MANCHESTER
1824

The University
of Manchester

Modelling the influence of periodic prequalification criteria on project performance

A thesis submitted to the University of Manchester for the degree of
Doctor of Philosophy
in The Faculty of Engineering and Physical Sciences

2005

Donny Marga Mangitung

School of Mechanical, Aerospace and Civil Engineering

Table of contents

List of figures

List of tables

Abstract

The process of contractor selection, such as contractor prequalification, is an important part of a project procurement life cycle in order to reduce risks from irresponsible or incompetent contractors and find appropriate and responsible contractors that can perform project tasks to the expected project performance requirements and client satisfaction.

Periodic prequalification, a type of prequalification system, is commonly used to assess contractors' competence in the construction industry in order to develop a standing list of contractors relevant for a certain periodic time frame including a certain project size, range and type, which can be used by a client for short listing or invitation to bid.

In order to investigate the relationship between periodic prequalification criteria and project performance, a literature review and two questionnaire surveys in the UK construction industry, followed by statistical analyses, were undertaken. The first stage is to identify the characteristics of periodic and project prequalification in order to develop appropriate periodic prequalification criteria for the next stage of the identification of periodic prequalification factors influencing project performance. Data obtained from the first questionnaire survey were obtained from client firms/organisations and construction firms in the UK construction industry, while the second survey elicited data from UK local authorities.

Through the application of Factor Analysis and Logistic Regression techniques, it was found that the past experience factor in relation to contractual experience with similar project value and type, as well business age, and the managerial and technical strength factor in respect of subcontractor relationships and competence, and also training schemes, are the periodic prequalification factors, along with sources of variation factor, namely, client and neither party factors, which may influence project time performance. In this case, additional work/cost due to unforeseen circumstances and changes with regards to design, contract or specification are causal factors of variation with regards to the client factor, while unforeseen circumstances and inclement weather are sources of variation factors under the neither party category. Moreover, client satisfaction is influenced by both past experience and client factors as a source of time variation.

Declaration

That no portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university, or other institution of learning.

Acknowledgements

I would like to express my gratitude to my supervisor, Dr. Margaret W. Emsley, for her encouragement and support made towards the completion of this work. Many thanks are due to her patience and invaluable advice during my study.

Many thanks go to the staff in the School of Mechanical, Aerospace and Civil Engineering at the University of Manchester for providing considerable assistance and help as well as to my colleagues in Room E20, Pariser Building for their valuable discussions and helpful advice during this work.

Many thanks go to anonymous Indonesian taxpayers that contributed to the expenses of this research through the Engineering Education Development Project in Jakarta and the British Council in Jakarta and Manchester for their management and administration services throughout my PhD programme in the UK. In addition, I wish to record my gratitude to the Rector of Universitas Tadulako Palu, Indonesia as well as my colleagues for their interest and support of my PhD programme.

Last but not least, I wish to thank my dearest parents and sister and brothers for always praying for me and supporting me during my study, and especially my beloved wife, Susilowati and my dearest sons, Koko, Lalang and Ikram for devoting their love and patience encouraging me not to give up but to finish this work.

CHAPTER 1

Introduction

1.1 BACKGROUND

Contractor prequalification is commonly accepted as a process of contractor selection at the early stage of a construction procurement system within a project life cycle in the construction industry. Additionally, it is also widely accepted as a process of contractor screening in order to determine the competence and capability of a winning contractor which can carry out construction tasks leading to successful project completion within the required cost, time and quality.

Most contractor prequalification research directly focuses on universal prequalification criteria or decision-making models of contractor selection as a tool for contractor selection at the project level without looking at the impact on the construction industry as a whole (Wong et al. 2003; Khosrowshahi 1999; Hatush and Skitmore 1998; Holt 1998; Holt 1996; Ng 1996; Russell et al. 1990a; Russell et al. 1990b). Additionally, there is lack of investigation of prequalification classifications and characteristics based on practical concern.

Therefore, before starting any model development, it is necessary to thoroughly investigate the key elements such as project, client and contractor characteristics (Russell 1996). Some approaches were used for collection and evaluation of contractors' data, which can influence the outcome of a prequalification model and also the use of different prequalification types in the construction industry (Mangitung and Emsley 2002a). Those approaches are the use of contractor data collection techniques, the utilisation of evaluation models, the regularity of evaluation of prequalification performance, the availability of formal published guidelines and the effort and resources required for preparation of a prequalification proposal.

Furthermore, research rarely identifies prequalification criteria based on project performance that are commonly used as an indicator of project success. One of the studies undertaken by Hatush and Skitmore (1997c), using the Delphi method, shows some prequalification criteria could influence project performance. However, these findings were only based on the opinions of eight professional experts consisting of three and five experts from UK public and private clients respectively. Briefly, project performance provides important indicators of the success of the implementation of contractor prequalification which can be used to evaluate the prequalification performance.

In terms of prequalification practices, previous research in the UK and the USA found several major problems in decision making, namely, an over reliance on subjective analysis, lack of a universal approach to contractor selection (Holt et al. 1994a) and lack of understanding of evaluative criteria and methodology (Russell 1996). These problems also arise due to the degree of uncertainty attributed to the imperfect and imprecise information collected, cognitive limitations of the decision maker, time and cost constraints, existing regulations and economical and political conditions (Russell and Skibniewski 1988)

In the UK, Latham (1994) reported that implementation of prequalification systems at the level of clients or projects tends to be repetitive. Contractors are asked to submit similar documents to every client and keeping separate lists incurs relatively large cost, including maintenance of prequalification records, information processing, issuing prequalification certificates and office storage. Such duplication of effort and maintenance of the lists is a wasteful burden for the construction industry. The report recommends centralisation of prequalification through a third party.

In order to implement this recommendation, a National Qualification System was established by the Department of Environment, Transport and the Regions (DETR) in 1998 as the single national database of registered contractors and consultants. The Capita group, under the name of Constructionline, manages this prequalification system under a seven-year contract, but following the Government review of July 2001, the responsibilities of the DETR passed to the Department of Trade and Industry (DTI) (Mangitung and Emsley 2002d).

According to the Constructors Liaison Group, repetitive qualification procedures cost the industry £130 million annually and Constructionline has the potential to save about 75% of prequalification cost, if periodic prequalification is outsourced to them instead of clients using in-house methods (Constructionline 2001). This type of prequalification as a single qualification system can be categorised as periodic prequalification (Mangitung and Emsley 2002a).

However, according to previous surveys (Holt and Proverbs 2001; Wong et al. 1999), the industry has not responded to the system and used it confidently. There are several factors why the list is not widely used, including lack of flexibility and lack of tolerance to clients' specific requirements such as consideration of clients' preferences, geographical concerns and project specific requirements.

In response to the prequalification problems identified above, a question can be raised in relation to the effectiveness of prequalification systems on construction project performance, especially at the practical level of the common use of prequalification systems, namely, standing list prequalification (i.e. periodic prequalification) that can be similarly found in some countries, such as Indonesia (Indonesian Government 1994), Malaysia (CIDB Malaysia 2000), Japan (Kunishima and Shoji 1996) and Queensland, Australia (Palaneeswaran and Kumaraswamy 2001). In addition, it has become a standard screening system of contractor's competence before entering tender stages or construction industrial practices. The research question can be therefore stated as **What are the key factors of periodic prequalification that can influence construction project performance?** It is important to note that for consistency, the term *construction project performance* will be replaced by *project performance* in all following discussions.

In order to obtain appropriate answers to the research question of the relationship between construction project performance and periodic prequalification criteria, it will be necessary to adopt an empirical approach through the study of prequalification characteristics, periodic prequalification and project performance mainly at a practical level in the construction industry.

1.2 RESEARCH AIM AND OBJECTIVES

The main aim of this research is to investigate the relationship between periodic prequalification criteria which are used to evaluate contractors' historical data as commonly used in a contractor periodic prequalification system and construction project performance (i.e. cost, time and quality variations). In order to achieve the aim, the following objectives will be met:

- To discuss and identify the appropriate data collection and analysis methods that can be used for this research. This research methodology is discussed and presented in Chapter 2;
- To review and investigate the characteristics of contractor prequalification systems including definition and classification and elements of periodic and project prequalification systems. These reviews and investigations are found in Chapters 3 and 4;
- To identify a common set of periodic prequalification criteria on the basis of the characteristics of the early stage of contractor selection system. This identification of the periodic prequalification criteria is discussed in Chapters 3, 4 and 5;
- To develop a conceptual framework of the relationship between contractors' prequalification data evaluated against periodic prequalification criteria and contractors' project performance on the basis of cost, time and quality. This topic is discussed in Chapter 6;
- To develop a relational model between periodic prequalification criteria and project performance using contractor's historical data obtained in the early stage of contractor selection. The development of this relational model is presented in Chapter 7;
- To identify key periodic prequalification factors and other factors influencing contractors' project performance. The identification is analysed and discussed in Chapter 7;

- To validate the model relationships between periodic prequalification criteria and project performance using contractor's historical data obtained in the early stage of contractor selection. The validation is discussed in Chapter 7; and
- To conclude the research findings and the contribution to knowledge as a result of this research investigation and also to provide recommendations for the construction industry and future research as limitation of the findings. This discussion is presented in Chapter 8.

1.3 RESEARCH SCOPE AND LIMITATIONS

The study of contractor prequalification systems is mainly confined to the UK construction industry. But it is extended to some other countries' contractor prequalification systems, especially where their periodic prequalification systems are commonly published in the form of guidelines. From these guidelines, common characteristics of the system may be obtained. In order to develop relational models between project performance and contractor historical data, collected data are limited to public clients in the UK (i.e. UK local authorities) who regularly carry out construction projects annually with a variety of project sizes and types and who use a prequalification system for selecting the winning contractor.

1.4 THESIS OUTLINE

The thesis consists of 9 (nine) chapters and this outline describes the contents of each chapter as depicted in Figure 1.1.

1.4.1 Chapter 1 Introduction

This chapter discusses the broad area of the research interest in prequalification systems in order to define the research problem and then to raise the research question. In addition, this chapter describes the research aim and objectives and also the research scope and limitations including outlining the structure of the contents of the thesis.

1.4.2 Chapter 2 Research methodology

This chapter presents and discusses research strategies used and the research methods/procedures and statistical techniques adopted for analysing the results of Empirical studies 1 and 2 in order to achieve the research aim and objectives. In addition, this chapter also presents a pictorial schematic summary of the research methodology.

1.4.3 Chapter 3 Contractor prequalification systems: a review

This chapter presents a critical literature review and develops conceptual frameworks of prequalification definition, types/classification and elements used for identification of prequalification characteristics.

1.4.4 Chapter 4 Characteristics of prequalification practices in the UK: Empirical study 1

This chapter presents and discusses the results of the identification of the differences and similarities of periodic and project prequalification practices in the UK construction industry, which is named Empirical study 1.

1.4.5 Chapter 5 Identification of periodic prequalification criteria

This chapter describes the identification of common periodic prequalification criteria which are used for further stages of the investigation of the relationship between project performance and prequalification criteria and other related influential factors.

1.4.6 Chapter 6 Relationship between periodic prequalification criteria and project performance: a review

This chapter critically reviews the literature in terms of the development of the conceptual framework of the relationship between project performance and prequalification criteria and other related influential factors.

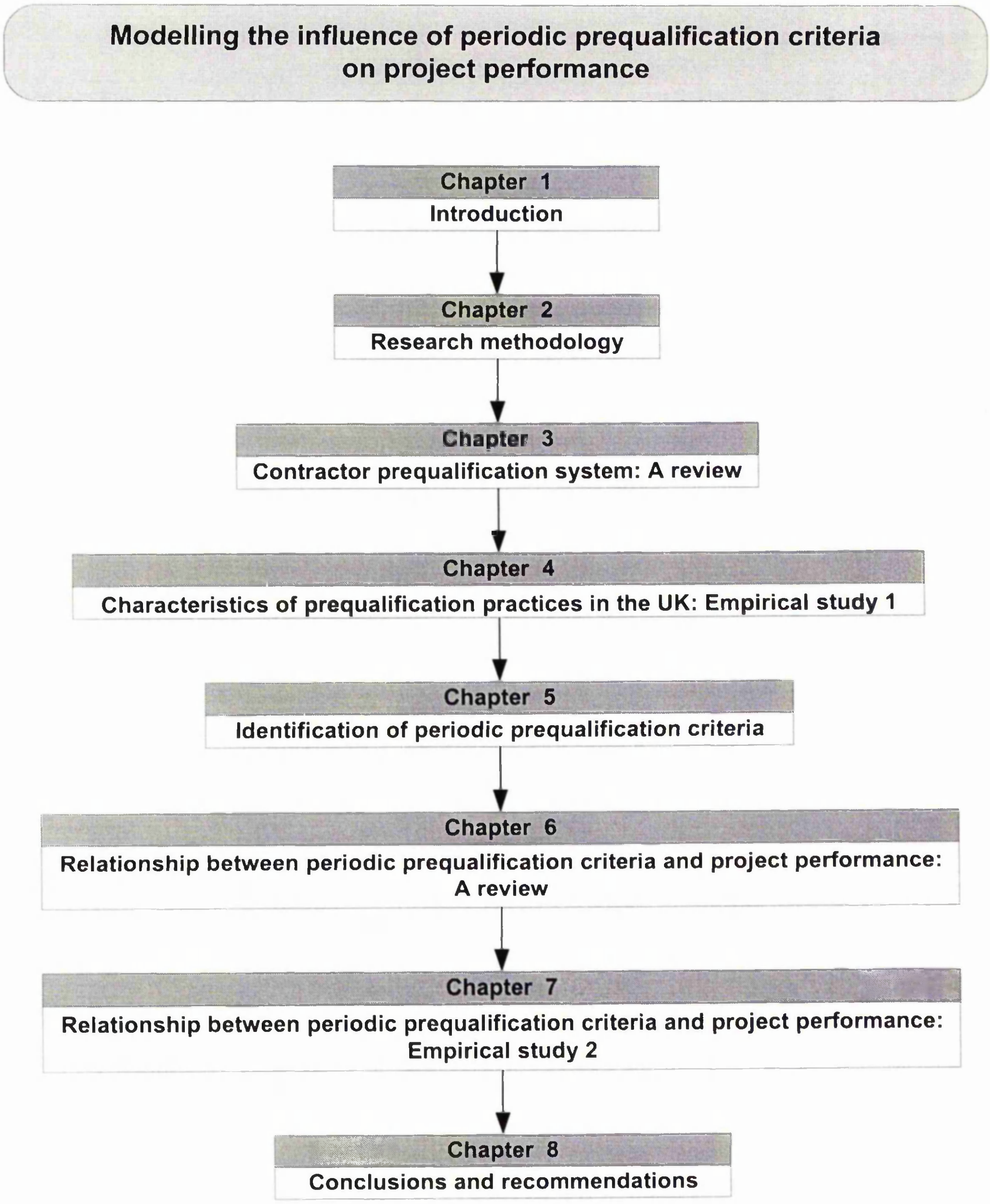


Figure 1.1 Thesis outline

1.4.7 Chapter 7 Relationship between periodic prequalification criteria and project performance: Emprical study 2

This chapter presents and discusses the results of the development of the model relationship between project performance and prequalification criteria and other related influential factors and determines the key periodic prequalification factors influencing project performance, which is named Empirical Study 2.

1.4.8 Chapter 8 Conclusions and recommendations

This chapter describes the process and progress of the achievement of the research aim and objectives, concludes the results of this investigation and recommends future research arising from the findings of this research.

CHAPTER 2

Research methodology

2.1 INTRODUCTION

This chapter presents the structure of research design that shows the use of appropriate research strategies adopted in order to answer the research question and to investigate the effectiveness of the early stage of a contractor selection system (i.e. periodic prequalification) within the life cycle of a project delivery or, more specifically, within the life cycle of contractor selection. To measure the effectiveness of the periodic prequalification system, it is necessary to investigate the relationship between periodic prequalification criteria and contractors' project performance which is related to the measurement of the common target of project delivery on the basis of cost, time and quality. Because there is a lack of research related to the periodic prequalification system and the previous research is much more related to the subject of prequalification as one system, and not based on existing types of prequalification system in the construction industry, it is necessary to conduct two subsequent empirical studies.

The first empirical study is to map and find the differences and similarities of periodic and project prequalification characteristics. The results of this study will be used to classify prequalification systems based on a conceptual framework established through the literature review in Chapter 3. Data collection at this stage was carried out via a postal questionnaire survey in order to cover a broad range of samples including contractor and client categories in both the public and private sectors in order to obtain a broad representation of prequalification participants.

The second empirical study is to identify key periodic prequalification factors influencing project performance. In other words, the study is to investigate the relationship between contractors' prequalification data evaluated against periodic prequalification criteria and contractors' project performance on the basis of cost, time and quality variations. Using a similar approach to Empirical study 1, a postal questionnaire survey was conducted to collect the data that cover most UK local authorities, excluding those local authorities that explicitly stated that they do not use in-house periodic prequalification, but outsource to Constructionline, based on the findings in the first survey.

According to the classification of survey approaches (Oppenheim 1986; Rosenthal and Rosnow 1984), the first empirical study, categorised as a descriptive inquiry survey, is focused on periodic and project prequalification characteristics based on five elements of prequalification systems identified in Chapter 3. While the second empirical study, categorised as a relational inquiry survey, is focused on developing a model relationship between periodic prequalification criteria used in contractor selection and project performance.

However, it is important to note that lack of ability to control variables/factors is one of the survey approach's limitations (Coolican 1999; Oppenheim 1986), but a researcher using the survey technique may have more control over the research process, which is relatively more time independent compared with experiments (i.e. experimental research) (Saunders et al. 1997). The structure of the research methodology described in this chapter, as seen in Figure 2.1, includes the adoption of research strategies, data collection methods, data analysis methods and research validation.

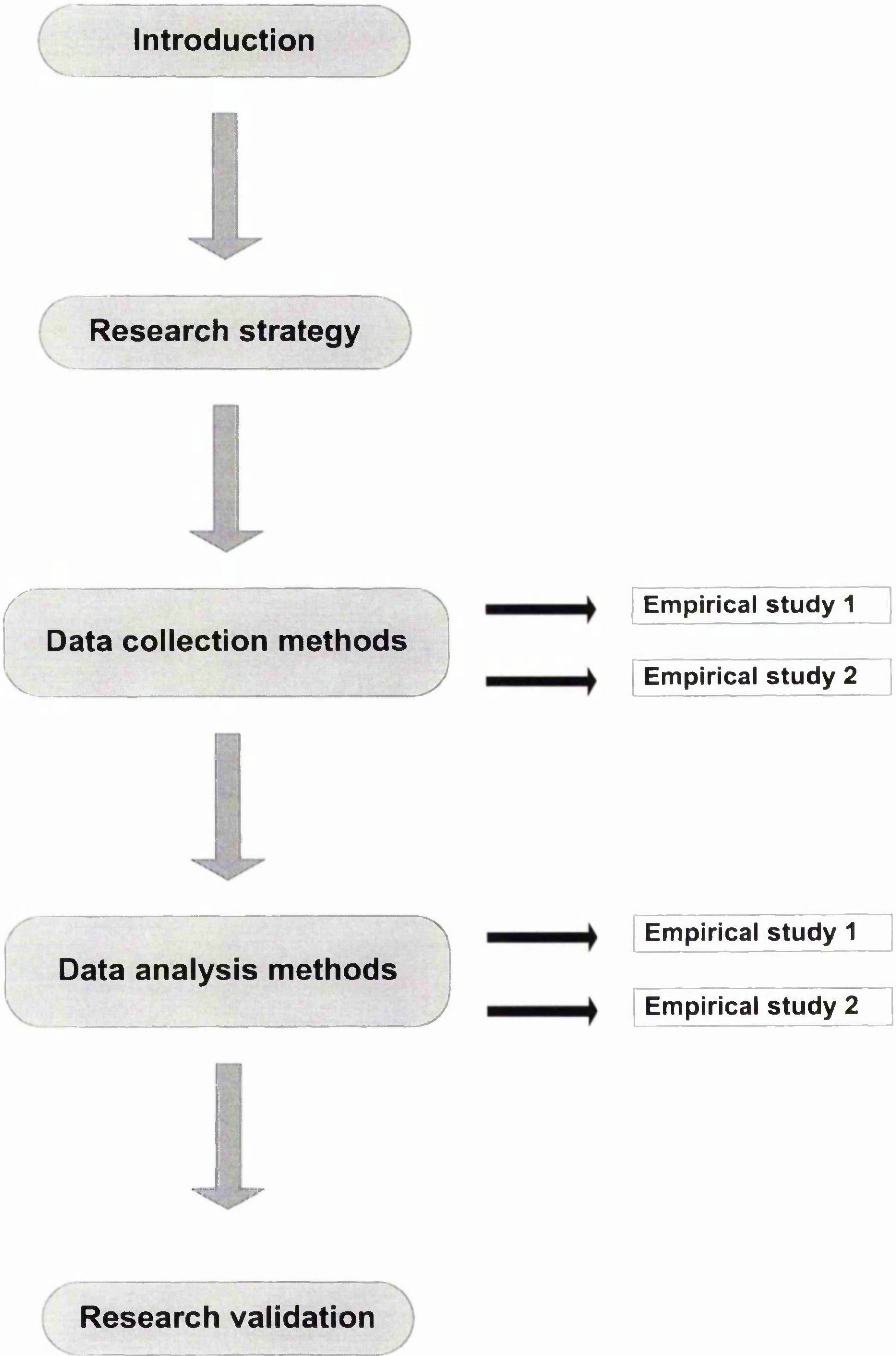


Figure 2.1 Structure of research methodology

2.2 RESEARCH STRATEGY

There are several stages of the research strategies used in this thesis:

- Literature review of periodic and project prequalification systems in order to develop the conceptual framework of periodic and project prequalification characteristics;
- Investigating periodic and project prequalification characteristics and practices through a questionnaire survey in the UK construction industry and analysing collected data mainly on the basis of nonparametric statistical analysis (Empirical study 1);
- Determining periodic prequalification criteria on the basis of literature review and common periodic prequalification practices (i.e. the result of questionnaire survey through Empirical study 1 and secondary data, mainly derived from UK local authorities' and several countries' prequalification guidelines in the public sector);
- Establishing the framework of the relationship between periodic prequalification criteria and project performance on the basis of reviewing relevant previous research and the results of the investigation of the characteristics of periodic prequalification systems in Empirical study 1 ; and
- Determining main periodic prequalification factors influencing project performance by developing the model relationship between project performance and contractor prequalification data and other influential factors. To analyse data collected through a questionnaire survey in UK local authorities (Empirical study 2), Factor Analysis (FA) for reducing the number of periodic prequalification criteria and Logistic Regression (LR) techniques for developing model relationships were utilised.

2.3 DATA COLLECTION METHODS

2.3.1 Empirical study 1

The postal questionnaire technique was used in order to cover a broad area of the subject and provide a widely dispersed sample. Through this type of survey, representation of common types, forms and trends of prequalification practices can be identified and then the characteristics of prequalification system can be established on the basis of the framework developed in the literature review in Chapter 3. The use of the postal questionnaire survey enables a large number of cases of relatively homogenous structured data to be obtained through asking the same questions to each respondent and so a comparison between periodic and project prequalification characteristics can be applied using a statistical analysis approach (Vaus 2002; Hoinville and Jowell 1987).

Even though there are some advantages of a postal questionnaire survey (see Table 2.1), some steps are necessary in order to reduce the disadvantages of the survey as seen in Table 2.1. Those steps or strategies are applied in order to enhance communication, response rate, the degree of completion of the questionnaires, accuracy and consistency of the answers and reduce delay.

Table 2.1 Advantages and disadvantages of the questionnaire technique (after Sekaran 2003; Hoinville and Jowell 1987; Oppenheim 1986)

Advantages	Disadvantages
• Possibly covering a large sample and reaching a wide geographic area • Cost effective compared with interview technique • Relatively convenient and sufficient time to answer questions	• Low response rate • Reliance on instructions in terms of clarification of questions • Motivation to complete and return a questionnaire on the basis of a clear cover letter, familiarity with the subject and the flow, structure and length of questionnaire

The strategies implemented are as follows:

- The cover letter, as seen in Appendices A and B:
  - has a letterhead with institutional name, postal address, phone and fax number and email address; particularly this information is used for any query or clarification of the questionnaire (Cohen et al. 2001);
  - indicates the date and reference number of the letter in order to organise data and ease further communication (Hoinville and Jowell 1987);
  - has priority to use the respondent's personal name and his/ her position, or, if not, uses *Sir/ Madam* (Hoinville and Jowell 1987);
  - explains the purpose of the research and its importance and benefits not only for the researcher but also for the respondents with respect to improvement of the prequalification system (Cohen et al. 2001; Hoinville and Jowell 1987);
  - assures confidentiality of the data received and indicates that only a summary will be published (Cohen et al. 2001; Hoinville and Jowell 1987; Oppenheim 1986);
  - indicates that respondents should have experience in the topic of the research (i.e. contractor prequalification) and asks, if necessary, the recipient to pass the questionnaire on to the right person who can complete it; and
  - encourages a response, invites comments about the research, persuades a prompt return and expresses thanks (Hoinville and Jowell 1987).
- The questionnaires, as seen in Appendices A and B:
  - explain the purpose of the research, provide general instructions and comments and indicate the contact address at the beginning of the front page;
  - include instructions for every question, and, if necessary, provide definitions (e.g. the definition of prequalification systems) or notes in order to enhance clarity or to reduce ambiguity (Hoinville and Jowell 1987; Oppenheim 1986);

- have a combination of closed and open-ended questions in order to enable respondents to express or choose their own ideas or terms (Oppenheim 1986);
- contain a majority of closed questions, multiple choices and ticked box answers in order to reduce effort and time in answering the questions (Oppenheim 1986);
- have few long questions in order to reduce misinterpretation, but it is important to note that sometimes long questions are needed, because for specific respondents short questions may simplify complex issues (Hoinville and Jowell 1987);
- have a style to keep respondents interested in answering the questions by an attractive look, such as avoiding complicated questions, compressed layout with little space, availability of lines for easy writing, consistency and appropriateness of font size and symbols used (Hoinville and Jowell 1987) and varied format/question style (Rosenthal and Rosnow 1984);
- have a *funnel* approach design style, where the questionnaire starts with broad questions and then narrows down the scope to some very specific issues (Oppenheim 1986). In other words, the first few questions are simple, and of general interest, and the questions in the middle or towards the end increase in complexity (Hoinville and Jowell 1987); and
- incorporate a reply slip containing the offer to be sent the research findings, asking for prequalification guidelines or other relevant information associated with this research, other persons who may give additional information and the details of the respondent.

- The questionnaires were sent between the end of April and the beginning of May 2001. To avoid delay it is advisable not to send them during the Christmas and summer holidays (Cohen et al. 2001; Oppenheim 1986).
- It is important to provide self-addressed envelopes in order to increase the response rate (Oppenheim 1986).

Thus, the purpose of this questionnaire is to collect data that can be used for finding the differences and similarities of periodic and project prequalification characteristics as the first stage of the investigation to enable further identification of key factors of periodic prequalification that may influence construction project performance. The investigation of the prequalification characteristics were based on six prequalification system elements including prequalification team, criteria development, prequalification criteria, data collection methods, evaluation models and prequalification performance.

Two types of questionnaire containing similar questions were designed for UK client organisations/firms and construction firms. These two main sample categories assume that clients regularly carry out and contractors are frequently involved in the prequalification process. MS Office 97 packages were used to organise the process of data collection and the information and data coding. In addition, each respondent has his/her own key reference number.

The content of the questionnaires consists of 28 and 26 questions for clients and contractors respectively. The first five questions are categorical questions and the remaining questions comprise mainly categorical and ordinal questions using a three-point scale which are related to prequalification characteristics including prequalification criteria and the relationship between project performance and prequalification criteria. Only a few open ended questions are utilised for providing further explanation, alternative unavailable answers or specific of general comments if considered necessary or important by respondents.

Furthermore, the detail of the questionnaire content consists of questions related the general characteristics of respondents (no. 1 - 3), project characteristics (no. 4 - 6), the purpose of the prequalification (no. 7) and the usage of prequalification types (no. 8), the elements of the prequalification system (i.e. prequalification team, criteria development, prequalification criteria, data collection methods, evaluation models and prequalification performance as discussed in Chapter 3) covering periodic and project prequalification types from no. 9 to no. 29 for the client questionnaire version and from no. 9 to 27 for the contractor questionnaire version.

The last part of this questionnaire provides the respondent with an option to receive a copy of the research findings (i.e. research summary), and invites the respondent to provide a copy of the guidelines and related information about prequalification systems, recommend other sources for additional information related to prequalification systems, provide their details and contact the author if they have any formal or informal enquiry and communication.

2.3.2 Empirical study 2

Using a similar approach to Empirical study 1, data in this study are collected through a questionnaire survey on the basis of project cases in UK local authorities. The usage of a postal questionnaire survey is appropriate, as a large structured data set is required for investigating the relationship between periodic prequalification criteria and project performance by using multivariate techniques such as Factor Analysis and Logistic Regression.

There are two main stages of data collection (i.e. pilot and main survey). Since the data being collected are relatively more complex and detailed than the previous survey, it is necessary to carry out a pilot study before the main survey. The pilot work is mainly intended to obtain feedback for refining the questionnaire and to verify the suitability of the contents to the targeted sample (i.e. prequalifiers in local authorities). The supplementary questionnaire was developed along with the main questionnaire and its questions include:

- total time to complete the questionnaire;
- clarity of the questions and diagrams;
- relevancy of the questions to the main topic (i.e. contractor prequalification in general and periodic prequalification specifically);
- any difficulty in answering the questions; and
- any comments and suggestions to improve the main survey.

All procedures used in Empirical study 1 in relation to data collection through questionnaire survey were employed and, in anticipation of a low response rate, a reminder letter (see Appendix K) was also used in both the pilot and main studies. Moreover, the calculation of response rate (R) was based on the following equation (Bryman 2004; Vaus 2002):

$$R = \frac{\textit{Number of usable questionnaires}}{\textit{Total sample - Unsuitable or uncontactable numbers of the sample}} \quad (2.1)$$

This survey is mainly to investigate which prequalification factors can provide an indication of a certain level of contractors' project performance at the early stage of contractor selection (i.e. periodic prequalification). Therefore, the questionnaire for Empirical study 2 was designed to obtain objective data from construction project cases in UK local authorities, based on contract and actual cost and time in order to measure contractors' construction cost and time performance as dependent variables. In addition, it is also used to obtain subjective data in respect of the measurement of contractors' quality performance as a dependent variable.

Moreover, the level of suitability of contractors to perform construction project tasks through evaluation at the periodic prequalification stage (i.e. standing list prequalification) was measured as a set of independent variables including variables related to parties or sources which have responsibility for occurrence of variation related to cost, time and quality variation.

UK local authorities were chosen as the targeted sample, as they have regular construction projects annually and most contractors that are involved in project tenders are initially evaluated through periodic prequalification. Additionally, their prequalification systems, especially periodic prequalification criteria, are relatively similar.

The questionnaire consists of four sections, as seen in Appendix K. The first section is to obtain general characteristics of respondents including their profession and experience in the prequalification process and construction project characteristics including contract and actual construction cost and time, project types, procurement types, where each case of a completed construction project is related to the contractor that won the project and where evaluation of the contractor's competence was based on periodic prequalification.

The second section is to provide alternative answers of construction cost and time performance in the form of qualitative cost and time variation data. Additionally, quality performance is obtained in this section on the basis of qualitative data which are the same as the Key Performance Indicator's (KPI's) quality performance measurement (KPI 1999). The scales of measurement of cost, time and quality performance can be seen in Table 2.2, Table 2.3 and Table 2.4 respectively. The degree of project performance being used for developing model relationship between project performance and periodic prequalification factor is based on the dichotomous variable consisting of *superior* and *inferior performance.*

Table 2.2 Scale of measurement of construction cost performance

Cost Performance	Degree of performance	Distribution of achievement*	Scale
$C \leq -10\%$	Superior	5%	6
$-10\% < C \leq -2.5\%$		10%	5
$-2.5\% < C \leq 0\%$		35%	4
$0\% < C \leq +2.5\%$	Inferior	25%	3
$+2.5\% < C \leq +10\%$		15%	2
$C > +10\%$		10%	1

Note: * Source: (KPI 1999)

Table 2.3 Scale of measurement of construction time performance

Time Performance	Degree of performance	Distribution of achievement*	Scale
$T \leq -20\%$	Superior	30%	6
$-20\% < T \leq -5\%$		20%	5
$-5\% < T \leq 0\%$		15%	4
$0\% < T \leq +5\%$	Inferior	10%	3
$+5\% < T \leq +20\%$		10%	2
$T > +20\%$		15%	1

Note: * Source: (KPI 1999)

Table 2.4 Scale of measurement of quality performance (recorded defects)

Degree of performance	Distribution of achievement*	Scale
Defect free	50%	5
Some defects and no significant impact on client	20%	4
Some defects and with some impact on client	22.5%	3
Some defects and with major impact on client	5%	2
Totally defective	2.5%	1

Note: * Source: (KPI 1999)

In this section also the respondents were asked to assess three sources which are responsible for occurrence of cost, time and quality variations (i.e. contractor, client and neither client nor contractor) including additional information on the reasons for the occurrence of the variations based on the sources which are responsible for the highest variation. While client satisfaction was measured to rate the degree of client satisfaction related to cost, time and quality performance achievement. The measure is based on a scale of 1 to 6.

The third section is to obtain the level of fulfilment of contractors' data evaluated against periodic prequalification criteria (25 criteria under the heading of five categories of prequalification criteria) in the form of subjective data (ordinal data) based on the result of the prequalification process related to the contractor who won and completed the construction project. In this section, the weighting of the five categories are rated by respondents for comparison of their level of importance, ranging from 1 to 6.

In the fourth section respondents were asked to provide information about the prequalification routes/procedures that they used for selecting their winning contractors. Additional information about the types of prequalification systems based on the main sources of expertise they use was required, such as in house or outsourcing prequalification systems.

Another question is related to the usage of the main criteria in the final selection for determining a winning contractor. Those criteria are either a combination between *price and competence* or *price only*. The last question was information about membership of Constructionline (i.e. a third party outsourcing prequalification system).

2.4 DATA ANALYSIS METHODS

2.4.1 Empirical study 1

Before analysing the main data (i.e. prequalification characteristics), respondent characteristics are examined in order to show the level of competence of respondents in terms of answering and supplying the required and relevant data and also to categorise the main data for further data analysis on the basis of a respondent's organisation and project characteristics.

The categorical/nominal data relevant to general prequalification characteristics in Chapter 4.3.1 are analysed on the basis of graphical representation or tabulation, but the ordinal data which are only related to contractor respondents in answering Question 7 (see contractor questionnaire in Appendix B) are analysed on the basis of Relative Rank Index (RRI) and Factor Analysis (FA) techniques that can enhance the results of the data analysis.

Because RRI and paired relationship (bivariate relationship) are not sufficient to provide thorough information, thus, it is necessary to analyse the interrelationship between variables through the FA technique as a multivariate relationship approach, where variables are loaded together into several common underlying dimensions or factors. The FA procedure can be seen in Table 2.5.

Analyses of the main data in Chapter 4.3.2, comprising periodic and project prequalification characteristics, are based on some relevant nonparametric statistical techniques. The choice of statistical methods relies on the nature of the data characteristics (i.e. nominal, ordinal data). The relationship between the relevant statistical techniques used and the data derived from both questionnaire types (i.e. client and contractor version) can be seen in Table 2.6 and Table 2.7. Additionally, for ordinal data, RRI and FA techniques were also employed.

The RRI technique is used for comparison between the importance level of variables and derived from the Likert scales which represent the level of importance of variables chosen by respondents which need to be transformed into a Relative Rank Index that has a value of one or less. The RRI can be calculated using the following formula:

$$RRI = \frac{1}{nN}\left(\sum_{i=1}^{n} l_i x_i\right) \tag{2.2}$$

Note:

RRI: Relative Rank Index n: The maximum Likert scale N: the total number of responses i: 1, 2….n l_i: Likert scale (l_1 is the least important and l_n is the most important) x_i: the frequency of the ith response

The RRI technique is very popular in the research fields of the built environment and the usage of this technique can be found in Mangitung and Emsley (2002c; Elinwa and Joshua (2001); Wong et al. (1999); Jennings and Holt (1998); Assaf et al. (1996); Kometa et al. (1995); and Holt et al. 1994b; Shash (1993). While the usage of the FA technique in the built environment can be found in Lowe and Parvar (2004); Mangitung and Emsley (2002c); Akintoye (2000); Awakul and Ogunlana (2000); Kaming et al. (1997); and Lowe (1996).

Factor Analysis is used to define a set of common underlying dimensions, known as factors, which explain the correlation among variables. It means that each variable can be explained by each dimension. The first usage is to identify the underlying factors of 8 variables of contractors' perceptions with regards to the main reasons for being involved with prequalification and also to enhance the understanding of intercorrelation among variables of contractors' perceptions. This result, presented in Chapter 4.3.1.1, can be used for finding the conformity between the main purpose of prequalification set up by clients and the most important factors in respect the main reasons for contractors being involved with prequalification.

Table 2.5 Factor Analysis procedure

References: Bryman and Cramer (2001); Conover (1999); Siegel and Castellan (1988)
First stage: Factor Analysis objectives The main purpose of Factor Analysis is to identify the structure of the relationships among variables as a multivariate relationship. In other words, to summarise the information in the original variables to a small set of composite dimensions or variates (factors) with minimum loss of information. In this research, the use of factor analysis technique can be seen in Chapter 4.3.1.1, 4.3.2.5 and 4.3.2.7.
Second stage: Factor Analysis design Initially the data have to be tested for the level of data reliability on the basis of Cronbach's alpha coefficient ranging from 0 to 1 and then the adequacy of the sample size determined in order to provide an adequate basis for the calculation of the correlation between variables. The Cronbach's alpha coefficient is such that less than 0.6.is considered poor, those in the 0.70 range acceptable and those over 0.80 good (Sekaran 2003). The acceptable limits of sample size are at least 5 cases per variable and preferably no fewer than 100 observations per analysis, although 50 observations are still acceptable (Hair Jr et al. 1998).
Third stage: Factor Analysis assumptions The data must have sufficient correlation to justify the application of Factor Analysis by visual inspection of the correlation coefficients that should reveal a sufficient number of correlations greater than 0.3. In addition, the Bartlett Test of Sphericity (BTS), a statistical test for the presence of correlations among variables, must be examined, as well as the Measure of Sampling Adequacy (MSA) that measures the degree of intercorrelation among variables, using an index ranging from 0 to 1which may be classified as *unacceptable* (≤0.5), *miserable* (0.5+), *mediocre* (0.6+), *middling* (0.7+), *meritorious* (0.8+), *marvellous* (≥0.9) (Sharma 1996).
Fourth stage: Deriving factors and assessing overall fit <u>Method of extracting the factors</u> There are two techniques to extract the determinant factors, namely Principal Component Factoring (PCF) and Principal Axis Factoring (PAF). Generally, the empirical results from both techniques are very similar (Hair Jr et al. 1998; Sharma 1996) especially if the number of variables exceeds 30, or the communalities exceed 0.60 for most variables, where a value of communality indicates the degree of variance in a particular variable being accounted for by factor solution (Hair Jr et al. 1998) Thus, the PCF technique is used in this research for estimating the shared variance being extracted by the factor solution. <u>Extraction of the number of factors</u> The latent roots or eigenvalues greater than 1 being considered significant, or Scree test criterion using a graphical plot approach, are commonly used for determining the number of factors to be extracted (Hair Jr et al. 1998; Sharma 1996). In addition, percentages of total variations of the retained factors are important information that can explain the relative importance/representation of the set of variables analysed and contained in the retained factors (Hair Jr et al. 1998).
Fifth stage: Interpreting the factors <u>Factor loadings</u> Rotated factor loadings obtained using the orthogonal rotation/varimax method are computed to assist in determining which variables have significant correlation with extracted factors, as long as correlations in the matrix of factors being identified using the oblique technique are less than 0.32 (Tabachnick and Fidel 1996). Thus, the oblique's correlation matrix of factors provides a guide as to whether the relationships between factors are dependent or not (Field 2000). Thus, if the relationship between the factors is shown as highly independent the use of the varimax technique is appropriate, otherwise, the oblique technique is appropriate for high correlations between the factors. Since the oblique rotation produces two matrices (i.e. pattern matrix and structure matrix), the pattern matrix is commonly used due its easier interpretation. While in the structure matrix for the case of high correlation between the factors, it is difficult to distinguish which variables load uniquely on to each factor (Field 2000; Hair Jr et al. 1998). But the structure matrix can be used for cross checking (Field 2000). Moreover, the significance of the factor loading equal to or greater than 0.60, 0.65, 0.70 and 0.75 needs 85, 70, 60 and 50 cases respectively. The significance is based on the 0.05 significance level (Hair Jr et al. 1998). <u>Labelling</u> Labelling of the factors is based on an intuitive approach, where each name should accurately reflect the variables with higher loadings on a particular factor. In other words, a factor's name can represent the characteristics of the variables loading on the particular factor (Hair Jr et al. 1998).

Table 2.6 Method for analysing prequalification characteristics

Data type	Sample	Comparison between client and contractor samples	Comparison between periodic and project prequalification characteristics
Nominal	Clients' periodic and project prequalification data Contractors' periodic and project prequalification data	**Chi square test** is used for testing whether client and contractor data can be combined or not for further comparison between periodic and project prequalification. **Statement of hypotheses:** **H_0:** The frequency of usage of the intended variable is equal in the two respondent types **H_a:** The alternative	If client and contractor samples are dependent, **McNemar test** will be run once (combination between client and contractor data), otherwise **McNemar test** will be run twice (separation between client and contractor data). **Statement of hypotheses:** **H_0:** The frequency of usage of the intended variable is not different due to the change of prequalification types **H_a:** The alternative
Ordinal	Clients' periodic and project prequalification data Contractors' periodic and project prequalification data	**Kolmogorov-Smirnov test** is used for testing whether client and contractor data can be combined or not for further comparison between periodic and project prequalification. **Statement of hypotheses:** **H_0:** The impact level of the intended variable is equal in the two respondent types **H_a:** The alternative	If client and contractor samples are dependent, **Wilcoxon signed ranks test** will be run once (combination between client and contractor data), otherwise **Wilcoxon signed ranks test** will be run twice (separation between client and contractor data). **Statement of hypotheses:** **H_0:** The impact level of the variable does not depend on the prequalification type **H_a:** The alternative

Table 2.7 Overview of several types of nonparametric tests

Type of nonparametric test	Description
References: Bryman and Cramer (2001); Conover (1999); Siegel and Castellan (1988)	
Chi-square test	This test is used to determine the significant difference between two independent samples of nominal/categorical data. The difference is based on the analysis of the relative frequency/proportion of several categories of the groups of categorical data.
Kolmogorov-Smirnov test	The test is used to determine the significant difference between two independent samples of ordinal data. This test is useful not only in testing the differences between two means or medians, but also in detecting the differences in variances where two samples are drawn from the same population and distribution functions.
McNemar test	The test is used to determine the significant difference between two related samples of nominal/categorical data (statistically paired test). For small samples the McNemar test is used, otherwise for large samples the Binomial test is used.
Wilcoxon signed ranks test	The test is used to determine the significant difference between two related samples of ordinal data (statistically paired test). The test for two related samples and non categorical data can determine the direction (a positive or negative sign) and magnitude (ranks) of the difference between two measures as a matched-pairs case. Test statistics are determined on the basis the number of ties and size of sample. For small samples T^+ distribution (Wilcoxon signed ranks test) is used, otherwise for large samples the normal distribution (z score) is used.

Similar to the purpose of the usage of the FA technique, 11 criteria development variables of both prequalification types are analysed in order to group variables or load them together into several distinctively general concepts (see Chapter 4.3.2.5). The last usage in Chapter 4.3.2.7 is to identify the common characteristics of 8 prequalification variables for both prequalification types, which are loaded together into several underlying factors. Thus, periodic and project prequalification criteria influencing project performance can be distinguished more properly.

In terms of nonparametric statistical tests, these techniques are employed, because the nature of the data being analysed is nominal/categorical and ordinal, according to Conover (1999) and Siegel and Castellan (1988). Additionally, nonparametric statistical techniques are suitable to be employed, as nonparametric statistical tests have fewer assumptions than parametric tests. The assumptions of nonparametric tests are not restricted to large sample sizes, normality and complex computation required by the application of parametric statistical tests (Siegel and Castellan 1988).

To compare between periodic and project prequalification characteristics in this emprical study, two stages of statistical analysis were performed, as seen in Table 2.6. The first stage is to test whether client and contractor data are associative/dependent or not (two-independent sample test). If both sets of data are associative/dependent, they are combined for further statistical analysis of comparison between prequalification types (two-related or paired sample test), otherwise the client and contractor data are analysed separately.

An overview of several types of nonparametric tests which have been used, such as Chi-square test, Kolmogorov-Smirnov test, McNemar test and Wilcoxon signed ranks test, are described in Table 2.7. All the calculations of these techniques are assisted by the statistical package program SPSS version 10 and also by Microsoft Excel 97. The summary of relevant statistical techniques for questions in the questionnaire forms and for relevant sections in Chapter 4 can be seen in Table 2.8.

Table 2.8 The usage of relevant statistical techniques

Relevant chapter	Question number		Data type	Statistical technique
	Client	Contractor		
4.2	1-5	1-5	Nominal	Tabulation
4.2	6	6	Continuous/ nominal	Tabulation
4.3.1.1	7	-	Nominal	Graph
4.3.1.1	-	7	Ordinal	Relative Rank Index/Factor Analysis
4.3.1.2	8	8	Nominal	Tabulation
4.3.1.3.	9	10	Nominal	Graph
4.3.1.4	13	12	Nominal	Graph
4.3.1.5	25-26	23-24	Nominal/ ordinal	Tabulation /graph
4.3.2.1	12	11	Nominal	Chi-square test (client & contractor) McNemar test (prequalification types)
4.3.2.2	10-11	9	Nominal/ continuous	Graph
4.3.2.3	15	9	Nominal/ continuous	Tabulation
4.3.2.4	14	13	Nominal	Chi-square test (client & contractor) McNemar test (prequalification types)
4.3.2.5	16	14	Ordinal	Cronbach's alpha coefficient Kolmogorov-Smirnov test (client & contractor) Wilcoxon signed ranks test (prequalification types) Relative Rank Index/Factor Analysis (prequalification types)
4.3.2.6	27	25	Nominal	Chi-square test (client & contractor) McNemar test (prequalification types)
4.3.2.7	28	26	Ordinal	Cronbach's alpha coefficient Kolmogorov-Smirnov test (client & contractor) Wilcoxon signed ranks test (prequalification types) Relative Rank Index/Factor Analysis (prequalification types)
4.3.2.8	17	15	Nominal	Chi-square test (client & contractor) McNemar test (prequalification types)
4.3.2.9	18	16	Nominal	Chi-square test (client & contractor) McNemar test (prequalification types)
4.3.2.10	19	17	Nominal	McNemar test (prequalification types)
4.3.2.10	21	19	Ordinal	Wilcoxon signed ranks test (prequalification types)
4.3.2.11	24	22	Ordinal	Wilcoxon signed ranks test (prequalification types)
4.3.2.11	22	20	Ordinal	Wilcoxon signed ranks test (prequalification types)
4.3.2.11	23	21	Ordinal	Wilcoxon signed ranks test (prequalification types)
4.3.2.12	20	18	Nominal/ ordinal	McNemar test (prequalification types) McNemar test (prequalification types)

2.4.2 Empirical study 2

Two stages were used to analyse the relationship between project performance and contractors' periodic prequalification data. In first stage, the Factor Analysis (FA) technique was used to identify the underlying factors that can explain the intercorrelation among periodic prequalification criteria in order to validate 25 predetermined periodic prequalification criteria being grouped under five predetermined groups of periodic prequalification criteria (i.e. financial strength, past experience, past performance, managerial and technical strength and compliance with regulation) and also to reduce the number of periodic prequalification criteria as independent variables.

In the second stage, the Logistic Regression (LR) technique was employed in order to develop LR models of the relationship between project performance and periodic prequalification criteria for identifying the key factors of periodic prequalification that can influence the variation in construction project performance. The underlying factors of periodic prequalification identified using the FA technique in the first stage and the organisational/non organisational factors which are responsible for occurrence of variations were utilised as independent variables. While variations related to project performance were utilised as dependent variables. The procedures for the development of the LR model are summarised in Table 2.9.

2.4.2.1 Factor Analysis overview

All the stages of the analysis process of the FA technique in this empirical study are the same as in Empirical study 1, where the technique in Empirical study 1 was used for only determining the underlying factors. While in this study, the FA technique is not only used for determining underlying factors, but also used for reducing the number of prequalification criteria. The data set of reduced number of the factors generated from the Factor Analysis technique will be used for the development of relational models. The use of this technique for the reduction of the number of variables is similar to that described by Lowe and Parvar (2004) and Soetanto and Proverbs (2002).

Lowe and Parvar (2004) utilised the FA technique for reducing 21 bid/no-bid variables to 6 underlying factors. These six underlying factors were then used for developing a Logistic Regression decision model of bid/no-bid. The used factor scores under the heading of the six factors were generated from the original data under the heading of the twenty bid/no-bid variables utilising the principal factors (i.e. principal axis factoring) extraction using the varimax rotation technique. The oblique rotation technique was not used due to the oblique factor correlation matrix revealing no correlation that exceeded 0.3. This means the low correlation values reveal the oblique rotation is nearly orthogonal. In other words, rotated factors determined by varimax rotation are not much different from the rotated factors obtained by oblique rotation (Field 2000; Tabachnick and Fidel 1989).

Soetanto and Proverbs (2002) utilised the FA technique for reducing 33 client performance criteria to 5 underlying factors. These five underlying factors were then used for developing linear regression contractor satisfaction models. The used factor scores under the heading of the five factors were generated from original data under the heading of the thirty-three client performance criteria on the basis of the principal components extraction with the oblique rotation technique.

In terms of the choice of two types of factors extraction (i.e. principal components and principal factors), Hair Jr et al. (1998) suggest that the principal components extraction technique is appropriate, if the primary objective of the FA is intended for prediction or the minimum number of factors needed to account for the maximum portion of the variance represented in the original variables. On the other hand, the principal factors technique is appropriate when the main purpose is to identify latent dimensions or constructs represented in the original variables. In addition, even though this approach has a more theoretical background, there is a limitation in using this technique, as the factor coefficient suffers from factor indertermінancy, which means that the factor score coefficient can influence not only one factor but also more than one factor for any case. However, both factors extraction techniques in most applications demonstrate similar results as long the number of variables is above 30 or the communalities are above 0.60 (Hair Jr et al. 1998; Sharma 1996).

Briefly, the principal components extraction technique for will be used for extraction of the factors, as the purpose of this technique is to reduce the variables in order to reduce the multicollinearity effect and to develop relational models on the basis of a predictive approach. To avoid the effect of indeterminacy, the principal factors extraction technique will not be used to generate factor scores for the further development of relational models using logistic regression. To further justify the use of the principal components extraction technique, the communalities were found to be above 0.60 as described in Chapter 7.

While the reason for the usage of the oblique rotation technique for interpreting the factors (i.e. factor loadings) is to present the correlation between factors/components. Bryman and Cramer (2001) and Hair Jr et al. (1998) suggest that the use of oblique rotation can produce correlation between factors and the result can give theoretically meaningful factors. Moreover, if the correlations of the factor correlation matrix are around 0.32 or above, the oblique rotation technique is appropriate (Tabachnick and Fidel 1996). However, the author found that there is not much difference between the two techniques. This finding confirms the suggestions of Tabachnick and Fidel (1996) that if the pattern of correlations in the data is fairly clear or borderline (i.e around 0.32) the different rotation techniques tend to give similar results. Therefore, in Empirical study 2 the oblique rotation technique was used, as the correlation between some factors was found above 0.3.

2.4.2.2 Logistic Regression overview

In order to obtain a systematic approach towards the development of the Logistic Regression (LR) model, it is necessary to summarise the procedures of the LR analysis, as seen in Table 2.9. The stages of the LR procedures will be utilised for analysing the data in Chapter 7. Several pervious researches in built environment fields using this technique can be found in Lowe and Parvar (2004); Wong and Holt (2001); Diekmann and Girard (1995); Severson et al. (1994); Russell and Jaselskis (1992); Jaselskis and Ashley (1991); Jaselskis (1988), but two of them will be explained in detail in the next paragraphs.

Table 2.9 Logistic Regression procedure

References: Field (2000); Kinniear and Gray (2000); Hair Jr et al. (1998); Norusis (1997); Sharma (1996)
First stage: Logistic Regression analysis objectives The main purpose of Logistic Regression (LR) analysis is to establish a non linear predictive model between a categorical/dichotomous variable as a outcome/dependent variable and continuous, ordinal and/or categorical variables as predictor/independent variables. In this research, the use of this technique is to identify the key factors of periodic prequalification criteria that can influence project performance (i.e. dichotomous variable: superior and inferior project performance) through LR modelling.
Second stage: Logistic Regression analysis design In order to obtain good estimation/classification, the acceptable limits of sample size are at least 5 cases per independent variable and also each group of the dichotomous variable must be at least 20 cases and also the size between the groups must not vary considerably. For validation of the model, the total of cases is randomly divided into two divisions, one group (analysis sample) is used for developing the LR function and another group (holdout sample) is used for testing the LR function. The number of cases under the dichotomous variables in the analysis sample are divided proportionally on basis of the total proportional division of the dichotomous variable (Hair Jr et al. 1998). During development of the model, the analysis sample is randomly resampled into 10 analysis samples in order to find a reliable model, as known a cross validation approach (Hair Jr et al. 1998). In other words, the cross validation technique is to ensure validity of a derived LR equation (i.e. estimation of predictors).
Third stage: Logistic Regression assumptions The Logistic Regression (LR) technique is distribution free (Lowe and Parvar 2004). It means data do not need to meet the normality assumption required by other multivariate techniques such as Discriminant Analysis, but LR techniques can still provide robust results (Hair Jr et al. 1998; Sharma 1996). High correlation or intercorrelation (i.e. multicollinearity effect) can effect the development and interpretation of the LR model; Factor Analysis (FA) is one multivariate technique that can solve this problem by grouping the variables that contain the effect of multicollinearity (Lowe and Parvar 2004; Soetanto and Proverbs 2002; Field 2000; Hair Jr et al. 1998; Sharma 1996; Diekmann and Girard 1995).
Fourth stage: Estimation of the Logistic Regression model and assessing overall fit Model estimation: Initially it is necessary to examine the correlation between the independent variables and dependent variable and the difference between two subgroups of the dependent variable data should be tested (Lowe and Parvar 2004; Severson et al. 1994). In addition, the correlation between independent variables and the dependent variable can be established by developing separate LR models using each independent variable and examining the established models visually and testing to determine if each predictor (independent variable) is statistically significant (Hair Jr et al. 1998). The Wald statistic is used to evaluate individual statistical significance of the estimate coefficient of independent variables. But if the regression coefficient value is large, it is not suitable to use the Wald statistic. By checking the change in the log likelihood value after removing or replacing that variable (i.e. likelihood ratio test), it is possible to determine the significance of the variables within the model. Model overall fit: There are three parameters that can be used to interpret model overall fit, that is, Goodness-of-fit statistics, R-square and classification matrix of predictive power. Goodness-of-fit uses Chi-square statistics by computing the likelihood ratio (i.e. the difference between constant value in the model and predictors included in the model) (Norusis 1997; Sharma 1996). Like in linear regression analysis, the multiple correlation coefficient (R-square) value ranges from 0 to 1 (i.e. value of 1 is the best fit), and is used to interpret the overall fit. There are two types of R-square in LR analysis, the first one is Cox and Snell R^2 which cannot reach the maximum value of 1 and the second one is Nagelkerke R^2 which can reach the maximum value of 1. Another test of the model overall fit is that examination of the classification matrix of predictive power can provide a comparison between the percentage of classification and misclassification of the outcome variable (dependent variable) (Kinniear and Gray 2000).

Table 2.9 Logistic Regression procedure (*continued*)

References: Field (2000); Kinniear and Gray (2000); Hair Jr et al. (1998); Norusis (1997); Sharma (1996)
`Fifth stage: Interpreting the results The Logistic Regression equation is: $P(Z) = \frac{1}{1+e^{-z}}$ where $Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_p x_p$ ***P(Z)*** is probability of occurrence of the outcome variable and Z score is the linear function of predictor variables, where β_{ith} is the predictor coefficient and x_{ith} is the predictor. A positive sign of predictor coefficient means that an increase in the predictor can increase the occurrence of the outcome variable, conversely for a negative sign of the predictor coefficient. Another important value is the odds ratio for a one unit change of a particular predictor formed as $e^{\beta ith}$ or annotated as Exp(B) in SPSS output that is equal to the ratio of the probability of occurrence divided by the probability of non occurrence after a one unit change in the particular predictor variable to the ratio of the probability of occurrence divided by the probability of non occurrence before change. Thus, for a one unit increase in x_p, the odds ratio will increase by the factor of $e^{\beta ith}$, if the β_{ith} has a positive sign or $e^{\beta ith}$ is greater than 1. Conversely, if the β_{ith} has negative sign or $e^{\beta ith}$ is less than 1, for a one unit increase in x_p, the odds ratio will decrease by the factor of $1/e^{\beta ith}$ (Field 2000; Norusis 1999). Sensitivity analysis can also be used for obtaining a better understanding and for identifying the impact of the predictors on the outcome variable. This technique can be performed by using a nominal value (i.e. average value of predictors) and also establish an impact function of a predictor on the outcome variable while other predictors are retained based on nominal values (average values) (Severson et al. 1994).
Sixth stage: Validation of the Logistic Regression model To establish the internal validity of the model, the degree of predictive power using a holdout sample is performed at an acceptable level in classifying the outcome variable, while external validity can be established using other samples (Hair Jr et al. 1998; Severson et al. 1994).
Seventh stage: Robustness analysis of the Logistic Regression model The consistency/robustness of the model can be established in order to understand the applicability and limitations of the model by comparing the outcome variables among several categories (e.g. project type and size, procurement type) from the original sample or other samples (Severson et al. 1994).

An example of the usage of the LR can be found in Lowe and Parvar (2004), where they use the LR technique for modelling the decision to bid process. It is important to note from this work that, before developing the model, the data should be tested using the statistical significance level of correlation between independent variables and the outcome variable and also the difference between subgroups of acceptance and rejection of the opportunity to bid on 21 independent variables. In this paper, Spearman's rho correlation and the Mann-Whitney U test were used for identifying correlation between dependent and independent variables and the difference between two sub groups on the 21 variables respectively.

Furthermore, another important aspect identified in this work is the effect of sample size. Since the proportion of the number of cases in the two subgroups of the outcome variables is quite different, one of the models was unsuccessfully developed, even though other required parameters are met. This result can be explained by sample size problems, where the *reject* sub group is only 16 cases, while the *accept* subgroup is 99 cases. In terms of reduction of misclassification in a LR model, the minimum number of cases in one sub group of the dichotomous variable should be 20 and the sample size between two groups of data under the dichotomous variable should not be considerably different (see Table 2.9).

Similar to the work above, Severson et al. (1994) developed a predictive model of contract surety bond claims based on contractor financial data using LR. Student's t test is initially employed to identify which independent variables have statistically significant difference between two outcome categories (i.e. claim and no claim categories). Moreover, at the beginning of development of the LR model, only financial data were introduced. Because the predictive power of the developed model using financial data is lower than 70%, the cost monitoring variable was added and then the predictive power of the new model demonstrated significant improvement.

Other important techniques to interpret the model applied in this work are sensitivity analysis and robustness test. Sensitivity analysis is performance analysis by using a nominal value (i.e. average value of predictors) and also analysis of the impact function of a predictor on the outcome variable while other predictors are retained based on their nominal values (average values). While robustness test is to examine the degree to which the model is sensitive to its assumptions. It means the model is analysed on the basis of comparison of the predictive power of the outcome variables for several contractor characteristics (e.g. construction type and size) from new contractor data (Severson et al. 1994).

Diekmann and Girard (1995) also employed this LR technique to develop a contract dispute model based on 38 dispute factors using 159 cases. According to them, after trying Linear Regression, Non Linear Regression and Artificial Neural Networks, the LR technique model provided the best result for contract dispute. Moreover, before developing the model, auto-correlations with one another within 38 independent dispute factors were verified and 21 potential factors for the model development were found.

These 21 factors were then combined to create 8 hybrid variables for obtaining the final LR model. In addition, validation of the model was based on 25 project dispute cases and the predictive power indicated 75%, 70% and 75% correct classification for probability of poor, average and good performance respectively in relation to a decrease in project disputes.

Furthermore, the Logistic Regression technique has less assumptions compared with relational model techniques such as Discriminant Analysis and Multiple Regression analysis. This technique can deal with non-linear relationships between independent and dependent variables and also has no assumptions of normal distribution. Moreover, the type of independent variables can be combined between continuous, categorical and ordinal data (Tabachnick and Fidel 1996).

Therefore, the reason why Logistic Regressions is used in this research is due to the fact that the nature of the independent variable consists of continuous data (i.e. factor scores of the reduced number of periodic prequalification variables) and the ordinal data for the source of variation variables. Additionally, the relationship between periodic prequalification and source of variation factors as independent variables and the project performance factor as a dependent variable is a non linear relationship, as periodic prequalification systems use a multi criteria decision making approach where each variable has a different degree of importance.

2.4.2.3 Conceptual background of methodology

According to Mertens (1997) there are two types of correlational research, namely, prediction research and relationship research. Mertens (1997) suggests that correlation/relational research can be extended to correlation/predictive research by using methods which are similar to those for relational research, as long as the amount of variance in the predictive model is high enough to be explained in an outcome variable. To obtain a good predictive model, the predictive variables should explain about 64% of the variance in the outcome variables. The main aim of this research in to identify the relationship between periodic prequalification criteria and project performance rather than to specifically develop predictive models. This approach usually investigates the relationship between measures of different variables that can influence a more complex characteristic.

Mertens (1997) suggests there are five steps to conduct the investigation using this approach. The first step is to identify an appropriate problem. In this study, the author was interested in identifying key factors of periodic prequalification factors influencing project performance in order to obtain a better understanding of the factors that can contribute to project performance. In other words, the outcome of this investigation can reveal that each key variable has a different level of influence on project performance.

The second step is to identify the variables to be included on this investigation. In this study 25 periodic prequalification criteria variables and 3 sources of variation variables were used as explanatory or predictor variables. An outcome or criterion variable is a dependent variable (i.e. variation or satisfaction variable). The inclusion of variables in the relational models needs a theoretical framework. It means that predictor variables have justification to influence the outcome variable based on previous research and theory. This framework is developed and discussed in Chapter 6.

The third step is to identify appropriate participants. It is important to include different sets of variables for different subgroups that can explain variance in criterion/outcome variables. In this investigation, not only were periodic and sub periodic prequalification criteria included in the relational models but also the sources of variation factors along with their subgroups (i.e. client, contractor and neither party). This inclusion of different sets of variables can enhance the explanation of the relationship.

The fourth step is to collect quantifiable data. The periodic prequalification data were obtained from recorded project cases in UK local authorities. The description of this data collection can be found in a previous section.

The fifth step is to analyse and interpret the results. Mertens (1997) suggests that there are many options of methods for data analysis, such as simple correlation, regression analysis including multiple regression, discriminant analysis, cross validation or factor analysis. As described in a previous section, this investigation used Logistic Regression and Factor Analysis as well as cross validation.

2.4.2.4 Summary of the combination of the two techniques utilised for Empirical study 2

The rationale of the usage of the combination of two techniques (FA and LR) for developing the model relationship between project performance and periodic prequalification factors is depicted in Figure 2.2 and Figure 2.3. The FA technique is utilised to identify underlying dimensions of 25 periodic prequalification criteria, where those criteria are grouped into the five main periodic prequalification factors or dimensions (i.e. financial strength, past experience, past performance, managerial and technical strength and compliance with regulations).

In addition, the FA technique is also intended to reduce 25 periodic prequalification criteria in terms of data summarisation in order to reduce the multicollinearity effect. The reduced number of periodic prequalification factors generated by the FA technique into the form of factor scores, along with sources of variation factors, will be used for the next stage, that is, the development of LR models. It is important to note that each variation and client satisfaction category consists of cost, time and quality factors.

The LR technique is used for developing the model relationship, as mentioned before, on the basis of two categories of independent variables (i.e. the reduced number of periodic prequalification factors and sources of variation factors). While dependent variables are the dichotomous project performance variables (i.e. variation and client satisfaction categories) as seen in Figure 2.3. It important to note that each model has only one dichotomous project performance variable, and as seen in Figure 2.3 there are six dichotomous project performance variables.

Even though this study focuses on the identification of key periodic prequalification factors influencing project performance, the inclusion of the sources of variation factors such as *client*, *contractor* and *neither party* is needed. This is because the project performance variables consisting of variation and satisfaction factors may be influenced by not only periodic prequalification factors representing contractors' historical data (i.e. periodic prequalification factor) but also their current data related to the *contractor* as a source of variation factor (controllable factor), such as poor workmanship, material delay, poor construction methods.

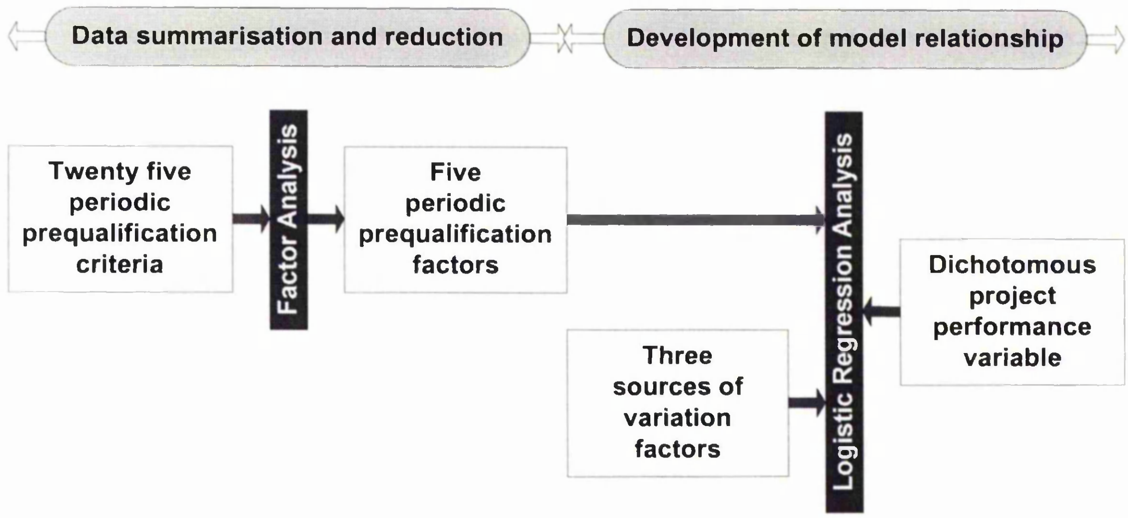


Figure 2.2 The combination of the FA and LR techniques for data analysis

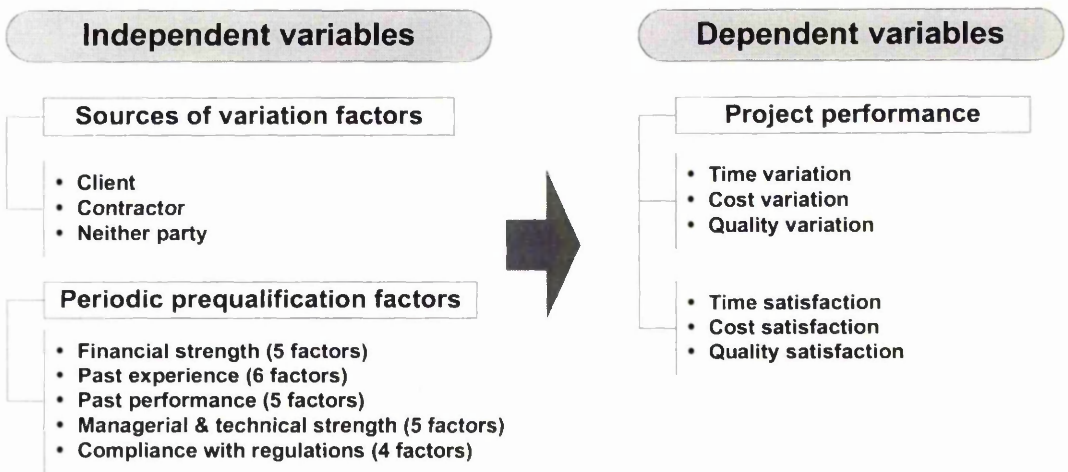


Figure 2.3 Independent variables and dependent variables for the LR models

In addition to influential factors arising from contractors' project performance, other sources of variation factors due to *client* (controllable factor of variation), such as design change or additional work, and *neither party* (uncontrollable factor of variation), such as unforeseen geological condition or inclement weather, need to be incorporated into the model relationship.

The rank order of causal factors of variation, such as poor workmanship, material delay, design change or inclement weather, is derived from the frequency of similar words/statements/meanings being used in answers by respondents. This technique is known as Content Analysis technique and was similarly applied by Soetanto et al. (2002) for determining contractor performance criteria.

To validate of the LR models, internal and external validations are performed and a schematic diagram showing the usage of data validation can be seen in Figure 2.4. The cross validation technique that is commonly used for validation in the Artificial Neural Network method, suggested by Hair Jr et al. (1998) and Weiss and Kulikowski (1991) and implemented by Kog et al. (1999 and Chua et al. (1997), is used for internal validity by randomly resampling 15 % of 58 cases 10 times to provide 10 holdout samples. It is important to note that these holdout samples are not used for developing the model relationship.

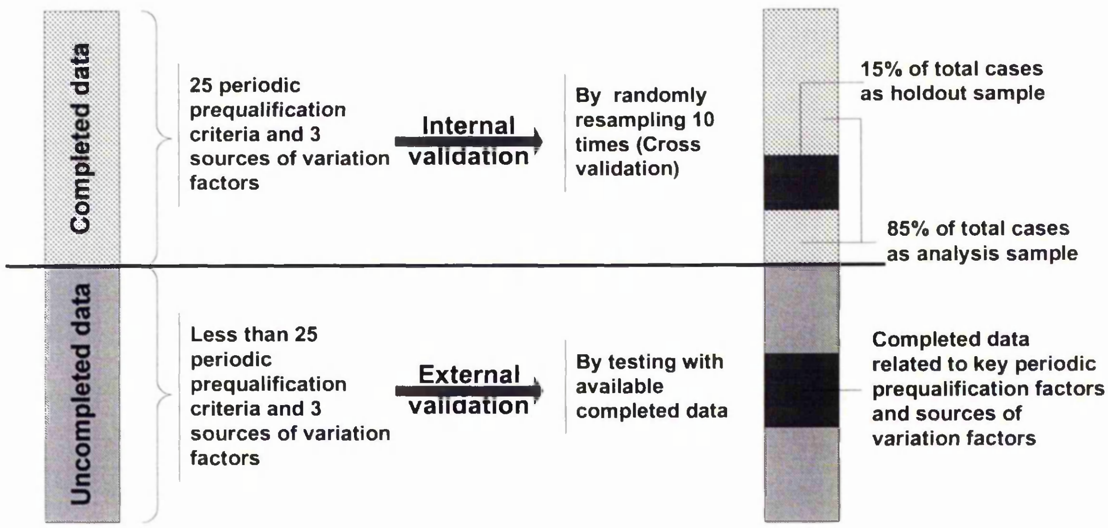


Figure 2.4 The usage of data validation

The data that are not utilised for resampling are prepared for testing the models, as long as cases are still available and contain the identified key factors in the developed models. This approach is considered as external validation since the data have not been used for developing the models or for internal validation.

2.5 RESEARCH VALIDATION

To validate the measure of the differences and similarities of periodic and project prequalification systems in Empirical study 1, the elements of prequalification characteristics are prequalification team, criteria development, prequalification criteria, data collection methods, evaluation models and prequalification performance that are discussed in Chapter 3. These elements as underlying dimensions of the prequalification system operationalising the concepts of prequalification systems into empirical indicators formed as variables into the questionnaires and tested by the use of relevant statistical tests are described in Table 2.6 and Table 2.7 and the results can be seen in Chapter 4. Thus, the validity and reliability of a measure rely on how well the concept is defined (Vaus 2002; Procter 1998) and also how well the usage of statistics as tools is understood (Cramer 1997). This kind of validity requires:

- a well established conceptual framework from general prequalification definition to specific prequalification definition based on the classification of periodic and project prequalification systems (clarifying concepts);
- a testable hypothesis deduced from the conceptual framework on the basis of previous research of prequalification and other publications (e.g. prequalification guidelines) related to prequalification (developing indicators); and
- multiple lines of relevant evidence to test the hypothesis from data collection through questionnaire surveys to data analysis using relevant non parametric statistical tests (evaluating indicators) (Vaus 2002; Mertens 1997).

Before comparing between periodic and project prequalification systems, client and contractor samples will be tested to determine whether both samples can be combined or not before comparison to obtain consistency (i.e. reliability) across the two categories (i.e. periodic and periodic prequalification categories). Client and contractor samples are combined if not significantly different or the samples are split if significantly different.

Moreover, for the usage of the FA technique, Cronbach's alpha coefficient is used for internal consistency of respondents' answer to all variables in measures that express the degree the variables are independent measures of the same concept, in other words, how well they are correlated with one another (Sekaran 2003). To ensure validity of the measurement using this FA technique, the sample size and the assumptions (see Table 2.5) must be satisfied (Hair Jr et al. 1998).

In terms of validation of the identification of periodic prequalification criteria (see Chapter 5), triangulation is utilised. The definition of triangulation is to verify information that is collected from different sources or methods at various times, in different locations and from a range of people/organisations for consistency of evidence across the data (McDonald and Tipton 1998; Mertens 1997). In this chapter, the sources of information are based on the previous research through literature review, prequalification guidelines from different organisations in different locations (UK local authorities, several countries) and at different times, that is, from data collection 1 in 2001 and data collection 2 in 2003.

In Empirical study 2, the FA technique is employed to validate twenty-five periodic prequalification criteria (see Table 5.5) corresponding to the five main prequalification criteria as seen in Table 5.4. While validation of the model relationship between periodic prequalification criteria and project performance is based on the measure of the predictive power described in Table 2.9. Moreover, the cross validation technique is applied in order to identify consistent predictors during model development as well as internal validity of the LR models. While the reliability of independent data is tested on the basis of Cronbach's alpha coefficient. In short, Table 2.9 and previous section describes all requirements to develop and validate the model development.

2.6 SUMMARY

The summary of research methodology is illustrated in Figure 2.5. This figure shows the hierarchical process of the research implementation from the beginning to the end. The left and right side arrows illustrate the contribution/influence of the hierarchical process on one level to other levels. While the double arrows represent the interaction or refinement process of the development of respective subjects.

The literature review plays a central role in developing identification of research interest, research question/problem definition and conceptual frameworks. The process of their development is an iterative process to refine them before continuing with further data collection, data analysis, research validation and research conclusions and recommendations in order to achieve the research aim and objectives. The research interest and the research question/problem definition are presented and discussed in Chapters 1 and 2. While literature review of prequalification systems and the relationship between periodic prequalification and project performance are respectively presented and discussed in Chapters 3 and 6. The literature reviews are intended to develop conceptual frameworks for clarifying the concepts, developing indicators for further developing questionnaires for data collection and also for further evaluating the indicators used in the empirical studies.

Following the development of the research question/problem definition and conceptual frameworks, research design/research strategies (see Chapter 2) are determined in order to structure the hierarchical process of the main research consisting of Empirical study 1 (see Chapter 4), identification of periodic prequalification criteria (see Chapter 5), Empirical study 2 (see Chapter 7) and research validation (Chapter 8). Briefly, the research methodology has been presented and discussed in this chapter in order to properly systemise or guide the process of this research and methodologically achieve the research aim and objectives.

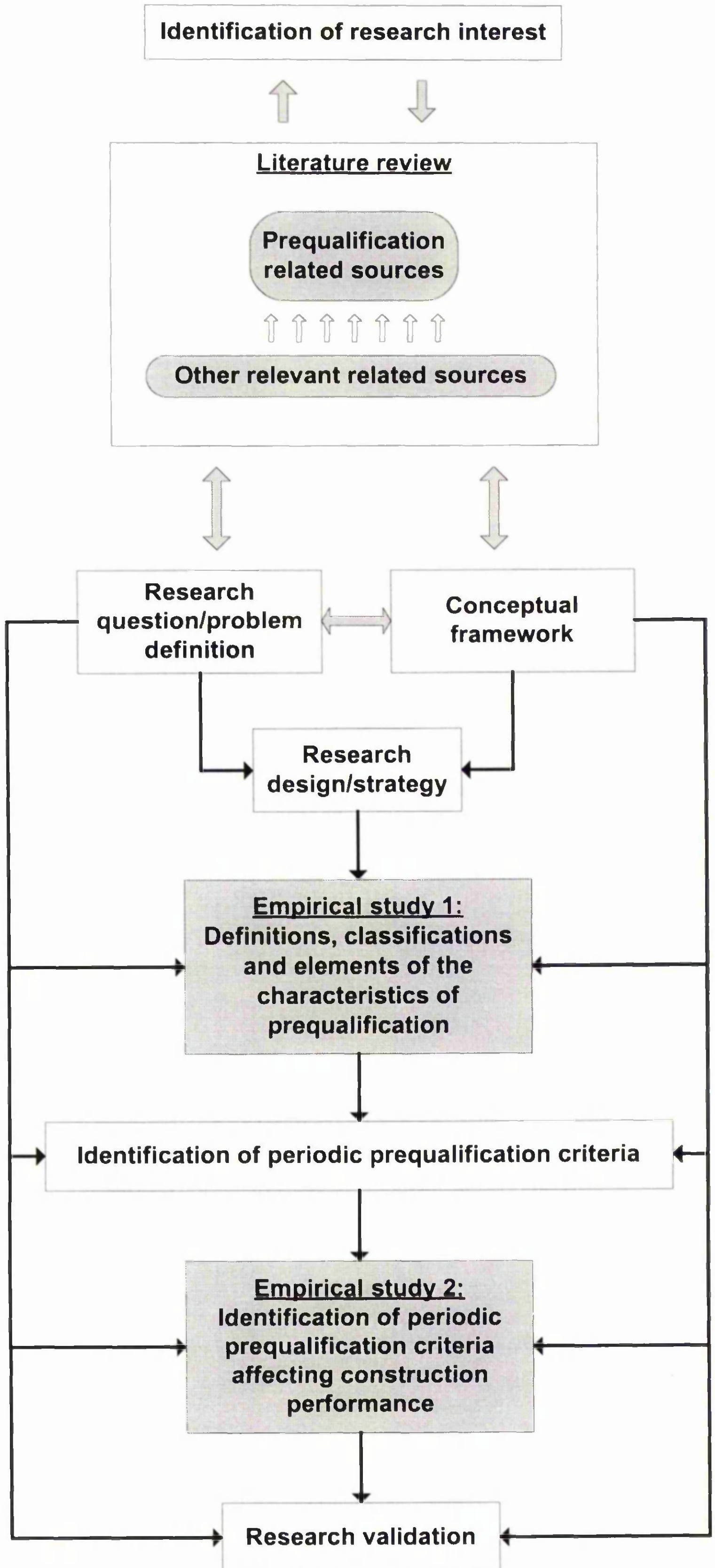


Figure 2.5 Hierarchical process of the research methodology

CHAPTER 3

Contractor prequalification systems: A review

3.1 INTRODUCTION

In order to obtain a broad knowledge of prequalification systems in academic research, it is necessary to carry out a literature review before further identification of prequalification characteristics in the UK construction industry that will be identified through questionnaire surveys. This literature review tries to identify the sources of problems mentioned in chapter one including a lack of methodology, a lack of a universal approach to contractor selection, a lack of understanding of evaluative criteria and over reliance on subjective analysis.

This review also investigates the wider perspectives of prequalification systems, but is not limited to decision criteria and models of evaluation predominantly found in the recent and past research of contractor prequalification. These wider perspectives will comprehensively discuss any aspect which can influence prequalification performance and especially those which make the systems more objective in the whole life cycle of the prequalification process at any level (e.g. projects, client organisations or the construction industry) including clarification of definition and type, investigation elements and prequalification practices which can contribute towards prequalification success.

In this chapter, three main topics of contractor prequalification, namely, definitions of prequalification, prequalification types and prequalification system elements are reviewed. Ten definitions obtained from ten different references in the period between 1989 and 2001 are discussed and also the two main types of contractor prequalification system (i.e. periodic prequalification and project prequalification) are reviewed and derived from five different references. The structure and detail of all the topics which are reviewed in this chapter are depicted in Figure 3.1.

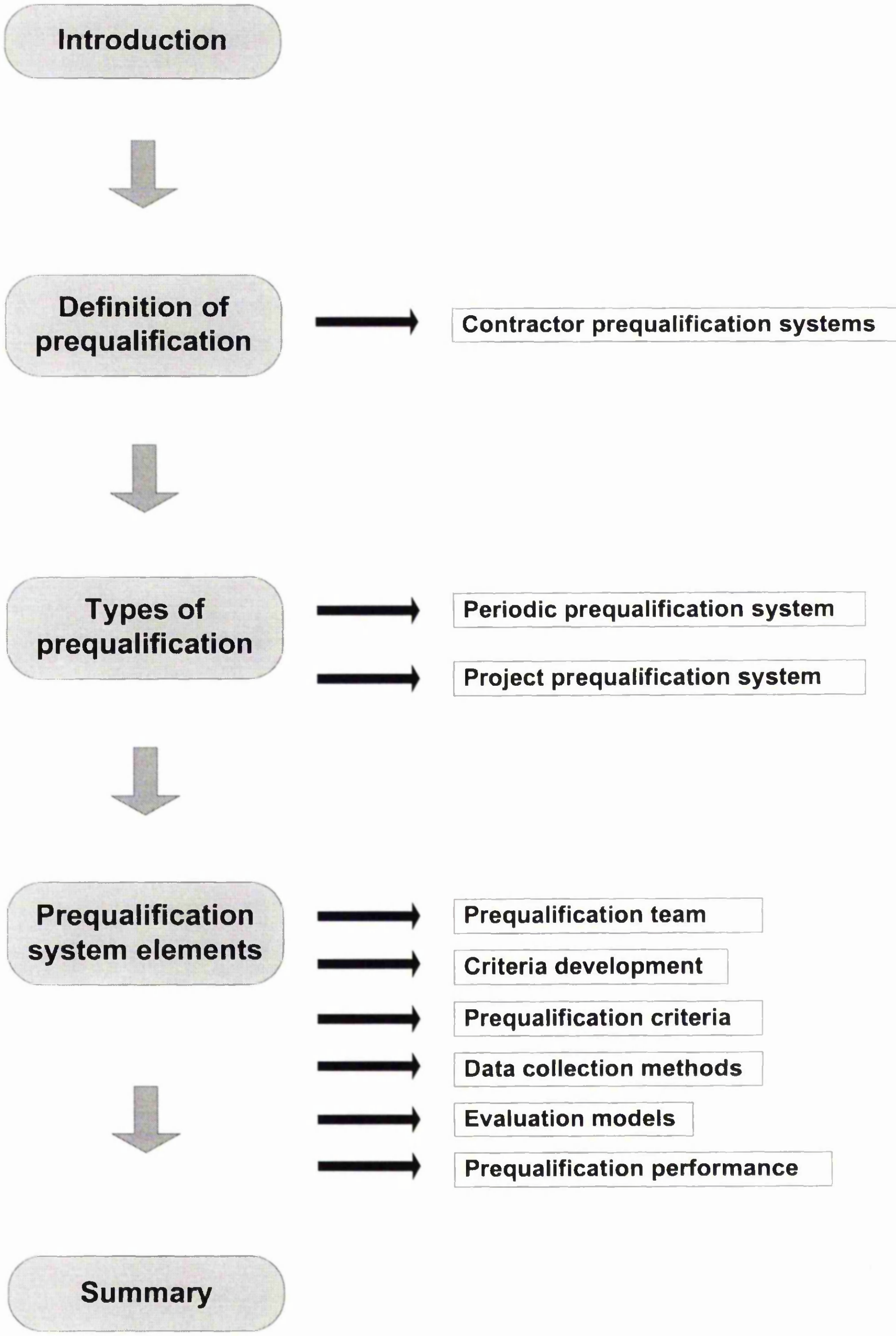


Figure 3.1 Structure and detail of contractor prequalification systems under review

Therefore, in this chapter the characteristics of prequalification systems in terms of the types and their relevant elements will be identified and discussed in order to develop a systematic further investigation of prequalification practices particularly the relationship between contractor project performance and periodic prequalification, which is the main purpose of this research.

3.2 DEFINITION OF PREQUALIFICATION

For over a decade there has been intensive and persistent research and development of prequalification systems as reflected by the references in Table 3.1. The definitions of contractor prequalification, which vary from the general to the specific, explain the process of contractor selection according to certain criteria. The majority of references (3, 6, 7,8 and 9) come from the UK, while references 1, 2 and 4 are from the USA and the fifth is from Saudi Arabia. The last one was defined after investigating and reviewing prequalification systems implemented in the public sector in Hong Kong, Australia and the USA. Table 3.2 shows that the main defining words in the first column are checked against each of the ten definitions in order to understand the meaning of contractor prequalification and to find appropriate words for defining contractor prequalification.

All of the definitions generally describe the purpose of a prequalification system in terms of contractor evaluation and selection with the object of evaluation being the *contractor*, but two of them, the first and the third definitions, specifically distinguish between *general* and *main contractor*. The majority of definitions use the term *contractor* which could imply that the target of evaluation is not only limited to the main contractor, but also to subcontractors and specialist contractors. Furthermore, even though only one definition is associated with public prequalification systems, most documented prequalification systems carried out in the public sector as an entry point for contractors for obtaining construction projects particularly in many countries such as Indonesia (Indonesian Government 1994), Japan (Kunishima and Shoji 1996), Malaysia (CIDB Malaysia 2000), the UK (Mangitung and Emsley 2002b; Holt et al. 1995; Merna and Smith 1990), Hong Kong, Queensland, Australia, the USA (Palaneeswaran and Kumaraswamy 2001) and Finland (Lahdenpera and Soini 2002) are referred to as periodic prequalification systems.

The term *pre-tender* refers to the tender stage, while the term *contract* refers to the contract stage. Both stages are usually carried out after the prequalification stage within the procurement lifecycle, while in the prequalification stage, contractors are evaluated and selected according to their competence leading to the development of a short list, known as a tender list or a group of contractors of similar classification or qualification also known as a standing list of contractors. Table 3.1 reveals that more definitions use the word *pre-tender* than *contract,* because in construction industrial practices the type of procurement mostly used by clients is typically traditional or conventional through a tendering channel.

Figure 3.2 shows that the use of the traditional procurement system is still high in the UK construction industry, even though there has been a decrease compared with other non conventional methods such as design and build and management approaches (Masterman 2002). Implementation of prequalification systems is not only restricted to the traditional method of project procurement, but to other procurement methods. Other types have inherently high complexity and risk where the problems may come from contractors. Recently the practice of design and build and other methods such as partnering or Build Operation and Transfer (BOT), known in the UK as Project Finance Initiative (PFI), have increased, and implementation of prequalification systems has become the usual approach for selecting a group of contractors before a final selection of a winning contractor, as reflected by research in the design and build area (Palaneeswaran and Kumaraswamy 2000b; Potter and Sanvido 1995; Potter and Sanvido 1994), the partnering approach (Matthews 1999) and as shown in the guidelines for PFI for National Health Service (NHS) projects (Department of Health 2003) and Constructionline (Constructionline 2002).

Table 3.1 Definitions of contractor prequalification

No	Definition	Reference
1.	Contractor prequalification is a process of qualifying general contractors as required by regulation in public work projects before issuing bidding documents or submitting a proposal.	(Clough 1986)
2.	Contractor prequalification is a process of the screening of contractors by a project owner, according to a given set of evaluation criteria such as finance, experience, resources, organisation, in order to determine their competence to perform the work completely if awarded the construction contract.	(Russell 1996; Russell and Skibniewski 1988)
3.	Contractor prequalification is a process of assessing main contractors in order to obtain a number of competitive, reasonable and easy-to-evaluate bids submitted by equally suitable and experienced main contractors based on financial stability, managerial capability, organisational structure, technical expertise and the previous record of comparable construction.	(Merna and Smith 1990)
4.	Contractor prequalification is a pre-screening technique of determining contractors' reputation, skill and financial capability prior to issuing bidding documents.	(Barrie and Boyd 1992)
5.	Contractor prequalification is a process of investigating and qualifying bidders as acceptable contractors, prior to the award of contracts, based on their skills, integrity and responsibility.	(Bubshait and Al-Gobali 1996)
6.	Contractor prequalification is a pre-tender process used to investigate and assess the capabilities of contractors to carry out a contract satisfactorily on the basis of a set of main criteria including financial soundness, technical ability, management capability, health and safety and reputation.	(Hatush and Skitmore 1997b; Hatush and Skitmore 1997c)
7.	Contractor prequalification is a process of evaluating contractors in terms of their potential ability to complete the project on time, within budgeted cost and to required quality.	(Holt 1997; Holt et al. 1994a)
8.	Contractor prequalification is a process to ensure that tenders are sought from contractors whom the employer/engineer has already checked as having the requisite resources and financial and technical capability to perform the intended work satisfactorily.	(Ng et al. 1999; Ng and Skitmore 1995a)
9.	Contractor prequalification is a process of evaluating a group of contractors for their suitability to be added to a contractor list (e.g. standing list, approved list or project list) based on past performance, experience, managerial, technical and financial characteristics.	(Wong et al. 1999)
10.	Contractor prequalification is a process of identifying eligible contractors and classifying them according to their financial, technical, organisational and managerial capacities, track records in terms of past performance, occupational health and safety, environmental concerns, and attitudes toward claims.	(Palaneeswaran and Kumaraswamy 2001)

Table 3.2 Relationship between defining word or words and definitions

Defining word or words	1	2	3	4	5	6	7	8	9	10
Evaluation and selection (screening, qualifying, identifying, evaluating, assessing, investigation)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Contractor		✓		✓	✓	✓	✓	✓	✓	✓
General/main contractor	✓		✓							
Project in public sector	✓									
Pre-tender	✓		✓	✓	✓	✓		✓		
Contract		✓			✓					
Contractor list			✓						✓	✓
Project completion		✓					✓			
Project performance							✓			
Satisfaction						✓		✓		
Competence		✓		✓	✓					
Capability			✓	✓		✓	✓	✓		
Capacity										✓
Integrity & responsibility					✓					
Financial strength		✓	✓	✓		✓		✓	✓	✓
Past experience		✓	✓			✓		✓	✓	✓
Past performance			✓	✓					✓	✓
Technical & managerial strength		✓	✓	✓		✓		✓	✓	✓
Compliance with regulations										✓

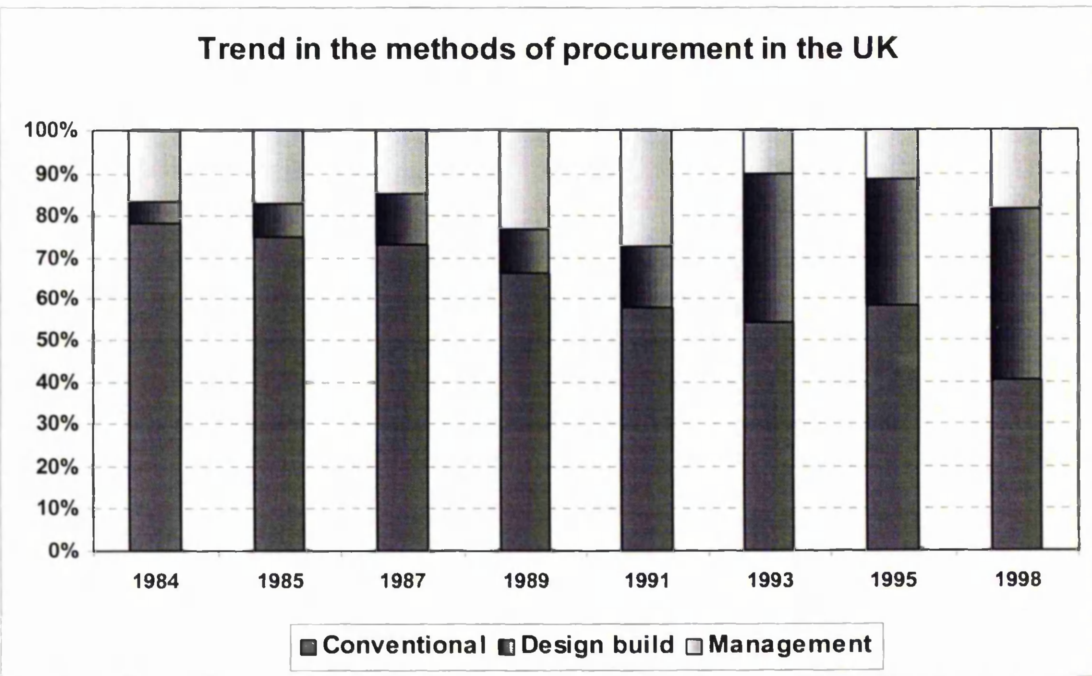


Figure 3.2 Trend in the methods of procurement (after Masterman 2002)

In addition, regarding the term *contractor list*, a prequalification system is sometimes only implemented for grouping contractors into a standing list of contractors (long listing process) based on similar classification or qualification. In other words this type is not intended for a particular project and is known as contractor registration (Palaneeswaran and Kumaraswamy 2001), or in the UK, as the Constructionline system (Constructionline 2001). This type of prequalification is commonly practised in the *public sector*. The other type of prequalification system is project prequalification which is only used for developing a short list before tendering (i.e. *pre-tender* stage) or for other procurement methods (Mangitung and Emsley 2002a). Usually this type of prequalification is carried out in one package of contractor procurement before a project *contract* is signed.

Referring to the outcomes of a project (i.e. *project completion*), that is, to complete it satisfactorily within budgeted cost, planned time and also to the required quality, has become not only an important part of the evaluation of *project performance*, but also of prequalification performance itself. Even though Table 3.1 shows 90% definitions do not explicitly mention project performance as reflected by the research and practices identified in this research (Mangitung and Emsley 2002a). Tthe inclusion of contractors' past performance has become important to indicate contractors' future performance, as a model proposed by Kashiwagi and Mohammed (2002) shows that, in the US, implementation of the Performance Information Procurement System (PIPS) over the past ten years has indicated a 9.7 performance rating based on the scale of 1 to 10, a 99% customer satisfaction rating, and 99% would use the contractor again.

Additionally, in the UK there is a model of prequalification systems associated with achievement of project success in order to evaluate the competence of contractors. The method was developed by Hatush and Skitmore (1997c) using the Delphi method that identified past performance based on past failure, financial strength, experience and managerial and technical strength in relation to ability, management personnel and management knowledge, which are the main prequalification criteria influencing the project success factors of cost, time and quality. Compliance with regulations related to the safety criteria can influence at least one of the project success factors. However, these findings are only based on the opinions of eight professional experts consisting of three and five experts from UK public and private clients respectively.

Regarding the word *competence*, there are some relevant terms commonly used, namely, *capability, ability, capacity, integrity* and *responsibility*. According to the Oxford Concise Dictionary, *competence* means the state of being adequately qualified or capable and could be based on the skills, abilities, or experience of a person to do something effectively and efficiently (Pearsall 1999).

However, care should be taken with regards to the use of the term *capability* which is not suitable for evaluation of the current workloads of contractors. For instance, contractor prequalification is sometimes only carried out for developing a list of contractors for projects of a certain size and type. But not for a particular project and when the time between the prequalification stage and the tender stage or awarding the contract is significantly different, which could be between one and three years (Mangitung and Emsley 2002a). It is possible that contractor's capability to perform a project task was acceptable at the prequalification stage but, at the time of awarding the contract, the contractor's capacity may have decreased due to commitment to other ongoing project tasks (Ng 1996; Russell 1996). It means that for a particular project, the term *capacity* of a contractor is more appropriate and will be discussed more thoroughly in the next section, which describes prequalification types. Additionally, the terms *integrity* and *responsibility* refer to the contractor's performance and can be evaluated and traced to their historical data associated with cost, time and quality performance, compliance with regulations (e.g. health and safety records) and the number or value of disputes, claims and contract breach records (Palaneeswaran and Kumaraswamy 2001).

Finally, the decision criteria chosen are a pivotal part of the prequalification process; most definitions in Table 3.1 refer to some common factors used in the system including financial strength, past experience, past performance, and technical and managerial strength. Even though compliance with regulations is only included in definition 10, this factor is an important criterion, particularly compliance with health and safety regulations and was found to be an important factor in a survey as a part of this research in the UK construction industry. The survey, based on the answers of a questionnaire survey from 76 client and 45 contractor respondents, shows the frequency of usage of a health and safety factor is 98% (Mangitung and Emsley 2002b). In addition, several models (Mahdi et al. 2002; Alsugair 1999; Hatush and Skitmore 1997a; Russell 1996) also use this factor.

The purpose of a multi-criteria approach is to propose improvement of the conventional contractor selection systems using price criteria only (Wong et al. 2000; Holt et al. 1995; Latham 1994; Herbsman and Ellis 1992; Merna and Smith 1990) and to reduce project risk (Hatush and Skitmore 1998; Russell 1996). According to news reports in Hong Kong, contractors selected through the lowest tender criteria often failed to complete projects because of lack of financial strength and other common factors (Fong and Choi 2000).

In addition, Lingard et al. (1998) argue, based on transaction theory, that the use of price based criteria, where probably less information is obtained compared with multi-criteria, incurs lower transaction costs (*ex-ante* category). While, after awarding the contract, a winning contractor tends to compensate the low contract value via claims or project disputes which can arise due to lack of information of the winning contractor's profile, leading to additional project costs; in other words after signing a contract the actual project cost will increase (*ex-post* category). For example, hidden costs could arise due to cost overrun, time overrun, rework, poor quality performance, accidents, environmental damage, claims and disputes (Kumaraswamy and Walker 1999). Moreover, clients may face high risks associated with construction failure, if contractors are solely evaluated using financial performance or using third party financial reports that are commonly used for evaluation of credit rating, bonding or insurance in terms of contractors' financial risks without being concerned in detail with technical or managerial aspects (Russell 1990).

Briefly, a definition of contractor prequalification can be developed from the main prequalification objectives and project outcomes on the basis of multi-criteria. Therefore, contractor prequalification may be defined as a process of selection of eligible contractors before awarding a contract using multi-criteria for investigation of the contractors' competence to perform a certain project task completely and satisfactorily as required by the contract. The various definitions of contractor prequalification as reflected in Table 3.1 cannot be avoided and it depends on the client's main and specific objectives, project objectives, prequalification objectives and final contractor selection objectives (Russell and Skibniewski 1988). These definitions need further analysis, based on the types of prequalification system as discussed in the next section.

3.3 TYPES OF PREQUALIFICATION

Contractor prequalification systems can be classified into two main types, namely, periodic prequalification and project prequalification. The first is performed to develop a standing list of contractors relevant for a certain periodic time frame including a certain project size, range and type, which can be used by a client for short listing or invitation to bid. The second one is performed to develop a list for a particular project, on a project by project basis, before invitation to bid or for short listing.

Several researchers have identified these prequalification types as follows:

- Standing list prequalification system and project list tendering system (Hatush 1996);
- Standing list prequalification system and ad-hoc list prequalification system (Ng 1996);
- Annual prequalification and project-by-project prequalification (Russell 1996);
- Standing list prequalification system and per project performed prequalification system (Jennings and Holt 1998); and
- Registration/periodical prequalification and project-by-project prequalification (Palaneeswaran and Kumaraswamy 2001).

Even though the terms are different, standing list prequalification system, annual prequalification, contractor registration and periodical prequalification can be categorised as periodic prequalification. While project list prequalification system, ad-hoc list prequalification system, project-by-project prequalification and per project performed prequalification system can be represented by project prequalification type. A flow diagram of the process for both prequalification types can be seen in Figure 3.3.

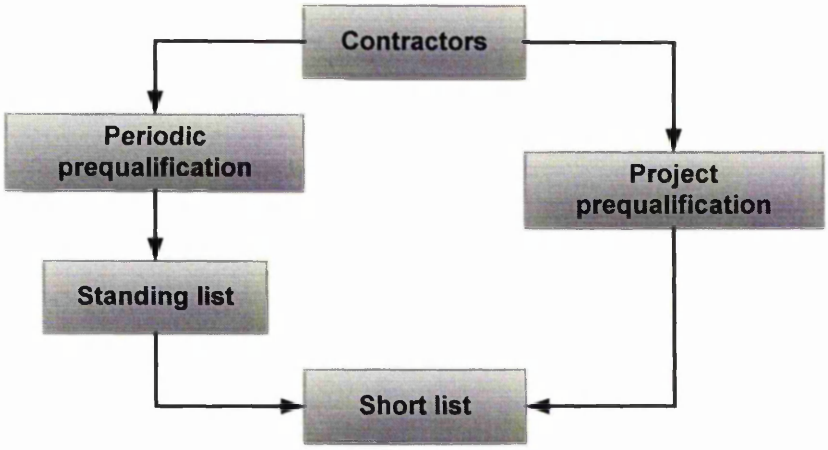


Figure 3.3 Flow diagram of the prequalification process

Palaneeswaran and Kumaraswamy (2001) identified the prequalification types based on interviews and correspondence with 108 experts/practitioners from around the globe including Australia, the USA and Hong Kong (22 personal contacts and 30 construction prequalification practices). Several issues are discussed as follows:

- The periodic prequalification system in Hong Kong and Australia was relatively static in terms of the contractors' rating. In other words, contractors' competence was categorised into specific static ranges of their ability to perform over a certain periodic time (from 1-2 years period), a certain range of project values and a certain project type. For example, Category 1 for contract value over Australian $4 million is implemented by the Government of South Australia and Group A for up to HK$20 million is implemented by the Hong Kong Work Bureau, Hong Kong;

- Periodic prequalification in the USA, illustrated by examples from four State Departments of Transportation, was relatively dynamic. The rating of contractors' competence was determined according to the maximum dollar amount of work that a contractor can perform at any time. This maximum dollar amount included the value of ongoing projects (current workloads); and

- According to the proposed model, there are two routes of contractor prequalification system. Contractors' competence in periodic prequalification is evaluated based on general filters in terms of responsiveness, responsibility and competency attributes and project category benchmarks for determining prequalification ratings (i.e. project value ranges). While in project prequalification, which is intended for high value/ technologically complex projects, contractors' competence is evaluated based on general filters in terms of responsiveness, responsibility and competency attributes and project specific benchmarks for determining prequalification ratings (i.e. project value ranges).

Jennings and Holt (1998) identified those two prequalification types based on a questionnaire survey sent to 80 construction firms in the UK with 34 completed returns. Randomly selected stratified sampling was used on the basis of work catchment area (based on regional, national and international definitions), size of construction firm organisation i.e. small, medium, large (based on annual turnover) and location of head office from ten geographical regions in England and Wales. Some interesting findings of prequalification characteristics in this survey are as follows:

- The frequency of contractors being prequalified is based on the size of the construction firm, or it can be assumed to be related to project size, as depicted in Figure 3.4 which shows that the larger firms are chosen more often through prequalification. The figure also shows that around 25% of large firms were selected without prequalification; in this case the firms might carry out small works and/or be procured through partnering; and

- There is a tendency to increase the number of construction firms being prequalified through periodic prequalification if their size is smaller and vice versa as depicted in Figure 3.5. This indicates that higher numbers of construction firms are selected for larger projects through project prequalification and also indicates the larger the project the less confidence clients have in the results of evaluation through periodic prequalification. Conversely, for smaller projects, clients are still satisfied to use a standing list. But the eligible time in the standing list is one year (72%).

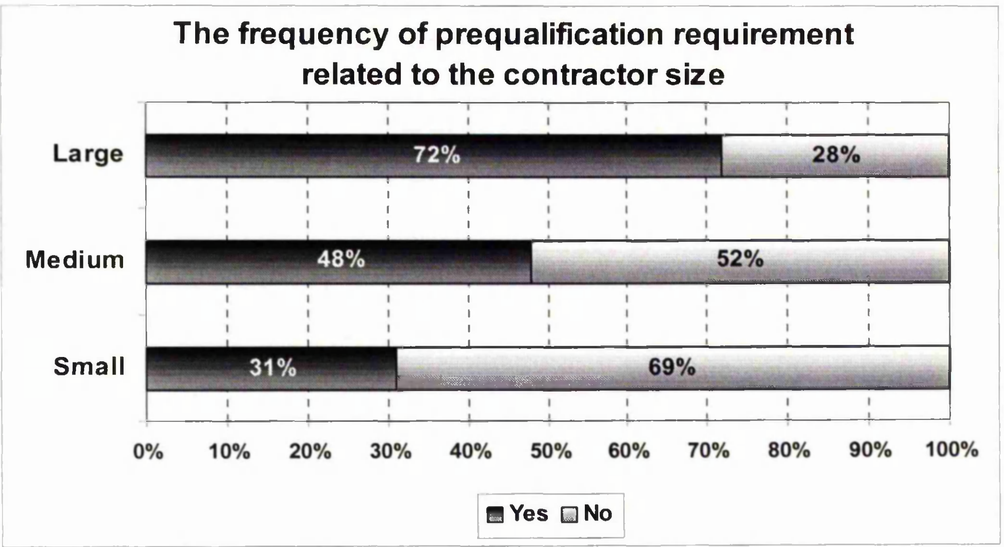


Figure 3.4 Prequalification requirement (after Jennings and Holt 1998)

Note: Small (turnover: £0-£5 million); Medium (turnover: £5-£50 million); Large (turnover > £50 million)

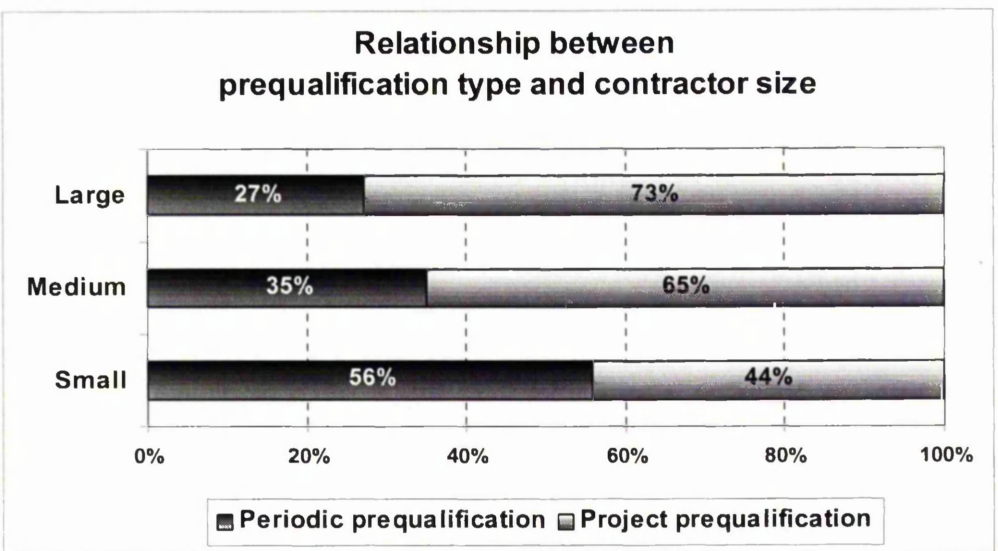


Figure 3.5 Relationship between prequalification type and contractor size (after Jennings and Holt 1998)

Note: Small (turnover: £0-£5 million); Medium (turnover: £5-£50 million); Large (turnover > £50 million)

Hatush (1996) found those prequalification types based on interviews with 10 different public and private client representatives in the North West of England. The main difference between these prequalification types is the time of the assessment. Some issues identified in this investigation are as follows:

- Reassessment cycles of contractors being eligible in the standing list are 1, 3 or 5 years;
- In periodic prequalification, clients can save time by updating contractors' competence according to a certain designated number of years cycle or an annual cycle. In contrast, in project prequalification they tend to lose time due to repetition of contractor evaluation for every project;
- Sometime a client loses time, because contractors listed in a standing list do not respond to an invitation, when they already have some invitations from other clients. Consequently, a client sometimes has to perform periodic prequalification more frequently in order to maintain a sufficient number of contractors on the list. In contrast, in the project prequalification system, contractors only submit a bid proposal if they want the project, and then a client can save time by inviting only interested contractors; and
- In project prequalification, a client can evaluate contractors' competence in more detail for a specific contract.

Ng (1996) found the prequalification types from the results of a questionnaire survey in the UK based on 111 respondents (22.2% of total sample) consisting of public clients (49.55%), private clients (13.51%) and consultant engineering firms (36.94%). The periodic prequalification system is widely used in both sectors representing 92% in the public sector and 71% in the private sector, while the project prequalification system is represented by only 64% in the public sector and 58% in the private sector.

Moreover, some issues identified and discussed in this questionnaire survey are as follows:

- 29% of client respondents reassess contractors' data in their standing list annually, while 27% assess them every 2-5 years;

- Information about contractors' competence gathered at the prequalification stage could be obsolete because of the time difference between prequalification and tender stages. While in the project prequalification system the information obtained is suitable for a particular project and information should be very current and detailed. But sometimes, as the project is unique in nature, the result of evaluation of contractors' competence could not be applied to other different projects and the process for this prequalification will take more time and incur more cost;

- In periodic prequalification, clients can save time by updating contractors' competence on the basis of a certain designated number of years cycle or an annual cycle. But this approach is only suitable for clients who have a significant number of small and medium sized projects which are less complex and low risk, while project prequalification is only suitable for large and complex projects, specific and non repetitive in nature;

- In project prequalification, a client can evaluate contractors' competence in more detail based on the specific objectives of a particular project but, in periodic prequalification, the evaluation is based on overall suitability for a certain work category and price band; and

- The cost incurred in project prequalification is relatively high compared with the cost of periodic prequalification, because contractors' data are collected and evaluated in more detail and project objectives are defined and known more clearly.

Russell (1996) found some typical characteristics of both prequalification types based on his research over the past eight years in the USA. A comparison between periodic and project prequalification is as follows:

- In terms of the type of analysis, project prequalification is relatively more dynamic, while its counterpart tends to be static;

- Project specific factors can be applied in project prequalification, so the depth of analysis can be in more detail. Conversely the depth of analysis tends to be less extensive in periodic prequalification, as project details have not been defined;

- In project prequalification, the type of information is much more current, while in periodic prequalification it is less current;

- In project prequalification, analysis of contractors' data focuses on a particular project, while in periodic prequalification, analysis of contractors' data is limited to identifying their capability on the basis of a maximum project value;

- The project prequalification criteria being used can be determined more precisely for certain project characteristics and objectives as well as it being relatively easy to quantify the need for contractors' resources. While the periodic prequalification criteria being used are financial stability, financial surplus and the performance track record of contractors as well as being limited to a qualitative approach rather than a quantitative approach in assessing contractors' capability;

- In terms of evaluation effort and cost, project prequalification incurs higher cost than its counterpart (*project prequalification*: 25 person-hours/contractor/project; US$2,670/contractor; 0.5% of total project cost; *periodic prequalification*: 8 person-hours/contractor/year; US$235/contractor; 1.1% of total construction expenditure). I addition, more detailed data can be analysed rather than focusing only on the general characteristics considered for periodic prequalification;

- The impact on competition is positive for project prequalification, whereas periodic prequalification it is possibly negative; and

- Resources are used relatively more efficiently, the ability to detect changes in contractor operation is higher and the chance of failure is lower for project prequalification than its counterpart.

The differences between periodic and project prequalification in terms of the different issues discussed before are summarised in Table 3.3.

Table 3.3 Summary of the differences between periodic and project prequalification

Issues	Periodic prequalification	Project prequalification	References
Reassessment cycles	Time dependent (1-5 years)	Time independent	1, 2, 4
Redundant assessment	Relatively low	Relatively high	2
Contractor response to tender invitation	Relatively low	Relatively high	2
Detailed in evaluation	Relatively low	Relatively high	1, 2, 4, 5
Criteria relevancy	Historical and general	Current and specific	1, 4, 5
Suitability	- Small and small medium and less complex projects - Certain range of project price bands	- Large size and complex projects - Particular projects, especially those with well defined projects	1, 3, 4, 5
Data updated	Relatively easy	Relatively difficult	4
Flexibility of analysis	Relatively low	Relatively high	5
Detection of data change	Relatively difficult	Relatively easy	4, 5
Cost	Relatively low	Relatively high	4, 5

Note:

Number	References
1	Palaneeswaran and Kumaraswamy (2001),
2	Hatush (1996).
3	Jennings and Holt (1998);
4	Ng (1996)
5	Russell (1996)

Briefly, it can be summarised that the main advantages of periodic prequalification are relative savings in time and cost and avoiding repetitive evaluation so that a client does not need to rerun contractor evaluation in a certain period of time for a number of similar projects. While the main disadvantages are that relatively less current information is obtained from contractors and that reliance is placed on contractors' historical data and the quality of those data may be low, depending on the reassessment cycle time. Moreover, the chance of failure with regards to contractors' project performance is higher, and it still requires additional assessment including the current workloads and specific project criteria. Therefore this approach is suitable for small and medium projects.

On the other hand, the project prequalification system also has main advantages and disadvantages. The benefits of the project prequalification system are that it is able to reduce project risk better compared with the periodic prequalification system, due to higher reliability of information obtained and germane to a particular project; to analyse contractors' current workloads more precisely and in detail; and to involve only serious contractors who are interested in an offered project.

While the drawbacks are the large amount of effort and resources required or the relatively higher cost and need for more time; and redundancy of contractor evaluation in some aspects, that is, repetition of historical contractors' data evaluation, especially for clients who have a number of similar project types and sizes annually.

Furthermore, the main problem encountered is the method used for analysing prequalification types only at the level of client organisations. The analyses have not been concerned with the impact of redundancy of contractor evaluation and the cost of separated storage of standing lists of qualified contractors by each client for the same contractors and for the same project characteristics (e.g. type and size) (Mangitung and Emsley 2002a; Latham 1994).

The impact of the cost, time and effort will be significant if they are taken into account at the level of the construction industry, or at least at the level of institutions that have a number of similar project types and sizes annually (e.g. local authorities in the UK). In other words, analysis of prequalification should consider a holistic approach by analysing the prequalification system not only at the project level or client level separately but also at the level of certain groups of similar institutions or at the industry level as whole.

To reduce the repetitive evaluation process by the client and the separated storage of lists, it is necessary to outsource the periodic prequalification process to a third party, since generalisation or standardisation of a prequalification system can be logically implemented through periodic prequalification that uses general and historical criteria for evaluation of contractors' competence.

Additional information about contractors' competence can be evaluated at the project level or at the clients' organisation level using a project prequalification system, since every client has different objectives and every project has unique objectives. In order to improve the weakness of the common existing process of prequalification it is necessary to transform the current system into an integrated prequalification system considering both types' advantages.

The notion of an integrated prequalification system is referred to in the Latham report which proposed a centralised prequalification system. This proposal was implemented with the name of Constructionline. The Constructionline system is a National Qualification System (NQS) that was established by the Department of Environment, Transport and the Regions (DETR) in 1998 as a single national database of registered contractors and consultants. This system has been managed by the Capita group under a seven year contract in order to develop and maintain a registered list of contractors and consultants in the UK. But following the Government review of July 2001, the responsibilities of the DETR in relation to Constructionline passed to the Department of Trade and Industry (DTI). The lists can now be accessed through www.constructionline.co.uk (Mangitung and Emsley 2002d).

But the framework of this centralised prequalification system is not clear, as survey findings indicate some clients fully rely on this system without further evaluation, while other clients require specific project criteria to complement this system. This assumption to some extent is not realistic, since every project has different objectives and requirements as well as the possible information gap which exists between the periodic prequalification stage and the tender stage. This has led to only a gradual increase in use of this system among public clients whose target is an increase in efficiency of the prequalification process. Additionally, there is no feedback program of contractors' performance in order to evaluate the performance and effectiveness of the implementation of Constructionline (Mangitung and Emsley 2002b; Mangitung and Emsley 2002a; Mangitung and Emsley 2002d).

Furthermore, besides screening contractors in order to list potential contractors which have the competence to perform a certain range of project tasks with regards to project size and type, periodic prequalification might be performed in order to balance and harmonise between freedom to enter into the construction market (i.e. free market advocate) on the side of contractors and protection of public interests due to market defects and failures or contractors' failure to meet contractual obligations (i.e. economic liberal advocate) on the side of clients (Schulman 1982).

3.4 PREQUALIFICATION SYSTEM ELEMENTS

There are some key elements necessary to develop and improve a prequalification system including prequalification team (Russell 1996; Ritz 1994; Russell and Skibniewski 1988), principal bases or references for developing prequalification criteria (Jackson-Robbins 1998; Russell 1996; Smith 1995; Russell and Skibniewski 1988), main prequalification criteria, contractors' data collection methods (Jackson-Robbins 1998; Russell 1996; Russell and Jaselskis 1992), models/tools used for evaluation, and evaluation prequalification performance (Kumaraswamy and Walker 1999; Smith 1995).

By investigating these elements, the prequalification process can be more systematically designed on the basis of relevancy and the priority of project and client objectives and constraints (Jackson-Robbins 1998). Additionally, drawbacks of the prequalification process can be reduced, such as the cost and time of procurement, decision making bias, low competition and barrier to entry for new comers (Russell 1996), project cost overrun, project time overrun and barrier to entry for local contractors (Lo et al. 1999). The details of drawbacks of prequalification systems for clients and contractors identified by Russell (1996) can be seen in Table 3.4.

Table 3.4 Shortcomings of prequalification systems (after Russell 1996)

Client	Contractor
The cost of an objective prequalification system including development, implementation and evaluation	Potential bias and erroneous result
The difficulty of accurate, sound and consistent decisions using a fully quantitative approach which takes account of specific project circumstances	The cost of participation in the prequalification process
The difficulty of avoiding bias in the decision process due to dependence on largely subjective judgement	The difficulty of inclusion in the list due to limited past track record in new area
Potential high mark-up due to limited number of potential contractors involved, or low level of competition	

3.4.1 Prequalification team

Like the need to have a solid project team to ensure project success, in the case of prequalification systems the quality and the number and composition of a prequalification team is an important part of the success of contractor prequalification. Therefore, quality, team size and composition of the appropriate number, expertise and experience level must be chosen carefully and appropriate to the project size, type and complexity.

In order to achieve full accountability and auditability, the number of prequalifiers must comprise of at least three competent persons from the client's organisation and professional team (Jackson-Robbins 1998). Moreover, Russell (1996) suggested that the availability of a variety of expertise from different areas may reduce bias and improve the analysis and decision making process; the client should keep the same prequalifiers in order to maintain consistency and accuracy in the evaluation and comparison of contractors' competence, especially the need for assessment by subjective judgement; and representation of various branches of an organisation with regards to various construction processes including purchasing, accounting and design should be fulfilled. Regarding the need for diversity of relevant knowledge and experience of the team, superior decisions can also be achieved through promotion of diversity of personality and individual expression (Spatz 2000).

In addition to larger projects that usually bear the increased burden of various activities (i.e. higher complexity) a project team must be set up from a wide spectrum of business and technical skills including team members from the areas of risk management, procurement, legal, accounting and tax and they should also be in team for the duration of the prequalification process in order to maximise the positive effects of repeated learning curves (Ritz 1994).

Furthermore, in the selection of an appropriate methodology for procurement systems, Rowlinson (1999) suggests that project characteristics, required technology and in-house capability issues are the basis of the determination of the level of a project personnel's competence, skill and experience. In terms of project characteristics, experienced personnel may reduce the effect of project complexity. A construction project usually requires a certain level of technology, consequently, special skills and trained employees are required on the project team. Finally, it is necessary to examine whether expertise is sufficiently capable of handling project tasks in-house or whether there is a need to outsource expertise. Practically, inexperienced and primary clients commonly rely on contractors or architects (Pettinger 1998; Masterman and Gameson 1994).

However, a combination of expertise is necessary to choose appropriately particular requirements for a certain project type (i.e. civil engineering and infrastructure, building, or housing). Ng et al. (1999) found that different areas of expertise have significantly different perceptions in terms of the importance level of prequalification criteria, but there is high consistency within the same groups of expertise (i.e. architect, civil engineer, quantity surveyor and project manager). Consequently, different perceptions in terms of the criteria used could lead to an inconsistent and inaccurate contractors prequalification process or a poor outcome in terms of the selection of responsive and responsible contractors. Thus, implementation of a prequalification system according to project type category is essential. Briefly, success and failure in the construction industry, compared with other industries, is more dependent on the qualities of its people than it is on technologies protected by patents (Barrie and Boyd 1992).

3.4.2 Principal bases for developing prequalification criteria

Since the decision making process usually deals with uncertainty and prequalification criteria are important elements of the decision making process, a quantitative approach towards prequalification analysis using suitable references is needed in order to reduce subjectivity. In other words, identifying appropriate factors influencing the choice and the weighting of contractor prequalification decision criteria is one way to improve the consistency of the decision-making process (Mangitung and Emsley 2002c). There are some factors that can be utilised as references for justification of the use of prequalification criteria. These factors are summarised in Table 3.5.

The choice of prequalification criteria alone is insufficient in a multi-criteria decision making process, thus it is important to embrace the analysis of weighting that can give alternative choices in decision making in relation to the level of importance of each criterion. The weighting approach can attribute the importance of each chosen decision criterion relative to each other. Additionally, varying the unequal criteria level of the important influencing factors, including the factors in Table 3.5 which may be utilised for various sensitivity analyses (Rogers 2001), can affect the outcomes of the contractor prequalification process.

Table 3.5 Bases for developing prequalification criteria

Basis/ reference/	Description
Client objectives	Clear and well defined client objectives can effectively define the project and prequalification objectives and also formulate the prequalification criteria more appropriately.
Project objectives	The project objectives are commonly defined as a project completed within budget, time and quality as required. The more detail of project objectives that is available, the more rational the weight applied to the prequalification criteria.
Procurement types	Every type of procurement influences the characteristics of prequalification criteria.
Risk analysis	Risk analysis is a part of project evaluation with regards to deviation of the estimate and forecast value or the likelihood of project failure.
Public accountability	Public clients are less flexible than private organisation/firms in terms of design and implementation of prequalification systems, since they have specific regulations and guidelines.
Standard procedure	Availability of formal standard guidelines can make the decision process more rational and systematic and be useful for regular evaluation of past prequalification performance or for information feedback.
Regulations	Compliance with regulations (e.g. health and safety, equal employment opportunity) should be considered to avoid some constraints that may influence project performance, such as time delay or cost increase.
Project size	Suitability of contractors' experience gained from their previously completed projects and the range of project size are necessary to assess their capability and capacity to perform construction tasks.
Project type	A particular type of resources, technology and typical previous experience is needed to perform a certain construction project type appropriately.
Individual experience	Suitable prequalifiers with a certain level of experience in respect of a particular project, client and environmental characteristics can enhance the expected outcome of the assessment system.
Professional judgement	To avoid bias and reduce subjective judgement, a structured and rational prequalification system should be established and the assessor should have sufficient professional experience and expertise as well as an appropriate number of decision-makers being involved.

3.4.2.1 Client objectives and project objectives

Client objectives and project objectives may impact upon the choice and preference of prequalification criteria (Ng 1996). According to Russell and Skibniewski (1988) the highest hierarchy is the client objectives factor which then influences project objectives at the lower level. The relationship between these factors can been described as a hierarchical relationship and influenced by internal and external forces within the environment boundary of a construction project, as seen in Figure 3.6.

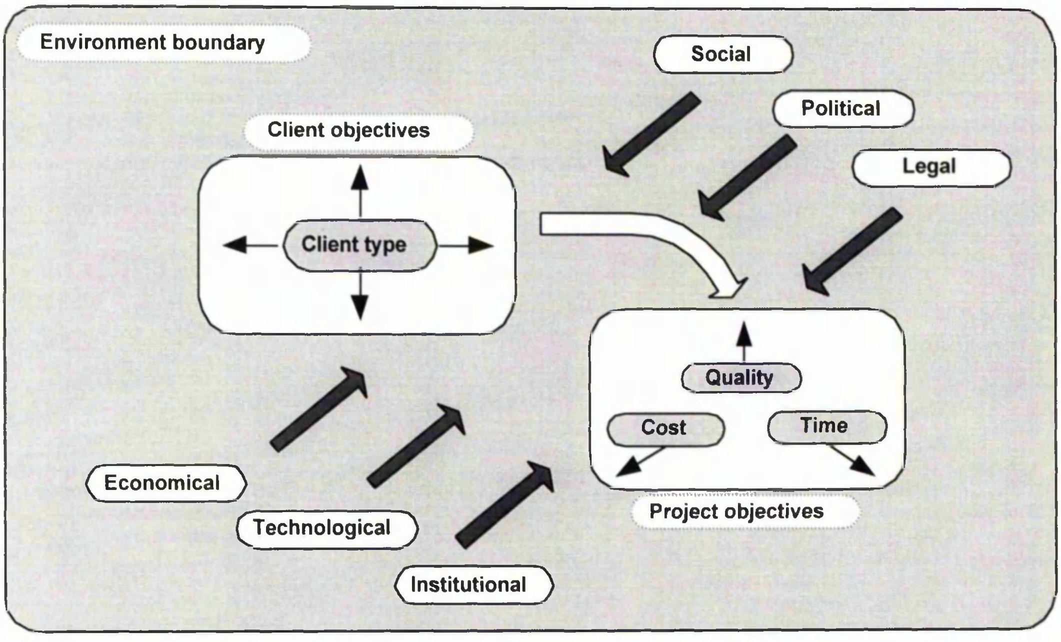


Figure 3.6 Relationship and interaction between client and project objectives

Client objectives can be characterised by client types as internal factors (Russell 1996). The typical client organisations that may have the different objectives and procedures in the construction industry are public and private clients. Private clients, who have responsibility for their stake holders and consumers, give more priority to profit and commercial aspects and more flexibility in determining their prequalification criteria. In contrast, public clients have to meet public policies and regulations because their funding sources mostly come from tax payers (Russell 1992). Moreover, external factors such as economical, technological, institutional, social, political and legal factors can create a complex environment to which client objectives need to respond and shape the dimensions of the project objectives (Walker 1996). These factors need to be analysed in order to prevent construction project performance problems such as cost overrun, time overrun and unexpected quality level.

Walker (1996) gives examples such as political and economic environments which influence government policy through educational, investment and taxation and financial policies (e.g. interest rate); such legal environments as regulations governing building, safety and planning; such institutional environments as the influence of professional institutions through rules of conduct, education, and conditions of engagement and similar applied to the members of trade and employer associations; and such cultural and sociological environments as the influence of trade unions.

As a result, the choice and importance of prequalification criteria in, for example, the public sector, usually includes and examines in more detail not only financial, technical and managerial criteria, but also other external factors such as compliance with regulations including health and safety and equal opportunities (Ng 1996); the requirements to conduct a certain measure of business volume with economically, socially disadvantaged contractors and women contractors such as Disadvantage Business Enterprise (DBE), Minority Business Enterprise (MBE) and Women Business Enterprise (WBE) (Taha 1994; Clough 1986); the criteria of preference for local contractors against foreign contractors within a certain project size range (Lo et al. 1999; Kumaraswamy 1996a); and in the third world clients may require the use of more intensive labour forces rather than construction equipment (Russell 1996).

Furthermore, the characterisation of the client objectives can also differentiate between project objectives. As it is commonly known, main project objectives are to complete the project on time, within budget and to specified quality. These three sub-factors are commonly employed in the construction industry to asses contractors' cost, time and quality performance (Ward et al. 2000). These sub-factors also confirmed that cost, time and quality are still predominant factors in the UK construction industry, based on a series of semi-structured interviews with highly experienced experts consisting of nineteen architects, ten private and two public clients (Soetanto and Proverbs 2002). In addition, according to Hatush and Skitmore (1997a), one way to achieve project success or to increase client satisfaction is to design evaluation criteria by differentiating the scales of each criterion on the basis of project objectives or to analyse the possible impact of contractors' data on construction cost, time and quality performance.

In practice, most project performance variables are a balance among these three variables, but in construction practice one variable sometimes is more dominant than the other variables, or all variables do not have the same weight, and so two or three way interactions cannot be avoided. For example, if client objectives emphasise a tight schedule and budget, contractors that have the capability and capacity to provide more than enough labour and equipment in order to work extra time and which also have good management cost control will be qualified. Contrarily, client objectives which emphasise high standard value, quality and a tight schedule require contractors that have capability and capacity and suitable experience of human resources with specific technical and managerial skills including quality design and project performance and availability of specific equipment (Pettinger 1998; Woodward 1997).

Moreover, Witt (1986) suggested that project objectives are subordinate to higher level organisation objectives (i.e. client objectives), and so a particular type of client organisation can characterise project objectives through its mixture of motives, objectives and disciplines. Capability of identification of priority of the mixture of motives, disciplines and an understanding of the hierarchy of objectives thus becomes a key to project success. It means that, for example, project cost overrun can be considered acceptable as long as the quality objective is fulfilled.

For example, the British Nimrod's initial project budget was £300 million with schedule of 4 years, but in reality the cost was £1,000 million and there was around four years delay. This project was still considered as a success since the Nimrod radar works as specified by the UK government. In other words, despite enormous cost overrun and time overrun, the performance of the radar was achieved, and so the project could be assumed to be a success due to the necessity motive for improving and maintaining superiority of the defence facility. Therefore, in the trade-off among project objectives, other objectives sometimes cannot be avoided, but investigation of the interaction among various levels of objectives through rating according to their relative importance level is one way to make criteria more understandable (i.e. acceptable), systematic, operational and measurable. Other factors such as project characteristics (e.g. size, type, risk), procurement used, existing regulations and the availability of experienced prequalifiers should be looked at in a similar way and how much those factors contribute to the success of implementation of contractor prequalification should be identified.

3.4.2.2 Procurement and risk analysis

Project objectives characterised by client needs and inherent risks identified as the nature of a construction project, can influence the choice of procurement (Masterman and Gameson 1994). Moreover, as described before in the previous section, political, economic, legal, institutional, technological and cultural environments can influence the change of project characteristics in terms of size and complexity, incentives, flexibility, competition, responsibility and risk allocation, all which can influence the selection of procurement route and risk management including how to quantify the risk through risk analysis (Rowlinson 1999; Masterman and Gameson 1994). In addition, Aboushiwa (2000) found that the criteria for selecting appropriate procurement routes are time, quality, management, variations, complexity, competition, accountability, price certainty, project nature, involvement and risk avoidance.

Thus, the analysis of interaction among project objectives (i.e. cost, time and quality) as subordinate clients' objectives and the environmental pressures affecting project characteristics (Rowlinson 1999) and the selection of procurement routes provide the major sources of risks (see Table 3.6) which need to be analysed not only in respect of technical aspects but also social aspects as well as a very approximate allocation of risks particularly between client and contractors (Gunning 1999). These interactions show that, to some extent, construction projects have inherently higher complexity leading to the analysis of prequalification criteria being more complex.

For example, if early completion is a priority, there is uncertainty about cost before construction starts and the client prefers to transfer the project risk to the contractor, to minimise variations and to select a winning contractor through competition, the choice of procurement type can lead to the selection of design and build. This procurement type can affect prequalification criteria, as there is then a need for successful contractors to have experience in a design and build contract before and in-house design capability.

Table 3.6 Sources of risk (after Thompson and Perry 1992)

Source	Example
Client, government, regulatory agencies	Bureaucratic delays, changes in regulations
Funding, fiscal	Change in government funding policy liaisons between several funders
Definition of project	Change in project scope
Project organisation	Authority of project manager, involvement of outside bodies
Design	Adequacy to meet need, realism of design programme
Local conditions	Local customs, weather windows
Permanent plant supply	Degree of novelty, damage or loss during transportation
Construction contractors	Experience, financial stability
Construction materials	Excessive wastage, quality, delivery
Construction labour	Industrial relations, multi-racial labour force
Construction plant	Resale value, spares availability
Logistics	Remoteness, access to site
Estimating data	Relevancy to specific project, availability
Inflation	
Exchange rate	
Force majeure	

3.4.2.3 Individual experience an d professional judgement

A combination of experience and subjective judgement capability is commonly acceptable in the decision making process in prequalification systems, since prequalification criteria comprise not only the measurement of quantitative data, but also qualitative data. In addition, uncertainty is naturally found in the decision making process due to subjective, incomplete and imprecise information at hand and possible conflict between many objectives, especially high project complexity (Russell and Skibniewski 1988; Kepner and Tregoe 1981).

To avoid bias and reduce subjective judgement, a structured and rational prequalification system should be established and the assessor should have sufficient professional experience and expertise as well as an appropriate number of decision-makers being involved who come from different relevant back grounds and demonstrate diversity of personality and individual expression in order to enhance the creativity of the decision (Spatz 2000; Russell 1996; Kepner and Tregoe 1981). In addition, suitable decision makers with a certain level of experience can enhance the expected outcome of the assessment system in order to identify appropriately important and relevant information (Nguyen 1985; Kepner and Tregoe 1981). The attitude towards risk of the decision makers in terms of risk aversion and risk seeking attitude can also become factors influencing judgement (Gunning 1999; Ng 1996). Briefly, different backgrounds in terms of experience and skill, including individual expression and personality, can also affect the decision process including the determination of prequalification criteria as well as their importance level.

3.4.2.4 Public accountability, standard procedure and regulations

The transparency of the selection process is essential and this is enhanced if the process is clearly written and published in the form of formal guidelines as standard procedures associated with the prequalification system. This approach can assure continuous improvement and control the performance level of prequalification performance. This transparency is part of accountability to project stakeholders including bidders (Kumaraswamy and Walker 1999). Additionally, after examining the legal implications of several cases of public tendering in Canada, Rankin et al. (1996) also recommended that prequalification criteria measurement must be quantitative wherever possible, clearly defined, equally applied to all bidders and firmly standardised. In order to achieve these recommendations, standard guidelines must be published and bidders can evaluate them before submitting their proposal for prequalification or tendering. Jackson-Robbins (1998) suggests that full accountability can be achieved as follows:

- Definition and recording of the key elements of the process including procedures, selection criteria and basis of scoring and weighting;
- Publishing guidelines of the prequalification process;
- Documentary recording of key points in the process;
- Judgements being made on the basis of multi-discipline expertise rather than individual judgement; and
- Informing unsuccessful applicants.

Furthermore, project guidelines are necessary to cover and clearly define possible impacts on project performance, particularly during and after the construction project due to the nature of the project circumstances where the construction project takes place. The analysis of the impact can assist prequalifiers to develop appropriate criteria relevant to contractors' competence in order to anticipate the project constraints, community concerns and compliance with regulations. For example, construction methods used for an urban area with dense population are different from those for a rural area, where it is more suitable to use driven piles rather than bored piles, as driven piles can generate higher vibration than bored piles. Clear, completed guidelines and standard procedures can help contractors anticipate possible construction problems before construction or at the tender process and also enhance communication among the project participants in handling project tasks.

3.4.2.5 Project size and type

Project characteristics including project size and type can also influence the choice and weighting of prequalification criteria. Contractors tend to use these factors whether they will be involved in tendering or not. The assumption of the involvement is based on the evaluation and estimation of their capability and capacity to win and perform a project completely and successfully.

There are five major factors of tendering behaviour, that is, project size, project type, regional market conditions, the current and projected workload of bidders and client type (Flanagan and Norman 1982). Additionally, several researchers found project type and size factors in the top ten factors influencing contractor project selection. Odusote and Fellows (1992) found the factor of project type and size were the second and third ranks respectively based on the questionnaire survey results from 48 UK based building contractors with yearly turnover above £8 million. Using the same factors, but in different countries, Ahmad and Minkarah (1988) identified the project type and project size factors as first and ninth respectively based on the returned questionnaire survey of 129 contractor respondents (34.14% return) in the USA, while in the UK, Shash (1993) identified the project type and project size factors as seventh and ninth respectively based on 85 responses (28.3%).

The importance of project type is related to the nature of the construction industry in which contractors tend to be involved in or specialised in a certain narrow range of project types (Ng and Skitmore 1995b). Understandably, every construction type, such as residential, building, engineering and industrial construction has different requirements, construction methods, trade and supervisory skills, contract provisions and financial arrangements (Clough 1986). An increase in the project size can raise the scale and number of construction tasks, leading to an increase in the requirements of the technical and management skills of contractors (Jackson-Robbins 1998) and an increase in the requirements of contractors' financial capability and capacity (Russell and Skibniewski 1988), including the contractors' capacity in relation to surety bonds and insurance for project financial protection (Russell 2000; Hughes et al. 1998).

3.4.3 Main prequalification criteria

The most interesting elements which academic researchers have investigated for over a decade are investigations into prequalification criteria. Main prequalification criteria can be divided into seven categories as seen in Table 3.7. These criteria were identified through empirical studies using questionnaire surveys, except for reference 4 where the survey intended to investigate the frequency of use of prequalification criteria (see Table 3.8). Before carrying out the questionnaire survey, literature reviews and interviews were used for identification of prequalification criteria. The detailed criteria for every category from the seven studies can be seen in Table 3.9.

The utilisation of these main criteria are quite consistent across studies of prequalification systems in the construction industry. The lists of sub criteria are also very similar for all studies. The difference between the studies in terms of prequalification criteria used are more at the level of the importance of each criterion. These main and sub criteria are then analysed against relevant contractors' data in order to determine their competence in terms of their capability and capacity to perform project tasks.

3.4.3.1 Financial strength

Financial statements including balance sheets, turnover, loss and profit, and other institutional reports and recommendations related to bonding, credit rating and insurance can provide vital information in terms of the assessment of the financial capability and capacity of contractors, based on historical and current data and indicating their future financial strength or weakness. Financial stability can be measured through ratio analysis using the financial statements provided by contractors. Ratio analysis is commonly used to diagnose liquidity, operations, leverage, coverage and specific expense items. Liquidity ratios measure adequacy of current assets to cover current liabilities. Operation ratios measure the effectiveness of management in conducting business. Leverage ratios measure the level of debt pressure and how vulnerable the company is to downturns in the economic business cycle. Coverage ratios measure a firm's ability to service debt.

Specific expense ratios relate expense items to net sales (Russell 2000; Hatush and Skitmore 1997b).

However, it must be noted that the financial ratio technique has limitations. This technique only provides partial measurement or highlights symptoms and other non financial factors must also be assessed, such as human resources effectiveness, production, service quality, business knowledge, managerial experience or industry weakness and government policy (e.g. interest rate). To rely on a mechanical and unthinking attitude is dangerous, as ratios need to be used selectively for the purpose at hand and their results interpreted with skill and judgement. Different accounting policies and practices should also be considered and, in the worst circumstances, the financial statement provided can be engineered or manipulated. So it is necessary to compare the ratios to the average of similar industry norms and compare them within a certain period of years as a trend comparison (Arditi et al. 2000; Brigham and Houston 1999; McMenamin 1999; Hatush and Skitmore 1997b). Briefly, in Table 3.9, financial stability is the most important factor considered by most clients.

Furthermore, bonding and insurance capacity and credit rating can be used to assess the maximum project value that contractors can perform including assessment of their financial reputation and performance for a certain period of time based on third party recommendations. Bonding and insurance are risk transfer mechanisms, where bonding is a three-party relationship in which the guarantor (bonding company) guarantees to a beneficiary (client) that a contractor will perform the work agreed to the contract and bonding capacity which is appraised according to their credit strength and construction expertise. While insurance is a two-party relationship in which an insurance company is obliged to compensate the loss to the insured (client) due to unforeseen adverse events and the minimum liability is determined by clients. Credit rating shows credit worthiness of construction firms and is measured based on their past and current financial profile including payment, credit and bankruptcy history (Russell 2000; Murdoch and Hughes 1998).

Table 3.7 Main prequalification criteria in academic research

Main prequalification criteria	1	2	3	4	5	6	7
Financial strength	✓	✓	✓	✓	✓	✓	✓
Past experience	✓	✓	✓	✓	✓	✓	✓
Past performance	✓	✓	✓	✓	✓	✓	✓
Managerial and technical strength	✓	✓	✓	✓	✓	✓	✓
Sufficient and suitable resources	✓	✓	✓	✓	✓	✓	✓
Compliance with regulations	✓	✓	✓	✓	✓	✓	✓
Current workload	✓	✓	✓	✓		✓	✓

Note: For details of reference numbers see Table 3.8.

Table 3.8 References used in the investigation of prequalification criteria

Reference	Places	N_s	N_r	Data	Note
1. Russell (1992)	USA	344	173 50.3%	O	Covering public & private clients & construction managers
2. (Holt et al. 1994c)	UK	225	53 23.6%	O	Covering public & private clients.
3. Ng (1996)	UK	500	111 22.2%	O	Covering public & private clients & consultants
4. Hatush and Skitmore (1997a)	UK	300	156 52%	N	Covering public & private clients
5. Khosrowshahi (1999)	UK	379	42 11.1%	O	All UK local authorities who are responsible for building contracts
6. Wong et al. (2000)	UK	450	86 19.1%	O	Covering public & private clients
7. Palaneeswaran (2003); Palaneeswaran et al. (2001)	World-wide	N/A	101	O	Covering public & private clients, consultants, academia. Hong Kong (36.6%) and USA (30.7%) respondents

Note: **N_s:** Sample size; **N_r**: number of usable responses;
O: Ordinal data for measuring importance level of prequalification criteria
N: Nominal data for measuring frequency of use of prequalification criteria

Table 3.9 Details of prequalification criteria

Russell (1992)	(Holt et al. 1994c)	Ng (1996)	Hatush (1996)	Khosrowshahi (1999)	Wong et al. (2000) and Wong et al. (2001)	Palaneeswaran et al. (2001)
Financial strength						
Financial stability Bonding capacity	Ratio analysis accounts **Bank reference** Credit reference **Turnover history**	**Financial stability** **Stability of firm** Credit rating Working capital	**Financial stability** **Financial status** **Credit rating** Bank arrangements and bonding	**Financial standing and record**	**Maximum financial capacity** Finance arrangement	**Finance** Insurance cover
Past experience						
Experience Geographic location of project	**Size of projects completed** **Type of projects completed** Form of contract Age **National or local catchment** Geographic experience Experience of similar construction **Weather**	Size of project Type of project Form of contract Length of time in business Method of procurement Location Amount of subcontracting work Project complexity	**Experience** Length of time in business	**General experience** **Project size** **Record of experience in similar projects** Age of organisation Flexible contractual form	Geographical familiarities **Experience with specific type of facility**	**Past experience**
Past performance						
References **Past performance** **Contractual failure** Substance abuse policy **Quality performance**	Image Litigation tendency **Contractual failure** Time overruns Cost overruns **Actually quality achieved** Prior relationship	**Performance** **Fraudulent activity** **Competitiveness** **Failed contract** **Progress of work** **Relationship with client** Previous debarment Reputation Claims and disputes	Past performance and quality **Client contractor relations** Relations **Past failures**	**Time performance** **Post business relationship** Reputation for low price Friendly cooperation Previous business relationship Recommendation by consultants Image of organisation	**Actual schedule achieved on similar works** **Actual quality achieved for similar works**	**Past performance** **Design and build team relationships** Dispute/claim history Partnering

Note: Bold characters indicate criteria which are considered important and so ranked higher

Table 3.9 Details of prequalification criteria *(continued)*

Russell (1992)	(Holt et al. 1994c)	Ng (1996)	Hatush (1996)	Khosrowshahi (1999)	Wong et al. (2000) and Wong et al. (2001)	Palaneeswaran et al. (2001)
Managerial and technical strength						
Project management capability Project control procedures Location of home office Company organisation	Size QC policy **Formal training regime** Home office location	**Management capability** **Standard quality** Quality assurance and control Level of technology Specialised trade Cooperative outlook	Project management organisation **Management knowledge** **Technical ability**	**Quality service** **Efficient organisation** Personal social contact Quality assurance registration Location of firm	**Project management capabilities** Location of home office Technical economic analysis Proposed construction methods Project execution of proposed project	**Quality concerns** **Organisation and management system** Technology Location of head office
Suitable and sufficient resources						
Staff available Manpower resources Equipment resources Work performed with own work forces	Qualification of key persons **Years with company** Plant resource available Key persons available **Qualification of the key persons** **Qualification of owners**	Resources	Experience of technical personnel **Personnel** Plant and equipment	**Personnel/team expertise** **Depth of technical resources**	**Manpower resources** Plant and equipment resources **Maximum resource** **Training or skill level of craftsmen**	**Human resources** Equipment
Compliance with regulations						
Safety performance	Health and safety policy	**Health and safety integrity**	Safety Management safety accountability OSHA EMR	**Health and safety record**	**Site organisation, rules and policies**	**Health and safety** Environmental concerns
Current workload						
Capacity of firm Current workload	**Current workload**	Capacity of work Number of previous bids	Present workload and capability		Current workload	Current workload

Note: Bold characters indicate criteria which are considered important and so ranked higher

3.4.3.2 Past experience and performance

Past experience reflects the capability of contractors in terms of their technical and managerial capability to perform construction project tasks in the last period of time, particularly for similar size and type of projects. This criterion, along with financial strength and past performance, is one of the very important criteria which is usually included in any prequalification system as shown in Table 3.9. To assess past experience, the prequalifier can identify the past records of contractors with respect to their technical capability demonstrating their knowledge and skills in order to handle project tasks at a certain type and level of construction complexity and contract value.

In order to know more about projects successfully completed by contractors, it is necessary to evaluate some performance indicators. Cost, time and quality performance of completed projects are required to be assessed including recommendations by previous clients. Assessment of past performance is not limited to indicator value as such, but it needs to evaluate in more detail why project performance did not meet the target rather than only how a contractor controlled schedule or project cost and achieved quality in the past, since the source of performance problems not only comes from contractors but also from clients or consultants (e.g. design change) or occurs due to uncontrollable situations (e.g. weather, flood). Moreover, performance related to claims, failure to perform the contract, contract terminated, deletion from standing list, withdrawn from contract prematurely or non resolution of contract dispute are also important and required as exhibited Table 3.9.

According to theory of liability of adolescence in terms of age in business criterion, an organisation is susceptible to increased failure at the beginning of a certain period of the organisation's life time and reaches a peak of probability of failure and decline thereafter as an organisation grows older. The adolescence period is 3 to 4 years, based on the data of USA construction firm failures in the period of 1985-1994. The liability of adolescence is due to the lack of organisational learning and the lack of legitimacy and the state of organisational size. Organisational learning is defined as the capacity of process within an organisation to maintain and improve its performance based on experience. The liability of adolescence decreases or performance variations may decrease as the organisation gains experience, its goals are institutionalised through to developing trust, co-ordination and co-operation are developed among organisational members and its activities are routinised through developing standard procedures (Kale and Arditi 1998). Thus, age in business factor is also included in the prequalification criteria particularly for young firms whose past performance and experience are assessed in order to reduce project risk.

3.4.3.3 Managerial and technical strength

Mismanagement and lack of managerial and technical skills are sources of business failure in the construction industry (Arditi et al. 2000; Russell 1991). Moreover, this factor also significantly influences claim performance along with risk management (Diekmann and Nelson 1985), and this factor, with respect to cost monitoring during construction along with the degree of evaluation effort, has a significant impact on contract failure (Jaselskis and Russell 1992; Russell and Jaselskis 1992). It is important to note that the project management and technical skill capability of contractors must be relevant to the client and project objectives (Jackson-Robbins 1998).

Project management capability including cost, time, organisational and risk management can be indicated by: the track record of contractors' performance indicators; internal standard managerial and technical procedures and guidelines including implementation of total quality management and relevant ISO certificates; clear, relevant and up to date programmes; and clear and effective organisational and managerial structure with clarity of staff responsibility, authority and objectives. Moreover, a track record of supply chain management capability can demonstrate contractors' competence to provide better value materials, equipment and workforce on time, within budget and to the required quality (Jackson-Robbins 1998). Technical capability including ability to implement technological innovation, investment research and development and design capability, particularly for design and build contractors, is represented by a track record of successful previously completed projects; employees with relevant qualifications and experience; and ability to manage the projects under review (Jackson-Robbins 1998; Hatush and Skitmore 1997b; Russell 1996).

3.4.3.4 Suitable and sufficient resources

The availability and suitability of human resources (e.g. engineering and administrative staff, craftsmen, workers), equipment and plant are factors influencing contractor performance. By examining the characteristics of human resources (i.e. qualifications, experience, training programme, record of achievement, the size and type of work forces) and equipment and plant (i.e. type of equipment, size of equipment, condition of equipment, availability and suitability), prequalifiers can obtain a profile of contractors' capability and capacity of implementation of their managerial and technical programmes (Jackson-Robbins 1998; Russell 1996). Furthermore, it is necessary to assess the track record of the relationship between contractors and trade unions and subcontractors (e.g. labour, equipment rental company). This includes specific trade and length of contracts in order to ensure that their reputation is acceptable to execute the project efficiently and that the contractor does not initiate project constraints (Russell 1996).

3.4.3.5 Compliance with regulations

The health and safety sub criterion is the most significant subcriterion according to the studies in Table 3.9. Occurrence of accidents, for example, can directly affect project cost and schedule and result in claims and disputes. Additionally, the response to accidents that have taken place is a more significant indicator than the number and severity of recorded injuries in terms of commitment to learning from experience (Jackson-Robbins 1998; Ritz 1994).

Key indicators of good management of health and safety include (Jackson-Robbins 1998):

- The availability of an appropriate health and safety policy that is understood and applied by all staff;
- The availability of practical and well-considered safety plans on current projects;
- The availability of relevant expertise, either in house or on a consultancy basis, well integrated into the overall management structure;
- Clearly allocated responsibility at board or partner level;

- Health and safety training implemented at all levels within the company, including induction and safety briefings on site for all operatives; and
- Ability to identify and co-ordinate design issues relevant to safety, both during construction and relating to the maintenance and use of the company structure.

In terms of safety practices, Russell (1996) suggests three criteria should be considered: Experience Modification Rating (EMR) that is based on two major issues: the number of claims and the cost of each claim, Occupational Safety and Health Administration (OSHA) incidence rates (i.e. lost time rate, lost workdays rate, first aid rate and number of recordable accidents) and contractors' Management Safety Accountability (MSA) that is related to their accountability for safety programmes and for safety violation. Other regulations that must be complied with are equal employment opportunities, labour regulations, environmental management policies, licensing requirements and restrictions, planning and building permits and tax regulations (Mangitung and Emsley 2002b; Russell 1996). These regulatory factors cannot be underestimated when clients are concerned with project delay, since negotiation and potential disputes could result in unpredictable time (Russell 1996).

3.4.3.6 Current workload

This criterion relates to contractors' capacity and their competence to perform a particular construction project and should be evaluated at the tender stage or at the state of the project being well defined. Contractor's current work load can be estimated as the difference between the potential new project value and their annual turnover, working capital, ongoing project contracts in hand, the proportion of subcontractor contract values and total number of resources (workers and staff and equipment/rental equipment capacity). Additionally, contractors' project values successfully completed in a certain period of time can be assessed to provide a picture or trend of their capacity and ability to perform new projects offered (Hatush 1996; Ng 1996; Russell 1996).

Jackson-Robbins (1998) suggests in point of view of recent financial resources profile that references from third parties (e.g. previous clients, financial institutions' reports) can provide a valuable picture of contractors' current capacity. There are some indicators that can be used for financial analysis including:

- Analysis of most recent public accounts;
- Bankers' references;
- Credit references from suppliers;
- Recent turnover history;
- Value of contracts recently successfully completed; and
- Value of work in hand and related exposure.

3.4.4 Contractors' data collection methods

Depending on contractor evaluation objectives (e.g. project list or standing list), the depth of information sought and the time and cost constraints, combinations of contractors' data collection techniques utilised may vary. Several techniques which are commonly employed in prequalification practices are questionnaires, interviews, presentations, site visits and references (Jackson-Robbins 1998; Preece et al. 1997; Russell 1996; Russell and Skibniewski 1988).

Russell (1996) found the most common data collection technique being used was questionnaires (56%); these data were based on 63 client respondents comprising 62% from public sectors and 34% from private sectors in the USA construction industry. The other data collection techniques were then ranked as references from client's previous contractor evaluations (21%), site visits to contractor (15%) and credit rating references from financial institutions (8%).

Questionnaires are more popular for data elicitation due to their relatively easy and quick evaluation process (Jackson-Robbins 1998) and also this instrument can be extensively applied in terms of the number of prequalification applicants as it is less costly compared with other techniques such as presentations and interviews. Questionnaires, along with references such as financial performance reports from third parties and clients' internal database of past contractor evaluation and/or prequalification, are important in prequalification systems to cross check accuracy, but the past internal database should be used with care in terms of current capacity that may have changed due to present operations (Russell 1996). Moreover, according to Jackson-Robbins (1998), references can enhance the evaluation process through the questionnaire approach particularly for qualitative issues, for example, some aspects can be identified as follows:

- The broad strengths and weaknesses of a contractor;
- Reasons underlying time or cost overruns or other apparent problems;
- The ability of the contractor's staff to work as part of the project team;
- The contractor's response to problems and contractual issues; and
- Some ways in which the contractor was able to add value positively to the project.

Especially clients who have regular projects annually can analyse and record the data results from past contractor prequalification and this, combined with contractors' construction project performance from past contracts, can be integrated into the form of an internal database. This gives such clients advantages through a feedback system by proper identification of the key features of the contractor's project performance throughout the period of involvement in the project, including design development and post completion, on the basis of contractors' participation in the review and judgement of qualitative issues mentioned in the previous paragraph (Jackson-Robbins 1998).

Through the presentation and/or interview process, clients can communicate face to face and elicit a more detailed picture of the construction firm profile related to their needs (Preece et al. 1997). At this stage, if necessary they can verify the result of contractor prequalification via questionnaire instrument through which the number of contractors has been reduced significantly in the form of a shortlist. By exchanging information through these approaches, the client allows the contractor to have an understanding of the project objectives and client needs, and the client can assess the degree of enthusiasm of the contractor in carrying out the project and also assess the capability and character of the individuals who will be assigned to the project, especially for their potential to work as a team with the other participants (Jackson-Robbins 1998).

Additionally, site visits are useful for assessing organisational operation levels and the efficiency of contractors, including being able to check and verify the amount and quality of their equipment fleet and physical plant mentioned in the result of the questionnaire inquiry and by visiting their offices and ongoing construction project sites (Russell 1996). Moreover, examples of the benefits of this approach are that they have chance to directly observe the use of contractors' quality management systems, safety procedures and information technology systems use such as project management software and management systems; to meet a number of staff on the job; to receive feedback from the relevant client representatives and professional team; and to establish better relationships and mutual understanding (Jackson-Robbins 1998).

3.4.5 Models/tools for evaluation

Similar to the extensive research that has been carried out for determining appropriate decision criteria for over a decade, many studies of suitable models for analysing contractors' data accommodating multi-criteria analysis have been developed in order to improve the prequalification system and also for structuring and systemising the decision process in order to assist decision makers before choosing potential contractors on a competitive list or determining a winning contractor for entering into a project contract. A variety of techniques in terms of evaluation of contractors' data against designated prequalification criteria has been established (see Table 3.10).

Before further discussion about the models, it is necessary to distinguish between prequalification and final selection. A prequalification system is a part of contractor selection. There are two types of contractor selection system. In the first type, the prequalification process is separated from the final selection process, and the prequalification process is employed to decrease the number of contractors or to group potential contractors in a list (e.g. short listing process). In the second type, the prequalification and the final selection processes are not separated and both are placed in one process of contractor selection. In the final selection, price criterion is usually included, particularly for competitive bidding.

Table 3.10 Classification of prequalification models and procedural analysis

Category	Model/ procedure	Reference
Systematic and rational modelling techniques	**Simple structured models (linear models):**	
	- Dimensional Weighting (DW)	Russell et al. (1990a); Russell (1988)
	- Multi-Attribute Analysis (MAA)	Holt et al. (1994a; Holt (1993)
	Complex structured models:	
	- Multi-Attribute Utility Theory (MAUT)	Hatush (1996); Holt et al. (1994b); Holt (1993)
	- Analytical Hierarchical Process (AHP)	Alarcon and Mourgues (2002); Mahdi et al. 2002; Al-Harbi (2001); Fong and Choi (2000)
	- Evidential Reasoning (ER)	Sonmez et al. (2002); Sonmez et al. (2001)
	Artificial Intelligence (AI) models:	
	- Fuzzy Sets (FS)	(Nguyen 1985)
	- Knowledge Based Expert Eystem (KBES)	Russell et al. (1990a)
	- Cased Based Reasoning (CBR)	Ng (1996)
	- Artificial Neural Networks (ANN)	Lam et al. (2000); Khosrowshahi (1999); Taha (1994)
	Statistical models:	
	- Cluster Analysis (CA)	Holt (1996)
	- Discriminant Analysis (DA)	Wong et al. (2003)
	- Logistic Regression (LR)	Wong et al. (2003)
	Hybrid models (combination of two or more modelling techniques)	Holt (1993); Russell (1992)
Systematic and rational procedures	**Multiple stage procedures**	Mahdi et al. (2002); Palaneeswaran and Kumaraswamy (2001); Holt (1993); Russell et al. (1990b)
	Performance based procedures	Alarcon and Mourgues (2002); Kashiwagi and Byfield (2002); Hatush (1996)

Table 3.11 Characteristics of prequalification model analysis

Model	Characteristic (Development and applicability, reference of source for development and evaluation)
Simple structured models (linear models):	
- Dimensional Weighting (DW)	Simple, expertise-based
- Multi-Attribute Analysis (MAA)	Simple, expertise-based
Complex structured models:	
- Multi-Attribute Utility Theory (MAUT)	Complex, expertise-based
- Analytical Hierarchical Process (AHP)	Complex, expertise-based
- Evidential Reasoning (ER)	Complex, expertise-based
Artificial Intelligence (AI) models:	
- Fuzzy Sets (FS)	Complex, expertise-based
- Knowledge Based Expert System (KBES)	Complex, expertise-based
- Cased Based Reasoning (CBR)	Complex, case-based
- Artificial Neural Networks (ANN)	Complex, expertise-based, case-based
Statistical models:	
- Cluster Analysis (CA)	Complex, case-based
- Discriminant Analysis (DA)	Complex, case-based
- Logistic Regression (LR)	Complex, case-based
Hybrid models (combination of two or more modelling techniques)	Complex, case-based and/or expertise-based

Additionally, prequalification models can be categorised into modelling technique and procedural approaches (see Table 3.10). The first category, characterised by the techniques of analysis and evaluation rather than procedure, is based on the complexity of their development and applicability (i.e. simple and complex models), the modelling of the knowledge transfer system from human expertise to machine expertise, known as artificial intelligence models (i.e. case-based, expertise-based models), statistical approaches or multivariate models and the combination of two or more models (i.e. hybrid models) as seen Table 3.11. The various emerging categories are due to the endeavour to reduce or eliminate the drawbacks of existing models, but the new models always have advantages and disadvantages particularly for their applicability and suitability in the real world of the construction industry. It is important to note that the development of prequalification model analysis relies on many aspects including client, project and prequalification characteristics and objectives as well as cost and time constraints and shortages of prequalification experts.

3.4.5.1 Simple and complex structured models

Linear models

Russell and Skibniewski (1988) introduced a dimensional weighting model, a type of linear model, in order to improve existing models that use irrelevant criteria and which are characterised by an ad-hoc approach that is an unsystematic, less formal approach. In addition to these existing problems, Hatush and Skitmore (1997b) and Holt (1998) also identified decision processes merely based on a dichotomous (yes/no or rejected/accepted) or trichotomous (bad/good/excellent) approach. These kinds of approaches may eliminate good contractors at the early stage of contractor selection (Holt 1998; Russell and Skibniewski 1988).

The first variant introduced is the dimensional weighting model in which every criterion used will be ranked according to its level of importance and contractor's data are rated against the relevant criteria. Aggregate values for each contractor are calculated by summing each multiplication of the rates of contractor data and the weights of the criteria and they are then compared and ranked in order to determine the appropriate contractors that can be included in the list or to determine the winning contractor. But this model cannot accommodate the level of uncertainty of contractor data in order to meet the designated relevant criteria.

Therefore, Russell et al. (1990b) developed the QUALIFIER 1 model from the simple dimensional weighting model which incorporates additional rating for contractors' data according to the optimistic, most likely and pessimistic level. The rate is calculated based on the equation used in PERT (Project Evaluation Review Technique) analysis (Russell and Ahmad 1990). Another technique used to reduce uncertainty of contractor data is to calculate the rate based on the probability score imposed on each factor of contractors' data; details can be seen in the multi-attribute model developed by Holt (1993).

However, this model still depends on decision makers' judgement (Russell 1992) and, without determining the minimum score of each factor, the analysis can be misleading due to the inappropriate way compensation scores between low and high scores are made from one dimension to another dimension. This dimensional weight model is a linear quantification approach and is commonly used in the construction industry due to its simplicity of design and implementation.

In addition, the advanced linear model mentioned before only incorporates the uncertainty level of expected project outcomes, but does not represent the uncertainty level of decision makers' preference toward their risk attitude (i.e. risk prone, risk neutral or risk averse) with respect to the possible impact of the actual occurrence of project outcomes (e.g. cost, time and quality project performance) (Holt et al. 1994a; Diekmann 1983).

Multi-Attribute Utility Theory

Hatush (1996) developed the Multi-Attribute Utility Theory (MAUT) for a contractor selection model where cost, time and quality project performances were used as the utility functions of these three attributes. This method ranks each contractor according to its expected utility, determined on the basis of weighting criteria, the likely impact of each criterion on cost, time and quality performance and three attribute utility functions based on the decision makers' preferences.

Hatush (1996) validated the model utilising the result of the contractor selection for an infrastructure project with a value of around £3 million in Manchester, UK. The list consisted of 39 bidders and used only one decision maker's utility function due to the difficulty of finding decision makers. The result, based on comparison between conventional and utility methods, shows the first 15 contractors on the list are identical, but that the utility method could rank these 15 contractors in order more precisely than the conventional method that could only categorise and rank them into 4 groups.

The drawback of this model is the exhausting and difficult process of determination of the utility functions that requires some steps and conditions as follows (Sonmez et al. 2001; Goodwin and Wright 1998; Lapin 1994):

- To achieve the decision makers' real preferences, an interviewer must carry out a large number of hypothetical lottery-type questions and requires skills in questioning during the elicitation process using a standard gambling technique;
- It is a lengthy process, if a substantial number of criteria are used;
- If the number of attributes is increased, the development of utility functions become more complex and a lot of effort and time is needed in the elicitation process; and

- To carry out the process and also the complex quantification needed appropriately, decision makers need to have good knowledge and skill in probability theory.

Due to its complexity, the use of this method is not largely applied in the decision making process including business decision making (Goodwin and Wright 1998; Lapin 1994). However, this method is a valuable tool for greater understanding of the problems, particularly if uncertainty and risk become vital elements (Goodwin and Wright 1998; Diekmann 1983).

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP), first introduced by Thomas L. Saaty, is another type of complex multi-criteria decision analysis, that can handle the decision process in terms of eliciting and sharing a group of decision makers' experience, knowledge and value and breaking down a problem into a hierarchy. This concept is based on pair wise comparison of decision criteria and the objectives of decision making judgement are formed into a hierarchy from the highest to the lowest levels that consist of the list of alternatives. To maintain decision makers' judgmental consistency, the model uses the consistency index ratio (Al-Harbi 2001; Fong and Choi 2000).

However, the drawback of this model, like the requirement to establish the exact probability values in developing utility functions in MAUT, is the use of a deterministic and subjective approach in determining the value of pair wise comparison between criteria, thus the model is relatively unsuitable to handle incomplete or missing information and shortcoming in expertise (Al-Harbi 2001; Sonmez et al. 2001).

Fong and Choi (2000) utilised this model for a final contractor selection system using eight main criteria at the first level, including tender price criterion, and eleven criteria at the second level. The eight main criteria were determined using nine ordinal scales through a questionnaire survey (33% response rate from a sample of 40 public clients in Hong Kong) and then ranked by using the AHP technique. Three sets of hypothetical contractors' data were utilised to exemplify the process of the AHP analysis. The rating used 15 criteria decomposed from the 19 criteria mentioned before, which were calculated by means of the AHP method, and the total score of each contractor determined is a function of criteria weights and contractors rates.

Evidential Reasoning

Another type of complex multi-criteria approach which can handle not only quantitative and qualitative data but also incomplete or missing information is the Evidential Reasoning (ER) method which uses decision makers' preference based on the degree of belief. The measurement of preference is based on the degree of belief that can expect a possible outcome with respect to a particular criterion (Sonmez et al. 2001). This approach is based of the concept of the Dempster-Shafer theory of evidence that distinguishes between uncertainty and ignorance by creating a belief function in order to deal with lack of or vague information (Turban and Aronson 2001). However, this technique has limitations when comparing contractors' total scores with each other, if they are very similar or close. To solve this problem, MAUT, exemplified in Sonmez et al. (2001) and Sonmez et al. (2002), is an appropriate method, but leads to more complex calculations due to the combination of analysis between ER and MAUT.

Briefly, MAUT can accommodate the preference of decision makers. AHP emphasises the structure of the decision making process into a clear hierarchy and comparison between criteria, while ER can handle incomplete or missing information as usually inherited in the decision making process. However, all these complex multi-criteria decision making models rely on human judgement which is subject to the quality and level of knowledge and the experience and skill of the decision makers.

3.4.5.2 Artificial intelligence models

Other models developed in prequalification research in the domain of artificial intelligence are Fuzzy Sets (FS), Knowledge Based Expert Systems (KBES), Case Based Reasoning (CBR) and Artificial Neural Networks (ANN). Through these methods, the system tries to process decision making like a human's decision making process but to some extent it is very limited to a certain level of human creativity and helps decision makers in terms of facilitation of the knowledge and experience by making such knowledge more widely available in the form of expert systems and supporting non experts or less experienced decision makers.

Fuzzy Sets

Nguyen (1985) utilised fuzzy sets (FS) theory for modelling tender evaluation based on the criteria of tender cost, reputation and performance records, and information with respect to sufficient resources, managerial and engineering expertise. Because prequalification process decisions largely involve subjective, qualitative and imprecise data, the fuzzy sets approach can deal with a variety of degrees of confidence representing linguistic variables such as *very poor*, *poor*, *average*, *good* and *excellent*. For example, contractor performance records criterion in a conventional method is usually treated through the use of a binary approach (zero or one), that is, good or bad performance records, while through the FS approach this criterion can be treated with varying degrees of confidence or as partial membership rather than non and full membership only. Partial membership is set from zero to one. Briefly, FS theory is associated with human perception or subjective probability judgement (Negnevitsky 2002; Holt 1998; Russell 1992; Nguyen 1985).

However, regarding its applicability in the decision making process, particularly for the contractor selection process, this model is difficult to use and has limited use due to the difficulty of practical estimation of the membership function; particular disagreement on this matter was found among researchers and the model still relies on the level of experts' knowledge and skill (Lam et al. 2000; Holt 1998; Nguyen 1985). Additionally, the FS approach is also limited as a managerial decision support tool because of the complexity of development and computation as well as the difficulty of explaining its use to the user, although in electronic consumer products (e.g. cameras, air conditioning, dishwashers) they are used extensively to deal with precise data through sensor systems rather than data supplied by people representing linguistic vagueness (Turban and Aronson 2001).

Knowledge Based Expert System

Russell et al. (1990a) introduced a Knowledge Based Experts System (KBES) for a contractor prequalification system. The model, a branch of the artificial intelligence domain, utilises heuristic decision rules (IF-THEN approach) derived from seven experts' knowledge and experience in prequalification (4 experts), in surety firms (2 experts) and in general building construction (1 expert). The structure of the model evaluation is a hierarchical process from the preliminary screening criterion covering references, reputation and past performance, through contractor resources including financial stability, status of current work program and technical expertise and concluding with other items that are flexible depending on project specific criteria. A contractor can be disqualified at the first stage of evaluation and analysis then is discontinued or optionally further analysis can be carried out or action required on the basis of the suggestions from the *help* module.

The advantage of this KBES model is that it is easy to perform an efficient prequalification process by structuring the evaluation process through a hierarchy from general to specific criteria, from simple to complex requirements. A number of problem-solution building-blocks and also three decision alternatives (qualified, disqualified, undecided) with explanation available for unfavourable outcomes are used for the evaluation process. However, to use this model, users require a complete understanding of the construction process (Russell 1996).

Additionally, regarding development of KBES models it is necessary to consider (Turban and Aronson 2001; Li 1997a; Li 1997b):

- the characteristics of the body of knowledge, where it is in a state of manageable size, so narrowing down to an established and stable knowledge domain is necessary to ease the development of the effective model;
- the high complexity of construction projects can result in accumulation of various tasks and create unstructured knowledge leading to tedious knowledge transfer and capture from experts and which is labour intensive for the model development;
- due to possible various change in different project environments, the model can face difficulty to adapt to changes of the rules based system, leading to limited utilisation of the model; and
- the availability of the appropriate level of experience and skill of experts within the knowledge domain for constructing a KBES model.

Case Based Reasoning

Ng and Smith (1998) developed a prequalification model based on Case Based Reasoning (CBR) technique that is one type of knowledge based system with an emphasis on the case-based approach. This approach is to help decision makers, particularly less experienced decision makers, in the decision making process, where cases for solving problems are assumed as experienced decision makers. There are several drawbacks that could arise if adopting this CBR approach including (Chua et al. 2001):

- Developers may face difficulty with respect to collection of cases (e.g. confidentiality of data required);
- A relatively large number of cases are needed to put in the system library for statistical purposes or reducing bias: and
- Time becomes an essential parameter for building up cases into the system (case library).

The basic mechanism of a CBR approach, based on the theory of human reasoning that tries to reuse and compare the successful solution of past experiential cases to solve the problems of a new case, consists of three essential tasks (Chua et al. 2001; Ng and Skitmore 1995a):

- Matching process through retrieving one or a small set of the most similar cases;
- Adaptation process through solving the new situation by reusing or revising former solutions; and
- Repository process through retaining the new case and solution as part of past cases for future retrievals.

For developing the model, particularly prequalification related modules such as criteria formulation, finance, performance and evaluation procedure modules, Ng and Skitmore (1995a) carried out a series of empirical studies to answer two main aspects, that is, availability of historical cases and availability of the body of knowledge in the prequalification process.

The model consists of five interrelated modules, namely, criteria formulation, screening and reviewing, overall suitability and final scoring, finance and performance modules. These interrelated modules are connected with an input system for feeding contractor, project and prequalification data on to the CBR system, and an output system for providing information in terms of a tender and standing list, reasons for disqualifying contractors and suitable decisions after processing within the system (Ng and Smith 1998).

Before verification and validation of the model, Ng and Smith (1998) identified several constraints, such as limited access to real cases due to confidentiality and inconsistent features in prequalification practices leading to the high possibility of bias because of incomplete or incompatible information from one client to another. For verification and validation, historical cases were used and provided by twenty five UK client organisations through a series of interviews. Of twenty five, fourteen cases were employed for training the model in order to apply the consistency test adopted for verification of the model. The result showed that there were no redundant or contradictory cases. Validation was conducted on the basis of the accuracy of solution, sensitivity of indices and performance. The result of the test related to the first aspect revealed that the model was more accurate than semi-experts' assessment. The second one, using sensitivity analysis, demonstrated that the model was applicable and the last test utilised a face validation approach and found that the experts have high satisfaction with the model performance.

It appears that the number and various types of case representation and case rules (e.g. matching algorithm) are crucial elements in the lifecycle of model development and maintenance, particularly at the prequalification project level which requires specific environment change criteria. The reasoning process is impractical in respect of maintaining consistency and reliability of the model which entails continuous verification and validation.

Artificial Neural Network

Lam et al. (2000); Khosrowshahi (1999); and Taha (1994) developed models for contractor prequalification using an artificial neural network approach as a branch of artificial intelligence. Feedforward-backpropagation architecture and supervised-delta rule for learning algorithm were adopted to develop all these prequalification models except Lam et al. (2000) who utilised the supervised-gradient descent technique in order to accelerate the learning process.

The main issues on development of the network pattern are the number of cases and the process of training and learning cycles in terms of validation and verification in order to obtain a generalised performance of the model relationship between input and output. Lam et al. (2000) and Khosrowshahi (1999) used hypothetical data to increase insufficient real data in order to enhance the generalisation of the model by means of data generated by a statistical approach using real data (Khosrowshahi 1999) and existing prequalification data reassessed by prequalification experts (Lam et al. 2000). Additionally, for training and testing the models where there were insufficient cases, all the researchers utilised the 10-fold cross validation technique. Moreover, to accelerate the speed of the learning process, Lam et al. (2000) adopted the conjugate gradient descent method.

There are some main differences between Expert Systems (ES) (e.g. KBES and CBR) and ANN including (Turban and Aronson 2001; Faghri et al. 1997):

- The ES approach emphasises heuristic and judgmental processes that follow explicit rules or human experience to solve the problem (rules mechanism), while ANNs use algorithms and intuitive processes that act like the human brain mechanism to solve the problem (learning mechanism), hence ANNs can map the complicated non linear relationship between input (e.g. prequalification data) and output (e.g. contractor performance) relatively easier;
- ESs are driven by knowledge, and thus are highly expert dependent, while ANNs are driven by data, so a high number of cases are required; therefore in the context of prequalification process decision making, prequalifiers are less dependent on the use of ES models than ANN models;

- Knowledge stored in the ESs are static and rule changes need reprogramming (no fault tolerance), while ANNs do not require reprogramming to accept new data (highly fault tolerant), and the ANN method is flexible to easily adopt new cases through training, so that it is suitable for prequalification characteristics; and

- ANNs are stronger in forecasting and classification than ESs, but weaker in explanation and are often considered as a black box process, where it is difficult to explain, for example, why a contractor is disqualified.

3.4.5.3 Statistical models

Cluster Analysis

Holt (1996) suggests that Cluster Analysis (CA) has benefits to be used for prequalifying contractors in terms of the larger numbers of criteria that can be utilised and identifying contractors in the list in one process of comparison analysis; minimising evaluation time and effort particularly the procedure of evaluation through statistical software; and potentially reducing the risk of eliminating *good* contractors in the short listing process using a simple procedure like the binary decision approach (i.e. YES or NO decision).

The CA technique, a kind of multivariate analysis, can be used for identifying a group of contractors into a small number of clusters that have similar characteristics meeting predetermined prequalification criteria. Holt (1997) provided an example of the usage of the CA technique in terms of the prequalification process using eighteen contractors' real data. Each contractor was rated from their data against twenty one relevant weighted criteria covering contractor organisation, financial consideration, management resource, past experience and past performance as the main criteria (see reference: Holt et al. (1994c) or Table 3.9 under column 2). The results of each attribute score for each contractor were compared to each other by the CA.

Two stages of clustering were performed to obtain the final two clusters. The first mapped the data into several clusters by means of hierarchical clustering using the centroid method for identifying the degree of similarity among contractors' characteristics as a no priori knowledge of the number of clusters as the starting point of the analysis. The second stage was performed to enforce the process of mapping into two clusters known as *k-means* clustering or classifying *good* contractors and *not-so-good* contractors. At this stage, the mean, standard deviation and variance of each contractor attribute within each cluster showed strong and weak contractors' designated attributes and significant discriminating criteria forming the clusters were identified by analysis of variance. To determine *good* contractors (score >5) and *not-so-good* contractors (score ≤ 5) as a priori knowledge, the mean score of each contractor using scale of 1 to 10 was calculated based on contractor cost, time and quality performance (Holt 1996; Holt 1997).

However, compared with the ANN method, and other multivariate methods such as the DA or LR technique, the drawback of this method is that the model can only be used for one-off results for contractors' competency comparison. In other words, it cannot create a model representation like the LR model which can be used repeatedly for other contractor's data. Moreover, prequalifiers still have to identify more precisely the importance of the criteria used and need to have prior knowledge about the CA technique.

Furthermore, this technique is a primarily explanatory approach rather than statistical inference, consequently the result may be different if different procedures and the number of variables used are applied. It requires replication analysis in varying conditions. Therefore, a user's knowledge of the subject under investigation and their skill in using the CA is important in order to obtain a better result (Hair Jr et al. 1998).

Discriminant Analysis and Logistic Regression

Wong et al. (2003) developed two models utilising the multivariate techniques of Discriminant Analysis (DA) and Logistic Regression (LR). These models used the same data for developing prequalification models that demonstrate the relationship between contractor performance as dependent variables and contractors attributes as independent variables. Both models are predictive models of contractor performance which have categorical dependent variables (*good* and *poor* contractors) and five ordinal independent variables (scale of 1 to 5) for the DA model (see Table 3.12) and three independent variables for the LR model (see Table 3.12) developed from sixty eight cases and thirty four prequalification criteria (see reference: Wong et al. (2000) or Table 3.9 under column 6).

Table 3.12 Discriminant Analysis and Logistic Regression prequalification predictive models (After Wong et al. 2003)

Discriminant Analysis model	Logistic Regression model
$Z = -8.375 + 1.098X_1 + 1.328X_2 + 0.5X_3 - 0.69X_4 - 0.893X_5$	$PCP = \frac{1}{(1+e^{-z})}$, where $Z = 19.844 - 2.521X_1 - 3.662X_2 - 1.341X_3$
Z score with cut-off value –1324 for good and poor contractor performance Independent variables (prequalification criteria): X_1: Suitability of equipment X_2: Past performance in similar project (cost) X_3: Contractor relationship with local authority X_4: Contractor reputation and image X_5: Past performance in similar project (time)	PCP: probability of contractor performance Independent variables (prequalification criteria): X_1: Suitability of equipment X_2: Past performance in similar project (cost) X_3: Contractor relationship with local authority
Data characteristics	
Cases: 43 public clients and 25 private clients in UK Project type: Building & civil engineering works Turnover: 30 firms (<£5 million), 30 firms (£5 million to £50 million) and 8 firms (>£50 million)	
Model development and validation	
Model development: stepwise procedure and 48 cases were used for development	Model validation: 20 cases were used for validation

In terms of model development that can impact on the estimation of the predictive function, both types require a sufficient number of cases overall and in each group size and also in the respect of the proportion of each group size. Hair Jr et al. (1998) suggest that the minimum size is five cases per independent variable and better results are achieved if a ratio of 20 cases exist for each independent variable. Additionally, the minimum group size must be greater than the number of independent variables and better results are achieved if each group has 20 cases. Due to these requirements, it is difficult to develop a model that covers the large number of criteria for contractor evaluation compared with non statistical models.

There are two main aspects where the LR method has more advantages than the DA method. These are as follows (Hair Jr et al. 1998; Sharma 1996):

- Independent variables could be metric (e.g. ordinal or continuous data) and/or non metric (e.g. categorical or nominal data) for LR, while DA can only treat metric data; and

- The distribution of independent variables should be assumed normal for DA, while LR does not require a normality test.

In the case of a prequalification system, it is more realistic to use a LR method, as this method develops the model on the basis of a non linear relationship between, at least, two different non-metric dependent variables and two or more dependent variables, while DA is based on the linear relationship approach.

3.4.5.4 Hybrid models

The concept of the hybrid model proposed by Russell (1992) is based on the premise that each modelling technique has restricted capabilities and flexibility for certain aspects of the problem domain. An integration of several modelling techniques into a hybrid model based on suitability to a certain type of problem domain which may represent quantitative and/or qualitative data would be an appropriate approach. For example, the LR model could be applied for developing a model of references/ reputation and past performance module, knowledge based expert systems for financial stability, current workloads and project specific criteria module, and fuzzy sets for a technical expertise module.

Holt (1993) proposed, as another example, a multiple stage model where Multi-Attribute Analysis (MAA) was employed to evaluate contractor competency at the prequalification stage and Multi-Attribute Utility Theory (MAUT) was utilised at the tender stage. The prequalification stage needs a less complicated process of contractor evaluation, due to the assumption that a large number of contractors will be evaluated for developing the shortlist of contractors, and, at the tender stage, MAUT is more appropriate since it needs a more detailed process.

3.4.5.5 Multiple stage procedures

Holt (1993) proposed multiple stage procedures for contractor evaluation up to the selection of a winning contractor. The first stage (P1), a prequalification stage, is intended to develop a list of contractors that have capability in general aspects including contractor organisation, financial considerations, management resource, past experience and past performance. In other words this stage is to identify potential bidders and develop a select list of contractors. The second stage (P2), pre-tender stage, is intended to evaluate contractors' competency emphasising specific-requirement related project and other specific requirements as shown in Table 3.13 or a combination of P1 and P2 criteria can be seen in Table 3.9 under column 2. In other words, the P2 stage is intended to develop the tender list. The third stage (P3), final selection stage, is intended to determine a winning contractor based on the criteria at the P2 stage combined with bid price criteria (Holt et al. 1994b; Holt et al. 1994a; Holt 1993).

Table 3.13 The second stage (P2) criteria (After Holt 1993)

Specific requirements related to the project	Experience within project geographic area Experience of similar construction to project Plant resource available for project Key persons available for project Qualification of these key persons
Other specific requirements	Current work load Prior relationship with clients Home office location to project Form of contract

In terms of which modelling techniques are used for contractor selection, the hybrid modelling approach is employed as discussed in the previous section. This model procedure tries to improve prequalification practices in terms of lack of universal approach, long term confidence attributed to pre-selection, predominant evaluation based on price criteria and reliance on subjective analysis (Holt 1993).

Similar to the procedure described above, Mahdi et al. (2002) proposed two stages of contractor evaluation. The first stage is to screen contractors in order to develop a short list from a large number of contractors to a manageable number of contractors utilising a set of criteria consisting of experience record, past performance record and financial stability as general criteria against the specific project conditions such as proposed project budget, proposed project quality, proposed project schedule, project complexity level, political influence of the project, risk sharing level of the client, uniqueness of the project, design sensitivity of the project and client involvement in project management. The second stage, named final contractor selection, is to evaluate current capabilities and submitted plans and method statements against the specific project conditions mentioned above (Mahdi et al. 2002).

The first stage evaluates contractors' historical data against specific project conditions and the second stage evaluates contractors' current data against specific project conditions. Both evaluation stages utilise a AHP method to determine the final weight of each contractor.

Both the proposed procedural models under discussion show all stages form an integrated process to evaluate contractors, at least at the level of the client organisation, particularly the last procedure demonstrates a series of contractor evaluations for a particular project. For this case, repeated measures may take place for the same contractor by different clients or by the same client for some degree related to the general criteria in the prequalification stage.

3.4.5.6 Performance based procedures

Multi-Parameter Bidding System

Herbsman and Ellis (1992) proposed a Multi-Parameter Bidding System (MPBS) which tries to reduce deficiencies of contractor selection practice. It needs a new approach to reduce poor contractor performance such as cost overrun, schedule delay, quality problems and an increase in the number of claims and litigation. This method of contractor evaluation is based on the combination of proposed performance in terms of the bid sum (cost parameter), proposed schedule being converted into bid sum (time parameter) on the basis of the time value per day being equal to a certain amount of money, past performance score being converted to bid sum (quality parameter) and other parameters like safety record.

Each parameter can be weighted to determine which parameter is relatively more important compared with other parameters and then ranked in order. All conversion units and weights and quantification methods should be declared in the guidelines in order to exhibit legal and fair competition in the selection system (Herbsman and Ellis 1992).

General Performance Model

Alarcon and Mourgues (2002) proposed a contractor selection system based on the predictive framework of the General Performance Model (GPM), having five levels: strategies, drivers, processes, outcomes and combined performance, in which the prequalification system is embedded. Prequalification is a part of the strategies level consisting of three strategy layers of conditions of interrelation, initial conditions and prequalification that can influence contractor performance at the subsequent four levels in a chain of impacts from strategy factors to final outcome of the combined performance. The condition of interrelation strategy that can influence project performance explains the characteristics of the client-contractor relationship consisting of contractor's knowledge of the contract and general bases, contractor technical inspection relationship and designers' participation. The initial conditions strategy that affects the contractor's capability to satisfy the client's requirements covers the characteristics of project quality, bidding quality and project change potential. The prequalification strategy represents the main factors including general experience, experience with the client organisation, financial situation, relative size (i.e. the ratio of contractor size to project size), and project personnel experience that can impact on project performance.

Driver variables that subsequently propagate the strategies on the next factors of the GPM comprise the contractor's field management, contract management and financial management. The next factors which receive impact from the drivers are the process variables that become the principal aspects influencing project outcomes. The process variables represent planning and programming, construction, procurement and supply and control. Outcome variables demonstrate the contractor's performance including cost, time, quality and safety (risk index) (Alarcon and Mourgues 2002).

This model requires complex procedures and methodology and combines subjective and empirical information. The decision making process of this model employs cross-impact analysis for determining interaction among project variables, probabilistic inference to cope with uncertainty and AHP technique for determining attributes from contractor information with prequalification and for ranking the contractors' performance (Alarcon and Mourgues 2002). Due to the complexity of this procedure, the proposed model of prequalification based performance requires great effort, cases and expertise for application of this model in prequalification practices which have a variety of characteristics.

Performance Information Procurement System

Kashiwagi and Byfield (2002) identified that the problem of contractor selection practice is hampered by price pressure, lack of technical skills, minimum standard based evaluation, lack of performance based evaluation and traditional procurement problems. A potential solution for the problems is that contractors' capability and capacity should be evaluated by discriminating between high and low potential contractor performance in order to achieve the best value for money with respect to contractor procurement and project delivery. To achieve this state of the best value, some aspects should be considered as follows:

- Performance must be maximised to achieve the best value along with price, thus contractors must compete in both aspects;
- Clients must encourage contractors to achieve better construction in order to increase performance;
- A win-win environment must be accommodated to balance client risk and contractor risk;
- The gap between perception and expectation levels for both client and contractor must be reduced; and
- Client control, particularly management control, in order to increase contractor capability must be minimised due to an ineffective and costly approach and increases in risk.

Kashiwagi and Byfield (2002) proposed a Performance Information Procurement System (PIPS) for systematising the procedure of contractor evaluation on the basis of performance. This system accommodates and encourages contractors to submit their maximum and best past performance and proposes alternative approaches for increasing performance and also the system avoids the use of minimum standard performance criteria.

Briefly, performance based contractor selection systems that include performance criteria in the contractor selection system can operationalise the predictable measurement of future performance of contractors' performance more clearly based on their competence.

3.4.6 Evaluation of prequalification performance

To measure prequalification performance and for continuous improvement and learning process of prequalification systems, it is necessary to implement a feedback mechanism (Kenley and Watson 2000; Kumaraswamy and Walker 1999). Depending on prequalification type, periodic prequalification can be evaluated periodically, such as annual assessment, and project prequalification can be assessed after a winning contractor has completed the project tasks and handed over the project to the client.

Project performance is commonly represented by cost, time and quality performance. These performance variables can be used to measure or to indicate the success or failure of project performance as well as prequalification performance. By determining the correlation between the ratio of actual to contract cost, time and quality performance and contractors data, clients or prequalifiers can analyse the important prequalification criteria that have been prioritised to be examined in order to increase the minimum requirements for the next prequalification process. However, the use of performance indicators should consider the factors of controllable risk source that possibly influence project performance. Akinci and Fischer (1998) categorise these into contractor controllable (e.g. productivity, material delivery) and uncontrollable risk sources (e.g. inflation, weather, unforeseen geological conditions).

For the continuous improvement of contractor performance, the Hong Kong Housing Authority use step wise increase in the minimum percentage (from 30% to 60% in a three-year period) of skilled workers with accredited training certificates that must be employed by a contractor. Additionally, a similar approach was applied by the South Australian Government through a benchmarking mechanism of criteria for contractor prequalification for the period 1997-1999 (Palaneeswaran and Kumaraswamy 2000a).

Documenting and recording prequalification processes and results systematically in the appropriate system, including procedures and practices, can enhance and ease the feedback mechanism. This approach demonstrates and promotes transparency in the contractor selection process particularly in the public sector where accountability has become a concern and also facilitates better understanding among contractors and between contractors and clients needs. For example, the Washington State Department of Transportation in the USA implements contractor benchmarking and publishes main contractors' performance rating; if necessary contractors can appeal regarding the result of their rating performance (Palaneeswaran and Kumaraswamy 2000a).

3.5 SUMMARY

This chapter has described and thoroughly discussed prequalification definitions, types and elements, covering prequalification team, principal bases or references for developing prequalification criteria, main prequalification criteria, contractors' data collection methods, models/tools used for evaluation and evaluation of prequalification performance.

This review will contribute to the development of the survey for investigating prequalification characteristics in construction industrial practice; the findings are discussed in the next chapter and the investigation is based on the differences and similarities of the identified prequalification types.

A variety of prequalification definitions have been addressed and it has been shown that the main purpose of prequalification is to screen potential contractors that can carry out project tasks completely on the basis of the fulfilment of client objectives, project objectives and regulations. But most of them are more concerned with contractor selection in relation to the development of a contractor tender list, which means that it is much more related to the project prequalification category. In contrast, previous research rarely mentions periodic prequalification that is commonly implemented by public clients.

To understand prequalification characteristics, two main types of prequalification system need to be considered, namely the periodic prequalification system which is characterised by time dependent evaluation, for reducing the number of contractors into a manageable size and is more appropriate to be used for evaluation of contractors' historical data, and the project prequalification system which is useful to evaluate contractors' competency for a particular project with respect to fulfilment of specific project criteria.

Furthermore, the definitions and the characteristics of periodic and project prequalification have been defined and described in some previous research (Hatush 1996; Ng 1996; Russell 1996; Jennings and Holt 1998; and Palaneeswaran and Kumaraswamy 2001). There is no further research of the identification of the differences and similarities of both types of prequalification characteristics or investigation of the relationship between periodic prequalification and project performance in respect of the findings of key periodic prequalification factors influencing project performance.

This review also found that there has been extensive research in the area of prequalification criteria in respect of different project types and sizes and in respect of client organisations and prequalification evaluation modelling from simple models to complex models, from statistical models to artificial intelligence models, from single stage to multiple stage procedures and from single objective (e.g. good contractor) to multi-parameter objectives (e.g. performance based criteria).

In the period 1998-2001, most academic researchers focused their research on the development of prequalification decision models, including the identification of prequalification criteria. In respect of doctoral research, Russell (1988), Taha (1994), Hatush (1996), Ng (1996), Palaneeswaran (2000), Mahdi (2001) and Wong (2001) mainly focused on the development of decision models for contractor selection based on a Knowledge Based System, Artificial Neural Networks, Multi-Attribute Utility Theory, Case Based Reasoning, a specific model for design and build, Analytical Hierarchical Process and Discriminant Analysis respectively.

Moreover, most of those developed models are seemingly intended at project level or at the tender stage, when the project objectives are relatively well defined, so that contractor selection needs a more thorough assessment based not only contractors' historical data but also on current data, where this kind of contractor selection is defined as project prequalification.

CHAPTER 4

Characteristics of prequalification practices in the UK: Empirical study 1

4.1 INTRODUCTION

Empirical study 1 is intended to obtain new facts and data to provide understanding of prequalification practices including types, forms and trends in the construction industry. This empirical study was designed on the basis of the previous literature review and prequalification elements, namely, prequalification team, criteria development, prequalification criteria, data collection methods, evaluation models and prequalification performance.

It is intended that the outcome of this investigation will identify the main differences and similarities of periodic and project prequalification characteristics. Additionally, the characteristics of the alternative application of contractor standing lists from third parties such as Constructionline, which are classified as outsourcing periodic prequalification systems, are also investigated. Moreover, for further stages of this research, the main issues of this investigation use and rely on the findings of the differences and similarities of the characteristics of both prequalification types. This empirical study emphasises the relationship between prequalification criteria and project performance and the main prequalification criteria used.

This research investigates the UK prequalification domain, since the implementation of prequalification using a multi-criteria approach exists in the UK construction industry practices, as discussed in the previous chapter, and also the UK government and independent bodies encourage the implementation of this type of contractor selection as shown in their some of their publications and guidelines.

Those publications and guidelines are as follows:

- The code of practice for selection of main contractors (Construction Industry Board 1997a);
- The framework for a national register for contractors (Construction Industry Board 1997b);
- Standard form of questionnaire for approved lists of contractors (NJCC 1994a);
- Standard form of questionnaire for select lists of contractors (NJCC 1994b);
- HM Treasury procurement guidance no. 3 (HM Treasury 1997); and
- Appointment of consultants and contractors, the Constructionline system (see its website: www.constructionline.co.uk).

An empirical study was conducted using a postal questionnaire technique for data elicitation, involving UK client organisations or firms and UK construction firms as the sample for the questionnaire survey. The sample was developed from client and contractor-listing books, construction news tabloids and contractor organisation web pages. The structure of the way this chapter is presented is depicted in Figure 4.1. Only results will be presented in this chapter; the methods for analysing the data are discussed in chapter 2.

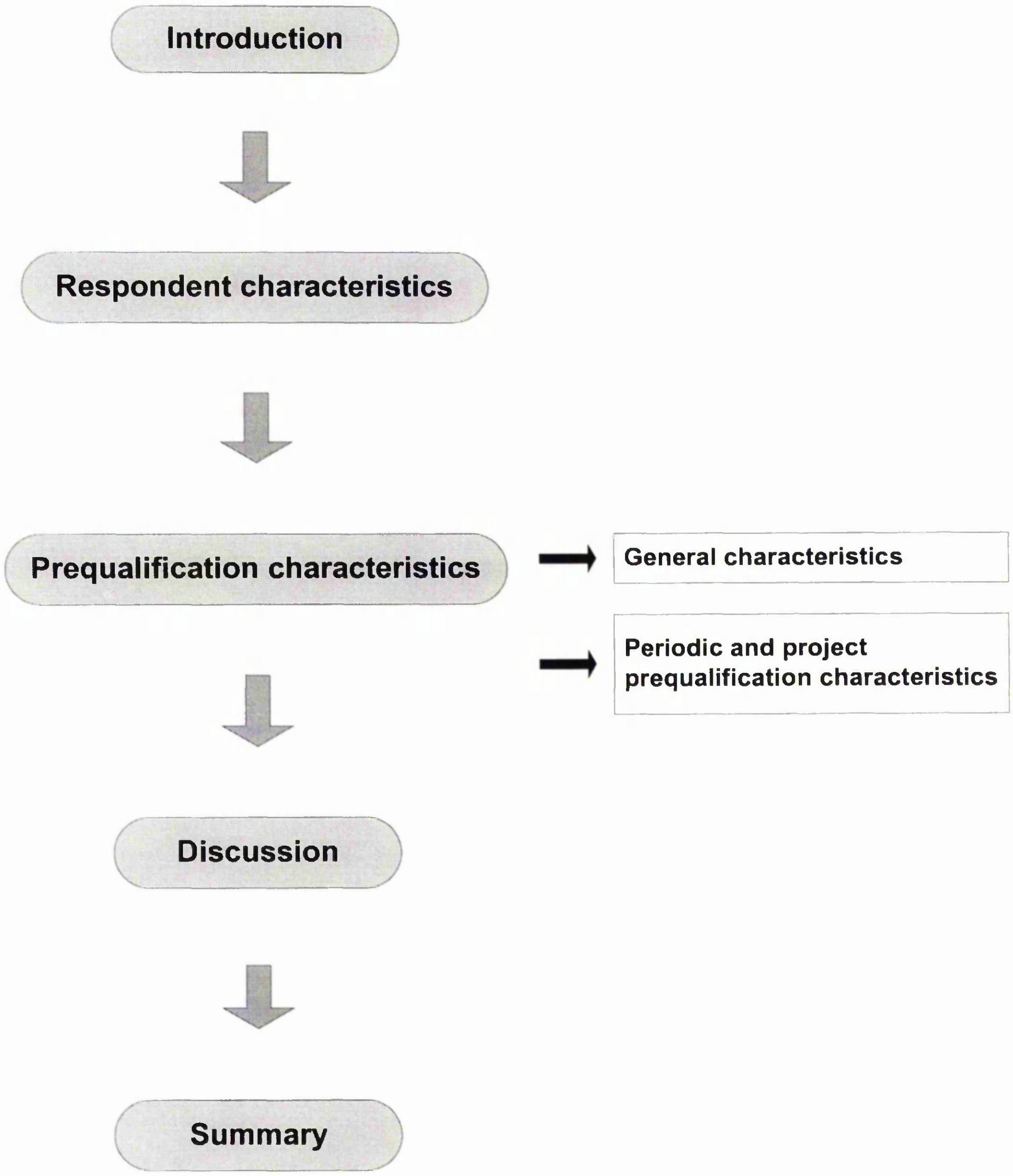


Figure 4.1 Structure of chapter 4: Empirical study 1

4.2 RESPONDENTS' CHARACTERISTICS

The questionnaires were distributed between the end of April and the middle of May 2001 to 312 UK client organisations or firms, who were selected randomly from Construction News tabloids 1999-2001 and Municipal Year Book 2000, and 332 UK construction firms, who were selected randomly from Construction News tabloids 2000-2001, the Chartered Building Company-Directory and Handbook 1998/1999 and the member list of Civil Engineering Contractors Association (CECA (Southern) Limited 2001).

A total of 136 questionnaires were returned between the beginning of May and the beginning of June 2001, representing an overall response rate of 21%. The returned questionnaires represented 85 client organisations/firms and 51 construction firms in terms of usable data.

Almost 40% (33) of client respondents are Quantity Surveyors, with Civil and Structural Engineers representing 25% (21) and Architects 12% (10). About 90% of respondents have been involved with prequalification for more than 5 years and deal with more than 5 projects on this basis per annum. They are predominantly engaged in building/ housing (about 70%; 62) followed by 30% (23) in civil engineering/ infrastructure. 90% of clients come from the public sector, with the remaining 10% from the private sector.

The result of this survey indicates that, in the previous three years, 90% (9137) of projects, with which respondents have been involved, have been awarded through the traditional procurement system, with a value of £2.8 billion, and 10% (842) in total via partnering, design and build and management systems, with contract values of £730 million, £560 million, and £30 million respectively. Moreover, if broken down by organisation category, the total amount of project values awarded is £2.3 billion for 7102 public clients' contracts and £1.8 billion for 1877 private clients' contracts. For prequalification types, 54% of client respondents develop their tender/short list of contractors through periodic prequalification, 14% through project prequalification and 32% through a combination of both prequalification types.

For contractor respondents, the Businessman category represents 40% (21) indicating the highest number of respondents with most of them coming from the marketing division, and Civil/Structural Engineers represent about 30% (16). 82% (42) of respondents have had more than 5 years experience of prequalification and are involved with more than 10 prequalification projects annually, which is relatively similar to client respondents. In terms of type of project, contractor respondents are involved almost equally in building/ housing and civil engineering/ infrastructure.

Furthermore, response rates from private and public sector contractors are also nearly equal. About 70% (2700) of the total number of projects in which contractor respondents have been involved during the previous three years have been procured traditionally, with a value of almost £2 billion. The remainder can be accounted for by design and build (12%), partnering (12%) and management systems (6%), with contract values of £1.2 billion, £1.6 billion and £110 million respectively. In addition, almost £3 billion in total for 2243 contracts has been awarded to public sector contractors and nearly £2 billion for 1596 contracts to private sector contractors. For inclusion in the tender/short list, only 8% of contractor respondents are qualified through either periodic or project prequalification, while 84% are qualified through both prequalification types.

Briefly, the majority of both types of respondent has significant experience in the prequalification process and represents various professions. The proportion and rank order of the procurement types in this survey match relatively well with the procurement trends in the UK, as presented in the previous chapter (see Figure 3.2). Even though the frequency of the private client category is very low compared with public client category, the average amount of project value awarded by private clients (£3 million) is much larger than by public clients (£0.8 million). Moreover, project values in this survey match with the construction industry trend, as small project values indicate a higher frequency compared with large project values.

Thus, this survey covers a broad range of respondents' characteristics with a divergence of project and organisation characteristics. The detailed frequency of the number of respondents' characteristics within various categories mentioned above can be seen in Table 4.1.

Table 4.1 Respondent characteristics

Category	Client		Contractor		Total	
	No.	%	No.	%	No.	%
Profession						
Architect	10	11.8%	0	0.0%	10	7.4%
Building system engineering	1	1.2%	1	1.9%	2	1.5%
Businessman	11	12.9%	21	41.2%	32	23.5%
Civil/Structural Engineering	21	24.7%	16	31.4%	37	27.2%
Project/Construction Manager	9	10.6%	8	15.7%	17	12.5%
Quantity surveyor	33	38.8%	5	9.8%	38	27.9%
Total	85	100.0%	51	100.0%	136	100.0%
Experience in prequalification						
< 1 year	0	0.0%	1	1.9%	1	0.7%
1 – 5 years	8	9.4%	8	15.7%	16	11.8%
> 5 years	77	90.6%	42	82.4%	119	87.5%
Total	85	100.0%	51	100.0%	136	100.0%
Number of projects involved with prequalification						
1	4	4.7%	0	0.0%	4	3.0%
2 - 5	9	10.6%	0	0.0%	9	6.6%
5 - 10	16	18.8%	9	17.6%	25	18.4%
> 10	55	64.7%	42	82.4%	97	71.3%
None	1	1.2%	0	0.0%	1	0.7%
Total	85	100%	51	100%	136	100%
Organisation characteristic						
Public sector	76	89.4%	28	54.9%	104	76.5%
Private sector	9	10.6%	23	45.1%	32	23.5%
Total	85	100.0%	51	100.0%	136	100.0%
Project type						
Residential/ Housing	22	25.9%	6	11.8%	28	20.6%
Building/ Industrial Building	40	47.0%	22	43.1%	62	45.6%
Civil engineering/ infrastructure	23	27.1%	23	45.1%	46	33.8%
Total	85	100.0%	51	100.0%	136	100.0%
Annual project value						
≤ £1M	12	16.2%	1	2.3%	13	11.1%
> £1M - £5M	20	27.0%	5	11.6%	25	21.4%
> £5M - £25M	31	41.9%	18	41.9%	49	41.9%
> £25M - £50M	6	8.1%	11	25.6%	17	14.5%
> £50M	5	6.8%	8	18.6%	13	11.1%
Total	74	100.0%	43	100.0%	117	100.0%
Annual project number						
≤ 2	10	14.1%	1	2%	11	2.3%
> 2 - 5	10	14.1%	2	5%	12	4.5%
> 5 - 50	30	42.2%	35	80%	65	79.5%
> 50 - 100	12	16.9%	5	11%	17	11.4%
> 100	9	12.7%	1	2%	10	2.3%
Total	71	100.0%	44	100%	115	100.0%
Annual average project value						
≤ £0.25M	53	74.7%	18	41.8%	71	62.3%
> £0.25M - £0.50M	5	7.0%	11	25.6%	16	14.0%
> £0.50M - £1M	7	9.9%	6	14.0%	13	11.4%
> £1M - £5M	5	7.0%	7	16.3%	12	10.5%
> £5M	1	1.4%	1	2.3%	2	1.8%
Total	71	100.0%	43	100.0%	114	100.0%

4.3 PREQUALIFICATION CHARACTERISTICS

4.3.1 General Characteristics

4.3.1.1 The purpose of prequalification

It can be seen in Figure 4.2 that client respondents perceive that the main purpose of a prequalification system is to select contractors according to their financial and technical competence and to enhance project performance (i.e. time, cost and quality aspects). However, *compliance with regulations* and *meeting standard procedures* are not the main reason to implement a prequalification system, since *the standard procedure* factor is simply the techniques to achieve the main objectives or to enhance the prequalification process. In respect to the fairness of contractor selection, *compliance with regulations*, especially in the public sector, is an important factor to consider as an appropriate procedure to be fulfilled rather than meeting the aims of prequalification.

Moreover, the implementation of prequalification does not always mean *to reduce competition*, especially in the case of the periodic prequalification stage, where a number of contractors of similar competence are grouped together, so this is why very few client respondents consider this factor as significant. On the other hand, project prequalification tends to significantly reduce the number of contractors compared with periodic prequalification, which means that the number of contractors tends to be small in a project prequalification list.

For contractor respondents, when considering the main reasons for being involved with prequalification according to the Rank Relative Index (RRI) it is not surprisingly that it is found that profit orientation is the main purpose for contractors, where Figure 4.3 shows that *the opportunity of winning a contract* is the most important factor (89.3%). While around two thirds of contractor respondents consider becoming involved in prequalification if their past experience including their capability and capacity, are similar to the offered projects (i.e. *projects offered by a client similar to type of previously completed projects, need work for continuity in employment of key personnel and workforce, projects offered by a client similar to size of previously completed projects*).

In addition, their familiarity with clients (i.e. *relationship with client* and *identity of client/consultant*) have been established possibly through previous collaboration or convincing information obtained about clients. In addition, clients usually consider these factors as highly important prequalification criteria.

Factors of promotion/self evaluation and prequalification cost are not considered of high importance. As prequalification can incur significant cost, especially application to more than one client, it is reasonable for a contractor not to be involved in prequalification only for promotion/self evaluation without having the possibility of winning a contract or without having appropriate competence to meet the offered project's needs (see Figure 4.3).

Furthermore, as this simple ranking technique does not provide clear cut evidence of the groups of variables which have similar characteristics or high correlation, as seen in Figure 4.3, the factor analysis technique was then used in order to improve understanding of the groups of influential factors. Table 4.2 shows that three groups of factors have eigenvalues greater than 1, explaining almost 70% of the variance being loaded together. The data are also reliable in respect of the measurement of the 3 points of the ordinal scales using Cronbach's alpha coefficient (around 0.7) and an acceptable number of cases (50) for the usage of the FA technique as seen in Table 4.2. These grouped factors can be defined as *appropriateness of firm competence* (component factor 1), *firm demand and opportunity* (component factor 2) and *firm image and relationship* (component factor 3). It is important to note that Principal Component Factoring was used to extract the determinant factors, as most identified communalities (88%) were above 0.60 and varimax rotation technique was used to interpret the factors (see Figure C.2 in Appendix C), since all the oblique correlation values were below 0.3 (see Figure C.3 in Appendix C). Factor loadings above 0.75 were considered significant, as the number of cases is 50 (see Table 2.5).

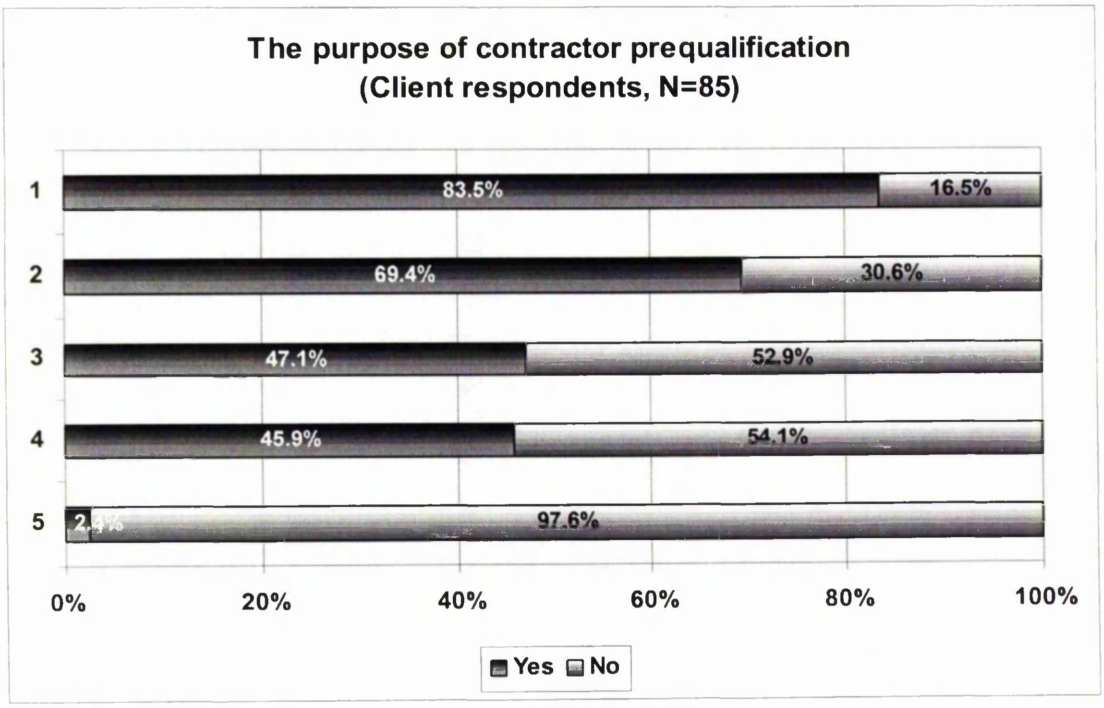


Figure 4.2 The purpose of prequalification (clients' perception)

Note:

No.	Purpose of prequalification (N=85)
1.	To eliminate the incompetent, overextended, underfinanced and inexperienced contractors in terms of performing a certain level of project tasks
2.	To minimise risks including extensive time delay, cost overrun, inferior quality
3.	To comply with regulations
4.	Standard procedure
5.	To reduce competition

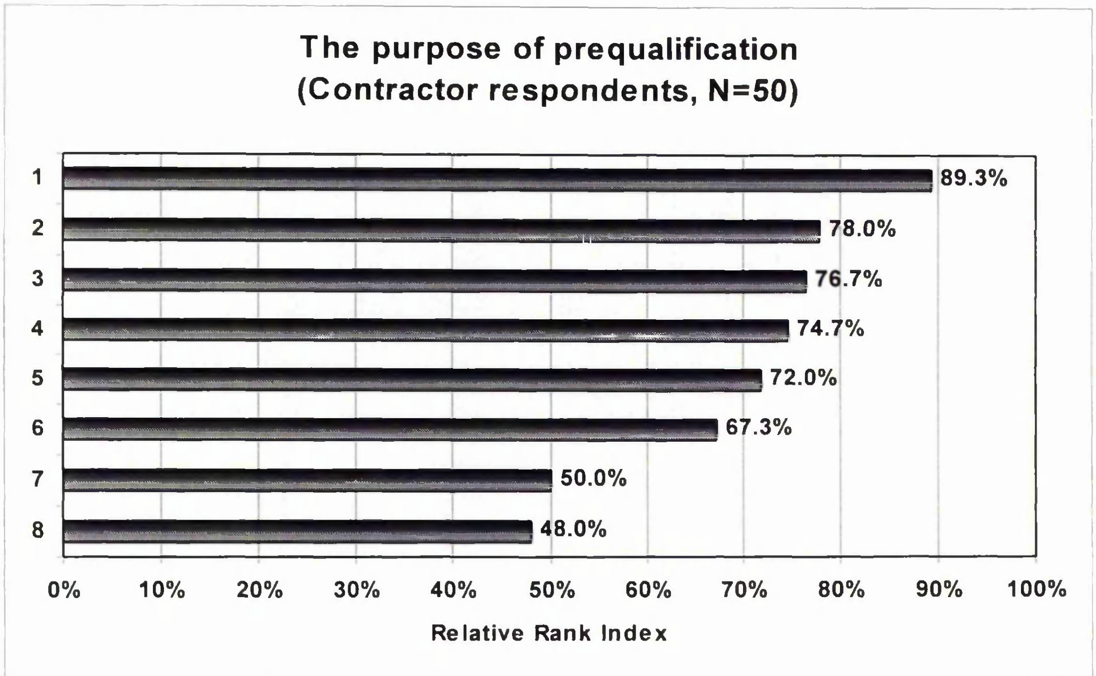


Figure 4.3 The purpose of prequalification (contractors' perception)

Note:

No.	The purpose of prequalification (N=50)
1.	The opportunity of winning a contract
2.	Projects offered by a client similar to type of previously completed projects
3.	Need work for continuity in employment of key personnel and workforce
4.	Relationship with clients
5.	Projects offered by a client similar to size of previously completed projects
6.	Identity of client/ consultant
7.	As part of self evaluation and promotion
8.	The cost effectiveness of prequalification

Table 4.2 Factors for the purpose of prequalification (contractors' perception)

No.	Variable (N=50)	Factor loadings			Rank
		1	2	3	
1.	Projects offered by a client similar to size of previously completed projects	**0.86**	0.09	0.27	5
2.	Projects offered by a client similar to type of previously completed projects	**0.84**	0.10	0.14	2
3.	The cost effectiveness of prequalification	0.59	0.10	-0.42	8
4.	Need work for continuity in employment of key personnel and workforce	0.00	**0.82**	0.16	3
5.	The opportunity of winning a contract	0.15	**0.78**	0.20	1
6.	Relationship with clients	0.25	0.60	-0.51	4
7.	As part of self evaluation and promotion	0.17	0.37	**0.79**	7
8.	Identity of client/ consultant	0.13	0.08	**0.78**	6
	Variance (%)	33.0	20.5	16.1	
	Cronbach alpha	0.679			

Briefly, these findings show that there are similar perceptions for both types of respondent in terms of the high importance of the contractor competence criterion, where this criterion is the main purpose of the application of a prequalification system in order to obtain well-performing contractors. However, based on clients' perception, *compliance with regulations* and *standard procedure* are not really the main purpose of prequalification, but these factor are tools for minimising constraints and disputes in the contractor selection process. Because, without proper procedures for contractor prequalification, disputes may arise leading to high cost due to project delay.

This is similar to the second and third groups of factors respectively, according to contractors' perception, which is related to construction firms' business continuity and presenting the company image in order to maintain the relationship with previous clients or to establish a relationship with new clients and also related to harmonising between a firm's capacity and winning opportunity without scarifying profit margin.

4.3.1.2 Implementation of prequ alification types

Table 4.3 shows that almost 90% of client and contractor respondents implement periodic prequalification or a combination of both prequalification types for screening capable contractors. However, the periodic prequalification system was used less in the private category than in the public category and the both types category has relatively high usage across all respondent categories. It seems that public clients have relatively high confidence to use periodic prequalification rather than its counterpart, as they have routine projects at hand and a relatively high number of projects every year. On the other hand, private clients tend to scrutinise their contractor selection system by using both prequalification types due to the relatively big size of projects and the low volume of annual projects.

Table 4.3 The usage of prequalification types

Respondent category	Prequalification type		
	Periodic	Project	Both types
Client (N=85)	54.10%	14.10%	31.80%
Contractor (N=51)	7.80%	7.80%	84.30%
Public (N=104)	42.30%	11.50%	46.20%
Private (N=32)	18.80%	12.50%	68.80%
Overall (N=136)	36.80%	11.80%	51.50%

4.3.1.3 Reassessment cycle time in the periodic prequalification system

Figure 4.4 indicates a similar proportion between client and contractor respondents in terms of the reassessment cycle for periodic prequalification. The most common reassessment cycle (around 50%) is 3 years and more, while 2 years and 1 year or less are both around 20%. This result indicates that most clients still maintain a list of contractors for a long period without evaluation.

There are possible reasons for this long period of reassessment cycles, especially for the public client category. They usually have similar and routine project types annually and, if necessary, the contractors are further evaluated through project prequalification, considered as the usage of both prequalification categories, and also they are familiar with the same contractors being enlisted in their standing list and which commonly perform their construction projects every year.

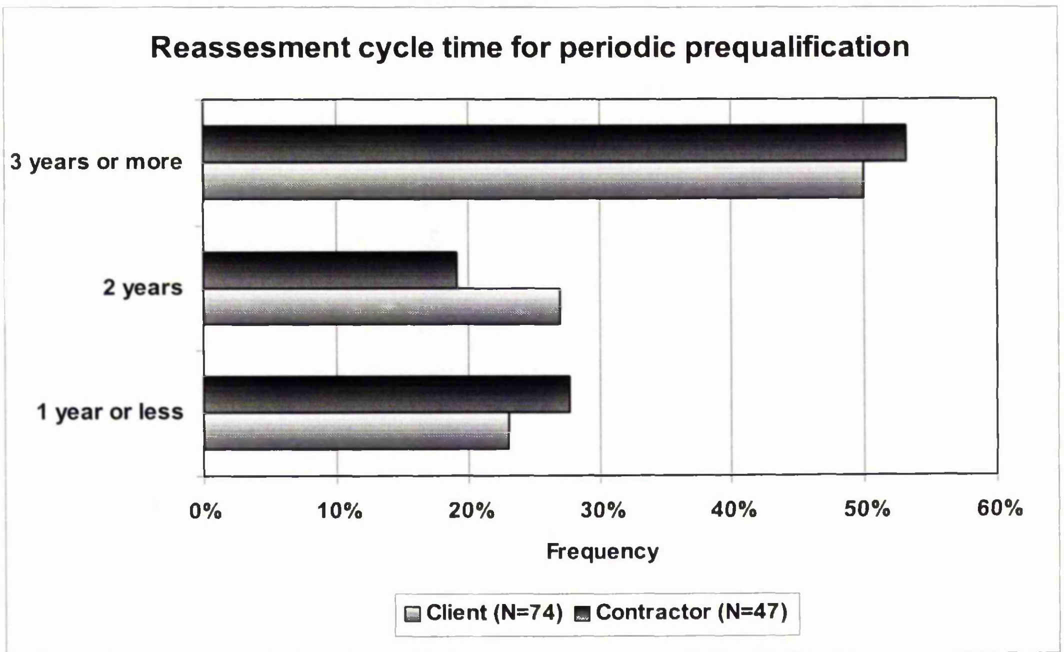


Figure 4.4 Reassessment cycle time for periodic prequalification

4.3.1.4 The main people being responsible for the prequalification process

According to client respondents, *quantity surveyors* (around 45%) are the main people who are responsible for the development and evaluation of the prequalification system, while contractor respondents indicate that *businessmen* (60%) are the main people who are responsible for preparing prequalification proposals (see Figure 4.5). It seems reasonable that client organisations rely on *quantity surveyors*, because accurate prediction of project cost, time and quality is vital for project success. On the other hand, in construction firms, a *businessman,* especially a marketing manager, has an important role in coordinating a prequalification team to achieve its firm's objectives, such as an annual turnover and profit targets within their business plan (see Figure 4.6).

The involvement of other professions, like *architect* and *civil/structural engineer*, is dependent on the project type. For residential/housing and building/industrial building projects, *architect* and *quantity surveyor* (about 90%) become the dominant professions, while *civil/structural engineer* (about 75%) is the major profession involved the prequalification process in civil engineering and infrastructure projects (see Figure 4.7).

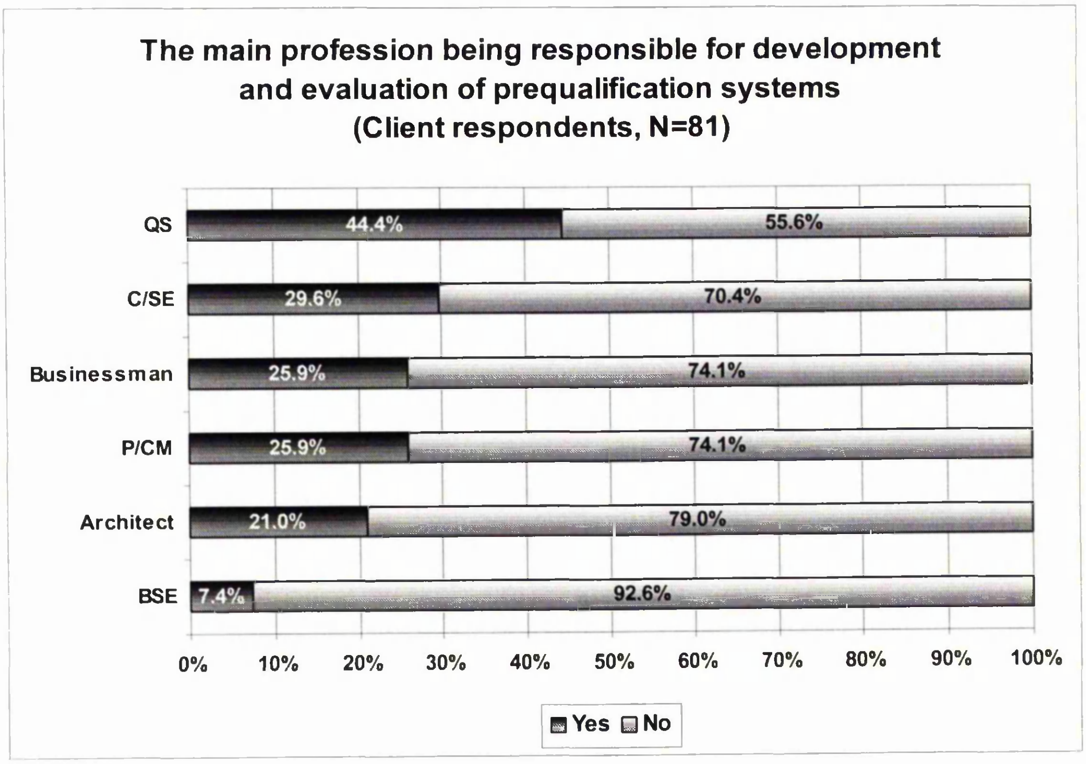


Figure 4.5 The main profession being responsible for development and evaluation of prequalification systems (client respondents)

Note:
QS: Quantity Surveyor; **C/SE:** Civil/Structural Engineer; **P/CM:** Project/Construction Manager and **BSE:** Building Services Engineer

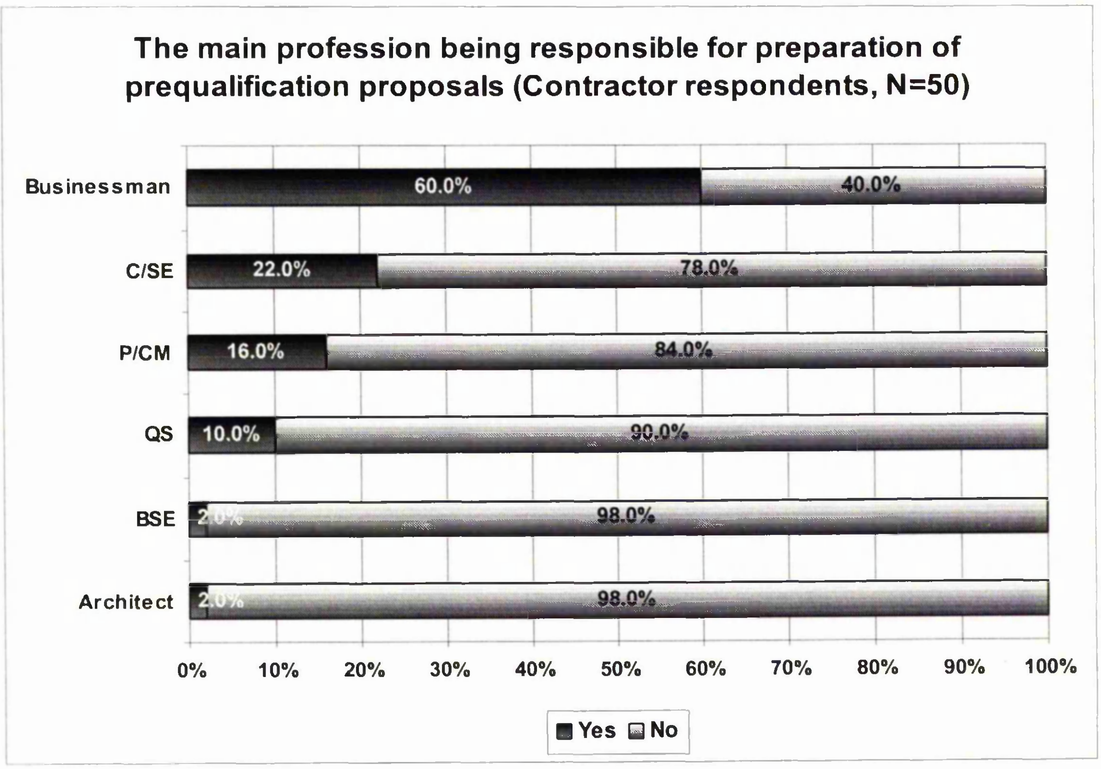


Figure 4.6 **The main profession being responsible for preparation of prequalification proposals (contractor respondents)**

Note:
QS: Quantity Surveyor; **C/SE:** Civil/Structural Engineer; **P/CM:** Project/Construction Manager and **BSE:** Building Services Engineer

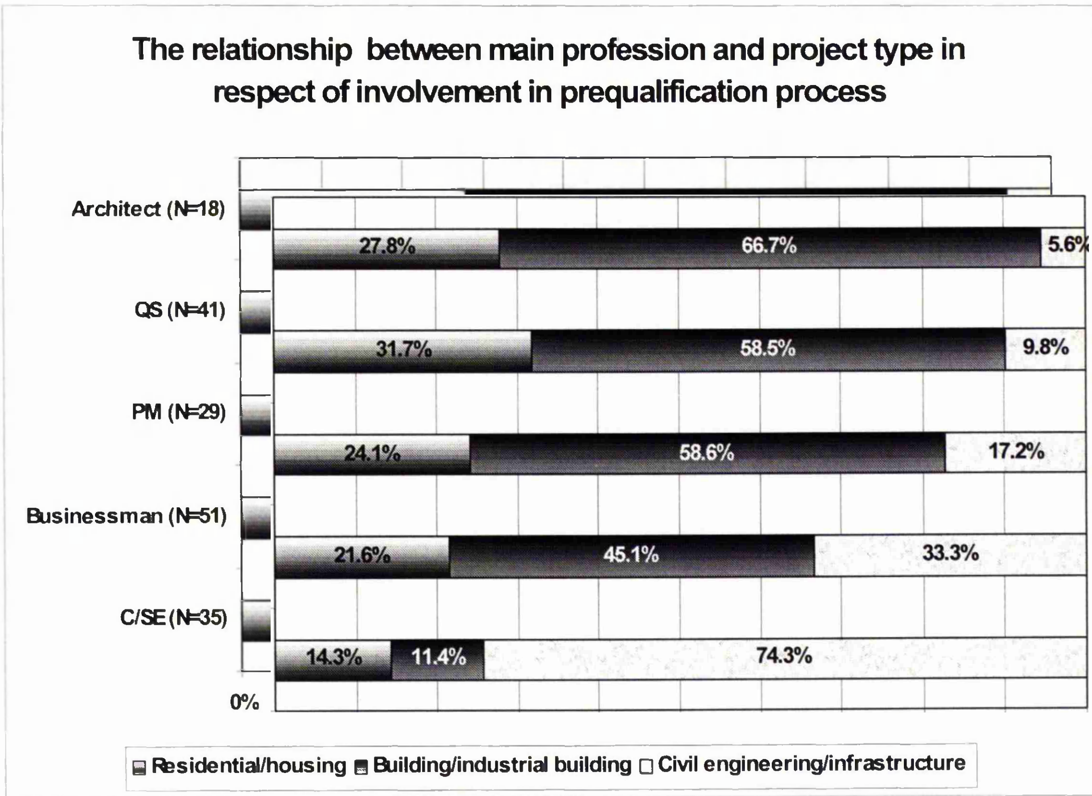


Figure 4.7 Relationship between the main profession and project type in respect of involvement in prequalification process

Note:
QS: Quantity Surveyor; **C/SE:** Civil/Structural Engineer; **P/CM:** Project/Construction Manager and **BSE:** Building Services Engineer

4.3.1.5 Outsourcing periodic prequalification

As mentioned in the previous chapter, Constructionline produces a list of registered contractors and may be considered as outsourcing prequalification carried out by a third party; the list can be used for a first filter and the scheme reduces questionnaire information and duplication.

Around 65% of all respondents are members of Constructionline, but if the data are broken down into respondent categories, half of the client respondents are members of Constructionline, while almost 90% of contractor respondents are registered (see Figure 4.8). Moreover, of 77 respondents from both client and contractor categories, 14% indicate clients usually accept the list without further prequalification, 47% sometimes, and 39% never, while of 68 respondents from the same categories, 26% indicate clients accept the list but with further prequalification, 59% sometimes, and 15% never (see Table 4.4).

Some reasons from clients who do not fully utilise the list, which are similar to comments from a previous survey (Wong et al. 1999), are as follows:

- The system is not concerned with regulations such as statutory requirements of Health and Safety, equal opportunities considerations, certification of quality assurance system (e.g. ISO 9000) and environmental management system (e.g. ISO 14000);
- The system provides inadequate information about size, and specific and geographical operation of contractors, and only low grade checks on various criteria or not as detailed as the clients' requirements (e.g. insurance out of date, cash-flow problems and other financial matters); and
- Relationships between clients and contractors are already well established.

Detailed comments from respondents are given in Table 4.5.

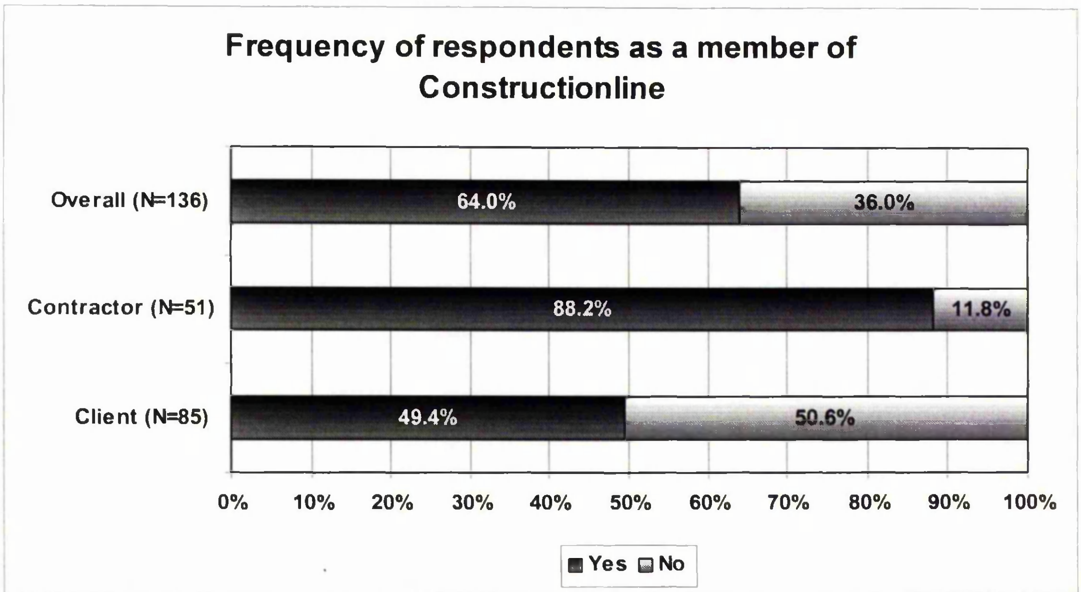


Figure 4.8 Frequency of respondents as a member of Constructionline

Table 4.4 The acceptance of Constructionline registered contractors in the clients' periodic prequalification list

Degree of acceptance	Frequency of acceptance					
	Accept without further prequalification			Accept with further prequalification		
	Client	Contractor	Overall	Client	Contractor	Overall
never	50.0%	30.2%	39.0%	14.3%	15.0%	14.7%
rarely	5.9%	32.6%	20.8%	17.9%	15.0%	16.2%
sometimes	8.8%	27.9%	19.5%	21.4%	22.5%	22.1%
often	11.8%	2.3%	6.5%	14.3%	25.0%	20.6%
usually	23.5%	7.0%	14.3%	32.1%	22.5%	26.5%
N	34	43	77	28	40	68

Table 4.5 Respondents' comments about Constructionline

Client	Contractor
– Constructionline list is used mainly as a reference database. – We have considered Constructionline list but this does not adequately prequalify contractors so we would still to do our own checks and hence have continued to use our own standing list. – Constructionline list is not considered appropriate especially for smaller local contractors. – It would be preferable to share these developments with other authorities (as Constructionline has done in a limited but unacceptable way), to reduce the cost and avoid paperwork for contractors. – Constructionline has a limited number of contractors and we utilise a combination of this and our own approved list of contractors. – Constructionline list is used for monitoring only – We do not use Constructionline list due to perceived poor quality/ low grade checks on various criteria. – Sometimes the information on Constructionline list is not as good as our own enquiries, e.g. insurance out of date; contracts with cash flow problems; firm with poor Health & Safety record not stated on Constructionline. – Constructionline scheme often produces a large list and, in practice, we select the firms we know already. – We are still vetting the suitability of Constructionline's vetting procedures e.g. for Health & Safety, equal opportunities, financial matters.	– Constructionline appear to be struggling to get acceptance. – Clients still rely on their own questionnaire for prequalification. – Constructionline gives an entry to prequalification but is not accepted as the basis for prequalification (i.e. for first filter only). – Local Authority select list managers require more detail and information than Constructionline provides. – Constructionline covers several areas of information on a contractor, and where it has been adopted by a public or private client to administer their approved list this has helped us greatly in reducing questionnaire information and duplication. – Constructionline does not seem to provide clients with all of the information they require/ not specific enough. – As a regional contractor, use of centrally based registration (i.e. in London) is not always appropriate for local authorities. This is the main reason for not favouring Constructionline. – Constructionline list is not being used effectively by clients. – Registration (Constructionline) is not working for specialist companies where clients still require individual prequalification to match their requirements. – In general Constructionline was found to be fairly useless, most clients use it along side their own approved list, it is very difficult to amend. – Not enough clients using it.

Furthermore, regarding other third party prequalification systems other than Construction line, 74% (37) of contractor respondents are not registered, but 26% (13) are registered in Achilles (9) and other systems (4) such as First Point Assessment Limited. The Achilles system (see their website: www.achilles.co.uk) consists of two categories, that is, Utilities Vendor Database (UVDB) providing a single focus point for the collection and sharing of contractor prequalification information and Linkup providing a list of registered contractors which have specific competency in the rail industry. The main purpose of the systems is to share better information and to minimise duplication in the process of prequalification.

4.3.2 Characteristics of periodic and project prequalification systems

4.3.2.1 Prequalification types related to procurement type

Table 4.6 shows the rank order of frequency of use of both periodic or project prequalification are the same for all procurement types, that is, *traditional*, *design and build*, *partnering* and *management* from high to low frequency. This result is similar to the national trends in procurement route as depicted in Figure 3.2. The only difference between periodic and project prequalification is that the use of the *traditional* approach tends to decrease in project prequalification, conversely the usage of *design and build*, *partnering* and *management* types tends to increase. These tendencies are due to many complex projects, especially those with high project values, being delivered through non traditional procurement systems such as *partnering* and *design and build.*

Table 4.6 Relationship between prequalification and procurement types

Procurement type	Frequency of usage					
	Periodic			Project		
	Client	Contractor	Overall	Client	Contractor	Overall
Traditional	92.8%	72.7%	94.7%	97.7%	87.2%	79.4%
Design and build	36.2%	56.4%	42.5%	52.3%	80.9%	67.6%
Partnering	24.6%	40.0%	33.6%	47.7%	70.2%	53.9%
Management	10.1%	20.0%	10.6%	11.4%	14.9%	17.6%
N	69	44	113	55	47	102

Before testing the difference between the frequency of usage of procurement types for both prequalification categories, it is necessary to test whether client and contractor samples are independent or not. Table 4.7 indicates that *design and build* and *partnering* data must be tested separately on the basis of the sample categories (i.e. client and contractor samples). The result of McNemar's paired test shows similar findings based on visual examination of Table 4.6, where the frequency of usage of *traditional* and *design and build* procurement is different, if the prequalification type is changed.

Table 4.7 Chi-square and McNemar tests for the frequency of usage of procurement types

Prequalification criteria	Chi-square test		McNemar test
	Periodic	Project	
	1	2	3
Traditional	0.250	0.071	0.000*
Design and build	0.093	0.008*	0.0031*/0.004*
Partnering	0.011*	0.002*	0.064/0.143
Management	0.838	0.500	0.344

Note: - Columns 1 & 2: level of significance, two-sided (client versus contractor)
- Column 3: level of significance, two-sided (periodic versus project prequalification)
- Column 3: all values of level of significance are based on binomial distribution
- * Significant at 0.05 (two-tailed)

4.3.2.2 Prequalification types related to project size

The average project value of periodic prequalification (£0.5 million, N=105) is around half the average project value of project prequalification (£0.9 million, n=105). If project size is classified into a five-range classification, the proportions of the use of prequalification systems in the case of clients and the number of awarded projects in the case of contractor respondents are as depicted in Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12 which indicate the different trends between periodic and project prequalification. Figure 4.9 and Figure 4.11 indicate that there is a tendency to increase the use of periodic prequalification type as the value of project becomes smaller.

On the other hand, in the case of project prequalification, Figure 4.10 and Figure 4.12 do not show unique trends. In other words, the figures indicate relatively low variations for client respondents (40%-55%) and high variations for contractor respondents (3%-32%) across different ranges of project size. For these variations, according to some respondents, project prequalification is needed to meet specific requirements even though the project size is small, or if the project value is above the threshold of European Currency Unit (ECU) 5 million (equivalent to around £3.7 million), at which contracts are subject to European Procurement Directives (Public sector procurement rules 2001; Council Directive 93/37/EEC 1993).

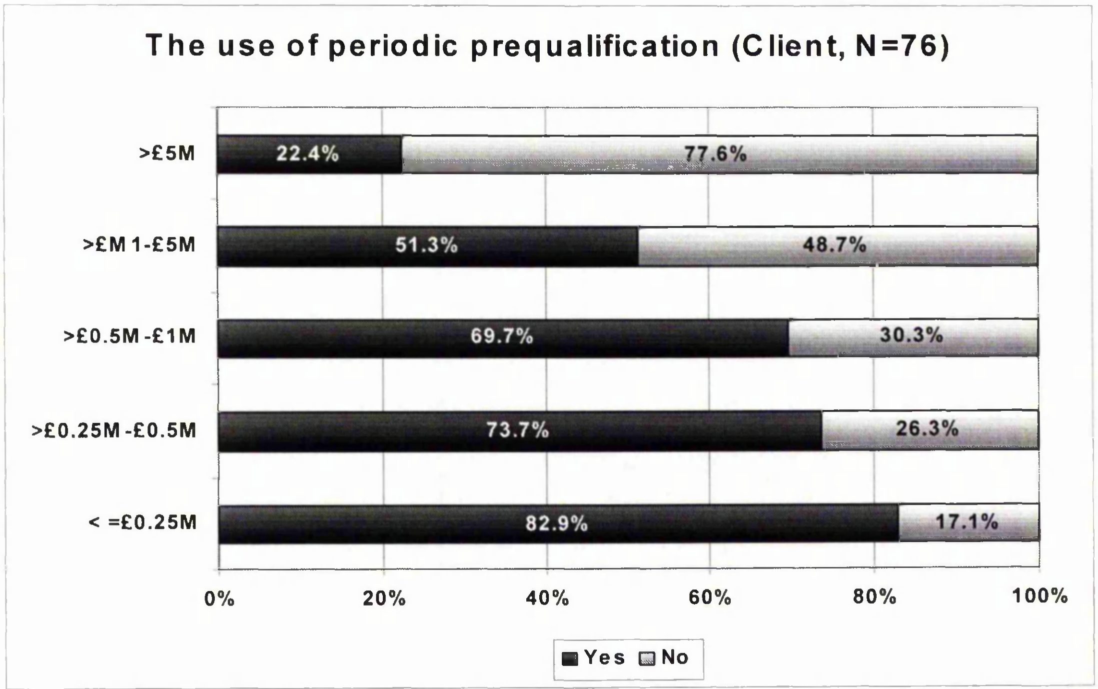


Figure 4.9 The use of periodic prequalification related to the project size (Client respondents)

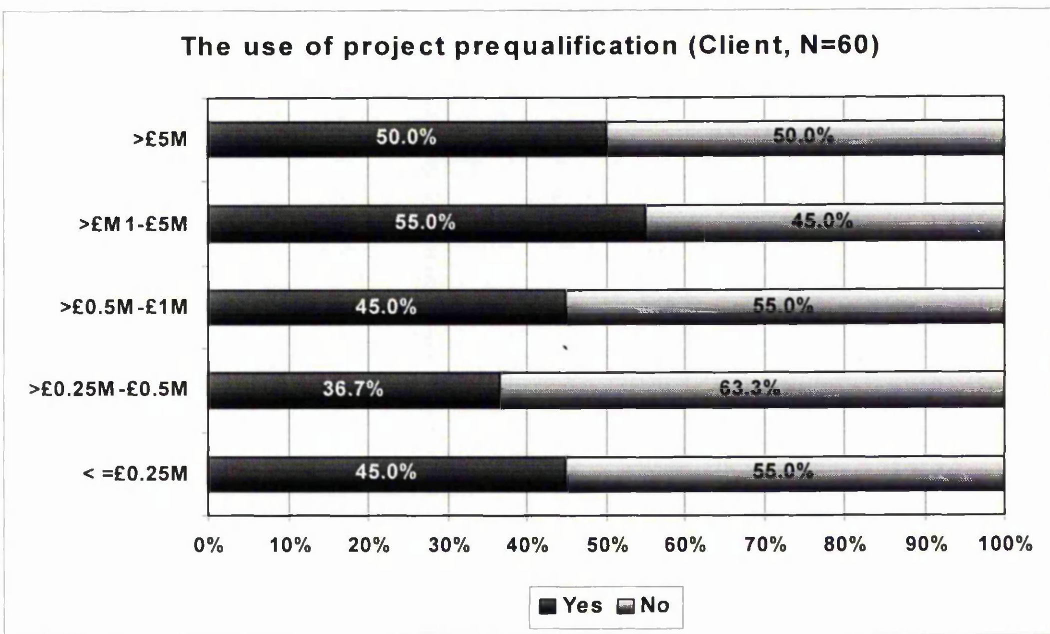


Figure 4.10 The use of project prequalification related to the project size (Client respondents)

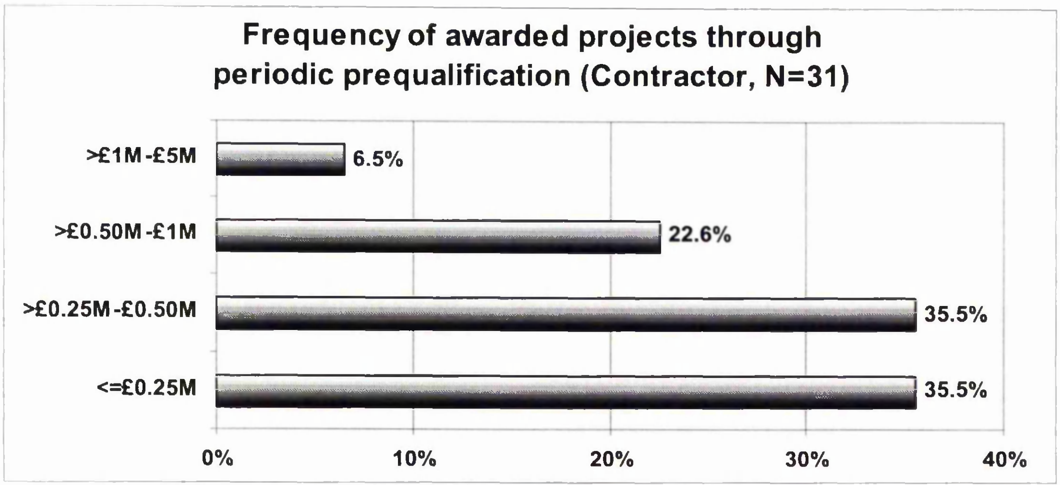


Figure 4.11 Frequency of awarded projects through periodic prequalification on the basis of project size (Contractor respondents)

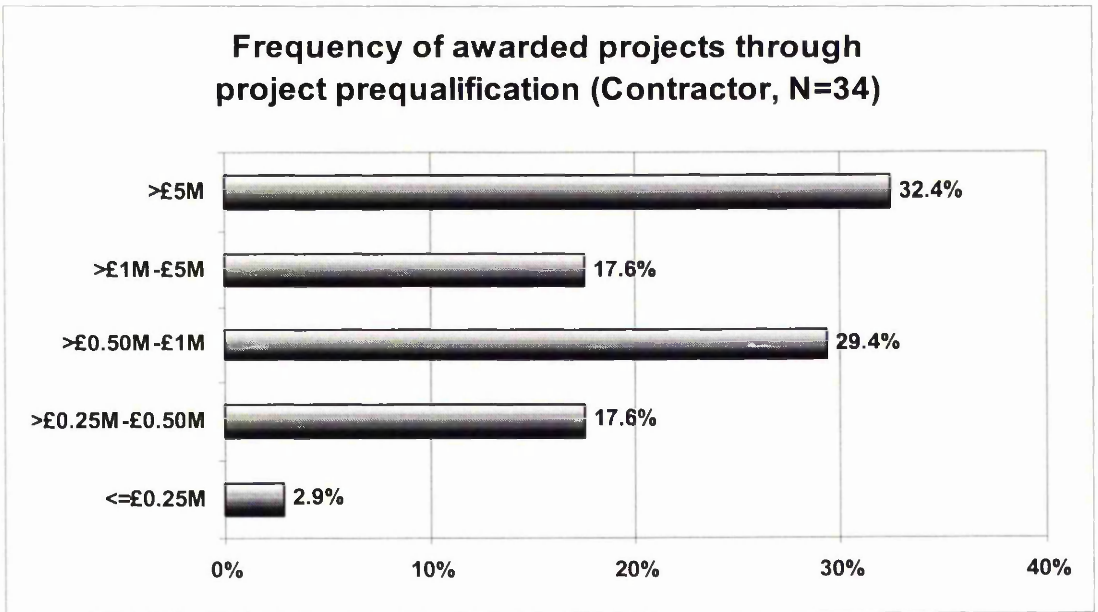


Figure 4.12 Frequency awarded projects through project prequalification on the basis of project size (Contractor respondents)

4.3.2.3 Ratio of the number of awarded contracts to inclusion in prequalification lists

In order to identify the efficiency of prequalification process, the data, derived from question numbers 15 (client questionnaire) and 9 (contractor questionnaire) as seen in Appendix A and B, were presented into the form of the ratio of the number of awarded contracts to the number of inclusions either in periodic or project prequalification. It should be noted that the ratio values were categorised into four ratio ranges as seen in the Table 4.8.

This survey found, as seen in Table 4.8 that there is similar trend across all frequency categories, that is, the higher the ratio the lower the occurrence that a contractor in any prequalification type can win a project. For the case of periodic prequalification this trend may be improved by outsourcing periodic prequalification from a client to a third party through periodic prequalification, such as Constructionline. Thus, contractors do not need to be prequalified every time for inclusion in a client's standing list, especially for projects of a similar type and size. While for project prequalification the trend can be improved by decreasing the number of participants for project prequalification/tender stage in every particular project.

Furthermore, if looking at the total frequency of ratio greater than 0.25, the chance of winning a contract at the periodic prequalification stage (i.e. contractor: 65%, client: 50%) is relatively higher than at the stage of project prequalification (i.e. contractor: 60%, client: 27%), since a contractor in the periodic prequalification list can be involved in more than one project at the bidding stage.

Table 4.8 Frequency of the ratio of the number awarded contracts to the number of inclusions in the prequalification lists

Ratio	Frequency of the ratio			
	Contractor		Client	
	Periodic prequalification	Project prequalification	Periodic prequalification	Project prequalification
≤ 0.25	34.4%	40.0%	50.0%	72.7%
> 0.25 - 0.5	28.0%	22.9%	21.4%	11.4%
> 0.5 - 0.75	18.8%	17.1%	11.4%	2.3%
> 0.75	18.8%	20.0%	17.2%	13.6%
Total	100.0%	100.0%	100.0%	100.0%
N	32	35	70	44

4.3.2.4 Prequalification types related to sources of the prequalification team

Table 4.9 indicates that client, contractor and overall categories have relatively similar frequencies in respect of the sources of the prequalification team with in house being predominant. These findings are confirmed by the McNemar test which shows there is no significant difference between both prequalification types in respect of the *in house* variable as seen in Table 4.10, where client and contractor data are tested separately due to the significant difference of frequency of usage between client and contractor respondents. However, for the *combination* variable, there is significant difference between periodic and project prequalification categories as seen in Table 4.10. This result indicates that, in the project prequalification system, it is necessary to involve various sources of the prequalification team, as contractors' data need to be examined thoroughly as, in this stage, contractor evaluation is based on a particular project's objectives. The *outsourcing* variable is not tested due to very small and zero frequency of usage.

Table 4.9 Source of the prequalification team

Source	Frequency of usage					
	Periodic prequalification			Project prequalification		
	Client	Contractor	Overall	Client	Contractor	Overall
In house	74.7%	93.6%	82.0%	70.9%	83.0%	76.5%
Outsourcing	8.0%	0.0%	4.9%	0.0%	2.1%	1.0%
Combination	17.3%	6.4%	13.1%	29.1%	14.9%	22.5%
N	75	47	122	55	47	102

Table 4.10 Chi-square test and McNemar test for frequency of usage of source of the prequalification team

Source	Chi-square test		McNemar test
	Periodic	Project	
	1	2	3
In house	0.008*	0.152	0.118/0.250
Combination	0.081	0.087	0.021*

Note: - Columns 1 & 2: level of significance, two-sided (client versus contractor)
- Column 3: level of significance, two-sided (periodic versus project prequalification)
- Column 3: all values of level of significance are based on binomial distribution
- * Significant at 0.05 (two-tailed)

4.3.2.5 Prequalification types related to criteria development

A Kolmogorov-Smirnov test (see Figure D.1 in Appendix D) demonstrates that both client and contractor data are relatively associative/dependent so that they can be combined into one sample for further statistical analysis. Comparing periodic and project prequalification, *project objectives*, *client objectives*, *project size*, *procurement type*, *risk analysis*, *public accountability* and *standard procedure* variables are significantly different using the Wilcoxon Signed Ranks test (see Figure C.2 in Appendix D), while *project type*, *individual experience*, *professional judgement* and *regulations* variables are not significantly different.

Moreover, the rank differences within each variable such as *project objectives*, *client objectives*, *project size*, *procurement type* and *risk analysis* variables in project prequalification are significantly higher than in periodic prequalification. Conversely, *public accountability* and *standard procedure* variables are significantly lower (see Figure D.3. in Appendix D). The reasons behind these findings are that at the project prequalification stage, *project* and *client objectives* can be well defined and most projects at the project prequalification stage are relatively bigger leading to the need for the application of *risk analysis* and alternative complex *procurement types*.

While *public accountability* and *standard procedure* factors are important in respect of criteria development or weighting application in the periodic prequalification system, as clients need to achieve a balance between reducing the barrier to entry for any contractor involved in the tender process, especially in the public sector, and maintaining an appropriate contractor evaluation method through the periodic prequalification system in order to reduce the number of contractors in the tender list.

In terms of ranking among variables, Table 4.11 indicates both RRIs for periodic and project prequalification data are similar. *Project size* and *type* factors have the highest influence for both prequalification types. However, the *project objectives* factor is not relatively important in periodic prequalification compared with project prequalification.

Table 4.11 Relative Rank Index (RRI) of periodic prequalification data

References/bases	Periodic prequalification (N=99)		Project prequalification (N=88)	
	RII	Rank	RII	Rank
Project objectives	0.59	9	**0.72**	**4**
Project size	**0.79**	**1.5**	**0.82**	**1.5**
Project type	**0.79**	**1.5**	**0.82**	**1.5**
Individual experience	**0.71**	**3**	**0.80**	**3**
Professional judgement	0.60	8	0.63	6
Client objectives	**0.62**	**5**	**0.68**	**5**
Procurement type	0.52	10.5	0.55	10
Risk analysis	0.52	10.5	0.58	8
Public accountability	**0.65**	**4**	0.55	9
Standard procedure	0.61	7	0.47	11
Regulations	0.62	6	0.58	7

But the RRI approach is not sufficient to provide the picture of the interrelationship among variables; in order to obtain the interrelationship, the Factor Analysis technique is employed and the results are indicated in Table 4.12 and Table 4.13 and detailed results, which meet factor analysis procedures as discussed in Chapter 2, are shown in Appendix D. In addition, Cronbach's alpha coefficient shows the data are sufficiently reliable.

Table 4.12 Rotated component factors for periodic and project prequalification

References/bases	Factor loadings					
	Periodic prequalification (N=99)			Project prequalification (N=88)		
	1	2	3	1	2	3
Client objectives	**0.714**	0.264	-0.084	**0.735**	0.304	-0.053
Individual experience	**0.700**	-0.265	-0.010	**0.800**	-0.226	-0.083
Professional judgement	**0.699**	0.068	0.139	**0.640**	0.314	0.259
Project objectives	0.596	0.331	0.015	**0.635**	0.245	0.350
Standard procedure	0.003	**0.862**	0.051	0.238	**0.765**	0.061
Public accountability	0.081	**0.801**	-0.019	0.019	**0.851**	0.022
Regulations	0.226	**0.725**	0.054	0.192	**0.809**	0.141
Project size	-0.174	0.165	**0.839**	0.061	0.162	**0.875**
Project type	0.181	-0.067	**0.659**	0.269	0.005	**0.845**
Variance	28.81%	28.81%	12.01%	37.38%	14.67%	10.77%
Cronbach's alpha coefficient	0.738			0.821		

As seen in Table 4.12 and Table 4.13, the factors affecting the weighting and development of prequalification criteria, namely, individual and organisational characteristics, compliance with regulations and project characteristics, for both periodic and project prequalification systems, explain around 60% of the variance being loaded together for both prequalification types.

To extract the determinant factors, the Principal Component Factoring method was used, since communalities above and around 0.6 were 64% and 84% respectively for the periodic and project prequalification categories. In order to interpret the factors, the varimax factor rotation technique was employed, since all and most of the oblique correlation values of periodic and project prequalification categories respectively were below 0.3. While the significant factor loadings were above 0.6, as the number of cases for both prequalification categories was above 88.

Table 4.13 Summary of factor labelling

Factor	Name	References/bases (variables)
1	Individual/organisational characteristics	Client objectives, individual experience and professional judgement
2	Compliance with regulations	Standard procedure, public accountability and regulations
3	Project characteristics	Project size and type

The inclusion of the *project objectives* variable in project prequalification, but not in periodic prequalification, can be explained by the fact that project prequalification is intended only for a particular project. It means there is high correlation between project objectives and individual/organisational characteristics in the weighting for the development and evaluation of the project prequalification system. In that case, according to the way each factor is named, it is more appropriate to include the variable as in factor 1. Furthermore, all important variables within the three factors have the same positive sign, suggesting that these perceptions are quite similar among respondents as they do not act in different directions.

4.3.2.6 Prequalification types related to the usage of main criteria

Regarding frequency of usage of prequalification criteria, *financial strength*, *past performance*, *past experience* and *health and safety record* have visually similar frequencies under both prequalification categories. However, the criteria related to the project prequalification category, such as *managerial and technical strength*, *suitable and sufficient resources* and *current workload* have higher frequencies than those criteria related to the periodic prequalification category (see Figure 4.13).

Before statistically examining the similarities and differences of both prequalification types in respect of the usage of prequalification criteria, Chi-square tests were employed to determine whether the client and contractor samples can be combined or not. For both prequalification categories there is no significant difference between the client and contractor samples for all criteria except the financial strength criterion at 0.05 level of significance, as seen in Table 4.14. Thus, the financial strength criterion was tested separately.

The results for both prequalification types, as shown in Table 4.14 and Figure D.2 in Appendix E, indicate *financial strength*, *past experience*, *past performance* and *health and safety record* have similar frequency of usage, but *managerial and technical strength*, *suitable and sufficient resources* and *current workload* have different frequencies of use. These findings show that current contractors' data are more strongly related to the project prequalification category and historical data are evaluated for both prequalification types.

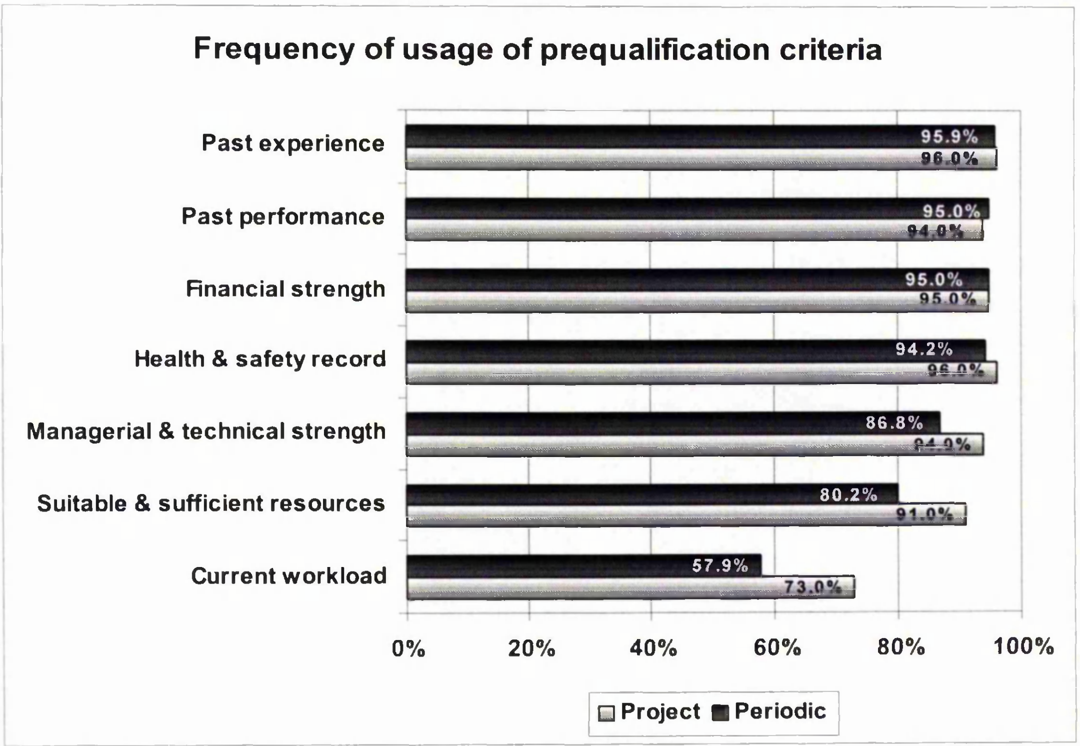


Figure 4.13 Frequency of usage of prequalification criteria

Table 4.14 Chi-square and McNemar tests for the frequency of the usage of prequalification criteria

Prequalification criteria	Chi-square		McNemar test
	Periodic	Project	
	1	2	3
Financial strength	0.286	0.034*	1.000
Past experience	0.894	0.390	1.000
Past performance	0.841	0.521	1.000
Managerial & technical strength	0.101	0.137	0.031*
Health and safety record	0.196	0.380	1.000
Suitable & sufficient resources	0.972	0.922	0.001*
Current work load	0.990	0.849	0.039*
N	121	100	87

Note: - Columns 1 & 2: level of significance, two-sided (client versus contractor)
- Column 3: level of significance, two-sided (periodic versus project prequalification)
- Column 3: all values of level of significance are based on binomial distribution
- * Significant at 0.05 (two-tailed)

4.3.2.7 Prequalification types related to the impact of main criteria on project performance

To compare between periodic and project prequalification data, the impact values of the main criteria on project performance being used are based on the average values of the summation of their impact levels on cost, time and quality performance as described in Chapter 2. In Appendix E (see Figure E.1) the result of Kolmogorov-Smirnov test indicates that only the impact level related to the *financial strength* criterion is different between client and contractor data, therefore all comparisons between periodic and project prequalification data can be combined, except for the *financial strength* criterion. As seen in Appendix F, Figures F.2 and F.4, the paired comparison for seven variables influencing project performance using the Wilcoxon test indicates only the *managerial and technical strength* criterion has a significantly different impact on project performance for both prequalification types.

Furthermore, in terms of comparison of the importance level among prequalification criteria impacting on project performance, Figure 4.14 shows that the Relative Rank Index of contractors' prequalification data on project performance for periodic prequalification and project prequalification categories are similar and *past experience*, *past performance* and *managerial and technical strength*, *suitable and sufficient resources* have the highest ranks compared with other prequalification criteria (i.e. *health and safety record*, *financial strength* and *current workload*). The detailed values of the RRIs, including the impact on cost, time and quality performance under both prequalification types, can be seen in Tables F.1 and F.2 in Appendix F

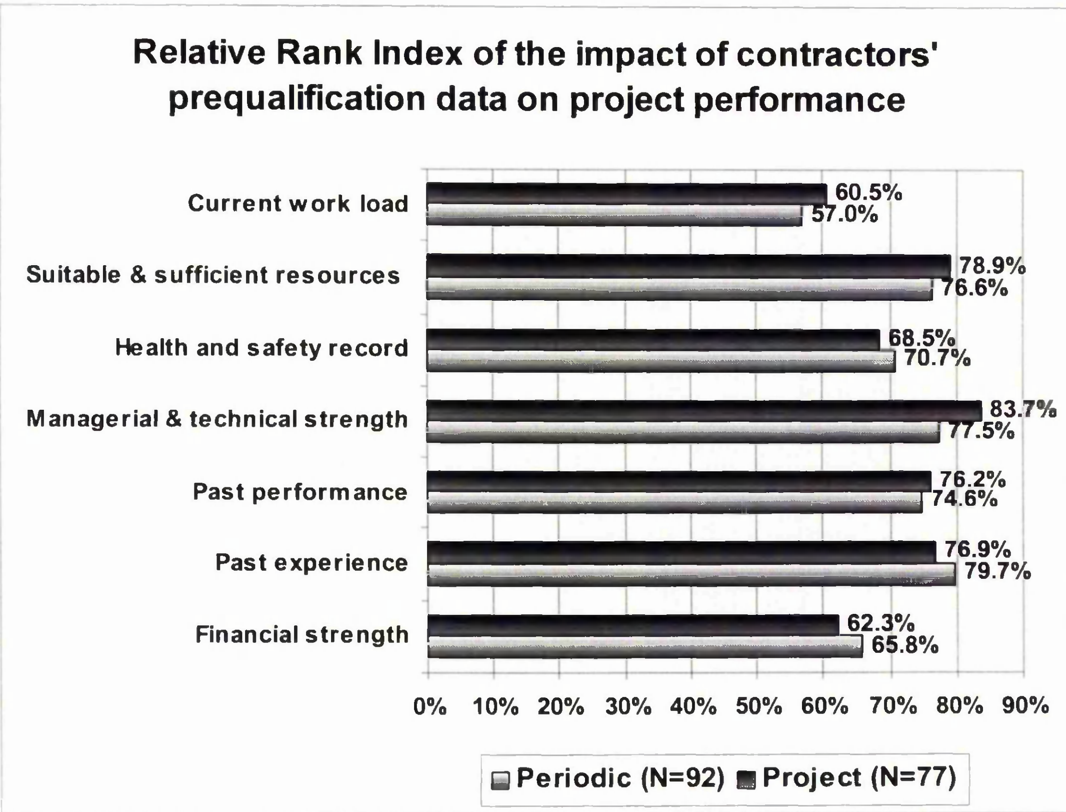


Figure 4.14 Relative Rank Index of the impact of contractors' prequalification data on project performance

However, further visual examination of Figure 4.14 and Figure F.3 in Appendix F, shows that the impact ranks of *financial strength*, *past experience* and *health and safety record* criteria have relatively higher importance, where contractors' data are evaluated at the periodic prequalification stage rather than at the project prequalification stage. On the other hand, the impact ranks of *past performance*, *managerial and technical strength*, *suitable and sufficient resources* and *current workload* criteria are higher in project prequalification. These findings show that current data which are possibly represented by *suitable and sufficient resources* and *current workload* criteria are more important in project prequalification, while *past experience* and *health and safety record* criteria, that can be characterised as historical data, are more important in periodic prequalification.

Furthermore, before conducting factor analysis to determine the interrelationship between prequalification criteria for both prequalification types, both sets of prequalification data were checked for reliability using the Cronbach's alpha coefficient and both sets of data are sufficiently reliable as seen in Table 4.15 and Table 4.17. In terms of the impact on project performance under periodic prequalification, Table 4.15 and Table 4.16 indicate that all prequalification criteria related to technical aspects such as *past experience*, *past performance*, *managerial and technical strength*, *suitable and sufficient resources* and *current workload* are loaded together and this factor explains 43.61% of the variance. While the second loaded factor represents non technical aspects (i.e. *financial strength* and *health and safety record*) with 14.36% of the variance explained.

To extract the determinant factors, the Principal Component Factoring method was used, since communalities of the periodic prequalification category above and around 0.6 were more than 50%. In order to interpret the factors, the varimax factor rotation technique was employed, since around 70% of the oblique correlation values of the periodic prequalification category were below 0.3. While the significant factor loadings were above 0.6, as the number of cases for periodic prequalification category was above 85.

Moreover, under project prequalification, Table 4.17 and Table 4.18 show that there are three factor solutions explaining 68.02% of the variance. These factors, as seen Table 4.18, can be characterised as current data (i.e. *managerial and technical strength*, *suitable and sufficient resources* and *current workload*), historical data (i.e. *past experience*, *past performance*) and non technical factors (*financial strength* and *health and safety record*). The detailed stages in order to meet the requirements of the factor analysis technique are shown in Appendix F.

To extract the determinant factors, the Principal Component Factoring method was used, since communalities of the periodic prequalification category above and around 0.6 were almost 90%. In order to interpret the factors, the varimax factor rotation technique was employed, since all the oblique correlation values of the periodic prequalification category were below 0.3. While the significant factor loadings were above 0.65, as the number of cases for periodic prequalification category was above 77.

Table 4.15 Rotated component factors for periodic prequalification

Periodic prequalification criteria	Factor loadings (N=92)	
	1	**2**
Managerial & technical strength	**0.739**	0.058
Suitable & sufficient resources	**0.736**	0.103
Current work load	**0.732**	0.058
Past performance	**0.701**	0.387
Past experience	**0.686**	0.298
Health and safety record	0.011	**0.856**
Financial strength	0.256	**0.645**
Variance	43.61%	14.36%
Cronbach's alpha coefficient	0.772	

Table 4.16 Summary of factor labelling for the periodic prequalification category

Factor	Name
1	Technical factor
2	Non technical factor

Table 4.17 Rotated component factors for project prequalification

Project prequalification criteria	Factor loadings (N=77)		
	1	**2**	**3**
Managerial & technical strength	**0.788**	0.174	0.087
Current work load	**0.786**	0.046	-0.049
Suitable & sufficient resources	**0.687**	0.208	0.238
Past experience	0.101	**0.870**	0.021
Past performance	0.236	**0.844**	0.119
Financial strength	0.022	-0.042	**0.849**
Health and safety record	0.143	0.176	**0.763**
Variance	35.80%	17.22%	15.00%
Cronbach's alpha coefficient	0.678		

Table 4.18 Summary of factor labelling for the project prequalification category

Factor	Name
1	Current data factor
2	Historical data factor
3	Non technical factor

Briefly, the difference between periodic and project prequalification in respect of the result of these factor analyses is that technical criteria under periodic prequalification are grouped together, while under project prequalification, technical criteria are loaded separately into two groups that are based on current and historical data characteristics. This result shows that the criteria impact on project performance in periodic prequalification is apparently influenced by variations of the reassessment cycle time in periodic prequalification (see Figure 4.4). For short reassessment cycle times, for example, one year's eligibility time in the prequalification list, the current data are still relevant, but for two years or more, the contractors' current data become out of date. While in the project prequalification system, current data are perceived to have the highest importance compared with historical data and non technical data, but the last two factors are still necessary to be included in contractor evaluation.

4.3.2.8 Prequalification types related to data collection methods

Table 4.19 shows that for both prequalification types *questionnaire form with data endorsed by related parties* and *third parties' published reports* (e.g. surety/ insurance company, financial consultant report) are ranked the first and second highest frequency of usage respectively. However, *interview*, *visit to the office* and *contractor presentation* have a higher frequency for project prequalification category than under periodic prequalification. The significant differences, based on client and contractor data separately tested using McNemar test, can be seen in Table 4.20. This conforms with the comment from a contractor respondent that is as follows:

> *Major projects may require an initial prequalification document, followed by a more detailed questionnaire, followed by presentation and interview before a place is achieved on the tender list.*

These differences are also shown in Table 4.21, where, in the project prequalification system, clients tend to use 3 or 4 techniques to obtain contractors' data, while in periodic prequalification they prefer only 1 or 2 techniques. From this result, the project prequalification system requires more detailed contractors' data. But it is important to note that *interview* and *contractor presentation* techniques only have around 60% frequency of usage and *visit to the office* is about 30%. This means that the questionnaire is the only method which is predominantly used in both prequalification types.

Promotion by contractors has higher frequency of usage by contractor respondents than their counterparts. Contractor respondents use this technique more frequently in project prequalification than periodic prequalification.

Table 4.19 Frequency of usage of data collection methods

Data collection method	Frequency of usage					
	Periodic prequalification			Project prequalification		
	Client	Contractor	Overall	Client	Contractor	Overall
Questionnaire form with data endorsed by related parties (e.g. accountants, previous clients, bank etc.)	83.1%	95.7%	88.1%	74.1%	93.3%	82.8%
Questionnaire form without data endorsed by related parties	18.3%	42.6%	28.0%	16.7%	42.2%	28.3%
Interview	23.9%	34.0%	28.0%	57.4%	71.1%	63.6%
Visit to the office	14.1%	29.8%	20.3%	25.9%	44.4%	34.3%
Contractors' presentation	25.4%	34.0%	28.8%	52.8%	84.4%	67.3%
Third parties (e.g. surety/ insurance company, financial consultant report)	50.7%	40.4%	46.6%	53.7%	40.0%	47.5%
Proactive promotion by contractors	12.7%	36.2%	22.0%	14.8%	53.3%	32.3%
N	71	47	118	54	45	99

Table 4.20 Chi-square test and McNemar test for frequency of usage of data collection methods

Data collection method	Chi-square test		McNemar test
	Periodic	Project	
	1	2	3
Questionnaire form with data endorsed by related parties (e.g. accountants, previous clients, bank etc.)	0.038*	0.011*	0.219/1.000
Questionnaire form without data endorsed by related parties	0.04*	0.005*	1.000/1.000
Interview	0.162	0.158*	0.000*/0.000*
Visit to the office	0.038*	0.053	0.031*/0/039*
Contractors' presentation	0.308	0.001*	0.000*
Third parties (e.g. surety/ insurance company, financial consultant report)	0.273	0.174	1.000
Proactive promotion by contractors	0.003*	0.000*	0.500/0.021*

Note:
- Columns 1 & 2: level of significance, two-sided (client versus contractor)
- Column 3: level of significance, two-sided (periodic versus project prequalification)
- Column 3: all values of level of significance are based on binomial distribution
- * Significant at 0.05 (two-tailed)

Table 4.21 Frequency of the number of data collection techniques used

The number of data collection techniques used	Frequency of usage	
	Periodic prequalification (N=118)	Project prequalification(N=99)
1	**26.3%**	9.1%
2	**28.8%**	19.2%
3	18.6%	**23.2%**
4	16.1%	**24.2%**
5	5.1%	9.1%
6	3.4%	10.1%
7	1.7%	5.1%
1&2	**55.1%**	28.3%
3&4	34.7%	**47.4%**

4.3.2.9 Prequalification types related to evaluation models

Table 4.22 indicates that *checklist approach* is more popular in periodic prequalification than in project prequalification,. On the other hand, *simple aggregate rating* is more preferred in project prequalification than periodic prequalification. These differences are significant for both prequalification types, except in the contractor category for *simple aggregate rating*, as seen in Table 4.23.

The combination of both techniques has relatively lower usage and similar frequency of usage between both prequalification categories, as depicted in Table 4.24. Other advanced evaluation methods are rarely used, such as Multi-Attribute Analysis, Knowledge Based System or Case Based Reasoning. It seems that the advanced methods are still too complicated to be implemented.

Table 4.22 Frequency of usage of evaluation model

Evaluation model	Frequency of usage					
	Periodic prequalification			Project prequalification		
	Client	Contractor	Overall	Client	Contractor	Overall
Simple aggregate rating (dimensional weighting/scoring)	56.1%	75.0%	50.0%	69.8%	92.9%	74.60%
Checklist approach (e.g. Yes or No)	72.7%	75.0%	73.2%	62.3%	42.9%	58.2%
N	66	16	82	53	14	67

Table 4.23 Chi-square test and McNemar test for frequency of usage of evaluation model

Evaluation model	Chi-square test		McNemar test
	Periodic	Project	
	1	2	3
Simple aggregate rating (dimensional weighting/ scoring)	0.026*	0.078	0.020*/0.500
Checklist approach (e.g. Yes or No)	0.854	0.190	0.006*

Note: - Columns 1 & 2: level of significance, two-sided (client versus contractor)
- Column 3: level of significance, two-sided (periodic versus project prequalification)
- Column 3: all values of level of significance are based on binomial distribution
- * Significant at 0.05 (two-tailed)

Table 4.24 Frequency of the number of evaluation models used

The number of evaluation models used	Frequency of usage	
	Periodic (N=82)	Project (N=67)
1	59.8	47.8
2	31.7	34.3

4.3.2.10 Prequalification related to prequalification performance

Regular review

It is necessary to review the effectiveness of prequalification systems in relation to the impact on the awarded contractor's performance, but the findings indicate around fifty percent and less of clients applied this approach (see Table 4.25). As seen in Table 4.26, a similar result was obtained from contractor respondents when asked whether they review any prequalification system in which they have been involved, especially if disqualified. Moreover, around one third of both respondent types do not regularly evaluate their systems. In addition, about 15% and less of clients annually evaluate their systems, while around 10% and less of contractors try to evaluate the prequalification system before they propose their prequalification documents. The findings for both samples for both prequalification categories are similar with respect to the evaluation of prequalification performance.

Table 4.25 Review of prequalification performance (client respondents)

Evaluation time	Frequency of application	
	Periodic prequalification	Project prequalification
After project completion	50.0%	46.2%
No evaluation	33.8%	32.7%
Annual evaluation	14.7%	9.60%
N	68	52

Table 4.26 Review of prequalification performance (contractor respondents)

Evaluation time	Frequency of application	
	Periodic prequalification	Project prequalification
After prequalification	53.8%	65.7%
No evaluation	35.9%	25.7%
Before prequalification	10.3%	8.6%
N	39	35

Using a paired McNemar test confirms that there are no significant differences in terms of the frequency of application of evaluation of prequalification performance between periodic and project prequalification for client and contractor respondents (see Figure F.1 and Figure G.2 in Appendix G).

Impact and effectiveness

Before determining the differences between the impact of prequalification system implementation on project performance, it is necessary to carry out a Kolmogorov-Smirnov test in order to check the differences between client and contractor samples. In order to simplify the calculation, the average impact values of cost, time and quality performance were used under the headings of periodic and project prequalification; it then was found that both prequalification types have significantly different ranks and distribution (see Figure G.3 in Appendix G). Thus, comparison of the impact is tested separately according to the sample types. The result indicates the impact for clients' data is significantly different between both prequalification types and the impact for the project prequalification category is higher than its counterpart (see Figures F.4 and F.5 in Appendix G). However, for contractors' data the tests are not able to discriminate any difference between both prequalification types (see Figures G.4 and G.5 in Appendix G).

Furthermore, further examination of the mean impact of implementation of both prequalification systems on project performance, as shown in Table 4.27, indicates that client respondents perceive the impact to be slightly higher than moderate level. On the other hand, contractor respondents' perception is slightly lower than moderate level for an impact scale of 1 to 3. The result indicates that the clients are more confident than contractors in terms of the usefulness of implementation of prequalification systems. These findings of the mean impacts on project performance indicate that both respondent types do not show high confidence, except at a moderate level.

Table 4.27 The mean impact of implementation of prequalification on project performance

Project performance	Periodic prequalification			Project prequalification		
	Client	Contractor	Overall	Client	Contractor	Overall
Cost	2.13	1.93	2.05	2.43	1.98	2.21
Time	2.14	1.81	2.01	2.34	1.88	2.12
Quality	2.38	1.88	2.18	2.4	1.86	2.15
Average	2.21	1.87	2.078	2.39	1.90	2.16
N	64	43	107	47	42	89

4.3.2.11 Prequalification related to project cost

Implementation of prequalification will add additional cost to a construction project. According to this survey, as seen in Table 4.28, the cost of project prequalification is slightly higher than that of periodic prequalification, but this difference is not significant if tested using a Wilcoxon sign ranks test (see Figures H.1 and H.2 in Appendix H) on the basis of overall data combined from the client and contractor respondent categories. It is necessary to note that there is no difference between client and contractor categories using a Kolmogorov-Smirnov test for data combination for both respondent categories (see Figure H.3 in Appendix H). This result agrees with the comment from a respondent which will be mentioned shortly.

Table 4.28 Prequalification cost related to project cost

Periodic prequalification			
Cost category	**Client (N=49)**	**Contractor (N=36)**	**Overall(N=85)**
<0.2% of project cost	77.6%	66.7%	72.9%
≥0.2% of project cost	22.4%	33.3%	27.1%
Project prequalification			
Cost category	**Client (N=45)**	**Contractor (N=40)**	**Overall(N=85)**
<0.2% of project cost	64.5%	65.0%	64.7%
≥0.2% of project cost	35.5%	35.0%	35.3%

Furthermore, regarding the detailed cost of both prequalification types to the client, around 85% of them spend up to 10 man-hours conducting a periodic prequalification per contractor and around 15% of them spend more than 10 man-hours. While for project prequalification about 70% of them spend 10 man-hours per project per contractor, and about 30% spend greater than 10 man-hours.

For the contractor respondent category, there is relatively the same frequency between the use of 10 man-hours or less and greater than 10 man-hours in respect of the preparation of a periodic prequalification proposal. While for a project prequalification proposal, the up to 10 man-hours category has a two times higher frequency than the greater than 10 man-hours category.

Using a Wilcoxon signed ranks test, there is no significant difference between periodic and project prequalification for either client or contractor respondents in terms of the cost of prequalification per contractor (see Figure H.4 Appendix H).

In the case of the contractors' experience, they assume the implementation of prequalification will increase the additional cost of a project, especially if evaluation is repeated with the same system but different clients. Two interesting comments from contractor respondents regarding the implementation of prequalification systems are as follows:

> *There needs to be more of a focus by clients on what they are really looking for. There is a move to target project specific issues with limited volume on response. This is to be encouraged. More up-front assessment criteria would be of benefit and would reduce costs. It appears at times clients do not appreciate that preparing prequalifications has a cost attached which the industry has to pay for. Longer term relationships are to be encouraged and this will reduce the need for the large number of prequalifications which the industry has seen in recent years.*

> *Prequalification is getting ever more tedious and time consuming. The same information is sent time and time again. The working system has high subjectivity factors. Prequalification for a £5 million project costs much the same to prepare as a £50 million project.*

However, in the case of clients' perception, the implementation of a prequalification system is necessary in order to select responsible and appropriate contractors, since construction project complexity and the numerous and various resources needed are tending to increase, as illustrated in the following comment from one of the respondents:

> *The construction industry is facing many changes and complexities. It is also interesting to note that the construction industry now serves more knowledgeable clients within a knowledge economy. Therefore I believe prequalification will become more stringent for contractors.*

4.3.2.12 Prequalification related to formal published guidelines

The availability of formal published guidelines is important and provides clear information about procedures, requirements and evaluation systems to interested contractors as well as being able to be used as a reference or as a rule bases for disputes, for example. In the case of client respondents, Figure 4.15 shows that the availability of guidelines in periodic prequalification systems is slightly higher than project prequalification, but below 50% of clients provide them for both systems. This result is confirmed by the contractor respondents' experiences (see Figure 4.16), where they say 70% and 60% of clients *rarely* provide the guidelines in periodic and project prequalification respectively. Only around 6% and 10% of contractor respondents say *usually* provided in periodic and project prequalification respectively, while about 20% and almost 30% of them say *sometimes*.

If further analysis of clients' and contractors' data for comparison between both prequalification categories using non parametric statistical techniques is carried out, there is no significant difference in both categories in the case of client respondents using a McNemar test (see Figure I.1 in Appendix I), but for contractor respondents it is significantly different and the availability is higher in project prequalification than in periodic prequalification using a Wilcoxon signed ranks test (see Figures I.2 and I.3 in Appendix I).

There is an interesting comment from a client respondent related to this case:

> *In the house building industry, developers tend to have a list of contractors who they commonly use (partner with). There are still tendering procedures on most projects, although certain contractors have agreed rates that are reviewed annually. The qualification procedures are very informal and there are no formal guidelines.*

Briefly, the difference between prequalification categories is not so important compared with the very few guidelines available. This indicates a large number of clients have still not perceived the importance of formal published guidelines, particularly as references for evaluation of prequalification performance, where this matter is confirmed by low frequency of performance evaluation as depicted in Table 4.25 and Table 4.26.

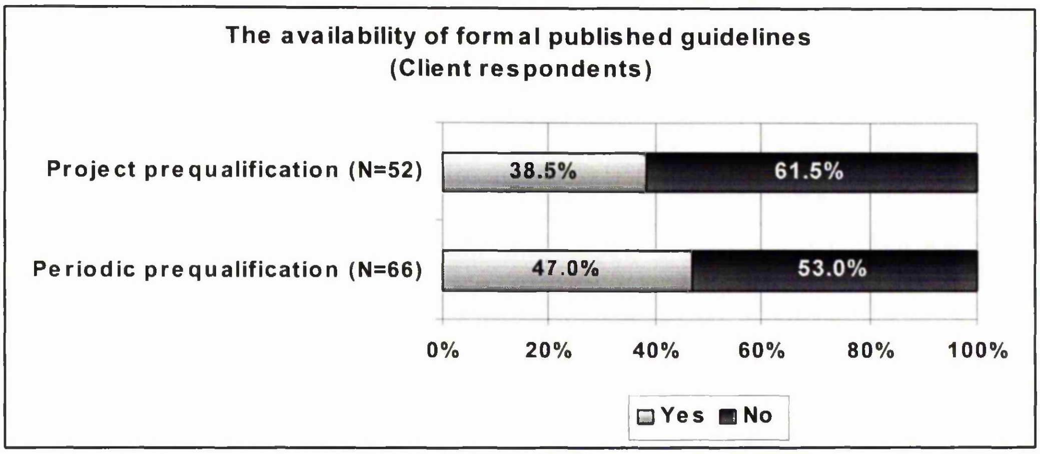


Figure 4.15 Frequency of the availability of formal published guidelines (client respondents)

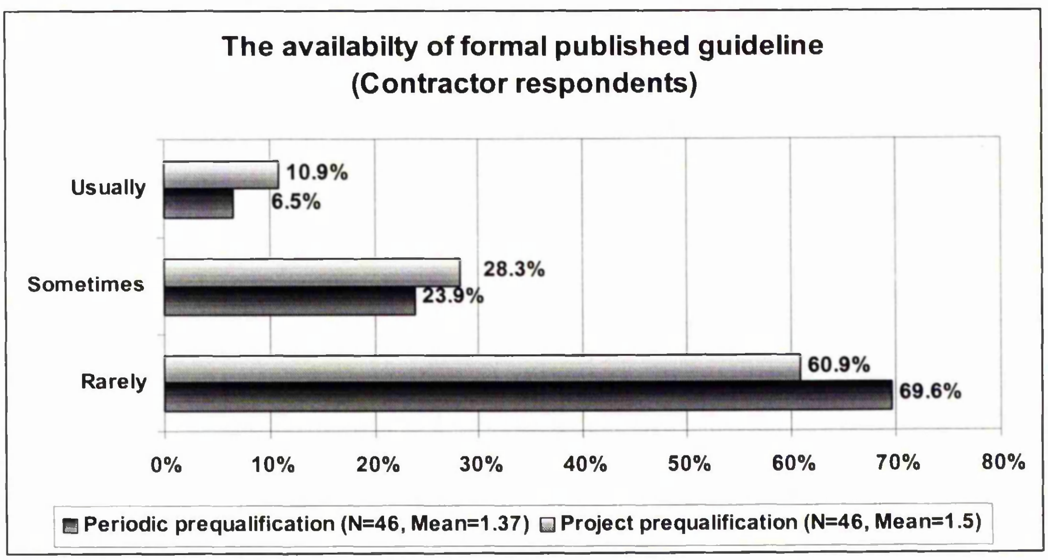


Figure 4.16 Frequency of the availability of formal published guidelines (contractor respondents)

4.4 DISCUSSION

The findings of the purpose of prequalification systems in section 4.3.1.1 are quite consistent with the findings in section 4.3.2.7 (see Table 4.29 and Table 4.30). Clients and contractors agree that technical factors related to contractors' historical and current data and non technical factors, which are a multi-criteria approach, can influence project performance. These factors should be examined together thoroughly due to the likelihood of their impact on project performance, if the contractors' data evaluated against the main criteria are lower or less than commonly expected.

Furthermore, the findings show that the main differences between both prequalification types, as seen in Table 4.30 and illustrated in Figure 4.17, are characterised by general factors for periodic prequalification and by specific factors for project prequalification, because project characteristics are less defined at the periodic prequalification stage than at the project prequalification stage and also project prequalification is intended for a particular project. Moreover, contractors' historical data are relevant to be evaluated in periodic prequalification due to the reassessment cycle of contractor evaluation which is characterised by a certain period of time. While contractors' current data are more appropriate to project prequalification as long as periodic and project prequalification are implemented as an integrated system.

The similarities of both prequalification systems depend on the requirements of all elements being incorporated in the prequalification system in order to succeed in the implementation of the systems. Thus, the differences are mainly related to the comparison level of simple and complex and general and specific requirements being applied, including procedures and methods/techniques used. The similarities are mainly related to the similar need and use of factors or criteria including procedures and methods/techniques used in the system.

Table 4.29 Summary of general prequalification characteristics

Section	Subject	Findings
4.3.1.1	The purpose of prequalification	**Client:** To obtain technically and financially competent contractors To reduce risk of poor project performance **Contractor:** Firm's competence to meet project characteristics Firm's demand and opportunity with regards to winning the contract Firm's image and relationship in respect of firm's promotion
4.3.1.2.	Proportion of prequalification types	50% of respondents implement both prequalification types and 50% use either periodic or project prequalification
4.3.1.3.	Reassessment cycle time	Predominantly long term (equal to or more than 2 years)
4.3.1.4	Prequalification team	**Client**: QS, Engineer and Businessman **Contractor**: Businessman, Engineer and Project Manager
4.3.1..5	Constructionline	Increase in its popularity as one type of periodic prequalification, but clients still dominantly prequalify contractors based on their in house periodic prequalification system or combine both prequalification types

Table 4.30 Summary of the differences and similarities of periodic and project prequalification characteristics

Section	Subject	Findings
4.3.2.1.	Procurement type	*Traditional type* is predominantly used compared with other methods in **both prequalification types** **Effect of prequalification types:** *Traditional type* (**significant difference**) *Design and build* (**significant difference**)
4.3.2.2	Project size	**Periodic prequalification:** A tendency to increase as the value of the project becomes smaller **Project prequalification:** No unique trend when the project sizes are changed
4.3.2.3	Relationship of contract and prequalification list numbers	**Periodic prequalification:** Opportunity of winning the contract is relatively lower **Project prequalification:** Opportunity of winning the contract is relatively higher
4.3.2.4	Prequalification team	*In house* team work is predominantly used compared with other sources in **both prequalification types** **Effect of prequalification types:** *In house* sources have **similar** frequency of usage *Combination* sources have **significant difference** in use
4.3.2.5	Criteria development	**Both prequalification types:** *Project size* and *type* are the highest influencing factors, the grouped factors under the heading of *project characteristics* have lower influence than those under the headings of *compliance with regulations* and *individual/organisational characteristics* **Effect of prequalification types:** The factors under *project characteristics* have a **significant difference** for both prequalification types, but factors under both *compliance with regulations* and *individual/ organisational characteristics* are **similar**

Table 4.30 Summary of the differences and similarities of periodic and project prequalification characteristics (*continued*)

Section	Subject	Findings
4.3.2.6	Frequency of usage of prequalification criteria	**Both prequalification types:** *Past experience, past performance, financial strength* and *health and safety record* have the highest frequency of usage **Effect of prequalification types:** **Both prequalification types** are **similar** in respect of **historical data** (*past experience, past performance, financial strength and, health and safety record*), but **current data** (*current workload, suitable and sufficient resources and management and technical strength*) are **significantly different**
4.3.2.7	The impact of main criteria on project performance	**Both prequalification types:** The highest ranks are *past experience, past performance* and *managerial and technical strength, suitable and sufficient resources* and the second highest are *health and safety record, financial strength* and *current workload* **Periodic prequalification:** There are two groups of factors having high correlation within the groups, namely, *technical factor* and *non technical factor* **Project prequalification:** There are three groups of factors, namely, *current data factor, historical data factor* and *non technical factor* **Effect of prequalification types:** Only the *managerial and technical* criterion has **significantly different** impact on project performance in respect of the prequalification types
4.3.2.8	Data collection method	**Both prequalifications types** use *Questionnaire form with data endorsed by related parties* as the main method **Periodic prequalification:** *Questionnaire form with data endorsed by related parties* and *third party formal information* are the main methods to be used (mainly use two combined techniques) **Project prequalification:** *Questionnaire form with data endorsed by related parties, interview, contractors' presentation* and *third party formal information* are the main methods to be used (mainly use four techniques combined) **Effect of prequalification types:** *Interview, visit to the office and contractor presentation* are **significantly different** *Proactive promotion by* contractors is **significantly different** (contractor data)
4.3.2.9	Evaluation techniques	**Periodic prequalification:** *Checklist approach* (e.g. Yes or No) is mostly used and a popular technique **Project prequalification:** *Simple aggregate rating* (dimensional weighting/scoring) is the most popular and tends to be combined with *Checklist approach* (mainly used on the basis of two combined techniques) **Effect of prequalification types:** *Simple aggregate rating* is **significantly different** (client data) *Checklist approach* is **significantly different**

Table 4.30 Summary of the differences and similarities of periodic and project prequalification characteristics (*continued*)

Section	Subject	Findings
4.3.2.10	Prequalification performance (Review of prequalification performance)	**Both prequalification types** are **similar** in terms of frequency of the review of prequalification performance which is relatively infrequently **Effect of prequalification types:** All related variables are **not significantly different**
4.3.2.10	Implementation of prequalification systems (impact and effectiveness on project performance)	**Project prequalification** is more effective than **periodic prequalification** based on clients' perception, but contractors perceive both have the same impact on project performance **Effect of prequalification types:** All related variables are **not significantly different**
4.3.2.10	The cost of prequalification	**Both prequalification types** are **similar** in respect of the cost ratio of prequalification to total project cost and unit cost per contractor per project **Effect of prequalification types:** All variables related are **not significantly different**
4.3.2.10	Formal published guidelines	**Both prequalification types** provide few formal published guidelines **Effect of prequalification types:** There is **no significant difference** between both **prequalification types** under client respondent category in respect of availability of formal published guidelines, but under contractor respondent category it is **significantly different**

In the periodic prequalification system, contractor evaluation emphasises contractors' competence at a certain level of project characteristics, especially a certain range of project size and type or competence comparison among the contractors in the form of benchmarking or a ranking system. This limitation of this evaluation type is due to lack of detail and clear definition of project characteristics. While in the project prequalification system, contractors are evaluated for a particular project where, at this stage, the project has reached the detailed level for project execution.

The result of the impact of prequalification criteria on project performance shows that periodic prequalification does provide clear cut of evidence of what types of criteria characteristics influence project performance, instead of showing the tendency of criteria related to historical data which have a higher impact than current data. While in project prequalification, current data have a higher impact.

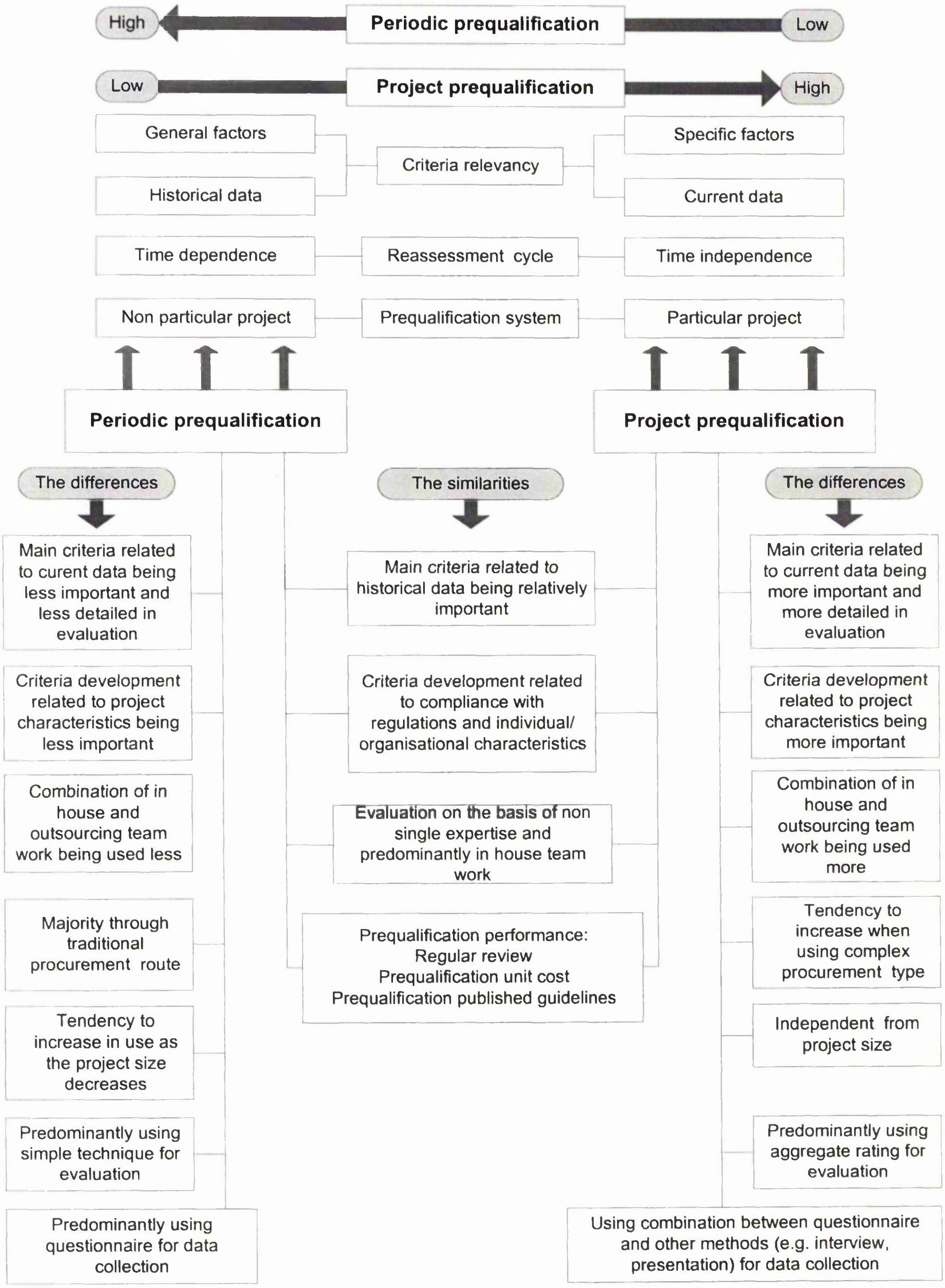


Figure 4.17 Schematic diagram of the identification of periodic and project prequalification characteristics

Additionally, criteria related to the technical factors have higher impact than those related to the non technical factors in the periodic prequalification category and current data, historical data and non technical factors are subsequently ordered from high to low impact in the case of project prequalification. It is quite difficult to separate the technical factor into factors related to historical and current data in the periodic prequalification category due to data in this survey coming from several types of reassessment cycle times, where the data in the one year reassessment system are more current than the two-year reassessment system.

Regarding the result in section 4.3.2.10, it seems that there is possible improvement of prequalification performance in terms of regular review of prequalification performance including the impact and effectiveness of implementation of prequalification on project performance and the availability of formal published guidelines.

In the case of prequalification cost, even though the unit cost of project prequalification is slightly higher than its counterpart, the unit cost is not statistically different between both prequalification types. The cost of periodic prequalification might be relatively high; for the client, the cost includes maintenance of prequalification records, information processing, issuing prequalification certificates and office storage. For the contractor, especially at the level of the construction industry, duplication of the prequalification process can not be avoided as long as clients still maintain their own periodic prequalification system.

To reduce the impact of periodic prequalification implemented at the client level, this prequalification can be outsourced to a third party. Thus, a client can share information about contractors' data which is relevant to their project requirements. This third party periodic prequalification can also be integrated with project prequalification at the client/particular project level. This means periodic prequalification applied at the outsourcing level would mainly deal with historical data and project prequalification applied at the project level would mainly be concerned with current data that meet the specified requirements of a particular project.

However, the execution of this prequalification type is not easy, even though the idea is good. For example, Constructionline, an outsourcing periodic prequalification system, has had slow acceptance in the UK construction industry during the last 3 years (King 2002) and one of the respondents said *"Constructionline scheme a great idea, poorly executed"* (see Table 4.5).

The identified problems described in section 4.3.1.5 are in parallel with the Constructionline Working Group Report, even though one County Council with a construction programme of £60 million and partially using the scheme, has saved £20,000 per year and a London Borough with a programme of £30 million, fully using the scheme, has saved £60,000 per year and on the contractors' side there have been also savings shown to the industry. But the scheme has several problems, including *functional issues* that are related to technology such as access and speed of operation, problems with terminology, the currency, completeness and range of information available, like that on local firms, and *presentational issues* that are related to the need for an explanation of the scheme limitations such as a client could not fully rely on the Constructionline list for their procurement process, and it is necessary to further asses contractors' competence, if required, on the basis of a particular client and project requirements. This second issue is that the procurement process is the responsibility of clients to manage, so that they are obliged to remain transparent and provide freedom of movement and quality of treatment for their contractor evaluation including the limitations of Constructionline if they fully or partially use the system (King 2002).

The taxonomy of contractor prequalification found in this empirical study can be classified into two main categories, namely, periodic and project prequalification and each category can be divided into two sub categories, in house and outsourcing prequalification (see Figure 4.18). Select list, approved list or standing list is a type of in house periodic prequalification system, while Constructionline is outsourcing periodic prequalification system. Most project prequalification systems are in house prequalification systems, because this prequalification system is intended to be used for a particular project as well as a particular client. Outsourcing project prequalification is rarely found due to the nature of project prequalification system. However, a combination of outsourcing periodic prequalification and in house project prequalification has been identified.

It is important to note that taxonomy is a categorical system that can specify the units of empirical realities and also describe the relationship or interdependency among constructed categories on the basis of empirical observations (Frankfort-Nachmias and Nachmias 1996). Moreover, the objectives of this taxonomy are to provide an orderly scheme for classification and description and to summarise and inspire descriptive studies (Frankfort-Nachmias and Nachmias 1996).

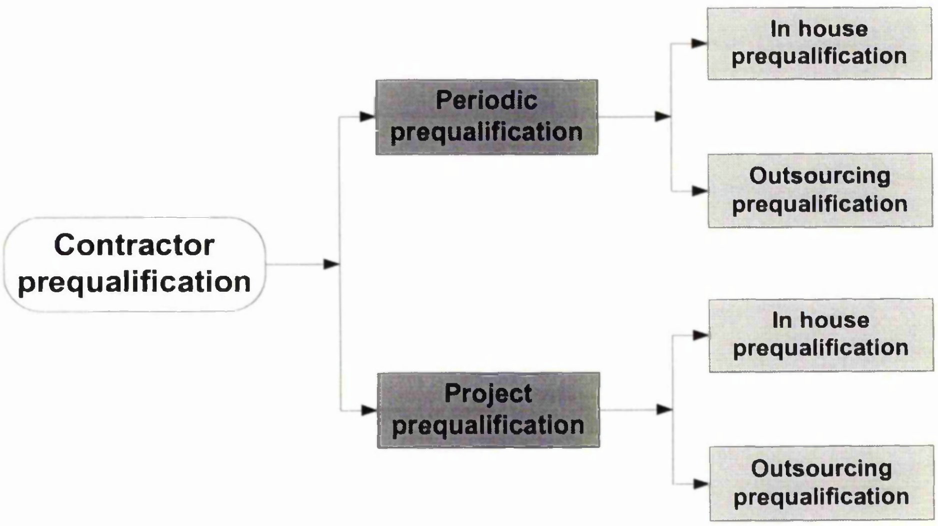


Figure 4.18 Classification of contractor prequalification

4.5 SUMMARY

The characteristics of both prequalification types have been presented, analysed and discussed thoroughly. If both periodic and project prequalifications are an integrated system, periodic prequalification criteria are applicable to the evaluation of contractors' historical data with the assumption that this prequalification type is time dependent and the evaluation system is outsourced to a third party and the data evaluation is based on of a certain range of project size and type and/or benchmarking system. Project prequalification criteria are applicable for current data and can be combined with the results of contractor evaluation on the basis of periodic prequalification that is relevant to particular project and client objectives.

The taxonomy of the periodic prequalification system can be divided into two main types: in-house periodic prequalification that is applied at the level of the client's organisation and where its characteristics are based on the annual number of projects, project and client characteristics, and outsourcing periodic prequalification that is applied at the level of similar organisations (e.g. certain groups of local authorities with similar project size and type) or at the industry level (e.g. Constructionline system).

This development of the taxonomy of contractor prequalification is important in order to identify and categorise existing prequalification practices and so appropriate characteristics of a particular subject or type of prequalification system may be understood and a certain type of prequalification system distinguished from other types.

The findings of the main periodic prequalification criteria related to the usage and the impact on project performance will be used for further development of the detailed periodic prequalification criteria as the main part of this research.

CHAPTER 5

Identification of periodic prequalification criteria

5.1 INTRODUCTION

Generally, previous research of contractor prequalification has been concerned with identifying common sets of prequalification criteria. However, every construction project is naturally characterised by both specific and common requirements. Therefore, it is difficult to universalise the criteria at project level, when specific criteria are usually associated with a particular project. To improve the process, periodic prequalification is an alternative choice to enable contractors' common competence to be screened at the early stage, while project prequalification is considered for specific requirements at the tender stage.

This chapter presents the most common criteria found in periodic prequalification practices based on a questionnaire survey and the formal guidelines of some prequalification systems in the UK. The most common criteria are summarised and discussed under the headings of financial strength, past experience, past performance, technical and managerial strength and compliance with regulations.

In addition to identification of periodic prequalification criteria, some guidelines from other countries such as Japan, Malaysia, Australia and the USA are used for references in order to confirm the most common usage of prequalification criteria in periodic prequalification systems, including relevant sub criteria. The structure of the way this chapter is presented is depicted in Figure 5.1.

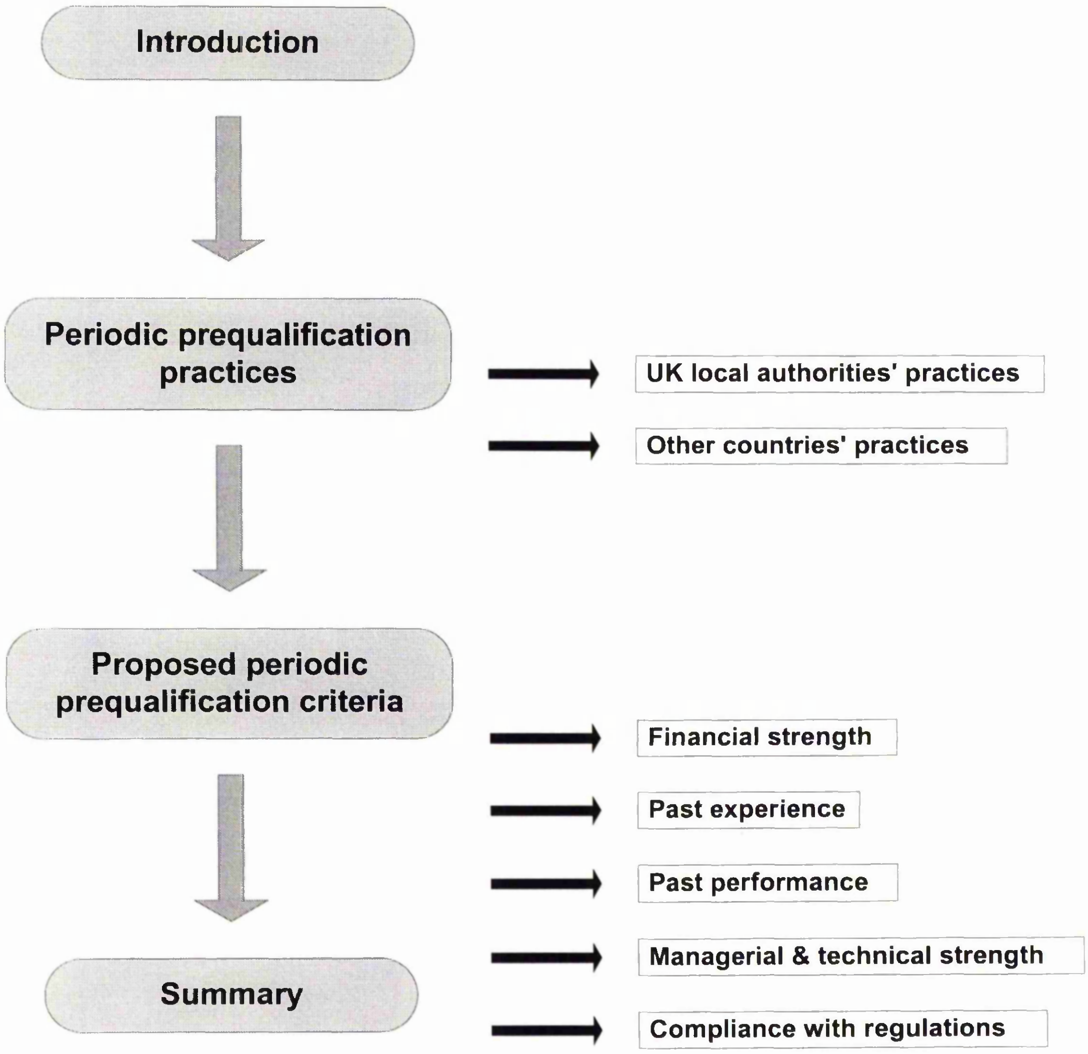


Figure 5.1 Structure of chapter 5

5.2 THE UK LOCAL AUTHORITIES' PRACTICE

5.2.1 Required contractor data

Of seven periodic prequalification guidelines of UK local authorities, the common contractors' data required are: general information, financial information, technical resources and references information, health and safety information and equal opportunities information. Environmental issues information is also sometimes included in the prequalification proposal. After examining the Standard Form of Tendering Questionnaire for application for admission to approved lists of contractors published by the National Joint Consultative Committee (NJCC) for Building, the required information in the seven prequalification guidelines is designed on the basis of the NJCC's approved lists guideline (NJCC 1994a). This guideline is intended as a reference to design a standard questionnaire for developing a list of potential contractors for future projects. This guideline is also similar to the report of Working Group 5 of the Construction Industry Board entitled "A framework for a national register for contractors" (Construction Industry Board 1997c).

According to Hatush (1996), based on a literature review and interviews with eight public clients and one private client in the UK, there are five categories of information required by the clients, namely, general information, financial information, technical information, managerial information and safety information. General information is mainly used for administrative purposes in respect of the construction firms' legal status, litigation tendency, size, age and image. Other information is mainly used for assessing their financial, technical and managerial competence as well as their capability and capacity to comply with health and safety.

However, if general information is not carefully examined, a contractor could fail to perform or complete a construction project contract. Russell and Jaselskis (1992) found that the familiarity of a client with the contractors' abilities is a significant variable. This variable includes the firm's telephone references and contact address of personnel within an organisation familiar with the contractor's recent performance.

Referring to the main prequalification criteria discussed in Chapter 3, technical resources and references information can be used for assessing the contractors' competence through past experience, past performance and technical and managerial criteria. Information related to health and safety, equal opportunities and environmental issues is evaluated against compliance with regulations criteria. The findings of the relationship between prequalification criteria and the required contractor data in the local authorities' periodic prequalification system are the main sources for determining the periodic prequalification criteria for further analysis.

5.2.1.1 General information

The common general information includes detailed company information and the name of the representative of the company who deals with prequalification proposals and the legal status of the company. Clients sometimes require the structure of the organisation including details of persons in charge in the main positions. The common information used can be seen in Table 5.1 and Table 5.2 shows the cross tabulation of general information required in the seven guidelines. Professional misconduct information is also required by some clients and it is possible to reject further contractor evaluation during the prequalification process.

Table 5.1 General information

General information
Name of the firm
Main address details including branch address, telephone and fax number and email address
Legal status of the firm (e.g. limited firm)
Names and positions of the most senior people in the firm
Organisational structure including detail of managers
Name and position of the person applying for prequalification on behalf of the firm
Relative relationship between the firm's employers and employees and the client's employees especially persons who have senior position with both parties
Historical background of managers in respect of financial matters (e.g. bankruptcy, liquidation)
Type of company (i.e. sole trader, partnership, company)/ legal status of the firm including the firm's registration date and number if the firm is a limited company.

Table 5.2 General information required by local authorities

Required general information	Local authorities						
	1	2	3	4	5	6	7
Company Name	✓	✓	✓	✓	✓	✓	✓
Correspondence details	✓	✓	✓	✓	✓	✓	✓
Type of firm including details of registration	✓	✓	✓	✓	✓	✓	✓
Contact person and position	✓	✓	✓	✓	✓	✓	✓
Organisational structure including the names and positions of the persons in charge in the structure	✓		✓		✓	✓	✓
Historical background of managers in respect of financial matters (e.g. bankruptcy, liquidation), family relationship with the client's employees, working experience with the client	✓				✓	✓	✓

5.2.1.2 Prequalification criteria and contractors' main information

To identify the required contractor data used for evaluation of a contractor's competence in periodic prequalification systems, the guidelines from seven local authorities mentioned before were inspected and summarised and prequalification criteria identified in the previous chapter were also considered. The summary of contractors' data required can be seen in Table 5.3.

5.2.2 Prequalification criteria and contractors' data

5.2.2.1 Financial Strength

Analysis of financial strength is usually required to indicate the likelihood of contract failure in terms of contractor capability and capacity, for any type of prequalification system. But in the case of periodic prequalification, the evaluation of this factor emphasises financial historical data in order to obtain a picture of financial stability over a certain period of time rather than the current financial position. Of seven guidelines, the majority of clients require financial data for the last three years.

Table 5.3 Prequalification criteria and main contractor data required by local authorities

Prequalification criteria	Contractor data	Local authorities						
		1	2	3	4	5	6	7
Financial strength	Information including: turnover; profit and loss; balance sheet, full notes to the account; auditor's report	✓	✓	✓	✓	✓	✓	✓
	Bank reference	✓	✓	✓	✓	✓	✓	✓
	Insurance including employers liability and public liability	✓	✓	✓	✓	✓	✓	✓
	Tax related information	✓	✓	✓	✓	✓	✓	✓
	Data for the last 2 or 3 years	✓	✓	✓	✓	✓	✓	✓
Past experience	Project characteristics including: type of works; type and size of contracts; time schedule and locations	✓	✓	✓	✓	✓	✓	✓
	Technical reference from clients/ client's data	✓	✓	✓	✓	✓	✓	✓
Past performance	Performance related to: claims; failure to perform the contract, contract terminated; deleted from standing list; withdrawn from contract prematurely; non resolution of contract dispute	✓	✓	✓	✓	✓	✓	✓
Managerial & technical strength	Standard and level of competence (i.e. registration in specialist association or regulatory body)	✓	✓	✓	✓	✓	✓	✓
	Quality assurance policy or certificate	✓	✓		✓	✓		
	An approximate number and qualification of regular employees engaged in the specific type of work including at the managerial, administrative, technical and operative levels		✓	✓	✓	✓		
Suitable & sufficient resources	List of trade/ work with subcontractors	✓	✓	✓	✓	✓	✓	
	Capacity and type of equipment, plant and transport					✓		
Compliance with regulations	Health and safety policy and procedures including number of accidents	✓	✓	✓	✓	✓	✓	✓
	Equal opportunities (the Race Relations Act)	✓	✓	✓	✓	✓	✓	✓
	Environmental management policy	✓	✓	✓	✓			✓
Current workload	Details of work currently being undertaken	✓		✓			✓	
	Range of annual capacity of work values for every type of work	✓	✓	✓	✓	✓	✓	✓

Ratio analysis, which is derived from a financial statement or a balance sheet, is commonly used to determine liquidity, operations, leverage, coverage and specific expense items. Moreover, the recommended average of the latest three years turnover must be three times greater than any individual project value and is used to determine the range of project value. As suggested by the Construction Industry Board (1997c), profitability, liquidity and adequate net assets are financial criteria which have been well established. This financial information, along with previous performance in respect of project size and type, can be used to determine the recommended maximum financial value of a contract. One of the guidelines states clearly that allowable project size for a contractor is not more than one third of its annual average of the latest 3 years' turnover.

Other financial information, such as bank references and tax information, is needed to show the contractor's financial reputation and sources (e.g. bank, creditor) and insurance cover in the case of unforeseen adverse events. According to the guidelines, clients require employer's liability insurance and public liability insurance with the minimum values of £ 5-10 million and £ 2-10 million respectively, depending on project values.

5.2.2.2 Past experience

This criterion is used to trace successfully completed projects based on project type, size and location. This information, along with financial information as discussed before, is required in order to determine a contractor's ability level to perform projects within certain value bands and types. The data must include previous client references. Besides validation of the contractor's technical competence, clients need to know their relationship with previous clients. Most information required is limited to contract time and value, client details, project location and description of work.

5.2.2.3 Past performance

The guidelines show that clients focus more on analysis of historical claims, failure to perform contracts, deletion from standing lists and non resolution of contract disputes rather than time, cost and quality performance. Only one guideline requires more detail about previous contracts and actual time and cost as mentioned before. Additionally, another guideline makes a limit of one project at a time until performance on this project has been assessed, if a contractor has not previously worked with the client.

5.2.2.4 Managerial & technical strength

All clients in the guidelines require certification from an appropriate regulatory body or association, referring to the standard and level of specific competence such as CORGI (The Council for Registered Gas Installers) and NICEIC (The National Inspection Council for Electrical Installation Contracting). Some clients require knowledge of the qualifications of personnel related to specific types of work, either at management or technical level, as well as certification of quality assurance such as ISO 9000.

5.2.2.5 Suitable & sufficient resources

In terms of the suitable and sufficient resources factor, lists of trade or work subcontractors like suppliers and specialist subcontractors are common requirements. In addition, the capacity and type of equipment, plant and transport are examined in order to complement a contractor's proposal related to its specific work type and size.

5.2.2.6 Compliance with regulations

Regarding compliance with regulations, health and safety and equal opportunities criteria are the most important criteria, and all clients in the guidelines ask contractors to submit organisation and management structures, policies and procedures and recording systems for both related regulations in detail. Detailed requirements commonly found in the seven guidelines can be seen in Appendix J.

5.2.2.7 Current workload

Some guidelines require details of work currently being undertaken by a contractor. But this factor has limitations in showing a contractor's capacity, especially if the frequency of assessment cycle is longer than one year as the contractor's capacity could drop below the previous level due to ongoing current projects or the influence of external criteria such as bad economic conditions or regulation changes. Additionally, contractors at the level of periodic prequalification must confirm their annual capacity for every type of work in which they are interested. But this approach has the same limitation for assessment cycles of more than one year.

5.2.3 Summary of main criteria for periodic prequalification

The periodic prequalification criteria in Table 5.4 are summarised and can be used for evaluation against contractor historical data. Past experience and past performance criteria are definitely related to historical data. But financial strength, managerial and technical strength and compliance with regulations criteria could be in both categories, either historical or current data.

By examining the certain periodical year of the financial statement in the case of historical data related to financial strength criteria, it could be possible to indicate a contractor's financial management abilities. Examination of their certificates of quality assurance, training systems and employment turnover, for example, can provide information about the certain quality level of a contractor's maintainability competence for a certain periodical time. Additionally, it is not sufficient to examine the management system or policy of compliance with regulations, without examining the historical data for the last certain periodical time, such as accident records, unlawful racial discrimination records, recruitment system of employees or law suite records of related environmental cases. Therefore, the chosen appropriate contractors' data relevant to historical data in the periodic prequalification system can be acceptable.

On the other hand, for the case of current data, their relevancy becomes less important in periodic prequalification. It might happen that contractor capacity, for example, would no longer satisfy the construction workload requirements of a particular project due to current project workloads. In other words, working capital, resources or key personnel may have reduced to a level that may significantly influence a contractor's project performance in respect of time, cost and quality due to their other ongoing projects. Thus, suitable and sufficient resources and current workload criteria can be excluded in the periodic prequalification system as long as current data are evaluated in detail at the tender stage or in project prequalification.

Therefore, the proposed periodic prequalification criteria are based on several assumptions as follows:

- The first assumption is to eliminate the current workload criterion that is less relevant to periodic prequalification characteristics. This is because of the fact that the assumption is more concerned with contractors' historical data for periodic prequalification; and

- Another assumption is to be more concerned with capability rather than capacity, where capacity is more related to information about the amount or the number of specific resources being needed in the project prequalification process in order to meet the particular project objectives. On the other hand, capability is more related to ability and achievement of contractors' historical data Hence, this assumption is related to general issues or trends for periodic prequalification rather than specific or detailed issues, as periodic prequalification characteristics are time dependent and not intended for a particular project.

Table 5.4 Summary of periodic prequalification criteria

Prequalification criteria	Contractor data
Financial strength	Information including: turnover; profit and loss; balance sheet, full notes to the account; auditor's report
	Bank reference
	Insurance including employers liability and public liability
	Tax related information
	Data for the last 2 or 3 years
Past experience	Project characteristics including: type of works; type and size of contracts; time schedule and locations
	Technical reference from clients/ client's data
Past performance	Performance related to: claims; failure to perform the contract, contract terminated; deleted from standing list; withdrawn from contract prematurely, non resolution of contract dispute
Managerial & technical strength	Standard and level of competence (i.e. registration in specialist association or regulatory body)
	Quality assurance policy or certificate
	An approximate number and qualification of regular employees engaged in the specific type of work including at the managerial, administrative, technical and operative levels
	List of trade/ work with subcontractors
Compliance with regulations	Health and safety policy and procedures including number of accidents.
	Equal opportunities
	Environmental management policy

5.3 PREQUALIFICATION CRITERIA FROM OTHER COUNTRIES' PRACTICES

5.3.1 Japan

Contractors are classified according to the designated value bands of project contracts and categorised project types. This classification system is intended to ensure contractors' competence which is suitable for a certain project size and type and to protect small and medium-size construction firms by appropriately distributing construction work. The prequalification system is applied as a national mandatory standard requirement for entering any construction public works and the reassessment cycle time is 2 years (Kunishima and Shoji 1996).

Contractors are classified against criteria, known as *business evaluation*, which are as follows (Ministry of Land Infrastructure and Transportation 2000; Kunishima and Shoji 1996):

- Business size;
  - Turnover relevant to the sought project type;
  - Net worth;
  - Number of employees;
  - Bonding capacity;
- Business status;
  - Financial ratio;
  - Working capital (i.e. how long it can be maintained);
- Technological competence;
  - Number of engineers relevant to the sought project type;
  - Past experience and past performance evaluated on the basis of the sought project type;

- In respect of past experience, credit is given for the application of advanced construction techniques such as construction facilities of a special structural type, use of special construction methods, or use of special construction management methods;
- Past performance based on projects completed in the last 2 years;

- Others (e.g. social conditions);
  - Workers' welfare conditions;
  - Construction safety record;
  - Years in business;
  - Construction business accounts.

5.3.2 Malaysia

In Malaysia, before carrying out any construction project, every contractor must be prequalified or registered in the Construction Industry Development Board (CIDB). Contractors are classified according to the designated value bands of project contracts and designated project types. Project type consists of project category (i.e. civil engineering construction, building construction and mechanical/electrical) and specialisation (e.g. railway track, soil investigation and stabilisation) (Rashid 2002).

This prequalification system is applied as a national mandatory standard requirement for entering any construction works and the reassessment cycle time is 3 years and 60 days before registration expires a contractor must apply for renewal and the whole prequalification process is repeated (Rashid 2002).

Contractors are classified against the criteria as follows (Rashid 2002; CIDB Malaysia 2000):

- Adequate financial capacity (i.e. paid-up capital and net capital worth), which means a contractor must have a minimum paid up capital or net capital worth equivalent to 5% of the allowable maximum project contract;

- Sufficient number of qualified and experienced key technical personnel relevant to the applied work category/specialisation/firm's experiences relevant to applied work categories; the key technical personnel must be fulltime employees not associated professionally with or employed by any other third party;

- Sufficient number of plant and equipment relevant to the applied work category/specialisation;

- Good performance record;

- Subcontractor lists along with contractual documents containing a description of past executed projects (e.g. value, type);

- Relevant certification issued by regulatory bodies for specific work types such as electricity, gas or plumbing; and

- Compliance with regulations of any written law or rule affecting construction activities relevant to the project category/specialisation.

5.3.3 New South Wales Public Works and Services

The Department of Public Works and Services of New South Wales (NSW) in Australia requires every contractor to be prequalified before submitting a tender. Through this periodic prequalification every contractor is classified according to the designated value bands of project contracts and the designated project types. Project types are categorised into building and water and wastewater treatment works (NSW Department of Public Works and Services 2001).

This prequalification system is applied as a standard system at the client level and the reassessment cycle time is 2 years and previous prequalification records, along with other performance reports prepared by NSW Government and other agencies, are considered to be reviewed during the contractor prequalification renewal process. This prequalification scheme is applied to contract values with a minimum value of AUS$2 million based on the 2001-2003 scheme (NSW Department of Public Works and Services 2001).

Contractors are classified on the basis of the criteria as follows (NSW Department of Public Works and Services 2001):

- Business age is a minimum of 2 years;
- Satisfactory recent performance on contracts similar to the sought project value and type;
- Submission of annual audited financial statements for the last 3 years;
- Adequate financial capacity which requires a minimum turnover of A$1 million for works more than A$500,000, a net worth (total assets less total liabilities) of not less than 5% of the sought financial range (contract value), a current ratio of more than 1 and working capital of more than 10% of the maximum sought financial range;
- Possession of acceptable quality assurance system/certification;
- Possession of accredited occupational health safety and rehabilitation management system for contracts valued at A$3 million and above;
- Possession of certified environmental management system for contracts value at A$10 million and above;
- Submission of a statement of compliance with regulations (i.e. industrial relations management, training management guidelines, aboriginal participation in construction); in the case of the Occupational Health Safety and Rehabilitation (OHS&R) management system, prequalification applicants are required to provide any past records for the last 2 years including improvement notes, prohibition notes, fines and convictions; in the case of environmental issues, prequalification applicants are required to provide court orders recorded against the firm for the 2 previous years;
- Performance record (e.g. cost, time performance);
- References (e.g. previous clients, banks);
- Current workloads;
- Liquidated damages retained;

- Geographical location for each category selected;
- Information on the number of qualified and experienced key technical and managerial personnel relevant to the applied work category; and
- Information on the number of plant and equipment relevant to the applied work category.

5.3.4 Indiana Department of Transportation (IDOT) USA

Clients from the States Department Of Transportation (SDOT) in the USA commonly implement annual prequalification and prequalify contractors based on maximum rating systems such as the maximum dollar amount of work size that a contractor can enter at the tender stage for a particular project (Palaneeswaran and Kumaraswamy 2001; Russell 1996; Russell and Skibniewski 1988). In addition, the main criteria commonly used by SDOTs are similar to the main criteria in Table 5.3 (Minchin and Smith 2001).

Indiana Department Of Transportation (IDOT), for example, qualifies a contractor using a set of criteria including financial ability, condition and adequacy of plant and equipment, organisation, prior experience, record of construction, and other pertinent and material facts which may affect its classification such as contractor's attitude toward department rules, the general public, and equal employment opportunity requirements. Current workload criteria are also evaluated in order to determine the maximum work capacity of the contractor including its subcontractors' work capacity in respect of the type and quantity of uncompleted works (Indiana Department of Transportation USA 2004).

Furthermore, classification of the maximum dollar amount of work size and work type is based on criteria including (Indiana Department of Transportation USA 2004):

- Financial ability of a contractor assessed on the basis on an audited financial statement, where prequalifiers can determine the maximum aggregate rating from net current assets; construction equipment assets (net book value); net fixed and other assets;
- Construction equipment assets assessed based on information about their age, capacity, type, manufacture, date of purchase, and cost when purchased; and the date if rebuilt;

- Personnel, quality of workmanship on contract, contract experience, prosecution of work on previous contract and the contractor's attitude toward department rules, the general public, and equal employment opportunity requirements; and
- Current workload that is assessed on the basis of the type and quantity of uncompleted work.

5.4 DISCUSSION

The usage of main periodic prequalification criteria is quite similar for all guidelines examined. The differences lie in the techniques of grading or classifying contractors in terms of their level of capability and capacity to perform project tasks suited to a certain project size and type.

In respect of the financial strength criterion, financial historical data such as turnover and ratio analysis from financial statements are commonly used to determine the range of allowable project size, but for short periodic prequalification (i.e. annual prequalification) current financial data are combined with historical data.

The magnitude of a contractor's allowable project size range can be also be influenced by the previous work size, past performance records and the level of technical and managerial resources suited to the size of previous works, especially for annual periodic prequalification. In addition, the level of management system in accordance with compliance with regulations is also considered in order to determine the allowable project size range.

Furthermore, a suitable project type for a contractor is based on its past experience, past performance and the type of technical and managerial resources and suitable management system in accordance with compliance with regulations.

Briefly, the use of a weighting/rating system conforms to the findings from Empirical study 1 which established that project size and type are the main factors for contractor prequalification criteria development.

5.5 PROPOSED PERIODIC PREQUALIFICATION CRITERIA

After reviewing the relevant literature, surveying prequalification practices and examining prequalification guidelines, sets of criteria and sub criteria for periodic prequalification have been developed and can be used as a common set of periodic prequalification criteria.

The main assumptions of this proposed periodic prequalification, as seen in Table 5.5, are based on the characteristics of the periodic prequalification system as discussed in the previous chapter, where prequalification criteria are characterised by general factors and historical data, the eligibility of inclusion of a contractor in the standing list is only valid for a certain period of the reassessment cycle and the contractor prequalification system is not intended for a particular project, but for certain project sizes and types.

5.6 SUMMARY

Periodic prequalification criteria, which will be used for further investigation of the relationship between periodic prequalification criteria and project performance, have been identified from various prequalification practices. The bases/references for criteria development identified in prequalification practices are based on the factors of project size and type.

Most periodic prequalification systems are implemented for contractor evaluation in the public sector in order to maintain the balance between the competition among contractors and the reduction of the number of inappropriate/irresponsible contractors involved in the project tender.

Table 5.5 Proposed periodic prequalification criteria

A. Financial strength	Code
1. Annual turnover	F1
2. Profit and loss	F2
3. Financial standing including the result of financial ratio analysis	F3
4. Insurance /bonding capacity	F4
5. Availability of supporting documents/certificates/evidence/recommendations from third parties/clients including contact address for verification	F5
B. Past Experience	
1. The number of previously completed contracts similar to this project value and type	E1
2. The number of previously completed contracts similar to this project value	E2
3. The number of previously completed contracts similar to this project type	E3
4. The number of years of the firm's experience with regards to previously completed contracts similar to this project value and type	E4
5. Geographical area of previously completed contracts close to this project area	E5
6. Availability of supporting documents/certificates/evidence/recommendations from third parties/clients including contact address for verification	E6
C. Past Performance	
1. Cost performance record of previously completed contracts similar to this project value and type including an adequate number of previous projects	P1
2. Schedule performance record of previously completed contracts similar to this project value and type including an adequate number of previous projects	P2
3. Quality performance record of previously completed contracts similar to this project value and type including an adequate number of previous projects	P3
4. Historical claim, dispute and /or fail project completion record	P4
5. Availability of supporting documents/certificates/evidence/ recommendations from third parties/clients including contact address for verification	P5
D. Managerial & technical strength	
1. Suitability and competence of regular technical, managerial and administrative staff including the number and average years of service in the office and on the construction site	M1
2. The number, suitability and competence of the list of trade/ work with subcontractors including subcontractor selection system, performance evaluation and/or registration in a specific competency	M2
3. Quality assurance policy and procedure and/ or management system for all resources including the system of planning, controlling and evaluating construction and firm performance	M3
4. Availability of training and development system for employees at any level	M4
5. Availability of supporting documents/ certificates/ evidence/ recommendations from third parties/ clients including contact address for verification	M5
E. Compliance with regulations	
1. Documentation demonstrating compliance with Health and Safety regulations including management, policy and procedures in order to meet the standard guidelines of the regulations	R1
2. Documentation demonstrating compliance with equal opportunity regulations including management, policy and procedures in order to meet the standard guidelines of the regulations	R2
3. Documentation demonstrating compliance with environmental regulations including management, policy and procedures in order to meet the standard guidelines of the regulations	R3
4. Availability of supporting documents/certificates/evidence/recommendations from third parties/clients including contact address for verification	R4

CHAPTER 6

Relationship between periodic prequalification criteria and project performance: A review

6.1 INTRODUCTION

This chapter presents a review and discussions of relevant theories in order to establish the framework of the relationship between project performance and periodic prequalification criteria. Two assumptions of the relationship are made as follows:

- Project performance variables in terms of project variations and client satisfaction may be influenced not only by periodic prequalification criteria, but also by three sources who are responsible for cost, time and quality variation, that is, client, contractor and neither party; and
- Because previous research has shown a lack of the establishment of the relationship between prequalification criteria and project performance, especially periodic prequalification and project performance, the establishment of the relationship framework between periodic prequalification criteria and project performance is based on the relevant factors which influence project performance theories, including, but not limited to, project success, business failure, project risk (claims, project delay, project cost overrun etc.) and construction productivity, as long as those relevant factors are still close to or within the framework of the periodic prequalification criteria being used in this study.

The structure of this chapter, which can be seen in Figure 6.1, is divided into six main sections, namely, introduction, project performance, sources of variation influencing project performance, periodic prequalification factors influencing project performance, model relationship and summary.

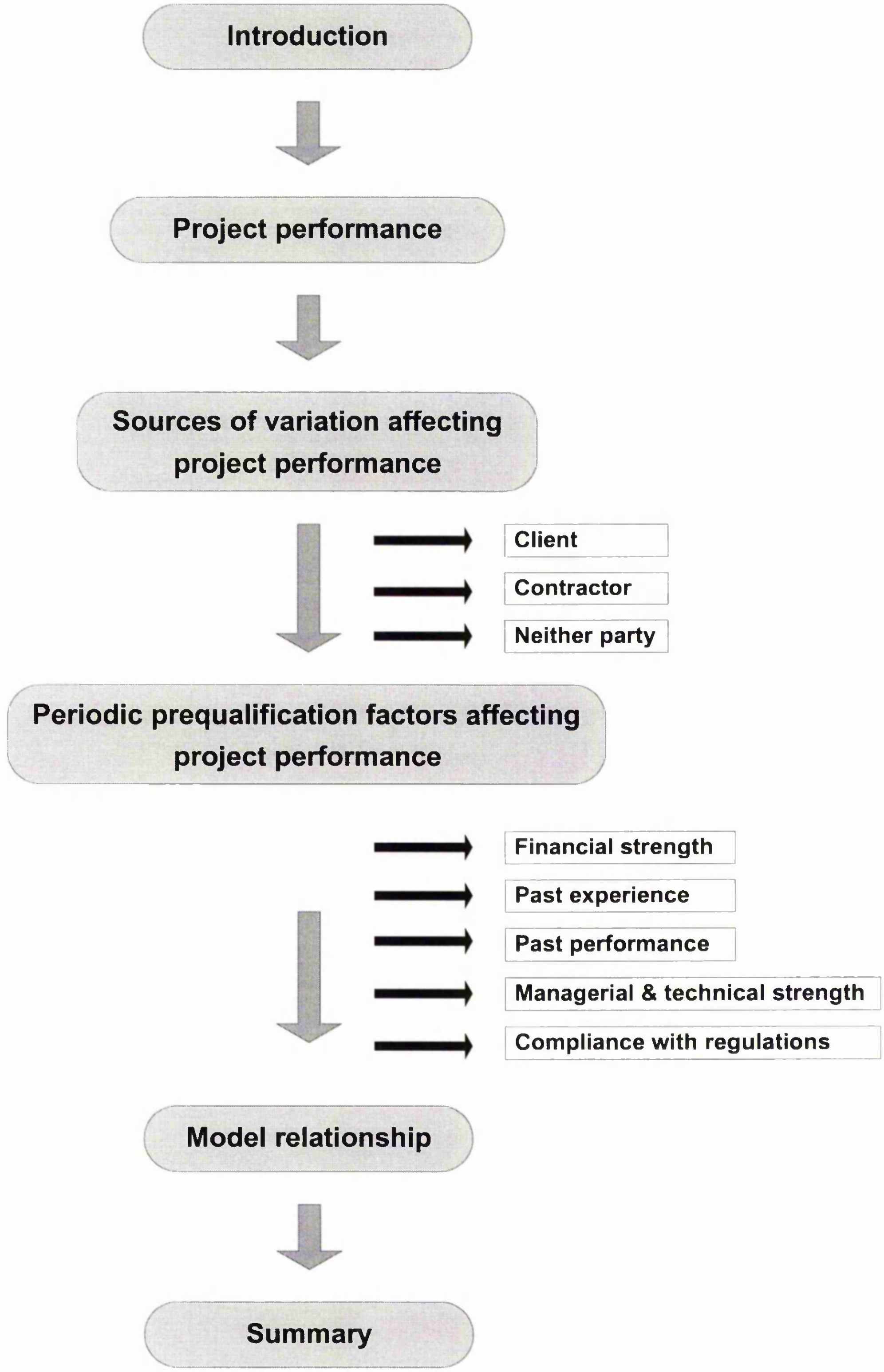


Figure 6.1 Structure of the investigation of the relationship between project performance and periodic prequalification criteria

6.2 PROJECT PERFORMANCE

Project performance is commonly related to cost, time and quality issues. These three performance attributes can be used for evaluating successful project outcomes. The degree of project performance improvement can influence the level of satisfaction of project participants.

Liu and Walker (1998) define three issues concerning project success. The first issue is to fulfil the *project goals* that are commonly cited as project completion within budgeted cost, planned time and expected functionality/quality/technical specification. The second one is the *satisfaction of the claimant(s)*, concerning for example, client satisfaction. The last issue is the *perception and awareness of different claimant(s)*, where project claimants with different views may perceive what constitutes a successful project outcome differently.

Furthermore, because uncertainties and risks usually occur in construction projects, changes or variations cannot be avoided in order to meet clients' objectives, such as a design change leading to a modification of the original scope. Alternatively, contractors' performance may be below standard so that the project outcomes do not meet the requirements mentioned in the specification/contract due to project delay due to poor planning or poor working practice, for example. Additionally, changes are inevitable due to unknown circumstances such as unknown geological conditions where the cause is not related to project participants (i.e. client and contractor) (Hanna et al. 2002; Akinci and Fischer 1998; Antill and Woodhead 1982).

In terms of the measurement of project performance, Cheng et al. (2000) suggest that cost, time and quality variations can be utilised for measuring partnering success. Cost and time variations are measured on the basis of the differences between actual and budgeted cost and actual and planned time respectively. While quality variation is based on the percentage of work rejected or rework required.

Similar to the objective measurement of cost and time performance in respect of project success, Dissanayaka and Kumaraswamy (1999) utilised time and cost indices for developing a model for evaluation of factors influencing time and cost performance in Hong Kong building projects. The percentage of actual duration divided by programmed duration is defined as the time index, while the percentage of final cost divided by the original cost estimate is defined as the cost index.

Xiao and Proverbs (2003) also employed three performance attributes for developing the model relationship that identifies factors influencing contractor performance based on an international investigation. Each attribute consists of three indicators, except quality performance that comprises four indicators. For cost performance, construction cost, cost certainty and client satisfaction are measured on the basis of the unit price per square metre, probability of finishing the project on budget (%) and a Likert scale of 1 to 10 respectively. While the measurement of time performance factors are based on construction project duration (weeks) for construction time, probability of finishing the project on time (%) for time certainty and a Likert scale of 1 to 10 for client satisfaction with time performance. Finally, quality performance consisting of defects compared with the number of defects on similar projects, liability period (years) and clients satisfaction with quality (Likert scale of 1 to 10).

Furthermore, in respect of project performance control in reconstruction projects, McKim et al. (1998) measured cost, time and quality performance based on the ratio of total value of change orders issued during construction to the original contract value, the ratio of total project delay to original project duration and quality parameters based on cost of rework, number of rework requests and number of users' complaints respectively.

6.3 SOURCES OF VARIATION INFLUENCING PROJECT PERFORMANCE

Behaviour and performance of project participants (i.e. clients/consultants and contractors) can influence project performance in different directions leading to the results of variations coming from different sources. In other words, project performance is a function of the performance of each project participant, where project participants with different views may perceive what constitutes a successful project outcome differently (Liu and Walker 1998). Thus, it can be assumed that *client*, *contractor* or *neither client nor contractor* may be considered as sources of cost, time and quality variations as project performance variables.

The first assumption is the *client* (or consultant) *related factor* that may influence the risk of time overrun. Cost and time variation may be due to work changes caused by incompleteness of design, inspection and approval delay, for example. These problems may lead to additional work being required or work being reduced, resulting in additional time or less time (i.e. time variation) and can also influence project cost (cost variation). The second is the *contractor related factor* that has an ability to influence cost and time variation. This time variation may occur when a contractor cannot control factors of material delivery, availability of labour, subcontractor competence, provision of detailed working drawings and financial ability. The third assumption is the uncontrollable sources of risks (i.e. the *neither contractor nor client related factor* or alternatively named as the *neither party factor*), such as in strikes and industrial action, unusually inclement weather and unpredictable site circumstances. Briefly, the first two can be categorised as controllable source risk factors and the last one as an uncontrollable risk factor (Gulezian and Samelian 2003; Akinci and Fischer 1998; Antill and Woodhead 1982).

Based on a questionnaire survey in Hong Kong with 46 responses (N=225), Dissanayaka and Kumaraswamy (1999) found that *client*, *contractor* and *neither party* were significant as the sources of cost and time variation, where causal factors are change order, experience, timely decision making (client category), material cost control, strength of management staff, subcontractors' work quality, response to instruction (contractor category), unexpected ground condition and obstruction due to underground utilities (neither party category)

Furthermore, the *client*, *contractor* and *neither party* as the sources of quality variation can also be included along with cost and time variation, as *client*, *contractor* and *neither party* may influence contractors' work quality due to causal factors mentioned in the previous paragraph. Based on 2879 rework cases due to construction errors and defects in the Swedish construction industry, Josephson et al. (2002) identified that clients contributed to the causes of rework such as unsuitable and faulty design, wrong information and extra orders, while bad choice of material, erroneous workmanship, lack of coordination, late deliveries and mistakes in planning are caused by contractors, for example.

In terms of rework cases in the Australian construction industry based on 87 respondents from 161 samples, Love and Smith (2003) suggested that clients contributed to the causes of rework, such as change order, lack of experience of design knowledge and lack of funding for site investigation, while poor planning and coordination of resources, ineffective use of quality management practices and poor managerial and supervisory skills by subcontractors are caused by contractors, for example. Additionally, in nine construction projects in the USA, quality deviations were caused by neither contractor nor client (Burati et al. 1992). Change orders due to unforeseen ground conditions was one of the significant factors.

6.4 PREQUALIFICATION FACTORS INFLUENCING PROJECT PERFORMANCE

6.4.1 Financial strength

It is commonly found that financial information, such as turnover, profit and loss and financial statements, which can be used for determining financial ratios, may be used to analyse the failure rate of a construction company. Because the failure rate obtained through financial analysis can indicate the likelihood of a firm's failure level that potentially causes project failure. As a result, many financial models have been developed and used in industry, including the construction industry.

Annual turnover, profit and loss and financial ratios can be used to predict the company health and the level of potential failure. Several predictive models of business failure based on financial ratio analysis and macroeconomic parameters can be seen in Table 6.1.

However, Argenti (1976) argues that financial analysis using predictive models relying on financial ratios merely shows the symptoms rather than causes of business failure. In order to know further causes of business failure, it is necessary to evaluate non financial aspects of unhealthy firms such as management (e.g. one-man rule, non-participating board, unbalanced top team, weak finance function, lack of management depth), accounting information (e.g. budgetary control, cash flow forecast, valuation of assets), change (e.g. political change, economic change, technology change), overtrading (e.g. underestimation of loan amount, expansion through an increase of turnover at the expense of profit margins), big project issues (e.g. merger, diversification programme, introduction of new services), financial ratios and creative accounting (concealing the truth in the their published accounts and using unreliable financial ratios).

In the construction industry, Abidali and Harris (1995) have developed model combinations between financial (see Table 6.1) and non financial models, similarly proposed by Argenti (1983) (i.e. Altman's Z-score) which reveal the symptoms of business failure (Table 6.1) and Argenti's A-score related to the identification of non financial factors causing business failure. Abidali and Harris (1995) identified several causal factors of business failure as follows:

- Management factors such as an autocratic chief executive, the same person as both chief executive and chairman, the company boards (e.g. non contributing directors, non working persons), lack of engineering skills, lack of financial director, defective managerial skills, incomplete accountancy system, defective bidding system and poor marketing skills; and

- Past managerial errors in decision making, for example, too much reliance on short term loans, overtrading, project losses (e.g. contract claim, overseas contracting), acquisition of a potentially failing firm.

Table 6.1 Financial models of business failure prediction

Kangari (1988)
Key factors of construction business failure: X_1 = change in new business index (liability of adolescence), X_2 = change in federal interest bank loan rate index (interest index) and X_3 = change in contract value index (volume of construction market)
Business failure score, $Z= 2.1X_1 + 1.8X_2 - X_3$
The model developed using Linear Regression is based on a sample from Bankruptcy statistical tables 1970-1979, 1983; Bankruptcy Laws, 1984; Contractor Bankruptcies Double 1983; and Moody's Industrial Manual 1986 in the USA
Altman (1968)
Key factors of business failure: X_1 = working capital/total assets, X_2 = retained earnings/total assets, X_3 = earnings before interest and taxes/total assets, X_4 = market value of equity/book value of total liabilities and X_5 = sales/total sales, where $Z < 1.81$ (bankruptcy state), $Z > 2.99$ (non bankruptcy state), Z between 1.81 and 2.99 as undefined state
Business failure score, known Z-score, $Z= 0.012X_1 + 0.014X_2 + 0.033X_3 + 0.006X_4 + 0.999X_5$
The model developed using Discriminant Analysis is based on 66 US manufacturing companies in the period 1946-1965 consisting of 50% bankruptcy cases with asset size ranging from US$0.7M-US$25.9 and 50% non bankruptcy cases with asset size ranging from US$1M-US$ 25
Edmister (1972)
Key factors of small business failure: $X_1 = 1$ if annual funds flow/current liabilities ≤ 0.05, otherwise $X_1 = 0$; $X_2 = 1$ if equity/sales ≤ 0.07; otherwise $X_2 = 0$; $X_3 = 1$ if networking capital/sales divided by its respective Robert Morris Association (RMA) average ratio ≤ -0.02, otherwise $X_3 = 0$; $X_4 = 1$ if current liabilities/equity divided by its respective Small Business Association (SBA) average ratio ≤ 0.48, otherwise $X_4 = 0$; $X_5 = 1$ if inventory/sales divided by its respective RMA average ratio has shown upward trend or ≤ 0.04, otherwise $X_5 = 0$; $X_6 = 1$ if quick ratio divided by RMA trend is down and its level just prior loan ≤ 0.34, otherwise $X_6 = 0$; and $X_7 = 1$ if quick ratio divided by RMA quick ratio has shown an upward trend, otherwise $X_7 = 0$
Business failure score, $Z= 0.951 - 0.423X_1 - 0.293X_2 - 0.482X_3 - 0.277X_4 - 0.452X_5 + 0.352X_6 - 0.924X_7$, where $Z < 0.52$ (failure state) and $Z > 0.52$ (non failure state)
The model developed using Discriminant Analysis is based on 42 US small business enlisted in the RMA and BSA in the period 1958-1965 consisting of equal number of bankruptcy and non bankruptcy cases with the average total assets of US$0.165M
Abidali and Harris (1995)
Key factors of construction business failure:
X_1 = earnings after tax and interest charge/net capital employed, X_2 = current assets/net assets, X_3 = turnover/net assets, X_4 = short term loans/earning before tax and interest charge , X_5 = tax trend profit/total assets, X_6 = earnings after tax trend and X_7 = short term loan trend
Business failure score, $Z = 14.6+82X_1 - 14.5X_2 + 2.5X_3 - 1.2X_4 + 3.55X_5 - 3.55X_6 - 3X_7$
The model developed using Discriminant Analysis is based on UK contractor data consisting of 11 failed contractors in the period 1978-1986 and 20 non failed contractors in the period 1982-1986 and both categories are medium to large size companies employing more than 50 staff on building and civil engineering work
Russell and Zhai (1996)
Key factors of construction business failure: X_1 = slope-prime interest rate, X_2 = intercept-new construction value in place, X_3 = slope-new construction value in place, X_4 = intercept-net worth/total assets, X_5 = slope-gross profit/total assets and X_6 = standard deviation-networking capital/total assets
Business failure score, $Z = 2.569+0.079X_1 -0.000004579X_2 + 0.0000088813X_3 - 0.965X_4 - 1.009X_5 +2.244X_6$
The model developed using stochastic dynamics of economic and financial variables is based an economic data from the Federal Reserve Bulletin, US Bureau of the 1975-1993 Census and financial data from 5 insurance companies that underwrite construction contract surety bonds consisting of 49 failed and 71 non failed contractors for the minimum period of three consecutive years, where contractor failure is defined as termination of contractor's operation.

Arditi et al. (2000) also identified causal factors and symptoms of business failure in the US construction industry:

- Organisational factors as *determinant factors*, such as lack of business knowledge, lack of managerial experience, lack of line experience, poor working habits, over expansion, family problems, fraud and insufficient capital; and
- Environmental factors as *determinant factors*, for example, industry weakness, poor growth prospect and high interest rates; and
- Performance factors as *symptoms*, such as insufficient profits, heavy operating expenses, receivable difficulties, inadequate sales, not competitive and business conflicts.

Using a similar approach, again in the US construction industry drawn from 11 bankruptcy construction firms enlisted in the Westlaw and LexisNexis online database and 41 non bankruptcy construction firms enlisted in Associated General Contractors of America for 2000, Koksal and Arditi (2004) developed a model of construction firm decline consisting of several stages of company decline, that is, cause of decline, initial decline, recognition of decline, response of decline and outcome of decline (i.e. failure and turnaround). The results of this study, using Factor Analysis and Logistic Regression techniques, identified key factors that may influence firm decline as follows:

- Competition based on innovation:
  - Ability to activate competitive strategy
  - Defining competitive advantage
  - Adaptation to advances in managerial practices
  - Adaptation to advances in construction technologies
- Organisational strategies:
  - Specialisation
  - Resources utilisation

- Managers' qualification:
  - Managers' business knowledge
  - Managers' work experience
  - Managers' managerial experience

Moreover, macro economics can also influence the health of the firm, for example, an increase in loan rates or a decrease of construction market volumes (Kangari 1988; Russell and Zhai 1996; Arditi et al. 2000). Additionally, certain financial predictive models are sensitive to industrial type and business size, where Kangari (1988) suggests that Altman's predictive model (see Table 6.1) is not appropriate to be applied in the construction industry, since this model was developed using the data obtained from the manufacturing industry. On the other hand, Edmister's predictive model of small business failure is more appropriate in the construction industry category, as many business failures occur in relatively small size or young business firms.

For insurance and bonding capacity, financial institutions such as surety firms commonly evaluate companies' financial data using financial ratios and other general contractor data such as plan of continuity, longevity of firm and company operation procedures (Russell 1996).

But there is weakness of the surety approach that merely focuses on financial data (i.e. past claim history) rather than adding non financial factors, such as technical and managerial factors and compliance with regulations as commonly undertaken in the prequalification process (Russell 1991).

Thus, the focus of suretyship through bonding system protection is only concerned with contractor failure and ability to cover losses, and does not concern contractors' competence and ability, as the resolution of project failure through bonding mechanism claims can influence or disrupt project operation or progress (Russell 1990).

In respect of comparison between surety and prequalification approaches, Severson et al. (1994) identified that their claim predictive model, as seen in Table 6.2 has poor classification without the inclusion of non financial factors (i.e. cost monitoring) and also Filippone (1976) cited in Russell (1996) found that non financial factors such as trade payment rating related to prompt payment to subcontractors and contractor's experience (i.e. years in business) are additional significant factors along with financial factors in their predictive claim model (see Table 6.2).

Table 6.2 Predictive model of construction business failure in respect of claims

Filippone (1976) cited in Russell (1996)
Key factors of construction business failure in relation to claim:
X_1 = Dunn and Bradstreet composite credit rating, X_2 = sales growth ratio, X_3 = final net profit/net worth (rate of return), X_4 = trade payment rating , X_5 = experience of contractor (i.e. years in business) and X_6 = bank line of credit/net worth
Business failure score, $Z = -0.706X_1 + 0.547X_2 - 0.537X_3 - 0.509X_4 - 0.385X_5 + 0.226X_6$, where Z<-8.00 as claim contractors, Z>-8.00 as non claim contractors
The model developed using Discriminant Analysis is based on 28 Northern Ohio Surety company's data consisting of 14 claim and 14 non claim contractors
Severson et al. (1994)
Key factors of construction business failure in relation to claim:
X_1 = cost monitoring, X_2 underbillings/sales, X_3 = total current liabilities/sales, X_4 = retained earnings/sales rating and X_5 = net income before tax/sales
Business failure score, $Z = 2.27 - 7.72X_1 + 0.547X_2 + 45.057X_3 - 0.509X_4 - 0.385X_5 + 0.226X_6$, where Probability of claim $= \frac{e^z}{1+e^z}$
The model developed using Logistic Regression is based on 4 surety companies' data consisting of 36 claim and 51 non claim contractors during 1991 in the USA

In addition, the supporting documents/certificates/evidence/recommendations from third parties/previous clients are important for examining the validity and accuracy of the contractors' submitted data and there is also need to verify the next periodic prequalification criteria in order to enhance the quality of contractors' submitted information in the prequalification process. As a result, contractors' project performance can be improved, as appropriate information obtained through prequalification can reduce transaction costs.

This assumption is based on transaction cost theory, when proper information prior to the contractual stage (*ex-ante* category) may incur less cost compared with claims or disputes at the post contractual stage that tends to incur higher cost (*ex-post category*) (Lingard et al. 1998). Kashiwagi and Byfield (2002) suggest that the selection of contractors should be based on high performance contractors before the contractual stage in order to avoid a less responsible contractor performing the project tasks.

6.4.2 Past Experience

There are four key words related to past experience records, that is, project size, project type, project location and business age, which reflect a contractor's competence to perform project tasks in respect of its level of capacity and capability. Tracking the past record of a contractor's project experience in relation to those key words is a useful approach to indicate the contractor's future performance (Russell 1996). It means that the contractor's past experience should be relevant to a client's project scope based on similar project size, type and location as well as a maturity of business age corresponding to the level of project complexity.

It is necessary to note that the experiential combination of a certain project size, type and location, as well as reaching the maturity level of business age in relation to being similar to a client's projects' characteristics, are the best criteria of past experience compared with a single or double combination of those issues. Merely considering similar project size, for example, but with a different project type or location, may decrease the relevancy of a contractor's competence level, as a different project type entails different or specific characteristics being required. Similar to different project size for the same project type, the scale of technical, managerial and financial requirements also have different services and approaches as discussed in section 3.4.2.5. Lack of past experience related to those issues may create constraints during the construction process which may influence project performance.

Furthermore, to examine the internal organisation, contractors' past experience can be considered and analysed in order to improve project performance based on the following categorisation of contractors' past experience domains as follows (Fu et al. 2003):

- Managerial experience (material and labour logistics, working programs, subcontracting management, etc.);
- Technological experience (know-how, appropriateness of construction methods);
- Costing experience (cost planning, estimation, monitoring and evaluation as well as past and present cost data documenting system);
- Local experience (trade practice, industrial/social norms, legal environment, local knowledge of resources, etc.); and
- Organisational/institutional experience (client preference, workmanship standards and policies, health and safety policy and management, bidding and prequalification procedures, etc.).

6.4.2.1 Project size and type issues

There is tendency that repetition of similar job operations can shorten the job times. This is due to the fact that repetition increases familiarity with the nature of work. This process of skill improvement through experience can be explained by learning curve theory (Pilcher 1992). Additionally, Kog et al. (1999) identified that the Project Manager experience factor in past projects of similar size and duration can reduce time variation of current projects. Thus, to some extent, experience in certain project characteristics may improve project performance.

6.4.2.2 Project location issue

The issue of project location can be associated with the local knowledge of local contractors, for example. Local contractors can mobilise resources relatively easily compared with the ability of non-local contractors. Lo et al. (1999) identified that the involvement of local contractors along with international contractors in the case of the Mass Rapid Transportation project in Taiwan can reduce cost and time overrun, because of their advantages of local knowledge, including their country's regulations. Additionally, Holt et al. (1994b and 1994c) identified that the local/geographical experience criterion is one of the important prequalification criteria, where this criterion is to assess a contractor's knowledge of the strength, weakness and availability of local labour.

6.4.2.3 Business age issue

Regarding business age, new business activity is susceptible to a higher failure rate due to lack of experience, lack of legitimacy/reputation, limited financial reserves or being in a precarious position (Kale and Arditi 1998; Kangari 1988). Additionally, it is necessary to carefully examine young contractors in business construction, especially their business activity in the first three years and the unhealthy state of the construction industry caused by high interest rates and low number of construction activities taking place, in order to avoid business failure that may cause project failure (Kangari 1988). In other words, the liability of adolescence in business is not only caused by inadequate legitimacy/reputation as a result of lack of past experience or past performance causing difficulties or limitations of financial access, but also can be pressured by external factors (i.e. macroeconomic conditions) such as high interest rates and competition leading to marginal profit.

6.4.3 Past Performance

Past performance is one important prequalification criteria identified in the previous research as seen Table 3.9 and in Empirical study 1. In the proposed periodic prequalification criteria, which can be seen in Table 5.5, the past performance criterion includes cost, time and quality performance sub criteria as well as claim/disputes/project failure records.

These sub criteria can provide a preliminary indication of contractors' competence in relation to contractors' achievement on previous projects of project completion, especially their management and technical ability to perform project tasks. Combined with their past experience, the contractors' competence can show their ability and achievement within project size, type, location in the last period of time.

In the UK construction industry, construction cost, time and quality performance indicators are measured on the basis of a set of Key Performance Indicators (KPI) for benchmarking contractors' past performance. Thus, through these performance indicators a contractor's past performance can be compared to the average performance in the construction industry according to cost, time and quality performance indicators (KPI 1999).

The past performance criterion is also included in the first screening stage of Kashiwagi's best value model of contractor selection in order to obtain high performance contractors, known as the Performance Information Procurement System (PIPS). The PIPS process consists of four screening stages in respect of the selection of a winning contractor. The stages are as follows (Kashiwagi et al. 2003; Kashiwagi and Byfield 2002; Kashiwagi and Mohammed 2002):

1. A contractor has to provide proven information of past performance;

2. A contractor has to have ability to identify and minimise risk on a unique project including risk information, minimising risk, value engineering and bid price;

3. A contractor is evaluated using performance and price criteria; and

4. A contractor has to present risk minimised processes and material systems in order to achieve performance.

This model had been tested over 300 times on US$180M construction project values and achieved a performance rating of 9.7 out of 10, a customer satisfaction rating of 99% and 99% of contractors would use the system again.

6.4.3.1 Cost, time and quality performance issues

Cost and time performance indicators may reflect the ability to perform project tasks in relation to the level of contractors' managerial and technical strength. Thus, high levels of this factor may lead to the achievement of project success (Jaselskis 1988). Chua et al. (1997), Jaselskis and Ashley (1991) and Kog et al. (1999) identified some key project management factors influencing cost and time performance as seen in Table 6.3. Jaselskis (1988) suggests that the achievement of project success relies on project management actions/inputs. It important to note that Jaselskis and Ashley's model (1991) for cost and time performance distinguishes the sources of performance factors such as client and contractor, while Chua et al. (1997) and Kog et al. (1999) did not consider distinguishing the sources of performance factors in their models.

To identify quality performance, the percentage of rejection of work or rework due to defects or not fulfilling the specification is commonly used to measure quality performance (Love and Smith 2003; Josephson et al. 2002; Cheng et al. 2000; KPI 1999). A poor quality performance indicator reflects contractors' competence below standard which can be reflected by lack of experience at managerial and technical levels, poor working practices including health and safety programme, environmental management system, unskilled workers and poor quality inspection.

Table 6.3 Key Project Management factors influencing project cost and time

Project Management factor	Category	1		2	3
		Cost	Time	Cost	Time
Project Manager levels to craftsmen	Project Manager			✓	
Project Manager time devoted					✓
Project Manager meetings					✓
Project Manager scope experience (similar cost and duration)					✓
Project Manager technical experience		✓	✓	✓	
Team turnover	Project team	✓	✓	✓	
Design incentives					✓
Design complete at construction start	Planning			✓	
Constructability program			✓	✓	✓
Control system budget	Control	✓		✓	
Budget updates		✓	✓	✓	
Construction control meeting		✓		✓	
Design control meeting		✓			

Note:

1. Jaselskis and Ashley (1991)
2. Chua et al. (1997)
3. Kog et al. (1999)

6.4.3.2 Claim and dispute issues

Claim and contractual dispute records caused by contract failures are commonly used to indicate contractors' past performance achievement. Through these indicators, clients can avoid non performing contractors being included in a potential list of contractors for new projects and may reduce future project risks in terms of contractors' project cost, time and quality performance. The examination of the number of claims and amount of compensation paid by contractors in previous projects can provide early warning to clients for further investigation in respect of contractor selection and risk mitigation.

Additionally, to some extent, claims and disputes are inevitable in construction projects, and the past experience records of dispute resolutions are also important in order to have information about capability and attitude of contractors with regards to efforts of solving these issues. Most of the typical claims disputes are caused by factors such as differing site conditions, design errors, change orders, delays, impact effects of delays, inspection problems, differences in the interpretation of plans and specifications, acceleration, inefficiency and disruption, unrealistic contract duration and cost and adverse weather conditions (Scott 1997; Arditi and Patel 1989; Diekmann and Nelson 1985)

Furthermore, according to Diekmann and Girard (1995) and Jergeas and Hartman (1994), disputes can be reduced through examination of contractors' management and organisation (i.e. client satisfaction with regards to previous projects, past experience in respect of project success, type and complexity), knowledge of contract, project planning and scheduling system, project information system (e.g. record keeping, preservation of rights) and financial planning.

6.4.4 Managerial and technical strength

There are four criteria related to managerial and technical strength, namely:

- The suitability and competence of the regular technical, managerial and administrative staff of the main contractor including the number and average years of service in the office and on the construction site;
- Quality assurance policy and procedures and/or management system for all resources including system planning and controlling and the evaluation of construction and firm performance;

- Availability of training and development systems for employees/workers at any level; and
- The number, suitability and competence of subcontractors including subcontractor selection system, performance evaluation and/or registration in a specific competency.

To analyse internal organisational strength, the first criterion is focused on evaluation of the qualification level of personnel (individual aspect) and the second is related to the organisational capability of the management process (organisational aspect). The third considers the historical relationship with and evaluation system of subcontractors' competence in the framework of the supply management system. While the fourth is individual and organisational aspects through personnel training in order to strengthen the organisation structure.

In addition to important factors for managerial and technical strength as seen in Table 6.3, Assaf et al. (1996) identified that some managerial and technical strength factors based on cases in Saudi Arabia, are field inspection and supervision, planning and scheduling, contractor quality of work, material procurement and logistics and knowledge of contractor requirement, can influence contractor performance.

6.4.4.1 Personnel issues

Based on an empirical study in the Hong Kong public sector, Shen et al. (2004) suggest that one approach of successful controlling cost overrun can be carried out through implementation of a strict assessment process of professional qualifications such as surveyors, architects or engineers through corresponding professional bodies in order to ensure that registered professional are knowledgeable, experienced and capable of providing service.

Moreover, the results of a survey into project management turnover or lack of continuity that can be related to years in business, which sampled project managers in Australia and the USA, indicate that there was significant impact on project performance, especially performance of their project team leading to a potential increase in project cost, time and quality project performance (Parker and Skitmore 2004). Similarly, Xiao and Proverbs (2003) also found that a commitment towards lifetime employment is one of the significant independent variables in the predictive model of project performance based on 99 respondents (N=659) through an international survey (Japan, UK and USA).

6.4.4.2 Quality assurance and project management issues

In terms of quality assurance influencing project performance, implementation of quality assurance in construction project organisations, compared with non quality assurance organisations, reveals that productivity in quality assurance organisations is better, as an increase in productivity may lead to improved project performance. This implementation can increase coordination and information flow, even though the findings have not shown significant improvement in building quality in terms of a comparison between quality assurance organisations and non quality assurance organisations (Langford et al. 2000).

Moreover, based on an empirical study in the Hong Kong public sector, Shen et al. (2004) suggest that one approach of successful controlling cost overrun can be carried out through implementation of proper contractor evaluation through certification of contractors' quality management systems, and relevant ISO standards for contractors undertaking major or medium sized projects.

A potential benefit of the implementation of quality assurance in organisations through certification such as ISO 9000 standard may effectively control process engineering in order to achieve continuous performance improvement through control mechanisms. For example, the reduction of waste and workforce inefficiency in the production and delivery process, an improvement of construction material delivery within budget, on time and to the quality required and also improvement of management services and supervision during the construction process (Love and Li 2000; Seeley 1996).

6.4.4.3 Training scheme issues

In terms of the importance of training schemes, workmanship performance can be improved through appropriate training strategies and programmes which are useful to upgrade the knowledge, skills and attitude of workers and managers, since the improvement of workmanship can enhance the productivity and quality levels in construction processes and achieve outcomes leading to an increase in the level of project cost, time and quality performance (Gann and Senker 1998; Kumaraswamy 1996b).

Kumaraswamy (1996b) suggests that it is important to integrate training strategies and programmes through synergy of different disciplines and levels of personnel at different stages in their career progression and to standardise assessment systems of training programmes, including specific requirements of trained personnel within the construction industry.

Moreover, Gann and Senker (1998) suggest that formal training programmes should be innovative through appropriateness of content and adequate in quantity in order to improve project performance and to counter rapid business process changes. Well trained workforces may substantially reduce reworks and accidents, increase productivity and finish a project on schedule. There are several approaches for training system improvement, including as follows:

- It is necessary to implement an accreditation system of skilled operatives on the basis of a quality assurance system and customer satisfaction in order to adequately supply skilled and quality workforces;
- A training scheme programme should be included in a long term partnering system through intra and inter organisational team building and development programmes including multi-skilled, cross functional skills development and negotiation and communication skills development;
- The manufacturers should be involved in training schemes by introducing new products or technologies; and
- A change of training programmes based on performance improvement targets through the implementation of new technology and business process skills, new business process communication and information and technological skills and communication skills is needed to satisfy client pressures.

Training and development systems for employees/workers have become an important part of an organisation's system of continuous improvement for personnel development and strengthening organisational structures. The training scheme is not only to enhance management practices such as cost control, scheduling and quality assurance, but also to enhance knowledge in respect of compliance with regulations including issues related to health and safety, equal opportunities and environmental management systems in order to increase project performance (Bennett 2000; Burati et al. 1991a; Burati et al. 1991b; Smith and Roth 1991).

6.4.4.4 Subcontractor issues

In terms of subcontractor issues, subcontractor lists, historical relationships and implementation of a subcontractor selection system become important aspects to be assessed. Examination of the historical relationship, associated with historical claims and disputes, which commonly influence project performance as discussed before, is a necessary approach in order to assess how well main contractors manage their supply chains.

Main contractors' efforts to establish appropriate partnering approaches with subcontractors and also the use of prequalification models based on past performance in selecting subcontractors may provide a better indication of their potential contribution to the future project performance of main contractors (Kumaraswamy and Matthews 2000; Latham 1994). Kumaraswamy and Matthews (2000) identified that subcontractor pricing levels were reduced by an average of 10%, as partnering concepts can establish trust, dedication to common objectives and understanding of each other's individual expectations and values leading to potential reduction of claims and disputes

Furthermore, Loh and Ofori (2000) identified that contractors in the List of Trade Subcontractors (SLOTS) selected through a prequalification system were perceived to achieve better performance than those which were not in the SLOTS. In addition, based on 76% of a sample of 355 residential construction firms in Toronto, Canada, Oliver (1997) identified that task environment relationships (i.e. developers, subcontractors, suppliers and banks) significantly influence the construction firms' organisation performance (i.e. profitability and productivity). Xiao and Proverbs (2003) also found that partnering with a contractor is one of significant independent variables in the predictive model of project performance based on 199 respondents (N=659) an international survey (Japan, UK and USA).

6.4.5 Compliance with regulations

Compliance with regulations including health and safety, environmental management systems and equal opportunity regulations, are one of the important assessment criteria in periodic prequalification systems in order to assess contractors' competence in respect of the prevention and protection of people in the workplace from physical injuries and discrimination including mental abuse (e.g. rumours in the workplace, intimidation, humiliation, discreditation, and isolation and harassment) and the maintenance of an appropriate environment in the workplace. Claims related to non-compliance with these types of regulations are very costly; illustrations of the cost can be seen in the next two paragraphs.

> *There are an estimated 1.6 million accidents resulting in injury each year and 2.2 million workers suffer ill-health caused or made worse by their work. 30 million working days are lost each year with a cost to industry of some £700 million. Estimates of the overall cost to employers vary from between £4,000 - £9,000 million a year, some 5-10% of gross trading profit. On a national basis (including Social Security and NHS costs) it is estimated that the total cost to society is some £10-£15 billion per year* (Wyre BC 2004).

> *In December 2003, the Equal Opportunities Review presented its annual survey of awards made in discrimination cases. One of the most unsettling statistics for UK employers was that a total of £6.41 million compensation was awarded by employment tribunals in cases of unlawful discrimination, a 65% increase in the previous year's figure of £3.88 million* (Capita 2004).

Additionally, according to the Health and Safety Executive, the cost of accidents in construction work equals 8.5% of the tender price (Dalton 1998) and of 156 fatal injuries in the UK industry in the period 2003-2004, about one third of fatal injuries (56) come from the construction industry categories (HSE 2004).

Based on 573 injury reports from 103 construction firms and 34 different states in the USA, Hinze and Applegate (1992) identified that the average direct cost of medical case injuries was around US$520 and the average cost of restricted activity/lost workday cases was around US$7,000. These costs predominantly include medical costs (80%) within the medical case category and medical and indemnity costs (66%) within the restricted activity or lost workday category.

While impact costs of these construction injuries, defined as indirect costs, may be demonstrated by lost and reduced productivity, required training of replacement workers, repair of property damage, accident investigation and loss of managers' time. An estimate of the average indirect cost based on 11,472 injuries reported on domestic U.S. Army Corps of Engineers projects from 1977 to 1987 was about US$400 for the medical cost category and about US$1,600 for the restricted activity or lost workday category (Hinze and Applegate 1992).

In the UK, the total cost of an injured worker to a company due to an unguarded drilling machine was £45,000+ based on loss of time comprising wages for injured worker over the period (£10,000), loss of production/remedial work required (£8,000+), overtime wages to cover lost production (£3,000+), loss of managers' time (£4,000), legal expenses (£3,000), fine and court costs (£4,000) and increase in employers' liability insurance premium (£8,000). Since all the costs arising from that case cannot be insured, only injury, ill health and damage are covered (HSE 2002).

6.4.5.1 Health and safety issue

Accidents in construction activities are inevitable but they can be reduced through proper management and preventative and protection approaches. Since construction accidents can cause lost productivity and an increase in project cost leading to the influence of project performance, the health and safety criterion is also important to be included in periodic prequalification.

Accident/injury rates along with contractors' health and safety formal guidelines and management policies is usually included in prequalification criteria in UK local authorities (see Chapter 3) and other prequalification systems (Khosrowshahi 1999; Hatush and Skitmore 1997b; Russell et al. 1992). But these parameters only provide an indication of contractor health and safety performance; if necessary, further detailed examination is needed to investigate other factors causing injuries, such as site conditions, poor construction methods and design problems. Suraji et al. (2001) argue that construction accident causation can be influenced by all participants in construction projects including the client, consultant, contractor and subcontractors due to the constraints arising from the complexity of project environment at project conception, project management or construction management levels and inappropriate responses to those constraints increasing project risks leading to a state which may cause undesired events or accidents. These causes of accidents are categorised as distal factors or indirect causal factors.

Based on 500 construction accident records categorised as proximal factors (i.e. factors directly causing accidents) obtained from the UK Health and Safety Executive, Suraji et al. (2001) identified that 88% of all accidents are due to inappropriate construction operation (e.g. breach of regulations and codes, inappropriate construction procedures), followed by inappropriate operative action (29.8%) (e.g. failure to follow instructions, errors of judgement), inappropriate construction planning (28.8%) (e.g. inadequate method statement, inadequate preparatory planning), inappropriate operation control (16.6%) (e.g. inadequate supervision of operative work, inadequate control of systems of work) and inappropriate site conditions (6%) (e.g. unsuitable weather, inappropriate site conditions).

6.4.5.2 Equal opportunity issues

The equal opportunity criterion is commonly used as one of periodic prequalification criteria (see Chapter 3) in UK local authorities' periodic prequalification systems. Management at all levels must implement and have knowledge about this issue in order to create a better work place setting, including a harmonious and well managed multicultural workforce, since the legal costs of non-compliance of the equal opportunity related regulations are costly (Loosemore and Chau 2002; Holley and Field 1976).

For example, racism in organisations/firms can lead to higher levels of work-related stress, accidents, low morale, low productivity and high turnover rates leading to poor organisational or project performance (Loosemore and Chau 2002). Important indicators, along with contractors' equal opportunity formal guidelines and management policies commonly used in UK local authorities in order to examine contractors' competence related to the equal opportunity criterion, are as follows:

- Unlawful racial discrimination records against the contractor by courts or industrial tribunals due to the breaches of racial equality regulations within the past 3 years; and
- Formal investigation of alleged unlawful racial discrimination records against the contractor by the Commission for Racial Equality within the past 3 years.

6.4.5.3 Environmental management issues

Due to construction activities being susceptible to environmental impacts or accidents, implementation of an Environmental Management System (EMS) (e.g. the International Organisation for Standardisation (ISO) 1400, the EU Eco-Management and Audit Scheme (EMAS)) for construction projects is essential in order to improve contractors' environmental performance. The application of an EMS may reduce environmental liability and risks (e.g. substantial amount of hazardous substance on site) through resource conservation and waste minimisation, reduce insurance premiums and enhance organisations' image and credibility by involving all employees in environmental issues through leadership, training and dialogue (Tse 2001; Kein et al. 1999; Dalton 1998; Ofori 1992).

Sources of environmental implication or hazards at the construction workplace may come from material used, design, construction method, location and layout, physical structure and the construction operation itself (Ofori 1992). If these sources create undesired circumstances, the disruption of construction operations is inevitable, and, as a result, the expected project performance level cannot be achieved. Handling hazardous material in construction maintenance or demolition, such as asbestos, requires a contractor having specific knowledge and expertise Therefore, the reduction of environmental impact through an appropriate EMS is needed to improve project performance, since environmental claims and disputes leading to litigation can be costly.

6.5 MODEL RELATIONSHIP

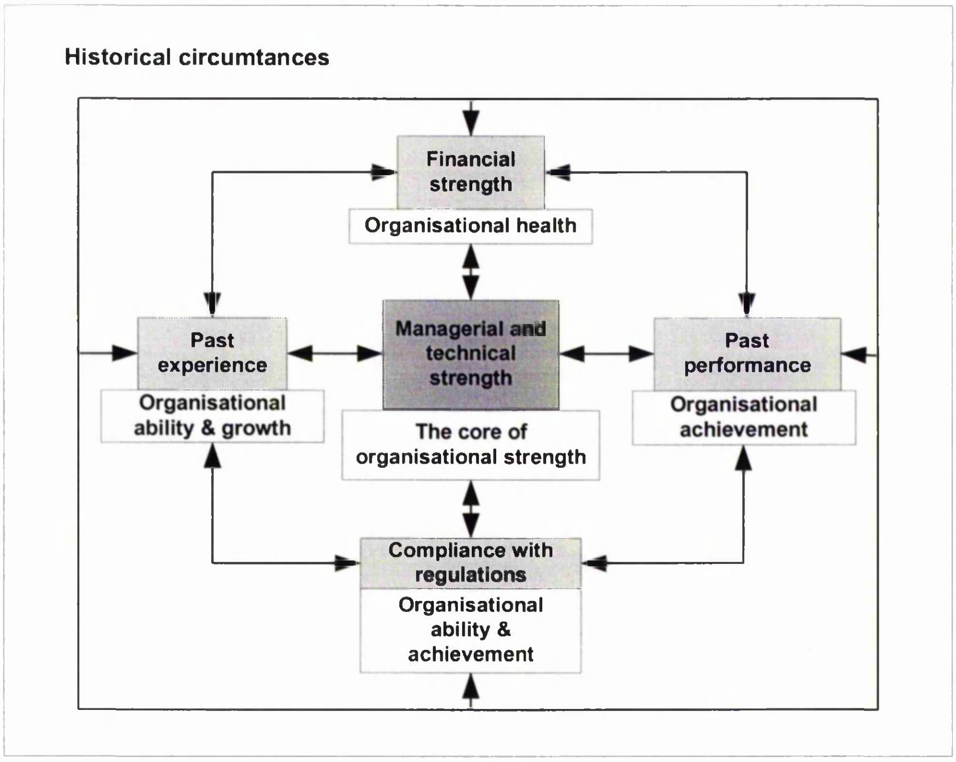
To develop the conceptual framework of the relationship between project performance and periodic prequalification, project performance may be influenced not only by periodic prequalification factors that represent contractors' stability showing their capability to perform past project tasks in a certain period of time (e.g. the last three to five years), but also factors which are responsible for project variation during project construction until completion, where these factors represent the contractor, client and any current circumstance that possibly causes variation, especially reflecting the capability and capacity of the contractor and client.

Project performance attributes consist of two dimensions, namely, variation and client satisfaction. Each dimension has cost, time and quality factors. Cost and time variations are measured using objectively recorded data, while quality variation and clients' cost, time and quality satisfaction are subjectively rated by prequalifiers' experience related to the particular project under investigation.

While periodic prequalification criteria have five main attributes, that is, financial strength reflecting the health of construction firms, past experience reflecting past organisational ability and growth, past performance reflecting past organisational achievement, managerial and technical strength reflecting the core of organisation strength and compliance with regulations reflecting organisation ability and achievement.

Factors which are responsible for project variation, named as sources of variations, have three attributes, that is, cost, time and quality factors. These factors represent the capability and capacity of the contractor and client at the project construction stage (i.e. current circumstances), while neither party represents uncertainties and risks also at project construction stage.

Details of the influential factors in two different circumstances (i.e. historical and current circumstances) on project performance and the conceptual framework of factors influencing project performance are depicted in Figure 6.2 and Figure 6.3 respectively.



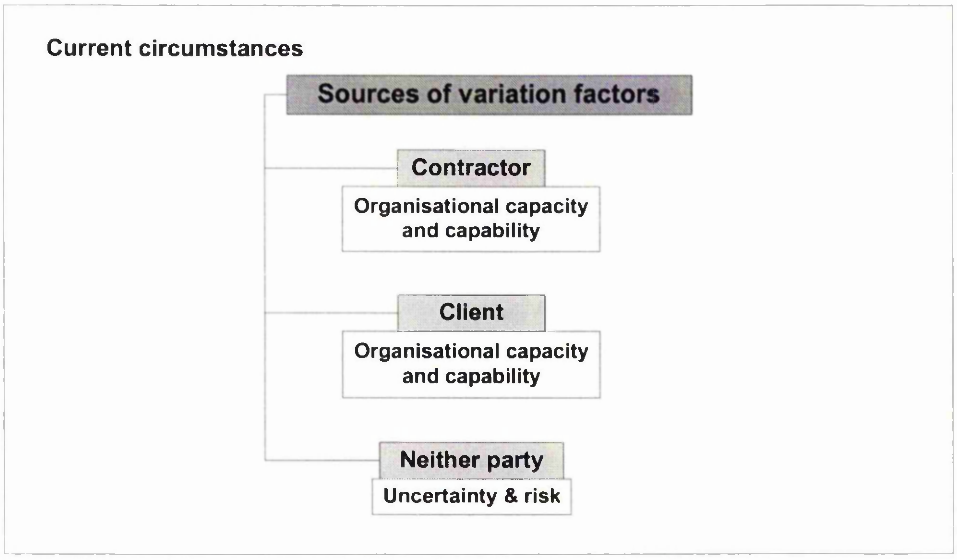


Figure 6.2 Details of influential factors in respect of project performance

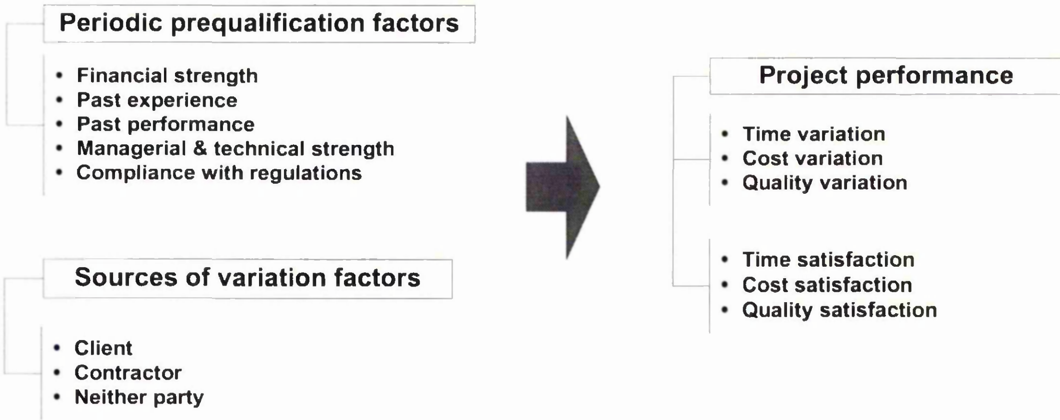


Figure 6.3 The conceptual framework of factors influencing project performance

All periodic prequalification criteria are characterised by a reciprocal effect on each other as discussed in section 6.4. All criteria are important to be included on the basis of the concept of a multi-criteria contractors' competence assessment system, which means that all criteria are assumed important as part of a whole system assessment. Financial strength, past experience, past performance and compliance with regulations can provide an indication of the ability and/or achievement of construction firms in the past and they may be capable of similar performance on future projects with similar characteristics (e.g. size and type). However, the core of organisational strength lies with contractors' managerial and technical strength, where they have ability to manage financial, resource, training and compliance with regulation aspects, and ability to obtain construction work profitably and productively in order to increase their organisational and personnel experience ability.

6.6 SUMMARY

This chapter has described and thoroughly discussed the relationship between project performance and prequalification criteria including sources of variation factors influencing project performance. In addition, sub periodic prequalification criteria and issues of periodic prequalification criteria that influence project performance have also been discussed.

This review and development of the framework of the relationship will contribute to the development of the survey for investigating key periodic prequalification criteria that may influence project performance in construction industrial practices, especially in the public sector. The findings are discussed in the next chapter and the investigation is based on data from projects completed by UK local authorities.

Regarding project performance, variation and client satisfaction will be used in the framework of cost, time and quality performance. While periodic prequalification criteria as contractors' historical data and the sources, which are responsible for cost, time and quality variation related to current circumstance aspects, will be employed as influential factors.

CHAPTER 7

Relationship between periodic prequalification criteria and project performance: Emprical study 2

7.1 INTRODUCTION

This chapter presents the results of the analyses of Empirical study 2, where the key periodic prequalification factors that influence project performance were identified. This chapter also describes the process of data collection, including the pilot and main survey as well as respondent characteristics.

Before developing model relationships for identifying the key periodic prequalification factors, prequalification characteristics and cost, time and quality performance characteristics, including the factors influencing project performance, are discussed. The results of the identification of prequalification characteristics will be used to verify the consistency of the level of importance of periodic prequalification criteria being identified in Empirical studies 1 and 2 as well as being identified through literature review, especially the frequency of usage and also the weighting of periodic prequalification criteria.

In addition, project performance characteristics, including controllable issues of cost, time and quality variations in relation to *client* and *contractor*, and uncontrollable issues of variation related to *neither party*, are also investigated. The results of this investigation will be used to enhance the model relationship, specifically the findings of causal factors of variations.

The data analyses related to the usage of the Factor Analysis (FA) and the Logistic Regression (LR) techniques are described and analysed in detail and the identified key periodic prequalification factors are discussed. The detailed explanation and analysis are related to project time performance only, due to the data available being suitable for the model development of the relationship between project time performance and periodic prequalification criteria. It means that the detailed procedures of the FA and LR will be presented according to the procedures described in Table 2.5 and Table 2.9 in Chapter 2.

The other model relationships related to project cost and quality performance that do not fit the LR requirements are analysed and discussed accordingly. In order to present the contents of this chapter systematically, the main structure of this chapter is summarised in Figure 7.1.

7.2 DATA COLLECTION PROCESS

The questionnaires were distributed in two main stages (i.e. pilot and main surveys) to 704 UK local authorities' offices, which are mainly listed in the Municipal Year Book 2000 and 2001 under the headings of Chief Architects who regularly carry out house/building projects and Highway Officers who regularly carry out civil engineering/infrastructure projects. Based on responses from Empirical study 1, ten local authorities which confirmed that they did not carry out periodic prequalification, but placed full reliance on the Constructionline scheme, were excluded in this survey.

The pilot questionnaires were distributed at the end of October 2002 and returned between the beginning of November 2002 and December 2002. Due to the low response rate of the pilot survey, reminder letters were sent and then the response rate increased to around 20% (see Table 7.1).

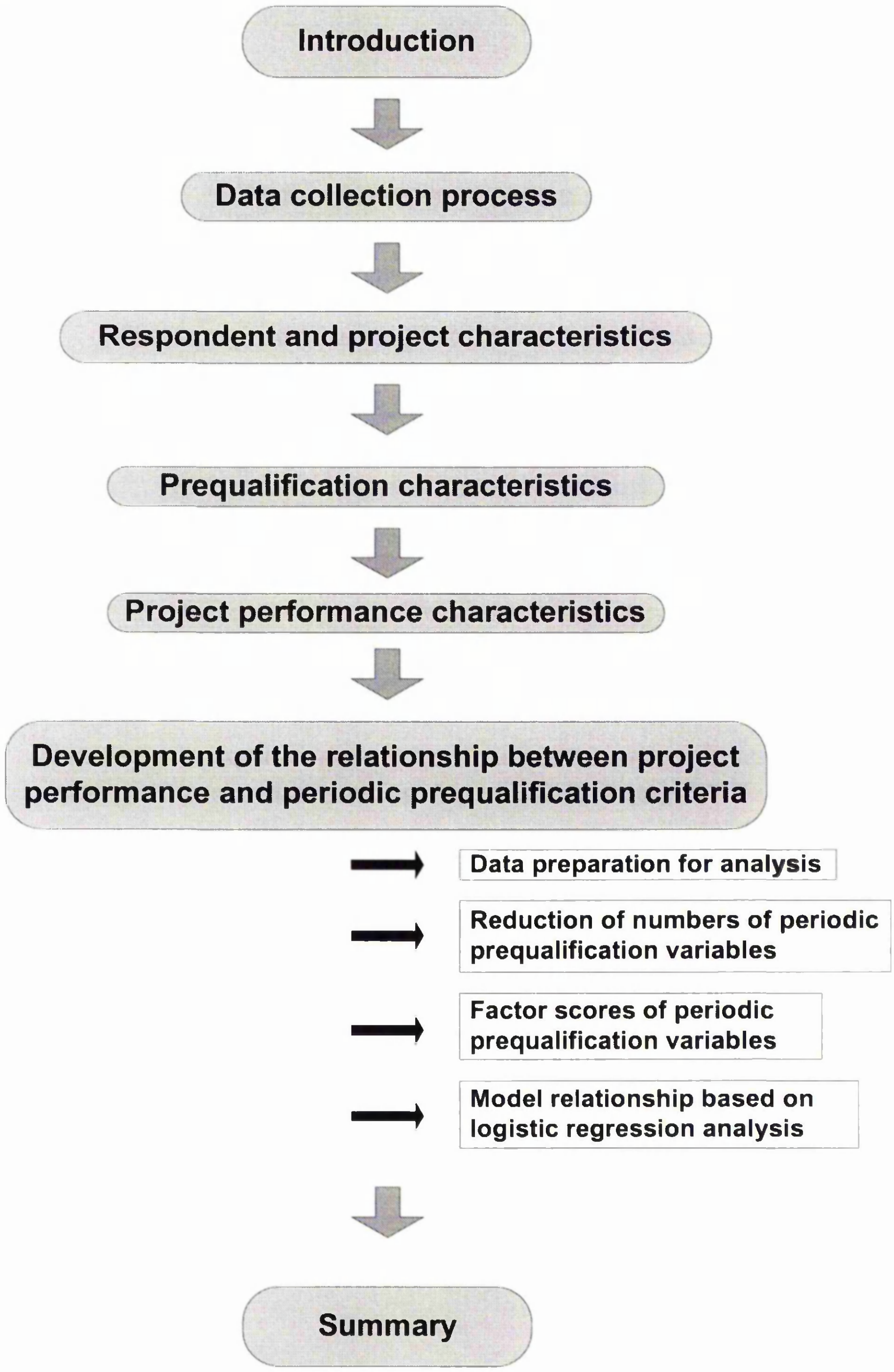


Figure 7.1 Structure of Chapter 7: Empirical study 2

Table 7.1 UK local authorities' response data for the pilot study

Response to questionnaire	The number of respondents			Note:
	RAD	RAR	Total	Sample = 75
Returned unanswered	3	4	7	9.33% were returned
Return with answers	5	11	16	21.33% were returned
Total	8	15	23	30.67% were returned

Note: RAD: Response after first distribution
RAR: Response after reminder letter

According to respondents' feedback, generally the questionnaire is clear and unambiguous (see Figure 7.2). However, several minor changes in the questionnaire were necessary. The recommendations and responses from respondents are summarised as follows:

- Questions in section II are ambiguous and need to be changed in order to provide more explanation.
- It is necessary to change the main questionnaire survey related to the diagram which is not clear in section IV including the questions.
- The difficulty in completing the questions:
  - Lack of data (2 respondents who completed their questionnaire); and
  - Complicated questions (3 respondents who completed their questionnaire) due to some unclear terms/definitions.

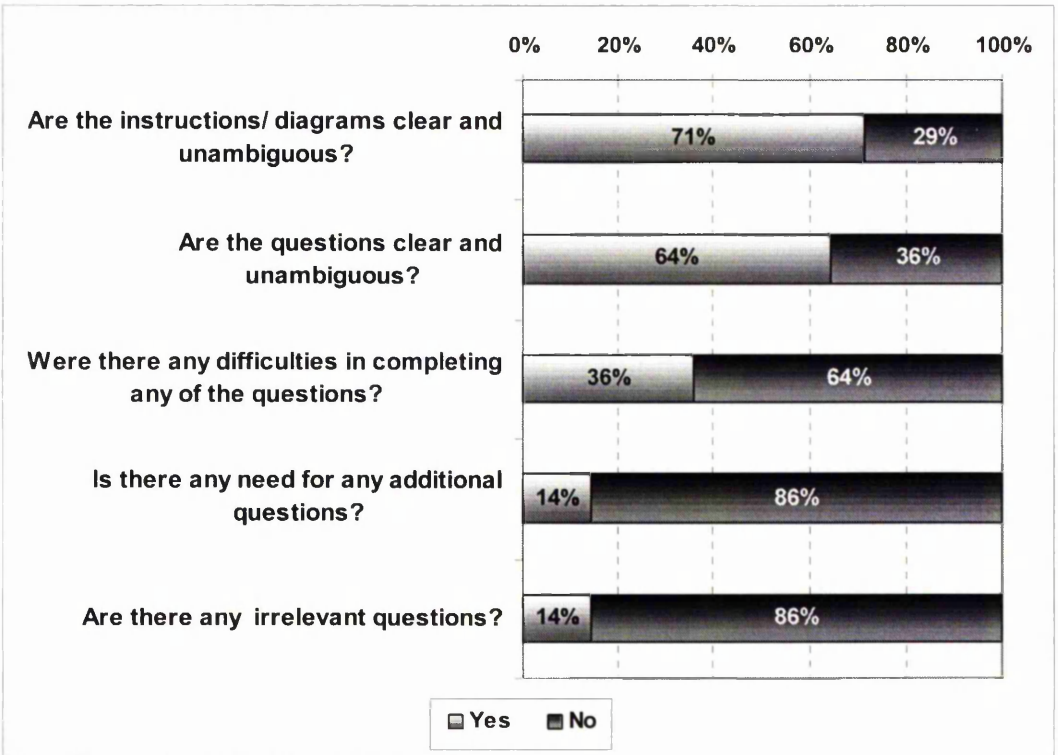


Figure 7.2 Feedback for the questionnaire from local authority respondents based on the pilot study (N = 14)

After obtaining feedback, the questionnaires were refined and distributed between the end of January 2003 and the beginning February 2003. Because response rates were low after the first distribution, reminder letters were sent between the middle and the end of February 2003. Additionally, to maximise uncompleted questions or to clarify questionable answers, respondents who provided contact addresses were contacted immediately via phone or email.

Up to the end of March 2003, the response increased from 49 to 149 respondents. Details of the sample size and response at the two main stages can be seen in Table 7.2 and Table 7.3. Total response rate, including questionnaires returned unanswered in the calculation, is 29.90%, but, if using equation 2.1 in Chapter 2, the response rate is around 17.52%. Questionnaires returned unanswered with response letter or email are due to several reasons, as seen in Table 7.4.

Table 7.2 Sample size and response rate

Empirical survey 2		Pilot	Main	Total
Sample		75	664	739
Response	After first distribution (RAD)	8	49	57
	After reminder letter (RAR)	15	149	164
	Total response	23	198	221
		30.67%	29.82%	29.90%

Table 7.3 Response data categories

Data category	Pilot		Main		Total
	RAD	RAR	RAD	RAR	
Returned unanswered	3	4	17	87	111 (15.02%)
Return with answers	5	11	32	62	110 (14.88%)
Total	8	15	49	149	221 (29.90%)

Note: RAD: Response after first distribution
RAR: Response after reminder letter

Table 7.4 Reasons for non return of questionnaire

Reason	Cases			
	Main	Pilot	Total	
Unavailable data	51	1	52	47%
Current workload/no time to answer	21	4	25	22%
No further response after sending initial information	13	0	13	12%
No further response after forwarding to another relevant section	9	1	10	9%
Other: - Contact person retired/leaving - Not allowed to provide information	9	1	10	9%
Blank response without letter	1	0	1	1%
Total	104	7	111	100%

7.3 RESPONDENTS' AND PROJECT CHARACTERISTICS

Of all returned questionnaires (110 respondents), half of the respondents are Civil and Structural Engineers and the rest consist of Quantity Surveyors (24.6%) and others (25.4%) such as Architects (13.6%) and Project Managers (7.3%). Most of them (90%) had been involved in the prequalification process for more than 5 years

In terms of project information, of 110 projects, around 40% were completed between 1998 and 2001 and 60% between 2002 and 2003 and most projects (around 75%) were procured through the traditional approach (e.g. tendering system) followed by partnering (15%) and 10% by design and build approaches. But the total values of partnering and design and build (£80 million for 26 projects) were not much different from the total values of the traditional approach (nearly £100 million for 82 projects). While lump sum (40%) and unit price (about 30%) systems were predominantly used for contract payment and the remainder was target cost, monthly valuation or stage payment.

Regarding project types, housing/building (45%) and civil engineering/infrastructure (55%) occurred in almost equal proportion, while for work types, about 60% were new works and the rest was repair/maintenance and a combination of both types.

For project size, the size ranges of 108 respondents with a total project value of around £180 million and an average of around £1.7 million are distributed as follows: nearly 40% for less than or equal to £0.5 million, almost 25% for the values between above a half million to a million pounds and around 35% for greater than a million pounds. Moreover, the sum of project size equal to or less than £5 million is nearly £100 million for 101 projects compared with that of the project size greater than £5 million which is around £80 million for 7 projects. While the completion time ranges of 107 respondents consist of 54% for less than a half year, 30% for the time range between 0.5-1 year and 16% for greater than one year.

Briefly, most respondents are very experienced prequalifiers with various backgrounds of expertise that represent and relate to project types. Moreover, most data are related to small to mid size projects and are distributed approximately equally between project types. But the traditional procurement approach is predominantly used. It is reasonable that these characteristics occur, as all data come from the public sector (i.e. local authorities) and are similar to those discussed in Chapter 4. However, the value of projects procured through partnering and design and build is similar to that of projects procured through the traditional approach. In addition, the data show that the total contract value for the small number of large size projects is higher than the sum of project values within the small and mid size. These characteristics are commonly found in the construction industry.

7.4 PREQUALIFICATION CHARACTERISTICS

7.4.1 Prequalification procedures

In terms of four categories of prequalification procedures in section 4 of the questionnaire, the frequency of the usage of three prequalification routes and the two final selection criteria for determining a winning contractor are similarly distributed across those respective categories (see Table 7.5). While in house prequalification is predominantly used in UK local authorities (around 75%). Additionally, a number of UK local authorities are still reluctant to join the Constructionline scheme and still carry out contractor prequalification in house. In the case of prequalification routes for the final selection of a winning contractor as seen in Figure 7.3, the frequencies across the three possible routes are similarly distributed (see Table 7.5).

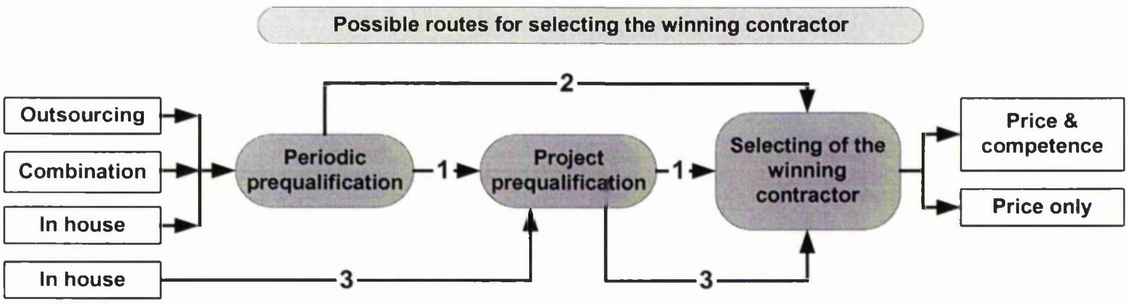


Figure 7.3 Prequalification routes for selecting the winning contractor

Table 7.5 Frequencies of prequalification procedures and characteristics

Category	Frequency
Prequalification route for the winning contractor	
Periodic prequalification → project prequalification → the winning contractor	28.3%
Periodic prequalification. → the winning contractor	38.4%
Project prequalification → the winning contractor	33.3%
Total	100.0%
N	99
Prequalification system based on the sources of expertise	
In house	75.8%
Outsourcing	9.1%
Combination	15.2%
Total	100.0%
N	99
Final selection criteria for the winning contractor	
Price and competence (Mean weight: Price = 0.58; Competence = 0.42)	48.5%
Price only	51.5%
Total	100.0%
N	97
Membership of Constructionline	
No	60.9%
Yes	39.1%
Total	100.0%
N	87

In the case of prequalification routes for the final selection of a winning contractor as seen in Figure 7.3, the frequencies across the three possible routes are similarly distributed (see Table 7.5). However, if examining prequalification routes in more detail by breaking down the data into procurement types and selection criteria (i.e. price and competency and price only), there are some unique relationships.

Even though the total frequencies of traditional and design and build combined with partnering are quite different, both categories have similar contract sums (see Table 7.6 and Table 7.7). Thus, comparison is still reasonable, especially as the data exhibit similar trends to the construction industry as whole. According to the biennial survey in the UK by The Royal Institution of Chartered Surveyors (RICS) from 1985 to 2001, the frequency of procurement through the traditional approach is usually is much higher than through design and build combined with partnering (see Figure L.1 in Appendix L), but the contract sums of the traditional approach are relatively similar to those of design and build and partnering (see Figure L.2 in Appendix L).

Table 7.6 Relationship between prequalification route and procurement type

Prequalification route	Traditional		Design & Build and Partnering	
	Cases	Contract	Cases	Contract
Route 1	16	17.021	11	20.3737
Route 2	32	40.3979	5	11.2136
Route 3	24	36.3204	9	50.3055
Total	72	93.7393	25	81.8928

Table 7.7 Relationship between selection criteria and procurement type

Selection criteria	Traditional		Design & Build and Partnering	
	Cases	Contract (£ million)	Cases	Contract (£ million)
Price and competence	26	46.8642	20	78.337
Price only	44	41.1734	5	3.5558
Total	70	88.0376	25	81.8928

Table 7.6 shows that there is a tendency to increase the use of route 2 representing a less complex route in traditional procurement, when project complexity becomes lower. On the other hand, the frequencies of routes 1 and 3 representing more complex routes tend to be higher in design and build and partnering , which represent high complexity projects compared with the traditional approach which represents low complexity projects.

Additionally, Table 7.7 shows that *price and competence*, as the final selection criteria for determining a winning contractor, are more important in the complex procurement types (i.e. design and build and partnering) than in the traditional approach that commonly deals with less complex projects. This means for higher project values, more criteria are implemented in the contractor selection system.

7.4.2 Frequency of usage, weighting and contractors' competence

Table 7.8 column 2 suggests that *past experience* has the highest frequency of usage in terms of periodic prequalification criteria, and the second group, where the frequencies of the criteria are close to each other, are *past performance* and *managerial & technical strength.* It is important to note that the frequency of usage in column 2 is computed after consolidating the data from 25 periodic prequalification sub criteria based on average frequency within each of the 5 main criteria.

The most important criteria weightings (see Table 7.8 column 3) rated by prequalifiers are *past experience* and *past performance*, followed by the criterion of *compliance with regulations.* The weighting combination (see Table 7.8 column 4) between frequency of usage and weighting scale shows that *past experience, past performance* and *managerial & technical strength* are the top three using the Relative Rank Index (RRI) technique.

Table 7.8 Frequency of usage, weighting and contractors' competence

Periodic prequalification criteria	Usage	Weighting	Criteria	Degree
1	2	3	4	5
Financial strength	84.5%	76.3%	80.3%	**74.1%**
Past experience	**92.0%**	**83.7%**	**87.8%**	**75.1%**
Past performance	**87.6%**	**83.9%**	**85.7%**	71.3%
Managerial & technical strength	**84.9%**	78.9%	**81.8%**	71.5%
Compliance with regulations	71.8%	**80.6%**	76.1%	**73.3%**

Note:

2: Frequency of usage based on 97 respondents' answers related to Section III.a of the questionnaire in Appendix L

3: Weighting of the criteria rated by qualifiers and computed on the basis of the Relative Rank Index (RRI) technique derived from an ordinal scale rated by respondents related to Section III.b of the questionnaire in Appendix L

4: Criteria on the basis of the combination of usage and weighting indices and the computation based on the square root of multiplication of columns 2 and 3

5: The rating degree of the winning contractors (i.e. contractor data evaluated against criteria rated by qualifiers) based on the RRI technique derived from an ordinal scale rated by respondents related to Section III.a of the questionnaire in Appendix L

Their degrees of contractors' competence evaluated against periodic prequalification criteria using a rating scale ranging from 1 to 6 and rated by prequalifiers (see Table 7.8 column 5) indicate that the competence is far above average (the average value means RRI equal to 50% or equal to 3 on basis of a maximum scale of 6) and *financial strength*, *past experience* and *compliance with regulations* factors are the top three rank order of contractors' competence. It is important to note the rating scales are based on the rating scale of the project winning contractors' data: 1 (*unsatisfactory*); 2 (*minimum acceptable*); 3 (*between 2 & 4*); 4 (*typical average*); 5 (*between 4 & 6*); 6 (*maximum desirable*).

Furthermore, when the data in columns 2 and 3 are combined as depicted in Table 7.8 column 4, *past experience* and *past performance* and *managerial and technical strength* are in the top three. If these findings are cross-checked with the results in Chapter 4.3.2.6 and 4.3.2.7, there are very similar trends of the top three ranked periodic prequalification criteria. However, for the level of contractors' competence rated by qualifiers, only the *past experience* criterion in column 5 corresponds to the criteria in column 4.

If the winning contractors' competence factors (i.e. contractors' periodic prequalification factors) are verified against the final selection criteria, all the RRIs of the factors evaluated against the *price and competence* criterion are much higher than those evaluated against the *price only* criterion in respect of *compliance with regulations*, *managerial and technical strength* and *past performance* criteria, except the *past experience* and *financial strength* criteria that are slightly higher (see Figure 7.4). These results are based on the data consolidated from 25 sub criteria to 5 main criteria. Therefore, the results of contractor selection through a combination of price and competence may obtain better contractors' competence that can lead to improved construction project performance.

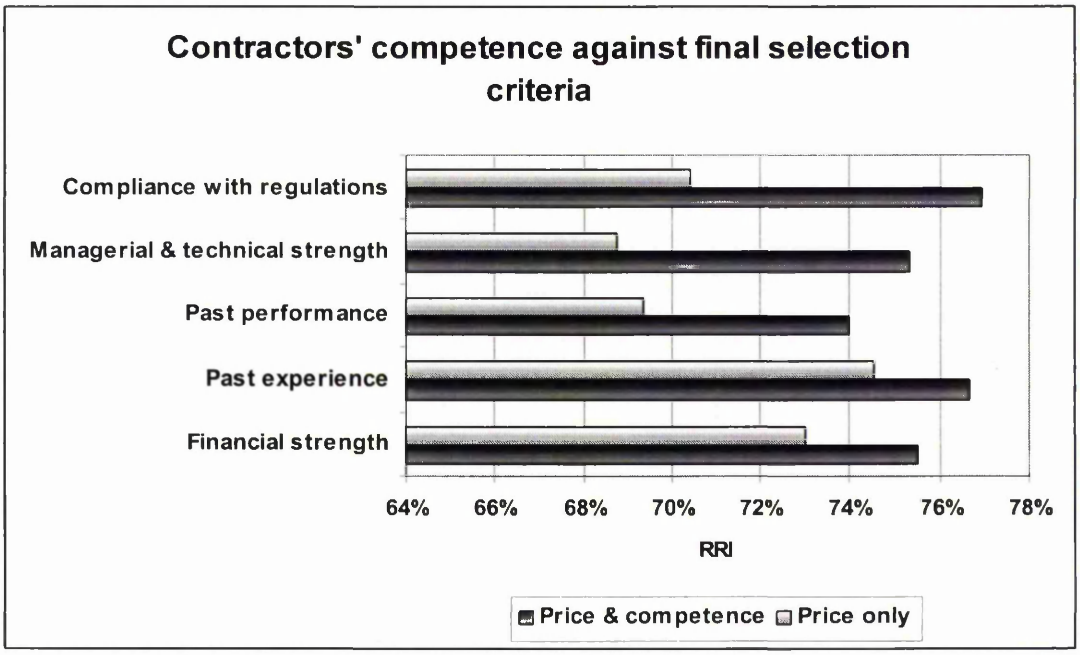


Figure 7.4 Contractors' competence versus final selection criteria

7.5 PROJECT PERFORMA NCE CHARACTERISTCS

There are three dimensions of project performance characteristics (i.e. cost, time and quality performance) being measured through two kinds of indicators, namely, variations and client satisfaction. Cost and time variations are calculated on the basis of the differences between the actual and budgeted cost and actual and planned time of recorded project cases (see Section II of the questionnaire in Appendix L). These measurements of cost and time on the basis of continuous data were then transformed into an ordinal number from 1 to 6 (see Table 2.2 and Table 2.3 in Chapter 2) and also into a dichotomous variable for the Logistic Regression analysis (i.e. *superior* and *inferior* performance). While quality variation is rated by respondents on the basis of a scale measurement on a scale of 1 to 5 as seen in Table 2.4 in Chapter 2.

Table 7.9 indicates that the average value of cost is nearly 3 with a median of 3, which means costs are close to zero variation in the range of *0%< Cost variation ≤+2.5%*. In the case of time, the variation is close to the lower level in the range of *0% < Time variation ≤ +5%* with a mean of 2.8 but a median of 2. While the average value of quality variation is nearly 4, which means that the average value of quality variation is relatively high and is at the level of *some defects and no significant impact on client*. Moreover, the average values of clients' overall cost, time and quality satisfaction are between 4 and 5 (median: 5), indicating that client satisfaction level is relatively high and similar across all three dimensions of project performance (see Table 7.9).

Table 7.9 Mean and median of variation and satisfaction

Statistical parameter	Variation			Satisfaction		
	Cost	Time	Quality	Cost	Time	Quality
Mean	2.93	2.81	3.86	4.56	4.51	4.61
Median	3	2	4	5	5	5
N	107	109	105	106	105	105

To complement the performance factor, respondents were also asked to provide subjective judgement about three sources, which are responsible for occurrence of cost, time and quality variations. There are three variables used in this study, namely, *contractor* (coded as CVCO: cost; TVCO: time; and QVCO: quality variation), *client* (CVCL: cost; TVCL: time; and QVCL: quality variation), and *neither party* (CVNOR: cost; TVNOR: time; and QVNOR: quality variation).

The measurement of the degree of responsibility for causing variation is based on a proportion level and, for each project under investigation, respondents were asked to asses the degree of contribution of each of three categories of the source of variation factors with regards to cost, time and quality performance. The summation of the proportion causing variations is assumed to be 100 percent for each case. The averages for each factor are shown in Figure 7.5, Figure 7.6 and Figure 7.7.

To obtain a clear picture about cost and time performance, the data sets for each factor (i.e. contractor, client, neither party) are divided into two groups of *superior* performance and *inferior* performance.

Figure 7.5 shows that the *client*, as a source of variation factor, significantly contributes to cost variation and also indicates a difference between *superior* and *inferior* performance, followed by *contractor* and then *neither party.* Additionally, *superior* performance and *inferior* performance is visually different in relation to *client* and *neither party* factors, but not for the *contractor* factor where they seem to be similar.

Moreover, Figure 7.6 exhibits that the *contractor* factor responsible for time variation has similar proportions of impact on *superior* performance and *inferior* performance, even though this factor has a higher contribution to overall time performance than the other two factors. Conversely, the *client* factor tends to influence time variation much more and has an especially high contribution to *inferior* performance. *Neither party* factor also has similar influence on *inferior* performance, but with a lower degree of impact than that of the *client* factor.

In respect of quality variation, all three factors have practically no variation influence on *superior* and *inferior* performance. However, the party most responsible for quality variation is the *contractor* factor, while the other factors have little effect (Figure 7.7).

In order to know reasons for the variations taking place and which source of variation factors were responsible for them, respondents were asked to answer open questions. The reasons given by respondents are based on the source of variation factors which had the highest contribution to the variation. The results of the frequencies of reasons causing variation, based on the three factor categories (i.e. *contractor*, *client* and *neither party* factors), are shown in Table 7.10, Table 7.11 and Table 7.12 in relation to cost variation; Table 7.13, Table 7.14 and Table 7.15 in relation to time variation; and Table 7.16 in relation to quality variation.

The results of the lists of causal factors for variation are summarised in Table 7.17 and can provide useful information for the developing the model relationship between project performance and periodic prequalification factors as they are representative of historical data and the list of sources of variation factors being responsible for variation during the construction process represents current data.

As seen Table 7.17, *design/contract/specification change* and *unforeseen circumstances* are the causal factors coming from the client that create additional work leading to an increase in cost and time variations, and sometimes *unforeseen circumstances* enforce a client to change design, for example (see detailed causal factors in Table 7.10 and Table 7.13). These findings demonstrate that there is strong correlation between cost and time variations, as both of these factors were found to be responsible for cost and time variations. In addition, *design change* may influence quality performance as seen in Table 7.16. However, *design/contract/ specification change* is necessary to reduce cost due to some of the work items being eliminated (see Table 7.10).

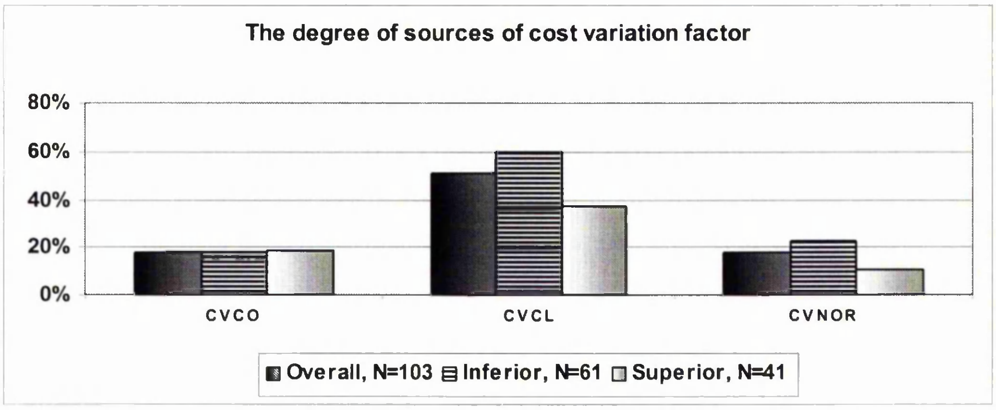


Figure 7.5 The degree of sources of cost variation factor

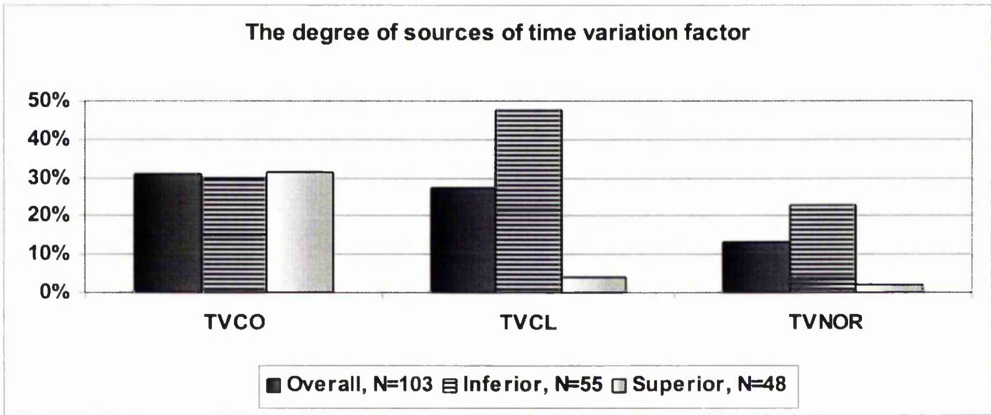


Figure 7.6 The degree of sources of time variation factor

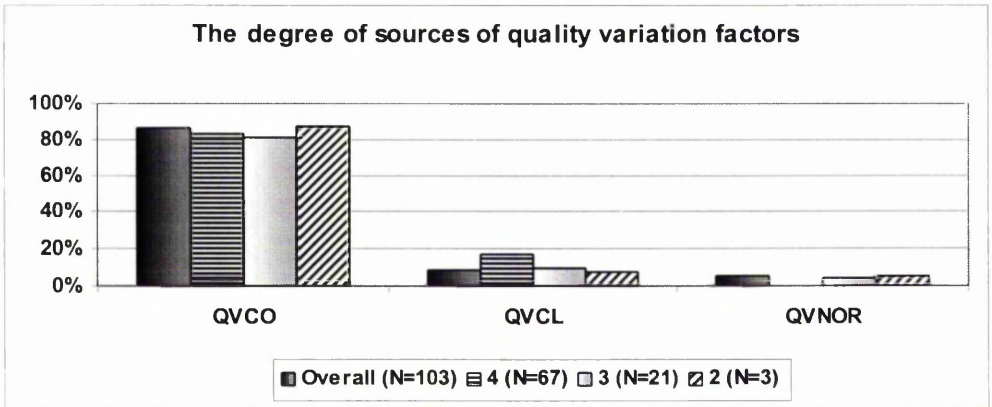


Figure 7.7 The degree of sources of quality variation factor

Note:

4: Some defects and no significant impact on client
3: Some defects and with some impact on client
2: Some defects and with major impact on client

Table 7.10 Causal factor for cost variation related to client

Additional works/cost variation increase		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Additional work/cost due to unforeseen circumstances	Refurbish work, archaeological findings, unforeseen ground/geological condition, increase in statutory authority costs, parking demands, Unexpectedly poor condition of the building, unforeseen circumstances quality governed by specification, access to site problem	17
Design/contract/specification change	Tenant parking demands, insufficient system information, brief change, remeasure, specification revision, change material, increase material cost	15
Unclassified additional work		9
Work reduction/cost variation decrease		
Design/contract/specification change	Reduction in work content, bill of approximate quantities-remeasured sections, reappraisal of selected rates, reduced ground work, alternative materials, client required a cost saving	11
Unused contingency	Contingency not fully required	6

Table 7.11 Causal factor for cost variation related to contractor

Cost variation increase		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Poor estimate (Partnering case)		3
Additional work due to unforeseen circumstances (Partnering case)		2
Design change (Partnering case)		1
Cost variation decrease		
Alternative material being used		1

Table 7.12 Causal factor for cost variation related to neither party

Cost variation increase		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Additional work/cost due to unforeseen circumstances	Unforeseen groundwater condition	13
Inclement weather		1

Table 7.13 Causal factor for time variation related to client

Time variation increase		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Additional work/cost due to unforeseen circumstances	Unforeseen condition, ground condition, third party problems, access to site problems	14
Design/contract/specification change	Design error, restoration method change, contract was halted and restarted	6

Table 7.14 Causal factors for time variation related to contractor

Time variation increase		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Lack of planning and coordination	Lack of subcontractor control, poor coordination between trades, poor project planning & management, poor time estimation	5
Lack of resources	Insufficient equipment, inadequate resource, lack of brick layers	3
Unclassified poor time performance	Poor contractor performance	3
Poor method of working practice/poor performance		2
Material delay		1
Time variation decrease		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Good resource management and planning	High productivity-efficient use of resources, contractor increase resources, contractor efficient use of subcontract earthworks/ demolition	5
Good planning and coordination	Good team working, early completion, design change (partnering)	5
Good method of working practice	Revised work sequence, efficiency of contractors methods of work	3

Table 7.15 Causal factor for time variation related to neither party

Time variation increase		
Causal factor	**Detailed causal factor based on the respondents' response**	**Frequency**
Inclement weather		6
Unforeseen circumstances	Archaeological findings, ground conditions causing defects at completion, presence of British Telecom Fibre Optic cables	6

Table 7.16 Causal factor for quality variation

Quality variation related to client	Frequency
Design change	3
Quality variation related to contractor	**Frequency**
Poor/substandard workmanship	18
Poor method of working practice/poor performance	7
Poorly finished project	6
Poor site supervision	3
Quality variation related to neither party factor	**Frequency**
Inclement weather	1
Unforeseen circumstances	1

Note: Risk findings based on the respondents' response

In the case of contractors that are responsible for time variation, most causal factors are related to the competence level of *managerial and technical strength*. This technical and management factor is believed to influence project success and failure. When the contractor's work includes design due to there being a partnering or design and build contract, causal factors may also come from the contractor's side, similar to the client's side as a source of variation factor. The occurrence of quality variation is mostly due to the competence level of contractors' *managerial and technical strength*, such as *poor/substandard workmanship, poor method of working practice, poorly finished project* or *poor site supervision*.

To confirm the correlation between the variation and satisfaction variables described before, the Spearman-rho correlation technique was used and the results show both factors are statistically significant (see Table 7.18). In addition, quality variation can influence project duration due to poor work items being rejected or needing to be reworked. But, in this study, no correlation was found between cost variation and quality. This can be explained by the client predominantly causing the cost variation in this study, while quality variation is mostly related to contractor problems.

The correlation within client satisfaction variables in Table 7.18 indicates that all clients' satisfaction variables are significantly correlated. Additionally, correlation between satisfaction and variation variables is also significant, as seen in Table 7.19. However, correlation between cost and quality variation, as well as variation and satisfaction variables in respect of cost and quality factors, is not significant. These findings can be due the fact that sometimes clients decide to increase the project cost and cause a time extension in order to meet their project objectives, including the project being completed with a high quality level of satisfaction (see Table 7.18 and Table 7.19).

Table 7.17 Summary of causal factors of variation

Causal factor	CVCL	CVCO	CVNOR	TVCL	TVCO	TVNOR	QVCL	QVCO
Additional work/cost due to unforeseen circumstances	✓			✓				
Design/contract/ specification change	✓			✓			✓	
Unforeseen circumstances			✓			✓		
Inclement weather			✓			✓		
Lack of planning and coordination					✓			
Lack of resources					✓			
Poor method of working practice								✓
Poor/substandard workmanship								✓
Poorly finished project								✓
Poor site supervision								✓
Design/contract/specification change	✓							
Unused contingency	✓							
Good resource management and planning					✓			
Good planning and coordination					✓			
Good method of working practice					✓			

Note:

CVCL	Cost variation caused by client
CVCO	Cost variation caused by contractor
CVNOR	Cost variation caused by neither party
TVCL	Time variation caused by client
TVCO	Time variation caused by contractor
TCNOR	Time variation caused by neither party
QVCL	Quality variation caused by client
QVCO	Quality variation caused by contractor

Table 7.18 Spearman-rho correlation between cost, time and quality variation and satisfaction variables

Correlation	Variation			Satisfaction		
	Cost	Time	Quality	Cost	Time	Quality
Cost	1			1		
Time	**0.35**	1		**0.65**	1	
Quality	0.11	**0.26**	1	**0.50**	**0.53**	1

Note: Bold values are statistically significant at the 0.05 level (2 tailed) with N: 104-109

Table 7.19 Spearman-rho correlation between variation and satisfaction variables

Correlation	Variation			
	Performance	**Cost**	**Time**	**Quality**
Satisfaction	**Cost**	**0.55**	**0.37**	**0.27**
	Time	**0.23**	**0.62**	**0.33**
	Quality	0.0954	**0.26**	**0.50**

Note: Bold values are statistically significant at the 0.05 level (2 tailed) with N: 104-109

7.6 DEVELOPMENT OF A MODEL RELATIONSHIP BETWEEN PROJECT PERFORMANCE AND PERIODIC PREQUALIFICATION CRITERIA

7.6.1 Data preparation for an alysis

This section explains the preparation of data for developing a model relationship in respect of identification of the key periodic prequalification factors influencing project performance, as the main objective of Empirical study 2.

It is important to note that for each case of data collected through Empirical study 2, both dependent and independent variables were related to a particular project case and the winning contractor that carried out and completed that project was selected through a prequalification system.

As discussed in Chapter 2, the Logistic Regression (LR) technique was used for developing the model relationship. While the Factor Analysis (FA) technique was employed for reducing the number of periodic prequalification variables due to the reduction of the multicollinearity effect and also for generating factor scores.

In this empirical study, six possibly different models can be developed as depicted in Figure 7.8 which are based on the complete independent and dependent variables. Any missing periodic prequalification factors and source of variation factors, consisting of organisational (contractor and client parties) and non organisational (neither party: e.g. inclement weather) factors being responsible for performance as independent factors, and project performance as dependent variables are then excluded in the model development. Figure 7.8 also shows the detailed independent and dependent variables.

After coding and transferring the collected data into electronic media and then making a preliminary examination, 58 cases were identified that can be used for reducing the number of independent variables (i.e. prequalification data in section III of the questionnaire), using the Factor Analysis (FA) technique, and less than 58 cases for developing the model relationship between project performance and periodic prequalification criteria using the Logistics Regression (LA) technique.

The decrease of usable periodic prequalification criteria data from 97 to 58 cases is due to the assumption that if one of the prequalification criteria within a case is unused by a respondent's prequalification system, the case is excluded from the analyses or model development. While the use of less than 58 cases is due to the missing of project cases with regards to source of variation factors consisting of organisational and non organisational factors being responsible for performance as independent factors.

In terms of dependent variables, the measurement of project performance is based on dichotomous variables. The dichotomous variables of *time* variation and *cost* variation, which are objective data related to particular project cases, are measured according to *superior* performance (less than or equal to 0% variation) and *inferior* performance (above 0% variation).

While the dichotomous variables of *quality* variation, *time* satisfaction, *cost* satisfaction and *quality* satisfaction, being categorised as subjective data (ordinal data) related to particular project cases, are measured on the basis of *superior* performance (positive z-scores based on above average standardised values) and *inferior* performance (negative z-scores based on below average standardised values). The assumption of this approach is due to the proportional distribution of the dichotomous data set.

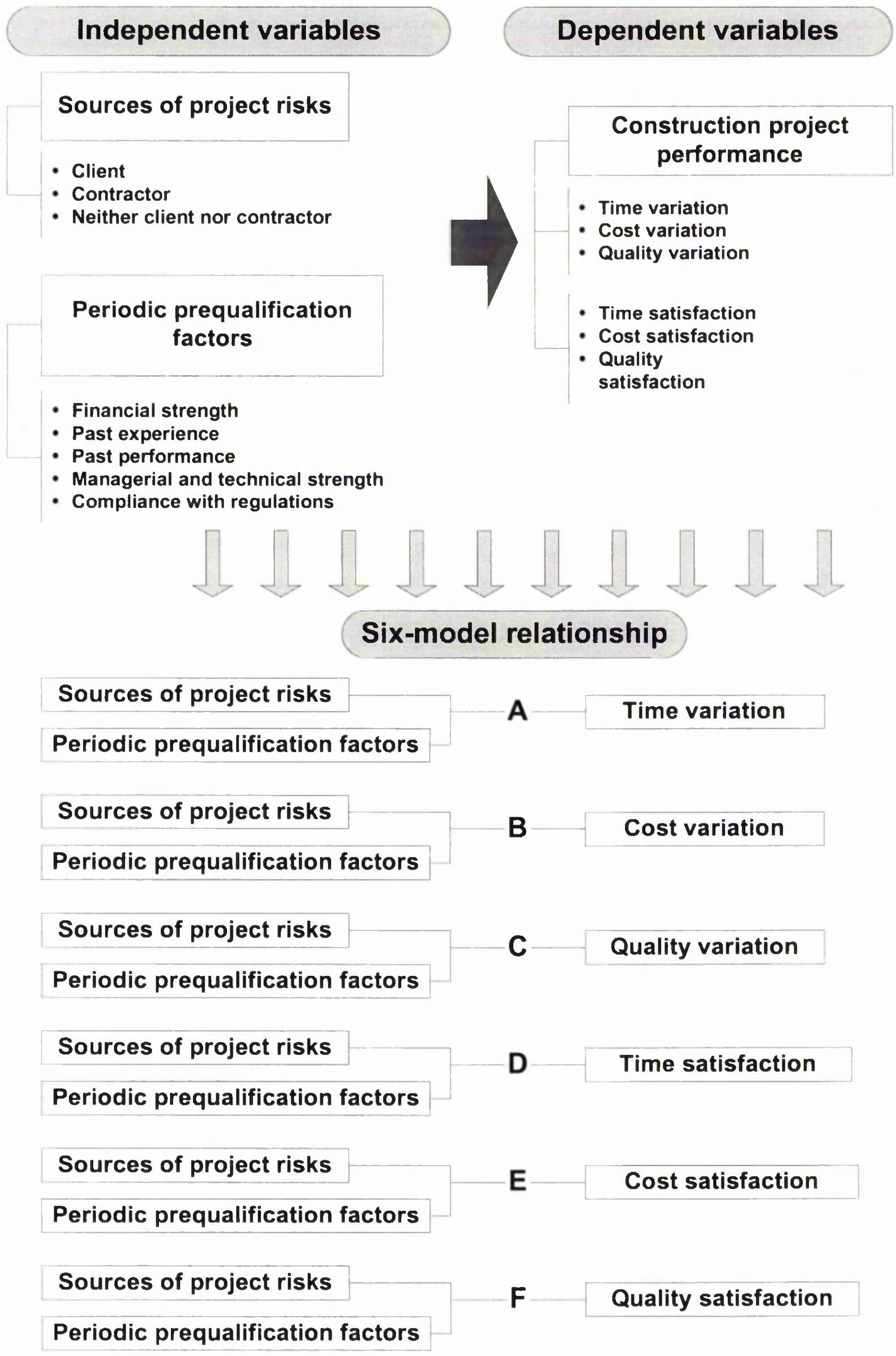


Figure 7.8 Variables in the six model relationships

Furthermore, source of variation factors and periodic prequalification factors, as independent variables obtained through the questionnaire, were transformed from a scale of 0-100% to a 1-6 ordinal scale. While the measurement of periodic prequalification factors is based on the factor scores obtained through the FA technique, which were derived from the winning contractors' data rated by respondents using a scale of 1 to 6 against periodic prequalification criteria mentioned in Table 5.5. The Factor Analysis (FA) technique and the computation of these factor scores are described in detail in Section 7.6.2.

The six identified factors of periodic prequalification variables, using the FA technique in the form of factor scores and on the basis of 58 cases, were utilised for further LR analysis. While for developing relational models using the LR technique, the number of cases was slightly less than 58 cases. For example, for time performance 57 cases were used and 55 for cost performance.

The data utilised for FA and LR were based on the 55-58 complete cases and the frequencies of the used data in respect of respondent categories and project categories are not much different from the total response data as seen in Table 7.20 and Table 7.21 respectively.

Table 7.20 Respondents' characteristics used for modelling

Category	Frequency	
	Used for model	All
	N=58	N=110
Profession		
Civil/Structural Engineer	44.8%	50.0%
Quantity Surveyor	24.1%	24.6%
Architect	13.8%	13.6%
Project Manager	12.1%	7.3%
Other	5.2%	4.5%
Total	100.0%	100.0%
Experience		
>5 years	91.4%	89.9%
>3-5 years	3.5%	5.5%
1-3 years	5.2%	4.5%
Total	100.0%	99.9%

Table 7.21 Project characteristics used for modelling

Category	Frequency	
	Used for model	All
Contract value		
<=£0.25M	13.8%	17.6%
>£0.25M-£0.5M	15.5%	22.2%
>£0.5M-£1M	29.3%	24.1%
>£1M-£5M	32.8%	29.6%
>£5M	8.6%	6.5%
Total (N=108)	100.0%	100.0%
N	58	108
Contract time		
<=0.5 year	51.7%	54.2%
>0.5-1 year	29.3%	29.9%
>1-1.5 years	10.3%	11.2%
>1.5 years	8.6%	4.7%
Total	100.0%	100.0%
N	58	107
Project type		
Housing/building	46.6%	44.6%
Civil engineering/infrastructure	53.4%	55.4%
Total	100.0%	100.0%
N	58	110
Work type		
New work	59.6%	61.7%
Repair & maintenance	35.1%	32.7%
Combined	5.3%	5.6%
Total	100.0%	100.0%
N	58	107
Procurement type		
Traditional	65.5%	75.5%
Design and build	15.5%	9.1%
Partnering	19.0%	15.5%
Total	100.0%	100.0%
N	58	110
Payment type		
Lump Sum	39.3%	40.8%
Unit price	30.4%	28.2%
Other	30.4%	31.0%
Total	100.0%	100.0%
N	58	103
Project year		
1998-2001	39.6%	41.2%
2002-2003	60.4%	58.8%
Total	100.0%	100.0%
N	58	109

7.6.2 Reduction of the number of periodic prequalification variables

The stages of the reduction of the number of periodic prequalification variables using the FA technique are described in the following sections.

7.6.2.1 First stage: Factor Analysis objectives

The main purpose of factor analysis is to reduce the number of periodic prequalification criteria and to generate factor scores of the reduced number of periodic prequalification criteria.

7.6.2.2 Second stage: Factor Analysis design

The data are highly reliable in respect of the measurement of the 6 points of the ordinal scales using Cronbach's alpha coefficient (0.94) and an acceptable number of cases (58) for the usage of the FA technique.

7.6.2.3 Third stage: Factor Analysis assumptions

The data reveal a sufficient number of correlations greater than 0.3 (71.3%). In addition, a statistical test for the presence of correlations among the variables using the Bartlett Test of Sphericity (BTS) indicates statistically high significance. While the Measure of Sampling Adequacy (MSA) that measures the degree of intercorrelation among variables has a *middling* index (0.765).

7.6.2.4 Fourth stage: Deriving factors and assessing overall fit

The Principal Component Factoring technique was utilised for extracting the factors. Since the communalities of most factors are above 0.7 as seen in Figure M.2. in Appendix M (only two variables are 0.59 and 0.69), these results indicate there is no significant difference between extracting factors using Principal Component Factoring (PCF) and Principal Axis Factoring (PAF).

In terms of the number of factors extracted, Table 7.22 show that 6 factors were extracted on the basis of eigenvalues greater than 1 where total variance of the 6 retained factors is 78.4% which explains the relative importance/representation of 25 variables. The detail of the variance explained for each extracted factor can be seen in the bottom row of both tables.

7.6.2.5 Fifth stage: interpreting the factors

To obtain simple factor matrices that can present meaningful interpretation, oblique techniques are used, as 40% of the correlations between the factors in the component correlation matrix show values above and around 0.3 (see Figure M.3 in Appendix M). It means that the use of oblique technique is appropriate (see Table 2.5). Due to the limitation of the number of cases (58), the value of around 0.7 was used for interpreting the significance level of factor loading (see Table 2.5 describing the Fifth stage: Interpreting the factors). In Table 7.22 the results validate 18 sub periodic prequalification criteria being grouped into the appropriate 5 main periodic prequalification factors. Moreover, details of the factor labelling can be seen in Table 7.23.

Table 7.22 Factor loadings based on the pattern matrix of oblique rotation

Periodic prequalification criteria	New periodic prequalification factors based on oblique rotation					
	FAC1_2	FAC2_2	FAC3_2	FAC4_2	FAC5_2	FAC6_2
R2	**0.933**	0.041	-0.082	0.055	-0.130	0.078
R3	**0.848**	0.096	0.103	-0.170	-0.149	0.001
R4	**0.847**	-0.112	-0.202	-0.030	0.017	-0.060
R1	**0.682**	0.054	-0.045	0.023	0.103	0.097
M3	0.513	0.124	0.070	0.144	0.363	0.450
E3	0.024	**0.807**	-0.207	-0.131	-0.020	-0.024
E4	0.074	**0.733**	0.038	-0.087	0.095	0.256
E1	0.066	**0.686**	-0.142	-0.279	0.160	-0.307
F2	-0.040	0.050	**-0.942**	0.003	-0.045	0.164
F1	0.019	-0.013	**-0.855**	-0.026	0.062	0.122
F3	0.141	0.287	**-0.788**	-0.016	-0.125	-0.115
F4	0.204	-0.355	-0.455	-0.363	0.237	-0.195
P1	-0.014	0.109	0.033	**-0.895**	0.010	-0.014
P4	-0.088	-0.019	-0.080	**-0.818**	0.038	0.033
P2	-0.004	0.140	0.035	**-0.798**	0.116	0.083
P3	0.137	0.066	-0.068	**-0.776**	-0.183	0.083
P5	0.208	-0.138	-0.147	**-0.665**	0.161	0.022
E5	-0.204	0.105	0.038	-0.050	**0.845**	0.141
E2	0.105	0.501	-0.257	0.153	0.505	-0.109
F5	0.268	-0.103	-0.235	-0.297	0.504	-0.287
E6	0.347	0.099	0.110	-0.378	0.495	0.028
M4	0.197	-0.027	-0.094	-0.064	-0.062	**0.749**
M2	-0.043	0.033	-0.250	-0.178	0.186	**0.661**
M5	0.352	-0.223	-0.117	-0.223	0.115	0.497
M1	0.083	0.283	0.099	-0.459	-0.092	0.475
Variance	**43.5%**	**10.0%**	**8.5%**	**6.9%**	**5.1%**	**4.4%**

Note: - The meaning of codes in the first column can be seen in Table 5.5
- Bold values mean significant factor loadings

Table 7.23 Summary of factor labelling

New name of independent variables	Variable codes of oblique
Financial strength	FAC3_2
Past experience	FAC2_2
Past performance	FAC4_2
Managerial and technical strength	FAC6_2
Compliance with regulations	FAC1_2
Verification of financial and experience information	FAC5_2

7.6.3 Factor scores of periodic prequalification variables

Factor scores of the six identified periodic factors were determined on the basis of the regression technique. The factor scores can be calculated according to the following equation:

$$\xi_i = w_1 z_1 + w_2 z_2 + w_3 z_3 + w_4 z_4 + w_5 z_5 + w_6 z_6 \qquad (7.1)$$

Where w_1 to w_6 are the factor score coefficients, i is the number of cases, that is 58 cases and z_1 to z_6 are z-scores/standardised values of the 6 reduced factors that can be obtained from the following equation:

$$z_n = \frac{x_n - \bar{x}_n}{s_n} \qquad (7.2.)$$

Where x_n is the value case; $\bar{x}$ is the average value; s_n is the standard deviation.

The factor scores' coefficients can be seen in Table 7.24. Moreover, the periodic prequalification criteria related to the factor score coefficients which have significant values in both tables are the same as the significant periodic prequalification criteria in Table 7.22.

The SPSS program can generate factor scores easily for each case and also determine its coefficients directly. But for sensitivity analysis, it is better to use a spreadsheet program because it is relatively easy to control the calculation, especially if the original values of the periodic prequalification variables being expressed as ordinal data need to be changed during sensitivity analysis.

Table 7.24 Factor score coefficient matrix using the oblique rotation technique

Periodic prequalification factors	FAC1_2	FAC2_2	FAC3_2	FAC4_2	FAC5_2	FAC6_2
F1	-0.038651	-0.043681	**-0.312805**	0.022883	0.005931	0.053034
F2	-0.058978	-0.011343	**-0.348549**	0.029316	-0.058305	0.079333
F3	0.019094	0.105012	**-0.279327**	0.018417	-0.116227	-0.073559
F4	0.038669	-0.199520	-0.158221	-0.086377	0.121504	-0.128023
F5	0.066661	-0.095544	-0.059050	-0.054029	0.264098	-0.180176
E1	0.017476	**0.279764**	-0.014064	-0.051932	0.027794	-0.178169
E2	0.017526	0.182704	-0.061463	0.088774	0.248899	-0.068354
E3	-0.006484	**0.345221**	-0.042802	-0.006420	-0.078327	-0.026053
E4	-0.000153	**0.312878**	0.051315	0.014990	-0.004112	0.114755
E5	-0.091839	-0.010570	0.037506	0.031422	**0.469051**	0.070051
E6	0.081800	0.001329	0.083342	-0.064738	0.245923	-0.028041
P1	-0.030322	0.021281	0.038798	**-0.240319**	-0.046348	-0.040822
P2	-0.033125	0.030118	0.042780	**-0.203548**	0.014547	0.009703
P3	0.013818	0.013318	-0.002059	**-0.208380**	-0.153716	0.005820
P4	-0.057751	-0.038949	-0.011413	**-0.219581**	-0.020399	-0.009423
P5	0.030891	-0.098356	-0.028888	**-0.164892**	0.054924	-0.028621
M1	-0.013273	0.116286	0.062821	-0.102270	-0.099392	0.217427
M2	-0.073813	-0.017976	-0.078201	-0.007570	0.077905	**0.325496**
M3	0.123360	0.031950	0.061604	0.092578	0.185564	0.195920
M4	0.008979	-0.020230	-0.023108	0.015187	-0.054495	**0.364125**
M5	0.061276	-0.122635	-0.024906	-0.028821	0.048312	0.220568
R1	**0.194199**	0.012532	0.016142	0.039024	0.034851	0.006003
R2	**0.275840**	0.020878	0.004046	0.043120	-0.100690	-0.014742
R3	**0.256134**	0.047382	0.075631	-0.027145	-0.117602	-0.055959
R4	**0.248069**	-0.061776	-0.044061	0.018399	-0.012014	-0.083938

Note:
- The meaning of codes in the first column can be seen Table 5.5
- Bold values mean significant factor score coefficients

7.6.4 Model relationship based on Logistic Regression analysis for time variation

Since the model relationship of time performance (i.e. model A as seen in Figure 7.8), which is related to time variation, exhibits better results than other models, the process of model development using the Logistic Regression (LR) technique is described in the detail in the following sections based on time performance. Other model results are summarised for comparison and identification of the key periodic prequalification factors influencing project performance.

7.6.4.1 First stage: Logistic Regression analysis objectives

The use of this technique is to identify the key factors of periodic prequalification criteria that can influence project performance (i.e. dichotomous variable: *superior* and *inferior* project performance).

7.6.4.2 Second stage: Logistic Regression analysis design

Of 57 cases available, 48 (85%) cases are used for developing model A and 9 (15%) cases for testing (i.e. validation) model A, known as a holdout sample. It is important to note the 85% cases are not static samples but randomly chosen. In addition, the number of cases under the dichotomous dependent variable (i.e. *superior* and *inferior* performance related to time variation) are randomly and proportionally divided on the basis of the total proportional division of the dichotomous variable (i.e. 27 *superior* performance cases and 30 *inferior* performance cases). The number of 48 cases still meets the requirement of 5 cases per independent variable (minimum 45 cases). During development of this model, 48 cases are randomly resampled 10 times in order to find reliable models. The purpose of this approach, known as cross validation, is to ensure the validity of the derived LR equation.

7.6.4.3 Third stage: Logistic Regression assumptions

The FA technique is employed to reduce the number and multicollinearity effect of periodic prequalification criteria as independent variables. Therefore, only six variables of periodic prequalification factors identified in the previous section (Chapter 7.6.2 and 7.6.3) are included during the development of the LR equations.

7.6.4.4 Fourth stage: Estimation of the Logistic Regression model and assessing overall fit

After initially examining the bivariate correlation between dependent variables and independent variables, the Wald statistic is used to evaluate the individual statistical significance of the predictors using single predictor models of the LA approach. The variables of *managerial and technical strength* and *client* as a source of variation factor are significantly correlated to time performance and very strong predictors within the LA models as seen in Table 7.25. It means model relationships can be further developed on the basis of multiple predictors, and, at least, both the identified predictors will be included in the final model as the predictors of time variation.

Table 7.25 Correlation and Wald statistic for time variation

Independent variables	Oblique rotation				
	Code	Pear.	Spear.	B	Sig.
Past performance	FAC4_2	0.03	-0.04	0.05	0.84
Compliance with regulations	FAC1_2	0.13	0.13	0.28	0.31
Financial strength	FAC3_2	0.12	0.12	0.24	0.37
Past experience	FAC2_2	0.16	0.13	0.34	0.22
Managerial and technical strength	FAC6_2	**0.40**	**0.37**	**0.93**	**0.00**
Verification of financial and experience information	FAC5_2	0.15	0.12	0.32	0.25
Contractor risk factor	TVCO	-0.06	-0.10	-0.06	-0.10
Client risk factor	TVCL	**-0.66**	**-0.74**	-0.66	-0.74
Neither party factor	TVNOR	-0.22	**-0.36**	-0.22	-0.36

Note:
- Code: Code for independent variables
- Pear.: Pearson correlation
- Spear.: Spearman correlation
- B: Predictor coefficient
- Sig.: Wald statistic significance level
- TVxx codes in the bottom three rows: Source of time variation factors
- Bold value means statistically significant at 0.05 level (2 tailed)

In addition to the initial analysis, the Mann-Whitney U test is also used to distinguish whether there is any difference between independent variables in respect *of superior* performance and *inferior* performance. As can be seen in Appendix N, the results suggest that *managerial and technical strength* (FAC6_2), *client* (TVCL) and *neither party* factors (TVNOR) are significantly different.

Before developing a LR model using the stepwise technique on the basis of data separation between analysis and holdout samples, it is useful to verify the model using all data available without separation between analysis and holdout samples, especially as this approach can provide an indication of which independent variables are significant in the model relationship. The results of initial verification can be seen in Table 7.26.

Table 7.26 LR model parameters of time variation based on full data set (57 cases)

Variable	B	Wald sig.	Exp(B)	R-square		Classification		
				Cox-Snell	Nagelkerke	Inferior	Superior	Overall
TVCLR	-2.578	**0.002**	0.076	0.62	0.83	93.3%	96.3%	94.7%
TVNOR	-1.241	**0.027**	0.289					
FAC2_2	1.450	**0.043**	4.263					
FAC6_2	1.920	**0.036**	6.822					
Constant	6.400	**0.001**	602.008					

Note:
- Goodness-of-fit tests for all models are statistically significant at 0.05 level (2 tailed)
- The cut value of classification has a probability of 0.5

Furthermore, after analysing 10 random data sets with 48 cases using oblique based factor scores, 4 independent variables were identified as significant predictors for time variation: *client* (TVCL, 10 times) and *neither party* (TVNOR, 9 times) factors as sources of time variation along with *past experience* (FAC2_2, 5 times) and *managerial and technical strength* (FAC6_2, 5times) factors as periodic prequalification factors. These findings can be seen in Table 7.27.

In respect of coefficient predictors and significant Wald statistic in Table 7.28, *managerial and technical strength* is the most significant factor *positively* influencing the likelihood of *superior* time performance (i.e. zero or negative time variation) followed by *past experience*. While *client* as a source of time variation factor is the most significant variable that can reduce the probability of *superior* time performance followed by *neither party* as a source of time variation factor.

Table 7.27 Identification of key independent variables through cross validation in relation to time variation

Random order	Independent variables						Total
1		TVCL	TVNOR				2
2	TVCOR	TVCL	TVNOR	FAC1_2	FAC2_2	FAC6_2	6
3		TVCL				FAC6_2	2
4		TVCL	TVNOR		FAC2_2	FAC6_2	4
5		TVCL	TVNOR		FAC2_2	FAC6_2	4
6		TVCL	TVNOR			FAC6_2	3
7		TVCL	TVNOR				2
8		TVCL	TVNOR				2
9	TVCOR	TVCL	TVNOR		FAC2_2		4
10	TVCOR	TVCL	TVNOR		FAC2_2		4
Total	3	10	9	1	5	5	33

However, of ten models, only two models in Table 7.28, indicated as bold characters, can include four predictors for further analysis. Additionally, the models found using the prequalification data derived from both FA rotation techniques contain the same significant predictors in relation to periodic prequalification criteria (i.e. *past experience*, FAC2_2 and *managerial and technical strength*, FAC6_2). These predictors are key factors that can influence time performance in relation to time variation and these factors correlated to the factors on the basis of the FA results can be seen in Table 7.29.

Regarding model overall fit (see models 4 and 5 in Table 7.28), R square values, the multiple regression coefficient showing the fitness of the model relationship, demonstrate quite good model fit, where Cox-Snell's R square values are around 0.6 and Nagelkerke's R square value is around 0.8. Moreover, another goodness of fit model test is the prediction power that demonstrates how well the models can correctly classify *inferior*, *superior* and *overall* time performance in respect of the change of time variation. The results indicate that the models have shown above 90% correct classifications of those three time variations. In addition, if the values of –2 log-likelihood (-2LL) based on multiple predictors are significantly less than the value of – 2LL based on a single variable (i.e. constant value), the predictive model is a good fit. The results are statistically significant, indicated by a Chi-square value of the significant change of –2LL values from the models based only a constant variable compared to the models containing multiple variables (see Appendix O).

Table 7.28 Predictor coefficient, R-square and classification (oblique rotation)

No	Variable	B	Wald sig.	Exp(B)	R-square		Classification		
					Cox-Snell	Nagelkerke	Inferior	Superior	Overall
1	TVCLR	-3.695	0.003	0.025	0.58	0.77	88.00	91.30	89.58
	TVNOR	-0.823	0.029	0.439					
	Constant	6.747	0.000	851.711					
2	TVCOR	-1.676	0.135	0.187	0.69	0.92	96.00	95.65	95.83
	TVCLR	-4.456	0.040	0.012					
	TVNOR	-4.964	0.096	0.007					
	FAC1_2	-4.665	0.081	0.009					
	FAC2_2	5.327	0.096	205.780					
	FAC6_2	3.361	0.129	28.821					
	Constant	23.509	0.065	1.622E+10					
3	TVCLR	-1.892	0.002	0.151	0.53	0.70	92.00	91.30	91.67
	FAC6_2	1.559	0.018	4.754					
	Constant	3.390	0.002	29.667					
4	**TVCLR**	**-2.622**	**0.003**	**0.073**	**0.63**	**0.84**	**96.0**	**100.0**	**97.9**
	TVNOR	**-1.390**	**0.035**	**0.249**					
	FAC2_2	**1.860**	**0.031**	**6.423**					
	FAC6_2	**2.212**	**0.040**	**9.133**					
	Constant	**6.601**	**0.002**	**735.936**					
5	**TVCLR**	**-2.355**	**0.002**	**0.095**	**0.60**	**0.80**	**92.00**	**95.65**	**93.8**
	TVNOR	**-1.102**	**0.047**	**0.332**					
	FAC2_2	**1.420**	**0.055**	**4.137**					
	FAC6_2	**1.642**	**0.073**	**5.166**					
	Constant	**5.647**	**0.002**	**283.429**					
6	TVCLR	-1.9028	0.002	0.149	0.57	0.76	92	91.3	91.7
	TVNOR	-0.7623	0.057	0.467					
	FAC6_2	1.53948	0.043	4.662					
	Constant	4.70816	0.001	110.847					
7	TVCLR	-1.705	0.002	0.182	0.60	0.80	84.00	95.65	89.58
	TVNOR	-10.487	0.840	0.000					
	Constant	14.447	0.781	1.881E+06					
8	TVCLR	-3.1618	0.049	0.042	0.68	0.91	96	95.7	95.8
	TVNOR	-11.561	0.860	0.000					
	Constant	17.8322	0.786	5.552E+07					
9	TVCOR	-1.364	0.117	0.256	0.64	0.86	92	95.7	93.8
	TVCLR	-3.042	0.014	0.048					
	TVNOR	-3.011	0.061	0.049					
	FAC2_2	3.136	0.064	23.015					
	Constant	16.044	0.048	9.290E+06					
10	TVCOR	-0.968	0.096	0.380	0.6173	0.8236	88	91.3	89.6
	TVCLR	-2.163	0.002	0.115					
	TVNOR	-1.749	0.025	0.174					
	FAC2_2	1.597	0.038	4.940					
	Constant	10.532	0.024	37483.676					

Note:
- Goodness-of-fit tests for all models are statistically significant at 0.05 level (2 tailed)
- The cut value of classification has a probability of 0.5

Table 7.29 Key periodic prequalification factors influencing time performance

Key periodic prequalification criteria	
Model variables	**Related factor based on Factor Analysis result**
Managerial and technical strength	- The number, suitability and competence of the list of trade/ work with subcontractors including subcontractor selection system, performance evaluation and/or registration in a specific competency (M2) - Availability of training and development system for employees at any level (M4)
Past experience	- The number of previously completed contracts similar to this project value and type (E1) - The number of previously completed contracts similar to this project type (E3) - The number of years of the firm's experience with regards to previously completed contracts similar to this project value and type (E4)

Note: The code of the identified periodic prequalification criteria can be seen in Table 5.5

7.6.4.5 Fifth stage: Interpreting the results

The positive sign of *past experience* variables (FAC2_2), and *managerial and technical strength* (FAC6_2) indicate that an increase in these variable values will be likely to result in an increase in *superior* time performance. On the other hand, an increase in *client* (TVL) and *neither party* (TVNOR) predictor values increases the probability of *inferior* time performance.

The parameters in Table 7.28 demonstrate that the degree of impact on time performance may be measured by the odds ratio (i.e. Exp. (B)). The indicators of the odds ratios (see bold characters in both tables) related to *managerial and technical strength* has slightly higher impact on *superior* time variation than *past experience*, indicated by exponent to the power of *managerial and technical strength* coefficients, Exp. (B)s, in the range of 5.1 to 9.1 and the Exp. (B)s of *past experience* ranging from 4.1 to 6.8. These results mean that a one unit increase of input based factor scores of the *managerial and technical strength* factor, will increase the probability of *superior* time performance about 5 to 9 times over *inferior* time performance. This is similar to the *past experience* factor, where the likelihood of *superior* time performance will increase about 4 to 7 times over *inferior* time performance.

While for the source of time variation factors caused by the *client*, the odds ratios ranging from 1/0.1 to 1/0.07 (i.e. 10 to 14), have much higher impact on *inferior* time performance than those of the *neither party* factor (1/0.3-1/0.2 or 3 to 5). In terms of the odds ratios, since the odds ratios are less than 1, the results mean that for a one unit increase of the *client* factor, the likelihood of *superior* time performance will decrease about 10 to 14 times over *inferior* time performance. In respect of the *neither party* factor, the likelihood of *inferior* time performance will increase about 3 to 5 times for a one unit increase of the factor. It is necessary to note that a negative coefficient of the predictor or an odds ratio less than 1 will reversely effect the probability of time performance, therefore, it is necessary to explain the impact with regards to the odds ratio on the basis of the reverse value.

However, the Exp. (B) values for comparison between periodic prequalification and source of variation factors cannot provide a clear picture of the differences, since the scale of periodic prequalification factors uses factor scores transformed from a Likert scale, while the measurement of source of variation factors is an ordinal number (Likert scale). To compare the degree of impact on time variation between those two main factors identified in the models, sensitivity analysis can give a much better picture.

Using Equations 7.1 and 7.2, original data sets of E1, E3 and E4 under the *past experience* factor, and M2 and M4 under the *managerial technical strength* factor can be utilised to analyse the sensitivity of periodic prequalification to project performance based on the identified LR equations. Only one model relationship, which is model 4 in the oblique based LR model, was investigated, as seen in Figure 7.9.

To distinguish individual independent variables of periodic prequalification criteria which have sensitivity to *superior* time performance on the basis of time variation as a dependent variable, eight figures of *superior* time performance were created to represent the specific variables under investigation using various values ranging from 1 to 6, while other values of independent variables were retained at certain values. Retained values rely on the positive or negative signs of the predictor coefficients in order to obtain clear pictures of the sensitivity analysis; if it is a positive sign, a value of 1 is used, conversely, a value of 5 is used for a negative sign.

Based on the six calculations of each individual periodic prequalification factor with various values ranging from 1 to 6 and other factors being retained with a value of 1, including source of time variation factors, Figure 7.9a and Figure 7.9b suggest that *managerial and technical strength* factors (M2 and M4) have much higher influence on the likelihood of *superior* time project performance than *past experience* factors (E3 and E4) at the same value of greater than 3; this difference can also be demonstrated by the LR coefficients (predictor coefficients, Exp.(B) values) in Table 7.28, and more clearly in Figure 7.9c.

Additionally, the *past experience* factor of E1 is likely to be linearly influential on *superior* time performance and also has a smaller effect than the other variables (E3 and E4) at a value above 4. While *managerial and technical strength* factors (M2 and M4) have similar influence.

Five periodic prequalification factors show positive influence on *superior* time performance as expected. Particularly for M2, M4, E3 and E4, an increase in the level of the input range of 4 to 6 can sharply improve the probability of *superior* time performance (see Figure 7.9d).

In respect of the likelihood *of inferior* time performance, indicated by a negative sign for both variables, *client* factor (TVCL) has a much higher impact than *neither party* factor (TVNOR), especially in the value range of 2 to 4 (see Figure 7.9e). In addition, Figure 7.9f shows that various input values of 1 to 3 indicate the most influential range with regards to the combined source of variation factors of *client* and *neither party* categories.

In order to assess the interaction effect between *client* or *neither party* factors and the combined factors of *past experience* and *managerial and technical strength* factors on the likelihood *of superior* time performance, three curves were created at three impact levels with various levels of the combined factors of periodic prequalification key factors ranging from 1 to 6, as seen in Figure 7.9g and Figure 7.9h for TVCL and TVNOR respectively.

The results suggest that the probability of *superior* time performance by improving the level of the combined *past experience* and *managerial and technical strength* factors can be increased above 80% at levels 1 and 2 of the *client* factor and levels 1 to 3 for *neither party* factor. While at level 3 of TVCL, the probability of *superior* time performance is up to around 80% for the maximum level of the combined factors of *past experience* and *managerial and technical strength* at level 6. In addition to the relatively high predictive power, this relational model can be used as predictive model, as predictors (i.e. *past experience* and *managerial and technical strength* factors) can explain 60%-80% (i.e. R-square) of the variance of project time performance outcome (i.e. time variation outcome) if using the assumptions described in Section 2.4.2.3.

7.6.4.6 Sixth stage: Validation of the Logistic Regression model

The cross-validation technique was employed to internally validate the identified models on the basis of holdout samples which were obtained by resampling 10 times. Each holdout data set consists of 5, 4 and 9 cases with *inferior* performance, *superior* performance and *overall* performance respectively. Data sets of *past experience, managerial and technical strength*, *client* and *neither party* as source factors of time variation were utilised to test the 10 identified models.

In Table 7.30, the results of the predictive power of the 10 randomised samples indicate that *inferior*, *superior* and *overall* performance is well predicted. Particularly, models 4 and 5 within the data sets exhibit around and above 90% of the correct classification. It means that the identification of the key periodic prequalification factors (i.e. *past experience* and *managerial and technical strength*) influencing time project performance is valid.

In addition to internal validation, some project cases which were not used in the cross validation test due to there being one or more missing values in the 25 periodic prequalification criteria (i.e. respondents do not use those periodic prequalification criteria for their system) were utilised for external validation. Based on the equation of the LR model 4 in Table 7.28, of 14 total cases, 78.57% (11), 83.83% (5) and 75% (6) are correctly classified for *overall, inferior* and *superior* time performance respectively.

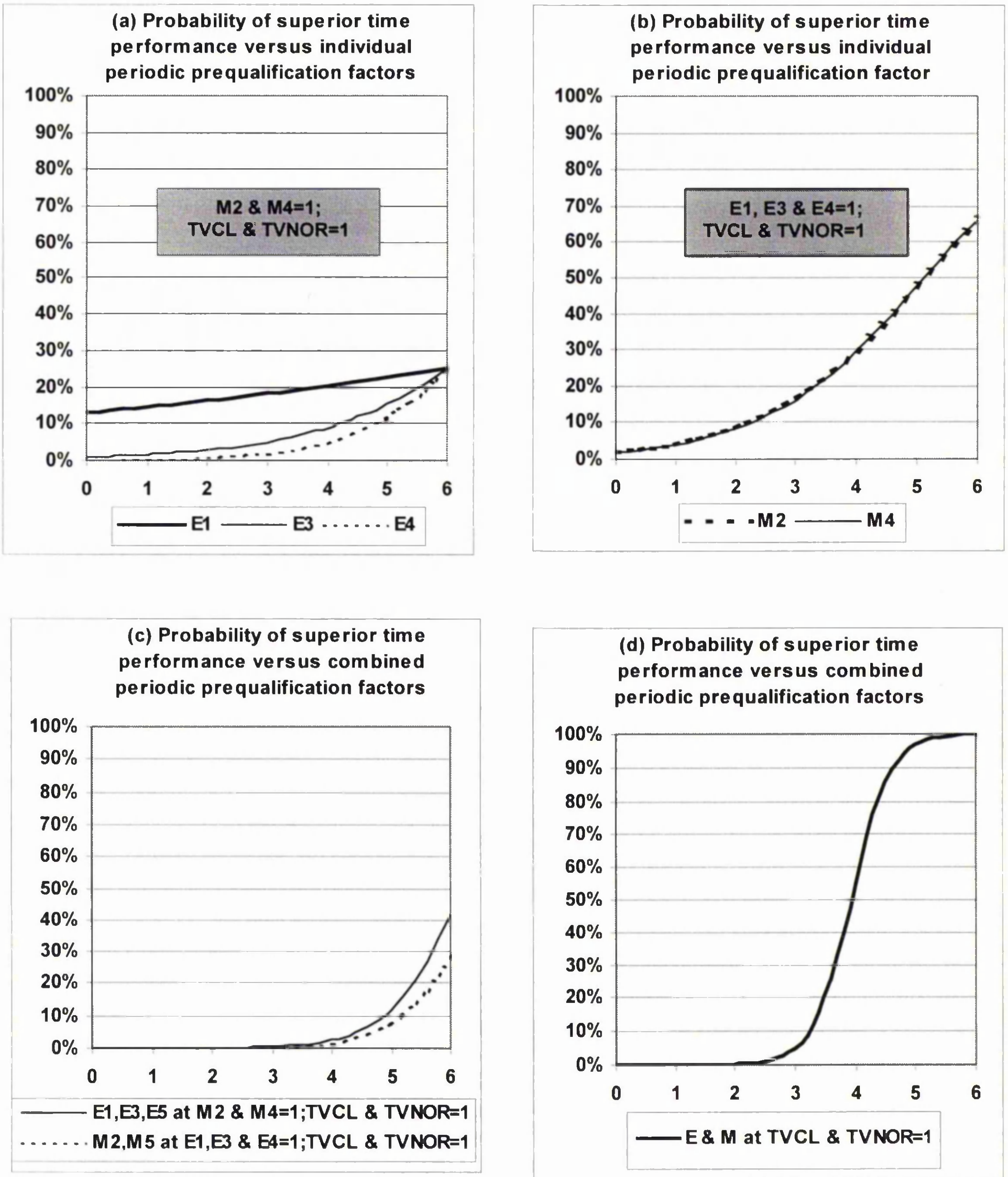


Figure 7.9 Sensitivity analysis of the Logistic Regression equation 4 based on the oblique data set of periodic prequalification factors

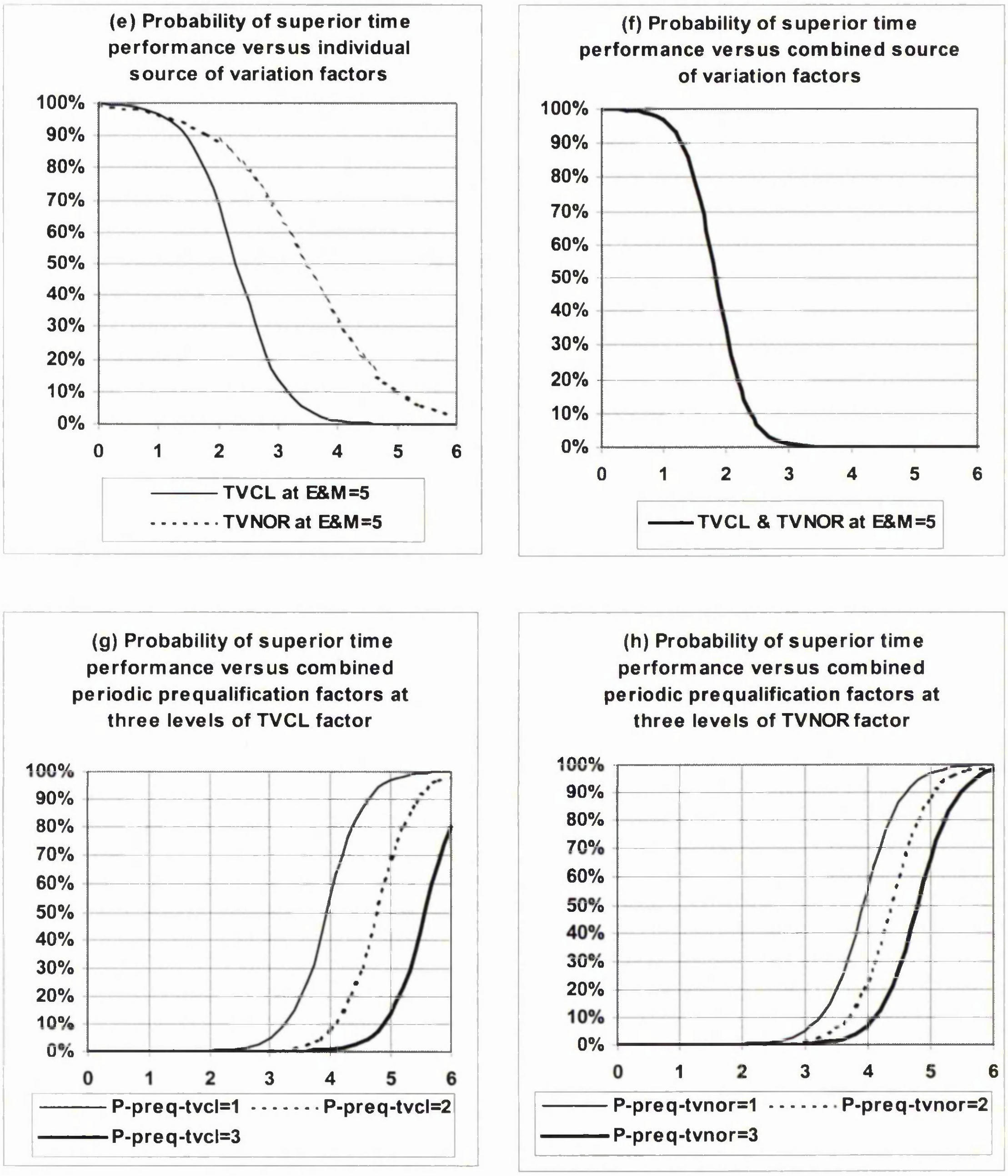


Figure 7.9 Sensitivity analysis of the Logistic Regression equation 4 based on the oblique data set of periodic prequalification factors

Table 7.30 Predictive power of analysed sample and holdout sample

Random order	Analysed sample			Holdout sample			Rotation
	Project time performance						
	Inferior	Superior	Overall	Inferior	Superior	Overall	
	N=25	N=23	N=48	N=5	N=4	N=9	
1	100.0%	75.0%	89%	88.0%	91.3%	89.6%	Oblique
2	40.0%	100.0%	66.7%	96.0%	95.7%	95.8%	
3	60.0%	100.0%	77.8%	92.0%	91.3%	91.7%	
4	**80.0%**	**75.0%**	**77.8%**	**96.0%**	**100.0%**	**97.9%**	
5	**100.0%**	**100.0%**	**100.0%**	**92.0%**	**95.7%**	**93.8%**	
6	80.0%	100.0%	88.9%	92.0%	91.3%	91.7%	
7	100.0%	75.0%	88.9%	84.0%	95.7%	89.6%	
8	100.0%	33.3%	66.7%	96.0%	95.7%	95.8%	
9	60.0%	80.0%	77.8%	92.0%	95.7%	93.8%	
10	80.0%	75.0%	77.8%	88.0%	91.3%	89.6%	

Note: The bold characters means the best model identified containing 4 variables (2 source factors and 2 periodic prequalification factors)

7.6.4.7 Robustness analysis of th e Logistic Regression model

Robustness analysis was carried out in order to identify internal consistency of the predictive power of the model relationship across project cost, project duration, project type and procurement type categories identified in this study.

Based on 2 LR models and 57 cases consisting of analysed and holdout samples, the average misclassification of *overall*, *inferior* and *superior* time performance is relatively small indicated by an overall average of misclassification across project cost, project duration, project type and procurement type categories of between around 5% and 13% and between around 3% to 6% for the varimax and oblique based LR models respectively (see Table 7.31) at the third row from the bottom row). Moreover, these findings suggest that the predictive power of oblique based LR models are better than their counterparts.

Furthermore, if the results of misclassification were screened throughout the 5 LR models, only one 50% misclassification is found referring to design and build procurement type with *inferior* time performance and also several misclassifications of about 20% for procurement type category such as design and build or partnering. These high percentages of misclassification, especially the 50% misclassification, are due to the small number available of the particular sub categories as seen in the bold values in Table 7.32.

Briefly, the 5 identified LR models across project cost, project duration, project type and procurement type categories seems fairly consistent in respect of their predictive power. But the trend shows that the models have better predictive power in the case of *superior* project performance than its counter part.

Table 7.31 Average misclassification of the time variation according to project characteristic categories

Project characteristics		Oblique		
		Project performance (time variation)		
Main category	Sub category	Overall	Inferior	Superior
Construction project cost	≤ £0.5M	2.9%	0.0%	5.6%
	> £0.5M-£1M	11.8%	14.3%	0.0%
	> £1M	2.2%	0.0%	3.3%
Construction project time	≤ 0.5 year	5.2%	5.9%	4.2%
	>0.5 -1 year	8.8%	11.1%	6.3%
	>1 year	0.0%	0.0%	0.0%
Project type	Housing/ building	7.4%	10.5%	0.0%
	Civil engineering/ infrastructure	3.3%	0.0%	5.3%
Procurement type	Traditional	3.9%	4.3%	3.3%
	Design & build	11.1%	20.0%	0.0%
	Partnering	5.0%	0.0%	6.3%
Overall	Average	5.6%	6.0%	3.1%
	Maximum	11.8%	20.0%	12.5%
	Minimum	0.0%	0.0%	0.0%

Note: Average misclassification based on 3 varimax and 2 oblique based LR models and 58 cases

Table 7.32 Frequency distribution of the total of time variation according to project characteristic categories

Project characteristics		Frequency of total		
		Project performance (time variation)		
Main category	Sub category	Overall	Inferior	Superior
Construction project cost	≤ £0.5M	17	8	9
	> £0.5M-£1M	**17**	14	3
	> £1M	23	8	15
Construction project time	≤ 0.5 year	29	17	12
	>0.5 -1 year	17	9	8
	>1 year	11	4	7
Project type	Housing/ building	27	19	8
	Civil engineering/ infrastructure	30	11	19
Procurement type	Traditional	38	23	15
	Design and build	9	**5**	4
	Partnering	10	**2**	**8**

Note: Bold values indicate that the individually maximum values before computing average values presented in Table 7.31 refer to specific project characteristic category.

7.6.5 Model relationship based on Logistic Regression analysis for time satisfaction

Because the data distribution is skewed toward the high value of satisfaction (6) with a median of 5, it can be assumed that the dichotomous time satisfaction variable is on the basis of positive Z scores as *superior* time performance and negative Z scores as *inferior* time performance, where Z scores are standardised values of the mean. In other words, the data below mean values are considered as *inferior* time performance, while above mean values are *superior* time performance. Additionally, this LR model development is based on a similar approach to the LR model development of time variation in the previous sections and is based the oblique rotation based data with regards to the usage of the periodic prequalification data set.

Initial examination of independent variables in relation to their level of significance, based on the bivariate correlation between dependent and independent variables, uses the Wald statistic to evaluate the individual statistical significance of the predictors using the single predictor models of the LA approach; and the Mann-Whitney U test is used to test the difference between *inferior* and *superior* categories of time performance. The results related to the independent variables having statistically significant values are shown in Table 7.33.

Table 7.33 Correlation, Wald statistic and Mann-Whitney U test (time satisfaction)

Independent variables	Code	Pear.	Spear.	B	Sig.	Man-WU
Past experience	FAC2_2	**0.308**	**0.266**	**0.708**	**0.026**	**0.046**
Client	TVCL	-0.222	**-0.265**	-0.249	1.00	**0.048**
Neither party	TVNOR	-0.192	**-0.350**	-0.378	0.177	**0.009**

Note:
- Code: Code for independent variables
- Pear.: Pearson correlation
- Spear.: Spearman rho correlation
- B: Predictor coefficient
- Sig.: Wald statistic significance level
- Man-WU: Significance level based on Mann-Whitney U Test
- TVxx codes in the bottom two rows: source of time variation factors
- Bold value means statistically significant at 0.05 level (2 tailed)

Like the previous approach for identification of the significance of independent variables using the full data set in Section 7.6.4.4 in Table 7.26, Table 7.34 shows the inclusion of significant variables in the LR model using the full data set without separation between analysis and holdout samples based on stepwise regression technique. These identified variables conform to the identification of significant variables based on the cross validation approach.

Table 7.34 LR model parameters of time satisfaction based on full data set (57 cases)

Variable	B	Wald sig.	Exp(B)	R-square		Classification		
				Cox-Snell	Nagelkerke	Inferior	Superior	Overall
TVCLR	-0.312	0.064	0.732	0.194	0.260	60.0%	87.5%	75.4%
TVNOR	-0.547	0.055	0.579					
FAC2_2	0.781	**0.019**	2.184					
Constant	1.838	**0.009**	6.284					

Note:
- Goodness-of-fit tests for all models are statistically significant at 0.05 level (2 tailed)
- The cut value of classification has a probability of 0.5

The three identified variables in Table 7.33 and Table 7.34 were used for the basis of the development of the LR equations by resampling the data set 10 times into analysis and holdout samples. The detailed parameters of the best LR model identified is presented in Table 7.35. This LR equation is derived from random order number 6 of the data set, similar to the use of the development model for time variation as a project performance variable.

Table 7.35 The LR parameters of time satisfaction for the best model

No	Variable	B	Wald sig.	Exp(B)	R-square		Classification		
					Cox-Snell	Nagelkerke	Inferior	Superior	overall
6	TVCLR	-0.424	**0.033**	0.654	0.227	0.305	71.4%	88.9%	81.3%
	TVNOR	-0.672	**0.044**	0.511					
	FAC2_2	0.757	**0.037**	2.132					
	Constant	2.171	**0.006**	8.768					

Note:
- Goodness-of-fit tests for all models are statistical significance at 0.05 level (2 tailed)
- The cut value of classification has a probability of 0.5

Using 9 cases of holdout sample based on random order no. 6, the predictive power of the model 6 demonstrates 66.7% (6), 75.0% (3) and 60.0% (3) correct classification for *overall*, *inferior* and *superior* time performance respectively. While using 21 other project cases which were not utilised for cross validation, the predictive powers exhibit 66.7% (14), 50.0% (3), 73.7% (11) correct classification for *overall*, *inferior* and *superior* time performance respectively. These marginal results indicate an *inferior* category of time performance. In addition, even though overall fit of the identified model measurement is still acceptable, the results of R-square and predictive powers of time satisfaction are lower than those of time variation.

Furthermore, using a similar approach to the sensitivity analysis for the LR model of time variation, Figure 7.10a and Figure 7.10b in respect the likelihood of *superior* time performance demonstrates that three significant *past experience* factors (E1, E3 and E4), which are responsible for time satisfaction, are individually similar, except E4 is slightly lower and decreases from an input value of above 4. While *client* factor (TVCL) and *neither party* factor (TVNOR) are slightly different, where the TVCL factor with regards to the probability of the impact on *superior* time satisfaction is slightly higher, if the input level is greater than 1. Conversely, the likelihood of the impact of the TVNOR factor slightly increases compared with the TVCL factor, when the input level is less than 1.

In Figure 7.10c and Figure 7.10d, the combined *past experience* factors indicate a significant increase which is nearly linear in the range 2 to 4 with almost 20% probability of *superior* time performance for every unit of input, when the input level of TVCL and TVBOR is retained at 1. On the other hand, the probability is likely to decrease by around 30% for every unit increase of the TVCL variable in the range of value of 2 to 4 at the combined *past experience* input level of 5.

To compare the impact between *past experience* and *client* factors on *superior* time performance, it is necessary to create curves exhibited in Figure 7.11a and Figure 7.11b. The negative effect of the *client* factor for every one degree of input value differences is likely to be lower than that of *neither party* factor.

These results confirm the predictor coefficient factors and Exp. (B) parameters presented in Table 7.35, where the TVCL coefficients are smaller than the TVNOR factor. In other words, for the case of Exp(B) values, TVNOR with a lower value than TVCL has a stronger impact than TVCL due to the negative signs of both predictor coefficients (B values).

Figure 7.11a shows the interaction effect between *past experience* factor ranging from 1 to 6 and three levels of TVCL (1, 2 and 3), while the interaction effect between past experience and TVNOR can be seen in Figure 7.11b. These figures also confirm that TVNOR has a stronger influence than TVCL on the probability of inferior project performance. Additionally, the probability of superior project performance decrease in the range of input levels of 3 to 5.

In the case of the internal consistency of the predictive power of the model relationship of time satisfaction across project cost, project duration, project type and procurement types categories, which are similar to the time variation analysis in the previous section, the average of percentages of misclassification of time satisfaction are 20.6%, 31.9% and 15.4% for *overall*, *inferior* and *superior* project performance respectively and relatively consistent across those categories. These results are lower than those of time variation (see Table 7.36). In several cases, high misclassification, especially for small frequency numbers such as the partnering sub category (100%), can be seen in Table 7.37.

Based on analysis above, only the *past experience* factor was identified as a key factor of periodic prequalification criteria influencing time performance with regards to the dependent variable of time satisfaction. However, the predictive power of this model is relatively low, as the variances (20%-30%) are very low, where predictors can explain about 30% or less of the variances in the time satisfaction variables if using the assumptions described in Section 2.4.2.3.

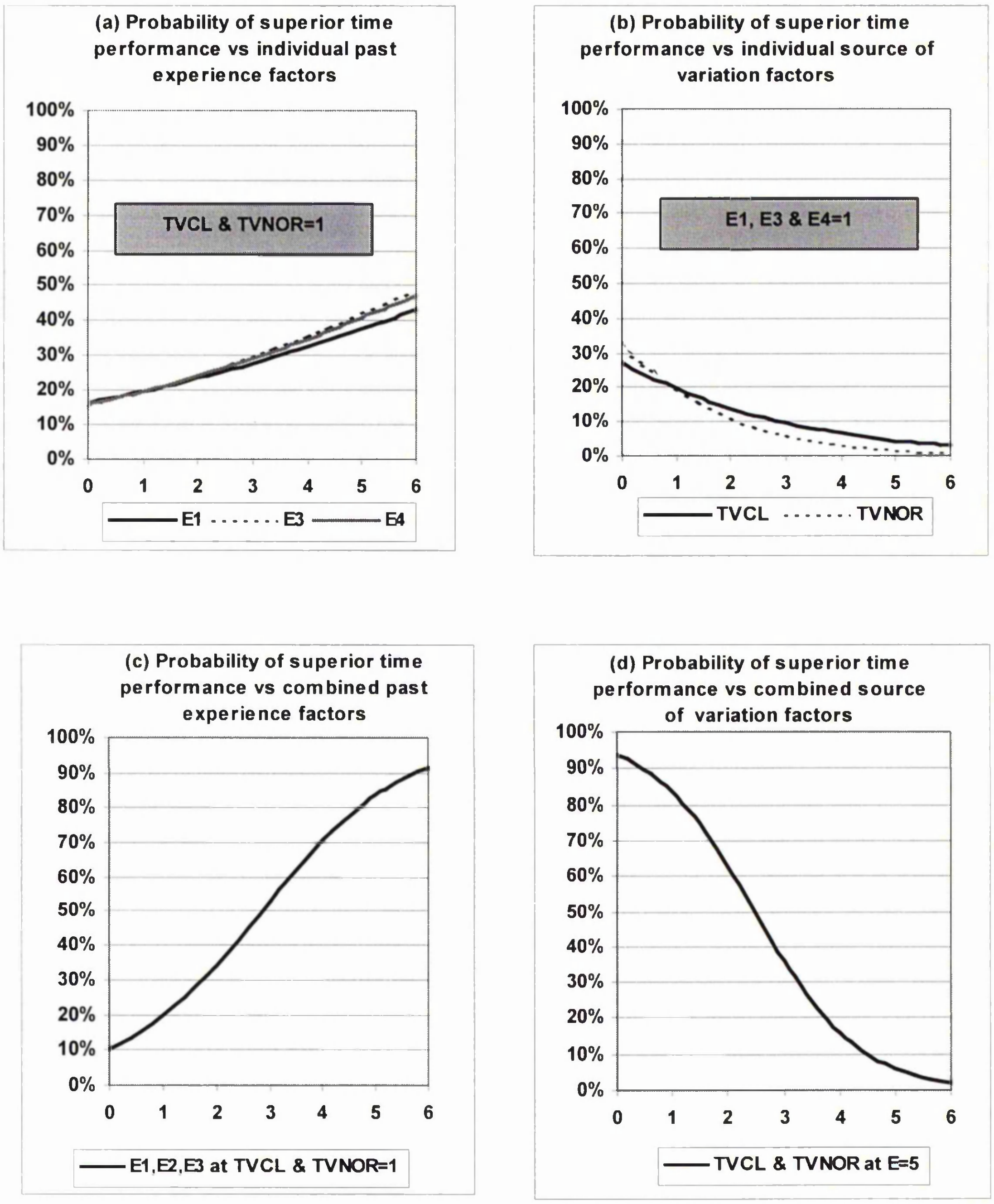


Figure 7.10 Sensitivity analysis of the Logistic Regression in respect of time satisfaction

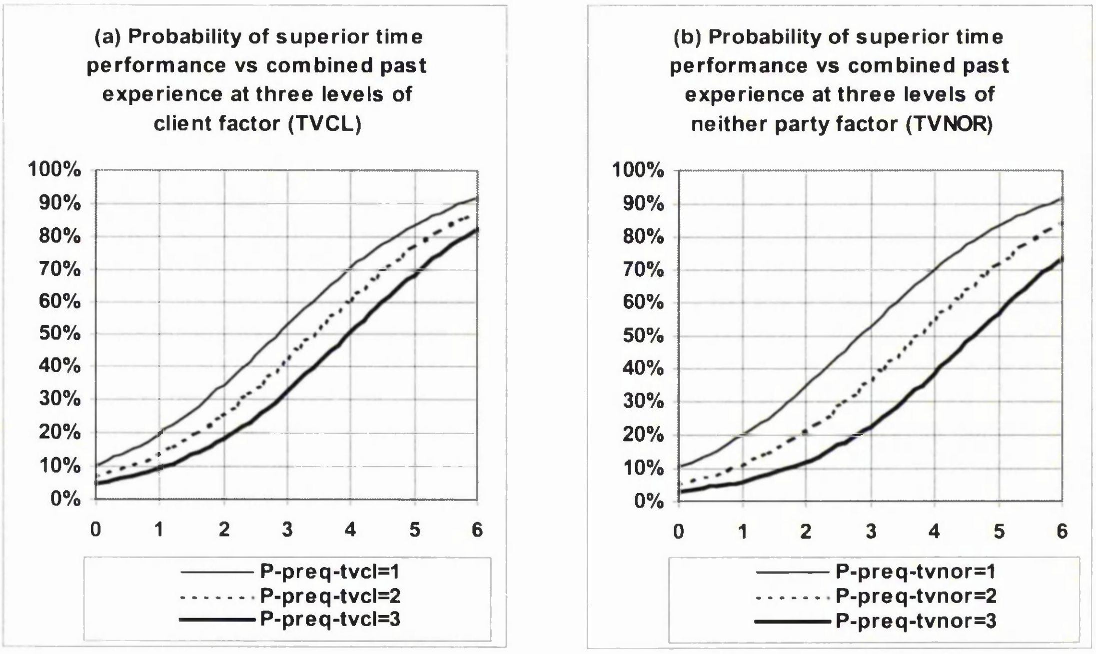


Figure 7.11 Sensitivity analysis of time performance at three levels of client as a source of variation factor in respect of time satisfaction

Table 7.36 Percentages of the misclassification of time satisfaction according to project characteristic categories

Project characteristics		Project performance (time satisfaction)		
Main category	**Sub category**	**Overall**	**Inferior**	**Superior**
Construction project cost	≤ £0.5M	11.8%	0.0%	16.7%
	> £0.5M-£1M	23.5%	27.3%	16.7%
	> £1M	26.1%	44.4%	14.3%
Construction project time	≤ 0.5 year	17.2%	15.4%	18.8%
	>0.5 -1 year	35.3%	50.0%	22.2%
	>1 year	9.1%	25.0%	0.0%
Project type	Housing/building	18.5%	13.3%	25.0%
	Civil Engineering/infrastructure	23.3%	50.0%	10.0%
Procurement type	Traditional	21.1%	25.0%	16.7%
	Design and build	11.1%	0.0%	16.7%
	Partnering	30.0%	100.0%	12.5%
Total	Average	20.6%	31.9%	15.4%

Note:

- Average misclassification based on the oblique based LR model for random order no. 6
- Frequency of 11.8% (see the first row and third column in the table above), for example, being based on the frequency of 2 (see Table 7.37 in the same cell) divided by the frequency of 17 (see Table 7.32 in the same cell)

Table 7.37 Frequencies of the misclassification of time satisfaction according to project characteristic categories

Project characteristics		Frequency of misclassification Project performance (time satisfaction)		
Main category	**Sub category**	**Overall**	**Inferior**	**Superior**
Construction project cost	≤ £0.5M	2	0	2
	> £0.5M-£1M	4	3	1
	> £1M	6	4	2
Construction project time	≤ 0.5 year	5	2	3
	>0.5 -1 year	6	4	2
	>1 year	1	1	0
Project type	Housing/building	5	2	3
	Civil Engineering/infrastructure	7	5	2
Procurement type	Traditional	8	5	3
	Design & build	1	0	1
	Partnering	3	2	1

7.6.6 Other models related to cost and quality performance

In the case of the available data in relation to cost and quality performance, the model relationship cannot be developed due to an insignificant indication of the relationship with periodic prequalification factors and source of variation factors based on initial analysis of correlation coefficients, the differences of dichotomous data in respect of *inferior* and *superior* project performance and also single predictor models of the LA technique (see Table 7.38 and Table 7.42).

In respect of the results of correlation, LR Wald statistic and Mann Whitney U test, the CVCL factor looks significant, but when further verified using the stepwise LR technique with the full data set (55 cases), the model does not demonstrate a strong goodness of fit, where superior cost performance has only about 50% correct classification (see Table 7.39). In addition, this study is mainly intended to identify key factors of periodic prequalification and factors related to source of variation factors as complementary variables in order to meet the criteria of the model relationship.

While FAC2_2 (past experience) factor has partial significance with regards to correlation, the LR Wald statistic and Mann Whitney U test, as well as very low R square values, demonstrate poor predictive power of inferior cost performance (see Table 7.40 and Table 7.41).

Regarding quality performance related to quality variation, there is no indication of the relationship between independent and dependent variables as seen in Table 7.42. Additionally, similar to the model relationship of cost satisfaction, quality satisfaction is only partially significant and only superior quality performance has good predictive power (see Table 7.43 and Table 7.44). Thus, no further analysis is carried out.

Table 7.38 Correlation, Wald statistic and Mann-Whitney U test (cost variation)

	Code	Pear.	Spear.	B	Sig.	Man-WU
Financial strength	FAC1_2	-0.100	-0.058	-0.212	0.460	0.671
Past experience	FAC2_2	0.043	0.007	0.090	0.751	0.959
Past performance	FAC3_2	0.049	0.030	0.100	0.714	0.825
Managerial & technical strength	FAC4_2	0.130	0.120	0.261	0.342	0.377
Compliance with regulations	FAC5_2	0.030	0.032	0.068	0.822	0.812
Verification of finance and experience information	FAC6_2	-0.105	-0.088	-0.209	0.439	0.519
Contractor factor	CVCO	-0.059	-0.086	-0.081	0.664	0.527
Client factor	CVCL	**-0.331**	**-0.341**	**-0.336**	**0.017**	**0.012**
Neither party factor	CVNOR	-0.028	-0.163	-0.037	0.838	0.231

Note:
- Code: Code for independent variables
- Pear.: Pearson correlation
- Spear.: Spearman correlation
- B: Predictor coefficient
- Sig.: Wald statistic significance level
- CVxx codes in the bottom three rows: source of cost variation factors
- Bold value means statistically significant at 0.05 level (2 tailed)

Table 7.39 LR model parameters of cost variation based on full data set (55 cases)

Variable	B	Wald sig.	Exp(B)	R-square		Classification		
				Cox-Snell	Nagelkerke	Inferior	Superior	Overall
CVCLR	-0.336	0.017	0.715	0.106	0.142	74.19%	54.17%	65.45%
Constant	0.932	0.099	2.540					

Table 7.40 Correlation, Wald statistic and Mann-Whitney U test (cost satisfaction)

	Code	Pear.	Spear.	B	Sig.	Man-WU
Financial strength	FAC1_2	-0.032	-0.038	-0.069	0.805	0.775
Past experience	FAC2_2	**0.278**	0.222	**0.632**	**0.041**	0.094
Past performance	FAC3_2	0.184	0.148	0.404	0.169	0.262
Managerial & technical strength	FAC4_2	-0.039	-0.114	-0.082	0.768	0.390
Compliance with regulations	FAC5_2	-0.052	-0.018	-0.113	0.690	0.889
Verification of finance and experience information	FAC6_2	0.020	0.014	0.042	0.880	0.915
Contractor factor	CVCO	-0.028	-0.041	-0.036	0.852	1.000
Client factor	CVCL	-0.150	-0.139	-0.153	0.281	0.287
Neither party factor	CVNOR	0.090	0.015	0.165	0.447	0.502

Note:
- Code: Code for independent variables
- Pear.: Pearson correlation
- Spear.: Spearman correlation
- B: Predictor coefficient
- Sig.: Wald statistic significance level
- TVxx codes in the bottom three rows: source of time variation factors
- Bold value means statistically significant at 0.05 level (2 tailed)

Table 7.41 LR model parameters of cost satisfaction based on full data set (58 cases)

Variable	B	Wald sig.	Exp(B)	R-square		Classification		
				Cox-Snell	Nagelkerke	Inferior	Superior	Overall
FAC2_2	0.632	0.041	1.882	0.077	0.106	35.00%	92.1%	72.4%
Constant	0.698	0.017	2.009					

Table 7.42 Correlation, Wald statistic and Mann-Whitney U test (quality variation)

Factor	Code	Pear.	Spear.	B	Sig.	Man-WU
Financial strength	FAC1_2	-0.066	-0.072	-0.173	0.617	0.585
Past experience	FAC2_2	0.158	0.185	0.414	0.234	0.162
Past performance	FAC3_2	-0.145	-0.083	-0.388	0.277	0.532
Managerial & technical strength	FAC4_2	0.036	0.014	0.093	0.787	0.913
Compliance with regulations	FAC5_2	-0.085	-0.078	-0.233	0.522	0.558
Verification of finance and experience information	FAC6_2	-0.130	-0.112	-0.348	0.327	0.399
Contractor factor	QVCO	0.034	0.077	0.077	0.795	0.563
Client factor	QVCL	-0.029	-0.151	-0.084	0.826	0.254
Neither party factor	QVNOR	-0.006	-0.203	-0.020	0.963	0.125

Table 7.43 Correlation, Wald statistic and Mann-Whitney U test (quality satisfaction)

Factor	Code	Pear.	Spear.	B	Sig.	Man-WU
Financial strength	FAC1_2	-0.081	-0.052	-0.180	0.538	0.693
Past experience	FAC2_2	**0.352**	**0.306**	**0.861**	**0.011**	**0.021**
Past performance	FAC3_2	0.110	0.090	0.242	0.405	0.496
Managerial & technical strength	FAC4_2	-0.163	-0.199	-0.354	0.222	0.132
Compliance with regulations	FAC5_2	0.149	0.224	0.318	0.264	0.091
Verification of finance and experience information	FAC6_2	0.110	0.097	0.240	0.405	0.465
Contractor factor	QVCO	0.076	0.091	0.145	0.566	0.494
Client factor	QVCL	0.002	-0.055	0.004	0.990	0.679
Neither party factor	QVNOR	-0.095	-0.112	-0.248	0.485	0.400

Note for Table 7.42 and Table 7.43:

- Code: Code for independent variables
- Pear.: Pearson correlation
- Spear.: Spearman correlation
- B: Predictor coefficient
- Sig.: Wald statistic significance level
- QVxx codes in the bottom three rows: source of quality variation factors
- Bold value means statistically significant at 0.05 level (2 tailed)

Table 7.44 LR model parameters of quality satisfaction based on full data set (58 cases)

Variable	B	Wald sig.	Exp(B)	R-square		Classification		
				Cox-Snell	Nagelkerke	Inferior	Superior	Overall
FAC2_2	0.861	0.011	2.365	0.123	0.173	38.89%	92.5%	75.9%
Constant	0.919	0.004	2.507					

7.7 DISCUSSION

Only the relationship between time project performance and periodic prequalification criteria and source of variation factors could be developed through the Logistic Regression (LR) technique. The results of the relationship are depicted in Figure 7.12, where *past experience* and *managerial and technical strength* are key factors of periodic prequalification criteria influencing project time performance in relation to time variation. While only *past experience* can influence project time performance which is related to time satisfaction.

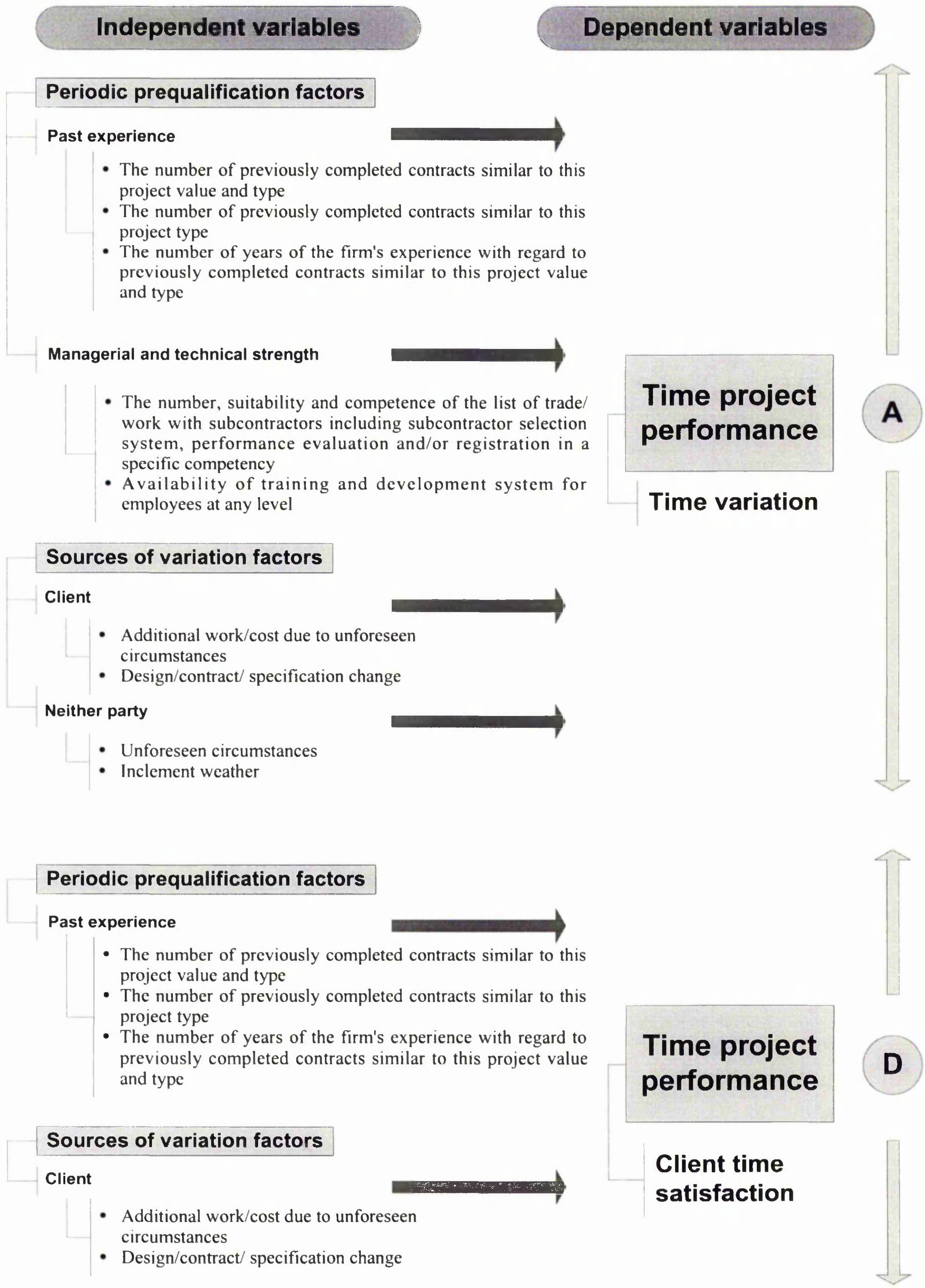


Figure 7.12 Model relationships A and D in relation to project time performance

Note: The numbers related to models can be seen in Figure 7.8.

Regarding the past experience factor, there are three key issues that should be emphasised in respect of the evaluation of contractors' competence, which are a certain length of business age within the scope of project size and type of a particular project pursued by the contractors.

Furthermore, the important criteria associated with *managerial and technical strength* are related to two key terms, namely, *subcontractor list* and *training scheme*. Subcontractors' relationship with main contractors and internal prequalification system of subcontractors in order to meet the relevant subcontractors' competence in respect of a certain project size and type, become important issues. While a training scheme for continuous improvement of the staff and managers as well as construction workers may also improve contractor project performance, especially in respect of reducing time variation and increasing client satisfaction.

It is important to note that these issues related to the two key periodic prequalification factors are based on the results obtained from their identification through the Factor Analysis technique. Additionally, the inclusion of source of variation factors in the model relationship assumes that project performance may be influenced by current and historical prequalification factors as well as the non prequalification criteria (i.e. *client* and *neither party* as causal source factors of time variation more relevant to current circumstances). Historical factors are related to periodic prequalification criteria, while *contractor* as a source of variation factor can be assumed at the level of contractors' current capacity.

Other important factors, which can influence project performance, are *client* as a source of project risks that can still be controllable, and also *neither party* as a source of variation factor that is likely to be difficult to control. Design/specification changes, an example of the first factor, may lead to contract amendments, commonly found in the construction industry. In addition, design changes are sometimes due to unforeseen circumstances such as lack of geological investigation which may increase the scope of project works causing an extension of project duration.

Unforeseen circumstances and inclement weather as causal factors within the second factor category are also common as an uncontrollable occurrence that may influence project time performance.

Therefore, minimising those causal factors with regards to project performance through appropriate risk analysis and mitigation and also improving training schemes and the selection of and relationship with subcontractors may increase the probability of *superior* project time performance in relation to time variation.

For the case of time satisfaction, only one key periodic prequalification factor was identified. This can be explained by the assumption that the hierarchical level of client objectives is higher than project objectives. Sometimes during the construction process a client needs to change the design in order to meet the client objectives (i.e. client satisfaction) regardless of any resulting extension of project schedule. Even though a contractor has a strong managerial and technical competence level, as also commonly identified as a key factor for project success, time variation may still occur.

Thus, this factor is less relevant than the *past experience* criterion, since the level of detail is more related to the *managerial and technical* criterion than the *past experience* criterion that is more general and historical in nature. This assumption can be related to the client objectives which are more general than the project objectives that are more closely related to the level of technical specification.

Furthermore, in spite of having found significant key factors of periodic prequalification in respect of project time performance, including the consistency of the model relationship across several project characteristics such as project cost, time and type and procurement type, there are some limitation of the findings.

Firstly, the data set used for Empirical study 2 with regards to periodic prequalification factors is based on winning contractors which, in the majority, have levels of competence related to 25 periodic prequalification criteria typically equal to or above the *typical average* (median of 4 is 60% and median of 5 is 40%) and scale 1 to 3 only occurring in the range 10% to 20% on the basis of Likert scale ranging from 1 to 6. Thus, despite the fact that only two key periodic prequalification factors are identified, the winning contractor minimum prerequisite stated levels of other periodic prequalification criteria should be considered at the *minimum acceptable* level.

Secondly, based on sensitivity analysis in respect of probability of the achievement of *superior* time performance related to time variation (model A), the combination of *past experience* and *managerial and technical strength* factors must be considered at scale 4 (typical average) or above and the state of *client* or *neither party* as a source of variation factor at the minimum level (1). An increase of source of variation factors is likely to reduce the achievement of superior project time performance; this fall should be compensated by an increase in the level of combined periodic prequalification factors.

Thirdly, regarding the likelihood of the achievement of superior time performance related to time satisfaction (model D), it is necessary to have a *past experience* minimum level of 3 (measurement scale between minimum acceptable and typical average) and a state of *client* or *neither party* as a source of variation factor at the minimum level (1). Similar to model A, an increase of the *past experience* factor must compensate for an increase in source of variation factors.

Furthermore, even though time, cost and quality performance are statistically significantly correlated to one to another, the development of model relationship of cost and quality is difficult to develop, because the data sets with regards to periodic prequalification factors are skewed to high scales or cannot discriminate between inferior (low scales of periodic prequalification factors) and superior performance (high scales of periodic prequalification factors). In addition, cost performance is much more influenced by *client* factors as a source of variation factor and quality performance is predominantly influenced by high levels of the winning contractors as a prerequisite to obtain the project task through the prequalification process.

7.8 SUMMARY

The results of Empirical study 2 have been presented and discussed in this chapter and show that the only the models of the relationship between project time performance and periodic prequalification criteria are able to be developed well, while others related to cost and quality performance are difficult to develop. In addition, the combination of Factor Analysis (for factor reduction) and Logistic Regression (for identification of key factors) techniques as multivariate statistical approaches has enhanced the results of the investigation of the relationship.

Even though there are two (*past experience* and *managerial and technical strength*) and one (*past experience*) key periodic prequalification factors influencing project time performance with regards to time variation and time satisfaction respectively which have been identified, the prerequisite of the average level of contractors' competency in relation to three other periodic prequalification criteria (*financial strength*, *past performance* and *compliance with regulations*) is still necessary to be included in the process of prequalification in order to reduce time variation and increase time satisfaction.

Past experience and *managerial and technical strength* factors are also confirmed as the top two important periodic prequalification factors (i.e. *past experience* and *managerial and technical strength* as seen in column 4 in Table 7.8) based on the frequency of usage and applied weighting of periodic prequalification criteria.

The findings of Empirical study 2 will be discussed further in the next chapter which contains discussions of the results in association with the findings, reviews and discussions in the previous chapters.

CHAPTER 8

Conclusions and recommendations

8.1 INTRODUCTION

This chapter presents the conclusions of the achievement of the main aim of this research, that is, to investigate the relationship between periodic prequalification criteria which are used to evaluate contractors' historical data as commonly used in a contractor periodic prequalification system and project performance. In order to achieve the main aim of this research, the fulfilment of the research objectives, as described in Chapter 1, is concluded in this chapter, followed by providing recommendations.

It is important to note that the main aim of this research mentioned above could be achieved through establishing the set of research objectives. To meet the objectives, several stages in this research were conducted including the investigation of the differences and similarities of periodic and project prequalification characteristics. The findings of characteristics of periodic prequalification were used for identifying the common set of periodic prequalification criteria. From the identified periodic prequalification criteria, the framework of the relationship between periodic prequalification criteria and project performance was established. In this framework, the influences of periodic prequalification criteria on project variations and client satisfaction as a representation of project performance were identified.

To identify the key factors of periodic prequalification influencing project performance, models that can show a relationship between periodic prequalification criteria and project performance were developed. Thus, the results of this investigation can demonstrate that the implementation of a periodic prequalification system is useful for contractor prequalification in the early stage of contractor selection using contractor historical data. In addition, recommendations for the construction industry and future research have been presented as to the implications of the research findings.

8.2 CONCLUSIONS

The research question (i.e. **What are the key factors of periodic prequalification that can influence project performance?)** has been answered, as the main aim of this research has been achieved through identification of the relationship between periodic prequalification criteria and project performance. Where **past experience** and **managerial and technical strength** factors as periodic prequalification criteria along with **client** and **neither party** factors as source of time variation significantly influence **project time performance** in respect of **time variation**.

Furthermore, t*he number of previously completed contracts similar to this project value and type* and *the number of years of the firm's experience with regards to previously completed contracts similar to this project value and type* have shown significant correlation to the **past experience** factor. While *the number, suitability and competence of the list of trade/work with subcontractors including subcontractor selection system, performance evaluation and/or registration in a specific competency* and *availability of training and development system for employees at any level* have shown significant correlation to the **managerial and technical strength** factor.

Moreover, *additional work/cost* caused by unforeseen circumstances and *design/contract/specification change* are the most frequent factors causing time variation for the **client** category. While *unforeseen circumstances* and *inclement weather* are the most frequent factors causing time variation for the **neither party** category.

In the case of **client time satisfaction**, only **past experience** as a periodic prequalification factor with the same sub factors as above and **client** as a source of time variation with the same causal factors of variation as above, significantly influence **project time performance**. Thus, this relational model related to time satisfaction has a less significant number of factors influencing project time performance than the relational model related to time variation.

In order to meet the research aim, the achievement of the research objectives has been concluded as follows:

Objective: *To discuss and identify the appropriate data collection and analysis methods that can be used for this research*

The research methods used were discussed and carefully chosen in order to obtain appropriate results, including the following techniques and methods:

- A literature review was used to develop the framework of prequalification systems related to its definitions, classifications and elements as discussed in Chapter 3, identification of periodic prequalification criteria (see Chapter 5) and the framework of the relationship between periodic prequalification criteria and project performance (see Chapter 6);

- Tabulation, graphical representation, Relative Rank Index, nonparametric statistical techniques such as Chi-square test, McNemar test Kolmogorov-Smirnov test and Wilcoxon signed ranks test as well as the Factor Analysis technique (the detailed explanation of these techniques can be seen in Chapter 2) were utilised for analyses of the data elicited through the questionnaire survey in Empirical study 1 in order to investigate the differences and similarities of periodic and project prequalification as well as verify and validate the conceptual definitions discussed in Chapter 3. The data were obtained from client firms/organisations and construction firms in the UK construction industry and the results of data analyses are presented in Chapter 4;

- The triangulation approach, a type of validation technique for information verification, was utilised in respect of identification of five main periodic prequalification criteria containing 25 sub criteria established through a literature review, the results of the questionnaire survey in Empirical study 1, and secondary data (e.g. prequalification formal guidelines); and

- A questionnaire survey was used for Empirical study 2 and the obtained data were analysed using a combination of Factor Analysis for reducing independent variables and validating prequalification factors and Logistic Regression for developing predictive models in terms of prequalification factors influencing project performance. In addition, the Content Analysis technique was employed to determine the most influential factors that are responsible for variations.

Briefly, the literature review plays a central role in identifying research interest, defining the research question/problem, developing conceptual frameworks and enabling comparison with the results of this study. In respect of data collection in Empirical studies 1 and 2, a questionnaire survey was used to carry out extensive data elicitation. In respect of data analysis in Empirical study 1, the usage of nonparametric tests as the main tools for analysing ordinal and nominal data was able to draw conclusions about the differences and similarities of periodic and project prequalification characteristics. While in Empirical study 2, the Factor Analysis technique was used for reducing the number of independent variables and the Logistic Regression technique was used for analysing ordinal and continuous data, where the LR technique is able to draw conclusions about the relationship between periodic prequalification criteria and project performance.

<u>Objective</u>: *To review and investigate the characteristics of contractor prequalification systems including definition and classification and elements of periodic and project prequalification systems*

There are ten issues of the differences between both prequalification types being described by researchers in Table 3.3, but every researcher did not mention all issues. Only several important issues were repeatedly described, such as reassessment cycles, detailed evaluation, criteria relevancy and suitability. They also did not include the issues of the similarities. Thus, it can be implied that there is still inadequate knowledge or understanding of the classification of prequalification systems in previous research, where the differences of both prequalification types are still presented as the introductory description, but not as parts of their main research.

Furthermore, the five elements described in Chapter 3 Section 3.3 were identified in order to establish the framework of the differences and similarities of periodic and project prequalification characteristics. Those elements are prequalification team, criteria development, prequalification criteria, data collection methods, evaluation models and prequalification performance.

Based on this framework, the data collection and analysis in Empirical study 1 were conducted and the results are as follows:

- Various experts should be represented in prequalification team in order to meet the prequalification requirements, which usually use multi criteria for both prequalification types However, the number and type of the experts are influenced by the project type and size (see sections 4.3.1.4 and 4.3.2.4);
- In relation to criteria development of prequalification systems, the periodic prequalification type requires less detailed data about project characteristics than the project prequalification type, as it is commonly found at the periodic prequalification stage that project objectives have not been defined well compared with at the project prequalification stage. But compliance with regulations and organisation characteristics criteria are similar for both prequalification types. Moreover, project type and size criteria are the important factors for developing both prequalification types (see section 4.3.2.5);
- Prequalification criteria that are used for evaluating contractors' current data are more strongly related to project prequalification than periodic prequalification, while prequalification criteria related to historical data are still relevant for both types (see sections 4.3.2.6 and 4.3.2.7);
- The number of data collection methods being used in project prequalification tends be higher than its counterpart. Additionally, data collection methods such as interview, visit to the office and contractor presentation, which may gather more detailed information of contractors' competence, have significantly higher frequency of the usage in project prequalification than in periodic prequalification (see section 4.3.2.8);

- The simple evaluation technique tend be used in periodic prequalification compared to its counterpart, since the data elicited through periodic prequalification are relatively less detailed and less specific to a particular project (see section 4.3.2.9); and

- There are two issues in relation to prequalification performance, that is regular review and impact of effectiveness of prequalification implementation. Both issues indicate that the implementation of periodic and project prequalification systems provide less regular review of prequalification performance including no differences between both prequalification types in respect of the impact of prequalification implementation on project performance. The results indicated a moderate level, which means that the implementation of contractor prequalification is not one of the factors used to evaluate project success.

From the findings in this empirical study and literature review, it can be generally concluded that there are consistent characteristics of both prequalification types that are revealed in the literature review and in this empirical study. Some issues of the differences between periodic and project prequalification include reassessment cycle, criteria relevancy and project characteristics. Periodic prequalification criteria are more relevant to deal with general and historical contractors' data. On the other hand, project prequalification criteria are more relevant to deal with specific and current data. Additionally, because the project objectives have not been well defined in the periodic prequalification system, this prequalification type is appropriate for non particular projects or can be used in a certain project type and a certain project value band. Conversely, project prequalification can be used for a particular project characteristic, as project objectives have been relatively well defined. All these differences may occur as long as the assumption of reassessment cycles still exists in periodic prequalification or the time difference between the periodic prequalification stage and the tender stage still exists (i.e. periodic prequalification is time dependent).

While the similarities found in this empirical study indicate that both prequalification types require multi criteria to evaluate contractors' data, consequently the prequalification team must consist of non single expertise. Compliance with regulations criterion is also important for both prequalification types. Evaluation of prequalification performance receives less attention for both prequalification types.

Furthermore, for the main purpose of contractor prequalification, either periodic or project prequalification, there is an agreement of perceptions between clients and contractors, where they consider that the importance of the contractor competence criterion is related to the ability to perform a project successfully within budgeted cost and planned time and to required quality.

Therefore, the investigation and mapping of the characteristics of both prequalification types were appropriate approaches to be conducted in this research, before further steps of the identification of periodic prequalification criteria and the investigation of the relationship between periodic prequalification criteria and project performance were carried out.

Objective: *To identify a common set of periodic prequalification criteria on the basis of the characteristics of the early stage of contractor selection system*

The periodic prequalification criteria being identified through the literature review and Empirical study 1 consist of five main criteria that can evaluate contractors' competence through the records of past experience and performance in relation to financial, technical, managerial and regulation aspects. Those criteria are financial strength, past experience, past performance, managerial and technical strength and compliance with regulations. From these five main criteria twenty-five sub criteria were determined. It is important to note that the proposed five main criteria are similar to previous research, except for compliance with regulations. In previous research, only the health and safety sub criterion was related to compliance with regulation criterion, while in Empirical study 1 there are three criteria that are commonly included in compliance with regulations (i.e. health and safety, equal opportunities and environmental management system). The identification of periodic prequalification criteria was based on the assumptions of historical and general data representing capability of contractors to perform project tasks in the past as well as a significant time gap between the periodic prequalification stage and tender stage. In addition, the introduction of compliance with regulations is one of the main periodic prequalification criteria, rather than only the health and safety criterion as found in previous research.

Thus, the issues being relevant in determining sub periodic prequalification criteria are based on annual turnover, profit and loss, ratio analysis, insurance and bonding capacity for the financial strength criterion. Project type, size, location and business age issues are adopted for developing the periodic prequalification sub criteria of past experience. Time, cost and quality performance indicators and claims and disputes issues are adopted for developing the periodic prequalification sub criteria of past performance. Personnel, quality and project management, training scheme and subcontractor issues are adopted for developing the periodic prequalification sub criteria of managerial and technical strength. While the related sub criteria related to compliance with regulations have been described in the previous paragraph. Thus, the use of these periodic prequalification criteria may provide early indication of the contractors' competence to perform project tasks successfully, at least for a certain range of project size and type.

Objective: *To develop a conceptual framework of the relationship between contractors' prequalification data evaluated against periodic prequalification criteria and contractors' project performance on the basis of cost, time and quality*

The measurements of project performance attributes consist of two dimensions, namely variation and client satisfaction. The measurements are based on recorded data of project performance in relation to cost, time and quality from a particular project being completed by a contractor. While the measurement of project performance can be influenced by two dimensions. Those dimension are contractors' capability based on historical data that can be evaluated through periodic prequalification and also sources of variations which can come from client, contractor and neither client nor contractor (i.e. neither party). The sources of variations may occur during the construction process, especially for contractor as a source of variations representing contractors' current data or their capacity to perform project tasks.

The conceptual framework of the relationship between periodic prequalification criteria and project performance is assumed to have one directional cause and effect. An increase in a periodic prequalification factor, for example, will increase project performance. While periodic prequalification factors are characterised by a reciprocal effect on each other. It means that all factors are required to be included at the minimum levels (i.e. multi criteria assumption) and have different levels of importance in respect of their influence on project performance (i.e. relational or cause and effect assumption). Moreover, financial, experience, performance and compliance with regulations factors may be assumed as indicators which can show the symptoms but the cause is embodied in the managerial and technical strength factor as sources of good and bad performance of contractors, so an indication of bad performance could be traced through within a contractor organisation. Thus, managerial and technical strength can show directly the organisation's weakness and strength.

Objective: *To develop a relational model between periodic prequalification criteria and project performance using contractor's historical data obtained in the early stage of contractor selection*

Six model relationships were designed, but only two models, which revealed the relationship between periodic prequalification criteria and project time performance (i.e. time variation and client time satisfaction), were successfully developed. The use of Factor Analysis was able to reduce the number of variables from 25 to 6 and to generate factor scores for the six variables. The data used fulfilled all stage requirements of the FA technique including the utilisation of Principle Component Analysis and oblique rotation techniques (see section 7.6.2).

In terms of the model relationships, the data fulfilled all stage requirements of the Logistic Regression such as predictors' Wald significance, R square and classification/predictive power. But the relationship between periodic prequalification factors and project time performance related to variation have a better relationship than the relationship between periodic prequalification related to time satisfaction, as the three parameters of time variation category mentioned above, and required to develop the models, are better than the time satisfaction parameter. Moreover, the relational model related to time variation can also be used for a predictive model of time variation, because R-square values are above 0.6. However, the relational model related to time satisfaction only indicates that there is a relationship between periodic prequalification factor and time satisfaction, as R-square values are below 0.6.

While the development of model relationships of cost and quality are difficult to develop, because the data sets with regards to periodic prequalification factors are skewed to high scales or cannot discriminate between inferior (low scales of periodic prequalification factors) and superior performance (high scales of periodic prequalification factors).

Objective: *To identify key periodic prequalification factors and other factors influencing contractors' project performance*

Only past experience and managerial and technical strength factors within the periodic prequalification category along with client and neither party factors which are responsible for time variation (i.e. sources of time variation factor) have shown significant influence on project time performance in terms of time variation. While only one periodic prequalification factor (i.e. past experience) along with the client factor as a source of time variation factor can significantly influence project time performance in respect of client time satisfaction.

In the case of time satisfaction, only one key periodic prequalification factor was identified. This can be explained by the assumption that the hierarchical level of client objectives is higher than the project objectives. Sometimes during the construction process a client needs to change the design in order to meet the client objectives (i.e. client satisfaction) regardless of any resulting extension to project schedule. Even though a contractor has a strong managerial and technical competence level, also commonly identified as a key factor for project success, time variation may still occur.

Thus, this factor is less relevant than the past experience criterion, since the level of detail is more related to the managerial and technical criterion than the past experience criterion that is more general and historical in nature. This assumption can be related to the client objectives which are more general than the project objectives that are more closely related to the level of technical specification. This means that past experience merely shows an indication of organisational ability on the basis of project size and type and organisational growth based on business age.

Even though two key prequalification factors are identified, the findings in Empirical study 2 show other periodic prequalification factors, such as financial strength, past performance and compliance with regulations, are still important to be incorporated in the assessment system to ensure that the contractor has minimum to average values of these indicators. This means that the postulate of the prequalification process should satisfy the assessment system based on multi-criteria.

Furthermore, the model relationship on the basis of a statistical model relationship (e.g. Logistic Regression) using a small number of key periodic prequalification factors as indicators may provide early warning information about the contractors' competence and a client then needs further investigation of other parameters. The statistical model relationship is commonly used in financial analysis using financial ratios as indicators on the basis of a company's historical data to predict the level of firms' health (company's bankruptcy level/failure rate). Thus, to identify the trend of construction firms' competence at the early stage of contractor evaluation is appropriate, using a small number of periodic prequalification factors on the basis of historical data. In contrast, in the project prequalification stage, the contractor evaluation system needs a more complex assessment system, where all of the main criteria should be included and detailed assessment is paramount. Every aspect of contractors' data evaluated against the prequalification criteria can contribute to the aggregate final score, so advanced decision models such as Multi-Attribute Utility Theory, Analytical Hierarchical Process or Knowledge Based Systems, as seen in Table 3.10, are relevant to be used.

Regarding past experience as one of the key factors associated with project size and type, as well as business age issues, previous research shows that good past experience is very important in order to reduce time variation, as experience through repetition of similar job operations is the process of skill improvement and development (Kog et al. 1999; Pilcher 1992). While business age is one of the experience indicators that can provide information about failure rate in relation to construction firms' ability when facing bad economic conditions (e.g. high interest rates) and low construction market volume (Koksal and Arditi 2004; Arditi et al. 2000; Kale and Arditi 1998).

Managerial and technical strength, associated with subcontractor issues as supply chains of a main contractor and also training programme issues, is also a pivotal factor that can influence project performance. For example, material delay and unskilled workers may increase time variation. Thus, a good in house prequalification system used by the main contractor can facilitate the process of selection of responsible subcontractors (Kumaraswamy and Matthews 2000; Loh and Ofori 2000). In addition, a good historical relationship may provide prospective indicators for future project performance (Xiao and Proverbs 2003; Kumaraswamy and Matthews 2000).

Training programmes through appropriate training strategies and programmes which are useful to upgrade the knowledge, skills and attitude of workers and managers in relation to managerial and technical strength can enhance management practices such as cost control, scheduling, quality assurance and also compliance with regulations (i.e. health and safety management policies, environmental management systems and equal opportunity management policies). Good training skill programmes may reduce time variations or improve project time performance and enhance productivity, where reworks or accidents can be reduced, for example (Bennett 2000; Gann and Senker 1998; Kumaraswamy 1996b; Burati et al. 1991b; Smith and Roth 1991).

In spite of having found significant key factors of periodic prequalification in respect of project time performance, including the consistency of the model relationship across several project characteristics such as project cost, time and type and procurement type, there are some limitation of the findings as follows:

- The data set used for Empirical study 2 with regards to periodic prequalification factors is based on winning contractors which, in the majority, have levels of competence related to the 25 periodic prequalification criteria typically equal to or above the *typical average*; and

- Based on sensitivity analysis in respect of probability of the achievement of *superior* time performance in respect of time variation and client satisfaction, an increase of source of variation factors is likely to reduce the achievement of superior project time performance; this fall should be compensated by an increase in the level of combined periodic prequalification factors (i.e. past experience and managerial technical strength factors).

Objective: *To validate the model relationships between periodic prequalification criteria and project performance using contractor's historical data obtained in the early stage of contractor selection*

There are four validation approaches being used for validation of the model relationships and the results can be concluded as follows:

- The cross validation technique was employed which found the consistency of two model relationships (i.e. time variation and satisfaction) in respect of variables that could be included in the models. In this investigation, the inclusion of two variables of periodic prequalification criteria (i.e. past experience and managerial and technical strength factors) are relatively consistent in the models and two other variables of the sources of time variation are highly consistent (client and neither party factors);

- Internal validation using Goodness of fit (Chi-square test), the magnitude of the relationship between predictors and outcome variables (R-square values) and predictive power (percentage of correct classification) suggest that both models are valid. But the time variation model (R square-Negelkerke: 0.84; predictive power: 98% overall) has a higher degree of validity than the time satisfaction model (R square-Negelkerke: 0.30; predictive power: 78% overall). Similarly, the predictive powers of external validation for time variation is higher (75%) than for time satisfaction (67%);

- Robustness analysis indicates that across construction project cost, construction project time, project type and procurement type the overall misclassifications are around 6% and 21% for the time variation and satisfaction models respectively;

It can be concluded that the validity of the relational models of time variation is better than the models of time satisfaction. Specifically, the time variation models have better prediction than the time satisfaction models. In other words, the time variation models could be utilised as predictive models, while the time satisfaction models only show that there is relationship between periodic prequalification criteria and time satisfaction with relatively lower predictive power.

Objective: *To conclude the research findings and the contribution to knowledge as a result of this research investigation and also to provide recommendations for the construction industry and future research as limitation of the findings*

Conclusions have been presented and can be summarised as follows:

- A general definition of contractor prequalification is "a process of selection of eligible contractors before awarding a contract using multi-criteria for investigation of the contractors' competence to perform a certain project task completely and satisfactorily as required by the contract". This definition was derived from common definitions in the literature review and was commonly used by researchers for developing various models of contractor evaluation through prequalification systems;

- Contractor prequalification can be classified into periodic and project prequalification. In the construction industry practices periodic prequalification can divided again into in house periodic prequalification (e.g. standing list, select list or approved list prequalification) and outsourcing periodic prequalification which is a type of third party prequalification such as Constructionline. While in house project prequalification is commonly practised in the construction industry, but not for outsourcing contractor selection for a certain project, even if it is possible to implement such a system;

- Periodic prequalification is defined as "a process of the development of a standing list of contractors relevant for a certain periodic time frame including a certain project size, range and type, which can be used by a client for short listing or invitation to bid";

- Project prequalification is defined as "a process of contractor selection in order to develop a list for a particular project, on a project by project basis, before invitation to bid or for short listing";

- There are five main prequalification criteria identified, namely, financial strength, past experience, past performance, managerial and technical strength and compliance with regulations. These criteria are characterised by non specific project, historical data and time dependence;

- Past experience and managerial and technical strength are the key factors influencing time variation. This model relationship can be used as a predictive model to measure the degree of cause and effect. However, client and neither party can increase the probability of time variation in this model relationship; and

- Past experience is the key factor influencing time satisfaction, but this model indicates very week cause and effect. Client factor as source of variation can also influence time satisfaction.

8.3 RECOMMENDATIONS

8.3.1 Recommendations for the construction industry

Some findings of this research can be applied in the construction industry in respect of the improvement of existing prequalification practices. The first proposal is based of the results of Empirical study 1 that can be explained as follows:

- Based on the characteristics of periodic and project prequalification, a single integrated prequalification process can be implemented by combining in house project prequalification and outsourcing periodic prequalification systems. This implementation can be improved in relation to the reduction of the repeated submission of contractors' data to different clients for similar periodic prequalification requirements. In other words, clients can share the contractors' data in the place where third party periodic prequalification takes place;

- This integration means that outsourcing periodic prequalification, applied at the level of clients that have similar project characteristics or at the industry level, would mainly deal with contractors' historical data such as financial strength, past experience, past performance, managerial and technical strength and compliance with regulations. While in house project prequalification applied at the project level would mainly be concerned with contractors' current data workload such as current financial position and current remaining resources as criteria which have to meet specified requirements;

- To link between both prequalification types, the contractor data at the outsourcing level should be categorised into project characteristics such as project size and type, into client characteristics such as organisation type (i.e. private and public), and into environmental characteristics such as geographical experiences (e.g. local, national, and international operation). Thus, clients would not need to evaluate the whole contractors' data at the project level but only the specific requirements related to their particular projects; and

- This integrated prequalification model can be assumed to be screening contractors as a hierarchical process from contractor long list to standing list to short list to tender list; and from general requirements to specific requirements. At the periodic prequalification level, the barrier to entry to the construction industry can be minimised, where a high number of contractors can be included and a low number of prequalification criteria can be used, as the evaluation concept is to obtain a standing list of contractors having capability in relation a certain range of project characteristics. Additionally, the predictive model for contractor evaluation is more appropriate in association with project performance. On the other hand, at project prequalification level, the assumption of protection from inappropriate or irresponsible contractors can be maximised, where the low number of contractors allowed to apply can be justified due to previous screening at the periodic prequalification stage and a high number of prequalification criteria can be used, as the evaluation concept is to obtain a limited number of contractors having capacity in relation to a particular project's characteristics. Because of the limited number of contractors in the list, a lot of information is needed and the use of advanced evaluation models, such as Knowledge Based System and Analytical Hierarchical Process that incorporate many project prequalification criteria, can be accommodated and the usage of the advanced models can be justified in respect of cost.

To compare the integrated process mentioned above with the separated process that is commonly found in construction industry, Figure 8.1 shows the transformation from the separated process to the integrated process. In the case of periodic prequalification, contractor C, for example, is evaluated 3 times in the separated process, but only once in the integrated process. In addition, the feedback with regards to prequalification improvement and standardisation in the separated process is isolated within every client's self periodic prequalification system and the system is difficult to be generalised and to enable knowledge or information to be shared with other clients' systems. For example, contractor A is familiar with the system of client 1 and client 2, but not with client 3. This case can be improved and repetitive evaluation can be reduced, if the periodic prequalification process is outsourced as an integrated process. If contractors need to be further evaluated for specific criteria related to a particular project, in house project prequalification can be implemented at the particular client level or project level.

As every construction project is naturally characterised by both specific and common requirements, common requirements may be associated with periodic prequalification characteristics. Theoretically, standardisation and universalisation of prequalification criteria are then relatively easier to apply at the level of outsourcing periodic prequalification, as flow and exchange of information are not isolated, while specific requirements associated with a particular project are handled better through in house project prequalification. The time gap between the periodic prequalification stage and project prequalification stage can also be reduced if the process of contractor evaluation and feedback from clients in the outsourcing periodic prequalification system is an online process through the internet (i.e. e-prequalification system). Thus, the conceptual model of the integrated process of prequalification systems is a potential improvement of the current prequalification systems found in the construction industry. These issues in respect of an integrated prequalification process can be the subjects of future research.

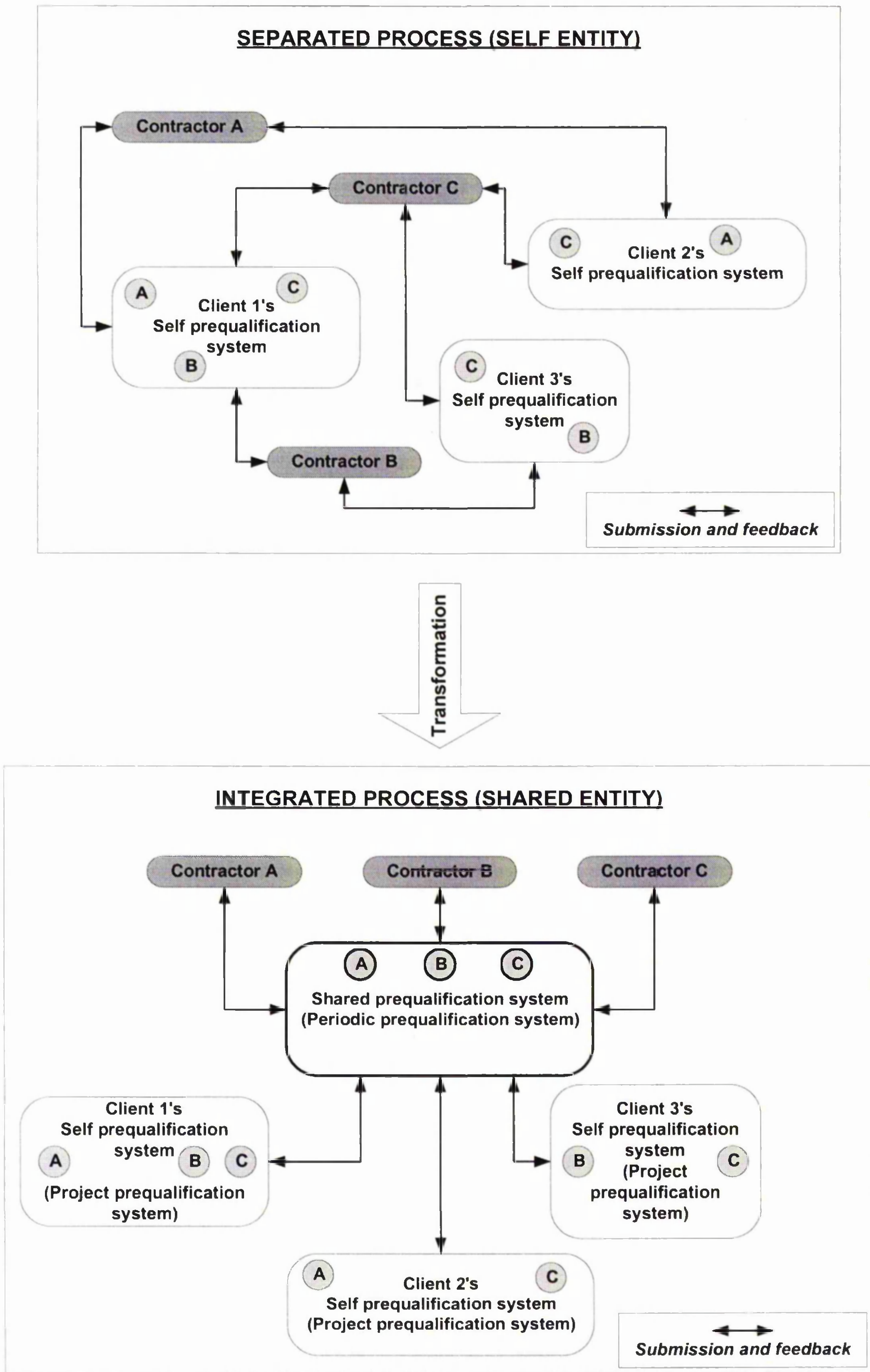


Figure 8.1 Transformation model for improving the prequalification process

However, there are some limitations with regards of the implementation of outsourcing periodic prequalification. These limitations are as follows (Mangitung and Emsley 2002d):

- The characteristics of contractors' data are limited to historical data rather than current data, so clients are required to inspect the capacity of a contractor at the time of a tender stage, because there is often a relatively long time span between evaluation of periodic prequalification and tender stages, although implementation of e-prequalification can facilitate the updating of contractors' data;

- Protocol standardisation tends to increase information flow. Such development of information flow to a single data base in a third party periodic prequalification system could influence the speed, timeliness, reliability, storage and interpretation of large amounts of contractors' data. Additional effort and development of the system are required to fulfil the variety of client demands. Recently, electronic data exchanges through the advanced technology associated with intranet and internet systems have become possible in order to manage the complexity of the contractors' data (Bud-Frierman 1994); and

- To meet various project and client requirements, the outputs of periodic prequalification or contractor classifications should not be limited to the basis of project size value bands and types but categorisation must be extended to project characteristics (e.g. geographical location, contract, procurement experience of contractors, claim performance), previous work with clients, subcontractors and suppliers in respect of their characteristics (e.g. client, subcontractor and supplier types) and other external factors (e.g. local or national regulations related to health and safety, equal opportunities or environmental regulations).

The second proposal concerns the results of Empirical study 2. The model of the relationship between periodic prequalification criteria and time variation could be used to predict potential contractors to carry out project tasks for certain project type and size at the early stage of contractor selection based on the small number of prequalification factors. The indicators of project time variation that are likely to come from the contractors could be identified on the basis of their historical data.

Clients can gain benefits in terms of the reduction of poor project time performance and the justification of elimination of incompetent contractors at the early stage of contractor selection. While contractors can gain benefits using this model in terms of self-assessment of their strengths and weaknesses. Through this evaluation system they can understand their competence level before entering a tender stage or can anticipate at the early stage scheduling problems arising during construction before entering a project contract. Even though the relational models were developed from the public sector domain, the representation of procurement types is relatively similar to the distribution of procurement types being used in the UK construction industry (see section 7.4 in Chapter 7).

8.3.2 Recommendations for future research

In terms of the relationship between periodic prequalification criteria and project performance with regards to project cost and quality performance, the results of the model relationships did not reveal statistically significant levels, as one dichotomous variable category for each model related to cost and quality is not sufficient to regress or develop the predictive model as required by the Logistic Regression technique.

Even though some findings in respect of periodic and project prequalification characteristics and identification of key periodic prequalification factors influencing project performance have been established and contribute to the knowledge of this subject, it is necessary to address several recommendations that can improve future research in respect of the subject of contractor prequalification. Several recommendations are as follows:

- In order to reduce subjectivity in the development of the predictive model, identification of key periodic prequalification factors or using all identified periodic factors for the decision making process of contractor evaluation requires the development of objective measurement of periodic prequalification criteria, such as turnover and ratio analysis for financial strength, business ages in years and past project values for past experience, personnel turnover and qualification for managerial and technical strength, and accident rates and accident cost ratio to overall project cost for compliance with regulations, and also quality performance (i.e. percentage/frequency of reworks, quality cost due to reworks).

- Effort is needed to proportionally obtain contractor data in respect of both good and bad performance of contractors by encouraging, for example, every respondent to supply good and bad performance types in order to develop the proper predictive model relationship, as in this research it was found that only one dimension of the dichotomous variable in relation to cost and quality performance was not sufficient enough to develop model relationships.

- If adequate data are available, it is better to develop model relationships on the basis of different project domains, such as building category separated from civil engineering/infrastructure, in order to increase the accuracy of the identification of periodic prequalification factors and, in terms of a large data bank, Constructionline which contains data about a large number of prequalified contractors, has potential as a data source.

- In order to obtain the best and most appropriate techniques with regards to the development of a predictive model, it is necessary to compare at least two methods such as a comparison between Discriminant Analysis and Logistic Regression techniques or Artificial Neural Network and Logistic Regression techniques, as long as an adequate number of quality cases is available.

- Cost benefit analysis can be used in order to obtain more understanding of the benefits of outsourcing periodic prequalification (e.g. Constructionline) compared with in house periodic prequalification (at client level) or to provide a comparison between periodic and project prequalification.

REFERENCES

Abidali, A. F., and Harris, F. (1995). "A methodology for predicting company failure in the construction industry." *Construction Management and Economics*, 13(3), 189-196.

Aboushiwa, M. A. A. (2000). "Promoter briefing on the procurement and selection of contract strategy offering the best value for money," Unpublished PhD thesis, University of Manchester Institute of Science and Technology (UMIST), Manchester, UK.

Ahmad, I., and Minkarah, I. (1988). "Questionnaire survey on bidding in construction." *Journal of Management in Engineering*, 4(3), 229-243.

Akinci, B., and Fischer, M. (1998). "Factor affecting contractors' risk of cost overburden." *Journal of Management in Engineering*, 14(1), 67-76.

Akintoye, A. (2000). "Analysis of factors influencing project cost estimating practice." *Construction Management and Economics*, 18, 77-89.

Alarcon, L. F., and Mourgues, C. (2002). "Performance model for contractor selection." *Journal of Management in Engineering*, 18(2), 52-60.

Al-Harbi, K. M. A. S. (2001). "Application of the AHP in project management." *International Journal of Project Management*, 19(1), 19-27.

Alsugair, A. M. (1999). "Framework for evaluating bids of construction contractors." *Journal of Management in Engineering*, 15(2), 72-78.

Altman, E. I. (1968). "Financial ratio, discriminant analysis and the prediction of corporate bankruptcy." *Journal of Finance*, 23(4), 589-609.

Antill, J. M., and Woodhead, R. W. (1982). *Critical path methods in construction practice*, John Wiley and Sons, New York, USA.

Arditi, D., Koksal, A., and Kale, S. (2000). "Business failures in the construction industry." *Engineering, Construction and Architectural Management*, 7(32), 120-137.

Arditi, D., and Patel, B. K. (1989). "Expert system for claim management in construction projects." *Project Management Journal*, 7(3), 141-146.

Argenti, J. (1976). *Corporate collapse: The causes and symptoms*, McGraw-Hill, New York.

Argenti, J. (1983). *Predicting corporate failure*, Accountant Digest No. 138, London.

Assaf, S. A., Al-Hammad, A. M., and Ubaid, A. (1996). "Factors effecting construction contractors' performance." *Building Research and Information*, 24(3), 159-163.

Awakul, P., and Ogunlana, S. O. (2000). "The effect of attitudinal differences on interface conflicts in large scale construction projects: A case study." *Construction Management and Economics*, 20(4), 365-377.

Bennett, B. T. (2000). "Orientation program for casual contractors in the chemical industry." *Professional Safety - American Society of Safety Engineering*, 24-28.

Brigham, E. F., and Houston, J. F. (1999). *Fundamentals of financial management*, 9th ed., Thomson Learning, USA.

Bryman, A. (2004). *Social research methods*, 2nd ed., Oxford University press, Oxford, UK.

Bryman, A., and Cramer, D. (2001). *Quantitative data analysis with SPSS Release 10 for Windows*, Routledge, Hove, East Sussex, UK.

Bubshait, A. A., and Al-Gobali, K. H. (1996). "Contractor prequalification in Saudi Arabia." *Journal of Management in Engineering*, 12(2), 50-54.

Burati, J., Farrington, J. J., and Lebetter, W. B. (1992). "Causes of quality deviations in design and construction." *Journal of Construction Engineering and Management*, 118(1), 34-49.

Burati, J., Matthews, M. F., and Kalidindi, S. N. (1991a). "Quality management organizations and techniques." *Journal of Construction Engineering and Management*, 118(1), 112-128.

Burati, J. L., Matthews, M. F., and Kalidindi, S. N. (1991b). "Quality management in the construction industry." *Journal of Construction Engineering and Management*, 117(2), 341-359.

Capita. (2004). "Capita Learning and Development." http://www.capta-ld.co.uk (viewed 02 December 2004).

CECA (Southern) Limited. (2001). "The members of Civil Engineering Contractors Association." http://www.nationline.co.uk/cecasouthern/members.html (viewed 30 March 2001).

Cheng, E. W. L., Li, H., and Love, P. E. D. (2000). "Establishment of critical success factors for construction partnering." *Journal of Management in Engineering*, 16(2), 84-92.

Chua, D. K. H., Kog, Y. C., Loh, P. K., and Jaselskis, E. J. (1997). "Model for construction budget performance - neural network approach." *Journal of Construction Engineering and Management*, 123(3), 214-222.

Chua, D. K. H., Li, D. Z., and Chan, W. T. (2001). "Case Based Reasoning approach in bid decision making." *Journal of Construction Engineering and Management*, 127(1), 35-45.

CIDB Malaysia. (2000). "Construction Industry Development Board Malaysia: Registration of contractors, requirements and procedures." http://www.cidb.gov.my/contractreg_cont.htm (viewed 08 December 2000).

Clough, R. H. (1986). *Construction contracting*, 5th ed., John Wiley and Sons, New York, USA.

Cohen, L., Manion, L., and Morrison, K. (2001). *Research methods in education*, 5th ed., RoutledgeFalmer, London.

Conover, W. J. (1999). *Practical nonparametric statistics*, John Wiley & Sons, Inc., New York, USA.

Construction Industry Board. (1997a). *Code of practice for selection of main contractors. Working Group 3*, Thomas Telford, London, UK.

Construction Industry Board. (1997b). *Framework for a national register for consultants. Working Group 4*, Thomas Telford, London, UK.

Construction Industry Board. (1997c). *Framework for a national register for contractors. Working Group 5*, Thomas Telford, London, UK.

Constructionline. (2001). "What are the benefits of Constructionline?" http://www.constructionline.co.uk/benefits/ (viewed 12 Jul. 2001).

Constructionline. (2002). "Contractor application forms." http://193.130.99.1/CONSTRUCTIONLINE/contractor download.html (viewed 28 Aug. 2002).

Coolican, H. (1999). *Research methods and statistics in psychology*, 3rd ed., Hodders and Stoughton, London.

Council Directive 93/37/EEC. (1993). "Directive on public works contracts." http://www.tendersdirect.co.uk/thelaw/thelawmain.asp (viewed 6 Jan 2005).

Cramer, D. (1997). *Basic statistics for social research*, Routledge, London.

Dalton, A. J. P. (1998). *Safety, Health and Environmental Hazards at the workplace*, Cassell, London.

Department of Health. (2003). "Private Finance and Investment (PFI)." http://www.www.doh.gov.uk/pfi/pqq.htm (viewed 03 Sept. 2003).

Diekmann, J. E. (1983). "Cost-plus contractor selection: an analytical method." *Engineering cost and production economics*, 7, 147-158.

Diekmann, J. E., and Girard, M. J. (1995). "Are contract disputes predictable?" *Journal of Construction Engineering and Management*, 121(4), 355-363.

Diekmann, J. E., and Nelson, M. C. (1985). "Construction claims: frequency and severity." *Journal of Construction Engineering and Management*, 111(1), 74-81.

Dissanayaka, S. M., and Kumaraswamy, M. M. (1999). "Evaluation of factors affecting time and cost performance in Hong Kong building projects." *Engineering, Construction and Architectural Management*, 6(3), 287-298.

Edmister, R. O. (1972). "An empirical test of financial ratio analysis for small business failure prediction." *Journal of Financial and Quantitative Analysis*, 7(2), 1477-1493.

Elinwa, A. U., and Joshua, M. (2001). "Time-overrun factors in Nigerian construction industry." *Journal of Construction Engineering and Management*, 127(5), 419-425.

Faghri, A., Martinelli, D., Demetsky, M. J., Taha, M. A., and Park, S. C. (1997). "Neural network applications in transportation engineering." *Artificial neural network for civil engineers: Fundamentals and Applications*, N. Kartam, ed., ASCE Press, New York, USA, 137-159.

Field, A. (2000). *Discovering statistics: Using SPSS for Windows*, Sage Publications, London.

Filippone, R. W. (1976). "A statistical analysis of some common underwriting measures used by contract surety underwriters," Unpublished thesis submitted in partial fulfilment of Master Degree in Business Administration, Cleveland State University, Cleveland , Ohio, USA.

Flanagan, R., and Norman, G. (1982). "Making good use of low bids." *Chartered Quantity Surveyor*, 226-227.

Fong, P. S. W., and Choi, S. K. Y. (2000). "Final contractor selection using analytical hierarchy process." *Construction Management and Economics*, 18, 547-557.

Frankfort-Nachmias, C., and Nachmias, D. (1996). *Research methods in the social sciences*, 5th ed., Hodder Arnold, London.

Fu, W. K., Drew, D. S., and Lo, H. P. (2003). "Competitiveness of inexperienced and experienced contractors in bidding." *Journal of Construction Engineering and Management*, 129(4), 388-395.

Gann, D., and Senker, P. (1998). "Construction skills training for the next millennium." *Construction Management and Economics*, 16, 569-580.

Goodwin, P., and Wright, G. (1998). *Decision analysis for management judgment*, 2nd ed., John Wiley and Sons, Chicester, England.

Gulezian, R., and Samelian, F. (2003). "Baseline determination in construction labor productivity-loss claims." *Journal of Management in Engineering*, 19(4), 160-165.

Gunning, J. G. (1999). "A review of the application of risk assessment procedures in construction management research." *Journal of Financial Management of Property and Construction*, 4(1), 59-74.

Hair Jr, J. F., Anderson, R. E., Tatham, R. L., and Black, W. C. (1998). *Multivariate data analysis*, 5th ed., Prentice Hall, Inc., New Jersey, USA.

Hanna, A. S., Camlic, R., Peterson, P. A., and Nordheim, E. V. (2002). "Quantitative definition of projects impacted by change orders." *Journal of Construction Engineering and Management*, 128(1), 57-64.

Hatush, Z. (1996). "Contractor selection, using multiattribute utility theory," Unpublished PhD thesis, Department of Surveying, University of Salford, Salford, UK.

Hatush, Z., and Skitmore, M. (1997a). "Assessment and evaluation of contractor data against client goals using PERT approach." *Construction Management and Economics*, 15(4), 327-340.

Hatush, Z., and Skitmore, M. (1997b). "Criteria for contractor selection." *Construction Management and Economics*, 15, 19-38.

Hatush, Z., and Skitmore, M. (1997c). "Evaluating contractor prequalification data: selection criteria and project success factors." *Construction Management and Economics*, 15, 129-147.

Hatush, Z., and Skitmore, M. (1998). "Contractor selection using multicriteria utility theory: an additive model." *Building and Environment*, 33(2-3), 105-115.

Herbsman, Z., and Ellis, R. (1992). "Multi parameter bidding system - innovation in contract administration." *Journal of Construction Engineering and Management*, 118(1), 142-150.

Hinze, J., and Applegate, L. L. (1992). "Costs of construction injuries." *Journal of Construction Engineering and Management*, 117(3), 537-550.

HM Treasury. (1997). *Procurement guidance no. 3: Appointment of consultants and contractors*, Treasury Public, London.

Hoinville, G., and Jowell, R. (1987). *Survey research practice*, Gower, Hants, UK.

Holley, W. H., and Field, H. S. (1976). "Equal employment opportunity and its implications for personnel practices." *Labor Law Journal*, 27(5), 278-286.

Holt, G. D. (1993). "A conceptual alternative to current tendering practice." *Building Research and Information*, 21(3), 167-172.

Holt, G. D. (1996). "Applying cluster analysis to construction contractor classification." *Building and Environment*, 31(6), 557-568.

Holt, G. D. (1997). "Classifying construction contractors: A case study using cluster analysis." *Building Research and Information*, 25(6), 374-382.

Holt, G. D. (1998). "Which contractor selection methodology?" *International Journal of Project Management*, 16(3), 153-164.

Holt, G. D., Olomolaiye, P. O., and Harris, F. C. (1994a). "Evaluating performance potential in the selection of construction contractors." *Engineering, Construction and Architectural Management*, 1(1), 29-50.

Holt, G. D., Olomolaiye, P. O., and Harris, F. C. (1994b). "Evaluating prequalification criteria in contractor selection." *Building and Environment*, 29(4), 437-448.

Holt, G. D., Olomolaiye, P. O., and Harris, F. C. (1994c). "Factors influencing U.K. construction clients' choice of contractor." *Building and Environment*, 29(2), 241-248.

Holt, G. D., Olomolaiye, P. O., and Harris, F. C. (1995). "A review of contractor selection practice in the U.K. construction industry." *Building and Environment*, 30(4), 553-561.

Holt, G. D., and Proverbs, D. G. (2001). "A survey of public sector procurement in England." *Journal of Construction Procurement*, 7(1), 3-10.

HSE. (2002). *Reduced risks - cut costs: The real costs of accidents and ill health at work*, 3rd ed., Health and Safety Comission.

HSE. (2004). *Statistics of Fatal Injuries 2003/04*, Health and Safety Comission, UK.

Hughes, W. P., Hillebrandt, P., and Murdoch, J. R. (1998). *Financial Protection in the UK Building Industry: bonds, retentions and guarantees*, Spon, London.

Indiana Department of Transportation USA. (2004). "Rules for prequalification of contractors and bidding." http://www.in.gov/dot/business/contract/prequal.html (viewed 16 May 2004).

Indonesian Government. (1994). *Technical guidance of the decree of President of Republic of Indonesia No. 16, year 1994 concerning implementation of state revenues and expenditures budget*, PT Magna Systrindo (Indonesian text), Jakarta, Indonesia.

Jackson-Robbins, A. (1998). *Selecting contractors by value*, CIRIA, London.

Jaselskis, E. J. (1988). "Achieving construction project success thorugh predictive discrete choice," Unpublished PhD thesis, University of Texas at Austin, Austin, Texas, USA.

Jaselskis, E. J., and Ashley, D. B. (1991). "Optimal allocation of project management resources for achieving success." *Journal of Construction Engineering and Management*, 117(2), 321-340.

Jaselskis, E. J., and Russell, J. S. (1992). "Risk analysis approach to selection of contractor evaluation method." *Journal of Construction Engineering and Management*, 118(4), 814-821.

Jennings, P., and Holt, G. D. (1998). "Prequalification and multi-criteria selection: a measure of contractors' opinion." *Construction Management and Economics*, 16, 651-660.

Jergeas, G. F., and Hartman, F. T. (1994). "Contractor construction-claims avoidance." *Journal of Construction Engineering and Management*, 120(3), 553-560.

Josephson, P.-E., Larsson, B., and Li, H. (2002). "Illustrative benchmarking rework and rework costs in Swedish construction industry." *Journal of Management in Engineering*, 18(2), 76-83.

Kale, S., and Arditi, D. (1998). "Business failure: Liabilities of newness, adolescence and smallness." *Journal of Construction Engineering and Management*, 124(6), 458-464.

Kaming, P. F., Olomolaiye, P. O., and Holt, G. D. (1997). "Factors influencing construction time and cost overruns on high-rise projects in Indonesia." *Construction Management and Economics*, 15, 83-94.

Kangari, R. (1988). "Business failure in construction industry." *Journal of Construction Engineering and Management*, 114(2), 172-190.

Kashiwagi, D. T., and Byfield, R. E. (2002). "Selecting the best contractor to get performance: on time, on budget, meeting quality expectations." *Journal of Facilities Management*, 1(2), 103-116.

Kashiwagi, D. T., and Mohammed, M. (2002). "A study comparing US construction delivery systems based on business and management." *Construction Building Research Conference (COBRA) 2002*, School of Property & Construction, The Nottingham Trent University, UK, 37-53.

Kashiwagi, D. T., Parmar, D., and Savicky, J. (2003). "The impact of minimizing specifications and management at the University of Hawaii." *Journal of Facilities Management*, 2(2), 131-141.

Kein, A. T. T., Ofori, G., and Briffett, C. (1999). "ISO 1400: Its relevance to the construction industry of Singapore and its potential as the next industry milestone." *Construction Management and Economics*, 17, 449-461.

Kenley, R., and Watson, J. (2000). "Strategic procurement in the construction industry: Mechanisms for public sector clients to encourage improved performance in Australia." *Journal of Construction Procurement*, 6(1), 4-19.

Kepner, C. H., and Tregoe, B. B. (1981). *The new rational manager*, Princeton Research Press, Princeton, USA.

Khosrowshahi, F. (1999). "Neural network model for contractors' prequalification for local authority projects." *Engineering, Construction and Architectural Management*, 6(3), 315-328.

King, R. J. (2002). "Local government task force: Constructionline working group report." http://www.constructionline.co.uk/news/list.asp?blocktypeID=3 (viewed 01 July 2002).

Kinniear, P. R., and Gray, C. D. (2000). *SPSS for Windows made simple: Release 10*, Psychology Press Ltd., Hove, East Sussex, UK.

Kog, Y. C., Chua, D. K. H., Loh, P. K., and Jaselskis, E. J. (1999). "Key determinants for construction schedule performance." *International Journal of Project Management*, 17(6), 351-359.

Koksal, A., and Arditi, D. (2004). "Predicting construction company decline." *Journal of Construction Engineering and Management*, 130(6), 799-807.

Kometa, S. T., Olomolaiye, P. O., and Harris, F. C. (1995). "An evaluation of clients' need and responsibilities in construction process." *Engineering, Construction and Architectural Management*, 2(1), 57-76.

KPI. (1999). *Key Performance Indicators (KPI) 1999: Industry progress report*, Construction Best Practice Programme, Watford, UK.

Kumaraswamy, M. M. (1996a). "Contractor evaluation and selection: a Hong Kong perspective." *Building and Environment*, 31(3), 273-282.

Kumaraswamy, M. M. (1996b). "Improving industry performance through integrated training programs." *Journal of Professional Issues in Engineering Education and Practice*, 123(3), 93-97.

Kumaraswamy, M. M., and Matthews, J. D. (2000). "Improved subcontractor selection employing partnering principles." *Journal of Management in Engineering*, 16(3), 47-57.

Kumaraswamy, M. M., and Walker, D. H. T. (1999). "Multiple performance criteria for evaluating construction contractor." *Procurement systems: A guide to best practice in construction*, S. Rowlinson and P. McDermott, eds., E & FN Spon, London, 228-251.

Kunishima, M., and Shoji, M. (1996). *The principles of construction management*, Sankaido Publishing Co., Ltd., Tokyo, Japan.

Lahdenpera, P., and Soini, P. (2002). "A national system for certification and registration of construction enterprises' competence in Finland." *The 10th International CIB Symposium of the W65 Commission on Organisation and Management of Construction: Construction Innovation and Global Competitiveness*, University of Cincinnati, Ohio, USA, 1228-1243.

Lam, K. C., Ng, S. T., Skitmore, R. M., and Cheung, S. O. (2000). "Decision support system for contractor prequalification - artificial neural network model." *Engineering, Construction and Architectural Management*, 7(3), 251-266.

Langford, D. A., El-Tigani, H., and Marosszeky, M. (2000). "Does quality assurance deliver higher productivity?" *Construction Management and Economics*, 18, 775–782.

Lapin, L. L. (1994). *Quantitative methods for business decisions*, 6th ed., Duxbury Press, Belmont, USA.

Latham, S. M. (1994). *Constructing the team. Joint Review of Procurement and Contractual of Project Management*, HMSO, London, UK.

Li, H. (1997a). "Determinants of knowledge-based expert system success in construction engineering." *Building Research and Information*, 25(2), 101-106.

Li, H. (1997b). "Selecting KBES development techniques for applications in the construction industry." *Construction Management and Economics*, 14, 67-74.

Lingard, H., Hughes, W. P., and Chinyio, E. A. (1998). "The impact of contractor selection method on transaction costs: A review." *Journal of Construction Procurement*, 4(2), 89-102.

Liu, A. M. M., and Walker, A. (1998). "Evaluation of project outcomes." *Construction Management and Economics*, 16, 209-219.

Lo, W., Krizek, R. J., and Hadavi, A. (1999). "Effect of high prequalification requirements." *Construction Management and Economics*, 17, 603-612.

Loh, W. H., and Ofori, G. (2000). "Effect of registration on performance of construction subcontractors in Singapore." *Engineering, Construction and Architectural Management*, 7(1), 29.

Loosemore, M., and Chau, D. W. (2002). "Racial discrimination towards Asian operatives in the Australian construction industry." *Construction Management and Economics*, 20, 91-102.

Love, P. E. D., and Li, H. (2000). "Overcoming the problems associated with quality certification." *Construction Management and Economics*, 18, 139-149.

Love, P. E. D., and Smith, J. (2003). "Benchmarking, benchaction, and bench learning: Rework mitigation in projects." *Journal of Management in Engineering*, 19(4), 147-159.

Lowe, D. J. (1996). "Experiential learning in design cost estimating," Unpublished PhD thesis, University of Manchester Institute of Science and Technology (UMIST), Manchester, UK.

Lowe, D. J., and Parvar, J. (2004). "A logistic regression approach to modelling the contractor's decision to bid." *Construction Management and Economics*, 22, 643-653.

Mahdi, I. M. (2001). "Decision support system for selection of the optimum contractor in construction projects," Unpublished PhD thesis, Southampton University, Southampton.

Mahdi, I. M., Riley, M. J., Fereig, S. M., and Alex, A. P. (2002). "A multi-criteria approach to contractor selection." *Engineering, Construction and Architectural Management*, 9(1), 29-37.

Mangitung, D. M., and Emsley, M. W. (2002a). "The characteristics of periodic and project prequalification practices in the UK." *The 10th International CIB Symposium of the W65 Commission on Organisation and Management of Construction: Construction Innovation and Global Competitiveness*, University of Cincinnati, Ohio, USA, 960-972.

Mangitung, D. M., and Emsley, M. W. (2002b). "Decision criteria for periodic prequalification in the UK construction industry." *Construction Building Research Conference (COBRA) 2002*, School of Property & Construction, The Nottingham Trent University, UK, 273-285.

Mangitung, D. M., and Emsley, M. W. (2002c). "Factors affecting the weighting of contractor prequalification decision criteria: the UK prequalifiers' perception." *The 3rd International Conference on Decision Making in Urban and Civil Engineering (DMinUCE) 2002*, University of London, School of Oriental & African Studies, London.

Mangitung, D. M., and Emsley, M. W. (2002d). "Standardisation of periodic prequalification criteria through identification of the relationship between prequalification factors and project performance." *The First International*

Conference on Information Standardisation, Exchanges and Management in Construction (CISEMIC) 2002, University of Salford, School of Construction & Property Management, Salford, 243-251.

Masterman, J. W. E. (2002). *Building procurement systems*, 2nd ed., Spon Press, London.

Masterman, J. W. E., and Gameson, R. N. (1994). "Client characteristics and needs in relation to their selection of building procurement systems." *Proceedings of CIB W92 - Procurement systems: East meets West*, The Department of Surveying, Hong Kong University, 79-87.

Matthews, J. (1999). "Applying partnering in the supply chain." *Procurement systems: A guide to best practice in construction*, S. Rowlinson and P. McDermott, eds., E & FN Spon, London, 252-275.

McDonald, K., and Tipton, C. (1998). "Using documents." *Researching social life*, N. Gilbert, ed., Sage Publications, London, 187-200.

McKim, R., Hegazy, T., and Attalla, M. (1998). "Project performance control in reconstruction projects." *Journal of Construction Engineering and Management*, 126(2), 137-141.

McMenamin, J. (1999). *Financial management: an introduction*, Routledge, London, UK.

Merna, A., and Smith, N. J. (1990). "Bid evaluation for UK public sector construction contracts." *Proceedings of the Institution Civil Engineers Part I*, 88, 91-105.

Mertens, D. M. (1997). *Research methods in education and psychology*, Sage Publications, London.

Minchin, J. R. E., and Smith, G. R. (2001). *Quality-based performance rating of contractors for prequalification and bidding purposes*, NCHRP Web Document 38, USA.

Ministry of Land Infrastructure and Transportation. (2000). "Japanese procurement procedures for public works." http://www.mlit.go.jp/sogoseisaku/const/kengyo/kokyo-e.htm (viewed 17 May 2004).

Murdoch, J. R., and Hughes, W. P. (1998). *Construction contracts: law and management*, Spon, London.

Negnevitsky, M. (2002). *Artificial intelligence: A guide to intelligent systems*, Addison-Wesley, London.

Ng, S. T. (1996). "Case-based reasoning decision support for contractor prequalification," Unpublished PhD thesis, University of Manchester Institute of Science and Technology (UMIST), Manchester, UK.

Ng, S. T., and Skitmore, R. M. (1995a). "Case-based reasoning for contractor prequalification - a feasibility study." *Developments in Artificial Intelligence for Civil and Structural Engineering*, 61-66.

Ng, S. T., and Skitmore, R. M. (1995b). "CP-DSS: Decision support system for contractor prequalification." *Civil Engineering Systems*, 12, 133-159.

Ng, S. T., Skitmore, R. M., and Smith, N. J. (1999). "Decision-makers' perceptions in the formulation of prequalification criteria." *Engineering, Construction and Architectural Management*, 6(2), 155-165.

Ng, S. T., and Smith, N. J. (1998). "Verification and validation of case-based prequalification system." *Journal of Computing in Civil Engineering*, 12(4), 215-226.

Nguyen, V. U. (1985). "Tender evaluation by fuzzy sets." *Journal of Construction Engineering and Management*, 111(3), 231-243.

NJCC. (1994a). *Standard form of tendering questionnaire: Application for admission to approved lists of contractors*, National Joint Consultative Committee for Building, London.

NJCC. (1994b). *Standard form of tendering questionnaire: Application for admission to select lists of contractors*, National Joint Consultative Committee for Building, London.

Norusis, M. J. (1997). *SPSS Professional statistics 7.5*, SPSS Inc., Chicago.

Norusis, M. J. (1999). *SPSS Regression models 10.0*, SPSS Inc., Chicago, USA.

NSW Department of Public Works and Services. (2001). *Contractor prequalification scheme for construction works 2001-2003*, New South Wales Department of Public Works and Services.

Odusote, O. O., and Fellows, R. F. (1992). "An examination of importance of resource considerations when contractors make project selection decisions." *Construction Management and Economics*, 10, 137-151.

Ofori, G. (1992). "The environment: The fourth construction project objective?" *Construction Management and Economics*, 10(5), 369-395.

Oliver, C. (1997). "The influence of institutional and task environment relationships on organizational performance: The Canadian construction industry." *Journal of Management studies*, 34, 99-124.

Oppenheim, A. N. (1986). *Questionnaire design and attitude measurement*, Gower, Hants, UK.

Palaneeswaran. (2003). "Results of questionnaire survey: phase I." http://web.hku.hk/~palanees/barchart.html (viewed 14 October 2003).

Palaneeswaran, E. (2000). "Contractor selection systems for Design-Build projects," Unpublished PhD thesis, Department of Civil Engineering, The University of Hong Kong, Hong Kong.

Palaneeswaran, E., and Kumaraswamy, M. (2000a). "Benchmarking contractor selection practices in public-sector construction - a proposal model." *Engineering Construction and Architectural Management*, 7(3), 285-299.

Palaneeswaran, E., and Kumaraswamy, M. (2000b). "Contractor selection for design-build projects." *Journal of Construction Engineering and Management*, 126(5), 331-339.

Palaneeswaran, E., and Kumaraswamy, M. (2001). "Recent advances and proposed improvements in contractor prequalification methodologies." *Building and Environment*, 36, 73-87.

Palaneeswaran, E., Kumaraswamy, M., and Zhang, X. Q. (2001). "Reforging construction supply chains: A source selection perspective." *European Journal of Purchasing and Supply Management*, 7, 165-178.

Parker, S. K., and Skitmore, M. (2004). "Project management turnover: Causes and effects on project performance." *World of Construction Project Management - The First International Conference*, Ryerson University, Toronto, Canada, 638-647.

Pearsall, J. (1999). "The Concise Oxford Dictionary." Oxford University Press, Oxford.

Pettinger, R. (1998). *Construction marketing strategies for success*, MacMillan, London.

Pilcher, R. (1992). *Principles of construction management*, 3rd ed., McGraw-Hill Inc., London.

Potter, K. J., and Sanvido, V. (1994). "Design/build prequalification system." *Journal of Management in Engineering*, 10(2), 48-56.

Potter, K. J., and Sanvido, V. (1995). "Implementing a design/build prequalification system." *Journal of Management in Engineering*, 11(3), 30-34.

Preece, C., Moodley, K., and Putsman, T. (1997). "More effective pre-qualification strategies and team presentations in contractual services." *CIB W92 Conference Procurement*, Montreal, 633-641.

Procter, M. (1998). "Measuring attitudes." *Researching social life*, N. Gilbert, ed., Sage Publications, London, 116-134.

Public sector procurement rules. (2001). "Thresholds for advertising public sector tenders and awards." http://http://www.hillhous.demon.co.uk/threshld.htm (viewed 12 July 2001).

Rankin, J. H., Champion, S. L., and Waugh, L. M. (1996). "Contractor selection: qualification and bid evaluation." *Canadian Journal of Civil Engineering*, 23, 117-123.

Rashid, K. B. A. (2002). "An assessment on the systems of registration of contracting firms in Malaysia." *Journal of Construction Procurement*, 8(2), 148-159.

Ritz, G. J. (1994). *Total construction project management*, McGraw-Hill Inc., New York, USA.

Rogers, M. (2001). *Engineering project appraisal*, Blackwell, Oxford.

Rosenthal, R., and Rosnow, R. L. (1984). *Essentials of behavioral research: Methods and data analysis*, John Wiley & Sons, New York.

Rowlinson, S. (1999). "Selection criteria." *Procurement systems: A guide to best practice in construction*, S. Rowlinson and P. McDermott, eds., E & FN Spon, London, 276-299.

Russell, J. S. (1988). "A knowledge-base system approach to the contractor prequalification process," Unpublished PhD thesis, Purdue University, Purdue, West Lafayette, USA.

Russell, J. S. (1990). "Surety bonding and owner-contractor prequalification: Comparison." *Journal of Professional Issue in Engineering*, 116(4), 360-374.

Russell, J. S. (1991). "Contractor failure: Analysis." *Journal of Performance of Construction Facilities*, 5(3), 163-180.

Russell, J. S. (1992). "Decision models for analysis and evaluation of construction contractors." *Construction Management and Economics*, 10, 185-202.

Russell, J. S. (1996). *Constructor Prequalification: Choosing the best contractor and avoiding constructor failure*, ASCE Press, New York.

Russell, J. S. (2000). *Surety bonds for construction contracts*, ASCE Press, New York, USA.

Russell, J. S., and Ahmad, I. (1990). "A PERT approach to contractor prequalification analysis." *Proceedings of 34th Annual Meeting, American Association of Cost Engineers*, USA, 1-6.

Russell, J. S., Hancher, D. E., and Skibniewski, M. J. (1992). "Contractor prequalification data for construction owners." *Construction Management and Economics*, 10, 117-135.

Russell, J. S., and Jaselskis, E. J. (1992). "Predicting construction contractor failure prior to contract award." *Journal of Construction Engineering and Management*, 118(4), 791-811.

Russell, J. S., and Skibniewski, M. J. (1988). "Decision criteria in contractor prequalification." *Journal of Management in Engineering*, 4, 148-164.

Russell, J. S., Skibniewski, M. J., and Cozier, D. R. (1990a). "Qualifier 1: Contractor prequalification model." *Journal of Computing in Civil Engineering*, 4(1), 77-90.

Russell, J. S., Skibniewski, M. J., and Cozier, D. R. (1990b). "Qualifier 2: knowledge-based system for contractor prequalification." *Journal of Construction Engineering and Management*, 116(1), 157-171.

Russell, J. S., and Zhai, H. (1996). "Prediction of contractor failure using stochastic dynamics of economic and financial variables." *Journal of Construction Engineering and Management*, 122(2), 183-191.

Saunders, M., Lewis, P., and Thornhill, A. (1997). *Research methods for business students*, Financial Times-Pitman Publishing, London.

Schulman, I. M. (1982). "Regulation of engineers in California." *Journal of Professional Activities*, 108(1), 33-48.

Scott, S. (1997). "Delay claims in UK contracts." *Journal of Construction Engineering and Management*, 123(3), 238-244.

Seeley, I. H. (1996). *Building economics: Appraisal and control of building design cost and efficiency*, 4th ed., McMillan, London.

Sekaran, U. (2003). *Research methods for business: A skill building approach*, 4th ed., John Wiley & Sons, New York.

Severson, D. G., Russell, J. S., and Jaselskis, E. J. (1994). "Predicting contract surety bond claims using contractor financial data." *Journal of Construction Engineering and Management*, 120(2), 405-420.

Sharma, S. (1996). *Applied multivariate techniques*, John Wiley & Sons, Inc., New York, USA.

Shash, A. A. (1993). "Factors considered in tendering decisions by top UK contractors." *Construction Management and Economics*, 11, 111-118.

Shen, L. Y., Xu, J., Chan, E. H. W., and Tam, V. W. Y. (2004). "Controlling cost-overrun risk in implementing public projects: A Hong Kong study." *World of Construction Project Management - The First International Conference*, Ryerson University, Toronto, Canada, 124-132.

Siegel, S., and Castellan, N. J. (1988). *Nonparametric statistics for the behavioral sciences*, 2nd ed., McGraw-Hill, New York, USA.

Smith, A. J. (1995). *Estimating, tendering and bidding for construction*, MacMillan Press, London.

Smith, G. R., and Roth, R. D. (1991). "Safety programs and the construction manager." *Journal of Construction Engineering and Management*, 117(2), 360-371.

Soetanto, R., and Proverbs, D. G. (2002). "Modelling the satisfaction of contractors: The impact of client performance." *Engineering, Construction and Architectural Management*, 9(5/6), 453-465.

Soetanto, R., Proverbs, D. G., and Cooper, P. (2002). "A tool for assessing contractor performance." *Journal of Construction Procurement*, 8(1), 48-64.

Sonmez, M., Yang, J. B., and Holt, G. D. (2001). "Addressing the contractor selection problem using an evidential reasoning approach." *Engineering, Construction and Architectural Management*, 8(3), 198-210.

Sonmez, M., Yang, J. B., and Holt, G. D. (2002). "Applying evidential reasoning to prequalifying construction contractor." *Journal Management in Engineering*, 18(3), 111-119.

Spatz, D. M. (2000). "Team-building in construction." *Practice Periodical on Structural Design and Construction*, 5(3), 93-105.

Suraji, A., Duff, A. R., and Peckitt, S. J. (2001). "Development of causal model of construction accident causation." *Journal of Construction Engineering and Management*, 127(4), 337-344.

Tabachnick, B. G., and Fidel, L. S. (1989). *Using multivariate statistics*, 2nd ed., HarperCollins College Publisher, New York, USA.

Tabachnick, B. G., and Fidel, L. S. (1996). *Using multivariate statistics*, 3rd ed., HarperCollins College Publisher, New York, USA.

Taha, M. A.-E. (1994). "Applying distributed artificial intelligence to the prequalification of construction contractors," Unpublished PhD thesis, Civil & Environmental Engineering, University of Wisconsin-Madison, Madison, USA.

Thompson, P., and Perry, J. (1992). *Engineering construction risks*, Thomas Telford, London, UK.

Tse, R. Y. C. (2001). "The implementation of EMS in construction firms: Case study in Hong Kong." *Journal of Environmental Assessment Policy and Management*, 3(2), 177-194.

Turban, E., and Aronson, J. E. (2001). *Decision support systems and intelligent systems, knowledge based system*, 6th ed., Prentice Hall, New York.

Vaus, D. D. (2002). *Survey of social research*, 5th ed., Routledge, London.

Verma, V. K. (1995). *Organizing projects for success*, Project Management Institute, Inc., Pennsylvania, USA.

Walker, A. (1996). *Project management in construction*, 3rd ed., Blackwell Science, London.

Ward, S. C., Curtis, B., and Chapman, C. B. (2000). "Objectives and performance in construction projects." *Construction Management and Economics*, 9, 343-353.

Weiss, S. M., and Kulikowski, C. A. (1991). *Computer systems that learn*, Morgan Kaufmann Publishers, San Francisco, USA.

Witt, A. D. (1986). "Measuring project success: An illusion." *Project Management Institute Seminar/ Symposium 1986*, Montreal Canada, 13-21.

Wong, C. H. (2001). "A discriminant model for classifying contractor performance on public works projects," Unpublished PhD thesis, University of Wolverhampton, Wolverhampton.

Wong, C. H., and Holt, G. D. (2001). "Classifying contractors using the multivariate discriminant technique." *The First International Postgraduate Research Conference in the Built and Human Environment*, University of Salford, 280-291.

Wong, C. H., Holt, G. D., and Cooper, P. A. (2000). "Lowest price or value? Investigation of UK construction clients' tender selection process." *Construction Management and Economics*, 18, 767-774.

Wong, C. H., Holt, G. D., and Harris, P. (1999). "UK construction clients' opinion of the contractor selection process." *Proceedings of the fifteenth Annual ARCOM Conference 1999*, Liverpool John Moores University, 695-703.

Wong, C. H., Holt, G. D., and Harris, P. (2001). "Multi-criteria selection of lowest price? Investigation of UK construction clients' tender evaluation preference." *Engineering, Construction and Architectural Management*, 8(4), 257-271.

Wong, C. H., Nicholas, J., and Holt, G. D. (2003). "Using multivariate techniques for developing classification models." *Engineering, Construction and Architectural Management*, 10(2), 99-116.

Woodward, J. F. (1997). *Construction Project Management*, Thomas Telford, London.

Wyre BC. (2004). "Accident-costs and statistics." http://www.wyrebc.gov.uk (viewed 02 December 2004).

Xiao, H., and Proverbs, D. (2003). "Factors influencing contractor performance: an international investigation." *Engineering, Construction and Architectural Management*, 10(5), 322-332.

APPENDICES

List of appendices

APPENDIX A

A. QUESTIONNAIRE AND COVER LETTER FOR CLIENT RESPONDENTS FOR EMPIRICAL STUDY 1

Questionnaire Survey

This questionnaire is designed to help discover new facts and data for understanding current contractor prequalification practice including the types, forms and trends in the construction industry. Individual responses will be kept confidential in any case. Only summaries will be published.

Please answer all questions if possible and you are invited to add your comments. If you are further interested in this research project, please use the reply slip on the last page of the questionnaire.

If you have any queries about the questions or require any information about my research please do not hesitate to contact me at the following address:

Donny Mangitung
PhD student
Dept. of Civil and Construction Engineering, UMIST
P.O. Box 88
Manchester M60 1QD
England - UK
Email: **d.mangitung@stud.umist.ac.uk**
Phone: +44-(0161)-200 4645
Fax: +44-(0161)-200 4252

1. Your profession (*please tick one box*)

   ❐ Architect ❐ Civil/ Structural engineer ❐ Building services engineer
   ❐ Quantity surveyor ❐ Project/ Construction manager ❐ Businessman
   ❐ Other ....

2. Your working experience in contractor prequalification (*please tick one box*)

   ❐ < 1 year ❐ 1 - 3 years ❐ 3 - 5 years ❐ >5 years ❐ None

3. The average number of projects per annum in which you are involved with prequalification (*please tick one box*)

   Note: Any questions which refer to project(s) mean construction project(s)

   ❐ 1 ❐ 2-5 ❐ 5-10 ❐ >10 ❐ None

4. The type of your organisation/ firm (*please tick one box*)

   ❐ Private sector ❐ Public sector ❐ Other..................

5. The main project type in your organisation/ firm (*please tick one box*)

   ❐ Residential/ housing ❐ Building including industrial building
   ❐ Civil engineering/ infrastructure ❐

Contractor Prequalification *Questionnaire Survey (Client version)* *1 of 9*

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1

6. The approximate number and total value of projects carried by your organisation/ firm in the last three years

Procurement type	Number	Total amount (£ million)
Traditional	....	....
Management	....	....
Design-build	....	....
Partnering	....	....

7. The purpose of prequalification in your organisation/ firm (*please tick one or more box as appropriate*)

- ❒ To minimise risks including extensive time delay, cost overrun, inferior quality.
- ❒ To eliminate the incompetent, overextended, underfinanced and inexperienced contractors in terms of performing a certain level of project tasks.
- ❒ To comply with regulations (e.g. European legislation).
- ❒ To reduce competition.
- ❒ Standard procedure.
- ❒ Other ....

8. The main type of prequalification performed (*please tick one box*)

Note: - **Standing list of contractors** is a list developed from a prequalification process that is not intended for a particular project, and is performed periodically (e.g. annual prequalification). In other words, the list is developed from a **periodic prequalification.**
- **Ad-hoc list of contractors** is a list developed from a prequalification process that is intended for a particular project, and is performed on a project by project basis. Another name **is project list** developed from a **specific prequalification.**

❒ Standing list ❒ Ad-hoc list ❒ Both types of list
❒ None ❒ Other ....

9. The eligible time in which a construction firm is listed in standing list of contractors before being updated (*please tick one box*)

❒ More than once a year ❒ Every year ❒ Every two-years
❒ Every three-years or more

10. The use of a standing list of contractors regarding project value (*please tick one or more box*)

❒ <£0.25 million ❒ £0.25 – £0.5 million ❒ £0.5-£1 million
❒ £1-£5 million ❒ >£5 million

Contractor Prequalification *Questionnaire Survey (Client version)* *2 of 9*

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

11. The use of an ad-hoc list of contractors regarding project value (*please tick one or more box*)

- ☐ <£0.25 million
- ☐ £0.25 – £0.5 million
- ☐ £0.5-£1 million
- ☐ £1-£5 million
- ☐ >£5 million

12. The type of procurement system used in your organisation/ firm regarding prequalification type (*please tick one or more box per type of prequalification, i.e. standing list or ad-hoc list*)

Procurement type	Standing list	Ad-hoc list
Traditional	☐	☐
Management	☐	☐
Design-build	☐	☐
Partnering	☐	☐

13. The main person in the team/ committee responsible for the development and evaluation of the prequalification system (*please tick one or more box*)

- ☐ Architect
- ☐ Civil/ Structural engineer
- ☐ Building services engineer
- ☐ Quantity surveyor
- ☐ Project/ Construction manager
- ☐ Businessman
- ☐ Other ……………

14. The team/ committee for prequalification are obtained from (*please tick one box per type of prequalification*)

Human resources	Standing list	Ad-hoc list
In house	☐	☐
Outsourcing (e.g. consultant)	☐	☐
Combination	☐	☐

15. The percentage of qualified contractors awarded contracts per annum from the total number of contractors in your firm's standing list or ad-hoc list (*please tick one box per type of prequalification*)

Percentage	Standing list	Ad-hoc list
<25%	☐	☐
25%-50%	☐	☐
50%-75%	☐	☐
75%-100%	☐	☐

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

16. The references/ bases of the design, development and evaluation of decision criteria and the degree of their impact on weighting/ scoring decision criteria in your organisation/ firm (*please tick one box in respect of the impact of the references on weighting/ scoring per type of prequalification*)

Note: The degree of the impact

0 = not used	1 = low	2 = moderate	3 = high

References/ bases	The degree of impact							
	Standing list				Ad-hoc list			
	0	1	2	3	0	1	2	3
Project objectives	☐	☐	☐	☐	☐	☐	☐	☐
Project size	☐	☐	☐	☐	☐	☐	☐	☐
Project type	☐	☐	☐	☐	☐	☐	☐	☐
Individual experience	☐	☐	☐	☐	☐	☐	☐	☐
Professional judgement	☐	☐	☐	☐	☐	☐	☐	☐
Client objectives	☐	☐	☐	☐	☐	☐	☐	☐
Procurement type	☐	☐	☐	☐	☐	☐	☐	☐
Risk analysis	☐	☐	☐	☐	☐	☐	☐	☐
Public accountability	☐	☐	☐	☐	☐	☐	☐	☐
Standard procedure	☐	☐	☐	☐	☐	☐	☐	☐
Regulations	☐	☐	☐	☐	☐	☐	☐	☐
Other...........	☐	☐	☐	☐	☐	☐	☐	☐

17. The sources of contractors' data (*please tick one or more box per type of prequalification*)

Data collection	Standing list	Ad-hoc list
Questionnaire form with data endorsed by related parties (*e.g. accountants, previous clients, bank etc.*)	☐	☐
Questionnaire form without data endorsed by related parties	☐	☐
Interview	☐	☐
Visit to the office	☐	☐
Contractors' presentation	☐	☐
Third parties (*e.g. surety/ insurance company, financial consultant report*)	☐	☐
Proactive promotion by contractors	☐	☐
Other..................	☐	☐

18. The tools/ models used for evaluation of contractors' data (*please tick one or more box per type of prequalification*)

Tools/ models	Standing list	Ad-hoc list
Simple aggregate rating (dimensional weighting/ scoring)	☐	☐
Checklist approach (e.g. Yes or No)	☐	☐
Complex method:		
▪ Multiattribute analysis	☐	☐
▪ Knowledge based system	☐	☐
▪ Artificial neural network	☐	☐
▪ Cased base reasoning	☐	☐
▪ Fuzzy analysis	☐	☐
▪ Other	☐	☐
Other	☐	☐

Contractor Prequalification — *Questionnaire Survey (Client version)* — *4 of 9*

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

19. The evaluation time to review the effectiveness of your prequalification systems regarding their impact on the awarded contractors' performance (i.e. time, cost, quality) (*please tick one box per type of prequalification*)

Evaluation time	Standing list	Ad-hoc list
After completion of the project	☐	☐
Annual evaluation	☐	☐
No evaluation	☐	☐
Other....................	☐	☐

20. The availability of formal published guidelines of your prequalification system so that interested contractors understand the evaluation approach (*please tick one box per type of prequalification*)

	Standing list	Ad-hoc list
Yes	☐	☐
No	☐	☐

21. In your experience, the impact on project performance (cost, time, and quality) regarding implementation of your prequalification system (*please tick one box per type of prequalification*)

Performance	Standing list			Ad-hoc list		
	high	moderate	low	high	moderate	low
Cost	☐	☐	☐	☐	☐	☐
Time	☐	☐	☐	☐	☐	☐
Quality	☐	☐	☐	☐	☐	☐

22. The cost of executing prequalification for a standing list of contractors per annum (*please tick one box*)

Note: The unit cost is Person-Hour/ Man-Hour

- ☐ < 5 person-hours per contractor
- ☐ 5-10 person-hours per contractor.
- ☐ 10-15 person-hours per contractor
- ☐ >15 person-hours per contractor
- ☐ Other........................

23. The cost of executing prequalification for an ad-hoc list of contractors per project (*please tick one box*)

Note: The unit cost is Person-Hour/ Man-Hour

- ☐ < 10 person-hours per contractor
- ☐ 20-30 person-hours per contractor.
- ☐ 30-40 person-hours per contractor
- ☐ >40 person-hours per contractor
- ☐ Other........................

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

24. The average cost of executing prequalification related to project value (*please tick one box per type of prequalification*)

Cost	Standing list	Ad-hoc list
<0.2% of project cost	☐	☐
0.2%-0.4% of project cost	☐	☐
0.4%-0.8% of project cost	☐	☐
0.8%-1.2% of project cost	☐	☐
Other........................	☐	☐

25. Please state if your organisation/ firm is a member of Constructionline (the former Central Government List of Approved Works Contractors and Consultants. The service has also been known as CMIS, ConReg and NQS during its history) (*please tick one box*)

☐ **Yes** ☐ **No**

If **Yes**, please state the acceptance of a registered contractor on your short list (*please tick one box for any appropriate column*)

Accept **without** further prequalification	Accept **with** further prequalification
☐ Never	☐ Never
☐ Rarely	☐ Rarely
☐ Sometimes	☐ Sometimes
☐ Often	☐ Often
☐ Usually	☐ Usually

Any other comments based on your organisation's/ firm's experience of using the list

26. Please state if your organisation/ firm uses the qualified contractor list of the European standard for prequalification system (*please tick one box*)

☐ **Yes** ☐ **No**

If **Yes**, please state the acceptance of a registered contractor on your short list (*please tick one box for any appropriate column*)

Accept **without** further prequalification	Accept **with** further prequalification
☐ Never	☐ Never
☐ Rarely	☐ Rarely
☐ Sometimes	☐ Sometimes
☐ Often	☐ Often
☐ Usually	☐ Usually

Any other comments based on your organisation's/ firm's experience of using the list

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

27. The decision criteria of the prequalification system used in your organisation/ firm (*please tick as many prequalification factors as your firm uses for the evaluation of contractors and add factors if not available on the list as relevant for each type of prequalification*)

Prequalification criteria	Standing list	Ad-hoc list
- Financial strength	☐	☐
- Past experience	☐	☐
- Past performance	☐	☐
- Managerial & technical strength	☐	☐
- Safety & health record	☐	☐
- Suitable & sufficient resources	☐	☐
- Current work load	☐	☐
-	☐	☐
-	☐	☐
-	☐	☐
-	☐	☐

28. In your experience, the degree of impact of criteria identified in question 27 on project performance (*please tick one box in respect of their degree of impact on cost, time and quality respectively per type of prequalification*)

Note:

- This question tries to determine the relationship between prequalification data of contractors and the contractors' project performance criteria, in other words what is the impact if the value of contractor's data evaluated against the criteria is lower or less than commonly expected
- The degree of impact on project performance (*if identified in question 27*):

1 = low	2 = moderate	3 = high

Prequalification criteria	The degree of impact																	
	Standing list									Ad-hoc list								
	Cost			Time			Quality			Cost			Time			Quality		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
- Financial strength	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Past experience	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Past performance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Managerial & technical strength	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Safety & health record	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Suitable & sufficient resources	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Current work load	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
-	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
-	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
-	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
-	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

29. Any other comments and suggestions

Contractor Prequalification *Questionnaire Survey (Client version)* *8 of 9*

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

Reply Slip

Thank you for completing this questionnaire. If you are further interested in my research project, please complete the following section and send it back to the address below:

- ☐ I wish to receive a copy of the research findings.
- ☐ I enclose a copy of our prequalification guidelines and other related information for your research.
- ☐ I recommend that you speak with:

- ☐ Information about myself:

Name:
Position:
Organisation/ Firm:
Address:
Telephone:
Fax:
Email address:

For any formal or informal enquiry, please contact:

Donny Mangitung
PhD student
Dept. of Civil and Construction Engineering, UMIST
P.O. Box 88
Manchester M60 1QD
England - UK
Email: **d.mangitung@stud.umist.ac.uk**
Phone: +44-(0161)-200 4645
Fax: +44-(0161)-200 4252

Figure A.1 Sample of the questionnaire for client respondents for Empirical study 1 *(continued)*

DEPARTMENT OF CIVIL AND CONSTRUCTION ENGINEERING

UMIST

Department Tel No: 0161-200 4605
Department Fax no: 0161-200 4646

Direct Tel No: 0161-200 **4645**
Direct Fax No: 0161-200 4252

PO Box 88
Manchester M60 1QD
United Kingdom

Tel: 0161-236 3311
Fax: 0161-228 7040

Aberdeenshire County Council
Mr. T.E. Mitchell
Head of Transportation & Roads
Gordon House
Inverurie AB51 3WA

Thursday, 26 April 2001
Reference no.: 164-QS1-Client-2001

Dear Mr. Mitchell

Enclosed is a questionnaire survey as a part of my PhD research into contractor prequalification being carried out in the Department of Civil and Construction Engineering, UMIST. This questionnaire is intended to identify the practices of prequalification systems for standing and ad-hoc list of contractors. I would be very grateful, if you are unable to complete the questionnaire yourself, you could pass it to someone within your organisation who is experienced in prequalification.
Several issues are raised regarding these prequalification systems:

- The different characteristics of both prequalification types related to cost effectiveness, project size and type.
- The effectiveness of alternative sources of contractor standing lists from third parties such as Constructionline, or European Standard for qualification of contractor enterprises.
- The impact of the main prequalification criteria used to evaluate against a profile of a contractor on project performance (cost, time and quality variations) after project completion.

I would really appreciate your response to the questionnaire, and invite you to add your comments to support my research. All responses will be kept confidential in any case. For your convenience, a self-addressed envelope is enclosed.

Thank you and please do not hesitate to contact me at the address above, if you have any queries, or use the reply slip on the last page of questionnaire. If you use phone or fax, please use the direct numbers given above, and not the department or the university numbers.

Yours faithfully

Donny Mangitung
N.B.: email address: d.mangitung@stud.umist.ac.uk

Transportation & Roads (Central)
Date: 30 APR 2001 7093
File 1/10/1
Action IM

Nothing in this letter constitutes an order unless accompanied by an official order form.

Figure A.2 Sample of the cover letter for client respondents for Empirical study 1

APPENDIX B

B. QUESTIONNAIRE AND COVER LETTER FOR CONTRACTOR RESPONDENTS FOR EMPIRICAL STUDY 1

Questionnaire Survey

This questionnaire is designed to help discover new facts and data for understanding current contractor prequalification practice including the types, forms and trends in the construction industry. Individual responses will be kept confidential in any case. Only summaries will be published.

Please answer all questions if possible and you are invited to add your comments. If you are further interested in this research project, please use the reply slip on the last page of the questionnaire.

If you have any queries about the questions or require any information about my research please do not hesitate to contact me at the following address:

Donny Mangitung
PhD student
Dept. of Civil and Construction Engineering, UMIST
P.O. Box 88
Manchester M60 1QD
England - UK
Email: **d.mangitung@stud.umist.ac.uk**
Phone: +44-(0161)-200 4645
Fax: +44-(0161)-200 4252

1. Your profession (*please tick one box*)

❒ Architect ❒ Civil/ Structural engineer ❒ Building services engineer
❒ Quantity surveyor ❒ Project/ Construction manager ❒ Businessman
❒ Other ....

2. Your working experience in preparing for contractor prequalification (*please tick one box*)

❒ < 1 year ❒ 1 - 3 year ❒ 3 – 5 years ❒ >5 years ❒ None

3. The average number of projects per annum in which you are involved with the preparation of prequalification (*please tick one box*)

Note: Any questions, which refer to project(s) mean construction project(s)

❒ 1 ❒ 2-5 ❒ 5-10 ❒ >10 ❒ None

4. The main proportion of project sources from which your firm is awarded contracts (*please tick one box*)

❒ Private sector ❒ Public sector ❒ Other.................

5. The main project type in which your firm is involved (*please tick one box*)

❒ Residential/ housing ❒ Building including industrial building
❒ Civil engineering/ infrastructure

Contractor Prequalification *Questionnaire Survey (Contractor version)* *1 of 9*

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1

6. The approximate number and total value of projects carried by your firm in the last three years (*please enter the number in the available columns*)

Procurement type	Number	Total amount (£ million)
Traditional	....	....
Management	....	....
Design-build	....	....
Partnering	....	....

7. The reasoning behind the decision for your firm to be involved with prequalification (*please tick one box in respect of each factor's degree of importance*)

Note: The degree of importance

1 = low	2 = moderate	3 = high

The reasoning behind the decision	The degree of importance		
	1	2	3
- Projects offered by a client similar to **size** of previous completed projects	❒	❒	❒
- Projects offered by a client similar to **type** of previous completed projects	❒	❒	❒
- The cost effective of prequalification	❒	❒	❒
- Need work for continuity in employment of key personnel and workforce	❒	❒	❒
- The opportunity of winning a contract	❒	❒	❒
- Relationship with clients	❒	❒	❒
- As a part of self evaluation and promotion	❒	❒	❒
- Identity of client/ consultant	❒	❒	❒
- Other	❒	❒	❒
-	❒	❒	❒

8. The type of prequalification in which your firm has been qualified (*please tick one or more box*)

Note: - **Standing list of contractors** is a list developed from a prequalification process that is not intended for a particular project, and is performed periodically (e.g. annual prequalification). In other words, the list is developed from **periodic prequalification**.
- **Ad-hoc list of contractors** is a list developed from a prequalification process that is intended for a particular project, and is performed on a project by project basis. Another name **is project list** developed from **specific prequalification**.

❒ Standing list ❒ Ad-hoc list ❒ Both types of list
❒ None ❒ Other ....

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

9. The approximate number of prequalifications in which your firm has been qualified, based on the routes identified in question **8**, and the subsequent number and amount of awarded contracts in the last three years (*please tick the routes identified in question 8 and enter the number in the next three columns*)

The type of prequalification	The no. of prequalifications in which your firm has been qualified	The no. of awarded contracts	The amount of awarded contracts (£ million)
☐ Standing list	....	....	....
☐ Ad-hoc list	....	....	....
☐ Both types of list	....	....	....
☐ Other	....	....	....

10. The common eligible time in which your firm is listed in standing list of contractors before being updated (*please tick one box*)

☐ More than once a year ☐ Every year ☐ Every two-years
☐ Every three-years or more

11. The type of procurement system your firm has been involved with regarding prequalification type (*please tick one or more box per type of prequalification, i.e. standing list or ad-hoc list*)

Procurement type	Standing list	Ad-hoc list
Traditional	☐	☐
Management	☐	☐
Design-build	☐	☐
Partnering	☐	☐

12. The main person in the team responsible for the preparation of a prequalification proposal (*please tick one or more box*)

☐ Architect ☐ Civil/ Structural engineer ☐ Building services engineer
☐ Quantity surveyor ☐ Project/ Construction manager ☐ Businessman
☐ Other.................

13. The team for the preparation of a prequalification proposal are obtained from (*please tick one box per type of prequalification*)

Human resource	Standing list	Ad-hoc list
In house	☐	☐
Outsourcing (e.g. consultant)	☐	☐
Combination	☐	☐

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

14. In your experience, the suitable references/ bases for determining weight/ score of prequalification criteria/ requirements and their impact on weighting/ scoring (*please tick one box in respect of the impact of the references on weighting/ scoring per type of prequalification*)

Note: The degree of impact

0 = not needed	1 = low	2 = moderate	3 = high

References/ bases	The degree of impact							
	Standing list				Ad-hoc list			
	0	1	2	3	0	1	2	3
Project objectives	☐	☐	☐	☐	☐	☐	☐	☐
Project size	☐	☐	☐	☐	☐	☐	☐	☐
Project type	☐	☐	☐	☐	☐	☐	☐	☐
Individual experience	☐	☐	☐	☐	☐	☐	☐	☐
Professional judgement	☐	☐	☐	☐	☐	☐	☐	☐
Client objectives	☐	☐	☐	☐	☐	☐	☐	☐
Procurement type	☐	☐	☐	☐	☐	☐	☐	☐
Risk analysis	☐	☐	☐	☐	☐	☐	☐	☐
Public accountability	☐	☐	☐	☐	☐	☐	☐	☐
Standard procedure	☐	☐	☐	☐	☐	☐	☐	☐
Regulations	☐	☐	☐	☐	☐	☐	☐	☐
Other...........	☐	☐	☐	☐	☐	☐	☐	☐

15. The ways clients gather your firm's data (*please tick one or more box per type of prequalification*)

Data collection	Standing list	Ad-hoc list
Questionnaire form with data endorsed by related parties (*e.g. accountants, previous clients, bank etc.*)	☐	☐
Questionnaire form without data endorsed by related parties	☐	☐
Interview	☐	☐
Visit to the office	☐	☐
Contractors' presentation	☐	☐
Third parties (*e.g. surety/ insurance company, financial consultant report*)	☐	☐
Proactive promotion by contractors	☐	☐
Other..................	☐	☐

16. The tools/ models used by clients for evaluation of your firm's data regarding prequalification (*please tick one box*)

☐ **Known** ☐ **Not known**

If known, please tick one or more box as appropriate based on your firm's experiences

Tools/ models	Standing list	Ad-hoc list
Simple aggregate rating (dimensional weighting/ scoring)	☐	☐
Checklist approach (e.g. Yes or No)	☐	☐
Complex method:		
▪ Multiattribute analysis	☐	☐
▪ Knowledge based system	☐	☐
▪ Artificial neural network	☐	☐
▪ Cased base reasoning	☐	☐
▪ Fuzzy analysis	☐	☐
▪ Other	☐	☐
Other	☐	☐

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

17. The evaluation time to review any prequalification systems in which your firm has been involved, particularly if disqualified (*please tick one box per type of prequalification*)

Evaluation time	Standing list	Ad-hoc list
After prequalification	☐	☐
Before prequalification	☐	☐
No evaluation	☐	☐
Other.....................	☐	☐

18. The availability of formal published guidelines of clients' prequalification system so that your firm understands the evaluation approach (*please tick one box per type of prequalification*)

Frequency	Standing list	Ad-hoc list
Usually	☐	☐
Sometimes	☐	☐
Rarely	☐	☐

19. In your experience, the impact on project performance (cost, time, and quality) regarding implementation of the prequalification system (*please tick one box per type of prequalification*)

Performance	Standing list			Ad-hoc list		
	high	moderate	low	high	moderate	low
Cost	☐	☐	☐	☐	☐	☐
Time	☐	☐	☐	☐	☐	☐
Quality	☐	☐	☐	☐	☐	☐

20. The cost of preparation of a prequalification proposal for a standing list of contractors per client (*please tick one box*)

Note: The unit cost is Person-Hour/ Man-Hour

- ☐ < 5 person-hours per contractor
- ☐ 5-10 person-hours per contractor.
- ☐ 10-15 person-hours per contractor
- ☐ >15 person-hours per contractor
- ☐ Other.........................

21. The cost of preparation of a prequalification proposal for an ad-hoc list of contractors per project (*please tick one box*)

Note: The unit cost is Person-Hour/ Man-Hour

- ☐ < 10 person-hours per contractor
- ☐ 20-30 person-hours per contractor.
- ☐ 30-40 person-hours per contractor
- ☐ >40 person-hours per contractor
- ☐ Other.........................

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

22. The cost of preparation of a prequalification proposal related to a project value (*please tick one box per type of prequalification*)

Cost	Standing list	Ad-hoc list
<0.2% of project cost	☐	☐
0.2%-0.4% of project cost	☐	☐
0.4%-0.8% of project cost	☐	☐
0.8%-1.2% of project cost	☐	☐
Other………………………	☐	☐

23. Please state if your firm is a registered contractor on the qualified contractor list at Constructionline (the former Central Government List of Approved Works Contractors and Consultants. The service has also been known as CMIS, ConReg and NQS during its history) (*please tick one box*)

☐ **Yes** ☐ **No**

If **Yes**, please state the acceptance of a registered contractor on clients' short lists based on your firm's experience (*please tick one box for any appropriate column*)

Accept without further prequalification	Accept with further prequalification
☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Usually	☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Usually

Any other comments based on your firm's experience as a registered contractor within the list

24. Please state if your firm is a registered contractor on a qualified contractor list in any other third party (e.g. European Standard for prequalification system) (*please tick one box*)

☐ **Yes** ☐ **No**

If **Yes**, please fill the available space below

Name of prequalification system	Organisation/ firm providing the service
…….. …….. ……..	…….. …….. ……..

Any other comments based on your firm's experience as a registered contractor within the list.

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

25. The decision criteria of the prequalification system commonly used by clients (*please tick as many prequalification factors as you are aware of for the evaluation of contractors and add factors if not available on the list as relevant for each type of prequalification*)

Prequalification criteria	Standing list	Ad-hoc list
- Financial strength	☐	☐
- Past experience	☐	☐
- Past performance	☐	☐
- Managerial & technical strength	☐	☐
- Safety & health record	☐	☐
- Suitable & sufficient resources	☐	☐
- Current work load	☐	☐
- …………………	☐	☐
- …………………	☐	☐
- …………………	☐	☐
- …………………	☐	☐

26. In your experience, the degree of impact of criteria identified in question 25 on project performance (*please tick one box in respect of their degree of impact on cost, time and quality respectively per type of prequalification*)

Note:

- This question tries to determine the relationship between prequalification data of contractors and the contractors' project performance criteria, in other words what is the impact if the value of contractor's data evaluated against the criteria is lower or less than commonly expected
- The degree of impact on project performance (*if identified in question 25*)

1 = low	2 = moderate	3 = high

Prequalification criteria	The degree of impact																	
	Standing list									Ad-hoc list								
	Cost			Time			Quality			Cost			Time			Quality		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
- Financial strength	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Past experience	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Past performance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Managerial & technical strength	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Safety & health record	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Suitable & sufficient resources	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- Current work load	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- …………………	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- …………………	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- …………………	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
- …………………	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

27. Any other comments and suggestions

Contractor Prequalification *Questionnaire Survey (Contractor version)* *8 of 9*

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

Reply Slip

Thank you for completing this questionnaire. If you are further interested in my research project, please complete the following section and send it back to the address below:

- ☐ I wish to receive a copy of the research findings.
- ☐ I enclose a copy of our prequalification guidelines and other related information for your research.
- ☐ I recommend that you speak with:

- ☐ Information about myself:

Name:
Position:
Organisation/ Firm:
Address:
Telephone:
Fax:
Email address:

For any formal or informal enquiry, please contact:

Donny Mangitung
PhD student
Dept. of Civil and Construction Engineering, UMIST
P.O.Box 88
Manchester M60 1QD
England - UK
Email: **d.mangitung@stud.umist.ac.uk**
Phone: +44-(0161)-200 4645
Fax: +44-(0161)-200 4252

Figure B.1 Sample of the questionnaire for contractor respondents for Empirical study 1 *(continued)*

DEPARTMENT OF CIVIL AND CONSTRUCTION ENGINEERING

UMIST

Department Tel No: 0161-200 4605
Department Fax no: 0161-200 4646

Direct Tel No: 0161-200 **4645**
Direct Fax No: 0161-200 4252

PO Box 88
Manchester M60 1QD
United Kingdom

Tel: 0161-236 3311
Fax: 0161-228 7040

Carter Lauren
08 MAY 2001

Carter Lauren Construction Ltd.
Bevan House, Penarth Road
Cardiff
South Glomorgan CF11 8UQ

Wednesday, 02 May 2001
Reference no.: 248-QS-Contractor-2001

Dear Sir/ Madame

Enclosed is a questionnaire survey as a part of my PhD research into contractor prequalification being carried out in the Department of Civil and Construction Engineering, UMIST. This questionnaire is intended to identify the practices of prequalification systems for standing and ad-hoc list of contractors. I would be very grateful, if you are unable to complete the questionnaire yourself, you could pass it to someone within your organisation/ firm who is experienced in prequalification.
Several issues are raised regarding these prequalification systems:

- The different characteristics of both prequalification types related to cost effectiveness, project size and type.
- The effectiveness of alternative sources of contractor standing lists from third parties such as Constructionline, or European Standard for qualification of contractor enterprises.
- The impact of the main prequalification criteria used to evaluate against a profile of a contractor on project performance (cost, time and quality variations) after project completion.

I would really appreciate your response to the questionnaire, and invite you to add your comments to support my research. All responses will be kept confidential in any case. For your convenience, a self-addressed envelope is enclosed.

Thank you and please do not hesitate to contact me at the address above, if you have any queries, or use the reply slip on the last page of questionnaire. If you use phone or fax, please use the direct numbers given above, and not the department or the university numbers.

Yours faithfully

Donny Mangitung
N.B.: email address: d.mangitung@stud.umist.ac.uk

Nothing in this letter constitutes an order unless accompanied by an official order form.

Figure B2 Sample of the cover letter for contractor respondents for Empirical study 1

APPENDIX C

C. THE PURPOSE OF PREQUALIFICATION (CHAPTER 4.3.1.1)

C.1 Factor Analayis

Table C.1 Correlation matrix

Purpose of prequalification (contractors' perception)		a	b	c	d	e	f	g	h
Projects offered by a client similar to size of previous completed projects	a	1.00	0.71	0.24	0.14	0.20	0.20	0.16	0.21
Projects offered by a client similar to type of previous completed projects	b	**0.71**	1.00	0.27	0.21	0.38	0.25	0.14	0.15
The cost effective of prequalification	c	0.24	0.27	1.00	-0.05	-0.11	0.14	0.33	-0.04
Need work for continuity in employment of key personnel and workforce	d	0.14	0.21	-0.05	1.00	0.59	0.15	-0.15	0.16
The opportunity of winning a contract	e	0.20	**0.38**	-0.11	**0.59**	1.00	0.44	-0.06	0.32
Relationship with clients	f	0.20	0.25	0.14	0.15	**0.44**	1.00	0.25	0.49
As a part of self evaluation and promotion	g	0.16	0.14	**0.33**	-0.15	-0.06	0.25	1.00	0.30
Identity of client/ consultant	h	0.21	0.15	-0.04	0.16	**0.32**	**0.49**	0.30	1.00

Note:

Shaded area means Correlation coefficient is significant at the 0.05 level (1-tailed).	
Number of correlation	28
Number of shaded area	9
Percentage of high correlation	30.0%
Number of correlation > 0.3 (bold value)	7 (25%)

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.593
Bartlett's Test of Sphericity	Approx. Chi-Square	107.451
	df	28
	Sig.	.000

Figure C.1 KMO and Bartlett's test (varimax rotation)

Communalities

	Initial	Extraction
Projects offered by a client similar to size of previous completed projects	1.000	.735
Projects offered by a client similar to type of previous completed projects	1.000	.821
The cost effective of prequalification	1.000	.539
Need work for continuity in employment of key personnel and workforce	1.000	.630
The opportunity of winning a contract	1.000	.787
Relationship with clients	1.000	.668
As a part of self evaluation and promotion	1.000	.681
Identity of client/ consultant	1.000	.701

Extraction Method: Principal Component Analysis.

Figure C.2 Communalities (varimax rotation)

Component Correlation Matrix

Component	1	2	3
1	1.000	-.009	.272
2	-.009	1.000	-.080
3	.272	-.080	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Figure C.3 Oblique correlation coefficients

APPENDIX D

D. PREQUALIFICATION TYPES RELATED TO CRITERIA DEVELOPMENT (CHAPTER 4.3.2.5)

D.1 Comparison between client and contractor categories (Kolmogorov-Smirnov test)

Test Statistics[a]

	Most Extreme Differences			Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
	Absolute	Positive	Negative		
N16OBJ_S	.047	.003	-.047	.230	1.000
N16SIZ_S	.193	.051	-.193	.943	.336
N16TYP_S	.176	.000	-.176	.861	.449
N16IND_S	.194	.194	.000	.948	.331
N16JUD_S	.205	.002	-.205	1.001	.269
N16COB_S	.128	.128	.000	.627	.827
N16PRC_S	.070	.011	-.070	.343	1.000
N16RSK_S	.154	.154	.000	.753	.622
N16ACC_S	.125	.069	-.125	.608	.853
N16STD_S	.165	.036	-.165	.805	.536
N16REG_S	.174	.170	-.174	.848	.468
N16OBJ_A	.097	.097	-.023	.454	.986
N16SIZ_A	.076	.076	-.053	.355	1.000
N16TYP_A	.076	.076	.000	.355	1.000
N16IND_A	.277	.277	.000	1.294	.070
N16JUD_A	.237	.125	-.237	1.107	.172
N16COB_A	.234	.234	.000	1.093	.183
N16PRC_A	.145	.133	-.145	.680	.744
N16RSK_A	.172	.172	.000	.806	.534
N16ACC_A	.258	.042	-.258	1.207	.109
N16STD_A	.133	.106	-.133	.624	.831
N16REG_A	.297	.091	-.297	1.391	.042

a. Grouping Variable: QSTYPE

Figure D.1Two-Sample Kolmogorov-Smirnov test (client vs. contractor category)

Note:

References/ bases	Prequalification category code	
	Periodic	Project
Project objectives	N16OBJ_S	N16OBJ_A
Project size	N16SIZ_S	N16SIZ_A
Project type	N16TYP_S	N16TYP_A
Individual experience	N16IND_S	N16IND_A
Professional judgement	N16JUD_S	N16JUD_A
Client objectives	N16COB_S	N16COB_A
Procurement type	N16PRC_S	N16PRC_A
Risk analysis	N16RSK_S	N16RSK_A
Public accountability	N16ACC_S	N16ACC_A
Standard procedure	N16STD_S	N16STD_A
Regulations	N16REG_S	N16REG_A

D.2 Comparison between periodic and project prequalification categories (Wilcoxon signed ranks test)

Test Statistics[c]

	Z	Asymp. Sig. (2-tailed)
N16OBJ_A - N16OBJ_S	-3.217[a]	.001
N16SIZ_A - N16SIZ_S	-2.471[a]	.013
N16TYP_A - N16TYP_S	-1.122[a]	.262
N16IND_A - N16IND_S	-1.827[a]	.068
N16JUD_A - N16JUD_S	-1.118[a]	.263
N16COB_A - N16COB_S	-3.258[a]	.001
N16PRC_A - N16PRC_S	-2.092[a]	.036
N16RSK_A - N16RSK_S	-2.475[a]	.013
N16ACC_A - N16ACC_S	-2.497[b]	.013
N16STD_A - N16STD_S	-2.685[b]	.007
N16REG_A - N16REG_S	-.587[b]	.557

a. Based on negative ranks.

b. Based on positive ranks.

c. Wilcoxon Signed Ranks Test

Figure D.2 Wilcoxon signed ranks test

Note:

a. *Based on negative ranks* means that the rank sum of periodic prequalification is greater than that of project prequalification

b. *Based on positive ranks* means that the rank sum of periodic prequalification is less than that of project prequalification

Ranks

		N	Mean Rank	Sum of Ranks
N16OBJ_A - N16OBJ_S	Negative Ranks	4	11.25	45.00
	Positive Ranks	21	13.33	280.00
	Ties	49		
	Total	74		
N16SIZ_A - N16SIZ_S	Negative Ranks	5	9.40	47.00
	Positive Ranks	16	11.50	184.00
	Ties	53		
	Total	74		
N16TYP_A - N16TYP_S	Negative Ranks	6	11.33	68.00
	Positive Ranks	13	9.38	122.00
	Ties	55		
	Total	74		
N16IND_A - N16IND_S	Negative Ranks	7	13.71	96.00
	Positive Ranks	18	12.72	229.00
	Ties	49		
	Total	74		
N16JUD_A - N16JUD_S	Negative Ranks	8	16.63	133.00
	Positive Ranks	18	12.11	218.00
	Ties	48		
	Total	74		
N16COB_A - N16COB_S	Negative Ranks	2	8.50	17.00
	Positive Ranks	16	9.63	154.00
	Ties	56		
	Total	74		
N16PRC_A - N16PRC_S	Negative Ranks	6	9.67	58.00
	Positive Ranks	15	11.53	173.00
	Ties	53		
	Total	74		
N16RSK_A - N16RSK_S	Negative Ranks	3	13.83	41.50
	Positive Ranks	17	9.91	168.50
	Ties	54		
	Total	74		
N16ACC_A - N16ACC_S	Negative Ranks	15	10.33	155.00
	Positive Ranks	4	8.75	35.00
	Ties	55		
	Total	74		
N16STD_A - N16STD_S	Negative Ranks	18	12.44	224.00
	Positive Ranks	5	10.40	52.00
	Ties	51		
	Total	74		
N16REG_A - N16REG_S	Negative Ranks	8	11.06	88.50
	Positive Ranks	9	7.17	64.50
	Ties	57		
	Total	74		

Figure D.3 Ranks sum differences of Wilcoxon signed ranks test

Note: Negative ranks: periodic > project in terms of sum of ranks

Positive ranks: periodic < project in terms of sum of ranks

Note for Figure D.3 Ranks sum differences of Wilcoxon signed ranks test

a. N16OBJ_A < N16OBJ_S	m. N16JUD_A < N16JUD_S	y. N16ACC_A < N16ACC_S
b. N16OBJ_A > N16OBJ_S	n. N16JUD_A > N16JUD_S	z. N16ACC_A > N16ACC_S
c. N16OBJ_S = N16OBJ_A	o. N16JUD_S = N16JUD_A	aa. N16ACC_S = N16ACC_A
d. N16SIZ_A < N16SIZ_S	p. N16COB_A < N16COB_S	bb. N16STD_A < N16STD_S
e. N16SIZ_A > N16SIZ_S	q. N16COB_A > N16COB_S	cc. N16STD_A > N16STD_S
f. N16SIZ_S = N16SIZ_A	r. N16COB_S = N16COB_A	dd. N16STD_S = N16STD_A
g. N16TYP_A < N16TYP_S	s. N16PRC_A < N16PRC_S	ee. N16REG_S < N16REG_A
h. N16TYP_A > N16TYP_S	t. N16PRC_A > N16PRC_S	ff. N16REG_A > N16REG_S
i. N16TYP_S = N16TYP_A	u. N16PRC_S = N16PRC_A	gg. N16REG_S = N16REG_A
j. N16IND_A < N16IND_S	v. N16RSK_A < N16RSK_S	
k. N16IND_A > N16IND_S	w. N16RSK_A > N16RSK_S	
l. N16IND_S = N16IND_A	x. N16RSK_S = N16RSK_A	

D.3 Factor Analysis for criteria development

Table D.1 Correlation matrix for periodic prequalification category

References/bases		a	b	c	d	e	f	g	h	I	j	k
Project objectives	a	1.00	0.27	0.18	0.25	0.39	0.46	0.25	0.29	0.00	0.03	0.16
Project size	b	0.27	1.00	0.24	-0.14	0.02	-0.09	-0.04	0.06	0.10	0.14	0.06
Project type	c	0.18	0.24	1.00	0.20	0.14	0.03	0.18	0.04	-0.01	0.01	0.07
Individual experience	d	0.25	-0.14	0.20	1.00	0.44	0.31	0.20	0.19	-0.03	-0.12	0.01
Professional judgement	e	**0.39**	0.02	0.14	**0.44**	1.00	0.30	0.28	0.35	0.15	0.08	0.26
Client objectives	f	**0.46**	-0.09	0.03	**0.31**	**0.30**	1.00	0.36	0.47	0.18	0.22	0.33
Procurement type	g	0.25	-0.04	0.18	0.20	0.28	**0.36**	1.00	0.39	0.31	0.27	0.22
Risk analysis	h	0.29	0.06	0.04	0.19	**0.35**	**0.47**	**0.39**	1.00	0.27	0.20	0.26
Public accountability	I	0.00	0.10	-0.01	-0.03	0.15	0.18	**0.31**	0.27	1.00	0.58	0.44
Standard procedure	j	0.03	0.14	0.01	-0.12	0.08	0.22	0.27	0.20	**0.58**	1.00	0.56
Regulations	k	0.16	0.06	0.07	0.01	0.26	**0.33**	0.22	0.26	**0.44**	**0.56**	1.00

Note:

Shaded area means correlation coefficient is significant at the 0.05 level (1-tailed).	
Total number of correlations	55
Number of shaded areas	34
Percentage of significant correlations	61.8%
Number of correlations > 0.3 (bold value)	14 (25.5%)
Number of cases	99

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.699
Bartlett's Test of Sphericity	Approx. Chi-Square	262.223
	df	55
	Sig.	.000

Figure D.4 KMO and Bartlett's test for periodic prequalification category (varimax rotation)

Communalities

	Initial	Extraction
Project objectives	1.000	.583
Project size	1.000	.762
Project type	1.000	.471
Individual experience	1.000	.560
Professional judgement	1.000	.513
Client objectives	1.000	.586
Procurement type	1.000	.412
Risk analysis	1.000	.465
Public accountability	1.000	.648
Standard procedure	1.000	.745
Regulations	1.000	.579

Extraction Method: Principal Component Analysis.

Figure D.5 Communalities for periodic prequalification category (varimax rotation)

Component Correlation Matrix

Component	1	2	3
1	1.000	-.170	.118
2	-.170	1.000	-.028
3	.118	-.028	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Figure D.6 Oblique correlation coefficients for periodic prequalification

Table C2 Correlation matrix for project prequalification category

References/bases		a	b	c	d	e	f	g	h	I	j	k
Project objectives	a	1.00	0.34	0.44	0.32	0.53	0.57	0.32	0.32	0.23	0.33	0.35
Project size	b	**0.34**	1.00	0.59	0.13	0.28	0.10	0.24	0.25	0.15	0.22	0.26
Project type	c	**0.44**	**0.59**	1.00	0.28	0.35	0.21	0.34	0.15	0.08	0.12	0.18
Individual experience	d	**0.32**	0.13	0.28	1.00	0.39	0.38	0.29	0.28	-0.12	0.13	0.03
Professional judgement	e	**0.53**	0.28	**0.35**	**0.39**	1.00	0.44	0.49	0.24	0.27	0.37	0.37
Client objectives	f	**0.57**	0.10	0.21	**0.38**	**0.44**	1.00	0.31	0.29	0.31	0.32	0.37
Procurement type	g	**0.32**	0.24	**0.34**	0.29	**0.49**	**0.31**	1.00	0.27	0.38	0.39	0.42
Risk analysis	h	**0.32**	0.25	0.15	0.28	0.24	0.29	0.27	1.00	0.15	0.25	0.28
Public accountability	I	0.23	0.15	0.08	-0.12	0.27	**0.31**	**0.38**	0.15	1.00	0.53	0.56
Standard procedure	j	**0.33**	0.22	0.12	0.13	**0.37**	**0.32**	**0.39**	0.25	**0.53**	1.00	0.61
Regulations	k	**0.35**	0.26	0.18	0.03	**0.37**	**0.37**	**0.42**	0.28	**0.56**	**0.61**	1.00

Note:

Shaded area means correlation coefficient is significant at the 0.05 level (1-tailed)	
Total number of correlations	55
Number of shaded area	45
Percentage of significant correlations	82%
Number of correlations. > 0.3 (bold value)	28 (51%)
Number of cases	88

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.799
Bartlett's Test of Sphericity	Approx. Chi-Square	315.759
	df	55
	Sig.	.000

Figure D.7 KMO and Bartlett's test for project prequalification category (varimax rotation)

Communalities

	Initial	Extraction
Project objectives	1.000	.589
Project size	1.000	.796
Project type	1.000	.787
Individual experience	1.000	.698
Professional judgement	1.000	.575
Client objectives	1.000	.635
Procurement type	1.000	.461
Risk analysis	1.000	.285
Public accountability	1.000	.725
Standard procedure	1.000	.646
Regulations	1.000	.711

Extraction Method: Principal Component Analysis.

Figure D.8 Communalities for project prequalification category (varimax rotation)

Component Correlation Matrix

Component	1	2	3
1	1.000	-.299	.331
2	-.299	1.000	-.225
3	.331	-.225	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Figure D.9 Oblique correlation coefficients for project prequalification

APPENDIX E

E. PREQUALIFICATION TYPES RELATED TO THE USAGE OF MAIN CRITERIA (CHAPTER 4.3.2.6)

Test Statistics[b]

	QSTYPE			
	Client		Contractor	
	N	Exact Sig. (2-tailed)	N	Exact Sig. (2-tailed)
Financial strength	45	1.000[a]	42	1.000[a]

a. Binomial distribution used.

b. McNemar Test

Figure E.1 Cross tabulation between financial strength criterion and respondent types for project prequalification category

N27FIN_S & N27FIN_A

QSTYPE	Financial strength	Financial strength 1	Financial strength 2
Client	1	41	1
	2	0	3
Contractor	1	41	0
	2	1	0

Figure E.2 Separated McNemar test for financial strength criteria for project prequalification category due to the frequency difference found between client and contractor data

Note: Yes: 1 and No: 2

APPENDIX F

F. PREQUALIFICATION TYPES RELATED TO THE IMPACT OF MAIN CRITERIA ON PROJECT PERFORMANCE (CHAPTER 4.3.2.7)

F.1 Comparison between client and contractor categories (Kolmogorov-Smirnov test)

Test Statistics[a]

	Most Extreme Differences			Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
	Absolute	Positive	Negative		
FIN28SC	.335	.000	-.335	1.570	.014
EXP28SC	.141	.141	-.040	.659	.777
PER28SC	.052	.030	-.052	.241	1.000
MT_S28SC	.232	.232	.000	1.087	.188
SH28SC	.141	.022	-.141	.659	.777
RES28SC	.151	.000	-.151	.706	.701
CWL28SC	.133	.111	-.133	.622	.833
FIN28AC	.136	.066	-.136	.596	.869
EXP28AC	.246	.246	-.118	1.077	.197
PER28AC	.121	.121	-.017	.528	.943
MT_S28AC	.242	.242	.000	1.059	.212
SH28AC	.192	.050	-.192	.842	.477
RES28AC	.138	.032	-.138	.602	.861
CWL28AC	.116	.116	-.060	.507	.959

a. Grouping Variable: QSTYPE

Figure F.1 Two-Sample Kolmogorov-Smirnov test (client vs. contractor category)

Note:

Prequalification criteria	Prequalification category code	
	periodic	project
Financial strength	fin_s28a	fin_a28a
Past experience	exp_s28a	exp_a28a
Past performance	per_s28a	per_a28a
Managerial & technical strength	mt_s28a	mt_a28a
Health and safety record	sh_s28a	sh_a28a
Suitable & sufficient resources	res_s28a	res_a28a
Current work load	cwl_s28a	cwl_a28a

F.2 Comparison between periodic and project prequalification categories (Wilcoxon signed ranks test)

Test Statistics[c]

	Z	Asymp. Sig. (2-tailed)
FIN_A28A - FIN_S28A	-.131[a]	.896
EXP_A28A - EXP_S28A	-.566[a]	.571
PER_A28A - PER_S28A	-1.113[b]	.266
MT_A28A - MT_S28A	-2.084[b]	.037
SH_A28A - SH_S28A	-.699[a]	.485
RES_A28A - RES_S28A	-1.655[b]	.098
CWL_A28A - CWL_S28A	-1.785[b]	.074

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Figure F.2 Wilcoxon signed ranks test

Note:

a. *Based on negative ranks* means that the rank sum of periodic prequalification is greater than that of project prequalification

b. *Based on positive ranks* means that the rank sum of periodic prequalification is less than that of project prequalification

Ranks

		N	Mean Rank	Sum of Ranks
Financial strength	Negative Ranks	6	11.75	70.50
	Positive Ranks	10	6.55	65.50
	Ties	50		
	Total	66		
Past experience	Negative Ranks	6	8.92	53.50
	Positive Ranks	7	5.36	37.50
	Ties	53		
	Total	66		
Past performance	Negative Ranks	5	8.10	40.50
	Positive Ranks	10	7.95	79.50
	Ties	51		
	Total	66		
Managerial & technical strength	Negative Ranks	4	7.00	28.00
	Positive Ranks	12	9.00	108.00
	Ties	50		
	Total	66		
Health & safety record	Negative Ranks	8	7.94	63.50
	Positive Ranks	6	6.92	41.50
	Ties	52		
	Total	66		
Suitable & sufficient resources	Negative Ranks	8	10.50	84.00
	Positive Ranks	15	12.80	192.00
	Ties	43		
	Total	66		
Current work load	Negative Ranks	6	9.58	57.50
	Positive Ranks	14	10.89	152.50
	Ties	46		
	Total	66		

Figure F.3 Ranks sum differences of Wilcoxon signed ranks test

Note - Negative ranks: periodic > project in terms of sum of ranks

Positive ranks: periodic < project in terms of sum of ranks

Test Statistics[c]

	QSTYPE			
	Client		Contractor	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
FIN_A28A - FIN_S28A	-1.119[a]	.263	-.900[b]	.368

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Figure F.4 Wilcoxon signed ranks test for financial strength criterion

Note: Separated tests conducted on the basis of sample categories (client and contractor categories)

F.3 Relative Rank Index and ranking

Table F.1 Relative Rank Index of the impact of contractors' prequalification data on project performance

Prequalification criteria	Periodic prequalification				Project prequalification			
	Cost	Time	Quality	Overall	Cost	Time	Quality	Overall
Financial strength	0.71	0.71	0.66	0.66	0.67	0.61	0.59	0.62
Past experience	0.75	0.75	0.84	0.80	0.72	0.78	0.81	0.77
Past performance	0.72	0.72	0.78	0.75	0.71	0.77	0.81	0.76
Managerial & technical strength	0.74	0.74	0.80	0.78	0.80	0.86	0.85	0.84
Health and safety record	0.70	0.70	0.72	0.71	0.67	0.68	0.71	0.69
Suitable & sufficient resources	0.73	0.73	0.78	0.77	0.77	0.81	0.78	0.79
Current work load	0.55	0.55	0.57	0.57	0.58	0.62	0.61	0.60

Table F.2 Ranking of the impact of contractors' prequalification data on project performance

Prequalification criteria	Periodic prequalification				Project prequalification			
	Cost	Time	Quality	Overall	Cost	Time	Quality	Overall
Financial strength	5.0	6.0	6.0	6.0	5.5	7.0	7.0	6.0
Past experience	**1.0**	**1.0**	**1.0**	**1.0**	**3.0**	**3.0**	**2.5**	**3.0**
Past performance	**4.0**	**4.0**	**3.5**	**4.0**	**4.0**	**4.0**	**2.5**	**4.0**
Managerial & technical strength	**2.0**	**2.5**	**2.0**	**2.0**	**1.0**	**1.0**	**1.0**	**1.0**
Health and safety record	6.0	5.0	5.0	5.0	5.5	5.0	5.0	5.0
Suitable & sufficient resources	**3.0**	**2.5**	**3.5**	**3.0**	**2.0**	**2.0**	**4.0**	**2.0**
Current work load	7.0	7.0	7.0	7.0	7.0	6.0	6.0	7.0

Note: Bold values means the ranks are top 4

F.4 Factor Analysis for the impact of prequalification criteria on project performance

Table F.3 Correlation matrix for periodic prequalification category

Prequalification criteria		a	b	c	d	e	f	g
Financial strength	a	1.00	0.34	0.27	0.28	0.25	0.26	0.18
Past experience	b	**0.34**	1.00	0.67	0.42	0.14	0.37	0.33
Past performance	c	0.27	**0.67**	1.00	0.46	0.31	0.39	0.43
Managerial & technical strength	d	0.28	**0.42**	**0.46**	1.00	0.09	0.42	0.39
Health & safety record	e	0.25	0.14	**0.31**	0.09	1.00	0.18	0.19
Suitable & sufficient resources	f	0.26	**0.37**	**0.39**	**0.42**	0.18	1.00	0.54
Current work load	g	0.18	**0.33**	**0.43**	**0.39**	0.19	**0.54**	1.00

Note:

Shaded area means correlation coefficient is significant at the 0.05 level (1-tailed).	
Total number of correlations	21
Number of shaded areas	20
Percentage of significant correlations	95%
Number of correlations > 0.3 (bold values)	11 (52%)

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.799
Bartlett's Test of Sphericity	Approx. Chi-Square	315.759
	df	55
	Sig.	.000

Figure F.5 KMO and Bartlett's test for periodic prequalification category (varimax rotation)

Communalities

	Initial	Extraction
Financial strength	1.000	.482
Past experience	1.000	.559
Past performance	1.000	.641
Managerial & technical strength	1.000	.550
Health & safety record	1.000	.734
Suitable & sufficient resources	1.000	.552
Current work load	1.000	.540

Extraction Method: Principal Component Analysis.

Figure F.6 Communalities for periodic prequalification category (varimax rotation)

Component Correlation Matrix

Component	1	2	3
1	1.000	.215	-.383
2	.215	1.000	-.266
3	-.383	-.266	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Figure F.7 Oblique correlation coefficients for periodic prequalification

Table F.4 Correlation matrix for project prequalification category

Prequalification Criteria		a	b	c	d	e	f	g
Financial strength	a	1.00	0.08	0.05	0.11	0.35	0.17	0.02
Past experience	b	0.08	1.00	0.55	0.21	0.13	0.20	0.24
Past performance	c	0.05	**0.55**	1.00	0.36	0.26	0.38	0.16
Managerial & technical strength	d	0.11	**0.21**	**0.36**	1.00	0.18	0.45	0.42
Health & safety record	e	**0.35**	0.13	**0.26**	**0.18**	1.00	0.23	0.15
Suitable & sufficient resources	f	0.17	**0.20**	**0.38**	**0.45**	**0.23**	1.00	0.33
Current work load	g	0.02	**0.24**	0.16	**0.42**	0.15	**0.33**	1.00

Note:

Shaded area means correlation coefficient is significant at the 0.05 level (1-tailed).	
Determinant of correlation matrix	0.269
Total number of correlations	21
Number of shaded areas	13
Percentage of significant correlations	62%
Number of correlations > 0.3	7(33%)

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.799
Bartlett's Test of Sphericity	Approx. Chi-Square	315.759
	df	55
	Sig.	.000

Figure F.8 KMO and Bartlett's test for project prequalification category (varimax rotation)

Communalities

	Initial	Extraction
Financial strength	1.000	.723
Past experience	1.000	.768
Past performance	1.000	.783
Managerial & technical strength	1.000	.659
Health & safety record	1.000	.634
Suitable & sufficient resources	1.000	.572
Current work load	1.000	.622

Extraction Method: Principal Component Analysis.

Figure F.9 Communalities for project prequalification category (varimax rotation)

Component Correlation Matrix

Component	1	2
1	1.000	.243
2	.243	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Figure F.10 Oblique correlation coefficients for project prequalification

APPENDIX G

G. PREQUALIFICATION CRITERIA RELATED TO PREQUALIFICATION PERFORMANCE (CHAPTER 4.3.2.10)

G.1 Comparison between periodic and project prequalification categories (McNemar test) with regard to regular review

Test Statistics[b]

	N	Exact Sig. (2-tailed)
After project completion	43	.250[a]
Annual evaluation	43	.500[a]
No evaluation	43	.500[a]

a. Binomial distribution used.

b. McNemar Test

Figure G.1 McNemar test in respect of review of prequalification performance for client respondent category

Test Statistics[b]

	N	Exact Sig. (2-tailed)
After prequalification	33	.250[a]
No evaluation	33	.125[a]
Before prequalification	33	1.000[a]

a. Binomial distribution used.

b. McNemar Test

Figure G.2 McNemar test in respect of review of prequalification performance for contractor respondent category

G.2 Comparison between client and contractor categories (Kolmogorov-Smirnov test) with regard to the impacts of implementation of both prequalification types

Test Statistics[a]

	Most Extreme Differences			Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
	Absolute	Positive	Negative		
the impact (periodic prequalification)	.278	.016	-.278	1.408	.038
the impact (project prequalification)	.391	.000	-.391	1.842	.002

a. Grouping Variable: QSTYPE

Figure G.3 Kolmogorov-Smirnov test for the difference between client and contractor respondent categories

G.3 Comparison between periodic and project prequalification categories (Wilcoxon signed ranks test) for the difference between the impact of implementation of both prequalification types for both client and contractor categories

Test Statistics[b]

	QSTYPE			
	Client		Contractor	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
The impact (project - periodic)	-2.138[a]	.033	-1.386[a]	.166

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Figure G.4 Wilcoxon signed ranks test

Note:

a. *Based on negative ranks* means that the rank sum of periodic prequalification is greater than that of project prequalification

b. *Based on positive ranks* means that the rank sum of periodic prequalification is less than that of project prequalification

Ranks

QSTYPE			N	Mean Rank	Sum of Ranks
Client	The impact (project - periodic)	Negative Ranks	2[a]	6.00	12.00
		Positive Ranks	10[b]	6.60	66.00
		Ties	27[c]		
		Total	39		
Contractor	The impact (project - periodic)	Negative Ranks	3[a]	7.17	21.50
		Positive Ranks	9[b]	6.28	56.50
		Ties	27[c]		
		Total	39		

a. project< periodic

b. project> periodic

c. periodic= project

Figure G.5 Ranks sum of Wilcoxon signed ranks test for the difference between the impact of implementation of both prequalification types for both client and contractor categories

Note: Negative ranks: periodic > project in terms of sum of ranks

Positive ranks: periodic < project in terms of sum of ranks

APPENDIX H

H. PREQUALIFICATION CRITERIA RELATED TO PREQUALIFICATION COST (CHAPTER 4.3.2.11)

H.1 prequalification cost related to project value

Test Statistics[b]

	Z	Asymp. Sig. (2-tailed)
N24A_CA - N24A_CS	-1.625[a]	.104

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Figure H.1 Wilcoxon signed ranks test for the difference between periodic and project prequalification with regard to the prequalification cost proportion related to the project cost

Note: - N24A_CA: % project prequalification cost of project cost

N24A_CS: % periodic prequalification cost of project cost

Ranks

		N	Mean Rank	Sum of Ranks
N24A_CA - N24A_CS	Negative Ranks	6[a]	9.50	57.00
	Positive Ranks	13[b]	10.23	133.00
	Ties	48[c]		
	Total	67		

a. N24A_CA < N24A_CS

b. N24A_CA > N24A_CS

c. N24A_CS = N24A_CA

Figure H.2 Ranks sum of Wilcoxon signed ranks test for the difference between periodic and project prequalification with regard to the prequalification cost proportion related to the project cost

Test Statistics[a]

		N24A_CS1	N24A_CA1
Most Extreme Differences	Absolute	.109	.006
	Positive	.109	.000
	Negative	.000	-.006
Kolmogorov-Smirnov Z		.496	.026
Asymp. Sig. (2-tailed)		.967	1.000

a. Grouping Variable: QSTYPE

Figure H.3 Kolmogorov-Smirnov test for the difference between the client and contractor samples with regard to the prequalification cost proportion related to the project cost

H.2 The unit cost of implementation of prequalification systems

Test Statistics[b]

QSTYPE		project prequalification cost- periodic prequalification cost
Client	Z	-.832[a]
	Asymp. Sig. (2-tailed)	.405
Contractor	Z	-1.732[a]
	Asymp. Sig. (2-tailed)	.083

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Figure H.4 Wilcoxon signed ranks test for between the difference between periodic and project prequalification

APPENDIX I

I. PREQUALIFICATION CRITERIA RELATED TO FORMAL PUBLISHED GUIDELINES (CHAPTER 4.3.2.12)

I.1 The availability of formal published guidelines for client respondents

Test Statistics[b]

	N	Exact Sig. (2-tailed)
the availabilty of prequalification guidelines	44	1.000[a]

a. Binomial distribution used.

b. McNemar Test

Figure I.1 McNemar test for the difference between periodic and project prequalification

I.2 The availability of formal published guidelines for contractor respondents

Test Statistics[b]

	periodic-project (contractor respondents)
Z	-2.111[a]
Asymp. Sig. (2-tailed)	.035

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Figure I.2 Wilcoxon signed ranks test for the difference between periodic and project prequalification

Ranks

		N	Mean Rank	Sum of Ranks
periodic-project (contractor respondents)	Negative Ranks	1[a]	4.00	4.00
	Positive Ranks	7[b]	4.57	32.00
	Ties	34[c]		
	Total	42		

a. project< periodic

b. project>periodic

c. periodic= project

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Figure I.3 Ranks sum of Wilcoxon test for the difference between periodic and project prequalification respondents

APPENDIX J

J. THE REQUIRED INFORMATION IN TERMS OF COMPLIANCE WITH REGULATIONS (CHAPTER 5.2.2.6)

J.1 Health and safety information

Table J.1 Health and safety information

Health and safety information
Formal guidelines or information about: - Organisation structures with regards to allocation of duties, delegation of responsibilities - Management systems with regards to planning, organising, controlling, monitoring and reviewing health and safety programmes - Management systems with regards to investigating and reporting injuries, accidents and dangerous accidents - Risk assessment programmes under the relevant health and safety regulations (Management of Health and Safety Regulations at Work, Control of Substances Hazardous to Health Regulations) - Procedures for developing and implementing the health and safety plan under the Construction (Design and Management) Regulations 1994 (CDM) - Competency assessments of subcontractors in terms of compliance with health and safety regulations Awareness and training programme for all employees regarding health and safety procedures and regulations in order to receive adequate information to enable them to work safely and without risk to health Key personnel information with regard to the health and safety competence (e.g. training, qualification, experience within 3 years) Health and safety records with regards to occurrences of (within 3 years): - accidents - injuries - dangerous events Health and safety records with regards to the breaches of health safety legislation within 5 years Health and safety records with regards to prosecutions, prohibitions, improvement or other enforcement notices issued against the firm within 5 years Health and safety records with regards to the awards of accident prevention within 5 years References: - Copies of the written safety policy, code of practice and safety instruction - Sample of risk assessment related to the Control of Substances Hazardous to Health Regulations 1987; the Management of Health and Hafety at Work 1992; the Manual Handling Operation Regulations 1992 - Details of protective equipment issued to employees - Detail of training programmes - Asbestos licence

J.2 Equal opportunities information

Table J.2 Equal opportunities information

Equal opportunities information
Formal guidelines or information or statement that indicates: - Policy as an employer to comply with statutory obligation under the Race Relation Act 1976, accordingly your practice not to treat one group of people less favourably than others because of their colour, race, nationality, or ethnic origin in relation to recruitment, training or promotion of employees - Descriptions of race relations equality implementation including instruction regarding recruitment, training and/or promotion; documents available to employees, recognised trade unions or other representative groups of employees; recruitment advertisements or other literature. - Practical guidance to employers and others on the elimination of racial discrimination and promotion of equality of opportunity in employment, including the steps that can be taken to encourage members of ethnic minorities to apply for jobs or take up training opportunities - Compliance with the Disabled Persons Employment Act 1944 Unlawful racial discrimination records against the contractor by courts or industrial tribunal due to the breaches of racial equality regulations within 3 years Formal investigation records regarding alleged unlawful racial discrimination records against the contractor by the Commission for Racial Equality within 3 years A statement, written instruction of the firm's racial equality policy which indicates at least: - Racial equality in recruitment, selection, training, promotion, discipline and dismissal - That victimisation, discrimination or harassment on racial grounds are disciplinary offences within the firm Regular Review of the firm's racial equality of opportunity policy and procedures and action to make change if necessary as a result of this review Regular monitoring of representation of ethnic minorities Regular consultation on racial equality issues within workforce References: Copies of the equal opportunities policy, arrangements for recruitment, training, promotion, copies of recruitment advertisements

J.3 Environmental issues information

Table J.3 Environmental issues information

Environmental issues information
Adoption of policies and procedures for energy saving systems, waste management systems to protect and enhance bio-diversity and sustainable development initiatives Environmental policy (the latest copy of the assessment that shows that policy meets the requirements) Environmental management system including external verification from Eco-management and audit scheme (EMAS) and ISO 14000 Information about registration with any other environmental schemes to manage environmental impact Information about licenses and the activities regulated by the Environmental Agency, a local authority or any other environmental regulatory organisation under any statutory provisions References: Copies of environmental policy, EMS manual, environmental audit and reports, signed environmental charter

APPENDIX K

K. QUESTIONNAIRE AND COVER LETTER FOR EMPIRICAL STUDY 2

Manchester Centre for Civil & Construction Engineering *UMIST*

Supplementary questionnaire survey for evaluation of the main questionnaire survey

Please tick and fill the space, as appropriate

I. General

1. The total time to complete the questionnaire: ________________minutes
2. The clarity of the instructions/ diagrams: ☐ Yes ☐ No
   If "No" please give the reasons:

II. Questions

1. The clarity of the questions: ☐ Yes ☐ No
   If "No" please give the reasons and suggestions:
2. The difficulties in completing the questions: ☐ Yes ☐ No
   If "Yes" please give the reasons and suggestions:
3. The need of additional questions: ☐ Yes ☐ No
   If "Yes" please give the reasons and suggestions:
4. The are irrelevant questions: ☐ Yes ☐ No
   If "Yes" please give the reasons and suggestions:
5. Any other comments and suggestions:

Page 1 of 1

Figure K.1 Sample of the questionnaire for evaluation of the main questionnaire for Empirical study 2

Main questionnaire

This questionnaire survey is intended to examine the relationship between contractor prequalification or selection factors and construction project performance. The results of the survey will help to determine the factors that can indicate future construction project performance at the early stage of contractor prequalification in the cases of clients whose routine projects are in the public sector.

This questionnaire is designed to be filled out by personnel knowledgeable about the contractor prequalification process for a contractor prequalification/ selection system including a standing list prequalification system, in conjunction with a review of construction project performance records.

Please complete these questions using **only the data taken from a project completed in the last 3 years** where the contractor was selected for that project through any prequalification process.

If you have any queries about the questions or require any information about my research please do not hesitate to contact me at the following address:

Donny Mangitung
Manchester Centre for Civil and Construction Engineering, UMIST
P.O. Box 88
Manchester M60 1QD
Email: **d.mangitung@stud.umist.ac.uk**
Phone: +44-(0161)-200 8963
Fax: +44-(0161)-200 4646

I. General information:

Please fill in the space or tick one box only, as appropriate

a. Project

1. Project name:______________________________
2. Project location:______________________________
3. Year completed:______________________________
4. Contract value (£): __________ Actual cost (£) after completion: ______________
5. Contract duration (days/weeks): _____ Actual duration after completion (days/weeks): _____
6. Project type: Residential/ housing Building Civil engineering/ infrastructure
7. Work type: New work Repair and maintenance
8. Procurement type: Traditional Management Design build Partnering
9. Payment method: Lump sum Unit price Other: ______________

b. Respondent

1. Your profession:

   Architect Civil/ Structural engineer Building services engineer
   Quantity surveyor Project/ Construction manager Businessman
   Other ______________

2. Your working experience in contractor prequalification or contractor selection process (e.g. for standing list or tender stage):

   < 1 year 1 - 3 years 3 - 5 years >5 years None

Figure K.2 Sample of the main questionnaire for Empirical study 2

II. Construction Project performance:

A. Variation

Please fill in the space or tick one box only, as appropriate

Note:

- When allocating responsibility for cost or time variation please consider the difference between desirable performance (i.e. actual cost or time is less than contract cost or time) and undesirable performance (i.e. actual cost or time is more than contract cost or time).
- When a client is responsible for cost or time change (especially 100%), please include only the change of contract cost or time within the original contract scope and exclude any change beyond the contract contingency. But if the winning contractor is responsible for the change, it must be included even if it is beyond the range of the contract contingency in terms of cost and time.

$$\text{cost variation} = \frac{\text{actual cost} - \text{contract cost}}{\text{contract cost}} \qquad \text{time variation} = \frac{\text{actual time} - \text{contract time}}{\text{contract time}}$$

1. Cost variation (C) during the construction phase (desirable ←→undesirable):

   C≤-10%   -10%<C≤-2.5%   -2.5%<C≤0%   0%<C≤+2.5%   +2.5%<C≤+10%   C>+10%

   ← Decreasing cost (negative sign)   Increasing cost (positive sign) →

   Responsibility for cost variation (*The summation of these percentages must equal 100%*):

   Contractor ________%   Client ________%   Neither contractor nor client _______%

   Why did the cost variation occur? (*Please refer to the party responsible for the highest cost variation*)

2. Time variation (T) during the construction phase (desirable ←→undesirable):

   T≤-20%   -20%<T≤-5%   -5%<T≤0   0%<T≤+5%   +5%<T≤+20%   T>+20%

   ← Decreasing time (negative sign)   Increasing time (positive sign) →

   Responsibility for time variation (*The summation of these percentages must equal 100%*):

   Contractor ________%   Client ________%   Neither contractor nor client _______%

   Why did the time variation occur? (*Please refer to the party responsible for the highest time variation*)

3. Quality variation during the construction phase:

   Defect free
   Some defects and no significant impact on client
   Some defects and with some impact on client
   Some defects and with major impact on client
   Totally defective

   Responsibility for quality variation (*The summation of these percentages must equal 100%*):

   Contractor ________%   Client ________%   Neither contractor nor client _______%

   Why did the quality variation occur? (*Please refer to the party responsible for the highest quality variation*)

Figure K.2 Sample of the main questionnaire for Empirical study 2 *(continued)*

B. Client satisfaction

Client satisfaction with overall cost performance: (Low←→High)	1	2	3	4	5	6
Client satisfaction with overall time performance: (Low←→High)	1	2	3	4	5	6
Client satisfaction with overall quality performance: (Low←→High)	1	2	3	4	5	6

III. Contractor prequalification data and prequalification criteria:

III. a. Contractor prequalification data evaluated against the prequalification criteria

Note:

- Each of the prequalification criteria should be rated by considering the data provided by the winning contractor evaluated against the designated criteria used in the contractor selection process related to the project contract detailed in Sections I and II.
- Please enclose the standard guidelines and an example of the measurement system used in your contractor selection system in association with the scale of 'minimum acceptable', 'typical average' and 'maximum desirable' being used below (if possible please enclose the data analyses of the winning contractor that are used as a reference to answer this questionnaire).

Please tick one box only, as appropriate, or leave blank if not applicable

Financial information						
The scale ranges for the rating of contractor's data: **1 (unsatisfactory)**; **2 (minimum acceptable)**; 3 (between 2 & 4); **4 (typical average)**; 5 (between 4 & 6); **6 (maximum desirable)**						
Prequalification criteria — **A. Financial strength**	**The rating of contractor data evaluated against the criteria**					
1. Annual turnover	1	2	3	4	5	6
2. Profit and loss	1	2	3	4	5	6
3. Financial standing including the result of financial ratio analysis	1	2	3	4	5	6
4. Insurance /bonding capacity	1	2	3	4	5	6
5. Availability of supporting documents/ certificates/ evidence/ recommendations from third parties/ clients including contact address for verification	1	2	3	4	5	6

Experience information						
The scale ranges for the rating of contractor's data: **1 (unsatisfactory)**; **2 (minimum acceptable)**; 3 (between 2 & 4); **4 (typical average)**; 5 (between 4 & 6); **6 (maximum desirable)**						
Prequalification criteria — **B. Past Experience**	**The rating of contractor data evaluated against the criteria**					
1. The number of previously completed contracts similar to this project value and type	1	2	3	4	5	6
2. The number of previously completed contracts similar to this project value	1	2	3	4	5	6
3. The number of previously completed contracts similar to this project type	1	2	3	4	5	6
4. The number of years of the firm's experience with regard to previously completed contracts similar to this project value and type	1	2	3	4	5	6
5. Geographical area of previously completed contracts close to this project area	1	2	3	4	5	6
6. Availability of supporting documents/ certificates/ evidence/ recommendations from third parties/ clients including contact address for verification	1	2	3	4	5	6

Figure K.2 Sample of the main questionnaire for Empirical study 2 *(continued)*

Performance information						
The scale ranges for the rating of contractor's data: 1 (**unsatisfactory**); 2 (**minimum acceptable**); 3 (between 2 & 4); 4 (**typical average**); 5 (between 4 & 6); 6 (**maximum desirable**)						
Prequalification criteria / **C. Past Performance**	**The rating of contractor data evaluated against the criteria**					
1. Cost performance record of previously completed contracts similar to this project value and type including an adequate number of previous projects	1	2	3	4	5	6
2. Schedule performance record of previously completed contracts similar to this project value and type including an adequate number of previous projects	1	2	3	4	5	6
3. Quality performance record of previously completed contracts similar to this project value and type including an adequate number of previous projects	1	2	3	4	5	6
4. Historical claim, dispute and / or fail project completion record	1	2	3	4	5	6
5. Availability of supporting documents/ certificates/ evidence/ recommendations from third parties/ clients including contact address for verification	1	2	3	4	5	6

Managerial & technical information						
The scale ranges for the rating of contractor's data: 1 (**unsatisfactory**); 2 (**minimum acceptable**); 3 (between 2 & 4); 4 (**typical average**); 5 (between 4 & 6); 6 (**maximum desirable**)						
Prequalification criteria / **D. Managerial & technical strength**	**The rating of contractor data evaluated against the criteria**					
1. Suitability and competence of regular technical, managerial and administrative staff including the number and average years of service in the office and on the construction site	1	2	3	4	5	6
2. The number, suitability and competence of the list of trade/ work with subcontractors including subcontractor selection system, performance evaluation and/or registration in a specific competency	1	2	3	4	5	6
3. Quality assurance policy and procedure and/ or management system for all resources including the system of planning, controlling and evaluating construction and firm performance	1	2	3	4	5	6
4. Availability of training and development system for employees at any level	1	2	3	4	5	6
5. Availability of supporting documents/ certificates/ evidence/ recommendations from third parties/ clients including contact address for verification	1	2	3	4	5	6

Figure K.2 Sample of the main questionnaire for Empirical study 2 *(continued)*

Compliance with regulations						
The scale ranges for the rating of contractor's data: **1 (unsatisfactory); 2 (minimum acceptable);** 3 (between 2 & 4); **4 (typical average);** 5 (between 4 & 6); **6 (maximum desirable)**						
Prequalification criteria **E. Compliance with regulations**	**The rating of contractor data evaluated against the criteria**					
1. Documentation demonstrating compliance with Health and Safety regulations including management, policy and procedures in order to meet the standard guidelines of the regulations	1	2	3	4	5	6
2. Documentation demonstrating compliance with equal opportunity regulations including management, policy and procedures in order to meet the standard guidelines of the regulations	1	2	3	4	5	6
3. Documentation demonstrating compliance with environmental regulations including management, policy and procedures in order to meet the standard guidelines of the regulations	1	2	3	4	5	6
4. Availability of supporting documents/ certificates/ evidence/ recommendations from third parties/ clients including contact address for verification	1	2	3	4	5	6

III. b. Weighting of main criteria related to their importance level
Please tick one box only as appropriate

Main prequalification criteria	The importance level of the criteria in your firm's prequalification system (low ←→high)					
A. Financial strength	1	2	3	4	5	6
B. Past experience	1	2	3	4	5	6
C. Past performance	1	2	3	4	5	6
D. Managerial & technical strength	1	2	3	4	5	6
E. Compliance with regulations	1	2	3	4	5	6

III. c. Any other comments and suggestions about this section

Figure K.2 Sample of the main questionnaire for Empirical study 2 *(continued)*

Manchester Centre for Civil & Construction Engineering **UMIST**

IV. Contractor prequalification route

Please tick one box only, as appropriate, and before answering please see the note and diagram below

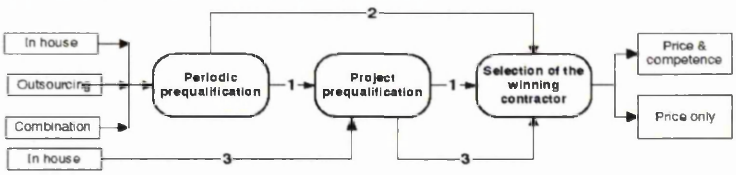
1. Prequalification route for the winning contractor related to the project contract detailed in Sections I and II
   - Route 1: periodic prequalification → project prequalification → the winning contractor
   - Route 2: periodic prequalification. → the winning contractor
   - Route 3: project prequalification → the winning contractor

2. Please specify the prequalification system and expertise used, if the answer to the previous question is route 1 or 2 where the selection process of the winning contractor involved periodic prequalification (e.g. via standing list/ approved list)
   - In house
   - Outsourcing (e.g. Constructionline)
   - Combination of in house and outsourcing

3. Please specify the bases of the final selection for the winning contractor
   - Price and competence (price weighting: ______% and competence weighting: ______%)
     (Note: *The summation of these percentages must equal 100%)*
   - Price only

4. Your organisation is a member of Constructionline
   - Yes
   - No

Possible routes for selecting the winning contractor



Note:

- **Periodic prequalification** is performed to develop a standing list of contractors relevant for a certain periodic time frame, which can be used by a client for short listing or invitation to bid. Periodic prequalification is usually separated from project prequalification in terms of time and purpose of evaluation. *Standing list, select list and approved list* are commonly classified as this prequalification type. Sometimes a client develops the tender list from these lists without further qualification.
- **Project prequalification** is performed to develop a list for a particular project, on a project by project basis, which can be combined with periodic prequalification, for short listing or invitation to bid. Project prequalification and selection of the winning contractor (e.g. tender stage) are usually one package of contractor evaluation for a particular project. An example of the output obtained through this prequalification type is a tender list.
- **Selection of the winning contractor** is the final selection of the contractor that will carry out construction tasks for a particular project. The winning contractor is thoroughly evaluated on the basis of **price only**, or **price and competence** (e.g. financial, technical & managerial aspects) suited to a particular project objectives. The winning contractor is commonly selected on the basis of several procurement types such as traditional, management, design & build and partnering.
- **In-house** in periodic prequalification, project prequalification or selection of the winning contractor is a process of development of a list of contractors through evaluation or qualification performed within the client organisation using its own system and expertise.
- **Outsourcing** in periodic prequalification is a process of development of a list of contractors through evaluation or qualification performed by a third party producing a list of contractors, such as Constructionline.
- **Combination** in periodic prequalification is a process of development of a list of contractors from a combination of the list produced through in-house and outsourcing processes.

Contractor Prequalification *Questionnaire for Local Authorities* ***Page 6 of 7***

Figure K.2 Sample of the main questionnaire for Empirical study 2 *(continued)*

Reply Slip

Thank you for completing this questionnaire. If you are further interested in my research project, please complete the following section and send it back to the address below:

- ☐ I wish to receive a copy of the research findings.
- ☐ I enclose the standard guidelines and an example of the measurement system used in our contractor selection system.
- ☐ I recommend that you speak with:

- ☐ Information about myself:

Name:
Position:
Organisation
Address:
Telephone:
Fax:
Email address:

For any formal or informal enquiry, please contact:

Donny Mangitung
PhD student
Manchester Centre for Civil and Construction Engineering, UMIST
P.O. Box 88
Manchester M60 1QD
England - UK
Email: **d.mangitung@stud.umist.ac.uk**
Phone: +44-(0161)-200 8963
Fax: +44-(0161)-200 4646

Figure K.2 Sample of the main questionnaire for Empirical study 2 *(continued)*

UMIST

Manchester Centre for
Civil and Construction Engineering
PO Box 88, Manchester, M60 1QD, UK
Tel No: 0161-200 4243
Fax No: 0161-200 4646
http://www.umist.ac.uk/civilandconstruction

THE UNIVERSITY of MANCHESTER

Erewash Borough Council
Mr. R.S. Walter
Principal Project Officer
Toll Bar House, 1 Derby Rd.
Ilkeston DE7 5FE

> NK
DP 18/2/03
RECD 17 FEB 2003
ACK.
FILE

Wednesday, 22 January 2003
Reference no.: 161-MQS-2003

Dear Mr. Walter

Enclosed is a questionnaire which seeks to investigate the relationship between prequalification factors and contractor project performance. This survey is a part of my ongoing PhD research into construction contractor prequalification being carried out in the Manchester Centre for Civil and Construction Engineering, UMIST.

The results of the survey will help to determine the prequalification factors that can indicate future contractor project performance at the early stage of contractor prequalification in the cases of clients whose routine projects are in the public sector. Therefore, please choose a construction project completed within your organisation in the last 3 years to answer the questionnaire.

If you are unable to complete the questionnaire yourself, I would be very grateful if you could pass it to someone within your organisation who is experienced and has been involved in a construction project including the process of selection of the winning contractor and the evaluation of contractor performance at the end of the completed project.

It is intended that the analyses of the completed main questionnaire will result in the following outcomes:

- The important contractor criteria evaluated against contractors' data using their historical data related to financial strength, past experience, past performance, technical and managerial strength and compliance with regulations.
- The appropriate choice of a predictive model of contractor performance using contractors' historical data at the early stage of contractor evaluation (i.e. standing list prequalification system/ Constructionline scheme).

I would really appreciate your response to the questionnaire, and invite you to add your comments to support my research. All responses will be kept confidential in any case. For your convenience, a self-addressed envelope is enclosed.

Thank you and please do not hesitate to contact me at my email address or phone number below or by post to the Centre address above, if you have any queries, or use the reply slip on the last page of questionnaire.

Yours sincerely

Donny Mangitung
N.B.: email address: d.mangitung@stud.umist.ac.uk
Phone number: 0161-200 8963

Nothing in this letter constitutes an order unless accompanied by an official order form.

Figure K.3 Sample of the cover letter for Empirical study 2

UMIST

Manchester Centre for
Civil and Construction Engineering
PO Box 88, Manchester, M60 1QD, UK
Tel No: 0161-200 4243
Fax No: 0161-200 4646
http://www.umist.ac.uk/civilandconstruction

THE UNIVERSITY of MANCHESTER

Erewash Borough Council
Mr. D. Young
Ass. Director (Engineering)
Bridge House
Long Eaton

OPER... Ref	PP 18/2/03 KE
RECD 19 FEB 2003	
ACK	
FILE	

Friday, 14 February 2003
Reference no.: 548-MQS-R-2003
Subject: **Reminder**

Dear Mr. Young

About three weeks ago I sent you a letter regarding my questionnaire survey (Reference no.: 548-MQS-2003). This survey is the final stage of data collection of my PhD research with regards to the study of contractor prequalification or contractor selection system, especially for investigation of the relationship between contractor evaluation/ prequalification criteria and construction project performance.

So far I have not yet received your questionnaire. If you have returned it to me please accept my thanks, and my apologies for writing to you again. But if you have not sent it back yet, I should like to ask you to take the time to complete the questionnaire. I would like to have the completed questionnaire by 15th March 2003, but if you feel it is unfeasible to complete the questionnaire by that date, please contact me at my email address below to discuss a possible date.

Additionally, if you think that you are not the appropriate person to fill in the questionnaire, could you please forward the first letter to the person who you think is the best person to do so.

I do greatly appreciate your involvement in this survey. Thank you again for all your help.

Yours sincerely

Donny Mangitung
N.B.: Email address: d.mangitung@stud.umist.ac.uk
Phone number: 0161-200 8963

Nothing in this letter constitutes an order unless accompanied by an official order form.

Figure K.4 Sample of the reminder letter for Empirical study 2

APPENDIX L

L. TRENDS IN MTHODS OF PROCUREMENT IN THE UK (CHAPTER 7.4.1)

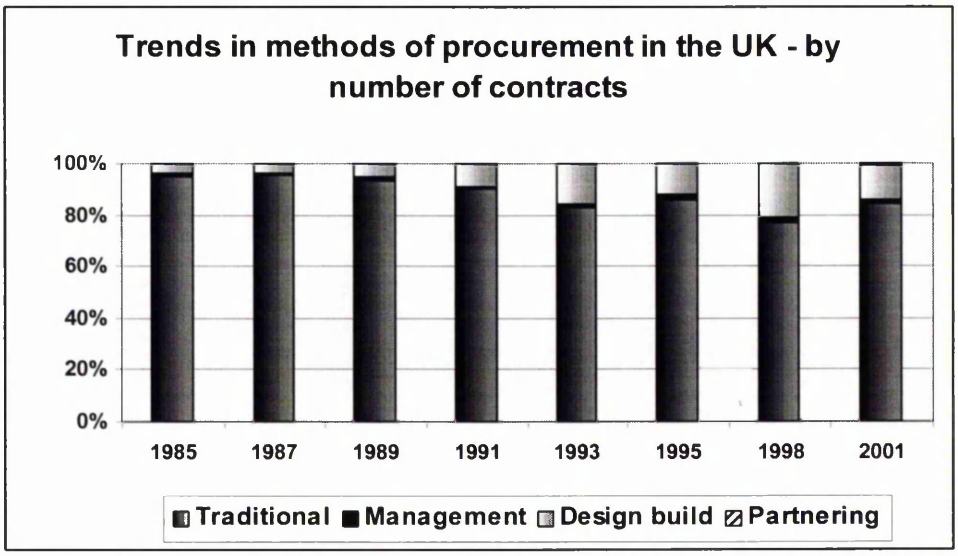


Figure L.1 Trends in methods of procurement in the UK – by number of contracts

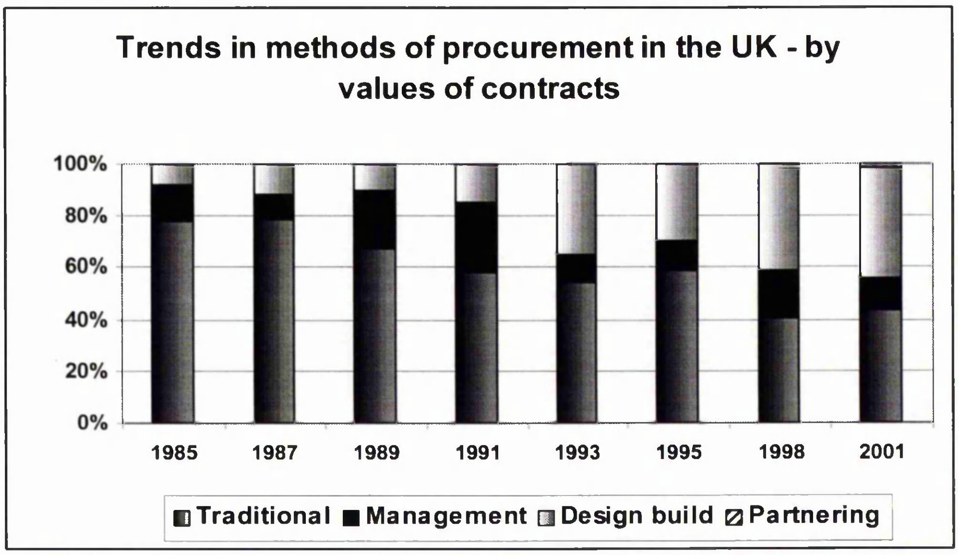


Figure L.2 Trends in methods of procurement in the UK – by value of contracts

Note: The figures were adapted from Contract in use 2001: A survey of building contracts in use during 2001, RISC, London.

APPENDIX M

M. FACTOR ANALYSIS FOR EMPIRICAL STUDY 2 (CHAPTER 7.6.2)

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.765
Bartlett's Test of Sphericity	Approx. Chi-Square	1262.579
	df	300
	Sig.	.000

Figure M.1 BTS and MSA (oblique rotation)

Communalities

	Initial	Extraction
F1	1.000	.816
F2	1.000	.879
F3	1.000	.846
F4	1.000	.778
F5	1.000	.791
E1	1.000	.855
E2	1.000	.753
E3	1.000	.835
E4	1.000	.774
E5	1.000	.763
E6	1.000	.795
P1	1.000	.827
P2	1.000	.797
P3	1.000	.768
P4	1.000	.689
P5	1.000	.804
M1	1.000	.707
M2	1.000	.708
M3	1.000	.768
M4	1.000	.733
M5	1.000	.734
R1	1.000	.588
R2	1.000	.913
R3	1.000	.792
R4	1.000	.886

Extraction Method: Principal Component Analysis.

Figure M.2 Communalities (oblique rotation)

Component Correlation Matrix

Component	1	2	3	4	5	6
1	1.000	.134	-.412	-.438	.217	.301
2	.134	1.000	-.170	-.238	.214	.133
3	-.412	-.170	1.000	.378	-.282	-.015
4	-.438	-.238	.378	1.000	-.293	-.226
5	.217	.214	-.282	-.293	1.000	.096
6	.301	.133	-.015	-.226	.096	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Figure M.3 Oblique correlation coefficients

APPENDIX N

N. LOGISTIC REGRESSION FOR EMPIRICAL STUDY 2 (CHAPTER 7.6.4)

Test Statistics[a]

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
FAC1_1	410.000	788.000	-.133	.895
FAC2_1	368.000	864.000	-.787	.431
FAC3_1	350.000	728.000	-1.068	.286
FAC4_1	376.000	872.000	-.663	.508
FAC5_1	251.000	747.000	-2.611	.009
FAC6_1	376.000	872.000	-.663	.508

a. Grouping Variable: TIME VARIATION

Test Statistics[a]

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
FAC1_2	356.000	821.000	-.783	.434
FAC2_2	328.000	793.000	-1.231	.218
FAC3_2	336.000	801.000	-1.103	.270
FAC4_2	376.000	754.000	-.464	.643
FAC5_2	360.000	825.000	-.719	.472
FAC6_2	233.000	698.000	-2.749	.006

a. Grouping Variable: TIME VARIATION

Test Statistics[a]

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
TVCO	359.500	737.500	-.769	.442
TVCL	87.500	465.500	-5.508	.000
TVNOR	289.500	667.500	-2.682	.007

a. Grouping Variable: TIME VARIATION

Figure N.1 Mann-Whitney U test for time variation related to Chapter 7.6.4.4

APPENDIX O

O. LOGISTIC REGRESSION FOR TIME VARIATION MODELS (CHAPTER 7.6.4)

O.1 Goodness of fit (model n o.4)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	25.573	1	.000
	Block	25.573	1	.000
	Model	25.573	1	.000
Step 2	Step	10.857	1	.001
	Block	36.430	2	.000
	Model	36.430	2	.000
Step 3	Step	6.600	1	.010
	Block	43.030	3	.000
	Model	43.030	3	.000
Step 4	Step	4.501	1	.034
	Block	47.532	4	.000
	Model	47.532	4	.000

Figure O.1 Chi-square values

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	40.886	.413	.551
2	30.029	.532	.710
3	23.428	.592	.790
4	18.927	.629	.839

Figure O.2 R square and –2LL values
Note: Initial -2 Log Likelihood: 66.459

O.2 Goodness of fit (model n o.5)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	27.811	1	.000
	Block	27.811	1	.000
	Model	27.811	1	.000
Step 2	Step	7.208	1	.007
	Block	35.020	2	.000
	Model	35.020	2	.000
Step 3	Step	5.762	1	.016
	Block	40.782	3	.000
	Model	40.782	3	.000

Figure O.3 Chi-square values

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	36.644	.463	.617
2	30.802	.524	.699
3	27.464	.556	.742
4	22.188	.602	.804

Figure O.4 R square and –2LL values

Note: Initial -2 Log Likelihood: 66.459

APPENDIX P

P. LOGISTIC REGRESSION FOR TIME SATISFACTION MODEL (CHAPTER 7.6.5)

P.1 Goodness of fit (model n o.6)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	12.384	3	.006
	Block	12.384	3	.006
	Model	12.384	3	.006

Figure P.1 Chi-square values

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	53.407	.227	.305

Figure P.2 R square and –2LL values
Note: Initial -2 Log Likelihood: 65.79