Form of the Collection of Data for Sample Projects Related to the Contractor

F: List of Experts Contacted Using Postal Questionnaires and Structured Interviews

G: Simulated Case Project – Case 1

H: Project Case Studies – Case 2 and Case 3

I: Optimum Contract Selection System Procedure

Appendix – A/o

A/o: Sample of Blank Questionnaire Form Used in Egypt and Kuwait

Main decision criteria groups of tender evaluation - Evaluation form:

A/o.1	Suggested Evaluation Scale
A/o.2	Contractor's Experience Record
A/o.4	Contractor's Past Performance
A/o.7	Contractor's Financial Stability
A/o.9	Contractor's Current Capabilities
A/o.12	Contractor's Submitted Plans to the Proposed Project

الغرض من هذه الأسئله هو عمل نظام لتقييم العطاءات مع ملاحظه النقاط التاليه :

١- اعطاء ترتيب مجموعات التقييم الرئيسيه لبيان الأهميه النسبيه لكل مجموعه بالنسبه للأخرى.

٢- بيان درجه اهميه كل مجموعه رئيسيه (عاليه جدا ، عاليه ، متوسطه أو ضعيفه) وذلك حسب الجدول المبين فى هذه الصفحه.

٣- بيان درجه اهميه كل عنصر من عناصر المجموعات الرئيسيه (عاليه جدا ، عاليه ، متوسطه ، ضعيفه أو ضعيفه جدا) وذلك حسب الجداول المبينه فى هذه الصفحات التاليه.

٤- يتم هذا التقييم من وجهه نظر المالك أو من يمثله وذلك سواء كان المالك حكومه ، قطاع عام أو خاص.

Degree of Importance درجه الأهميه				Criteria Group order	Criteria Group Name	C. G. Number
Low (<= 3)	Average (<= 5)	High (<=8)	Very High (<=10)			
					Experience Record	1
					Past Performance of the Completed Project	2
					Financial Stability Criteria	3
					Current Capabilities Criteria	4
					Contractor Plans for the Proposed Project	5
						6

Decision Criteria Group - 1 : Experience Record

Degree of Importance درجه الاهميه						هل هذا العنصر مقياس		عناصر تقيم خبره المقاول	
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	Contractor Past Experience Record	No.
								عدد سنوات العمل فى مجال التشييد Contractor Age in Construction Industry	A
								عدد سنوات العمل فى مشروعات مماثله Number of Years Working in Similar Projects	B
								بدايه و نهايه أكبر مشروع تشييد بصفه عامه خلال ٥ سنوات مضت Start and End Dates of the Largest Construction Project within last 5-years	C
								بدايه و نهايه أكبر مشروع تشييد مماثل خلال ٥ سنوات مضت Start and End Dates of the Largest Similar Construction Project within last 5-years	D
								حجم عمل أكبر مشروع تشييد بصفه عامه خلال ٥ سنوات مضت Work Volume of the Largest Construction Project within last 5-years	E
								حجم عمل أكبر مشروع تشييد مماثل خلال ٥ سنوات مضت Work Volume of the Largest Similar Construction Project within last 5-years	F
								اجمالى حجم أعمال المشروعات المنفذه خلال ٥ سنوات مضت Total Work Volume for the Performed Projects within last 5-years	G
								اجمالى حجم أعمال المشروعات المماثله المنفذه خلال ٥ سنوات مضت Total Work Volume for the Similar Performed Projects within last 5-years	H
								أنواع العقود المستخدمه بالمشروعات السابقه Contract types implemented for the Previous Projects	I
								أنواع العقود المستخدمه بالمشروعات المماثله السابقه Contract types implemented for the Similar Previous Projects	J
								Previous Project Types نوعيه المشروعات السابقه	K
								العمل تحت ظروف جويه مماثله بصفه عامه Working with Similar Weather Conditions - In General	L
								العمل تحت ظروف جويه مماثله للمشروعات المماثله Working with Similar Weather Conditions & Similar	M

Degree of Importance درجه الاهميه						هل هذا العنصر مقياس		عناصر تقييم خبره المقاول (تابع)	
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	Contractor Past Experience Record (Continue)	No.
								العمل فى مواقع جغرافيه مماثله بصفه عامه Working in Similar Geographical Conditions - In General	N
								العمل فى مواقع جغرافيه مماثله للمشروعات المماثله Working in Similar Geographical Conditions - In Similar Projects	O
								Another Suggested Objectives أهداف أخرى مقترحه	P
									I
									II
									III
									IV
									V
									VI

Decision Criteria Group -2 : Past Performance Criteria

Degree of Importance درجه الاهميه						هل هذا عنصر قياس		عناصر تقييم الاداء السابق للمشروعات المنتهيه Past Performance of the Completed Project	No.
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes		
								القدره على تحقيق اهداف المشروع وتشمل : Ability to Meet Project Objectives :	A
								Project Duration مده التنفيذ	A-1
								نسبه تأخير المشروع عن المده المحدده بالعقد Project Delay Percent	I
								سبب التأخير (مالك - مقاول عام - مقاول باطن) Source of project delay	II
								Project Budget ميزانيه المشروع	A-2
								Quality Control التحكم فى الجوده	A-3
								مستوى تحقيق المقاول للجوده المطلوبه Level of achieving the Required Quality	I
								خطط التحكم فى الجوده و طرق تأكيدها Quality Control Plans & Quality Assurance	II
								مستوى التفتيش لعمل المقاول الباطن Inspection Level for Subcontractor Works	III
								مستوى استلام و اختبار مواد التشييد Delivery and Testing Level of the Const. Material	IV
								Quality Control Meetings عقد اجتماعات لمراقبه الجوده	V
								تكرار التعاقد مع نفس المالك لمشروعات أخرى Contracting with the same Owner again	VI
								Another Suggested Objects اهداف أخرى مقترحه	A-4
									I
									II
									III
									IV
									V

Degree of Importance درجه الاهميه						هل هذا العنصر مقياس		عناصر تقييم الاداء السابق للمشروعات المنتهيه (تابع)	
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	Past Performance of the Completed Project (Continue.)	No.
								القدرات الفنيه والخبرات الاداريه : Technical Competence & Management Expertise :	B
								Safety Record سجل الأمان	B -1
								Accident Direct Cost التكلفه المباشره للحوادث	I
								Safety Program applied برنامج الامان المتبع	II
								استخدام نظام تكلفه للحوادث Use of accident cost system	III
								عدد الاجتماعات الخاصه بالأمن والسلامه Meeting number for Security & Safety	IV
								تواجد المقاول بصناعه التشييد Presence in Construction Industry	B -2
								حجم الأعمال السنوى للسنوات الخمس الماضيه : Annual Work Volume for the past 5-years	I
								In Construction - Generally بصفه عامه	-
								Similar Construction projects المشروعات المماثله	-
								Growth of Annual work volume نمو حجم الأعمال السنوى	B -3
								الميل نحو تصحيح الأخطاء و عدم استكمال الأعمال Attitude Toward correcting Faulty and Incomplete	B -4
								Number of Repeated Works عدد الأعمال المعاده	I
								Cost of Repeated Works تكلفه الأعمال المعاده	II
								Another Suggested Objectives أهداف أخرى مقترحه	B -5
									I
									II
									III
									IV

Notes ملاحظات	V. Low ضعيفه جدا	Low ضعيفه	Average متوسطه	High عاليه	V. High عاليه جدا	No لا	Yes نعم	Past Performance of the Completed Project (Continue.) عناصر تقييم الاداء السابق للمشروعات المنتهيه (تابع)	No.
Degree of Importance درجه الاهميه						هل هذا العنصر مقياس			
								Contractor Soundness سمعه المقاول	C
								السمعه لدى ملاك المشروعات السابقه Soundness at Pervious Projects Owners	C -1
								السمعه لدى مقاولى الباطن Soundness at Pervious Subcontractors	C -2
								السمعه لدى موردى المواد Soundness at Pervious Material Suppliers	C -3
								السمعه لدى شركات الضمان Soundness at Surety Companies	C -4
								السمعه لدى شركات التأمين Soundness at Insurance Companies	C- 5
								متوسط حجم المطالبات الماليه للمشروع الواحد Average Claims Value per Project	C- 6
								Another Suggested Objectives أهداف أخرى مقترحه	C- 7
									I
									II
									III
									IV
									V
									VI

Decision Criteria Group - 3 : Financial Stability

Degree of Importance درجه الاهميه						هل هذا عنصر قياس		عناصر تقيم الاستقرار المالي Financial Stability Criteria	No.
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes		
								Bonding Capacity قدره الضمان	A-1
								Bid Bond خطاب الضمان	I
								Performance Bond ضمان التزام فى أداء التنفيذ	II
								ضمان الدفع الى الموردين و مقاولى الباطن Payment Bond	III
								Maintenance Bond ضمان الصيانه	IV
								Financial Policy سياسه التمويل	A-2
								Source of Finance مصادر التمويل	I
								Self Finance تمويل ذاتى	*
								Loans Finance تمويل بقروض	*
								Overdraft تمويل بالسحب على المكشوف	*
								Banking Arrangement الترتيبات البنكيه	A-3
								عدد البنوك المتعامل معهم فى الخمس سنوات الأخيره Number of banking partners in last five years	I
								عدد سنوات التعامل مع البنك الحالى Numbers of years associated with current bank	II
								معدل الفائده للقروض قصيره الأجل Interest rate for short term financing	III
								Level of bank debt مستوى الاقتراض من البنك	IV
								Financial Statement Data بيانات الصحيفه الماليه	A-4
								عدد المراجعين المحاسبين المتعامل معهم للخمس سنوات الأخيره Number of accounting partners in last five years	I
								عدد سنوات التعامل مع المراجع المحاسبى الحالى Numbers of years doing business with current accountant	II
								Quality of financial statement جوده الصحيفه الماليه	III
								Type of accounting method طريقه الحساب المستخدمه	IV

Degree of Importance درجه الاهميه						هل هذا عنصر قياسى		عناصر تقييم الاستقرار المالى (تابع)	
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	Financial Stability Criteria (Continue)	No.
								Tax paid الضرائب المدفوعه	V
								Financial ratios النسب الماليه	A-5
								Liquidity (Solvency) Ratios نسب السيوله	I
								Quick Ratio نسبه السيوله السريعه	*
								Current Ratio نسبه السيوله الجاريه	*
								Total Liabilities to net worth الالتزمات الكليه لرأس المال	*
								Profitability Ratios نسب الربحيه	II
								Return to equity العائد على رأس المال	*
								Return to total asset العائد الى الأصول الثابته	*
								Return to annual volume العائد الى حجم العمل السنوى	*
								Efficiency (Leverage)Ratios نسب الفاعليه	III
								Fixed assets / tangible net worth فاعليه الأصول الثابته	*
								Inventory turnover فاعليه المخزون	*
								Total Liabilities to net worth الالتزمات الجاريه لرأس المال	*
								الأعمال الحاليه الغير مكتمله الى رأس المال الفعلى Uncompleted work on hand / tangible net worth	*
								Credit level مستوى الديون	A-6
								الدائنون : الموردين و مقاولى الباطن	*
								Creditors : suppliers , subcontractors	
								Another Suggested Objects أهداف أخرى مقترحه	II
									I
									II III

A6-E

Decision Criteria Group - 4 : Current Capabilities of Contractors.

Degree of Importance درجه الاهميه						هل هذا عنصر قياس		عناصر تقييم للامكانيات الحاليه	
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	Current Capabilities Criteria	No.
								أمكانيات المقاول الحاليه Current Contractor's capabilities	A-1
								Equipment Availability's الموارد المتاحه من المعدات	I
								أنواع المعدات المتاحه Types of the Available Equipment	*
								مواصفات المعدات المتاحه Specifications of the Available Equipment	*
								تاريخ الصنع للمعدات المملوكه لدى المقاول Equipment Manufacturing Date	* *
								عدد المعدات المتاحه لكل نوع من المعدات المتاحه Number of each type of the Available Equipment	*
								Rental system of Equipment امكانيه تأجير المعدات	*
								نظام الصيانه المتبع Maintenance System for the Equipment	*
								الموارد المتاحه من القوى البشريه The Available Manpower Rescues	II
								Volume of the Skilled Labors حجم العماله الماهره	*
								Volume of the Unskilled Labors حجم العماله العاديه	*
								Total Permanent Labors حجم العماله الدائمه	*
								Total Temporary Labors حجم العماله المؤقته	*
								Volume of each Labor type حجم كل نوع من العماله	*
								متوسط الأداء لكل نوع من العماله Average Production Rate for each Labor Type	*
								Material Resources الموارد المتاحه من مواد التشييد	III
								القدره على توفير مواد التشييد Capability of Material Delivery	*
								Number of Material Suppliers عدد موردى المواد المتاح	*
								Material Suppliers types أنواع الموردين للمواد	*

ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	مترسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	عناصر تقييم للامكانيات الحاليه (تابع) Current Capabilities Criteria (Continue)	No.
								الأعتماد على مقاول الباطن Subcontractor work Dependency	IV
								حجم الاعتماد على مقاول الباطن Subcontractor Work Volume	*
								أنواع الأعمال التى يقوم بها مقاول الباطن Subcontractor work's Types	*
								نظام متابعه مقاول الباطن Subcontractor Control System	*
								Management Organization الهيكل الأدارى للمقاول	V
								مستوى الخبره لأفراد الطاقم الادارى Experience Level Management Staff	*
								الهيكل التنظيمي لطاقم الاداره Management Staff Organization	*
								Management Techniques الأساليب الأداريه المستخدمه	A-2
								Planning and Control Tech طرق التخطيط و المتابعه	I
								Computer Facilities مدى الاستفاده من الكمبيوتر	II
								Long Range Planning التخطيط بعيد المدى	III
								Current Work Load حمل العمل الحالى	A-3
								الحالى لكل مشروع حجم العمل Current Work Volume for each Project	I
								نسبه الاستكمال لكل مشروع Complete Percent for each Project	II
								سعه المقاول لأستيعاب المشروعات Contractor Capacity for Project Undertaking	A-4
								عدد المشروعات المنتهيه للمده ٣ الى ٥ سنوات الماضيه Number of Completed Projects for Last 3-5 years.	I
								حجم العمل لكل مشروع فى الفتره ٣ - ٥ سنوات الماضيه Work Volume for the Completed Projects 3-yr ago	II
								أنواع المشروعات المنتهيه و مده تنفيذها Completed Project Types & Their Duration	III

A/o-10

ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	متوسطه Average	عاليه High	عاليه جدا V. High	هل هذا عنصر قياس لا No	نعم Yes	عناصر تقييم للامكانيات الحاليه (تابع) Current Capabilities Criteria (Continue)	No.
								آسماء مالكى المشروعات المنتهيه Name of the Previous Project's Owners	IV
								Home Office Location موقع المكتب الرئيسى	A-5
								المسافه بين المكتب الرئيسى و مواقع المشروعات Distance between Home Office and Proj. locations	I
								وسائل الأتصال بين المكتب الرئيسى و مواقع المشروعات Means of Communication between H. Off. & Proj.	II
								نسبه المشاركه فى تنفيذ الأعمال Percent of Construction Execution Participant	A-6
								نسبه الأعمال المنفذه بجهود المقاول الذاتيه Participation in Work Execution Percent by the Contractor Own Force	I
								نسبه الأعمال المنفذه بواسطه مقاول الباطن Participation in Work Execution Percent by the Subcontractor	II
								Another Suggested Objects أهداف أخرى مقترحه	A-7
									I
									II
									III
									IV

Degree of Importance درجه الاهميه						هل هذا عنصر قياس		عناصر التقيم للمشروع المطلوب تنفيذه	
ملاحظات Notes	ضعيفه جدا V. Low	ضعيفه Low	مترسطه Average	عاليه High	عاليه جدا V. High	لا No	نعم Yes	Evaluation Criteria for the Proposed Project	No.
								Total Price of Proposed Bid اجمالى سعر العطاء المقدم	A-1
								السعر الأجمالى كما هو مقدم بالعطاء	I
								Total Price Bid according to Tender documents	
								تكلفه التمويل بالنسبه للمالك طبقا للبرنامج الزمنى المستهدف	II
								Cost of Finance w.r.t Owner based on proj. plan	
								خطه التنفيذ المقترحه	A-2
								Construction Execution Plan of the proposed proj.	
								Project Duration مده تنفيذ المشروع	I
								اسلوب التخطيط المستخدم	II
								Management Planning Technique Used	
								الخطط المقترحه للتنفيذ	A-3
								Proposed Plans for the Project execution	
								خطط الامان المقترحه بالمشروع	I
								Safety Plans for the proposed project	
								Quality Control Plan خطه مراقبه الجوده	II
								Project Staff Organization الهيكل التنظيمى لطاقم العمل	III
								خطه المعدات المخصصه للمشروع	IV
								Plan of the Equipment Assigned for the project	
								Manpower Plan خطه العماله المقترحه	V
								Material Supply Plan خطه توريد المواد	VI
								Payment Schedule خطه الدفعات المقترحه	VII
								Another Suggested Objects أهداف أخرى مقترحه	A-4
									I
									II
									III

Appendix - A

Sample of Blank Questionnaire Form Used in the UK

Main decision criteria groups of tender evaluation - Evaluation form:

A.1 Letter sent with questionnaires to participant

A.2 Suggested Evaluation Scale

A.3 Questionnaires related to a Contractor's Experience Record

A.4 Questionnaires related to a Contractor's Past performance

A.5 Questionnaires related to a Contractor's Financial stability

A.6 Questionnaires related to a Contractor's Current Capabilities

A.7 Questionnaires related to a Contractor's Submitted Plans to the Proposed Project

24th July 1996

Dear Sir/Madam

One of the most difficult problems faced by construction clients is the selection of the main contractor; the number of contracts that have failed by simply selecting the lowest bid is legion. My ambition is to produce a Knowledge-Based System that will help the client and their professional advisors to make a better decision leading to fewer failures and reduced overall project costs.

I am seeking your direct help with this research ambition, the results of which will be fed back to you. In order to do this I am building up a Knowledge-Based related to contract award decision-making. This information has already been collected in Egypt and Kuwait, but needs input from the UK. If you are able to complete this questionnaire and given the benefit of your experiences, I would be most grateful.

Groups of questionnaires are divided into two stages. The questionnaires of the first stage are related to the pre-qualifications of a contractor and the second is related to the tender submitted to the proposed project by that contractor. For these questions/decision criteria in the following pages, please tick the column that most closely agrees with your experiences.

This questionnaire survey is a part of my research at the University of Southampton. I would like to thank you for your time and effort. Additional notes or suggestion regarding the questions would be most welcome. A free post envelope is provided to return the questionnaires. Your answer will be treated as strictly confidential. If you want your enterprise name to credit in the final research report add it to the end of the questionnaires.

Thank you again for your help.

You're Sincerely

I. Moustafa

All the questions below relate to the evaluation process carried out by the client to select the main contractor by competitive bid. Please tick the column that most closely agrees with your experience.

Main Five Decision Groups of Tender Evaluation:

Main Decision Criteria Groups	**Very High**	**High**	**Average**	**Low**	**Very Low**	**No**	**Notes**
Contractor's Experience Record							
Past Performance Level of the Contractor							
Contractor's Financial Stability							
Contractor's Current Capabilities							
Submitted Plans for the Proposed Project by the Contractor							

Note:
The degree of importance scale suggested as following:

Degree of Importance	**Evaluation Scale**
Very High	5
High	4
Average	3
Low	2
Very Low	1
No	0

Questionnaire related to a contractor's experience record

Criteria Description	Very High	High	Avg.	Low	Very Low	No	Notes
Number of Years Working in Similar Projects							
Contractor Age in Construction							
Maximum Project Delivery Rate within Last 3 yr. (Work value [£] / Project Duration)							
Total Work Value [£] in Similar Projects within Last 10 yr.							
Average Work Value [£] in Similar Projects - Last 5 Years							
Average Work Volume [£] in Construction Projects - Last 5 Years							
Contract Types of Pervious Similar Projects (Risk Share)							
Pervious Project Types (Diversity of experience in Construction)							
Total Work Value [£] in Similar Projects With Current Owner							
Total Work Value [£] in Dissimilar Projects With Current Owner							
Total Work Value [£] in Similar Projects With Similar Weather Condition							
Total Work Value [£] in Similar Projects With Similar Geographical Condition							
Total Work Value [£] in Similar Projects With Dissimilar Geographical Condition							
Other Suggested Criteria							

Questionnaire related to a contractor's past performance record

Criteria Description	Very High	High	Avg.	Low	Very Low	No	Notes
Ability to Meet Project Schedule as Planned Similar Projects Last 5 years							
Meeting Project Budget of Completed Similar Projects							
Meeting Project Quality of Completed Similar Projects							
Approved Quality Control Plans and Quality Assurance of Completed Projects							
Test Results of Completed Similar Projects							
Has previous work projects with the current owner							
Technical Competence Level in Construction for the Last 3 yr.							
Willingness of correcting Faulty Attitude in Similar Projects							
Safety Record Last 3 years							
Reputation with Previous Clients							
Reputation with suppliers							
Reputation with Subcontracting Contractors							
Reputation with Insurance Companies							
Average Value of Claims as a % of Previous Projects							
Other Suggested Criteria							

Questionnaire related to the contractor's financial stability

Criteria Description	Very High	High	Avg.	Low	Very Low	No	Notes
Bid Bond							
Performance Bond							
Maintenance Bond							
Financial Policy							
Source of Finance							
Cost of Finance							
Credit Level							
Financial Statement							
Status of Audited Financial Statement							
Liquidity Ratios (Solvency Ratios)							
Quick Ratios							
Current Ratios							
Leverage Ratios							
Total Liabilities / Tangible Net worth							
Hard Debt / Tangible Net worth							
Other Suggested Criteria							

Questionnaire related to the contractor's current capability

Criteria Description	Very High	High	Avg.	Low	Very Low	No	Notes
Current Work Value							
Available Resources							
Types of the available equipment							
Number of the available equipment							
Specifications of the available equipment							
Maintenance System available for the equipment							
Manpower work volume (skilled Labour) per each craft type							
Capability of material delivery							
Management Staff Organization Structure							
Experience Level of the Management Staff & their educational level							
Applied Management Technique							
Applied Management Technique							
Subcontracting work type							
Subcontracting work Value							
Contractor's Current Capacity to Carry an additional Work							
Percent Complete of Current Projects							
Other Suggested Criteria							

Questionnaire related to the contractor's submitted plans for the proposed project

Criteria Description	Very High	High	Avg.	Low	Very Low	No	Notes
Total Bid Amount							
Total Project duration							
Sub-Contractor Work Value							
Safety Plan Level							
Quality Assurance Plan Level							
Equipment Plan							
Manpower Plan							
Management Staff Experience Level							
Management Staff Organization Level							
Other Suggested Criteria							

Appendix - B

Statistical Results of Questionnaire Survey on the Basis of SPSS Program

B.1 HEgt - Heavy projects in Egypt

B.2 HKwt - Heavy projects in Kuwait

B.3 HUK - Heavy projects in the United Kingdom

B.4 BEgt - Building projects in Egypt

B.5 BKwt - Building projects in Kuwait

B.6 BUK - Building projects in the United Kingdom

HEgt: Decision Criteria Evaluation Results-Heavy

Level 0		
DCG1	18.4%*	83.87%**
DCG2	19.20%	87.50%
DCG3	19.77%	90.12%
DCG4	21.94%	100.00%
DCG5	20.70%	94.35%

Level 1		
DCG1.01	1.32%	95.50%
DCG1.02	1.14%	82.44%
DCG1.03	1.08%	77.94%
DCG1.04	0.71%	48.67%
DCG1.05	1.28%	92.72%
DCG1.06	0.73%	51.09%
DCG1.07	1.38%	100.00%
DCG1.08	1.16%	83.94%
DCG1.09	1.18%	85.44%
DCG1.10	0.67%	48.17%
DCG1.11	1.11%	80.09%
DCG1.12	1.24%	89.51%
DCG1.13	1.04%	75.16%
DCG1.14	0.90%	65.31%
DCG1.15	0.75%	54.39%
DCG1.16	1.11%	80.09%
DCG1.17	0.91%	65.95%
DCG2.01	3.20%	93.50%
DCG2.02	3.09%	90.36%
DCG2.03	34.20%	100.00%
DCG2.04	2.90%	84.91%
DCG2.05	3.36%	98.32%
DCG2.06	3.23%	94.55%
DCG3.01	3.58%	99.32%
DCG3.02	3.61%	100.00%
DCG3.03	2.64%	73.24%
DCG3.04	3.42%	94.78%
DCG3.05	3.30%	91.38%
DCG3.06	3.23%	89.57%
DCG4.01	6.04%	100.00%
DCG4.02	4.94%	81.74%
DCG4.03	5.20%	86.10%
DCG4.04	5.75%	95.23%
DCG5.01	7.27%	100.00%
DCG5.02	6.89%	95.93%
DCG5.03	6.45%	88.62%

Level 2		
DCG2.01.1	0.45%	97.68%
DCG2.01.2	0.47%	100.00%
DCG2.03.1	0.91%	92.02%
DCG2.03.2	0.85%	86.62%
DCG2.03.3	0.67%	68.08%
DCG2.03.4	0.99%	100.00%
DCG2.04.1	1.57%	100.00%
DCG2.04.2	1.33%	84.46%
DCG2.05.1	1.05%	100.00%
DCG2.05.2	0.73%	70.20%
DCG2.05.3	0.70%	66.60%
DCG2.05.4	0.88%	84.20%
DCG3.01.1	0.94%	94.99%
DCG3.01.2	0.99%	100.00%
DCG3.01.3	0.76%	77.34%
DCG3.01.4	0.90%	91.07%
DCG3.02.1	0.89%	87.00%
DCG3.02.2	0.83%	81.76%
DCG3.02.3	0.87%	85.53%
DCG3.02.4	1.02%	100.00%
DCG3.03.1	0.70%	59.95%
DCG3.03.2	0.78%	66.94%
DCG3.04.1	1.16%	100.00%
DCG3.04.2	0.76%	44.67%
DCG3.05.1	0.86%	51.47%
DCG3.05.2	1.68%	100.00%
DCG3.06.1	0.56%	96.30%
DCG3.06.2	0.58%	100.00%
DCG3.06.3	0.57%	98.77%
DCG3.06.4	0.58%	100.00%
DCG3.06.5	0.46%	79.75%
DCG3.06.6	0.47%	81.73%
DCG4.01.1	1.94%	100.00%
DCG4.01.2	1.21%	62.09%
DCG4.01.3	1.40%	72.11%
DCG4.01.4	1.49%	76.47%
DCG4.02.1	1.69%	100.00%
DCG4.02.2	1.68%	99.49%
DCG4.02.3	1.57%	93.11%
DCG4.02.4	1.68%	93.70%
DCG4.02.5	1.53%	82.40%
DCG4.03.1	1.57%	73.21%
DCG4.03.2	2.50%	92.64%
DCG4.03.3	2.70%	100.00%
DCG4.04.1	1.07%	100.00%
DCG4.04.2	0.99%	92.40%
DCG4.04.3	0.95%	89.22%
DCG4.04.4	0.90%	84.80%

Level 2 (continue....)		
DCG4.04.5	0.88%	82.84%
DCG4.04.6	0.96%	90.44%
DCG5.01.1	3.85%	100.00%
DCG5.01.2	3.42%	88.80%
DCG5.02.1	2.45%	100.00%
DCG5.02.2	2.33%	95.07%
DCG5.02.3	2.21%	90.15%
DCG5.03.1	0.39%	100.00%
DCG5.03.2	0.84%	46.43%
DCG5.03.3	0.82%	91.90%
DCG5.03.4	0.66%	73.35%
DCG5.03.5	0.85%	94.67%
DCG5.03.6	0.80%	89.77%
DCG5.03.7	0.74%	83.16%
DCG5.03.8	0.84%	94.03%

Level 3		
DCG2.04.1.1	0.81%	100.00%
DCG2.04.1.2	0.76%	94.41%
DCG2.04.2.1	0.81%	99.88%
DCG2.04.2.2	0.52%	64.31%
DCG3.05.1.1	0.15%	83.93%
DCG3.05.1.2	0.15%	83.93%
DCG3.05.2.1	0.17%	100.00%
DCG3.05.2.2	0.22%	84.25%
DCG3.06.6.1	0.26%	100.00%
DCG4.01.1.1	0.46%	100.00%
DCG4.01.1.2	0.42%	91.56%
DCG4.01.1.3	0.35%	75.54%
DCG4.01.1.4	0.39%	84.42%
DCG4.01.1.5	0.34%	73.81%
DCG4.01.2.1	0.28%	100.00%
DCG4.01.2.2	0.15%	55.79%
DCG4.01.2.3	0.21%	76.49%
DCG4.01.2.4	0.17%	62.81%
DCG4.01.2.5	0.19%	68.42%
DCG4.01.3.1	0.59%	100.00%
DCG4.01.3.2	0.47%	79.46%
DCG4.01.3.3	0.35%	59.52%
DCG4.01.4.1	0.39%	100.00%
DCG4.01.4.2	0.37%	95.35%
DCG4.01.4.3	0.35%	89.53%
DCG4.02.3.1	0.62%	100.00%
DCG4.04.6.1	0.52%	83.82%
DCG4.04.6.2	0.43%	68.79%

* The values in the 1st column next to each criterion reprsents its weight as % of the total criteria group(s) weights

** The values in the 2nd column next to each criterion reprsents its weight as % of the Maximum criterion's weight within the group(s)

HKwt: Decision Criteria Evaluation Results-Heavy			Level 2			Level 2 (continue....)		
Level 0			DCG2.01.1	0.72%	91.54%	DCG4.04.5	0.83%	76.46%
DCG1	18.45%	86.54%	DCG2.01.2	0.79%	100.00%	DCG4.04.6	0.97%	89.87%
DCG2	19.95%	93.37%	DCG2.03.1	0.91%	100.00%			
DCG3	20.08%	94.20%	DCG2.03.2	0.86%	94.84%	DCG5.01.1	3.56%	100.00%
DCG4	21.32%	100.00%	DCG2.03.3	0.73%	80.99%	DCG5.01.2	3.18%	89.29%
DCG5	20.26%	95.03%	DCG2.03.4	0.81%	89.44%	DCG5.02.1	2.45%	100.00%
			DCG2.04.1	1.33%	86.56%	DCG5.02.2	2.21%	90.55%
			DCG2.04.2	1.54%	100.00%	DCG5.02.3	2.29%	93.70%
			DCG2.05.1	1.00%	100.00%	DCG5.03.1	0.47%	48.24%
Level 1			DCG2.05.2	0.92%	92.46%	DCG5.03.2	0.86%	99.35%
DCG1.01	1.34%	100.00%	DCG2.05.3	0.94%	93.57%	DCG5.03.3	0.87%	99.78%
DCG1.02	0.93%	69.46%	DCG2.05.4	0.82%	81.60%	DCG5.03.4	0.73%	83.44%
DCG1.03	1.13%	84.38%				DCG5.03.5	0.87%	100.00%
DCG1.04	0.51%	38.28%	DCG3.01.1	0.97%	89.98%	DCG5.03.6	0.85%	97.17%
DCG1.05	1.05%	78.32%	DCG3.01.2	1.08%	100.00%	DCG5.03.7	0.80%	91.72%
DCG1.06	0.83%	62.00%	DCG3.01.3	0.93%	86.27%	DCG5.03.8	0.82%	94.34%
DCG1.07	0.91%	67.83%	DCG3.01.4	0.96%	89.32%			
DCG1.08	1.14%	85.08%	DCG3.02.1	0.89%	96.90%			
DCG1.09	1.07%	79.72%	DCG3.02.2	0.92%	100.00%	**Level 3**		
DCG1.10	1.28%	95.34%	DCG3.02.3	0.90%	98.09%	DCG2.04.1.1	0.66%	98.38%
DCG1.11	1.03%	76.92%	DCG3.02.4	0.83%	89.98%	DCG2.04.1.2	0.67%	100.00%
DCG1.12	0.91%	67.83%	DCG3.03.1	1.01%	93.42%	DCG2.04.2.1	0.82%	100.00%
DCG1.13	1.60%	86.01%	DCG3.03.2	1.08%	100.00%	DCG2.04.2.2	0.71%	86.61%
DCG1.14	1.12%	83.92%	DCG3.04.1	1.05%	96.55%			
DCG1.15	0.79%	46.27%	DCG3.04.2	0.82%	68.89%	DCG3.05.1.1	0.16%	100.00%
DCG1.16	1.22%	90.91%	DCG3.05.1	0.85%	71.72%	DCG3.05.1.2	0.16%	100.00%
DCG1.17	0.95%	70.86%	DCG3.05.2	1.19%	100.00%	DCG3.05.2.1	0.15%	98.55%
			DCG3.06.1	0.45%	93.96%	DCG3.05.2.2	0.22%	100.00%
DCG2.01	3.52%	95.69%	DCG3.06.2	0.47%	96.43%	DCG3.06.6.1	0.21%	94.63%
DCG2.02	3.23%	87.72%	DCG3.06.3	0.46%	95.33%			
DCG2.03	3.31%	90.09%	DCG3.06.4	0.48%	100.00%			
DCG2.04	2.87%	78.02%	DCG3.06.5	0.46%	96.15%	DCG4.01.1.1	0.41%	100.00%
DCG2.05	3.68%	100.00%	DCG3.06.6	0.43%	89.29%	DCG4.01.1.2	0.40%	97.29%
DCG2.06	3.30%	89.66%				DCG4.01.1.3	0.38%	91.67%
			DCG4.01.1	1.92%	100.00%	DCG4.01.1.4	0.38%	91.88%
DCG3.01	3.94%	100.00%	DCG4.01.2	1.13%	58.52%	DCG4.01.1.5	0.36%	86.25%
DCG3.02	3.54%	89.87%	DCG4.01.3	1.58%	82.34%	DCG4.01.2.1	0.21%	100.00%
DCG3.03	3.14%	79.74%	DCG4.01.4	1.39%	72.28%	DCG4.01.2.2	0.18%	84.27%
DCG3.04	3.82%	96.92%	DCG4.02.1	1.63%	100.00%	DCG4.01.2.3	0.17%	78.28%
DCG3.05	2.87%	72.69%	DCG4.02.2	1.51%	92.65%	DCG4.01.2.4	0.18%	83.52%
DCG3.06	2.76%	70.04%	DCG4.02.3	1.53%	93.84%	DCG4.01.2.5	0.19%	91.76%
			DCG4.02.4	1.81%	95.20%	DCG4.01.3.1	0.20%	93.26%
DCG4.01	6.03%	100.00%	DCG4.02.5	1.69%	85.09%	DCG4.01.3.2	0.62%	100.00%
DCG4.02	4.68%	77.69%	DCG4.03.1	2.53%	97.86%	DCG4.01.3.3	0.49%	79.60%
DCG4.03	5.12%	84.99%	DCG4.03.2	2.59%	100.00%	DCG4.01.4.1	0.47%	76.32%
DCG4.04	5.49%	91.08%	DCG4.03.3	0.00%	0.00%	DCG4.01.4.2	0.30%	58.92%
			DCG4.04.1	1.08%	100.00%	DCG4.01.4.3	0.35%	62.27%
DCG5.01	6.74%	97.00%	DCG4.04.2	1.01%	92.91%	DCG4.02.3.1	0.35%	61.94%
DCG5.02	6.95%	100.00%	DCG4.04.3	0.83%	76.20%	DCG4.04.6.1	0.35%	61.60%
DCG5.03	6.56%	94.42%	DCG4.04.4	0.77%	71.39%	DCG4.04.6.2	0.57%	100.00%

HUK: Decision Criteria Evaluation Results-Heavy

Level 0		
DCG1	19.58%	90.29%
DCG2	21.68%	100.00%
DCG3	19.58%	90.29%
DCG4	18.89%	87.13%
DCG5	20.26%	93.45%

Level 1		
DCG1.01	1.59%	92.75%
DCG1.02	1.23%	7.15%
DCG1.03	1.41%	82.25%
DCG1.04	0.00%	0.00%
DCG1.05	1.47%	85.75%
DCG1.06	0.00%	0.00%
DCG1.07	1.35%	78.50%
DCG1.08	1.16%	67.75%
DCG1.09	1.53%	89.25%
DCG1.10	0.00%	0.00%
DCG1.11	1.16%	67.75%
DCG1.12	1.71%	100.00%
DCG1.13	1.29%	75.00%
DCG1.14	1.35%	78.50%
DCG1.15	0.00%	0.00%
DCG1.16	1.41%	82.25%
DCG1.17	1.16%	67.75%
DCG2.01	3.57%	86.12%
DCG2.02	3.86%	93.15%
DCG2.03	4.14%	100.00%
DCG2.04	3.57%	86.12%
DCG2.05	2.97%	71.81%
DCG2.06	3.42%	82.61%
DCG3.01	2.60%	55.56%
DCG3.02	3.07%	65.46%
DCG3.03	3.24%	69.08%
DCG3.04	3.24%	69.08%
DCG3.05	4.69%	100.00%
DCG3.06	2.75%	58.70%
DCG4.01	4.95%	96.62%
DCG4.02	5.12%	100.00%
DCG4.03	4.24%	82.85%
DCG4.04	4.59%	89.61%
DCG5.01	7.52%	100.00%
DCG5.02	6.68%	88.71%
DCG5.03	6.06%	80.59%

Level 2		
DCG2.01.1	2.68%	100.00%
DCG2.01.2	0.00%	0.00%
DCG2.03.1	1.27%	85.23%
DCG2.03.2	1.16%	77.72%
DCG2.03.3	0.39%	0.00%
DCG2.03.4	1.49%	100.00%
DCG2.04.1	1.81%	100.00%
DCG2.04.2	1.75%	96.50%
DCG2.05.1	0.87%	100.00%
DCG2.05.2	0.71%	81.85%
DCG2.05.3	0.71%	81.85%
DCG2.05.4	0.67%	77.39%
DCG3.01.1	0.61%	82.53%
DCG3.01.2	0.93%	125.33%
DCG3.01.3	0.74%	100.00%
DCG3.01.4	0.00%	0.00%
DCG3.02.1	1.16%	100.00%
DCG3.02.2	0.98%	84.50%
DCG3.02.3	0.83%	66.90%
DCG3.02.4	0.00%	0.00%
DCG3.03.1	0.00%	0.00%
DCG3.03.2	0.00%	0.00%
DCG3.04.1	0.00%	0.00%
DCG3.04.2	0.74%	100.00%
DCG3.05.1	0.00%	0.00%
DCG3.05.2	3.20%	100.00%
DCG3.06.1	0.63%	85.67%
DCG3.06.2	0.00%	0.00%
DCG3.06.3	0.00%	0.00%
DCG3.06.4	0.00%	0.00%
DCG3.06.5	0.00%	0.00%
DCG3.06.6	0.00%	0.00%
DCG4.01.1	1.19%	87.96%
DCG4.01.2	1.30%	96.08%
DCG4.01.3	1.09%	80.11%
DCG4.01.4	1.36%	100.00%
DCG4.02.1	1.70%	89.61%
DCG4.02.2	1.90%	100.00%
DCG4.02.3	1.51%	79.47%
DCG4.02.4	1.72%	91.35%
DCG4.02.5	1.58%	87.50%
DCG4.03.1	2.21%	100.00%
DCG4.03.2	2.01%	90.95%
DCG4.03.3	2.03%	91.55%
DCG4.04.1	0.61%	41.15%
DCG4.04.2	0.61%	41.15%
DCG4.04.3	0.61%	41.15%
DCG4.04.4	0.61%	41.15%

Level 2 (Continue....)		
DCG4.04.5	1.47%	100.00%
DCG4.04.6	0.99%	67.34%
DCG5.01.1	4.41%	100.00%
DCG5.01.2	3.11%	70.58%
DCG5.02.1	2.31%	100.00%
DCG5.02.2	2.31%	100.00%
DCG5.02.3	2.05%	88.86%
DCG5.03.1	0.34%	41.35%
DCG5.03.2	0.91%	100.00%
DCG5.03.3	0.91%	100.00%
DCG5.03.4	0.71%	77.72%
DCG5.03.5	0.78%	85.23%
DCG5.03.6	0.74%	81.35%
DCG5.03.7	0.91%	100.00%
DCG5.03.8	0.71%	77.72%

Level 3		
DCG2.04.1.1	0.91%	100.00%
DCG2.04.1.2	0.91%	100.00%
DCG2.04.2.1	0.88%	100.00%
DCG2.04.2.2	0.88%	100.00%
DCG3.05.1.1	0.33%	100.00%
DCG3.05.1.2	0.27%	81.00%
DCG3.05.2.1	0.13%	38.00%
DCG3.05.2.2	0.13%	38.89%
DCG3.06.6.1	0.11%	34.11%
DCG4.01.1.1	0.26%	100.00%
DCG4.01.1.2	0.25%	94.83%
DCG4.01.1.3	0.22%	84.50%
DCG4.01.1.4	0.25%	94.83%
DCG4.01.1.5	0.22%	84.50%
DCG4.01.2.1	0.15%	43.00%
DCG4.01.2.2	0.15%	43.00%
DCG4.01.2.3	0.34%	95.33%
DCG4.01.2.4	0.15%	43.00%
DCG4.01.2.5	0.36%	100.00%
DCG4.01.3.1	0.15%	43.00%
DCG4.01.3.2	0.64%	100.00%
DCG4.01.3.3	0.22%	34.97%
DCG4.01.4.1	0.22%	34.97%
DCG4.01.4.2	0.00%	0.00%
DCG4.01.4.3	0.50%	100.00%
DCG4.02.3.1	0.16%	31.85%
DCG4.04.6.1	0.53%	100.00%
DCG4.04.6.2	0.20%	41.08%

BEgt: Decision Criteria Evaluation Results

Level 0		
DCG1	18.31%	84.21%
DCG2	19.32%	88.87%
DCG3	19.72%	90.69%
DCG4	21.74%	100.00%
DCG5	20.91%	96.15%
Level 1		
DCG1.01	1.34%	100.00%
DCG1.02	0.95%	70.88%
DCG1.03	0.99%	73.97%
DCG1.04	0.00%	0.00%
DCG1.05	1.12%	83.76%
DCG1.06	0.00%	0.00%
DCG1.07	1.17%	87.11%
DCG1.08	1.02%	75.77%
DCG1.09	1.17%	87.11%
DCG1.10	0.00%	0.00%
DCG1.11	0.99%	73.97%
DCG1.12	1.34%	100.00%
DCG1.13	1.08%	80.67%
DCG1.14	1.08%	80.67%
DCG1.15	0.00%	0.00%
DCG1.16	0.95%	70.88%
DCG1.17	0.86%	64.43%
DCG2.01	3.18%	92.93%
DCG2.02	3.08%	90.23%
DCG2.03	3.42%	100.00%
DCG2.04	2.98%	87.11%
DCG2.05	3.38%	98.75%
DCG2.06	3.29%	96.26%
DCG3.01	3.51%	99.31%
DCG3.02	3.53%	100.00%
DCG3.03	2.57%	72.81%
DCG3.04	3.41%	96.54%
DCG3.05	3.26%	92.17%
DCG3.06	1.44%	47.24%
DCG4.01	5.24%	93.11%
DCG4.02	5.40%	96.00%
DCG4.03	5.48%	97.33%
DCG4.04	5.63%	100.00%
DCG5.01	7.35%	100.00%
DCG5.02	7.08%	96.35%
DCG5.03	6.47%	88.03%

Level 2		
DCG2.01.1	0.38%	45.37%
DCG2.01.2	0.34%	41.31%
DCG2.03.1	0.95%	97.61%
DCG2.03.2	0.82%	84.25%
DCG2.03.3	0.25%	23.88%
DCG2.03.4	0.97%	100.00%
DCG2.04.1	1.01%	100.00%
DCG2.04.2	0.88%	86.45%
DCG2.05.1	1.03%	100.00%
DCG2.05.2	0.74%	71.80%
DCG2.05.3	0.73%	70.60%
DCG2.05.4	0.88%	85.60%
DCG3.01.1	0.92%	95.05%
DCG3.01.2	0.96%	100.00%
DCG3.01.3	0.35%	47.93%
DCG3.01.4	0.88%	91.44%
DCG3.02.1	0.86%	86.40%
DCG3.02.2	0.79%	79.71%
DCG3.02.3	1.00%	100.00%
DCG3.02.4	0.63%	44.63%
DCG3.03.1	0.38%	30.16%
DCG3.03.2	0.46%	36.94%
DCG3.04.1	0.73%	44.63%
DCG3.04.2	0.69%	38.44%
DCG3.05.1	1.64%	100.00%
DCG3.05.2	1.62%	99.07%
DCG3.06.1	0.51%	94.86%
DCG3.06.2	0.54%	100.00%
DCG3.06.3	0.53%	97.43%
DCG3.06.4	0.52%	96.50%
DCG3.06.5	0.39%	72.20%
DCG3.06.6	0.40%	73.13%
DCG4.01.1	1.18%	76.64%
DCG4.01.2	1.53%	100.00%
DCG4.01.3	1.10%	71.50%
DCG4.01.4	1.43%	93.46%
DCG4.02.1	1.87%	100.00%
DCG4.02.2	1.18%	76.64%
DCG4.02.3	1.10%	71.50%
DCG4.02.4	1.84%	98.20%
DCG4.02.5	1.69%	90.09%
DCG4.03.1	0.00%	0.00%
DCG4.03.2	2.64%	93.41%
DCG4.03.3	2.83%	100.00%
DCG4.04.1	1.03%	100.00%
DCG4.04.2	0.98%	94.58%
DCG4.04.3	0.94%	90.89%
DCG4.04.4	0.89%	86.21%

Level 2		
DCG4.04.5	0.83%	80.54%
DCG4.04.6	0.95%	92.36%
DCG5.01.1	3.91%	100.00%
DCG5.01.2	3.45%	88.20%
DCG5.02.1	2.51%	100.00%
DCG5.02.2	2.31%	91.90%
DCG5.02.3	1.13%	44.32%
DCG5.03.1	0.90%	100.00%
DCG5.03.2	0.87%	95.90%
DCG5.03.3	0.63%	69.55%
DCG5.03.4	0.85%	93.74%
DCG5.03.5	0.83%	91.79%
DCG5.03.6	0.82%	91.14%
DCG5.03.7	0.73%	80.99%
DCG5.03.8	0.85%	93.74%
Level 3		
DCG2.04.1.1	0.51%	100.00%
DCG2.04.1.2	0.35%	65.14%
DCG2.04.2.1	0.50%	99.02%
DCG2.04.2.2	0.51%	100.00%
DCG3.05.1.1	0.12%	0.00%
DCG3.05.1.2	0.12%	0.00%
DCG3.05.2.1	0.15%	0.00%
DCG3.05.2.2	0.17%	0.00%
DCG3.06.6.1	0.22%	0.00%
DCG4.01.1.1	0.30%	100.00%
DCG4.01.1.2	0.24%	81.70%
DCG4.01.1.3	0.20%	67.32%
DCG4.01.1.4	0.22%	75.49%
DCG4.01.1.5	0.21%	72.55%
DCG4.01.2.1	0.32%	100.00%
DCG4.01.2.2	0.21%	64.95%
DCG4.01.2.3	0.26%	81.07%
DCG4.01.2.4	0.23%	71.50%
DCG4.01.2.5	0.25%	77.34%
DCG4.01.3.1	0.48%	100.00%
DCG4.01.3.2	0.34%	71.00%
DCG4.01.3.3	0.28%	58.33%
DCG4.01.4.1	0.38%	100.00%
DCG4.01.4.2	0.37%	97.12%
DCG4.01.4.3	0.33%	86.09%
DCG4.02.3.1	0.65%	100.00%
DCG4.04.6.1	0.58%	89.49%
DCG4.04.6.2	0.45%	69.44%

BKwt: Decision Criteria Evaluation Results

Level 0		
DCG1	18.67%	87.87%
DCG2	19.80%	93.19%
DCG3	19.94%	93.83%
DCG4	21.25%	100.00%
DCG5	20.34%	95.74%
Level 1		
DCG1.01	1.36%	100.00%
DCG1.02	1.28%	94.05%
DCG1.03	1.02%	74.83%
DCG1.04	0.97%	71.40%
DCG1.05	1.18%	86.50%
DCG1.06	1.13%	83.07%
DCG1.07	1.32%	97.03%
DCG1.08	1.24%	91.30%
DCG1.09	0.93%	67.96%
DCG1.10	0.91%	66.59%
DCG1.11	1.18%	86.50%
DCG1.12	1.11%	81.46%
DCG1.13	1.06%	77.80%
DCG1.14	0.82%	59.95%
DCG1.15	0.88%	64.53%
DCG1.16	1.19%	87.41%
DCG1.17	1.08%	79.18%
DCG2.01	3.50%	95.32%
DCG2.02	3.11%	84.68%
DCG2.03	3.26%	88.94%
DCG2.04	2.91%	79.36%
DCG2.05	3.67%	100.00%
DCG2.06	3.36%	91.70%
DCG3.01	3.94%	100.00%
DCG3.02	3.63%	91.99%
DCG3.03	3.09%	78.35%
DCG3.04	3.75%	95.02%
DCG3.05	2.74%	69.48%
DCG3.06	1.80%	49.00%
DCG4.01	4.31%	72.83%
DCG4.02	5.42%	91.52%
DCG4.03	5.59%	94.35%
DCG4.04	5.92%	100.00%
DCG5.01	6.79%	98.28%
DCG5.02	6.91%	100.00%
DCG5.03	6.64%	96.12%

Level 2		
DCG2.01.1	1.72%	97.24%
DCG2.01.2	1.77%	100.00%
DCG2.03.1	0.91%	100.00%
DCG2.03.2	0.83%	91.12%
DCG2.03.3	0.46%	38.74%
DCG2.03.4	0.81%	89.49%
DCG2.04.1	0.82%	84.00%
DCG2.04.2	0.98%	100.00%
DCG2.05.1	0.98%	100.00%
DCG2.05.2	0.93%	95.18%
DCG2.05.3	0.95%	96.93%
DCG2.05.4	0.81%	82.89%
DCG3.01.1	0.99%	93.51%
DCG3.01.2	1.06%	100.00%
DCG3.01.3	0.42%	46.58%
DCG3.01.4	0.97%	91.99%
DCG3.02.1	0.93%	97.41%
DCG3.02.2	0.95%	100.00%
DCG3.02.3	0.92%	96.94%
DCG3.02.4	0.52%	46.35%
DCG3.03.1	0.99%	92.73%
DCG3.03.2	1.07%	100.00%
DCG3.04.1	1.27%	100.00%
DCG3.04.2	0.73%	44.63%
DCG3.05.1	0.83%	75.45%
DCG3.05.2	1.10%	100.00%
DCG3.06.1	0.39%	93.62%
DCG3.06.2	0.40%	94.68%
DCG3.06.3	0.39%	93.62%
DCG3.06.4	0.42%	100.00%
DCG3.06.5	0.40%	95.48%
DCG3.06.6	0.36%	85.90%
DCG4.01.1	0.85%	68.14%
DCG4.01.2	1.25%	100.00%
DCG4.01.3	1.08%	86.50%
DCG4.01.4	1.13%	90.27%
DCG4.02.1	1.87%	100.00%
DCG4.02.2	1.77%	94.41%
DCG4.02.3	1.78%	94.84%
DCG4.02.4	1.84%	98.20%
DCG4.02.5	1.69%	90.09%
DCG4.03.1	0.00%	0.00%
DCG4.03.2	2.78%	99.31%
DCG4.03.3	2.80%	100.00%
DCG4.04.1	1.15%	100.00%
DCG4.04.2	1.07%	92.68%
DCG4.04.3	0.92%	79.76%
DCG4.04.4	0.83%	72.44%

Level 2 (continue....)		
DCG4.04.5	0.90%	78.29%
DCG4.04.6	1.05%	91.46%
DCG5.01.1	3.65%	100.00%
DCG5.01.2	3.14%	86.23%
DCG5.02.1	2.44%	100.00%
DCG5.02.2	2.20%	90.15%
DCG5.02.3	1.17%	47.95%
DCG5.03.1	0.44%	48.83%
DCG5.03.2	0.90%	100.00%
DCG5.03.3	0.69%	77.28%
DCG5.03.4	0.88%	97.66%
DCG5.03.5	0.86%	95.75%
DCG5.03.6	0.86%	96.18%
DCG5.03.7	0.81%	89.81%
DCG5.03.8	0.85%	94.06%
Level 3		
DCG2.04.1.1	0.40%	97.12%
DCG2.04.1.2	0.42%	100.00%
DCG2.04.2.1	0.45%	100.00%
DCG2.04.2.2	0.43%	95.50%
DCG3.05.1.1	0.13%	99.44%
DCG3.05.1.2	0.14%	100.00%
DCG3.05.2.1	0.13%	98.87%
DCG3.05.2.2	0.18%	100.00%
DCG3.06.6.1	0.18%	98.49%
DCG4.01.1.1	0.20%	100.00%
DCG4.01.1.2	0.18%	89.80%
DCG4.01.1.3	0.16%	80.82%
DCG4.01.1.4	0.16%	80.82%
DCG4.01.1.5	0.15%	73.47%
DCG4.01.2.1	0.23%	100.00%
DCG4.01.2.2	0.21%	93.60%
DCG4.01.2.3	0.19%	86.53%
DCG4.01.2.4	0.20%	88.52%
DCG4.01.2.5	0.21%	92.94%
DCG4.01.3.1	0.44%	100.00%
DCG4.01.3.2	0.32%	72.87%
DCG4.01.3.3	0.32%	72.09%
DCG4.01.4.1	0.28%	95.98%
DCG4.01.4.2	0.28%	98.58%
DCG4.01.4.3	0.29%	100.00%
DCG4.02.3.1	0.67%	100.00%
DCG4.04.6.1	0.59%	88.33%
DCG4.04.6.2	0.52%	76.87%

BUK: Decision Criteria Evaluation Results

Level 0		
DCG1	19.08%	90.36%
DCG2	21.12%	100.00%
DCG3	21.02%	99.52%
DCG4	19.69%	93.25%
DCG5	19.08%	90.36%
Level 1		
DCG1.01	1.59%	100.00%
DCG1.02	1.12%	70.88%
DCG1.03	1.17%	73.97%
DCG1.04	0.00%	0.00%
DCG1.05	1.33%	83.76%
DCG1.06	0.00%	0.00%
DCG1.07	1.38%	87.11%
DCG1.08	1.20%	75.77%
DCG1.09	1.38%	87.11%
DCG1.10	0.00%	0.00%
DCG1.11	1.17%	73.97%
DCG1.12	1.59%	100.00%
DCG1.13	1.28%	80.67%
DCG1.14	1.28%	80.67%
DCG1.15	0.00%	0.00%
DCG1.16	1.12%	70.88%
DCG1.17	1.02%	64.43%
DCG2.01	3.52%	95.18%
DCG2.02	3.69%	100.00%
DCG2.03	3.52%	95.18%
DCG2.04	3.63%	98.22%
DCG2.05	3.52%	95.18%
DCG2.06	3.17%	85.79%
DCG3.01	4.06%	86.93%
DCG3.02	3.90%	83.47%
DCG3.03	3.27%	70.13%
DCG3.04	2.80%	60.00%
DCG3.05	4.67%	100.00%
DCG3.06	2.14%	48.13%
DCG4.01	4.72%	87.50%
DCG4.02	5.39%	100.00%
DCG4.03	5.23%	97.00%
DCG4.04	4.38%	81.25%
DCG5.01	7.09%	100.00%
DCG5.02	6.10%	86.00%
DCG5.03	5.91%	83.33%

Level 2		
DCG2.01.1	0.00%	0.00%
DCG2.01.2	0.00%	0.00%
DCG2.03.1	1.14%	90.13%
DCG2.03.2	0.97%	76.80%
DCG2.03.3	0.00%	0.00%
DCG2.03.4	1.26%	100.00%
DCG2.04.1	1.18%	93.75%
DCG2.04.2	1.26%	100.00%
DCG2.05.1	1.26%	100.00%
DCG2.05.2	0.87%	68.87%
DCG2.05.3	0.74%	58.68%
DCG2.05.4	0.91%	72.18%
DCG3.01.1	1.06%	70.50%
DCG3.01.2	1.50%	100.00%
DCG3.01.3	0.56%	37.17%
DCG3.01.4	0.95%	63.13%
DCG3.02.1	1.47%	100.00%
DCG3.02.2	0.83%	91.13%
DCG3.02.3	0.83%	98.61%
DCG3.02.4	0.00%	0.00%
DCG3.03.1	0.00%	0.00%
DCG3.03.2	0.00%	0.00%
DCG3.04.1	0.00%	0.00%
DCG3.04.2	1.40%	100.00%
DCG3.05.1	1.05%	73.24%
DCG3.05.2	2.48%	100.00%
DCG3.06.1	0.00%	0.00%
DCG3.06.2	0.00%	0.00%
DCG3.06.3	0.00%	0.00%
DCG3.06.4	0.00%	0.00%
DCG3.06.5	0.00%	0.00%
DCG3.06.6	0.00%	0.00%
DCG4.01.1	0.98%	89.14%
DCG4.01.2	1.10%	85.71%
DCG4.01.3	1.10%	100.00%
DCG4.01.4	1.02%	92.86%
DCG4.02.1	1.82%	100.00%
DCG4.02.2	1.82%	100.00%
DCG4.02.3	1.76%	96.57%
DCG4.02.4	1.82%	100.00%
DCG4.02.5	1.76%	96.65%
DCG4.03.1	0.63%	44.09%
DCG4.03.2	0.62%	43.77%
DCG4.03.3	0.64%	44.09%
DCG4.04.1	0.64%	43.77%
DCG4.04.2	0.58%	39.94%
DCG4.04.3	0.64%	43.77%
DCG4.04.4	0.58%	39.94%

Level 2 (Continue....)		
DCG4.04.5	1.45%	100.00%
DCG4.04.6	0.58%	39.94%
DCG5.01.1	3.61%	100.00%
DCG5.01.2	3.49%	96.65%
DCG5.02.1	2.22%	100.00%
DCG5.02.2	2.01%	90.50%
DCG5.02.3	0.87%	39.12%
DCG5.03.1	0.00%	0.00%
DCG5.03.2	0.83%	87.50%
DCG5.03.3	0.71%	75.00%
DCG5.03.4	0.74%	78.25%
DCG5.03.5	0.94%	100.00%
DCG5.03.6	0.80%	84.50%
DCG5.03.7	0.74%	78.25%
DCG5.03.8	0.83%	87.50%
Level 3		
DCG2.04.1.1	0.00%	0.00%
DCG2.04.1.2	0.00%	0.00%
DCG2.04.2.1	0.00%	0.00%
DCG2.04.2.2	0.00%	0.00%
DCG3.05.1.1	0.12%	88.31%
DCG3.05.1.2	0.13%	100.00%
DCG3.05.2.1	0.10%	76.92%
DCG3.05.2.2	0.15%	100.00%
DCG3.06.6.1	0.10%	40.64%
DCG4.01.1.1	0.68%	87.67%
DCG4.01.1.2	0.00%	0.00%
DCG4.01.1.3	0.00%	0.00%
DCG4.01.1.4	0.00%	0.00%
DCG4.01.1.5	0.00%	0.00%
DCG4.01.2.1	0.00%	0.00%
DCG4.01.2.2	0.00%	0.00%
DCG4.01.2.3	0.00%	0.00%
DCG4.01.2.4	0.00%	0.00%
DCG4.01.2.5	0.00%	0.00%
DCG4.01.3.1	0.75%	100.00%
DCG4.01.3.2	0.00%	0.00%
DCG4.01.3.3	0.00%	0.00%
DCG4.01.4.1	0.00%	0.00%
DCG4.01.4.2	0.14%	0.00%
DCG4.01.4.3	83.00%	100.00%
DCG4.02.3.1	0.00%	0.00%
DCG4.04.6.1	0.73%	100.00%
DCG4.04.6.2	0.73%	100.00%

Appendix - C

Sample of Statistical Analysis to Identify Decision Criteria

C.1 Appendix C.1: Sample of Statistical Analysis for the criteria Related to Building Projects in Ranked Order

C.5 Appendix C.2: Relative Weight Calculations for the criteria Related to Building Projects

Appendix C.1.1: Statistical Analysis for the Criteria of the UK Building Projects
Contractor's Experience record Decision Criteria

Variable	Mean	Std Dev	Variance	Minimum	Maximum
DCG1.12	3.88	1.36	1.84	1.00	5.00
DCG1.01	3.88	0.64	0.41	3.00	5.00
DCG1.09	3.38	0.74	0.55	2.00	4.00
DCG1.07	3.38	0.74	0.55	2.00	4.00
DCG1.05	3.25	0.71	0.50	2.00	4.00
DCG1.14	3.13	0.99	0.98	1.00	4.00
DCG1.13	3.13	1.13	1.27	1.00	4.00
DCG1.08	2.94	0.78	0.60	2.00	4.00
DCG1.03	2.87	1.13	1.27	1.00	4.00
DCG1.11	2.87	0.99	0.98	1.00	4.00
DCG1.16	2.75	1.49	2.21	0.00	4.00
DCG1.02	2.75	0.46	0.21	2.00	3.00
DCG1.17	2.50	1.20	1.43	1.00	4.00
DCG1.10	1.50	1.41	2.00	1.00	2.00
DCG1.04	1.25	0.46	0.21	1.00	2.00
DCG1.06	1.13	0.35	0.12	1.00	2.00
DCG1.15	1.13	0.35	0.12	1.00	2.00

18 Oct 96 SPSS for MS WINDOWS Release 6.1

Past Performance Level Decision Criteria

Variable	Mean	Std Dev	Variance	Minimum	Maximum
DCG2.04.2	4.00	0.76	0.57	3.00	5.00
DCG2.02	3.94	0.86	0.75	2.00	5.00
DCG2.04	3.87	0.64	0.41	3.00	5.00
DCG2.04.1	3.75	1.28	1.64	1.00	5.00
DCG2.05	3.75	1.28	1.64	1.00	5.00
DCG2.03	3.75	0.46	0.21	3.00	4.00
DCG2.01	3.75	0.89	0.79	2.00	5.00
DCG2.03.4	3.75	0.46	0.21	3.00	4.00
DCG2.05.1	3.63	1.30	1.70	1.00	5.00
DCG2.06	3.38	0.92	0.84	2.00	5.00
DCG2.03.1	3.38	0.52	0.27	3.00	4.00
DCG2.03.2	2.88	0.83	0.70	1.00	4.00
DCG2.05.4	2.62	1.19	1.41	1.00	4.00
DCG2.05.2	2.50	0.93	0.86	1.00	4.00
DCG2.05.3	2.13	0.64	0.41	1.00	3.00
DCG2.01.1	1.63	0.74	0.55	2.00	2.00
DCG2.01.2	1.38	0.52	0.27	1.00	2.00
DCG2.04.1.2	1.37	0.47	0.55	1.00	2.00
DCG2.04.2.2	1.25	0.46	0.21	1.00	2.00
DCG2.04.2.1	1.25	0.46	0.21	1.00	2.00
DCG2.04.1.1	1.25	0.46	0.21	1.00	2.00
DCG2.03.3	1.25	0.46	0.21	1.00	2.00

18 Oct 96 SPSS for MS WINDOWS Release 6.1

Appendix C.1.2: Statistical Analysis for the Criteria of the UK Building Projects
Financial Stability Decision Criteria

Variable	Mean	Std Dev	Variance	Minimum	Maximum
DCG3.05	3.75	1.16	1.36	1.00	5.00
DCG3.01.2	3.39	1.66	2.74	0.10	5.00
DCG3.01	3.26	1.64	2.69	0.10	5.00
DCG3.05.2	3.25	0.53	0.29	1.00	2.00
DCG3.05.1.1	3.25	1.61	1.79	2.00	4.00
DCG3.05.2.1	3.25	0.89	0.79	2.00	4.00
DCG3.02	3.13	0.35	0.13	3.00	4.00
DCG3.02.1	2.88	0.64	0.41	2.00	4.00
DCG3.02.3	2.84	0.74	0.55	1.00	3.00
DCG3.06.6.1	2.75	1.39	1.93	1.00	4.00
DCG3.02.2	2.63	0.74	0.55	1.00	3.00
DCG3.03	2.63	1.30	1.70	0.00	4.00
DCG3.04	2.50	1.16	1.36	1.00	4.00
DCG3.04.1	2.50	0.53	0.29	1.00	2.00
DCG3.01.1	2.39	1.28	1.63	0.10	4.00
DCG3.05.1	2.38	0.52	0.27	1.00	2.00
DCG3.05.2.2	2.25	0.53	0.29	1.00	3.00
DCG3.01.4	2.14	1.33	1.78	0.00	3.00
DCG3.06	1.88	0.83	0.70	1.00	3.00
DCG3.06.1	1.88	1.46	2.13	1.00	2.00
DCG3.06.2	1.75	0.89	0.79	1.00	2.00
DCG3.06.5	1.75	0.76	0.57	2.00	3.00
DCG3.06.3	1.55	0.89	0.79	1.00	2.00
DCG3.02.4	1.50	0.53	0.29	1.00	2.00
DCG3.03.1	1.50	0.53	0.29	1.00	2.00
DCG3.03.2	1.50	0.53	0.29	1.00	2.00
DCG3.04.2	1.50	0.53	0.29	1.00	2.00
DCG3.06.4	1.38	0.52	0.27	1.00	2.00
DCG3.01.3	1.26	0.68	0.47	0.10	2.00
DCG3.05.1.2	1.25	1.25	1.29	1.00	2.00
DCG3.06.6	1.25	1.60	2.57	1.00	2.00

18 Oct 96 SPSS for MS WINDOWS Release 6.1

Appendix C.1.3: Statistical Analysis for the Criteria of the UK Building Projects Contractor's Current Capability Decision Criteria

Variable	Mean	Std Dev	Variance	Minimum	Maximum
DCG4.02	4.00	0.53	0.29	3.00	5.00
DCG4.03	3.88	0.83	0.70	3.00	5.00
DCG4.03.2	3.75	0.89	0.79	3.00	5.00
DCG4.03.3	3.55	0.85	0.79	3.00	5.00
DCG4.01	3.50	1.20	1.43	1.00	5.00
DCG4.01.3	3.50	0.76	0.57	3.00	5.00
DCG4.01.3.1	3.50	0.76	0.57	3.00	5.00
DCG4.02.1	3.50	0.53	0.29	3.00	4.00
DCG4.02.2	3.50	0.53	0.29	3.00	4.00
DCG4.02.4	3.50	0.53	0.29	3.00	5.00
DCG4.02.3	3.38	0.74	0.55	3.00	5.00
DCG4.01.4	3.25	0.46	0.21	3.00	4.00
DCG4.04	3.25	0.46	0.21	3.00	4.00
DCG4.04.6	3.13	0.64	0.41	2.00	4.00
DCG4.01.1	3.12	1.46	2.13	1.00	5.00
DCG4.01.2	3.00	0.76	0.57	2.00	4.00
DCG4.02.5	2.75	0.83	0.64	2.00	4.00
DCG4.03.1	1.88	1.83	0.70	1.00	3.00
DCG4.01.1.2	1.75	1.46	0.21	2.00	2.00
DCG4.01.1.5	1.70	2.31	1.71	1.00	2.00
DCG4.01.1.1	1.63	1.74	0.55	1.00	2.00
DCG4.01.1.3	1.63	1.92	0.84	1.00	2.00
DCG4.01.2.1	1.63	1.74	0.55	1.00	3.00
DCG4.01.2.2	1.63	1.74	0.55	1.00	3.00
DCG4.01.2.4	1.63	1.74	0.55	1.00	3.00
DCG4.01.1.4	1.50	2.07	1.14	1.00	2.00
DCG4.01.4.2	1.50	0.76	0.57	1.00	3.00
DCG4.02.3.1	1.50	1.53	0.29	2.00	3.00
DCG4.04.1	1.38	0.52	0.27	1.00	2.00
DCG4.04.2	1.37	0.74	0.55	1.00	3.00
DCG4.04.4	1.37	0.74	0.55	1.00	3.00
DCG4.01.2.3	1.25	1.89	0.79	1.00	3.00
DCG4.01.3.2	1.25	0.46	0.21	1.00	2.00
DCG4.01.3.3	1.25	0.46	0.21	1.00	2.00
DCG4.01.4.1	1.25	1.46	0.21	1.00	2.00
DCG4.01.4.3	1.25	2.20	1.43	1.00	2.00
DCG4.04.3	1.25	0.46	0.21	1.00	2.00
DCG4.04.5	1.25	0.46	0.21	1.00	2.00
DCG4.04.6.1	1.25	0.46	0.21	1.00	2.00
DCG4.04.6.2	1.25	0.46	0.21	1.00	2.00
DCG4.01.2.5	1.16	1.93	0.86	1.00	3.00

18 Oct 96 SPSS for MS WINDOWS Release 6.1

**Appendix C.1.4: Statistical Analysis for the Criteria of the UK Building Projects
Contractor's Submitted Plans to the Proposed Project Decision Criteria**

Variable	Mean	Std Dev	Variance	Minimum	Maximum
DCG5.01	4.50	0.53	0.29	4.00	5.00
DCG5.03.5	4.00	0.76	0.57	3.00	5.00
DCG5.02.1	4.00	0.53	0.29	3.00	5.00
DCG5.01.1	3.88	0.83	0.70	3.00	5.00
DCG5.02	3.87	0.64	0.41	3.00	5.00
DCG5.03	3.75	0.46	0.21	3.00	4.00
DCG5.01.2	3.75	1.04	1.07	2.00	5.00
DCG5.02.2	3.62	0.52	0.27	3.00	4.00
DCG5.03.8	3.50	1.07	1.14	2.00	5.00
DCG5.03.2	3.50	0.53	0.29	3.00	4.00
DCG5.03.6	3.38	1.06	1.12	2.00	5.00
DCG5.03.7	3.13	0.35	0.13	3.00	4.00
DCG5.03.4	3.13	0.99	0.98	1.00	4.00
DCG5.03.3	3.00	1.07	1.14	1.00	4.00
DCG5.02.3	1.38	1.83	1.70	1.00	3.00
DCG5.03.1	1.38	0.52	0.27	1.00	2.00

18 Oct 96 SPSS for MS WINDOWS Release 6.1

Main Decision Criteria Groups

Variable	Mean	Std Dev	Variance	Minimum	Maximum
DCG3	4.13	0.64	0.41	3.00	5.00
DCG2	4.13	0.35	0.13	4.00	5.00
DCG4	3.87	0.64	0.41	3.00	5.00
DCG1	3.75	0.46	0.21	3.00	4.00
DCG5	3.75	0.46	0.21	3.00	4.00

Appendix C.2.1: Relative Weights Calculations for the Criteria of the UK Building Projects

Main Decision Criteria Groups

Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria
DCG1	3.750	0.19103	90.36%
DCG2	4.130	0.21039	100.00%
DCG3	4.130	0.21039	99.52%
DCG4	3.870	0.19715	93.25%
DCG5	3.750	0.19103	90.36%

Past Experience Decision Criteria

Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria
DCG1.01	3.880	0.01586	100.00%
DCG1.02	2.750	0.01124	70.88%
DCG1.03	2.870	0.01174	73.97%
DCG1.04	1.250	0.00511	32.22%
DCG1.05	3.250	0.01329	83.76%
DCG1.06	1.130	0.00462	29.12%
DCG1.07	3.380	0.01382	87.11%
DCG1.08	2.940	0.01202	75.77%
DCG1.09	3.380	0.01382	87.11%
DCG1.10	1.500	0.00622	38.66%
DCG1.11	2.870	0.01174	73.97%
DCG1.12	3.880	0.01586	100.00%
DCG1.13	3.130	0.01280	80.67%
DCG1.14	3.130	0.01280	80.67%
DCG1.15	1.130	0.00462	29.12%
DCG1.16	2.750	0.01124	70.88%
DCG1.17	2.500	0.01022	64.43%

Appendix C.2.2: Relative Weights Calculations for the Criteria of the UK Building Projects
Past Performance Decision Criteria

Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria	Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria	**Variable**	**Mean**	**Relative Weight**	**Weight as a % of the Maximum Criteria**
DCG2.01	3.750	0.03516	95.18%	DCG2.01.1	1.630	0.02547	100.00%				
				DCG2.01.2	1.380	0.00968	84.66%				
DCG2.02	3.940	0.03694	100.00%								
DCG2.03	3.750	0.03516	95.18%	DCG2.03.1	3.380	0.01055	90.13%				
				DCG2.03.2	2.880	0.00899	76.80%				
				DCG2.03.3	1.250	0.00390	33.33%				
				DCG2.03.4	3.750	0.01171	100.00%				
DCG2.04	3.870	0.03628	98.22%	DCG2.04.1	3.750	0.01183	93.75%	DCG2.04.1.1	1.250	0.00564	91.24%
								DCG2.04.1.2	1.370	0.00619	100.00%
				DCG2.04.2	4.000	0.01262	100.00%	DCG2.04.2.1	1.250	0.00631	100.00%
								DCG2.04.2.2	1.250	0.00631	100.00%
DCG2.05	3.750	0.03516	95.18%	DCG2.05.1	3.630	0.01173	100.00%				
				DCG2.05.2	2.500	0.00808	68.87%				
				DCG2.05.3	2.130	0.00688	58.68%				
				DCG2.05.4	2.620	0.00847	72.18%				
DCG2.06	3.380	0.03169	85.79%								

Appendix C.2.3: Relative Weights Calculations for the Criteria of the UK Building Projects
Financial Stability Decision Criteria

Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria
DCG3.01	326.00%	4.06%	86.93%
DCG3.02	313.00%	3.90%	83.47%
DCG3.03	263.00%	3.27%	70.13%
DCG3.04	225.00%	2.80%	60.00%
DCG3.05	375.00%	4.67%	100.00%
DCG3.06	188.00%	2.34%	50.13%

Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria
DCG3.01.1	**239.00%**	**1.06%**	**70.50%**
DCG3.01.2	339.00%	1.50%	100.00%
DCG3.01.3	126.00%	0.56%	37.17%
DCG3.01.4	214.00%	0.95%	63.13%
	918.00%		
DCG3.02.1	288.00%	1.47%	100.00%
DCG3.02.2	263.00%	0.83%	91.13%
DCG3.02.3	284.00%	0.83%	98.61%
DCG3.02.4	150.00%	0.77%	52.08%
DCG3.03.1	150.00%	0.94%	100.00%
DCG3.03.2	150.00%	0.94%	100.00%
DCG3.04.1	150.00%	0.52%	60.00%
DCG3.04.2	250.00%	0.86%	100.00%
DCG3.05.1	238.00%	1.05%	73.24%
DCG3.05.2	325.00%	1.14%	100.00%
DCG3.06.1	188.00%	0.45%	100.00%
DCG3.06.2	175.00%	0.32%	93.09%
DCG3.06.3	155.00%	0.32%	82.45%
DCG3.06.4	138.00%	0.16%	73.40%
DCG3.06.5	175.00%	0.35%	93.09%
DCG3.06.6	125.00%	0.29%	64.43%

Variable	**Mean**	**Relative Weight**	**Weight as a % of the Maximum Criteria**
DCG3.05.1.1	325.00%	0.12%	100.00%
DCG3.05.1.2	125.00%	0.13%	38.46%
DCG3.05.2.1	325.00%	0.10%	100.00%
DCG3.05.2.2	225.00%	0.15%	69.23%
DCG3.06.6.1	275.00%	0.14%	100.00%

Appendix C.2.4: Relative Weights Calculations for the Criteria of the UK Building Projects

Contractor's Current Capability Decision Criteria

Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria	Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria	Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria
DCG4.01	3.500	0.04716	87.50%	DCG4.01.1	3.079	0.01143	87.96%	DCG4.01.1.1	1.630	0.00223	38.60%
								DCG4.01.1.2	1.750	0.00233	43.10%
								DCG4.01.1.3	1.630	0.00212	44.50%
								DCG4.01.1.4	1.500	0.00212	44.83%
								DCG4.01.1.5	1.700	0.00223	54.50%
				DCG4.01.2	3.363	0.01099	96.08%	DCG4.01.2.1	1.630	0.00140	43.10%
								DCG4.01.2.2	1.630	0.00140	38.40%
								DCG4.01.2.3	1.250	0.00280	47.60%
								DCG4.01.2.4	1.630	0.00140	34.90%
								DCG4.01.2.5	1.160	0.00258	50.30%
				DCG4.01.3	2.804	0.01283	80.11%	DCG4.01.3.1	3.500	0.00748	100.00%
								DCG4.01.3.2	1.250	0.00267	47.50%
				DCG4.01.4	3.500	0.01283	100.00%	DCG4.01.3.3	1.250	0.00267	34.60%
								DCG4.01.4.1	1.250	0.00352	48.30%
								DCG4.01.4.2	1.500	0.00135	42.70%
								DCG4.01.4.3	1.250	0.00379	50.30%
				DCG4.02.1	3.360	0.01723	89.61%				
DCG4.02	4.000	5.39%	100.00%	DCG4.02.2	3.750	0.01923	100.00%				
				DCG4.02.3	2.980	0.01528	79.47%				
				DCG4.02.4	3.750	0.01923	100.00%	DCG4.02.3.1	1.500	0.01024	40.70%
DCG4.03	3.880	5.23%	97.00%	DCG4.02.5	3.433	0.01761	91.55%	DCG4.04.6.1	1.250	0.00366	42.60%
				DCG4.03.1	3.750	0.01923	100.00%	DCG4.04.6.2	1.250	0.00366	100.00%
DCG4.04	3.250	4.38%	81.25%	DCG4.03.2	3.433	0.01761	91.55%				
				DCG4.03.3	1.543	0.00791	41.15%				
				DCG4.04.1	3.750	0.01923	100.00%				
				DCG4.04.2	3.041	0.01560	81.15%				
				DCG4.04.3	2.112	0.01083	56.31%				
				DCG4.04.4	2.303	0.01181	61.42%				
				DCG4.04.5	3.750	0.01923	100.00%				
				DCG4.04.6	3.750	0.01923	100.00%				

Appendix C.2.5: Relative Weights Calculations for the Criteria of the UK Building Projects Contractor's Submitted Plans to the Proposed Project Decision Criteria

	Mean	Relative Weight	Weight as a % of the Maximum Criteria	Variable	Mean	Relative Weight	Weight as a % of the Maximum Criteria
DCG5.01	4.500	7.09%	100.00%	DCG5.01.1	3.880	0.03607	100.00%
				DCG5.01.2	3.750	0.03486	96.65%
DCG5.02	3.870	6.10%	86.00%	DCG5.02.1	4.000	0.02218	100.00%
				DCG5.02.2	3.620	0.02007	90.50%
				DCG5.02.3	1.380	0.01874	34.50%
DCG5.03	3.750	5.91%	83.33%	DCG5.03.1	1.380	0.00326	34.50%
				DCG5.03.2	3.500	0.00827	87.50%
				DCG5.03.3	3.000	0.00709	75.00%
				DCG5.03.4	3.130	0.00739	78.25%
				DCG5.03.5	4.000	0.00945	100.00%
				DCG5.03.6	3.380	0.00798	84.50%
				DCG5.03.7	3.130	0.00739	78.25%
				DCG5.03.8	3.500	0.00827	87.50%

Appendix - D

The Relative Weights of the Decision Criteria for Heavy and Building Construction

D.1 Table D.1. *Relative Weights of the Decision Criteria Groups of Heavy Construction*

D.4 Table D.2: *Relative Weights of the Decision Criteria Groups of Building Construction*

D.7 Table D.3: *Contractor's Experience Record Criteria Description*

D.8 Table D.4: *Contractor's Past Performance Criteria Description*

D.10 Table D.5: *Contractor's Financial Stability Criteria Description*

D.11 Table D.6: *Contractor's Current Capabilities Criteria Description*

D.13 Table D.7: *Contractor's Submitted Plans to the Proposed Project Criteria Description*

Table D 1: Relative Weight for the Decision Criteria of Heavy Construction Projects

Code of Group	Criteria Group Description	Relative Weight
DCG1	Contractor's Experience Record	18.80%
DCG2	Contractor's Past Performance	20.26%
DCG3	Contractor's Financial Stability	19.19%
DCG4	Contractor's Current Capabilities	20.72%
DCG5	Contractor's Submitted Plans to the Proposed Project	20.52%

Code of Criterion	Contractor's Experience Record Criteria (DCG1) Description	Relative Weight
DCG1.01*	Number of years working in S.Ps.**	1.42%
DCG1.02	Contractor age in Construction	1.23%
DCG1.03	Maximum project delivery rate within last 3 years (Work vol./ Proj. duration).	1.71%
DCG1.04	Low rate criterion (Excluded one)	0.00%
DCG1.05	Work volume of S.Ps. within last 10 years	1.47%
DCG1.06	Low rate criterion (Excluded one)	0.00%
DCG1.07	Average annual work volume of S.Ps. - Last 3 years	1.69%
DCG1.08	Average annual work volume of C.Ps.*** - Last 3 years	1.18%
DCG1.09	Contract type of previous S.Ps (Risk Share)	1.53%
DCG1.10	Low rate criterion (Excluded one)	0.00%
DCG1.11	Previous project types (Diversity of experience in construction).	1.16%
DCG1.12	Previous work in S.Ps. with Same Owner	1.93%
DCG1.13	Previous work in C.Ps. with Same Owner	1.49%
DCG1.14	Previous work in similar weather conditions and S.Ps.	1.35%
DCG1.15	Low rate criterion (Excluded one)	0.00%
DCG1.16	Previous work in similar geographical conditions and S.Ps.	1.48%
DCG1.17	Previous work in similar geographical conditions and C.Ps.	1.17%

Code of Criterion	Contractor's Past Performance Criteria (DCG2) Description	Relative Weight
DCG2.01	Meeting project schedule of S.Ps. last 5 years	3.43%
DCG2.01.1	Low rate criterion (Excluded one)	0.00%
DCG2.01.2	Low rate criterion (Excluded one)	0.00%
DCG2.02	Meeting project budget of completed S.Ps.last 5 years	3.39%
DCG2.03	Meeting project quality of completed S.Ps.last 5 years	3.62%
DCG2.03.1	Approved quality control plans and quality assurance of completed S.Ps.	1.03%
DCG2.03.2	Test results of completed S.P.s	0.96%
DCG2.03.3	Low rate criterion (Excluded one)	0.00%
DCG2.03.4	The contractor has previous projects with current owner	1.27%
DCG2.04	Technical competence level in construction in last 3 years	3.11%
DCG2.04.1	Willingness of correcting faulty attitude in S.Ps.	1.57%
DCG2.04.1.1	Low rate criterion (Excluded one)	0.00%
DCG2.04.1.2	Low rate criterion (Excluded one)	0.00%
DCG2.04.2	Safety record Last 3 years	1.54%
DCG2.04.2.1	Low rate criterion (Excluded one)	0.00%
DCG2.04.2.2	Low rate criterion (Excluded one)	0.00%
DCG2.05	Contractor reputation	3.34%
DCG2.05.1	Contractor reputation at previous owners	0.98%
DCG2.05.2	Contractor reputation at previous suppliers	0.79%
DCG2.05.3	Contractor reputation at previous subcontractors.	0.78%
DCG2.05.4	Contractor reputation at previous insurance companies.	0.80%
DCG2.06	Average value of claims as a percent of past project(s)	3.32%

* DCG1.1: This code means the first decision criterion (DC)in the first criteria group (G1)

** S.Ps.: means that project has a similar work type and hence similar experience and resources are required to caary out the proposed project.

*** C.Ps.: means construction projects.

Table D 1: Relative Weight for the Decision Criteria of Heavy Construction Projects (Continue...)

Code of Criterion	Contractor's Financial Stability Criteria (DCG3) Description	Relative Weight
DCG3.01	Bonding capacity	3.37%
DCG3.01.1	Bid bond	1.05%
DCG3.01.2	Performance bond	1.24%
DCG3.01.3	Low rate criterion (Excluded one)	0.00%
DCG3.01.4	Maintenance bond	1.08%
DCG3.02	Financial policy	3.41%
DCG3.02.1	Source of finance	1.26%
DCG3.02.2	Cost of finance	1.16%
DCG3.02.3	Financial arrangements	0.99%
DCG3.02.4	Low rate criterion (Excluded one)	0.00%
DCG3.03	Credit level	3.01%
DCG3.03.1	Low rate criterion (Excluded one)	0.00%
DCG3.03.2	Low rate criterion (Excluded one)	0.00%
DCG3.04	Financial statement reliability	3.49%
DCG3.04.1	Status of audited financial statement	3.49%
DCG3.04.2	Low rate criterion (Excluded one)	0.00%
DCG3.05	Financial performance	3.62%
DCG3.05.1	Liquidity ratios (Solvency ratios)	1.56%
DCG3.05.1.1	Current ratio	0.92%
DCG3.05.1.2	Low rate criterion (Excluded one)	0.00%
DCG3.05.2	Leverage ratios	2.16%
DCG3.05.2.1	Total liabilities / Tangible net worth	1.24%
DCG3.05.2.2	Hard debt /Tangible net worth	0.92%
DCG3.06	Low rate criterion (Excluded one)	0.00%
DCG3.06.1	Low rate criterion (Excluded one)	0.00%
DCG3.06.2	Low rate criterion (Excluded one)	0.00%
DCG3.06.3	Low rate criterion (Excluded one)	0.00%
DCG3.06.4	Low rate criterion (Excluded one)	0.00%
DCG3.06.5	Low rate criterion (Excluded one)	0.00%
DCG3.06.6	Low rate criterion (Excluded one)	0.00%
DCG3.06.6.1	Low rate criterion (Excluded one)	0.00%

Code of Criterion	Contractor's Current Capabilities Criteria (DCG4) Description	Relative Weight
DCG4.01	contractor's Management capabilities	4.67%
DCG4.01.1	Management organisation structure	1.43%
DCG4.01.1.1	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.2	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.3	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.4	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.5	Low rate criterion (Excluded one)	0.00%
DCG4.01.2	Experience level of managementstaff	1.08%
DCG4.01.2.1	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.2	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.3	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.4	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.5	Number of years working in S.Ps.	1.08%
DCG4.01.3	Management techniques	1.12%
DCG4.01.3.1	Planning and control techniques	1.12%
DCG4.01.3.2	Low rate criterion (Excluded one)	0.00%
DCG4.01.3.3	Low rate criterion (Excluded one)	0.00%
DCG4.01.4	Coordination between management office and site	1.04%
DCG4.10.4.1	Low rate criterion (Excluded one)	0.00%
DCG4.01.4.2	Low rate criterion (Excluded one)	0.00%

Table D 1: Relative Weight for the Decision Criteria of Heavy Construction Projects (Continue ...)

Code of Criterion	Contractor's Current Capabilities Criteria (DCG4) Description	Relative Weight
DCG4.01.4.3	Low rate criterion (Excluded one)	0.00%
DCG4.02	Equipment availability	7.44%
DCG4.02.1	Types of available equipment	1.86%
DCG4.02.2	Specifications of available Equipment	1.12%
DCG4.02.3	*Models of Available Equipment*	1.11%
DCG4.02.3.1	Low rate criterion (Excluded one)	0.00%
DCG4.02.4	Quantity of the available Equipment	1.72%
DCG4.02.5	Maintenance System of available equipment	1.63%
DCG4.03	Manpower resources availability	1.49%
DCG4.03.1	Labor craft type available	0.65%
DCG4.03.2	Number of labor from each craft type	0.88%
DCG4.03.3	Total number of permanent labor	0.61%
DCG4.04	Contractor's capacity to carry an additional construction work	3.28%
DCG4.04.1	Subcontractor's work volume	1.27%
DCG4.04.2	Subcontractor's work type	1.03%
DCG4.04.3	Subcontracting's control system applied by main contractor	0.58%
DCG4.04.4	Material delivery availability	0.78%
DCG4.04.5	Contractor's current capacity to carry out an additional work	3.05%
DCG4.04.6	Current work volume	1.15%
DCG4.04.6.1	Percentage complete of current projects	1.90%
DCG4.04.6.2	Current capacity to carry an additional construction work	1.34%

Code of Criterion	Contractor's Submitted Plans to the Proposed Project Criteria (DCG5) Description	Relative Weight
DCG5.01	Bid Price of the proposed project	9.38%
DCG5.01.1	Total Bid Amount	5.86%
DCG5.01.2	Cash-out Schedule	4.52%
DCG5.02	Job statement of proposed project	4.68%
DCG5.02.1	Construction method statement	2.40%
DCG5.02.2	Project Time Schedule	2.40%
DCG5.02.3	Low rate criterion (Excluded one)	0.00%
DCG5.03	Management plans to the Proposed Project	6.46%
DCG5.03.1	Payment schedule	0.00%
DCG5.03.2	Experience, continuity and organization structure of the assigned staff	1.01%
DCG5.03.3	Equipment Schedule	1.20%
DCG5.03.4	Manpower Schedule	0.51%
DCG5.03.5	Quality assurance and quality control plan	0.97%
DCG5.03.6	Safety plan	0.95%
DCG5.03.7	Procurement plan	0.87%
DCG5.03.8	Subcontracting works	0.96%

Table D 2: Relative Weight for the Decision Criteria of Building Construction Projects

Code of Group	Criteria Group Description	Relative Weight
DCG1	Contractor's Experience Record	18.69%
DCG2	Contractor's Past Performance	20.08%
DCG3	Contractor's Financial Stability	19.22%
DCG4	Contractor's Current Capabilities	20.90%
DCG5	Contractor's Submitted Plans to the Proposed Project	20.11%

Code of Criterion	Contractor's Experience Record Criteria (DCG1) Description	Relative Weight
DCG1.01*	Number of years working in S.Ps.**	1.80%
DCG1.02	Contractor age in Construction	1.51%
DCG1.03	Maximum project delivery rate within last 3 years (Work vol./ Proj. duration).	1.36%
DCG1.04	Low rate criterion (Excluded one)	0.00%
DCG1.05	Work volume of S.Ps. within last 10 years	0.97%
DCG1.06	Low rate criterion (Excluded one)	0.00%
DCG1.07	Average annual work volume of S.Ps. - Last 3 years	1.56%
DCG1.08	Average annual work volume of C.Ps.*** - Last 3 years	1.14%
DCG1.09	Contract type of previous S.Ps (Risk Share)	1.71%
DCG1.10	Low rate criterion (Excluded one)	0.00%
DCG1.11	Previous project types (Diversity of experience in construction).	1.51%
DCG1.12	Previous work in S.Ps. with Same Owner	1.45%
DCG1.13	Previous work in C.Ps. with Same Owner	1.18%
DCG1.14	Previous work in similar weather conditions and S.Ps.	1.43%
DCG1.15	Low rate criterion (Excluded one)	0.00%
DCG1.16	Previous work in similar geographical conditions and S.Ps.	1.66%
DCG1.17	Previous work in similar geographical conditions and C.Ps.	1.42%

Code of Criterion	Contractor's Past Performance Criteria (DCG2) Description	Relative Weight
DCG2.01	Meeting project schedule of S.Ps. last 5 years	3.40%
DCG2.01.1	Low rate criterion (Excluded one)	0.00%
DCG2.01.2	Low rate criterion (Excluded one)	0.00%
DCG2.02	Meeting project budget of completed S.Ps.last 5 years	3.29%
DCG2.03	Meeting project quality of completed S.Ps.last 5 years	3.40%
DCG2.03.1	Approved quality control plans and quality assurance of completed S.Ps.	1.18%
DCG2.03.2	Test results of completed S.P.s	1.13%
DCG2.03.3	Low rate criterion (Excluded one)	0.00%
DCG2.03.4	The contractor has previous projects with current owner	1.09%
DCG2.04	Technical competence level in construction in last 3 years	3.17%
DCG2.04.1	Willingness of correcting faulty attitude in S.Ps.	1.56%
DCG2.04.1.1	Low rate criterion (Excluded one)	0.00%
DCG2.04.1.2	Low rate criterion (Excluded one)	0.00%
DCG2.04.2	Safety record last 3 years	1.61%
DCG2.04.2.1	Low rate criterion (Excluded one)	0.00%
DCG2.04.2.2	Low rate criterion (Excluded one)	0.00%
DCG2.05	Contractor reputation	3.52%
DCG2.05.1	Contractor reputation at previous owners	0.86%
DCG2.05.2	Contractor reputation at previous suppliers	0.94%
DCG2.05.3	Contractor reputation at previous subcontractors.	0.95%
DCG2.05.4	Contractor reputation at previous insurance companies.	0.77%
DCG2.06	Average value of claims as a percent of past project(s)	3.27%

* DCG1.1: This code means the first decision criterion (DC)in the first criteria group (G1)

** S.Ps.: means that project has a similar work type and hence similar experience and resources are required to caary out the proposed project.

*** C.Ps.: means construction projects.

Table D 2: Relative Weight for the Decision Criteria of Building Construction Projects (Continue...)

Code of Criterion	Contractor's Financial Stability Criteria (DCG3) Description	Relative Weight
DCG3.01	Bonding capacity	3.84%
DCG3.01.1	Bid bond	1.22%
DCG3.01.2	Performance bond	1.45%
DCG3.01.3	Low rate criterion (Excluded one)	0.00%
DCG3.01.4	Maintenance bond	1.16%
DCG3.02	Financial policy	3.69%
DCG3.02.1	Source of finance	1.42%
DCG3.02.2	Cost of finance	1.12%
DCG3.02.3	Financial arrangements	1.15%
DCG3.02.4	Low rate criterion (Excluded one)	0.00%
DCG3.03	Credit level	2.98%
DCG3.03.1	Low rate criterion (Excluded one)	0.00%
DCG3.03.2	Low rate criterion (Excluded one)	0.00%
DCG3.04	Financial statement reliability	3.32%
DCG3.04.1	Status of audited financial statement	3.32%
DCG3.04.2	Low rate criterion (Excluded one)	0.00%
DCG3.05	Financial performance	3.55%
DCG3.05.1	Liquidity ratios (Solvency ratios)	1.34%
DCG3.05.1.1	Current ratio	1.34%
DCG3.05.1.2	Low rate criterion (Excluded one)	0.00%
DCG3.05.2	Leverage ratios	2.21%
DCG3.05.2.1	Total liabilities / Tangible net worth	1.28%
DCG3.05.2.2	Hard debt /Tangible net worth	0.93%
DCG3.06	Low rate criterion (Excluded one)	0.00%
DCG3.06.1	Low rate criterion (Excluded one)	0.00%
DCG3.06.2	Low rate criterion (Excluded one)	0.00%
DCG3.06.3	Low rate criterion (Excluded one)	0.00%
DCG3.06.4	Low rate criterion (Excluded one)	0.00%
DCG3.06.5	Low rate criterion (Excluded one)	0.00%
DCG3.06.6	Low rate criterion (Excluded one)	0.00%
DCG3.06.6.1	Low rate criterion (Excluded one)	0.00%

Code of Criterion	Contractor's Current Capabilities Criteria (DCG4) Description	Relative Weight
DCG4.01	Contractor's Management capabilities	4.72%
DCG4.01.1	Management organisation structure	1.06%
DCG4.01.1.1	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.2	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.3	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.4	Low rate criterion (Excluded one)	0.00%
DCG4.01.1.5	Low rate criterion (Excluded one)	0.00%
DCG4.01.2	Experience level of management staff	1.29%
DCG4.01.2.1	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.2	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.3	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.4	Low rate criterion (Excluded one)	0.00%
DCG4.01.2.5	Number of years working in S.Ps.	1.29%
DCG4.01.3	Management techniques	1.15%
DCG4.01.3.1	Planning and control techniques	1.15%
DCG4.01.3.2	Low rate criterion (Excluded one)	0.00%
DCG4.01.3.3	Low rate criterion (Excluded one)	0.00%
DCG4.01.4	Coordination between management office and site	1.25%
DCG4.10.4.1	Low rate criterion (Excluded one)	0.00%
DCG4.01.4.2	Low rate criterion (Excluded one)	0.00%

Table D 2: Relative Weight for the Decision Criteria of Building Construction Projects (Continue ...)

Code of Criterion	Contractor's Current Capabilities Criteria (DCG4) Description	Relative Weight
DCG4.01.4.3	Low rate criterion (Excluded one)	0.00%
DCG4.02	Equipment availability	4.21%
DCG4.02.1	Types of available equipment	0.83%
DCG4.02.2	Specifications of available Equipment	0.78%
DCG4.02.3	Models of Available Equipment	0.70%
DCG4.02.3.1	Low rate criterion (Excluded one)	0.00%
DCG4.02.4	Quantity of the available Equipment	0.92%
DCG4.02.5	Maintenance System of available equipment	0.99%
DCG4.03	Manpower resources availability	5.02%
DCG4.03.1	Labor craft type available	0.00%
DCG4.03.2	Number of labor from each craft type	2.86%
DCG4.03.3	Total number of permanent labor	2.16%
DCG4.04	Contractor's capacity to carry an additional construction work	2.10%
DCG4.04.1	Subcontractor's work volume	0.90%
DCG4.04.2	Subcontractor's work type	0.60%
DCG4.04.3	Subcontracting's control system applied by main contractor	0.60%
DCG4.04.4	Material delivery availability	2.15%
DCG4.04.5	Contractor's current capacity to carry out an additional work	3.70%
DCG4.04.6	Current work volume	1.48%
DCG4.04.6.1	Percentage complete of current projects	2.22%
DCG4.04.6.2	Current capacity to carry an additional construction work	0.76%

Code of Criterion	Contractor's Submitted Plans to the Proposed Project Criteria (DCG5) Description	Relative Weight
DCG5.01	Bid Price of the proposed project	8.91%
DCG5.01.1	Total Bid Amount	5.35%
DCG5.01.2	Cash-out Schedule	3.56%
DCG5.02	Job statement of proposed project	5.36%
DCG5.02.1	Construction method statement	2.84%
DCG5.02.2	Project Time Schedule	2.84%
DCG5.02.3	Low rate criterion (Excluded one)	0.00%
DCG5.03	Management plans to the Proposed Project	5.84%
DCG5.03.1	Payment schedule	0.00%
DCG5.03.2	Experience, continuity and organization structure of the assigned staff	0.93%
DCG5.03.3	Equipment Schedule	0.86%
DCG5.03.4	Manpower Schedule	0.66%
DCG5.03.5	Quality assurance and quality control plan	0.82%
DCG5.03.6	Safety plan	0.88%
DCG5.03.7	Procurement plan	0.83%
DCG5.03.8	Subcontracting works	0.86%

Table D.3: Contractor's Experience Record Criteria Description

Code of Criteria	Description of Criteria	Reasons for Criteria	Measure of Criteria
DCG1.01*	Number of years working in S.Ps.**	Time length experience and Present value in performing similar projects	Number of years working in similar projects.
DCG1.02	Contractor age in construction	Time length experience and Present value in performing construction projects	Number of years working in construction. <=3 yr., 5-10 yr. Or > 10 years
DCG1.03	Maximum project delivery rate within last 3 years (Work vol./ Proj. duration).	Contractor project delivery rate experience in similar projects (S. P.)** Contractor Capacity to carry out works	• Largest project work value (Contract value) / its duration. • Largest work volume/yr. Of S. P. Last 3 yr.
DCG1.05	Work volume of S.Ps. within last 10 years	Experience accumulation level and depth of experience	Total work value of similar projects (Contract value) in the last 10 years.
DCG1.07	Average annual work volume of S.Ps. - Last 3 years	Up to date experience level for a contractor by the recent conditions of S. P. Construction	Average annual work value in S. P. For the last 3 yr. (Av. Annual w. vol. = Contract value/ duration in years)
DCG1.08	Average annual work volume of C.Ps.*** Last 3 years	Up to date experience level for a contractor by the recent conditions of construction market	Average annual work value in construction for the last 3 yr.
DCG1.09	Contract type of previous S.Ps (Risk Share)	Determine the degree of project-risk share ability	Contractor bears all or most of projects' risk. Share risk equally Pass most of the risk early
DCG1.11	Previous project types (Diversity of experience in construction).	Contractor experience orientation	Work value of S.Ps./C.Ps.
DCG1.12	Previous work in S.Ps. with Same Owner	Owner-Contractor experience level in achieving objectives of similar project(s)	Excellent (100%), Good (75%), Acceptable (50%) Unacceptable (0%)
DCG1.13	Previous work in C.Ps. with Same Owner	Owner-Contractor experience level in achieving objectives of dissimilar project(s)	Excellent (100%), Good (75%), Acceptable (50%) Unacceptable (0%)
DCG1.14	Previous work in similar weather conditions and S.Ps.	Contractor experience capability in dealing with similar weather and project conditions	Work value of S. P. with similar weather conditions
DCG1.16	Previous work in similar geographical conditions and S.Ps.	Contractor experience capability in dealing with similar geographical & S. Project conditions	Work volume of S. P. with similar geographical conditions.
DCG1.17	Previous work in similar geographical conditions and C.Ps.	Contractor experience capability in dealing with similar geographical and Dissimilar project conditions.	Work volume of Dissimilar project with similar geographical conditions.

* DCG1.1: This code means the first decision criterion (DC) in the first criteria group (G1)

** S.Ps. : It means that project has a similar work type and hence similar experience and resources are required to carry out the proposed project.

*** C.Ps. : It means construction projects.

Table D.4: Contractor's Past Performance Criteria Description

Code of Criteria	Description of Criteria	Reasons for Criteria	Measure of Criteria
DCG2.01	Meeting project schedule of S.Ps. last 5 years	Contractor ability to perform project within its contracting time	Project delay as a % of contracting time. Source of delay: Owner (contractor =100%). Contractor (contractor =0%) Both (%).
DCG2.02	Meeting project budget of completed S.Ps. last 5 years	Assess contractor ability to meet project budget	Final project cost / Its Budgeted Cost
DCG2.03	Meeting project quality of completed S.Ps. last 5 years	Assess contractor ability to meet project quality	Quality control plan (Consultant Report) Quality assurance Construction test results Contractor has previous project (s) with this Client (Client Judgement)
DCG2.03.1	Approved quality control plans and quality assurance of completed S.Ps.	Assess their reliability and effectiveness	Quality control plan and quality assurance (Consultant Report)
DCG2.03.2	Test results of completed S.Ps	Contractor compliance to specs. Required	Rework volume due to fabrication errors (Consultant Report)
DCG2.03.4	The contractor has previous projects with current owner	Assess acceptance level of contractor quality with owner past project(s)	Quality level of previous project and Their work volume. (Client Judgement)
DCG2.04	Technical competence level in construction in last 3 years	Assess contractor technical competence level of performing past projects	Rework volume or % Safety system applied Safety documents available
DCG2.04.1	Willingness of correcting faulty attitude in S.Ps.	Its value is an indication of contractor technical competence in construction performance.	Rework value (volume or %) in completed project(s).
DCG2.04.2	Safety record Last 3 years	It is a factor in overall cost, quality, and schedule as well as the public relation benefits of safe construction.	Direct accident cost * Lost day cases * Doctor's cases Who receive and review accident reports and its frequency Safety meeting frequency.
DCG2.05	Contractor reputation	To detect his past performance level in past projects from other parties' points of view	Judgements of past project(s)'s clients, suppliers, subcontractors and insurance companies.
DCG2.05.1	Contractor reputation at previous owners	Contractor performance level in past projects based on owner judgement	Excellent (100%), Good (75%), Acceptable (50%): (i) Contractor involved in collusion with other contractor, (ii) Engaged in fraud activities, (iii) Debarred from bidding project by governmental agency, (iv) Failed to complete a project and (v) Performed poorly
DCG2.05.2	Contractor reputation at previous suppliers	Contractor performance level in past projects based on suppliers' judgement.	Contractor Keeps his promises Perform obligation in a timely manner (Supplier Judgement)

Table D.4: Contractor's Past Performance Criteria Description (Continue...)

Code of Criteria	Description of Criteria	Reasons for Criteria	Measure of Criteria
DCG2.05.3	Contractor reputation at previous subcontractors.	Contractor performance level in past projects based on subcontractors' judge.	Contractor Keeps his promises Performs obligations in a timely manner (subcontractors' judge)
DCG2.05.4	Contractor reputation at previous insurance companies.	Contractor reputation level based on judge of insurance companies.	Performs obligations in a timely manner
DCG2.06	Average value of claims as a percent of past project(s)	Assess contractor attitude toward claims and counter claims as an indicator of his behaviour and agreement with owner objectives.	Average value of approved claims as a % of past project(s).

Table D.5: Contractor's Financial Stability Criteria Description

Code of Criteria	Description of Criteria	Reasons for Criteria	Measure of Criteria
DCG3.01	Bonding capacity	Assess contractor has adequate financial resources, or the ability to secure such resources	Accepting bid bond, performance bond, and maintenance bond
DCG3.01.1	Bid bond	To ensure that a contractor is serious and he will carry out work if it is awarded	Bond value
DCG3.01.2	Performance bond	It guarantees a contractor performance to the owner	Bond value
DCG3.01.4	Maintenance bond	Contractor obligation during maintenance period to correct faulty work	Bond value
DCG3.02	Financial policy	It is mainly when a contractor is responsible for project finance or has suitable financial policy to owner	Source of finance, cost of finance and financial arrangements
DCG3.02.1	Source of finance	Assess a contractor capital adequacy and his financial skills in banking community	Banks willing to finance contractor when it has been awarded the proposed project
DCG3.02.2	Cost of Finance	To determine the most suitable cost of finance to the owner	The Interest Rate, Percentage Being, Currency of Payment, Financed and associated fees
DCG3.02.3	Financial arrangements	To assess if the financial schedule or arrangement is suitable to the owner	Repayment period, Security required, document required and financial package or other conditions
DCG3.03	Credit level	To track a contractor payment record	Creditor judgement: suppliers, subcontractors, and bank-credit report
DCG3.04	Financial statement reliability	To assess the quality of financial data	Compilation, review, or audit statement
DCG3.04.1	Status of Audited Financial Statement	To depict how income has been recognised.	Cash basis, Straight accrual, Percentage of completion or Completed
DCG3.05	Financial performance	To assess strength and weakness of current financial performance	Financial performance grade (g)
DCG3.05.1	Liquidity ratios (solvency ratios)	To assess the adequacy of current assets to cover current liabilities.	Quick ratio and current ratio
DCG3.05.1.1	Current ratio	To assess the adequacy of current assets to cover current liabilities	Total allowable current assets/total current liabilities
DCG3.05.2	Leverage ratios	To measure the amount of debt pressure	Total liabilities / tangible net worth and hard debt / tangible net worth
DCG3.05.2.1	Total liabilities / Tangible net worth	To measure amount of both short-term and long-term debt pressure.	Total liabilities / Tangible net worth
DCG3.05.2.2	Hard debt /Tangible net worth	To measure the amount of a contractor net worth and hence, the level of risk it assumed could be determined.	Hard debt / Tangible net worth

Table D.6: Contractor's Current Capabilities Criteria Description

Code of Criteria	Description of Criteria	Reasons for Criteria	Measure of Criteria
DCG4.01	Contractor's Management capabilities	To assess contractor's management capabilities for both office and field level.	Management Structure Org., Expertise of management staff, Applied management techniques, Computer facility utilisation, and co-ordination between management office and site.
DCG4.01.1	Management organisation structure	Assessing how a contractor's firm is organised and identify the key relationships among Its personnel and department.	Reviewing contractor organisation chart: Maintain flexibility in grouping, provide technical resources, Facilitate org. Co-ordination, key staff satisfy a specific requirement And continuity of organisation.
DCG4.01.2	Experience Level of Management Staff	Evaluation of key management staff to match their skills and experience with their assignment	Experience level of management staff: Total years working in Const. And S. Ps. Level of education Total work volume involvement work done for this contractor
DCG4.01.3	Management techniques	To ensure that a contractor has proper project management Techniques	Planning and control techniques, Utilisation of computer facilities.
DCG4.01.3.1	Planning and Control Techniques	To ensure that a contractor has proper project Planning and control techniques	Type applied planning techniques average project size. These techniques are used start of using them. The major area of their applications at what level of management these techniques are used on the average what are their application cost (%).
DCG4.01.4	Coordination between management office and site	To assess easy corrective actions by decision maker for good management	Means of communication and distance between management office and site
DCG4.02	Equipment availability	To assess if a contractor has the capability to provide project with the required equipment types, working conditions and sufficient quantity	Equipment available: types, model, specifications, and maintenance system available.
DCG4.02.1	Types of available Equipment	To assess if a contractor has the required equipment types to reduce risk of Proj. Delay	Types of available equipment: owned, rented
DCG4.02.2	Specifications of available Equipment	To ensure that the specs. of equip. Match the project requirement to meet Proj. Schedule	Specifications of available equipment
DCG4.02.3	Models of available Equipment	To assess the efficiency of the available equipment to secure risk of work breakdown	Models of available Equipment
DCG4.02.4	Quantity of the available Equipment	To assess that a contractor can secure the required number of equipment to project schedule	Quantity of the available equipment from each type required
DCG4.02.5	Maintenance System of available equipment	To ensure that the contractor can keep his equipment in good work conditions without downtime effect	Maintenance system of equipment, technicians, and maintenance tools available

Table D.6: Contractor's Current Capabilities Criteria Description (Continue...)

Code of Criteria	Description of Criteria	Reasons for Criteria	Measure of Criteria
DCG4.03	Manpower resources availability	To assess if a contractor has the capability to provide project with the required labour type, skills and number	Available labour types, number and skill level: permanent, temporary
DCG4.03.1	Labour craft type available	To assess if they will meet the required labour type	Labour type of available craft
DCG4.03.2	Number of labour from each craft type	To assess if they will meet the required work volume	Number of each labour craft type: Permanent, Temporary
DCG4.03.3	Total number of permanent labour	To assess the risk of labour shortage in construction	Total Number of Permanent Labour
DCG4.04	Contractor's capacity to carry an additional construction work	To assess the work capacity of a contractor in general.	Maximum contractor's work volume within last 5 years
DCG4.04.1	Subcontractor's work value	To determine which work area will be subcontracted. Hence, how the actual risk will be distributed.	The subcontracted work amount, type, and the control system applied to subcontractor's work
DCG4.04.2	Subcontractor's work type	To assess the degree of risk share by subcontractor.	Subcontractor's work type-risk value
DCG4.04.3	Subcontracting control system applied by main contractor	To assess how the prime contractor will control the risk transmitted to his subcontractor(s)	Subcontractor's work control system applied by the prime contractor
DCG4.04.4	Material availability	To assess if a contractor has the capability to provide project with the required material type, and quantity	Material supply specifications, costs and delivery schedule
DCG4.04.5	Contractor's current capacity to carry out an additional work	To determine the capability of a contractor to carry out additional work by matching contractor's current workloads and its percent of complete, by his own resource capabilities.	Cross match criterion DCG4.1 by the: Current workload and its percentage of complete.
DCG4.04.6	Current work volume	To assess the current work capacity of a contractor in relation to his current resource capabilities	Current work volume, Current resource capabilities (DCG4.1) if loaded, adequate, under load
DCG4.04.6.1	Percentage complete of current projects	To assess his capability to carry work load according to his work % of complete	Current work % of complete
DCG4.04.6.2	Current capacity to carry an additional construction work	To assess the work capacity of a contractor.	Annual average completed work volume last 3 yrs.

Table D.7: Contractor's Submitted Plans to the Proposed Project Criteria Description

Code of Criteria	Description of Criteria	Purpose of Criteria	Measure of Criteria
DCG5.01	Bid Price of the proposed project	To determine the bid price amount from a contractor and the cost of finance according to his cash schedule	Total bid price amount, Cost of finance based on the contractor's cash out schedule
DCG5.01.1	Total bid amount	To determine the lowest net present value of the proposed project Price	Total bid price amount (monetary value)
DCG5.01.2	Cash-out Schedule	To assess the degree of suitability of the contractor's cash out schedule to the owner financial resources and policy. To determine the least cost of finance	Cost of Finance
DCG5.02.1	Job statement of proposed project	To ensure that the contractor has reliable plans and he could meet the project objectives	Construction method statement reliability, total project duration, assigned staff experience and organisation. Also, quality, safety plan, procurement plan, and applied management techniques are considered.
DCG5.02	Construction method statement	It reflects a contractor's experience, understanding and familiarity with this project type and matching its plan with the assigned resources.	Method of construction for the key items. Contractor resource plan
DCG5.02.1	Project Time Schedule	To determine if the contractor schedule duration meets the required project duration	Total project duration based on contractor schedule
DCG5.03	Applied management planning techniques	To assess its flexibility, computability to the project conditions and characteristics	Type of applied Management technique, Owner or A/E familiarity with this technique
DCG5.03.2	Experience, continuity and organization structure of the assigned staff	To assess their org. Structure and identify key relationships among key personnel and department. To assess their continuity, and hence determine the longevity and ability of work continuity.	Staff organisation structure, Experience level of his staff.
DCG5.03.3	Equipment Schedule	To ensure that a contractor assigns the required key equipment type, specs., Quantity and maintenance system which secure work plan continuity without downtime or delay	Equipment plan - key equipment Project execution plan. Available equipment types, specs., Models, and owned or rented. Current work program % of complete, equipment maintenance policy.
DCG5.03.4	Manpower Schedule	To ensure that a contractor assigns the required key personnel, level of experience is adequate to perform proposed work load	Key personnel, Level of experience
DCG5.03.5	Quality assurance and quality control plan	To assess their reliability and effectiveness to reduce risk of low quality or cost overrun	Quality assurance and quality control plan
DCG5.03.6	Safety plan	To assess the risk of personnel continuity and work schedule interruption or claims	Safety plans: regulations, reporting system. Safety training programs, and safety responsibility-qualified representation
DCG5.03.7	Procurement plan	To assess a contractor capability of procurement, if it is important to the client	Procurement plan: Specs. Costs and delivery schedule.
DCG5.03.8	Subcontracting works	To assess the risk of work completion time, cost or quality by work subcontracting	Subcontracted work type, value and subcontractor capabilities.

Appendix - E

Blank Form of the Collection of Data for Sample Projects Related to the Contractor

E.1 Table E.1: Contractor's Experience Record Data

E.2 Table E.2: Contractor's Past Performance Data

E.3 Table E.3: Contractor's Financial Stability Data

E.4 Table E.4: Contractor's Current Capabilities Data

E.5 Table E.5: Contractor's Submitted Plans to the Proposed Project Data

Appendix E: Data Required by Construction Company

Table E.1: Contractor's Experience Record Data

No.	Past Experience Required Data	Value
1	Number of Years Working in Similar Projects	
2	Number of Years Working in Construction Projects	
3	Total Work Volume in Similar Projects	
4	Total Work Volume in Construction Projects	
5	Average Work Volume in Similar Projects - Last 5 Years	
6	Average Work Volume in Construction Projects - Last 5 Years	
7	Max. Project Delivery Rate	
8	Total Work Volume in Similar Projects - Lump Sum Contract	
9	Total Work Volume in Construction Projects - Lump Sum Contract	
10	Total Work Volume in Similar Projects - Unit Price Contract	
11	Total Work Volume in Construction Projects - Unit Price Contract	
12	Total Work Volume in Similar Projects - Project Management Contract	
13	Total Work Volume in Construction Projects - Project Management Contract	
14	Total Work Volume in Similar Projects With Current Owner	
15	Total Work Volume in Construction Projects With Current Owner	
16	Total Work Volume in Similar Projects With Similar Weather Condition	
17	Total Work Volume in Similar Projects With Similar Geographical Condition	
18	Total Work Volume in Similar Projects With Dissimilar Geographical Condition	

Table E.2: Contractor's Past Performance Data

No.	Past Performance Required Data	Value
1	Met Project Budget as Planned (Work Volume)	
2	Met Project Budget as Above 95% from Planned (Work Volume)	
3	Met Project Budget as Above 90% from Planned (Work Volume)	
4	Met Project Budget as Above 80% from Planned (Work Volume)	
5	Met Project Budget as Above 70% from Planned (Work Volume)	
6	Met Project Schedule as Planned (Work Volume)	
7	Met Project Schedule as Above 95% from Planned (Work Volume)	
8	Met Project Schedule as Above 90% from Planned (Work Volume)	
9	Met Project Schedule as Above 80% from Planned (Work Volume)	
10	Met Project Schedule as Above 70% from Planned (Work Volume)	
11	Met Project Quality - High level (Work Volume)	
12	Met Project Quality - Acceptable level (Work Volume)	
13	Met Project Quality - Min. level (Work Volume)	
14	Met Project Safety - High level (Work Volume)	
15	Met Project Safety - Acceptable level (Work Volume)	
16	Met Project safety - Min. level (Work Volume)	
17	Reputation With Previous Owner - High Level (Work Volume)	
18	Reputation With Previous Owner - Acceptable Level (Work Volume)	
19	Reputation With Previous Owner - Min. Level (Work Volume)	
20	Reputation With Supplier - High Level (Work Volume)	
21	Reputation With Supplier - Acceptable Level (Work Volume)	
22	Reputation With Supplier - Min. Level (Work Volume)	
23	Reputation With Insurance Company - High Level (Work Volume)	
24	Reputation With Insurance Company - Acceptable Level (Work Volume)	
25	Reputation With Insurance Company - Min. Level (Work Volume)	
26	Reputation With Current Owner - High Level (Work Volume)	
27	Reputation With Current Owner - Acceptable Level (Work Volume)	
28	Reputation With Current Owner - Min. Level (Work Volume)	

Table E.3: Contractor's Financial Stability Data

No.	Type of Required Data	Value
1	Total Current Bid Bond (Work Volume)	
2	Total Current Performance Bond (Work Volume)	
3	Total Current Maintenance Bond (Work Volume)	
4	Credit Level	
5	Quick ratio	
6	Current Ratio	
7	Total Liability to Net-Worth	
8	Hard Debt to Net-Worth	

Table E.4: Contractor's Current Capabilities Data

No.	Current Capability Required Data	Value
1	Current Work Volume - Contract # 1	
2	Percent Complete (Time %) - Contract # 1	
3	Percent Complete (Cost %) - Contract # 1	
4	Current Work Volume - Contract # 2	
5	Percent Complete (Time %) - Contract # 2	
6	Percent Complete (Cost %) - Contract # 2	
7	Current Work Volume - Contract # 3	
8	Percent Complete (Time %) - Contract # 3	
9	Percent Complete (Cost %) - Contract # 3	
10	Current Work Volume - Contract # Other	
11	Percent Complete (Time %) - Contract # Other	
12	Percent Complete (Cost %) - Contract # Other	
13	Types of the available equipment	
14	Number of the available equipment	
15	Specifications of the available equipment	
16	Maintenance System available for the equipment	
17	Manpower work volume (skilled Labour) per each craft type	
18	Capability of material delivery	
19	Subcontracting work volume (total)	
20	Subcontracting work type	
21	Management Staff Organization Structure	
22	Experience Level of the Management Staff & their educational level	
23	Applied Management Technique	
24		
25		
26		
27		
28		
29		
30		

Table E.5: Contractor's Submitted Plans to the Proposed Project Data

No.	Submitted Plans to the Proposed Project Required Data	Value
1	Total Bid Amount	
2	Total Project duration (Months)	
3	Sub-Contractor Work Volume	
4	Safety Plan Level	
5	Quality Assurance Plan Level	
6	Equipment Plan	
7	Manpower Plan	
8	Management Staff Experience Level	
9	Management Staff Organisation Level	
10	Material Supply Capability	
11	Project Statement	
12	Management Planning Technique	
13		
14		
15		
16		

Appendix – F

List of Experts Contacted Using Postal Questionnaires and Structured Interviews

Postal Questionnaire:

F.1 UK Sector: Heavy Construction

F.5 UK Sector: Building Construction

F.9 Egyptian Public Sector: Heavy Construction

F.10 Egyptian Public Sector: Building Construction

F.11 Egyptian Consultant Sector: Heavy and Building Construction

F.12 Kuwaiti Public Sector: Heavy Construction

F.13 Kuwaiti Public Sector: Building Construction

F.14 Kuwaiti Consultant Sector: Heavy and Building Construction

List of Structured Interviews:

F.15 List of Interviews – 1st round:

Egypt

Kuwait

F.17 List of Interviews – 2nd round:

Egypt

Kuwait

UK Sector: Heavy Construction

Barnsley Metropolitan Borough Council Public Services Department Central Offices Kendra Street Barnsley S70 2TN Director of Technical Services	Powys County Council, Highways & Transportation Dept Powys County Hall Llandrindod Wells Powys LD1 5NA Director of Technical Services	British Railways Research & Development Division PO Box 2 London Road Derby DE24 8YB Contracts Director
Leicestershire County Council Planning & Transportation Dept County Hall Greenfield Leicester LE2 8RJ Director of Technical Services	Shropshire County Council County Surveyors Dept, Consultancy Service Division Shire hall Abbey Fore gate Shrewsbury Shropshire SY2 6ND Director of Technical Services	Central Regional Council Roads and Transportation Dept View forth Stirling FK8 2ET Director of Technical Services
Cumbria County council Cumbria Highways Consultancy Citradel Chambers Carlisle CA3 8SG	South Glamorgan County Council Highways & Transportation County Hall Atlantic Wharf Cardiff CF1 5UW Director of Technical Services	Derbyshire County Council Planning and Highways Dept. County Offices Matlock Derbyshire DE4 3AG Director of Technical Services
Cornwall County Council County Surveyors Department County Hall Truro Cornwall TR1 3AY Director of Technical Services	Dudley Metropolitan Borough Public Works Dept Council House Mary Stevens Park Sturbridge West Midlands DY8 2AA Director of Technical Services	Staffordshire County Council Highways Dept Highways House River way Stafford ST16 3TJ Director of Technical Services
East Sussex County Council Highways and Transportation Dept Saukville House Brooks Close Lewes East Sussex BN7 1UE Director of Technical Services	Tayside Regional Council Water Services Dept Bullion House Inver Gowrie Dundee DD2 5BB Director of Technical Services	Royal Borough of Kingston-upon-Thames Directorate of Eng & Transp., Guildhall High Street Kingston-upon-Thames Surrey KT1 1EU Director of Technical Services
Cumbria Highways Consultancy Citadel Chambers Carlisle CA3 8SG Director of Technical Services	Thames down Borough Council Borough Engineers Dept Civic Offices Euclid Street Swindon SN2 2JH Director of Technical Services	Kirk lees Metropolitan Council - Highways Services Old gate House 2 Old gate Huddersfield HD1 6QQ Director of Technical Services
Fife Regional Council Engineering Department Roads &Water/Drainage Div. Fife House North Street Generates Fife KY7 5LT Director of Technical Services	Highland Regional Council Dept of Roads & Transport Glenurquhart Road Inverness IV3 5NX Director of Technical Services	Gwynedd County Council, Highways & Transportation Dept County Offices Caernarfon Gwynedd LL55 1SH Director of Technical Services

UK Sector: Heavy Construction (Continue...)

Humberside County Council Technical Services Dept County Hall Beverley North Humberside HU17 9XA Director of Technical Services	Hull City Council Environmental Services Dept 2nd Floor, Essex House Manor Street Hull HU1 1YD Director of Technical Services	Kettering Borough Council Municipal Offices Bowling Green Road Kettering Northants NN15 7QX Director of Technical Services
Mooched Group West Hall Purvis Road West By fleet Surrey KT14 6EZ Contracts Director	Lindbergh on Tees Borough Council, Dept of Engineering Cargo Fleet Offices Middlesborough Road PO Box South Bank 20 Cleveland TS6 6EL Director of Technical Services	Knowles Metropolitan Borough Council Dept of Planning & Development Archway Road Huston Merseyside L36 9FB Director of Technical Services
Mott MacDonald St Anne House 20-26 Wesley Road Croydon CR9 2UL Contracts Director	Wrecking District Council Planning & Environmental Services PO Box 212 Civic Offices Telford TF3 4LB Director of Technical Services	The MVA Consultancy MVA House Victoria Way Woking Surrey GU21 1DD Contracts Director
Travers Morgan Ltd 2 Kellick Street London N1 9JJ Contracts Director	Leicester City Council Environment & Development Dept New Walk centre Wellford Place Leicestershire LE1 6ZG Director of Technical Services	London Offshore Consultants Ltd 20 St Dustan's Hill London EC3Y 8HY Contracts Director
Highways Engineering & Technical Services Selecta post 6 Dudley House 133 Albion Street Leeds LS1 8JX Contracts Director	Atkinson Peck Consulting Engineers 14 School Lane Heaton Chapel Stockport Cheshire SK4 5DG Contracts Director	ECS Engineering Consultancy Services Unit 16 Withal Park Waterside South Lincoln LN5 7JN Contracts Director
Amec Design & Construction Ltd Timothy's Bridge Road Stratford-upon-Avon Warwickshire CV37 9NJ Contracts Director	Belmont Consultant Engineers 37 Station Road Belmont Sutton, Surrey SM2 6DF Contracts Director	Bailey Johnston Haynes 50 Barton Arcade Deans gate Manchester M3 2BH Contracts Director
Department of Transport Transport Research Lab Old Woking ham Road Crow Throne, Berkshire RG11 6AU Director of Technical Services	Offshore Design Engineering Ltd 6 Spring Gardens Tamworth Street London SE11 5AH Contracts Director	Brown & Root Ltd 150 The Broadway Wimbledon SW19 1RX Contracts Director

UK Sector: Heavy Construction (Continue...)

Ova Group Partnership 13 Fitzroy Street London WIP 6BQ Contracts Director	Veryard & Partners Crews House Crews Road Cardiff CF2 4NB Contracts Director	ADAS Gleadthorpe Grange Median Vale Mansfield Motts NG20 9PD Contracts Director
London Borough of Briny Engineering & Highway Services Brent House 349-357 High Road Wembley Middlesex HA9 6BT Director of Technical Services	Borough of Trafford Engineering Services Cons., Engineering & Planning PO Box 12 Trafford Town Hall Talbot Road, Stratford M23 0YX Director of Technical Services	Tony Gee and Partners TGP House 45-47 High Street Cobham Surrey KT11 3DP Contracts Director
Carl Bro Haste Newton House Newton Road Leeds LS7 4DN Contracts Director	International Mining Consultants Ltd PO Box 18 Sutton-in-Ash field Nottinghamshire NG17 2NS Contracts Director	WSP Consulting Engineers 15 New Bridge Street London EC4V 6AU Contracts Director
John Brown Engineers & Constructors 20 Eastbourne Terrace London W2 6LE Contracts Director	Scottish Power Technology Division 45/47 Haw bank Road College Melton North East Kenbridge Glasgow G74 5EG Contracts Director	Kennedy & Don kin Group Westbrook Mills Gloaming Surrey GU7 2AZ Contracts Director
Brown & Root Civil-Howard Humphrey's & Partners Thorn croft Manor Dorking Road Leatherhead Surrey Contracts Director	Man stock Geotechnical Consultancy Services Ltd 1 North Parade Parsonage Manchester M3 2FB Contracts Director	Norway plc Talbot Road Manchester M16 0HQ Contracts Director
London Borough of Croydon Public Services and Works Tavernier House Park Lane Croydon CR9 3RN Director of Technical Services	Multi Design Consultants Ltd Birdcall Lane Chewable Heath Stockport Cheshire SK3 0XP Contracts Director	Kvaerner H&G Offshore Ltd Davis House 69-77 Robert Street High Street Corydon CR0 0YA Contracts Director
Sir Alexander Gibbs & Partners Ltd Easley House 427 London Road Easley Reading RG6 1BL Contracts Director	Engineering & Power Development Consultants Ltd Marl owe House 109 Station Road Sid cup Kent DA15 7AU Contracts Director	ABP Research & Consultancy Ltd Pathfinder House Maritime Way Southampton SO1 1AE Contracts Director

UK Sector: Heavy Construction (Continue...)

Rough ton 321 Millbrook Road West Southampton SO1 0HW Contracts Director	The Maunsell Group Mau sell House 160 Corydon Road Buckingham Kent BR3 4DE Contracts Director	Hal crow Vineyard House 44 Brook Green Hammersmith London W6 7BY Contracts Director
Gwent Engineering Consultancy Highways Dept County Hall Cwmbran Gwent NP44 2XN Contracts Director	London Borough of Red bridge Lynton House 255/259 Alford High Road Ilford Essex Director of Technical Services	Flint & Neill Partnership 14 Hobart Place London SW1W 0HH Contracts Director
BNFL Engineering Ltd Room no. H/317 Riley Warrington Cheshire WA3 6AS Contracts Director		

UK Sector: Building Construction

Tay wood Engineering Ltd Tay wood House 345 Ruislip Road South all Middlesex UB1 2QX Contracts Director	Nuneaton & Bedworth Borough Council Town Hall Cotton Road Nuneaton, Warwickshire CV11 5AA Director of Technical Services	Bedfordshire County Council Consultant Division County Hall Bedford MK42 9AP Director of Technical Services
Upton McGowan & Partners Cherokee House St Thomas Street Winchester Hampshire SO23 9HJ Contracts Director	Birmingham City Council Engineers Department 1 Lancaster Circus Birmingham B4 7DQ Director of Technical Services	City of Salford, Technical Services Dept Civic Centre Charley Road Swanton Salford M27 2AB Director of Technical Services
London Brought of Baxley Sidcup Place Sidcup Kent DA14 6BT Director of Technical Services	Peterborough City Council Town Hall Bridge Street Peterborough PE1 1XG Director of Technical Services	Buckinghamshire County Council County Hall (5th Floor) Aylesbury Bucks HP20 1UY Director of Technical Services
Building Design Partnership PO Box 4WD 16 Grease Street London WIA 4WD Contracts Director	Portsmouth City Council City Engineers Dept Civic Offices Guildhall Square Portsmouth PO1 2A5 Director of Technical Services	Solihull Metropolitan Borough Council The Council House Solihull West Midlands B91 3QT Director of Technical Services
London Borough of Bromley Bromley Civic Centre Stock well Close Bromley BR1 3 UH Director of Technical Services	Bournemouth Borough Council Devpt Services Directorate Town Hall Annexe St Stephen's Road Bournemouth BH2 6EA Director of Technical Services	Norwest Holist Soil Engineering Park side Lane Dews bury Road Leeds LS11 5SX Contracts Director
Norwest Holist Soil Engineering Park side Lane Dews bury Road Leeds LS11 5SX Contracts Director	Surrey County Council County Hall Penury Road Kingston upon Thames KT1 2DY Director of Technical Services	Coventry County Council City Engineers Dpt Broad gate House Broad gate , Coventry CV1 1FS Director of Technical Services
MVM Mechanical & Electrical Consulting Engineers 78 London Road Corydon Surrey CR0 2TB Contracts Director	Michael Brad brook Consultants Ltd Green coat House 165-183 Clarence Street Kingston-upon-Thames Surrey KT1 1QT Contracts Director	Castle Rock Consultants Heath coat Building High Fields Science Park Nottingham NG7 2QJ Contracts Director

UK Sector: Building Construction (Continue...)

High-Point Europe King Edward House New Street Birmingham B2 4QJ Contracts Director	Sir Owen Williams & Partners Ltd Edgartown House 3 Duchess Place Harley Road Birmingham, B16 8NH Contracts Director	Rossford Derive Right well House Briton Centre Peterborough PE3 8DW Contracts Director
Metropolitan Borough of Rotherham Bailey House Raw marsh Road Rotherham S60 1TD Director of Technical Services	Maurice Bagley & Partners 45 Gatwick Road Crawley West Sussex RH10 2RD Contracts Director	Knight Pies old & Partners Kant hack House Station Road Ashford Kent TN23 1PP Contracts Director
Scott-White & Hopkins London House 42 West Street Carls Alton Surrey SM5 2PU Contracts Director	Vale of Glamorgan Borough Council Civic Offices Holton Road Barry South Glamorgan CF6 6RU Director of Technical Services	City of Dundee District Council 21 City Square Dundee DD1 3BS Director of Technical Services
Cass Hayward & Partners York House Welsh Street Chepstow Gwent NP6 5UW Contracts Director	Warwickshire County Council County Consultants Barrack Street Warwick CV34 4SX Director of Technical Services	Knowles Metropolitan Borough Council Dept of Planning & Development Archway Road Huston Merseyside L36 9FB Director of Technical Services
Babcock Energy Ltd Technology Centre High Street Renfrew Strathclyde PA4 8UW Contracts Director	Wessex Water Quay House The Ambary Bath Avon BA2 1YP Contracts Director	Wrexham Mellor Borough Council Guildhall Wrexham Cloyed LL1 1AY Director of Technical Services
Bedford & Eccles 13 Richmond Terrace Brighton East Sussex BN2 2SA Contracts Director	Stirling Maynard & Partners Stirling House Right well Breton Peterborough PE3 8DJ Contracts Director	Pearce Design Group 6 Marlborough Road Sheffield S10 1DB Contracts Director
Gateshead Metropolitan Borough Council Civic Centre Regent Street Gateshead; Tyne & Wear NE8 1HH Director of Technical Services	Upton McGowan & Partners Cherokee House St Thomas Street Winchester Hampshire; SO23 9HJ Contracts Director	Elliot & Brown Stanley House Pelham Road Nottingham NG5 1AQ Contracts Director

UK Sector: Building Construction (Continue...)

Hartlepool Borough Council Civic Centre Hartlepool Cleveland TS24 8AY Director of Technical Services	Rolton Consulting Engineers The Charles Parker Building Midland Road Hingham Farers Northamptonshire NN10 8DN Contracts Director	PPI Consultants 32 Saint Johns Road Tunbridge Wells Kent TN4 9NT Contracts Director
Amber Valley District Council Corn hill House Alorton Derbyshire DE5 7HN Director of Technical Services	Archibald Shaw & Partners 1 Little London Chichester West Sussex PO19 1PP Contracts Director	Curtains consulting Engineers plc 19 Rodney Street Liverpool L1 9EQ Contracts Director
Tay wood Engineering Ltd Tay wood House 345 Ruislip Road South all Middlesex UB1 2QX Contracts Director	The Acer Group Acer House Medway Road The Surrey research Park Guildford Surrey GU2 5AR	Veryard & Partners Crews House Crews Road Cardiff CF2 4NB Contracts Director
Password Divider Right well House Breton Centre Peterborough PE3 8DW Contracts Director	Kyle Stewart Design Services Merit House Edgware Road Colin dale London NW3 9AF Contracts Director	W A Airbursts & Partners Ashton House 52 We beck Street London W1M 7HE Contracts Director
M W Kellogg Ltd Kellogg House Stadium Way Wembley Middy HA9 OEE Contracts Director	Vincent Knight Sanchez Consultancy Ltd 108 Kingston Road Wimbledon London SW19 1LX Contracts Director	Curtails Engineering PO Box 11 Foresthill Road Coventry CV6 5AB Contracts Director
Montgomery Watson Ltd Terriers House Amersham Road High Welcome Bucks HP13 5AJ Contracts Director	White Young Andale Court Healingly Leeds LS6 2UJ Contracts Director	DHV Burrow Crocker Consulting Priory House 45/51 High Street Reigate Surrey RH2 9RU Contracts Director
KML Consulting Engineers 598-602 Holloway Road London N19 3PH Contracts Director	Building Design Partnership PO Box 4WD 16 Grease Street London WIA 4WD Contracts Director	Dossor Consultancy Group West Huntingdon Hall York YO3 9RE Contracts Director

UK Sector: Building Construction (Continue...)

Allot & Loma Fairborn House Ashton Lane Sale Manchester M33 1WP Contracts Director	Carl Bro Haste Newton House Newton Road Leeds LS7 4DN Contracts Director	Parkman Consulting Engineers Canard Building Liverpool L3 1ES Contracts Director
Dr Augusts Voucher & Sons Ltd 380 Bolo Lane Acton London W3 8QU Contracts Director	Davy Consultants Ashore House Richardson Road Stockton-on-Tees TS18 3RE Contracts Director	Nor dale Design Partnership Ltd Sark House 51-53 Burney Street Greenwich SE10 8EX Contracts Director
London Brought of Baxley Sidcup Place Sidcup Kent DA14 6BT Director of Technical Services	BSCP Seaton House Holt Park District Centre Leeds LS16 7SR Contracts Director	The Mark Baker Consultancy 19 West Walk Yates Bristol Avon BS17 4AX Contracts Director
Burt & Miller Thames House 58 Southwark Bridge Road London SE1 OAS Contracts Director	Byron Clarke Roberts Ltd The Building Centre 115 Portland Street Manchester M1 6DW Contracts Director	London Borough of Islington PO Box 3333 222 Upper Street London N1 1YA Director of Technical Services
London Borough of Bromley Bromley Civic Centre Stock well Close Bromley BR1 3 UH Director of Technical Services	Bay Associates Marine House 21 Mt Stuart Square Cardiff CF1 6DP Contracts Director	Project Management International plc 16 Rood Lane London EC3M 8AP Contracts Director
Design Group Partnership Brunet House 54 Princess Street Manchester M1 6HA Contracts Director	Gwent Engineering Consultancy Highways Dept County Hall Cwmbran Gwent NP44 2XN Contracts Director	

Egyptian Public Sector: Heavy Construction *:

National Authority of Highways and Bridges:
30 Kasser Al-Nile St., Adely, Cairo.

AL-Nile General Agency for Highways and Bridges	AL-Nile General Agency for Highways Construction	AL-Nile General Agency for Highways Paving
Contract admin. Project	Contract admin. Project	Contract admin. Project
Project Management admin.	Project Management admin.	Project Management admin.

Highway Construction Agency
Contract admin. Project
Project Management admin.

Ministry of public works
18 Abdul-Khalik Sarwit St., Adely, Cairo

Water Supply and Drainage	Highway Administration
Contract administration.	Contract administration.
Project management admin.	Project management admin.

Arab Contractors (OAO)
1 Mohy El-Din Abou El- Ezz St.

Bridges Administration	Highway Administration	Water Supply and Drainage
Contract administration.	Contract administration.	Contract administration.
Project management admin.	Project management admin.	Project management admin.

Hassan Allam Contractors
1Slah Salem St., Cairo

Bridges Administration	Highway Administration	Water Supply and Drainage
Contract administration.	Contract administration.	Contract administration.
Project management admin.	Project management admin.	Project management admin.

* Total number of questionnaire sent was 67 for heavy construction in public sector.

Egyptian Public Sector: Building Construction *:

Ministry of Housing
19 Ghandi St. , Cairo

Non Residential Building	Residential Building
Contract administration.	Contract administration.
Project management admin.	Project management admin.

Ministry of Education
32 Al-Thawrah ST., Cairo

Education Buildings Administration
Contract administration.
Project management admin.

Arab Contractors (OAO)
1 Mohy El-Din Abou El- Ezz St.

Building Administration
Contract administration.
Project management admin.

Hassan Allam Contractors
1Slah Salem St., Cairo

Building Administration
Contract administration.
Project management admin.

* Total number of questionnaire sent was 27 for building construction in public sector.

Egyptian Consultant Sector: Heavy and Building Construction *

Engineering Group For Consultation 12 Abou Bakr El Sedeik St., Cairo	Engineering Housing Consultant 20 El Forat St., Cairo	Egyptian Group For Engineering Consultation El Bahr ElAzam St. Safa Tower No. 2., Cairo
Dar Al-Khubraa For Engineering Consultation 12 Abou Bakr El Sedeik S., Cairo	Engineering Consultation Office-Enco 2 Abd El, Moneim El Hosseiny, Cairo	AMC for Engineering Consultation 5 El Riad St., Cairo
Eng Ismail Helmy Office 190 ,26 July St., Cairo	El Mohamadeya Consulting Office 3, El Shawarby St., Cairo	El Misreya Engineering Consultation 199, 26th July St., Cairo
El Marwa For Design and Consultation 1 El Shazly St., Cairo	Egyptian Consultation (Egypco) 15 Galal El-Din El Hamamsy St., Cairo	Egyptian Arabic Consultant. 5 El Sarai St., Cairo
Egyptian Arab Contracting 5 Hassan Badrawi St. From Haram St., Cairo	Delta For Engineering Consultation 45 Gamaet El- Dewal El Arabia St., Cairo	Dar El Miamar 13 El Lewaa Abdel Aziz, St., Cairo
Constulting Eng. Office 133 El Sudan St., Cairo	Construction Development Consultant 226 El Sudan St., Cairo	Builders Contract Consultant 48 Guiza St., Cairo
Arabia Housing and Development 1 El Borsa El Gedida St., Cairo	Arab Egyptian Consultant 5 Hasan Badrawy St., Alex	Ahmed Ibrahim 14 Gawad Hosni St., Cairo
Mancon Eng. And Management Consultation 40 El Ansar St., Cairo	Al Riyada For Building and Development 19 Al Ekbal St., Cairo	Volcano Km. 58, 59 Alex. - Matrouh Rd., Cairo
Cairo For Constructions and Consultations 89 El Merghany St., Cairo	Aresco 14 Road 279., Cairo	A B B Susa Inc. Rd. 254 At. 206 Digla., Cairo
D. E. G. Danish Egyptian Group 2 El Obour Bld. Salah Salem St., Cairo	Umran Eng. Barkat and Eng. Madany 47 Abd El Moneim Riad St., Cairo	Engineering Consultants Office 47 Goul Gamal St., Cairo
Prohcem 56 Nehro St. Behind El Marlnd, Cairo	Obrien Kreitzberg 37 Al Kods Al- Sharif St., Alex	El Memary Consultant 33 (a) Ramsis St., Alex.
El Said For Construction Management 8 Ibrahim Naguib St.,Cairo	El Wekala Ettogaria Salem 5 Suez Canal St., Cairo	Managment Support Systems 24 Mahmoud Bassiouni St.
Mens For Engineering Consultation and Development 42 A El Ryad St., Alex	Miser Consultants 72 Mosadak St., Cairo	Soutir Consultant 13 El Makrezy St., Alex.
Mekhail Eskandar 16 Gameaa El Sahaba St., Cairo	Arab Eng. Projects Consultant 5 Faroan St., Cairo	Center For Quality Assurance 12 El Nahda St., Alex.
		Gama Consultation Centre Beh. 226 Port Said St., Alex.

* Two copies were sent one for heavy and the other for building construction with equal total number of questionnaire sent for both heavy and building construction. It was 43 form of questionnaires.

Kuwaiti Public Sector: Heavy Construction *:

Ministry of Public Works:

Tel: 2449301, Fax: 2428362 - PO Box 8, Safat-13001

Special Project Departments	Maintenance Department	Highway Department
Contract admin. Project	Contract admin. Project	Contract admin. Project
Project Management admin.	Project Management admin.	Project Management admin.

Municipality Authority

Tel: 2479501, Fax: 2436371 - PO Box 5, Safat-13001

Water supply & Drainage Dept.	Highway Department
Contract administration.	Contract admin. Project
Project management admin.	Project Management admin.

Ministry of Electricity & Water
Tel: 4896000, Fax: 4897484 –

Special Project Department
Contract administration.
Project management admin.

TEXCO, Kuwait and Saudia Arabia Org.

Special Project Department
Contract administration.
Project management admin.

* Total number of questionnaire sent was 46 for heavy construction in public sector.

Kuwaiti Public Sector: Building Construction *:

Ministry of Housing
Tel: 2467300, Fax: 2428942 - PO Box 2935, Safat-13030

Non Residential Building	Residential Building
Contract administration.	Contract administration.
Project management admin.	Project management admin.

Kuwait University
Tel: 4811188, Fax: 4827159 - PO Box 5969, Safat-13060

Non Residential Building	Maintenance Department
Contract administration.	Contract administration.
Project management admin.	Project management admin.

Municipality Authority

Tel: 2479501, Fax: 2436371 - PO Box 5, Safat-13001

Non Residential Building	Residential Building
Contract administration.	Contract administration.
Project management admin.	Project management admin.

Ministry of Awqaf & Islamic Affairs

Tel: 2466300 - PO Box 13, Safat-13010

Non Residential Building	Maintenance Department
Contract administration.	Contract administration.
Project management admin.	Project management admin.

Ministry of Public Health
Tel: 2462900 - PO Box 5, Safat-13040

Non Residential Building	Maintenance Department
Contract administration.	Contract administration.
Project management admin.	Project management admin.

* Total number of questionnaire sent was 37 for building construction in public sector.

Kuwaiti Consultant Sector: Heavy and Building Construction *

AL-Arabi Consultant Office 23-Al-Estiklal St., Kuwait City	OHA Design and Consultation Office 121-Aman St. Al-Salmyia	Al-Dewalia Engineering Consulting Office 29- Beirut St. Hawali.
Al-Zamami Consultant Office 1th Ring Road, Kuwait City	Al-Khaliej Engineering Consulting Office 324 Al-Khaliej Al-Arabi St., Kuwait City.	Al-Mohandes AL-Kuwaiti Engineering Consulting Office 12-Al-Salhia Towers, AL-Mobarkiah, Kuwait City.
Baian Office for Design and Consultation 27 Souk Al-Salmyia St., Al-Salmyia.	Asian Office for Design and Consultation 32 Al-Khalil Ben Ahmed, Al-Yarmouk	Unitec Office for Design and Consultation 17 Hassan Al-Bana St. Roumithia
Al-Saquer Design and Consultation Office 26 Ahmed Al-Jaber St., Kuwait City	Al-Habashi Design and Consultation Office 35 Sharhabil St., Hawalli.	Kuwaiti Tech. Office for Engineering Consultation 9 Salem Al-Sabah St. Kuwait City
AL-Saadon Office for Design and Consultation 28 Abdulla Al-Salem St., Kuwait City	Al-Azmi Engineering Consulting Office 7 Moubark Al-Sabah St., Kuwiat City	Al-Otaibi Engineering Consulting Office 36 Al-Moghairah Ben Shubah, Al-Salmyia
SEMAC Office for Engineering Consultation 11 Al-Ferdous St., Kuwiat City	PROJACS Engineering Consultation Office 53-Anwar AL-Sabah Tower, Al- Salhiah, Kuwait City	Al-Enazi Engineering Consulting Office 16 Tunisia St., Hawali.
Al-Ajmi Engineering Consulting Office 34 Cairo St., Hawali	Kuwaiti-Manager Office 33 AL-Safat Tower, AL-Moubarikia, Kuwiat City	Tourist Projects Agency 15 Salem AL-Moobark St., Kuwait City

*Total number of questionnaire sent for heavy construction was 14 and for building construction was 18 form of questionnaires.

List of Interviews – 1st round:

Egypt:

1. ***Eng. Zakria Abdul-Hamid***: Consultant Engineer – Building Projects (18 years of experience) - 32 Dar Al-Moshah, Miser Al-Gadidah , Cairo

2. ***Eng. Mohamed Mahmoud***: Consultant Engineer – Building Projects (21 years of experience) - 15 Mustafa Kamel St., Ismailia.

3. ***Eng. Hisham Azmi***: Consultant Engineer – Heavy Construction Projects (26 years of experience) - 23 Abdul-Aziz Fahmi St., Al-Haram, Giza

4. ***Eng. Mohamed Abdullah***: Consultant Engineer – Heavy Construction Projects (17 years of experience) - 11 Abdul-Khalik Tharwut St., Adeli, Cairo

5. ***Dr. Eng. Yussof Mohi Al-Dean***: Consultant Engineer – Building Projects (19 years of experience) - Miser Consultants 72 Mosadak St., Cairo

6. ***Dr. Mohessen Ahmad***: Consultant Engineer – Heavy Construction Projects (20 years of experience) - 35 Mustafa Al-Nahas St., Madineh Nasser, Cairo

Kuwait:

1. ***Prof. Sami Fereig***: Consultant Engineer - Heavy Construction (30 years of experience) – Civil Eng. Dept., Kuwait University, AL-Khaldyiah, Kuwait City.

2. ***Dr. Nabil Qaddommi***: PROJACS Engineering Consultation - Building Projects Office 53-Anwar AL-Sabah Tower, Al-Salhiah, Kuwait City.

3. ***Dr. Nabil Kartam***: Consultant Engineer - Building Projects (17 years of experience) – Civil Eng. Dept., Kuwait University, AL-Khaldyiah, Kuwait City.

4. ***Dr. Ahmed Abdul-Hamid***: Consultant Engineer - Heavy Construction (24 years of experience) – Special Project Dept., Ministry of Public Works, 15 Sabah-Al-Salem St, Al-Moubarkiah, Kuwait City.

5. ***Eng. Ehab Halima:*** Consultant Engineer - Building Projects (15 years of experience) – Contract Dept., Kuwait University, AL-Shwaikh, Kuwait City.

6. ***Eng. Hussein Al-Awadi***: Consultant Engineer - Heavy Construction (17 years of experience) – Contract Dept., Ministry of Public Works, 15 Sabah-Al-Salem St, Al-Moubarkiah, Kuwait City.

7. ***Eng. Yussof Al-Alian:*** Consultant Engineer - Building Projects (19 years of experience) – Contract Dept., Ministry of Housing, 12 Salem Al-Mobark St, Al-Nogra, Kuwait City.

8. ***Eng. Said Al-Mossawi***: Consultant Engineer - Building Projects (15 years of experience) – Contract Dept., Ministry of Housing, 12 Salem Al-Mobark St, Al-Nogra, Kuwait City.

9. ***Eng. Hisham Al-Dosoki***: Consultant Engineer - Building Projects (15 years of experience) Civil Eng. Dept., Kuwait University, AL-Khaldyiah, Kuwait City.

10. ***Dr. Tarek Anwar***: Consultant Engineer - Building Projects (16 years of experience) Al-Mohandes AL-Kuwaiti Engineering Consulting Office, 12-Al-Salhia Tower, Kuwait City.

List of Interviews – 2nd round:

Egypt:

1. ***Dr. Mohessen Ahmad***: Consultant Engineer – Heavy Construction Projects (20 years of experience) - 35 Mustafa Al-Nahas St., Madineh Nasser, Cairo

Kuwait:

1. ***Prof. Sami Fereig***: Consultant Engineer - Heavy Construction (30 years of experience) – Civil Eng. Dept., Kuwait University, AL-Khaldyiah, Kuwait City.

1. ***Dr. Nabil Qaddommi***: PROJACS Engineering Consultation - Building Projects Office 53-Anwar AL-Sabah Tower, Al-Salhiah, Kuwait City.

2. ***Dr. Nabil Kartam***: Consultant Engineer - Building Projects (17 years of experience) – Civil Eng. Dept., Kuwait University, AL-Khaldyiah, Kuwait City.

3. ***Eng. Hussein Al-Awadi***: Consultant Engineer - Heavy Construction (17 years of experience) – Contract Dept., Ministry of Public Works, 15 Sabah-Al-Salem St, Al-Moubarkiah, Kuwait City.

4. ***Dr. Ahmed Abdul-Hamid***: Consultant Engineer - Heavy Construction (24 years of experience) – Special Project Dept., Ministry of Public Works, 15 Sabah-Al-Salem St, Al-Moubarkiah, Kuwait City.

Appendix - G

Simulated Case Project - Case 1

G.1 Table G: Simulated Project – Case 1

Table G: Simulated project [Case 1]

Code of Criterion	Criterion Description	CC1 ****	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG1.01*	Number of years working in S.Ps.**	6	7	8	9	10	9	8	7	6	5
DCG1.02	Contractor age in Construction	9	10	11	12	13	12	11	10	9	8
DCG1.03	Maximum project delivery rate within last 3 years (Work vol./ Proj. duration).	2000	2220	2470	2745	3050	2745	2470	2220	2000	1800
DCG1.04	Low rate criterion (Excluded one)	3000	3500	4000	4500	5000	4500	4000	3500	3000	2500
DCG1.05	Work volume of S.Ps. within last 10 years	20000	21000	22000	23000	24000	23000	22000	21000	20000	19000
DCG1.06	Low rate criterion (Excluded one)	1500	1750	2000	2250	2500	2250	2000	1750	1500	1250
DCG1.07	Average annual work volume of S.Ps. - Last 3 years	5000	5500	6000	6500	7000	6500	6000	5500	5000	4500
DCG1.09.1	Work Volume for S. P.S. - Lump Sum Contract	2500	3000	3500	4000	4500	4000	3500	3000	2500	2000
DCG1.09.2	Work Volume for C PS. - Lump Sum Contract	7500	8500	9500	10500	11500	10500	9500	8500	7500	6500
DCG1.09.3	Work Volume for S. PS. - Unit Price Contract	2500	3000	3500	4000	4500	4000	3500	3000	2500	2000
DCG1.09.4	Work Volume for C. PS. - Unit Price Contract	8000	10000	12000	14000	16000	14000	12000	10000	8000	6000
DCG1.09.5	Work Volume for S. Ps. - Const. Management Contract	1000	2000	3000	4000	5000	4000	3000	2000	1000	0
DCG1.09.6	Work Volume for C. Ps. - Const. Management Contract	2500	3000	3500	4000	4500	4000	3500	3000	2500	2000
DCG1.12	Previous work in S.Ps. with Same Owner	500	750	1000	1250	1500	1250	1000	750	500	250
DCG1.13	Previous work in C.Ps. with Same Owner	200	400	600	800	1000	800	600	400	200	0
DCG1.14	Previous work in similar weather conditions and S.Ps.	5000	6000	7000	8000	9000	8000	7000	6000	5000	4000
DCG1.16	Previous work in similar geographical conditions and S.Ps.	5000	7500	10000	12500	15000	12500	10000	7500	5000	2500
DCG1.17	Previous work in similar geographical conditions and C.Ps***.	15000	16000	17000	18000	19000	18000	17000	16000	15000	14000
DCG2.01a^	Ability to meet project duration of S.Ps exactly last 5 yr..	450	550	650	750	850	750	650	550	450	350
DCG2.01b	Ability to meet project duration of S.Ps by 5% over last 5 yr..	900	1000	1100	1200	1300	1200	1100	1000	900	800
DCG2.01c	Ability to meet project duration of S.Ps by 10% over last 5 yr..	1200	1300	1400	1500	1600	1500	1400	1300	1200	1100
DCG2.01d	Ability to meet project duration of S.Ps by 20% over last 5 yr..	550	650	750	850	950	850	750	650	550	450
DCG2.01e	Ability to meet project duration of S.Ps by 30% over last 5 yr..	350	450	550	650	750	650	550	450	350	250
DCG2.02a	Meeting project budget of completed S.Ps. exactly - last 5 years	750	1000	1250	1500	1750	1500	1250	1000	750	500
DCG2.02b	Meeting project budget of completed S.Ps. by 5% over last 5 yr..	1000	1250	1500	1750	2000	1750	1500	1250	1000	750
DCG2.02c	Meeting project budget of completed S.Ps.by 10% over last 5 yr..	650	750	850	950	1050	950	850	750	650	550
DCG2.02d	Meeting project budget of completed S.Ps. by 20% over last 5 yr..	700	800	900	1000	1100	1000	900	800	700	600
DCG2.02e	Ability to meet project Budget by 30% over last 5 yr..	500	600	700	800	900	800	700	600	500	400
DCG2.03a	Meeting project quality of completed S.Ps.- High Level	1250	1500	1750	2000	2250	2000	1750	1500	1250	1000
DCG2.03b	Meeting project quality of completed S.Ps.- Acceptable Level	1500	1700	1900	2100	2300	2100	1900	1700	1500	1300
DCG2.03c	Meeting project quality of completed S.Ps.- Minimum Level	1400	1500	1600	1700	1800	1700	1600	1500	1400	1300
DCG2.03.2a	Test results of completed S.Ps - High level	1750	2000	2250	2500	2750	2500	2250	2000	1750	1500
DCG2.03.2b	Test results of completed S.Ps - Acceptable Level	1000	1300	1600	1900	2200	1900	1600	1300	1000	700
DCG2.03.2c	Test results of completed S.Ps - Minimum Level	1700	1800	1900	2000	2100	2000	1900	1800	1700	1600
DCG2.04.2a	Safety record last 3 years - High Level	1600	1800	2000	2200	2400	2200	2000	1800	1600	1400
DCG2.04.2b	Safety record last 3 years - Acceptable Level	2200	2400	2600	2800	3000	2800	2600	2400	2200	2000
DCG2.04.2c	Safety record last 3 years - Minimum Level	1050	1150	1250	1350	1450	1350	1250	1150	1050	950

* DCG1.1: This code means the first decision criterion (DC)in the first criteria group (G1)

** S.Ps.: means that project has a similar work type and hence similar experience and resources are required to caary out the proposed project.

*** C.Ps.: means construction projects.

**** CC1 to CC10 refers to the ten different contractors

^ a, b, c, d or e indicates to the different levels or values that a contractors have within certain criterion

Table G: Simulated project [Case 1] (Continue...)

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG2.05.1a	Contractor reputation at previous owners - High Level	4500	5000	5500	6000	6500	6000	5500	5000	4500	4000
DCG2.05.1b	Contractor' Reputation at past project(s)'s owners- Acceptable Level	5000	6000	7000	8000	9000	8000	7000	6000	5000	4000
DCG2.05.1c	Contractor' Reputation at past project(s)'s owners - Minimum Level	2500	3000	3500	4000	4500	4000	3500	3000	2500	2000
DCG2.05.2a	Contractor reputation at previous suppliers - High Level	1450	1900	2350	2800	3250	2800	2350	1900	1450	1000
DCG2.05.2b	Contractor reputation at previous suppliers - Acceptable Level	1850	1950	2050	2150	2250	2150	2050	1950	1850	1750
DCG2.05.2c	Contractor reputation at previous suppliers - Minimum Level	950	1100	1250	1400	1550	1400	1250	1100	950	800
DCG2.05.3a	Contractor reputation at previous subcontractors - High Level	1500	1750	2000	2250	2500	2250	2000	1750	1500	1250
DCG2.05.3b	Contractor reputation at previous subcontractors - Acceptable Level	1000	1250	1500	1750	2000	1750	1500	1250	1000	750
DCG2.05.3c	Contractor reputation at previous subcontractors - Minimum Level	950	1250	1550	1850	2150	1850	1550	1250	950	695
DCG2.05.4a	Contractor reputation at previous insurance companies..- High Level	6500	7500	8500	9500	10500	9500	8500	7500	6500	5500
DCG2.05.4b	Contractor reputation at previous insurance companies. - Acceptable Level	4000	4500	5000	5500	6000	5500	5000	4500	4000	3500
DCG2.05.4c	Contractor reputation at previous insurance companies - Minimum Level	2500	3500	4500	5500	65000	5500	4500	3500	2500	1500
DCG3.01.1	Bid Bond	200	2500	300	350	400	350	300	250	200	150
DCG3.01.2	Performance Bond	125	200	275	350	425	350	275	200	125	50
DCG3.01.4	Maintenance Bond	100	125	150	175	200	175	150	125	100	75
DCG3.02.2	Cost of Finance	1	1	1	1	1	1	1	1	1	1
DCG3.02.3	Financial arrangements	Good	V Good	Avg.	Acceptable	Excelent	Good	Excelent	V Good	Avg.	Good
DCG3.03	Credit Level	1.8	1.6	1.4	1.2	1	1.2	1.4	1.6	1.8	2
DCG3.04	Financial Statement	0.6	0.7	0.8	0.9	1	0.9	0.8	0.7	0.6	0.5
DCG3.04.1	Status of Audited Financial Statement	Good	V Good	Avg.	Acceptable	Excelent	Good	Excelent	V Good	Avg.	Good
DCG3.05.1.1	Current Ratio	1	1	1	1	1	1	1	1	1	1
DCG3.05.2.1	Total liabilities / Tangible net worth	1	1	1	1	1	1	1	1	1	1
DCG3.05.2.2	Hard debt /Tangible net worth	1	1	1	1	1	1	1	1	1	1

Table G: Simulated project [Case 1] (Continue...)

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG4.01	Contractor's Management capabilities		These Contractors are exceluded from the Screening Phase		Good	V. Good	V. Good				
DCG4.01.1	Management organisation structure				Good	Excellent	V. Good				
DCG4.01.2	Experience level of management staff				Average	High	High				
DCG4.01.3	Management techniques				High	High	High				
DCG4.01.3.1	Planning and control techniques				High	High	High				
DCG4.01.4	Coordination between management office and site				High	High	High				
DCG4.02	Equipment availability				Average	High	Average		These Contractors are exceluded from the Screening Phase		
DCG4.02.1	Types of available equipment				Fair	Fair	Fair				
DCG4.02.2	Specifications of available Equipment				Fair	Fair	Fair				
DCG4.02.3	Models of Available Equipment				Adequate	Adequate	Adequate				
DCG4.02.4	Quantity of the available Equipment				Fair	Fair	Fair				
DCG4.02.5	Maintenance System of available equipment				Fair	High	Fair				
DCG4.03	Manpower resources availability				Average	High	High				
DCG4.03.1	Labor craft type available				Average	High	High				
DCG4.03.2	Number of labor from each craft type				Average	High	Average				
DCG4.03.3	Total number of permanent labor				12	20	16				
DCG4.04	Subcontractor's work value				30%	20%	28%				
DCG4.04.1	Subcontractor's work volume				4,275	3,860	4,353				
DCG4.04.2	Subcontractor's work type				4	3	3				
DCG4.04.3	Subcontracting's control system applied by main contractor				Adequate	Adequate	Adequate				
DCG4.04.4	Material delivery availability				no	no	no				
DCG4.04.5	Contractor's current capacity to carry out an additional work				Average	High	Average				
DCG4.04.6	Current work volume				14250	19299	15545				
DCG4.04.6.1	Percentage complete of current projects				0.625	0.503	0.51				
DCG4.04.6.2	Current capacity to carry an additional construction work				Average	High	Average				
DCG5.1	Bid Price of the proposed project										
DCG5.01.1	Total Bid Amount				4750	4850	4400				
DCG5.01.2	Cash-out Schedule				45	41	35				
DCG5.02	Job statement of proposed project				Average	High	Average				
DCG5.02.1	Construction method statement				Average	High	Average				
DCG5.02.2	Project Time Schedule				45	41	35				
DCG5.03	Applied management planning techniques				Average	High	High				
DCG5.03.2	Experience, continuity and organization structure of the assigned staff				Average	High	High				
DCG5.03.3	Equipment Schedule				Average	High	Average				
DCG5.03.4	Manpower Schedule				Average	High	Average				
DCG5.03.5	Quality assurance and quality control plan				Adequate	Adequate	Adequate				
DCG5.03.6	Safety plan				Adequate	Adequate	Adequate				
DCG5.03.7	Procurement plan				no	no	no				
DCG5.03.8	Subcontracting works				1500	1000	1250				

Appendix - H

Project Case Studies – Case 2 and Case 3

H.1 Table H.1: Real Projects [Case 2]

H.4 Table H.2: Real Projects [Case 3]

Table H.1: Real project [Case 2]

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG1.01*	Number of years working in S.Ps.**	3	10	6	6	3	1	7	5	6	4
DCG1.02	Contractor age in Construction	10	15	8	6	7	8	7	10	12	10
DCG1.03	Maximum project delivery rate within last 3 years (Work vol./ Proj. durati	2500	2220	2470	1800	2200	2300	1950	2000	2500	2700
DCG1.04	Low rate criterion (Excluded one)	6000	15000	10000	9000	6000	12000	12000	16000	10000	8000
DCG1.05	Work volume of S.Ps. within last 10 years	25000	18000	28000	19000	20000	18000	19000	22000	24000	16000
DCG1.06	Low rate criterion (Excluded one)	4500	6000	6600	5100	3500	1600	10000	6600	9000	4800
DCG1.07	Average annual work volume of S.Ps. - Last 3 years	4500	10800	8000	7000	5100	8810	10000	9000	12000	6600
DCG1.09.1	Work Volume for S. P.S. - Lump Sum Contract	3000	4000	2500	3500	2500	4000	3000	4500	4000	2000
DCG1.09.2	Work Volume for C PS. - Lump Sum Contract	11500	9500	7500	6500	8500	10500	7500	8500	9500	10500
DCG1.09.3	Work Volume for S. PS. - Unit Price Contract	4000	2500	3000	4000	3500	4500	2500	3500	4000	3000
DCG1.09.4	Work Volume for C. PS. - Unit Price Contract	12000	14000	16000	8000	10000	6000	12000	10000	14000	8000
DCG1.09.5	Work Volume for S. Ps. - Const. Management Contract	5000	4000	5000	3000	2000	3000	1500	4000	3000	2500
DCG1.09.6	Work Volume for C. Ps. - Const. Management Contract	4500	2500	5000	3000	2500	4500	5000	6000	5000	4000
DCG1.12	Previous work in S.Ps. with Same Owner	1500	2500	3000	2000	1800	2100	3000	1800	2000	1000
DCG1.13	Previous work in C.Ps. with Same Owner	1000	1800	1200	350	500	1000	400	800	350	800
DCG1.14	Previous work in similar weather conditions and S.Ps.	9000	3000	8500	4500	5000	6000	3000	4500	3000	6500
DCG1.16	Previous work in similar geographical conditions and S.Ps.	12000	3800	6000	10000	8000	10000	12500	14000	8000	6000
DCG1.17	Previous work in similar geographical conditions and C.Ps***.	10000	12000	11000	14500	12500	10500	15000	12000	10000	13500
DCG2.01a^	Ability to meet project duration of S.Ps exactly last 5 yr..	1750	2000	1500	1200	1000	2000	1100	2000	1500	1750
DCG2.01b	Ability to meet project duration of S.Ps by 5% over last 5 yr..	2500	1800	1200	1100	1400	1500	1200	1800	1600	1200
DCG2.01c	Ability to meet project duration of S.Ps by 10% over last 5 yr..	1100	850	900	1200	850	1100	600	1200	1000	750
DCG2.01d	Ability to meet project duration of S.Ps by 20% over last 5 yr..	1200	500	1300	800	750	1200	650	1100	1200	850
DCG2.01e	Ability to meet project duration of S.Ps by 30% over last 5 yr..	400	850	1200	1100	1300	1000	950	500	900	1100
DCG2.02a	Meeting project budget of completed S.Ps. exactly - last 5 years	900	600	850	1100	450	600	1100	1200	900	850
DCG2.02b	Meeting project budget of completed S.Ps. by 5% over last 5 yr..	1100	1300	900	800	950	1000	1900	600	850	1400
DCG2.02c	Meeting project budget of completed S.Ps.by 10% over last 5 yr..	2000	1500	1750	1100	1300	1800	1200	1500	1600	1300
DCG2.02d	Meeting project budget of completed S.Ps. by 20% over last 5 yr..	1000	800	1100	1200	1000	500	850	1100	800	1000
DCG2.02e	Ability to meet project Budget by 30% over last 5 yr..	500	800	900	500	1100	850	1000	750	550	600
DCG2.03a	Meeting project quality of completed S.Ps.- High Level	900	1100	1250	1000	1250	2000	1500	1100	800	900
DCG2.03b	Meeting project quality of completed S.Ps.- Acceptable Level	900	1100	1500	1800	1500	1200	900	1200	900	1800
DCG2.03c	Meeting project quality of completed S.Ps.- Minimum Level	1700	1100	1200	950	1500	1200	1100	900	1100	1500
DCG2.03.2a	Test results of completed S.Ps - High level	2200	1800	1500	2300	2100	1800	1500	2300	1800	2000
DCG2.03.2b	Test results of completed S.Ps - Acceptable Level	1300	1200	1900	1500	1350	2400	850	900	2100	500
DCG2.03.2c	Test results of completed S.Ps - Minimum Level	1500	1900	2100	1500	1800	2200	1400	2100	1200	2200
DCG2.04.2a	Safety record last 3 years - High Level	2100	2400	1800	1600	2200	2300	1500	2100	2000	1800
DCG2.04.2b	Safety record last 3 years - Acceptable Level	3000	2800	2100	2400	1500	1900	2500	2000	1750	1850
DCG2.04.2c	Safety record last 3 years - Minimum Level	800	550	950	1400	1100	650	850	900	1350	1450

* DCG1.1: This code means the first decision criterion (DC)in the first criteria group (G1)

** S.Ps.: means that project has a similar work type and hence similar experience and resources are required to caary out the proposed project.

*** C.Ps.: means construction projects.

^ a, b, c, d or e indicates to the different levels or values that a contractors have within certain criterion

Table H.1: Real project [Case 2] (Continue...)

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG2.05.1a	Contractor reputation at previous owners - High Level	7000	3000	4000	2800	2800	3500	3900	2800	4000	6500
DCG2.05.1b	Contractor' Reputation at past project(s)'s owners- Acceptable Level	3000	2500	5000	4500	6800	7500	2800	5000	4350	5000
DCG2.05.1c	Contractor' Reputation at past project(s)'s owners - Minimum Level	1500	2500	2200	3000	2800	2500	4500	5000	1800	1500
DCG2.05.2a	Contractor reputation at previous suppliers - High Level	2500	2100	1500	1400	2800	2500	1900	2200	1100	1500
DCG2.05.2b	Contractor reputation at previous suppliers - Acceptable Level	1500	1800	1100	1200	1500	1200	2000	1800	800	950
DCG2.05.2c	Contractor reputation at previous suppliers - Minimum Level	500	800	1200	1500	2000	1100	900	1500	850	1200
DCG2.05.3a	Contractor reputation at previous subcontractors - High Level	3000	2800	2100	2500	1500	1800	2500	1500	2100	1300
DCG2.05.3b	Contractor reputation at previous subcontractors - Acceptable Level	2500	2100	1800	1500	2000	1200	1500	2200	1500	1200
DCG2.05.3c	Contractor reputation at previous subcontractors - Minimum Level	1500	1400	800	950	2000	1100	1500	800	900	550
DCG2.05.4a	Contractor reputation at previous insurance companies..- High Level	3000	3500	4800	5000	6500	7000	5500	8000	8500	6500
DCG2.05.4b	Contractor reputation at previous insurance companies. - Acceptable Level	3500	2500	4000	6000	5800	2500	3000	3500	5000	4800
DCG2.05.4c	Contractor reputation at previous insurance companies - Minimum Level	7000	5500	3500	4500	8000	7500	3500	6000	7000	2500
DCG3.01.1	Bid Bond	500	600	400	250	200	550	400	600	350	450
DCG3.01.2	Performance Bond	350	550	250	400	350	500	245	350	450	200
DCG3.01.4	Maintenance Bond	150	175	200	250	125	200	150	175	150	200
DCG3.02.2	Cost of Finance	1	1	1	1	1	1	1	1	1	1
DCG3.02.3	Financial arrangements	V Good	V Good	Good	Avg.	Excelent	Good	Good	V Good	Excelent	Good
DCG3.03	Credit Level	1.1	1.8	1.5	2	1.5	1.6	1	1.2	1.5	1.1
DCG3.04	Financial Statement	0.85	0.5	0.7	1	0.8	0.95	1	0.6	1	0.85
DCG3.04.1	Status of Audited Financial Statement	Good	V Good	V. Good	Good	Good	V. Good	Excelent	V Good	Excelent	Good
DCG3.05.1.1	Current Ratio	1	1	1	1	1	1	1	1	1	1
DCG3.05.2.1	Total liabilities / Tangible net worth	1	1	1	1	1	1	1	1	1	1
DCG3.05.2.2	Hard debt /Tangible net worth	1	1	1	1	1	1	1	1	1	1

Table H.1: Real project [Case 2] (Continue...)

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG4.01	Contractor's Management capabilities				Good		Good		These Contractors are exceluded from the Pre-Tender Phase	V. Good	
DCG4.01.1	Management organisation structure				Excellent		V. Good			V. Good	
DCG4.01.2	Experience level of management staff				Average		High			Average	
DCG4.01.3	Management techniques				High		Average			High	
DCG4.01.3.1	Planning and control techniques				High		Average			High	
DCG4.01.4	Coordination between management office and site				Average		High			Average	
DCG4.02	Equipment availability		These Contractors are exceluded from the Pre-Tender Phase		High		Average			Average	
DCG4.02.1	Types of available equipment				Fair		Average			Fair	
DCG4.02.2	Specifications of available Equipment				Fair		Fair			Fair	
DCG4.02.3	Models of Available Equipment				Adequate		High			Adequate	
DCG4.02.4	Quantity of the available Equipment				Fair		High			High	
DCG4.02.5	Maintenance System of available equipment				High		Fair			Fair	
DCG4.03	Manpower resources availability				High		Fair			Average	
DCG4.03.1	Labor craft type available				Fair		High			High	
DCG4.03.2	Number of labor from each craft type				High		Average			Average	
DCG4.03.3	Total number of permanent labor				20		16			12	
DCG4.04	Subcontractor's work value				20%		28%			30%	
DCG4.04.1	Subcontractor's work volume				5,860		5,193			7,725	
DCG4.04.2	Subcontractor's work type				3		3			4	
DCG4.04.3	Subcontracting's control system applied by main contractor				Adequate		Adequate			Adequate	
DCG4.04.4	Material delivery availability				no		no			no	
DCG4.04.5	Contractor's current capacity to carry out an additional work				High		Average			Average	
DCG4.04.6	Current work volume				29299		18545			25750	
DCG4.04.6.1	Percentage complete of current projects				0.50		0.51			0.63	
DCG4.04.6.2	Current capacity to carry an additional construction work				High		Average			Average	
DCG5.1	Bid Price of the proposed project										
DCG5.01.1	Total Bid Amount				4750		4850			4400	
DCG5.01.2	Cash-out Schedule				45		41			35	
DCG5.02	Job statement of proposed project				High		Average			Average	
DCG5.02.1	Construction method statement				Average		High			Average	
DCG5.02.2	Project Time Schedule				41		45			35	
DCG5.03	Applied management planning techniques				High		Average			High	
DCG5.03.2	Experience, continuity and organization structure of the assigned staff				Average		Average			High	
DCG5.03.3	Equipment Schedule				Average		High			Average	
DCG5.03.4	Manpower Schedule				High		High			High	
DCG5.03.5	Quality assurance and quality control plan				Adequate		Adequate			Adequate	
DCG5.03.6	Safety plan				Adequate		Adequate			Adequate	
DCG5.03.7	Procurement plan				no		no			no	
DCG5.03.8	Subcontracting works				1500		1000			1250	

Table H.2: Real project [Case 3]

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG1.01*	Number of years working in S.Ps.**	8	6	9	11	7	5	8	8	4	6
DCG1.02	Contractor age in Construction	12	10	8	6	10	8	9	6	10	8
DCG1.03	Maximum project delivery rate within last 3 years (Work vol./ Proj. duration).	1950	2000	2300	1950	1700	2500	1950	2200	2500	3000
DCG1.04	Low rate criterion (Excluded one)	4800	16000	12000	12000	8000	14000	12000	1800	10000	6000
DCG1.05	Work volume of S.Ps. within last 10 years	21500	22000	18000	19000	18000	15000	19000	18000	24000	12000
DCG1.06	Low rate criterion (Excluded one)	5000	6600	1600	10000	4500	2000	10000	5200	9000	7500
DCG1.07	Average annual work volume of S.Ps. - Last 3 years	4500	9000	8810	10000	5000	6500	10000	7500	12000	8000
DCG1.09.1	Work Volume for S. P.S. - Lump Sum Contract	2500	4500	4000	3000	3500	4000	3000	5000	4000	3500
DCG1.09.2	Work Volume for C PS. - Lump Sum Contract	10500	8500	10500	7500	9000	8500	7500	6570	9500	8000
DCG1.09.3	Work Volume for S. PS: - Unit Price Contract	3500	3500	4500	2500	3000	5000	2500	4500	4000	4500
DCG1.09.4	Work Volume for C. PS. - Unit Price Contract	8950	10000	6000	12000	8500	7500	12000	8500	14000	10000
DCG1.09.5	Work Volume for S. Ps. - Const. Management Contract	7000	4000	3000	1500	1850	2500	1500	3500	3000	3500
DCG1.09.6	Work Volume for C. Ps. - Const. Management Contract	3450	6000	4500	5000	3000	3750	5200	7000	5000	6000
DCG1.12	Previous work in S.Ps. with Same Owner	1200	1800	2100	3000	1500	2500	3000	1650	2000	1450
DCG1.13	Previous work in C.Ps. with Same Owner	1350	800	1000	400	850	1200	400	1000	350	950
DCG1.14	Previous work in similar weather conditions and S.Ps.	7000	4500	6000	3000	4400	5000	3000	3500	3000	5500
DCG1.16	Previous work in similar geographical conditions and S.Ps.	10000	14000	10000	12500	7000	11000	12500	12000	8000	4500
DCG1.17	Previous work in similar geographical conditions and C.Ps***.	7500	12000	10500	15000	14000	12000	15000	10500	10000	12500
DCG2.01a	Ability to meet project duration of S.Ps exactly last 5 yr..	2100	1900	1650	1200	1000	2000	1100	2000	1500	1750
DCG2.01b	Ability to meet project duration of S.Ps by 5% over last 5 yr..	2750	1600	1400	1100	1400	1500	1200	1800	1600	1200
DCG2.01c	Ability to meet project duration of S.Ps by 10% over last 5 yr..	1500	1000	850	1200	850	1100	600	1200	1000	750
DCG2.01d	Ability to meet project duration of S.Ps by 20% over last 5 yr..	1200	1200	750	1100	750	1250	800	1000	1200	850
DCG2.01e	Ability to meet project duration of S.Ps by 30% over last 5 yr..	550	900	1300	500	1300	1200	950	750	900	1500
DCG2.02a	Meeting project budget of completed S.Ps. exactly - last 5 years	750	900	450	1200	450	800	1100	1200	1100	900
DCG2.02b	Meeting project budget of completed S.Ps. by 5% over last 5 yr..	1500	850	950	600	950	1100	1900	700	850	1200
DCG2.02c	Meeting project budget of completed S.Ps.by 10% over last 5 yr..	1850	1600	1300	1500	1300	800	1200	1250	1500	1500
DCG2.02d	Meeting project budget of completed S.Ps. by 20% over last 5 yr..	1250	800	1000	1100	1000	1350	850	1000	1100	900
DCG2.02e	Ability to meet project Budget by 30% over last 5 yr..	650	550	1100	750	1100	1200	1000	900	600	850
DCG2.03a	Meeting project quality of completed S.Ps.- High Level	450	800	1250	1100	1250	1000	1500	1250	750	900
DCG2.03b	Meeting project quality of completed S.Ps.- Acceptable Level	800	900	1500	1200	1500	1800	900	1000	1000	1600
DCG2.03c	Meeting project quality of completed S.Ps.- Minimum Level	1500	1100	1500	900	1500	950	1100	750	950	1350
DCG2.03.2a	Test results of completed S.Ps - High level	1850	1800	2100	2300	2100	2300	1500	2200	1650	1800
DCG2.03.2b	Test results of completed S.Ps - Acceptable Level	1500	2100	1350	900	1350	1500	850	750	2200	900
DCG2.03.2c	Test results of completed S.Ps - Minimum Level	1750	1200	1800	2100	1800	1500	1400	1850	1500	1850
DCG2.04.2a	Safety record last 3 years - High Level	2000	2000	2200	2100	2200	1600	1500	2500	1800	1600
DCG2.04.2b	Safety record last 3 years - Acceptable Level	3500	1750	1500	2000	1500	2400	2500	1800	1500	2100
DCG2.04.2c	Safety record last 3 years - Minimum Level	1200	1350	1100	900	1100	1400	850	1000	1200	1500

* DCG1.1: This code means the first decision criterion (DC)in the first criteria group (G1)

** S.Ps.: means that project has a similar work type and hence similar experience and resources are required to caary out the proposed project.

*** C.Ps.: means construction projects.

Table H.2: Real project [Case 3] (Continue...)

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG2.05.1a	Contractor reputation at previous owners - High Level	6500	5000	4250	3750	2500	4500	2750	4000	5500	7500
DCG2.05.1b	Contractor' Reputation at past project(s)'s owners- Acceptable Level	4000	3000	3500	4500	5500	6000	5000	5750	4250	4000
DCG2.05.1c	Contractor' Reputation at past project(s)'s owners - Minimum Level	2000	4500	2500	3500	2350	2800	4250	2750	1350	2250
DCG2.05.2a	Contractor reputation at previous suppliers - High Level	1500	2000	1250	1650	2500	2100	2250	2500	1550	1750
DCG2.05.2b	Contractor reputation at previous suppliers - Acceptable Level	1200	1500	950	1250	1850	1500	1800	2200	1150	750
DCG2.05.2c	Contractor reputation at previous suppliers - Minimum Level	650	1000	1500	1750	2200	1250	1100	1750	1450	1250
DCG2.05.3a	Contractor reputation at previous subcontractors - High Level	2500	3000	1750	2500	1200	1500	2750	1100	2250	1100
DCG2.05.3b	Contractor reputation at previous subcontractors - Acceptable Level	3000	1800	1500	1250	2000	1750	1250	2250	1650	1000
DCG2.05.3c	Contractor reputation at previous subcontractors - Minimum Level	1800	1650	1200	1000	2500	750	1850	1150	1350	800
DCG2.05.4a	Contractor reputation at previous insurance companies..- High Level	2500	2500	5000	4000	7500	4500	6500	9000	7500	8650
DCG2.05.4b	Contractor reputation at previous insurance companies. - Acceptable Level	4000	3000	3500	5500	5000	3500	2500	4500	3550	5250
DCG2.05.4c	Contractor reputation at previous insurance companies - Minimum Level	6500	4250	4000	3500	6500	6500	4000	5500	6500	2850
DCG3.01.1	Bid Bond	750	550	400	600	450	350	400	600	400	550
DCG3.01.2	Performance Bond	450	500	245	350	550	650	250	400	350	250
DCG3.01.4	Maintenance Bond	250	200	150	175	250	150	200	175	275	200
DCG3.02.2	Cost of Finance	1	1	1	1	1	1	1	1	1	1
DCG3.02.3	Financial arrangements	V Good	Good	Good	V Good	Excelent	Good	V. Good	Good	Excelent	V. Good
DCG3.03	Credit Level	1.25	1.6	1	1.2	1.5	1.6	1	1.2	1.5	1.1
DCG3.04	Financial Statement	0.75	0.95	1	0.6	1	0.95	1	0.6	1	0.85
DCG3.04.1	Status of Audited Financial Statement	V. Good	V. Good	Excelent	V Good	Good	V. Good	Excelent	V Good	Excelent	Good
DCG3.05.1.1	Current Ratio	1	1	1	1	1	1	1	1	1	1
DCG3.05.2.1	Total liabilities / Tangible net worth	1	1	1	1	1	1	1	1	1	1
DCG3.05.2.2	Hard debt /Tangible net worth	1	1	1	1	1	1	1	1	1	1

Table H.2: Real project [Case 3] (Continue…)

Code of Criterion	Criterion Description	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
DCG4.01	Contractor's Management capabilities		These Contractors are exceluded from the Pre-Tender Phase		V. Good		V. Good		These Contractors are exceluded from the Pre-Tender Phase	Good	
DCG4.01.1	Management organisation structure				V. Good		V. Good			Excellent	
DCG4.01.2	Experience level of management staff				Average		Average			Average	
DCG4.01.3	Management techniques				High		High			High	
DCG4.01.3.1	Planning and control techniques				High		High			High	
DCG4.01.4	Coordination between management office and site				Average		Average			Average	
DCG4.02	Equipment availability				Average		Average			High	
DCG4.02.1	Types of available equipment				Fair		Fair			Fair	
DCG4.02.2	Specifications of available Equipment				Fair		Fair			Fair	
DCG4.02.3	Models of Available Equipment				Adequate		Adequate			Adequate	
DCG4.02.4	Quantity of the available Equipment				High		High			Fair	
DCG4.02.5	Maintenance System of available equipment				Fair		Fair			High	
DCG4.03	Manpower resources availability				Average		Average			High	
DCG4.03.1	Labor craft type available				High		High			Fair	
DCG4.03.2	Number of labor from each craft type				Average		Average			High	
DCG4.03.3	Total number of permanent labor				12		12			20	
DCG4.04	Subcontractor's work value				30%		30%			20%	
DCG4.04.1	Subcontractor's work volume				4,275		5,790			3,109	
DCG4.04.2	Subcontractor's work type				4		4			3	
DCG4.04.3	Subcontracting's control system applied by main contractor				Adequate		Adequate			Adequate	
DCG4.04.4	Material delivery availability				no		no			no	
DCG4.04.5	Contractor's current capacity to carry out an additional work				Average		Average			High	
DCG4.04.6	Current work volume				14250		19299			15545	
DCG4.04.6.1	Percentage complete of current projects				0.625		0.503			0.51	
DCG4.04.6.2	Current capacity to carry an additional construction work										
DCG5.1	Bid Price of the proposed project										
DCG5.01.1	Total Bid Amount				4750		4850			4400	
DCG5.01.2	Cash-out Schedule				45		41			35	
DCG5.02	Job statement of proposed project				Average		Average			High	
DCG5.02.1	Construction method statement				High		Average			Average	
DCG5.02.2	Project Time Schedule				45		35			41	
DCG5.03	Applied management planning techniques				Average		High			High	
DCG5.03.2	Experience, continuity and organization structure of the assigned staff				Average		High			Average	
DCG5.03.3	Equipment Schedule				High		Average			Average	
DCG5.03.4	Manpower Schedule				High		High			High	
DCG5.03.5	Quality assurance and quality control plan				Adequate		Adequate			Adequate	
DCG5.03.6	Safety plan				Adequate		Adequate			Adequate	
DCG5.03.7	Procurement plan				no		no			no	
DCG5.03.8	Subcontracting works				1500		1000			1250	

Appendix. I

Optimum Contractor Selection System Procedure

I.1 I.1: Contract Awarding System Software Requirements

I.1 I.2: Necessary Equipment to Run the System

I.1 I.3: Installing the System

I.2 I.4: Contract Awarding System Running

Appendix I

Optimum Contractor Selection System Procedure

I.1 Contract Awarding System Software Requirements:

The following software is necessary to install the contract awarding system.

1. Windows 3.1 or higher

2. Level-5 Object Expert System Shell, Version 4 (1995) or higher

3. Spreadsheet Excel version 5 or higher

4. Database program of the extension dbf, Paradox version 4 or higher is preferable

I.2 Necessary Equipment to Run the System

The following equipment specifications are required to run the system in adequate manner:

1. IBM computer OS or any compatible set
2. 8MB or more of available RAM,
3. 200MB of hard disk at least
4. 66MHz hard disk speed at least
5. SVGA colour monitor 15" or more
6. 3.5" Floppy disk

I.3 Installing the System

(i) Before one can install the contract awarding system, make sure that the software listed in (I.1) are installed.

The contract awarding system is available as a backup disk. One should restore the system file through for example in win95:

- Select My computer icon

- Select the Hard disk (e.g. C)

- File command from the tool bar and then select proprieties.
- From proprieties win. Select tools and then backup now option.
- From the floppy disk select the contract awarding system backup file.
- Select Restore option and then proceed according the instruction given by the computer up to finishing the restore process.
- The system is now available on the Level-5 Object program.

(ii) Load the mathematical model file, which designed to solve AHP method on the spreadsheet Excel -5. The file name is Matrixmd.

(iii) Load the database files for the following items using Paradox program with the extension dbf on working directory:

- Experience Record Table file
- Past Performance Table file
- Financial Stability Table file
- Current Capabilities Table file
- Submitted plans Table file.

I.4 Contract Awarding System Running

Running the Contract Awarding System according to the following steps:

- Open the database files to fill the required data for the contractors in the pre-qualification stage (past experience, past performance and financial stability files) It does not matter to leave these files open or closed.
- Open the Matrixmd file through the Excel spreadsheet, keep it open up to the end of system running

- Open the expert system shell Level-5 Object.
- Open the Contract Awarding System (CAS) using file, open command.
- Press Run icon
- The follow steps are required to perform the evaluation process on the first evaluation level:

(1) Press continue to move to the Specific Project Condition's criteria Screen.

(2) Assign the first line of cells to give the relative weight for the first criteria related to the specific project condition (PF1) against the remaining criteria (PF2 up to PF 12)

(3) Press Calculate button to create the PFs matrix and then press Continue button to move to the combination of project specific criteria and pre-qualification criteria screen

(4) Assign the relative degree of importance for the pre-qualification criteria with respect to the project specific criteria based on the client's preferences, then press the Calculate button to complete their matrices and then press Continue.

(5) In the pre-qualification data screen, press the Load data button to call the data from the database file and then press calculate to complete the data matrix for the past experience pair comparison matrix. Press continue to move to the past performance matrix screen.

(6) Repeat step-5 to calculate the past performance matrix and then move to the financial stability matrix by pressing the continue button.

(7) Repeat step-6 to calculate the financial stability matrix.