Investigating the structural frame decision making process

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INVESTIGATING THE STRUCTURAL FRAME DECISION MAKING PROCESS

By
Hasan Haroglu

A dissertation thesis submitted in partial fulfilment of the requirements for the award of the degree Doctor of Engineering (EngD), at Loughborough University

December 2009

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ABSTRACT

Structural frames are widely used in sectors such as residential, education, commercial, health, retail, leisure etc. and the selection of a structural frame appropriate to a building's function and client needs is a key decision with significant short- and long-term implications. There is a wide choice of structural frame materials for building projects, i.e *concrete, steel, timber*, or *masonry.* Although many options are available, these tend to be based on structural steel or reinforced concrete for the simplest buildings. The nature of concrete frame buildings has developed significantly with the emergence of new technologies and innovations particularly in formwork, concrete as a material, and reinforcement developments. As a result, concrete frame construction has become a faster, more sustainable, and safer form of construction. However, competition from other framing materials such as steel have proved challenging. This research was initiated in response to this challenge and represents one organisation's attempt to deliver improvements in order to promote concrete in the UK structural frames market. The organisation is strongly focused on the continued development of concrete through design inspiration and construction efficiency, research strategy, education and training, new product and process innovation and the achievement of best performance of concrete in practice. The research programme was established to address issues that are considered by decision makers when choosing the optimum frame solution for a building project, and to identify how such decisions are made in practice. Both quantitative and qualitative research methods have been adopted during the EngD research including a literature review, industry questionnaire survey and case study.

From an initial set of interviews, ten key issues were identified at the early stage of the research as being the most important affecting the structural frame selection for a building project. The structural engineer was found, unsurprisingly, to be the most influential decision-maker in the choice of frame at each stage of design process from a subsequent survey of cost consultants, project managers and clients. The survey also revealed that Design-Build is the preferred procurement route amongst developers of building projects, ranging from complex, high quality projects to simple buildings which suggested that most contractors must be getting involved earlier in the design process and thus could be influencing major decisions, such as the selection of a structural frame. Four case study project teams were examined, from which it was clear that contractors could be influential in the frame selection process if they had the willingness to build in a particular frame type (provided that the frame type selected meets the client's requirements). Key findings on the choice of frame in a Design-Build project and the various actions taken by the contractor were highlighted by the research, including the important role played in the decision-making process by more informed clients, who are much more likely to be influential in deciding on the frame type. Further work could be carried out to assess the specific benefits of early contractor involvement, the factors that affect the extent to which contractors get involved with structural frame decision making and the risk relationship between client and contractor. The findings of this work have been presented in five peer-reviewed papers.

KEY WORDS

Structural frame, decision making, Design-build, procurement, building, contractor.

PREFACE

The Doctor of Engineering (EngD) is a four-year postgraduate award intended for the UK's leading research engineers who aspire to key managerial positions in industry. The major aim of the EngD programme is the solution of one or more significant and challenging engineering problems with an industrial context (CICE, 2006). This thesis describes the research undertaken between 2005 and 2009 to fulfil the requirements of an Engineering Doctorate (EngD) at the Centre for Innovative and Collaborative Engineering (CICE), Loughborough University, UK. The research was conducted within an industrial context and sponsored by The Concrete Centre, part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, lime, mortar and silica sand industries.

The EngD is examined on the basis of a discourse supported by publications or technical reports. This discourse is supported by two journal papers and three conference papers, each of which is numbered 1-5 and located in Appendices A-E. The main discourse provides an overview of the work undertaken, while the papers offer more specific aspects of the research. These papers are an integral part of, and should be read when referenced in conjunction with, the thesis.

USED ACRONYMS / ABBREVIATIONS

BCA	British Cement Association
BCSA	The British Constructional Steelwork Association
BRE	British Research Establishment Ltd
CICE	Centre for Innovative and Collaborative Engineering
CIOB	The Chartered Institute of Building
D&B	Design-build
EngD	Engineering Doctorate
EPSRC	Engineering and Physical Science Research Council
HCC	Hybrid Concrete Construction
IStructE	The Institution of Structural Engineers
MPA	Mineral Products Association
NEDO	National Economic Development Office
NJCC	National Joint Consultative Committee
OGC	Office of Government Commerce
QPA	The Quarry Products Association
RIBA	Royal Institute of British Architects
SCI	The Steel Construction Institute
TCC	The Concrete Centre
UK	United Kingdom

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PAPERS

The following papers, included in the appendices, have been produced in partial fulfilment of the award requirements of the Engineering Doctorate during the course of the research.

PAPER 1 (SEE APPENDIX A)

Haroglu, H., Glass, J. and Thorpe, T. (2009), A study of professional perspectives on structural frame selection, *Construction Management and Economics*, Vol. 27, No. 12, pp. 1209-1217.

PAPER 2 (SEE APPENDIX B)

Haroglu, H., Glass, J., Thorpe, T. and Goodchild, C. (2008), “Critical Factors Influencing the Choice of Frame Type at Early Design”, in *CSCE 2008 Annual Conference* (BISSONNETTE B. and PARADIS F. (eds)), Canadian Society For Civil Engineering, Quebec City, Canada, p. 158.

PAPER 3 (SEE APPENDIX C)

Haroglu, H., Glass, J., Thorpe, T. and Goodchild, C. (2008), “Who is the key decision maker in the structural frame selection process”, in *Proceedings of the International Conference on Concrete Construction: Excellence in Concrete Construction through Innovation*, 9-10 September 2008, Kingston University, London, UK, pp. 119-126.

PAPER 4 (SEE APPENDIX D)

Haroglu, H., Glass, J., Thorpe, T., Goodchild, C. and Minson, A. (2009), Evaluating the Main Contractors’ influence within the Concrete Frame Construction Decision Making Process, *The 11th Annual International fib Symposium;* CONCRETE: 21st CENTURY SUPERHERO, *22nd-24th June 2009.*

PAPER 5 (SEE APPENDIX E)

Haroglu, H., Glass, J., Thorpe, T., Goodchild, C. and Minson, A. (in press). Powerless or powerful? How contractors influence major construction decisions in Design-Build projects. *Journal of Engineering, Construction and Architectural Management*. (Submitted for publication, July 2009)

1 INTRODUCTION

This chapter sets out the background to the research undertaken to fulfil the requirements for the award of an Engineering Doctorate (EngD) of Loughborough University. The EngD is described as a "radical alternative to the traditional PhD, being better suited to the needs of industry, and providing a more vocationally-orientated doctorate in engineering" (CICE 1999). The Engineering Doctorate programme is intended "to produce doctoral graduates that can drive innovation in the engineering industry with the highest level of technical, managerial and business competence" (CICE 1999). This thesis presents the research undertaken as part of a 4-year Engineering Doctorate (EngD) programme, which was jointly launched by The Centre for Innovative and Collaborative Engineering (CICE) at Loughborough University and The Concrete Centre (TCC) to investigate the decision making process for structural frames, together with the procurement routes adopted, with the aim of improving the concrete frame procurement process.

This chapter first describes the background to the research which provides a general introduction to the subject domain and the context of the research within the sponsoring company. It then presents the aim and objectives of the research along with its justification. Lastly, the structure of the thesis is presented to provide the reader with a clear "map" of the research as well as the thesis itself. A synopsis is also included which provides an overview of each of the published papers that have been produced during the research (Appendices A-E).

1.1 BACKGROUND TO THE RESEARCH

This section gives the reader the background to the area of research together with the context of the research from the perspective of the industrial sponsor.

1.1.1 Introduction to the Structural Frame Decision Making Process

Although modern materials and methods can prove advantageous in terms of enhanced efficiency and safety (McNamee, 2006), the construction industry tends to reluctantly accept the advantages that new methods and technologies may bring. That said, construction should not just be about achieving the cheapest building possible, but in providing the best value for the client. A good example of this is in the decision made with regard to the choice of a structural frame, which can have a major influence on the value of the building to the client, because it provides a high degree of functionality and future flexibility, and largely determines the speed with which the construction process can be executed. Furthermore, frame choice can have a huge impact on both the short and long-term performance of the completed building. In the short term the frame must give its client the satisfaction of his/her needs, such as construction being completed on time and to budget, it must also satisfy future changes in functional requirements of the building in the long term (Soetanto *et al.*, 2006a).

Furthermore, procurement is a process and observable phenomenon entwined both culturally, politically and practically into the fabric and history of the construction industry (Goodier *et al.*, 2006). Since the Latham report in 1994 (Latham, 1994), the construction sector has pursued a major reform agenda. Striving for improvement across all areas of business – safety, client satisfaction, delivering on cost and time, environmental impact, employee satisfaction, repeat business and profitability – has been a challenge to all clients, contractors, consultants, specialists and suppliers. The Construction Act made some progress in bringing about reform but the industry still needs to improve its procurement practices (Ward, 2007). Problems are easier to plan for and more cheaply dealt with, if identified before construction. Nevertheless, there remains a difference between the theory of the integration of design and construction and actual practice. Not many understand the principles and values of working collaboratively, as indicated in a report by McIlwee (2006) who notes that current projects lack collective ownership as well as the creation of a culture of trust and collaboration between firms. Therefore, as McIlwee (2006) so succinctly put it, the current view of collaborative working, as practiced in the construction sector, is more one of ‘co-operation’ and ‘co-ordination’ than ‘collaboration’.

As a result, the decision on the choice of frame and the selection of the procurement route has a huge amount influence over framed-building projects’ success. This research examines the issues that are taken into consideration by construction practitioners when choosing the frame solution for a building project. Hence, such data proved invaluable to The Concrete Centre (TCC) where the Research Engineer is based. The investigation undertaken was focused towards the activities of structural frame decision making process of building projects during the Design Phase, also known as RIBA Plan of Work Stages C (Concept), D (Design Development) and E (Technical Design) – Design (RIBA, 2007).

1.1.2 The Context of the Research within the Industrial Sponsor - The Concrete Centre

The research project was jointly initiated and funded by The Concrete Centre (TCC; www.concretecentre.com) and Engineering and Physical Science Research Council

(EPSRC) in collaboration with CICE at Loughborough University. The Concrete Centre was formed in 2003 to improve the marketing of concrete. It was funded by 15 major cement and concrete organizations; the new body works alongside the British Cement Association, The Concrete Society, and the ready mix and precast concrete industries to ensure an integrated approach from the concrete sector to technical support, research, education, training and information services.

However, since the research began TCC has merged with the aggregate, quarry product and cement sector organisations to form the Mineral Products Association (MPA) which will allow for greater synergies between these sectors. The MPA has been formed through the merger of the British Cement Association (BCA), the Quarry Products Association (QPA) with its membership covering land based, marine, recycled and secondary aggregates, asphalt, ready-mixed concrete, agricultural lime, industrial lime, mortar, silica sand and TCC. It represents 222 members across the UK. The MPA - as the representative body for the aggregates, asphalt, cement, concrete, lime, mortar and silica sand industries - was established following the first meeting of its Board on Monday 2 March, 2009. MPA members supply around £5bn of essential materials to the UK economy; by far the largest single supplier of materials to the construction sector.

The aim of the MPA is to build on and enhance the strong reputation for protecting the interests of their members to operate in a manner that is economically viable and socially and environmentally responsible. The MPA’s mission is to continue to represent and promote the mineral products industry in order to (MPA, 2009):

- Secure and maintain the licence to operate for the sustainable supply of essential mineral products;

- Continue to innovate and deliver sustainable solutions;
- Maintain existing and develop new markets.

The chairman of the new merged organisation has said in a press release, dated 4th March, 2009 (see http://www.mineralproducts.org/index.php), that "*in these particularly difficult economic conditions, there is a real opportunity for the new organisation to add value to the work of its member companies and to provide a more effective voice for the industry*."

The MPA represents 100% of UK cement production, 90% of UK aggregates production and 95% of UK asphalt and ready-mixed concrete production. The industry operates from around 2000 locations in the UK (MPA, 2009) and produces:

- Aggregates: 248 million tonnes.
- Cement and cementitious materials: 13 million tonnes.
- Asphalt: 25 million tonnes.
- Ready-mixed concrete: 20 million cubic metres.

The industry is highly regulated and operates to high environmental standards. Over 1000 industry sites have certified environmental management systems. The industry is a leader in recycling. 25% of materials in the aggregates sector are from recycled and secondary sources and nearly 20% of the cementitious market is supplied from recycled sources (MPA, 2009).

The concrete industry has traditionally been diverse and fragmented due to a wide range of product and technologies; a situation made possible by the flexibility of the material. However, this diversity can be a powerful driver of innovation and development, but needs a focal point to ensure that the complexity and versatility of this material are communicated as a competitive advantage (TCC, 2006). This is the role of The Concrete Centre, the new central development organization for the concrete and cement sector.

TCC, which became part of the MPA in March 2009, provides a mechanism for research to be disseminated to the construction industry, so that the benefits of good practice and performance improvement can be properly realized. The establishment of the MPA represents a change to how the organisation is governed by the industry it represents, but will not affect the services available to specifiers from The Concrete Centre. The Concrete Centre is the market development organisation for the UK concrete industry. The major aim of TCC is to enable all those involved in the design, use and performance of concrete to fully appreciate the potential of concrete (TCC, 2006). TCC has a comprehensive store of information about the innovative ideas and products produced by the concrete sector and is available for consultation as part of integrated supply chain teams where it sets out to help teams deliver the best solutions for clients. As such, it embraces all of the principles set out in 'Rethinking Construction' and 'Accelerating Change' - reduction of costs, improvements in efficiency of designers and constructors, assistance with innovation and integration of the supply chain (TCC, 2007).

The Centre aims to assist all those who design and construct in concrete whether they work for national or local government, client bodies, architectural practices, civil and structural engineering consultancies, main and specialist contractors or house builders. Outputs from TCC and its partner organizations include the provision of design guidance on a wide range of topics such as structural design, fire, sustainability, acoustics, thermal properties and durability. A major role of The Concrete Centre is to influence the decision to use concrete by demonstrating its potential via the organisation and sponsorship of lectures, attendance at exhibitions and the organisation of competitions and awards events (TCC, 2009). The Concrete Centre's website, *www.concretecentre.com*, is recognised as being a major information resource for the concrete industry with an average of over 33,000 unique visitors every month.

1.2 AIM AND OBJECTIVES

The aim of the research is 'To examine the structural frame decision making process, focusing on concrete frames and assess to what extent the procurement route adopted can influence the choice of frame for a building project in the UK construction industry'.

For an aim to be successful, it must be supported by specific objectives. To achieve the stated aim for this research, a number of specific objectives were set. These objectives were developed after extensive review of previous literature, consultations with supervisors and the staff from the sponsoring organisation at the early stage of the research and informal contact with selected industrialists in the construction industry. The final two objectives were however, derived as the result of the research undertaken in achieving the first four objectives**.** All the objectives are related to each other logically and also are, each, self-sufficient which describe what the research hopes to achieve through the study (Fellows and Liu, 2003).The research objectives are:

1. To explore the concrete frame procurement process in the design phase.

2. To understand the key issues for the structural frame selection process on a building project.
3. To develop insights into how important these key issues are to the decision makers identified, when choosing which structural frame type to use on building projects.
4. To investigate the views of key decision-makers concerning the roles of project team members involved in choosing the structural frame at each stage in the design process.
5. To evaluate the influence of the main contractor in the structural frame decision-making process of building projects, with an emphasis on concrete frames, when using a Design-build procurement route.
6. To provide recommendations to help deliver an improved and efficient concrete frame building project, when using a Design-build procurement route.

The research question addressed by the research presented in this thesis was therefore given the following formulation:

Can the concrete frame procurement process be improved by optimising the structural frame decision making process?

1.3 JUSTIFICATION AND SCOPE

The framed structure market cuts across several traditionally defined sectors such as residential, education, commercial, health, retail, leisure etc, and the selection of a structural frame appropriate to a building's function and its client's needs is a key decision with significant short- and long-term implications (Soetanto *et al.*, 2007). The UK has a tradition of in-situ concrete construction and in the past in-situ concrete frame construction dominated the frame market. Over the past 20 years concrete has lost significant market share to structural steel in the framed structure market (BRE, 2005). However, concrete construction has gone through significant changes since the early 1990s and continues to develop (Rupasinghe and Eanna, 2007). The nature of the concrete frame buildings has changed significantly with the emergence of new technologies and innovations particularly in formwork, concrete as a material, and reinforcement developments. For instance, a report by Reading University Production Engineering Group (Gray, 1995) revealed that the formwork and its turnaround was the main drawback of the faster and more economical concrete construction. However, the Cardington Project, see http://projects.bre.co.uk/ecbp/insitu.html, showed that the concrete frame industry has changed quite considerably over the past 10 years. A subsequent BRE study of innovation in concrete frame construction 1995-2015 stressed the enormous effect that formwork innovation has had upon speed and efficiency since 1995 (Nolan, 2005). In addition, Nolan (2005) states that the impact of the research from the European Concrete Building Project at Cardington on the industry is difficult to assess, but indicates that it has had a positive impact on the concrete frame construction industry and that many of the innovations tested have been adopted and are regarded as important by industry.

Nevertheless, competition from other framing materials such as steel have proved challenging (Glass, 2002). The Concrete Centre's team is therefore strongly focused on the continued development of concrete through design inspiration and construction efficiency, research strategy, education and training, new product and process innovation and the achievement of best performance of concrete in practice. One of the primary aims of TCC is to help all those involved in the design and use of concrete to become more knowledgeable; to enable the construction clients, designers, engineers and contractors to realize the full potential of concrete (TCC, 2006).

As a result, this research programme was established to examine the structural frame decision making process and identify how these could help TCC promote concrete in the UK-framed-structures market. Although the project concentrated initially on the concrete frame procurement process, its remit was developed to include all framed buildings in the UK. This study builds on earlier research by Reading University Production Engineering Group (Gray, 1995) and European Concrete Building Project, Cardington by BCA, BRE, CONSTRUCT and others to improve the performance of the concrete industry, and is aimed at providing useful information for practical application in the concrete frame procurement process. The report by Reading University Production Engineering Group (Gray, 1995) identified the barriers to the concrete frame industry being able to produce a consistent product and service and established the fact that the procurement framework had an apparent influence over the design process. In this report, Gray (1995) highlighted the need for the procurement framework which aids process improvement rather than putting barriers along the way; and placed emphasis on the recognition of the production and process optimisation skills of the frame contractors and the need to restructure the roles and scope of the design team to maximise the input from the contractors. Nolan (2005) indicated that the role of contracts poses a serious challenge to the future of concrete frame construction.

In addition, to date, few published works has exclusively addressed the structural frame decision-making process. For instance Soetanto *et al.* (2006a) identified 31 issues, which were compiled based on a literature review perceived to be important in influencing the structural frame decision making process. Also, Soetanto *et al.* (2006b) investigated potential conflicts between key members of the project team in selecting an appropriate structural frame during early design stages. While this research and previous studies such as those do cover some common ground, they also differ in significant ways. First, this research investigates divergent and convergent opinions of the most influential people on the key issues when choosing the structural frame type. Secondly, this study examines the differences in perceptions of the most influential people about the attitudes of each other towards the key issues. Most importantly, this research builds on previous work by specifically addressing the issue of the relevance of the procurement route adopted in influencing the choice of frame for a building project. The need for the research was clear and it is believed to assist in understanding the structural frame decision making process, particularly the impact of procurement on the choice of building structure and thus to provide inspiration in order for TCC to promote the use of concrete frames in the UK-framed-structures market.

1.4 STRUCTURE OF THE THESIS

This thesis is structured in five main chapters and a series of supporting appendices, which are described in brief as follows:

Chapter 1 is an introductory chapter which provides an introduction to the general subject domain, identifies the aim and objectives and justifies the need for the research, and sets it within an industrial context.

Chapter 2 reviews previous work in this domain and highlights how this research project builds on those which have preceded it, focusing particularly on the activities in the concrete frame procurement process during the design phase.

Chapter 3 provides an overview of research methods used. It details those adopted for use in this research project and explains the reasons for their choice.

Chapter 4 details key achievements from the research undertaken to meet the research project's aim and objectives.

Chapter 5 presents the key findings of the research and reveals the original contribution of the research to knowledge. It identifies the impact of the research on the sponsor and wider industry and critically evaluates the overall project throughout the thesis. Finally, it concludes by suggesting some recommendations for the industry and presents suitable areas for further work.

Appendices A to E contain the five peer-reviewed published papers which are referred throughout the thesis that support this research. These papers are an integral part of, and should be read in conjunction with, the discourse.

Appendices F to I contain other essential supporting materials, i.e. survey instruments produced during the EngD programme".

1.5 SYNOPSIS OF RESEARCH PAPERS

All of the papers completed as part of this research, and included in this thesis, are listed in Table 1.1. Alongside the title, status and place of publication for each paper, a brief description is provided highlighting its contribution to the fulfilment of the research aim and objectives. Each paper has been identified by a number together with its Appendix letter.

Table 1.1 Synopsis of research papers

Paper ID	Title	Journal / Conference	Status	Description
Paper 1, Appendix A	Cost consultants, project managers and clients: a study of professional perspectives on structural frame selection	Construction Management and Economics	Published	Examined the attitudes of structural engineers, project managers, cost consultants and construction clients in analyzing the issues they typically consider when choosing the frame type of a building.
Paper 2, Appendix B	Critical factors influencing the choice of frame type at early design	CSCE 2008 Annual Conference / 6th Structural Specialty Conference, June 10-13, 2008, Quebec, QC, Canada	Published	Presented the key issues in order of importance for project team members to consider when choosing an appropriate structural frame for their building projects during the early design phase.
Paper 3, Appendix C	Who is the key decision maker in the structural frame selection process?	Excellence in Concrete Construction - through Innovation, September 9-10, 2008, Kingston University, London	Published	Established a ranking of the decision makers (or project team members) at each stage of the design process in relation to the structural frame selection process
Paper 4, Appendix D	Evaluating the main contractor's influence within the concrete frame construction decision making process	Concrete: 21st Century Superhero Conference, June 22-24, 2009 Building Design Centre, London	Published	Investigated whether the main contractor influences or actually changes any such specifications (i.e. structural frame or material types) on a Design-Build project
Paper 5, Appendix E	Powerless or powerful? How contractors influence major construction decisions in Design-Build projects	Engineering, Construction and Architectural Management	Submitted	Examined the factors affecting contractors' influence in Design-Build projects. Evaluating the contractors' influence in relation to the structural frame selection process

2 THE UK MARKET FOR CONCRETE FRAMES IN CONSTRUCTION PROJECTS

2.1 INTRODUCTION

The purpose of this chapter is to set the research undertaken in the context of work already carried out in this subject domain, for example Gray (1995) on in-situ concrete frames and Soetanto *et al.*, (2006a) on decision-making. It provides the results of a comprehensive review of both academic and industry literature, which was the initial task of the research as drawn by the work packages for Objective 1 and Objective 2 (see Table 3.1). In accordance with the aim and objectives of the research set in Chapter 1, the main areas of research to explore the key issues in structural frame selection, focusing on concrete frames, their procurement and the role of the main contractor.

The review starts with an exposition of a concrete building project in which the processes, activities and people involved are described, particularly during the design phase. The review underpins the first two research objectives in particular by recognising the processes and people involved in a building project during the design phase in the concrete frame procurement process, and also by identifying the issues that are important to the decision makers in the structural frame decision making process. Following the initial review of literature on this field, further reviews have been undertaken to investigate more specific areas, e.g. the Design-Build procurement approach.

2.2 THE CONTEXT: THE CONSTRUCTION PROJECT PROCESS AND ITS STAKEHOLDERS

The fragmented nature of the concrete frame construction process is due to the lack of coordination and integration between the different parties involved in various stages of project procurement process which makes this most basic of construction practices a major logistical exercise (Anumba and Evbuomwan, 1997; Cole, 1998). This is also consistent with the nature of a construction project in general. Experts within the concrete frame industry have long believed that their products can be designed and built more efficiently (Cole, 1998). However, nowadays buildings are much more complex than ever and many diverse skills are needed to design them. It is therefore essential to examine the decision making process of a building project, particularly in the design phase to understand how the structural frame for a building is selected. The following sections 2.2.1 and 2.2.2 explain in detail the project procurement process during the design phase and the project team members involved.

2.2.1 Project Procurement Process in the Design Phase

Wysocki (2007) defines a project as a "sequence of unique, complex, and connected activities having one goal or purpose and that must be completed by a specific time, within budget, and according to specification". From inception to completion, a project goes through a whole life-cycle that includes defining the project objectives, planning the work to achieve those objectives, performing the work, monitoring progress and closing the project (Sanghera, 2006). During the design phase, the various requirements from project stakeholders should be captured and considered appropriately to ensure appropriate decisions, i.e *the selection of a structural frame* (Soetanto *et al.*, 2006b). Since the overarching goal of this research is an examination of the structural frame decision making process for building projects, the research programme has mainly addressed the processes involved in the design phase rather than the whole procurement process, from concept to completion.

Design is typically defined as *"the formulation of an idea and turning it into a practical reality"* (Blockley, 2005). The design concept and design process in the construction industry have been defined in many ways. For instance, Gray and Hughes (2001) described the design as mainly a personal task with the whole projects' design becoming a combination of the motivation and expressions of many individuals. Akin (1986) stated that design is trade-off between many conflicting needs until there is a solution that enables everyone to move forward to the next aspect of the problem. On the other hand, the design process is defined by Pahl and Beitz (1988) as the intellectual attempt to meet certain demands in the best possible way. The design process is seen as a negotiation between problem and solution through the three activities of analysis, synthesis and evaluation. The common idea behind all these 'maps' of the design process is that it consists of a sequence of distinct and identifiable activities which occur in some predictable and identifiably logical order (Lawson, 2006). The work stages of the RIBA Plan of Work (2007) are used in this research because the stages are well-known and widely recognized throughout the UK construction industry. Within this framework the design stage consists of three main parts: Stage C (Concept), Stage D (Design Development) and Stage E (Technical Design), although it is generally acknowledged that design-related activities continue throughout subsequent stages of the project, including during construction.

Furthermore, design is a critical part of the project, and commences at the early stages of a project life cycle. Early design work involves defining client requirements and investigating these within the context of the overall project goals (Weerasinghe and Ruwanpura, 2008). Early design phase is a critical part of a building project and decisions made through this phase lay the foundations for the construction phase. These involve the evaluation of alternative frame types fulfilling key constraints in order to select the optimal structural solution. Moreover, a building's performance and its value are largely reflected in the quality of decisions taken in the early stages of the project (McGeorge and Palmer, 2002; Kolltveit and Grønhaug, 2004). This is a crucial part of the design process in which the project participants concentrate on project requirements as well as the needs of the client. Decisions are made regarding the form and material of the structural frame at the beginning of a project. Structural frame selection is of fundamental importance to a building project and the form of structure is normally considered, refined and developed during the early design stages in response to project and/or client requirements (Ballal and Sher, 2003; Soetanto *et al*., 2006b). For this study, 'early design' covers design development between RIBA Stages C (Concept) and D (Design Development), and is the phase when the structural frame of a building project is usually selected (Ballal and Sher, 2003). Paper 2 (Appendix B) examined the key project stakeholders and their views on the structural frame selection process during early design, the results of which are discussed further in Chapter 4, section 4.3.1.

2.2.2 Project Team Members

Although the precise contractual obligations of the project team members vary with the procurement option adopted, the project team members must undertake certain essential functions. The project team usually consists of client, architect, project manager, structural engineer, cost consultant and main (principal) contractor (CIOB, 2002). Each member has a different role to play at different stages of the design process. Each of these team members is described below:

Client: A client is a person or organisation paying for the services and can be represented by others, such as clients' representative, employer's agent, project manager, etc. Their chief interest would be to satisfy themselves that the contractor(s) is performing in accordance with the contract and to make sure they are meeting their obligations to pay all monies certified for payments to the consultants and the contractor(s) (CIOB, 2002). Thus, the client is a key project member, namely the organization or individual who makes the decision to purchase services from the construction industry (Barrett, 2000); this is discussed further in section 2.3.3.

Architect and Structural Engineer: The architect is in charge of the architectural issues, whereas the engineer is concerned with more technical issues, i.e. calculating loads and stresses, investigating the strength of foundations and analysing the behaviour of beams and columns in steel, concrete or other materials to ensure the structure has the strength required to perform its function safely, economically and with a shape and appearance that is visually satisfying (IStructE, 2009). The structural concept is developed as a collaborative venture. In this, the engineer and the architect must have mutual understanding and respect. The development of a structural concept should be a collaborative process whereby the contrasting requirements of a structural necessity, aesthetics and functional unity are synthesized into a workable and economic whole. The design should be developed with the involvement of both sides: architect and engineer. There are different driving forces: technical for the engineer whose main aim is to make things "work" without compromising the architects' concept. The architect deals with the appearance of the structure which needs to be true to the concept and fit the context and use (Larsen and Tyas, 2003).

Project manager: Construction and development projects involve the coordinated actions of many different professionals and specialists to achieve defined objectives. Project management, can be defined as a method and a set of techniques based on the accepted principles of management used for planning, estimating and controlling work activities to reach a desired result in time - within budget, and according to specifications (Wysocki, 2007). According to Westland (2006), project management incorporates “the skills, tools and management processes required to undertake a project successfully”. Effective management requires a project manager to add significant and specific value to the process of delivering the project. The value added to the project by project management is unique: no other process or method can add similar value, either qualitatively or quantitatively (CIOB, 2002). The project manager, as a qualified individual or firm, has a role which is principally that of coordinating time, equipment, money, tasks and people for all or specified portions of a specific project (Blockley, 2005).

Cost Consultant (quantity surveyor): The cost consultant is required to give advice on building cost and estimating, which can have two distinct roles (Morrison, 1984):

- Part of the design team for cost advice but not management of the budget.
- Appointed separately by the client as a cost consultant.

Main contractor: The principal management contractor has a duty to (CIOB, 2002):

- Mobilize all labour, subcontractors, materials, equipment and plant in order to execute the construction works in accordance with the contract documents.
- Ensure the works are carried out in a safe manner
- Indemnifying those working on site and members of the public against the consequences of any injury resulting from the works.

The extent to which the above-mentioned roles are likely to influence the choice of frame type for a building project depends on various matters such as the procurement route adopted, existing attitudes within the organisations involved, type of the building project, project value etc. Paper 3 (Appendix C) examines project team members' influence on the choice of frame type at each stage of the design process.

2.3 THE PROCUREMENT PROCESS – AN OVERVIEW

The procurement process plays a significant role in project success and determines the responsibilities of project team members (Rowlinson and McDermott, 1999), so there is good reason to examine its possible influence on choices made in relation to structural frames. In this section the way in which the procurement process is understood in the UK construction industry is investigated. In addition, the importance of fulfilling the clients' requirements is described and discussed as clients can play a significant part in the successful outcome of a building project (RIBA, 1993).

2.3.1 Procurement Systems

Procurement was defined by CIB W92 at its meeting in 1991 as the framework within which construction is brought about, acquired or obtained (Rowlinson and McDermott, 1999). Procurement is a process and observable phenomenon entwined both culturally, politically and practically into the fabric and history of the construction industry (Goodier *et al.*, 2006). Hibberd (1991) has argued that no standard definitions and classification of procurement approaches have become generally acceptable, quite simply because there are no formal structures or agreement on the terms. Furthermore, he highlights that either the term ‘procurement path’ or ‘procurement approach’ would be preferable, as the term ‘procurement system’ implies a degree of scientific rigour which does not exist. Figure 2.1 indicates the elements such as a contract strategy and the client that are functional parts of the procurement system.

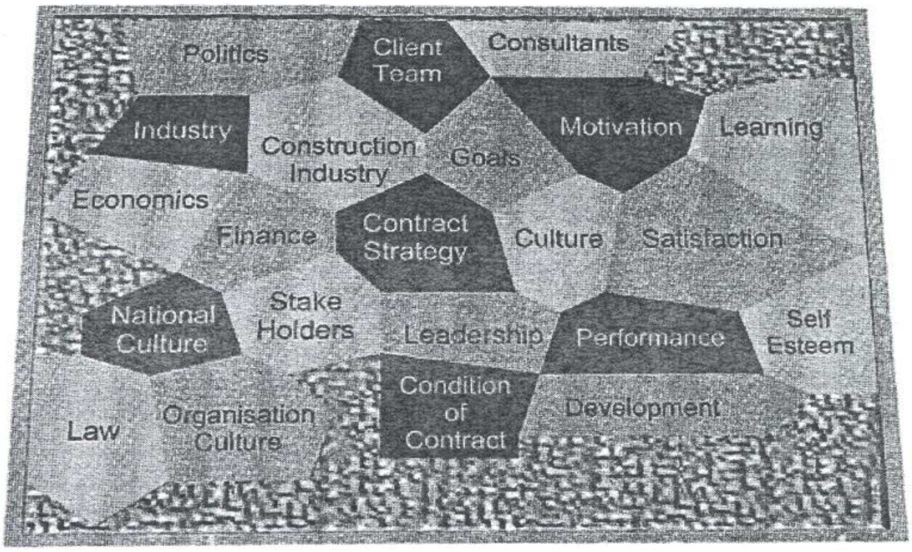

Figure 2.1 A systems view of procurement (Rowlinson and McDermott, 1999)

The presumption is that choice of an appropriate procurement system will lead to a successful project outcome; this makes an implicit assumption that the objective of a procurement system is to provide a successful project (Rowlinson and McDermott, 1999). Procurement decisions about construction projects should always be on the basis of value for money over the life of the facility and not on the initial capital cost alone (OGC-06, 2003) hence, procurement decisions have a profound effect on the balance of risk and reward on projects, and the roles of each party in that project.

Furthermore, the procurement route delivers the procurement strategy. It includes the contract strategy that will best meet the client’s needs. An integrated procurement route should be adopted to deliver the project, where all of these aspects namely; design; construction, operation and maintenance have been considered together (OGC-06, 2003). There are several established procurement routes that construction industry offers and a number of procurement options available, with several variations to each route, and recognized and well-tried forms of contract exist for the each option available. Each route is suited to a particular set of priorities. Therefore, the most appropriate procurement route is determined by the procurement strategy, including the contract strategy, to fit the project objectives and current circumstances.

Procurement systems can be broadly categorized as follows (Peace and Bennett, 2005; Masterman, 2006):

- Traditional procurement systems: The traditional approach is the most well established procurement route and commonly used; design by consultant is completed before contractors tender for, then carry out, construction (Broome, 2002; Peace and Bennett, 2005). This conventional procurement system has been used by the majority of clients in the industry for at least the past 150 years (Masterman, 2006). Therefore, its greatest strength is that it is widely used and so most building consultants and contractors understand it and are experienced in using it. However, the traditional approach can be slow, expensive, provides unreliable quality, and gives rise to claims against the client to provide extra time and money (Peace and Bennett, 2005).
- Integrated procurement systems (Design-Build): This category of procurement systems incorporates all of those methods of managing the design and

construction of a project where these two basic elements are integrated and become the responsibility of one organisation, usually a contractor (Masterman, 2006). The use of Design-Build and its variations have expanded significantly over the last decade (Ernzen and Schexnayder, 2000). Design-Build is explained in more detail in section 2.3.2.

- Management-oriented procurement systems: The management approach requires the client to be closely involved in the work of a project team comprising design consultants, construction management consultants and specialist contractors (Masterman, 2006). Although, design and manage is included in management-oriented systems, there are two main forms: Management Contracting and Construction Management. Management Contracting and Construction Management are slightly different. The main difference is that in Management Contracting the specialist contractors are subcontractors to the Management Contractor, and in Construction Management they have separate contracts with the client (Peace and Bennett, 2005). The management approach is best for clients who want their representative to work closely with creative design consultants to produce an original design within the constraints of time and cost management. The management approach is unnecessarily complex for clients who want straightforward buildings using well established designs and standard components.
- Partnering: The UK construction industry has recently witnessed a move to innovative working practices that involve greater collaboration and partnership than has been the case in the past (Hughes *et al.*, 2006). The idea for partnering grew out of the reforms by Sir Michael Latham (1994) and Sir John

Egan (1998). Strategic alliances or partnering arrangements reduce or remove the competitive tendering aspect of building procurement, thereby facilitating early involvement of specialist concrete contractors. Bennett and Jayes (1998) research on 200 case studies of partnering in the UK construction industry shows that partnering can be applied and is significantly more efficient than traditional competitive methods. Moreover, a BRE Report (2005) indicated that contractual arrangements which promote real project partnering and align the motivations of all contractors to those of the client should be pursued strongly by industry and government.

2.3.2 The Design-Build Approach

The last few years have seen a substantial increased market share in the use of Design-Build (Arditi and Lee, 2003; Gidado and Arshi, 2004) mainly as a result of clients becoming disappointed with the drawbacks brought about by the traditional procurement system (Deakin, 1999). Design-Build (D&B) is a form of procurement systems in which the main contractor is responsible for both design and construction to deliver a building to the satisfaction of the client (Akintoye and Fitzgerald, 1995; Lam *et al.*, 2008). Although some confusion exists amongst inexperienced clients, the term Design-Build has almost been unanimously interpreted and defined as (Masterman, 2006, p.67):

> *"An arrangement where one contracting organisation takes sole responsibility, normally on a lump sum fixed price basis, for the bespoke design and construction of a client's project."*

Design-Build arguably places more responsibility and liability on to the contractor than any other form of procurement (Akintoye, 1994; Peace and Bennett, 2005). Paper

5 (Appendix E) provides a clear understanding of the role which contractors currently play within the decision making process of Design-Build building projects in the UK.

The key benefits of Design-Build include single point responsibility, availability of the contractor's knowledge of 'buildability' and the standardisation of the construction process (Franks, 1990; Janssens, 1991; Akintoye, 1994; Turner, 1995). Furthermore, according to Peace and Bennett (2005), when compared to a traditional approach, Design-Build projects based on a minimal statement (i.e. list of the activities to be accommodated and the functions to be performed by the building with little or no design or specification information on the actual building) are completed 40% faster, while those based on an outline design are completed 25% faster. Also, Design-Build projects are much more likely to be completed on time and are reportedly 15% cheaper than equivalent traditional projects (Peace and Bennett, 2005). However, the Design-Build method also has a number of disadvantages, one of which is the poor quality of design (Franks, 1990; NJCC, 1995). The main reason for this may be that architects have less control over the design process than they would in a traditional approach, as they often become novated to the contractor in the latter (production design) stages. Finally, the advantages of competition (i.e. competitive tendering) may not be passed onto the client when using Design-Build (Rowlinson and McDermott, 1999; Peace and Bennett, 2005).

The principal variants of Design-Build (integrated) procurement systems are described according to Masterman (2006) as follows;

- Novated Design-Build;
- Package deals;

- Develop and construct; and,
- Turnkey.

In addition, a variety of tender and contractor arrangements can be adopted including Single-Stage (Competitive) and Negotiated Tendering, along with the more innovative Two-Stage Tendering and Partnering arrangements. Single-stage and Two-stage tendering arrangements are the most typical forms adopted on Design-Build projects in the UK construction industry (Drew and Skitmore, 1993). The adoption of two-stage tendering on Design-Build projects is beneficial in terms of the balance between client control over design development and the eventual transfer of design responsibility to the contractor. However, one key drawback is that the preferred contractors' role in design development will strengthen its negotiating position, enabling it to drive a particularly hard bargain in the closing stages of the second-stage tender (Rawlinson, 2006b). Single-stage competitive tendering provides the client with an early contractual commitment on price and the contractor is not given an opportunity to revisit this. However, second-stage tendering helps the contractor to understand the design. In adopting the single-stage route, the client sacrifices some opportunity to interface with the contractor's supply chain and is heavily reliant on the quality of their initial statement of design intent and specification to achieve expected quality standards on site (Rawlinson, 2008). Hence contractors would appear to be highly influential in the decision making process when using two-stage tendering in a Design-Build project. Paper 4 (Appendix D) in particular examines the influence that contractors have on the selection, design or production of the structural frame in a Design-Build project in terms of tendering arrangements, size of the contractor, etc.

In conclusion, Design-Build offers a variety of advantages to improve the implementation of projects (Rowlinson, 1997; Leung, 1999). Adams (1999) showed that majority of clients regard Design-Build as the optimal route to obtain value for money. However, the success of any construction project is attributed to a great many factors and project team members can only focus on the most important ones (Lam *et al*., 2008). Chan (2000) stated that the performance of an enhanced Design-Build project is based on the criteria of time, cost, quality, functionality and safety requirements, whilst Ndekugri and Turner (1994) suggested that the success of the Design-Build project depends heavily on meeting the client's criteria.

2.3.3 The need for a focus on clients' needs

Generally, a construction project is initiated by the needs of the client (Lam *et al*., 2008). The future direction of research and development in the concrete frame sector must take cognisance of the importance of understanding the clients' requirements (Nolan, 2005). According to Masterman (2006), the client is the organization, or individual, who commissions the activities necessary to implement and complete a project in order to satisfy its/his needs and then enters into a contract with the commissioned parties. The client is the sponsor of the construction process and provides the most important perspective on how the construction industry performs as far as procurement systems are concerned (Rowlinson and McDermott, 1999).

As clients have become more aware and demanding of the construction industry, they are also becoming less tolerant of the problems and the risks involved in the delivery of major projects (Smith *et al.*, 2004). While the focus of Sir Michael Latham's report (1994) was the client and clients' expectations of the construction industry, it should also be noted that a focus on the customer in the construction industry was one of the key drivers for change in the Construction Task Force Report (Egan, 1998). Different organisations understand the needs of their clients, but it is debatable whether there is an accurate overall market view. If this view exists, then it is not widely known and needs dissemination (BRE, 2005). In addition, client requirements are changing constantly, but they are not communicated to the whole project team resulting in non-conformities and costly changes at the construction phases (Kagioglou *et al.*, 1998). It has been in the area of strategy that the construction industry has been particularly weak in the past and this has led to the development of alternative procurement systems and the encroachment of other professions into the construction industry (Rowlinson and McDermott, 1999). The UK construction industry has never had the best reputation for meeting its clients' expectations (NEDO, 1974; NEDO, 1983; RIBA, 1993). Evidence of this poor performance is shown in a report from the National Audit Office (2005), which concludes that failure to fully implement best practice procurement and project management in central and local government currently costs £2.6bn a year in terms of avoidable capital and operating costs (Rawlinson, 2006b).

2.4 SELECTING THE STRUCTURAL FRAME FOR A BUILDING

The frame is a key element of any building. A structural frame is typically defined as "the load-bearing assembly of beams, columns and other structural members connected together and to a foundation to make up a structure" (Blockley, 2005). According to Soetanto *et al*. (2006a), the structural frame is the skeleton that defines and holds the whole building together. This section describes the structural frame selection process along with the major structural frame materials, i.e. concrete and steel. It aims to identify the principal criteria for project team members in their choice of whether to select concrete or another frame option, such as steel, timber, etc. Concrete frames and steel frames are also described in this section.

2.4.1 The Process of Structural Frame Selection

The choice of the primary structure of a building has a major influence on the value of the building to the client, because it provides both the functionality and future flexibility, and largely determines the speed with which the construction process can be executed (SCI, 2000). Furthermore, the choice of structural frame is of particular significance since it interfaces with many of the other elements of the building, thereby influencing their specification and buildability (Soetanto *et al.*, 2006b). Frame choice can have a huge impact on both the short and long-term performance of the completed building. In the short term the frame must give its client the satisfaction of his/her needs, such as construction being completed on time and to budget, it must also satisfy future changes in functional requirements of the building in the long term (Soetanto *et al.*, 2006a).

There is a wide choice of structural frame materials for building projects. There are four basic materials available: *concrete, steel, timber,* or *masonry.* Although many options are available, these tend to be based on structural steel or reinforced concrete for the simplest buildings (Soetanto *et al.*, 2007). Bibby (2006) indicated that the choice of whether to go for a concrete or steel frame is still mainly dependent on building type and site-specific constraints. Although the choice of frame is heavily influenced by the issues specific to that project there are a number of issues that are commonly considered by project team members (Soetanto *et al*., 2006b). The choice of primary structure is generally determined by cost with less regard to functionality and performance characteristics (SCI, 2000). This is further corroborated by Idrus and

Newman (2003) who state that frame selection criteria often focus on cost and time requirements and a previous survey by Soetanto *et al*., (2006b) identified 31 issues perceived to be important in influencing the structural frame decision making process. These are shown in Table 2.1 below:

Table 2.1 Criteria for assessing the potential performance of structural frames (Soetanto *et al*., 2006b)

No	**Performance Criteria**	No	**Performance Criteria**
1	The layout, structure and engineering systems are well integrated	17	The disposal (i.e. demolition and site clearance) costs can be minimized
2	The layout and size work well	18	The building minimises environmental impacts (in terms of energy/resource consumptions and waste).
3	The circulation works well	19	The building enhances the team/client's confidence (in the selected structural frame)
4	The building has sufficient floor to ceiling clear height	20	The design costs can be minimised
5	The building provides appropriate lettable area/spans	21	The building is perceived to be simple to build
6	The form is well conceived	22	The building reinforces the image of the occupier's organization
7	The frame is structurally efficient	23	The building reflects the status of the occupier
8	The building can be quickly constructed	24	The building overall meets the perceived needs
9	The construction costs can be minimised	25	The colour and texture of materials enhance enjoyment of the building
10	The building has been designed so it can be safely constructed and maintained	26	The quality and presentation of finishes are good
11	The overall risk is perceived to be low	27	The building overall looks durable
12	The building is designed for demolition and recyclability	28	The connections between components are well designed and buildable
13	The building is adaptable to changing needs	29	The tolerances of the components are realistic
14	The finishes are durable and maintainable	30	The building provides best value
15	The form and materials optimise the use of thermal mass	31	The client is satisfied with the finished product
16	The facility management (i.e. O & M, replacement) costs can be minimized		

Cost model studies published by The Concrete Centre (UK) revealed that the structural frame comprises between 7-12% of the final cost of a building in relation to the type of the building (Ryder, 2007). So, The Concrete Centre (2004) suggests that frame cost should not solely dictate the choice of frame. Indeed many other issues should also be taken into consideration when selecting the optimal frame solution such as programme, health and safety, environmental performance, etc. This was the subject of Paper 1 (Appendix A) and Paper 2 (Appendix B) which found that although the choice of frame is heavily influenced by the issues specific to the project in hand, ten key issues were identified that are particularly important during early design. These key issues are presented in section 4.2.2.

2.4.2 Concrete Frames

The concrete sector is worth about £5bn a year, with up to 120 million tonnes of concrete being used in UK construction projects every year. The UK's tradition of using in-situ concrete construction has meant that for many years in-situ concrete frame construction dominated the structural (skeletal) frame market. However, industry reports such as that compiled by the BRE (2005) have revealed that concrete lost significant market share to structural steel in the framed structure market in the UK in the 1980s and 1990s, although it still appears to perform well in commercial and residential applications. In addition, like the construction industry as a whole, concrete construction has been criticized for its poor productivity (e.g. Latham, 1994; Egan, 1998), but research and development has helped to improve various aspects of construction (e.g. Gray, 1995; Nolan, 2005) and is continuing. For instance, The Reading Production Engineering Group (Gray, 1995) identified the barriers to in-situ concrete frame construction process and produced a strategy which would remove these barriers in order to deliver improved and consistently efficient concrete construction. The main recommendation of Gray's report (1995) was that the concrete frame contractors and their suppliers should develop a definitive and straightforward specification so as to overcome the problem of great complexity in the production process of concrete frames. Also, BRE (2000) reported from the results of the European Concrete Building Project at Cardington that the improvements implemented as part of the research should produce time savings of over 30% and man hour savings of over 45% compared with the then current practice.

Concrete's range of structural frame solutions, its thermal efficiency, inherent fire resistance, acoustic and vibration performance, durability and low maintenance ensure that it performs well in a number of UK markets such as commercial and residential buildings (TCC, 2006). New cost model studies and research now add cost-effective construction and sustainability to that list (Ryder, 2007; Nolan and Rupasinghe, 2007). As stated by Stefanou (2004) high-rise residential apartment blocks often utilize the additional mass a concrete frame has for improved acoustic insulation, improved energy consumption from its increased thermal mass and a high quality finish from exposed concrete. Furthermore, Eustace (2008) stated that with the advent of new construction techniques and the desire to build larger and taller buildings, concrete has arguably become the construction material of choice. This is further corroborated by Korista (2009) "*Not long ago, most high rise structures were built with structural steel, such as the Sears Tower Chicago, which is the tallest building in the United States. However advancements in the concrete industry over the past few years have made the current trend toward concrete possible*". In addition, Feenan (2007) pointed out that from hotels to arenas, car parks to shopping centres, apartments to dock leveller pits, and even a digester tower, structural concrete is used throughout the construction industry.

Designers have a wide choice of structural systems for concrete frame buildings. They can choose from three basic types: in-situ, precast or hybrid constructions, which are described below.

In-situ concrete solutions: a form of construction where concrete is poured into forms for building elements, i.e. columns, beams, floors, walls, stairs or balconies at the building site. The main benefits of using in-situ construction are flexibility and economy.

Precast concrete solutions: In this form of construction, concrete is cast and cured in a controlled environment which is then transported to the construction site. These types of solutions could all be used to reduce or eliminate formwork, increase the speed of erection, provide high quality finishes, reduce snagging, increase certainty, reduce complexity on site etc. The biggest benefits usually come from repetition. Precast products are made to consistently high quality standards using a combination of skilled labour or automated processes (Holton, 2009). Precast construction is virtually unlimited in its application and is suitable for single and multi-storey construction.

Hybrid solutions: Hybrid Concrete Construction (HCC) is a method of construction which integrates precast concrete and cast in-situ concrete to take best advantage of their different inherent qualities (TCC, 2005). These types of solutions use standard precast members and in-situ elements. Hybrid concrete technology is used primarily to achieve fast and cost effective construction by removing labour-intensive operations on-site and replacing them with mechanized production in precasting yards and factories (Goodchild and Glass, 2004). Nevertheless it is felt that these solutions will still struggle to match the speed of erection of steel for most frame applications (BRE, 2005).

2.4.3 Steel Frames

In the UK, steel is the dominant framing material for multi-storey buildings with the latest figures showing a market share at nearly 70% (SCN, 2002). Structural steel's low cost, strength, durability, design flexibility, adaptability and recyclability are said to make it the material of choice in building construction (BCSA, 2009). Structural steel framing solutions have been confirmed as faster and cheaper to build than reinforced concrete alternatives in the latest update of a cost comparison study that dates back to 1993 (Barrett, 2007). Speed of construction remains the principal reason for choosing steel, with "lowest overall cost" coming second. Bartley (2009) indicated that "*Our team changed the design to steel for cost and speed of construction*" as steel generally lends itself to a faster construction programme.

Furthermore, the sustainability case for steel is arguably now a key factor in favour of steel (BCSA, 2009); the recycling and reuse rate for steel construction products in the UK is 94% and as high as 99% for structural steelwork (NSC, 2008). The British Constructional Steelwork Association (BCSA) was the first construction material sector to launch a Sustainability Charter which it did in November 2005. The objective of the Steel Construction Sustainability Charter is "*To develop steel as a sustainable form of construction in terms of economic viability, social progress and environmental responsibility*" (BCSA, 2007). Also, all steel construction products are manufactured off site and frames can be procured via all building procurement routes. Indeed steel framed buildings have been a successful choice for a wide range of building types procured in fast track, management packages as well as traditional methods (SCI, 2000).

2.5 RESEARCH PROBLEM

This section states the research problem in the form of statements elicited from the literature review and demonstrates an understanding of the current state of knowledge pertaining to the research problem. The review of the literature, although limited, contributed to the research problem identification in such a way that it led to analytical thinking on the part of the researcher with the aim of possible contributory information to the stated aim and objectives of the research set in Chapter 1. The aim of the study was to examine the structural frame decision making process, focusing on concrete frames and assess to what extent the procurement route adopted can influence the choice of frame for a building project. The research done and presented in this thesis addressed the question "*Can the concrete frame procurement process be improved by optimising the structural frame decision making process?*" In this study, the review of literature was fundamental for the development of Objectives 1 and 2 set in Chapter 1 (see section 1.2), and also served to provide a knowledge foundation for developing the Objectives 3, 4, 5 and 6 (see section 1.2). Further details about how the research's aim and objectives were met throughout the research are provided in Chapter 3 which describes the research methodology.

Recent years have seen almost every sector of the construction industry working to meet the aims of the Latham report. In the UK, both the influential Latham (1994) and Egan (1998) reports identified that improvements designed to reduce budget and timescale and to increase quality would only be achieved if main contractors were involved sufficiently early in the design process and fully understood the needs of the client. In addition, for concrete frame construction, Gray (1995) emphasized the need to restructure the roles and scope of the design team to maximise the input from the contractors. Hence, the rise in popularity of procurement routes and forms of contract that permit early contractor involvement (ECI) such as Design-Build within which contractors are involved early to improve supply chain integration. Although Design-Build has been used in the UK construction industry for decades, it gained increased market share in the late 1990s onwards (Ernzen and Schexnayder, 2000; Arditi and Lee, 2003). Indeed, a recent survey of UK project managers, cost consultants and clients (Paper 1, Appendix A) found that Design-Build is the preferred option amongst developers of building projects, ranging from complex, high quality projects to simple buildings. This illustrates a significant change in the UK construction industry, moving away from its conventional, 'traditional' procurement systems. So, as a result, one might sensibly presume that most contractors must be getting involved earlier in the design process and thus could be influencing major decisions, such as the selection of a structural frame, although there are question marks about how this affects the risk relationship between client and contractor.

With regard to the role of the structural frame, this has been investigated with respect to the ways in which the choice of frame type and material can meet the client's needs (e.g. Gray, 1995; Soetanto *et al.*, 2006b). There is clear evidence that the selection of an appropriate frame can be critical to the overall success of a building project (SCI, 2000; Soetanto *et al.*, 2006b), whether this is measured in terms of cost, programme or a perceived aspect of quality, such as architectural aesthetics, or even energy performance. Clearly, if the structural frame, which is the skeleton that defines and supports the building, can help deliver improvements in these areas this will represent a tangible benefit to the client in the completed building and, if combined with an appropriate form of contract, could result in further cost and time savings. However, one issue which was unclear and under-researched is the link between the form of contract and the structural frame (Paper 3, Appendix C) and specifically the typical level of 'contractual involvement' or influence that the main contractor has on the selection, design or production of the structural frame in a Design-Build project. This warranted consideration in terms of the various types of Design-Build procurement routes, the size of the contractor, the client-main contractor risk relationship, and the stage at which the main contractor is involved both informally and contractually.

2.6 SUMMARY

This chapter has provided an overview of the relevant research that has been conducted within the main areas of research, i.e. the procurement concepts used in the UK construction industry and research on structural frames. The research problem was structured with the contribution from the review of literature, which also helped clarify the aim and objectives of the research (see Table 3.1). The findings of the literature review suggested that the choice of frame and the procurement route adopted are fundamental for a successful project outcome which pointed towards the importance of the early stage of building design where the most important decisions are made, for example, in determining the choice of structural frame, as delineated by the work packages for Objectives 2 and 3 (see Table 3.1). Furthermore, the literature review highlighted the need to look at Design-Build procurement route and its variations (and consequently the need to examine the main contractors' role during design, particularly on the choice of frame type), as outlined by the work packages for Objective 5 (see Table 3.3). As a result, the need for the research is clear and should provide useful recommendations as a means to address potential barriers to improvement in the concrete frame building construction, as required for Objective 6

3 RESEARCH APPROACH

3.1 INTRODUCTION

Conducting any type of research should be governed by a well-defined research methodology based on scientific principles. Such methodologies are considered to be systems of explicit rules and procedures, upon which research is based, and against which claims for knowledge are evaluated (Frankfort-Nachmias and Nachmias, 1996). This chapter gives details of the research design and methodology adopted (in respect of the aim and objectives set out in Chapter 1) and explains the different research types and approaches. It begins with a description of research strategies; the research process is then tabulated in connection with the aim and objectives of this research which is followed by the adopted research methods and reasons for their use in this study.

3.2 REVIEW OF RESEARCH METHODS

Researchers have a wide choice of research methods and each method can be used to elicit a specific type of information or combined to support and complement each other (Kane, 1977; Frankfort-Nachmias and Nachmias, 1996). While five common research strategies are suggested by Yin (1994): experiment, survey, archival analysis, history and case study, Bell (1993) proposes the research styles including; Action, Ethnographic, Surveys, Case Study and Experimental. In addition, Steele (2000) argued the insertion of two more methods; action research and process modelling. Unfortunately, definitions of such styles vary and the boundaries between the styles are not clear (Fellows and Liu, 2003). However, requirements of the major research strategies are set out by Yin (1994) in Table 3.1 below.

Table 3.1 Relevant situations for different research strategies (Yin, 1994)

Strategy	Form of research question	Requires control over behavioural events?	Focus on contemporary events?
Experiment	How? Why?	Yes	Yes
Survey	Who? What? Where? How many? How much?	No	Yes
Literature review	Who? What? Where? How many? How much?	No	Yes/No
History	How? Why?	No	No
Case study	How? Why?	No	Yes

One of the simplest ways of classifying these research methods is whether they are broadly, quantitative or qualitative research. These are discussed below.

3.2.1 Quantitative research

Quantitative approaches tend to relate to positivism and seek to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously (Fellows and Liu, 2003). Brannen (1992) states that quantitative research is concerned with attitudes and large-scale surveys rather than simply with behaviour and small-scale surveys. There are different types of methods that can be used to gather quantitative data including; surveys, experiments and quasi-experiments (SJI, 1999). Of the three types of quantitative research, surveys are the most popular way of collecting data. The survey can comprise many different types of research; these include the questionnaire, structured interview and case studies. The choice is affected by consideration of the scope and depth required. The use of a questionnaire survey is explained in detail in section 3.4.2 of the thesis as it is one of the adopted methods for the research.

3.2.2 Qualitative research

Qualitative approaches seek to gain insights and to understand people's perceptions of 'the world' – whether as individuals or groups. An exploration of the subject is undertaken without prior formulations as the purpose is to investigate the beliefs, understandings, opinions, views etc. of people (Fellows and Liu, 2003). In qualitative research, information is gathered under two categories, namely exploratory and attitudinal research. Exploratory research is used when the researcher has a limited amount of knowledge about the research topic, whereas attitudinal research is used to subjectively evaluate the opinion of a person or a group of people towards a particular attribute, variable, factor or a question (Naoum, 2007). The primary methods of collecting qualitative data are individual interviews, focus groups, direct observation, action research and case studies (Hancock, 1998). Interviews and case studies are also discussed in detail in sections 3.4.2 and 3.4.3 of the thesis as these were part of the approach taken for this research.

3.2.3 Quantitative versus Qualitative Research

Quantitative approaches adopt scientific method in which initial study of theory and literature yield precise aims and objectives with hypotheses to be tested. Qualitative research, on the other hand, consists of detailed descriptions of events, people, interactions and general opinion. Therefore, whilst qualitative data is sometimes assumed a soft option and should be analyzed objectively often using quantitative methods, quantitative data could be assumed 'hard' and is often analyzed using analytical or descriptive statistics. However, qualitative data should not necessarily be assumed to be a soft option as the execution of a worthwhile research project using qualitative methods can be more intellectually demanding than if quantitative methods had been employed (Fellows and Liu, 2003).

Modern construction research benefits from the merits of both approaches (Seymour and Rooke 1995, Wing *et al.* 1998). The comparisons between the two different strategies are demonstrated in Table 3.2 below.

Table 3.2 Quantitative versus Qualitative Research (MacDaniel and Gates, 1998)

COMPARISON DIMENSION	QUALITATIVE RESEARCH	QUANTITATIVE RESEARCH
Types of questions	Probing	Limited
Sample Size	Small	Large
Information/Respondent	Much	Varies
Administration	Requires interviewer with special skills	Fewer special skills required
Types of analysis	Subjective, interpretative	Statistical, summarization
Hardware	Tape recorders, projection devices, video, pictures, discussion guides	Questionnaires, computers, printouts
Ability to replicate	Low	High
Training of the Researcher	Psychology, Sociology, social psychology, Consumer behaviour, marketing, marketing research	Statistics, decision models, decision support systems, computer programming, marketing, marketing research
Types of Research	Exploratory	Descriptive of Casual

3.3 ADOPTED RESEARCH APPROACH

Due to the business context changes during the EngD project it was necessary to have a portfolio of research methods that could be used as and when appropriate based on the contextual requirements at the time. To achieve its objectives, the research was performed in four phases. Each phase was used to form the foundations and shape the next phase and consisted of a number of different work packages, which were developed to tackle the research objectives (Table 3.3). Phase One involved reviewing current literature a focus group with TCC specialist staff to discover the specific needs of the sponsoring organization during the design phase in the concrete frame procurement process. Hence the first research objective was achieved through Phase One. Phase Two comprised carrying out semi-structured interviews with structural engineers and the second focus group which fulfilled the second research objective. Phase Three included the postal questionnaire survey aiming at cost consultants, project managers and construction clients in order to achieve research objectives 3 and 4. Lastly Phase Four entailed undertaking case studies for the research which required a significant depth and breadth of information on a more specific subject. Research objectives 5 and 6 were achieved through the case studies undertaken during Phase Four. The methodology identified above provided a structure and focus of the research, yet maintained the flexibility they required to meet the changing business needs. Table 3.3 below, a research map, illustrates the variety of research methods used along with the work packages with reference to the research objectives during the different phases of the research.

Table 3.3 Research Map; research phases, objectives, work packages, methods and outputs

Overall aim	To examine the structural frame decision making process, focussing on concrete frames and assess to what extent the procurement route adopted can influence the choice of frame for a building project in the UK construction industry			
Research Phases	**Research Objectives**	**Work packages**	**Research Method**	**Research Output**
Phase One	1. To explore the concrete frame procurement process in the design phase	1. Review the structural frame options, particularly the concrete frames and an appraisal of the past and current procurement approaches	Literature review	Internal Report
		2. Identify activities involved during design phase in the concrete frame procurement process		
		3. Discover the specific needs of the sponsoring organization	Focus group	
Phase Two	2. To understand the key issues for the structural frame selection process on a building project	4. Investigate the structural frame selection process	Literature review / Semi-structured interviews	Paper 1 Paper 2 Paper 3 Internal Reports and Presentation
		5. Identify the key issues (criteria) that are important when choosing the structural frame material of a building	Semi-structured interviews	
		6. Recognise the most influential decision makers in the structural frame selection process		
		7. Produce the list of key issues as being the most important affecting the structural frame selection	Semi-structured interviews / Focus group	
Phase Three	3. To develop insights into how important these key issues are to the decision makers identified when choosing which structural frame material to use building projects	8. Rank the key issues affecting choice of structural frame for a building project	Postal Questionnaire	
	4. To investigate the views of key decision-makers concerning the roles of project team members involved in choosing the structural frame at each key stage in the design process	9. Assess the influence of project team members upon choosing appropriate frame material for a building project		
Phase Four	5. To evaluate the influence of the main contractor in the structural frame decision-making process of building projects, with an emphasis on concrete frames, when using a Design-build procurement route	10. Examine the Design-build procurement and its use	Literature review / Case studies	Paper 4 Paper 5 Internal Reports and Presentation EngD Thesis
		11. Investigate the contractor involvement in Design-build projects	Case studies	
		12. Evaluate the contractors influence in relation to the structural frame selection process		
	6. To provide recommendations to help deliver an improved and efficient concrete frame building project when using a Design-build procurement route	13. Determine the potential areas of improvement relate to the structural frame decision-making process		

In order to make sure that the correct research methodology was selected and that each objective was assigned the right methodology, the factors used for choosing the research methodology were considered carefully and the relationship between the research objectives and the research methods was established. All stages of this research are eminently repeatable in principle as they employed conventional research methods, however, access to the precisely the same sets of subjects may not be possible because of the research's use of the sponsoring organisations confidential database. That said, it would be straightforward to emulate the survey and case studies through selection of similar subjects and project teams. It was important to ensure that the adopted research methodology achieved the research aim and objectives. By making sure that every objective was assigned the appropriate method(s).

The main priority in determining the most appropriate approach to adopt, is to ensure that research maximizes the chance of realizing its objectives (Fellows and Liu, 2003). Therefore, the research design took into consideration the research objectives (see section 1.2) and the type of data needed. In addition, since the aim of the Engineering Doctorate (EngD) Scheme requires that the research would contribute to the performance of the sponsoring organisation (CICE, 2006), the involvement of key members of the sponsor's staff in the research was vital in ensuring that the research delivered the results required, and that the solutions developed were integrated effectively within the organisation. It also provided feedback on the impact of the research on the business and supported buy-in to the research from staff.

As a result, considering the philosophy of the Engineering Doctorate (EngD) programme, which is to undertake practical research within an industrial environment;

action research was selected as the most appropriate underlying research approach for this study because this associates research and practice, so research informs practice and practice informs research synergistically (Avison *et al*., 1999). Although action research is considered to be qualitative, it can involve the collection of both quantitative and qualitative data (Greenwood and Levin, 1998; Fellows and Liu, 2003). For this research a combination of both ‘quantitative research’ and ‘qualitative research’ was found favourable in order to achieve the research aim and objectives successfully. Both strategies were therefore adopted in this research which led to the use of range of research methods for the duration of the EngD programme; these are detailed in the section 3.4. Action research is first described below in more detail.

3.3.1 Action Research

Action research is defined as an approach in which the researcher and a client (in this case The Concrete Centre) collaborate in the diagnosis of a problem and in the development of a solution based on the diagnosis (Bryman, 2001), Saunders *et al*., (2007) describes it as “*a research strategy concerned with the management of a change and involving close collaboration between practitioners and researchers*”. In action research, the emphasis is more on what practitioners actually do. Action research combines theory and practice (and researchers and practitioners) through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework (Avison *et al*., 1999). As a result, in action research, the researcher wants to try out a theory with practitioners in real situations, gain feedback from this experience, modifying the theory as a result of this feedback, and try it again (Avison *et al*., 1999). Fellows and Liu (2003) note that inasmuch as action research is designed to suggest and test solutions to particular problems, it falls within the applied research category, whilst the process of detecting the problems and alternative courses of action may lie within the category of basic research; the consideration of quantitative v. qualitative categories may be equally useful.

Action research is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning (Avison *et al.*, 1999). Fellows and Liu (2003) also noted that as change/innovation is the subject matter of the research, coordination and evaluation mechanisms are necessary which involve both the researcher and the participants. This research study met all the above-mentioned requirements for action research to be successful. Also, successful action research is unlikely where there is conflict between researchers and practitioners or among practitioners themselves (Avison *et al.*, 1999), which was not the case in this research study. Thus, by emphasizing collaboration between researchers and practitioners, action research appeared to represent an ideal meta-method over the course of the four-year EngD programme within the sponsoring organisation.

3.4 ADOPTED RESEARCH METHODS

Due to the broad scope of the study and the industrial context of the research, a wide range of research methods was adopted to achieve the research aim and objectives. Given the industrial context of this project the research methodology evolved as the research project progressed. As a result, three research methods were used in this research study; literature review, survey (interviews, a postal questionnaire and focus groups) and case study. Each method is explained in the following sub-sections; further details are provided in Chapter 4 which presents the research undertaken.

3.4.1 Literature Review

A literature review is defined as the compilation and assimilation of as much information as can be ascertained with regard to a given subject matter (Humphrey, 2005). The literature review helps stimulate for the thinking of the researcher on the previous work that has been undertaken in the subject domain (Fink, 1998). A comprehensive review of both academic and industry literature was undertaken to gather information for this research project. It was decided to focus the literature review on the research question, i.e. examining whether the concrete frame procurement process can be improved by optimising the structural frame decision making process. This necessarily meant examining the literature surrounding the construction project process and specifically the literature dealing with the structural frame selection process. The key words to focus the search, and this thesis, were concrete frames, procurement, project stakeholders, design, building and structural frame.

It was expected that the previous studies in this field would be very limited due to the scant research and recent technological breakthroughs in the concrete frame industry. Therefore, it was considered that the principal source of information would be recent articles and surveys published in professional journals and magazines. Hence, the information for the literature review was mainly collected from journals, magazines, the Internet, the library of The Concrete Society (TCS) and MetaLib. The literature review provided the basis for four of the work packages, Work Packages 1 and 2 and parts of Work Packages 4 and 10. The literature review was mainly used to complete the Work Packages 1 and 2 so as to achieve the first research objective during Phase One of the research (see Table 3.3). It is often the case that research reports based on a literature review identifies additional questions that would be fruitful to pursue (Burns, 2000). In this case, the literature review helped define the problem and indicated the areas, i.e. main contractors' involvement in Design-Build projects (Objective 5) that should be further investigated in order to satisfy the research objectives (see section 2.5). Thus, the literature review was ongoing throughout the research.

3.4.2 Survey

The main purpose of a survey is to collect information systematically from, or about, a defined set of cases (e.g. people, organisations, objects) (Thomas, 1996). Survey questions typically concern facts, knowledge and opinions, and appear in two primary forms – open and closed (Fellows and Liu, 2003). The nature of information required for this research, both quantitative and qualitative (exploratory), pointed towards the use of both closed (structured) and open questions. Surveys may be undertaken in many different ways; these include the questionnaire, structured interview and case studies. The choice is affected by consideration of the scope and depth required. Further details on survey aim and objectives, target population, questionnaire composition, method of distribution and the returns are given in Chapter 4 of this thesis and Paper 1 (Appendix A).

a) Questionnaire

The questionnaire is an important instrument of research, a tool for data collection. Questionnaires occur in two primary forms – open or closed. Open questions are designed to enable the respondent to answer in full; to reply in whatever form, with whatever content and to whatever extent the respondent wishes. Closed questions, have a set number of responses as determined by the researcher (Fellows and Liu, 2003). In general, closed questions are easier and quicker to answer; they require no writing, and quantification is straightforward. Disadvantages of closed questions are the loss of spontaneity and expressiveness. Open or free-response questions are not followed by any kind of choice, and the answers have to be recorded in full. Free-response questions are often easy to ask, difficult to answer, and still more difficult to analyze (Oppenheim, 1992). The goal of writing a survey questionnaire for self-administration is to develop a query that every potential respondent will interpret in the same way, be able to respond to accurately, and be willing to answer (Dillman, 2000). Each person has been requested to respond the same set of questions, therefore, it provides "an efficient way of collecting responses from a large sample" (Saunders *et al.*, 2000). When developing a questionnaire, the following items should be justified (Walker, 1997):

1. The purpose for asking it;
2. Its format;
3. The manner in which data gathered will be analyzed.

A questionnaire was used to carry out Work Packages 8 and 9 so as to achieve Objectives 3 and 4 of the research during Phase Three (see Paper 1, Appendix A; Paper 2, Appendix B; Paper 3, Appendix C). It was required to discover the key factors that project team members typically consider when choosing the type of a structural frame for a building. Therefore questions were designed to elicit this information with care taken so as not to bias any answer. All of the questions were closed questions, but had the ability to be open with the option of 'if other please specify'.

Furthermore, it is always desirable, if at all possible, to conduct a pilot study before administering a self-completion questionnaire to the sample. A pilot study allows the researcher to determine the adequacy of instructions to respondents completing a self-completion questionnaire (Bryman, 2004). In fact, it can sometimes be difficult to assess objectively how a questionnaire in which the researcher is involved will work (McGivern, 2003). Pilot-testing refers to testing the questionnaire on a sample of respondents to identify and eliminate potential problems (Malhotra and Birks, 2000). Having developed the questionnaire, a pilot study was carried out with a sample of nine people from TCC, Loughborough University and the construction industry to see how they understood the questions and the response options. It allowed the researcher to evaluate the impact of word selection, question sequencing, timing, and various formatting and layout issues (see Appendix F for an example of the survey instrument).

b) Interviews

The research interview is a prominent data-collection strategy in both quantitative and qualitative research (Bryman, 2004). Interviews vary in their nature, they can be: structured, semi-structured and unstructured. The major differences lie in the constraints placed on the respondent and the interviewer (Fellows and Liu, 2003). The structured interview is essentially a questionnaire, but without the restrictions on the respondent when answering. The structured interview does not provide great ability to probe ideas further, as the questions are set but some area for investigation is available. However, semi-structured interviews can yield a variety of kinds of information. Even within one interview a researcher could (Drever, 1995):

- gather factual information about people’s circumstances;

- collect statements of their preferences and opinions;
- explore in some depth their experiences, motivations, and reasoning.

The term ‘semi-structured’ means that the interviewer sets up a general structure by deciding in advance what ground is to be covered and what main questions are to be asked. This leaves the detailed structured to be worked out during the interview. The person interviewed can answer at some length in his or her own words, and the interviewer responds using prompts, probes and follow-up questions to get the interviewee to clarify or expand on the answers.

Because of these attributes, it was decided to undertake semi-structured interviews as part of the survey strategy used in four of the work packages, namely Work Packages 4,5,6 and 7 to highlight the key issues to structural frame selection process and therefore fulfil Objective 2 during Phase Two of the research (see Table 3.3). Semi-structured interviews enabled the RE and the respondents to have more flexibility than conventional structured interviews, while also providing a loose enough structure to enable the RE to cover all key topics and areas of the research investigation. All interviews were recorded and subsequently transcribed verbatim and analysed. The feedback from the interviews was also produced as a report and was then circulated to the interviewees (see Appendices G, for examples of the survey instrument)

c) Focus groups

Focus groups are a form of qualitative research, which can serve a number of different uses. In the self-contained uses, focus groups serve as the primary means of collecting qualitative data, just as participant observation or individual interviewing can serve as a primary means of gathering data. In supplementary uses of focus groups, the group discussions often serve as a source of preliminary data in a primarily quantitative study. In multi-method uses, on the other hand, focus groups typically add to the data that are gathered through other qualitative methods (Morgan, 1997).

Two focus groups were used at different stages of the research; they were in the form of Internal Workshops within the sponsoring organisation. The combination of focus groups and interviews undertaken with a selection of structural frame specialist staff (structural and civil engineers) of the sponsoring organisation were critical to the research in getting the sponsoring organisation's staff involved in the research at the outset and thus providing a structure of future collaborative activities for the next research phases. For instance, during Phase One of the research a focus group approach was primarily carried out for Work Package 3 to discover the specific needs of TCC and thus to fit those needs with the research objectives in order to produce the results from which TCC would benefit, plus enabling active collaboration between the TCC's staff and the RE. Another focus group was also held during Phase Two of the research together with the interviews for Work Package 7 so as to generate the final structure of the survey questionnaire. As with the interviews, transcript summaries were compiled (see Appendix H).

3.4.3. Case study

A case study is the method of choice when the phenomenon under study has not been investigated within its context (Yin, 2003; Fellows and Liu, 2003), or, as Naoum (2007, p.45) puts it:

> *"Case studies are used when the researcher intends to support his/her argument by an in-depth analysis of a person, a group of persons, an organization or a particular project"*

An advantage of the case study method is that it may be possible to make generalizations, but may not be possible to reject existing generalizations (Casley and Lury, 1982). Case study methods allow investigators to retain the holistic and meaningful characteristics of real-life events – such as individual life cycles, organizational and managerial processes, neighbourhood change, international relations, and the maturation of industries (Yin, 2003). Most studies look for what is common and pervasive, whereas the intent of the case study may not be generalization but rather to understand the particulars of that case in its complexity (Key, 1997). However, a common criticism of case study methodology is that its dependence on a single case renders it incapable of providing a generalizing conclusion (Tellis, 1997). To mitigate this problem, Hamel *et al.*, (1993) and Yin (1994) argue that the goal of the study should establish the parameters, and then should be applied to all research. Thus, even a single case could be considered satisfactory as long as it fulfilled the established objectives.

Yin (1994) asserts that case study research can be based on a (2 X 3) typology design, i.e. single- or multiple cases mapped with exploratory, descriptive or explanatory study. Whilst a single case study needs only to focus on one case, in multiple-case studies, cases should be selected so that they are replicating each other or predictably different (systematic) replications. Thus, due to the diversity of company size and structure, an exploratory case study design based on multiple cases with single units of analysis was adopted for this research, in accordance with guidance offered by Yin (2003). As a result, during Phase Four of the research a significant depth and breadth of information was required that led to the use of the case study as a research strategy in assessing the influence of main contractor in structural frame decision making process when using Design-Build. As the main advantages of case study research include richness of data and deeper insight into the phenomena under study (Hancock, 1998), multiple cases need to be employed to ensure that the results present a breadth and depth of main contractors' involvement in Design-Build projects (Objective 5). Case studies were used to undertake Work packages 10, 11, 12 and 13 during Phase Four of the research in order to satisfy the Objectives 5 and 6. Section 4.4 provides details of the case study protocol and the results of the case studies undertaken.

3.5 LIMITATIONS

This section will discuss the key limitations affecting the research relating to the research methods and the research environment. The quality of research findings is dependent on the choice of research methodology, the data gathered, and the statistical tools used (Walker, 1997). The reliability of the results can be influenced by the validity of the research instrument (e.g. the questionnaire), the validity of the data gathered, the appropriate use of statistics and the validity of the conclusions drawn. The research methods selected in this research did have their limitations; the effects of these on the validity and reliability of the research data is discussed below.

Questionnaire survey: Survey techniques, such as questionnaires, interviews etc., are highly labour intensive on the part of the respondents and particularly on the part of the researcher; one consequence can be a low response rate. The limitations of the survey can be divided into two categories. The first category comprises the limitations inherent in almost every postal survey such as low response rate, missing data, the length of the questionnaire, etc. However, the second category contains the limitations which are pertinent to this survey, as follows:

- Since the postal questionnaire was sent through the post from The Concrete Centre to the respondent, it may have been presumed that the main thrust of this survey was about concrete frames rather than structural frames generally; this was partly addressed by the covering letter and careful wording of the survey instrument.
- The survey needed to be answered by a specialist already involved in the selection of a structural frame for a multi-storey building, so the results may not reflect all levels of expertise within the industry.
- The number of key issues in the questionnaire was restricted to ten; this was to reflect the level of importance but also to enable the respondents to provide timely responses but may this have inadvertently imbalanced the results.
- There has been a huge increase in the importance and awareness of sustainability since the date of issue of the survey and therefore some of the results could be considered to be out of date; all research is time-limited so issues like this are somewhat inevitable.

Case study research: candidates for potential case studies were found through the results of a previous questionnaire survey (see Paper 1, Appendix A), within which respondents had volunteered specific building projects for consideration. Although the returned sample of the survey was considered to be representative of the actual decision-making population (Paper 1, Appendix A), it would be very useful to conduct case studies from a different sample which had not been investigated in order to further validate the reliability of the survey sample. Furthermore, it is not possible to generalise from the four case studies and individual interviews undertaken may not be representative of the corporate body. However, it is hoped that the findings presented provide in-depth knowledge about the nature of Design-Build projects in the UK.

Finally, working in TCC necessarily meant that the researcher needed to respond directly to the priorities for the sponsoring organisation, TCC, which included using its own database for contacts; this context may also have influenced objectivity to some degree when undertaking the research, i.e. in perhaps not fully considering the disadvantages of concrete, the drawbacks of concrete construction, etc. However, this bias was eliminated, if not reduced considerably, by reading professional journals and magazines in order to gauge the industry's perception towards structural frame materials. Also, the researcher was cognisant of this possibility from the outset and was always mindful to avoid bias. As a result, any such bias has not had a significant effect on the results.

3.6 SUMMARY

This chapter has discussed the research strategy adopted for the EngD research project. The application of both quantitative and qualitative research approaches which was based on action research methodology proved to be more powerful than one single approach in this type of research domain. The research work packages introduced in Table 3.3 were achieved by employing a range of research methods during the four phases for fulfilling the research objectives, namely: literature review; focus groups; interviews; questionnaire survey; and case study research. The key limitations have also been outlined in this chapter.

4 THE RESEARCH UNDERTAKEN

This chapter presents the research undertaken to meet the aim and objectives of the EngD research project that were introduced in Chapter 1 and explained further in Chapter 3. The research was conducted in line with the research approach described in Chapter 3. Where references are made to the appended papers, the reader is requested to read each paper in its entirety.

The research took four phases to fulfil the research objectives (see section 1.2) for the four-year EngD research. To achieve integration, each phase was used to prepare and develop the subsequent phase (see Table 3.3).

4.1 PHASE ONE – CONCRETE FRAME PROCUREMENT PROCESS

This phase involved reviewing current literature and a focus group with TCC structural frame specialist staff (structural and civil engineers) in order to achieve Objective 1 - *Explore the concrete frame procurement process in the design phase* – of the research. For this research, the term of "design" is meant to cover the RIBA Plan of Work Stages C (Concept), D (Design Development) and E (Technical Design) (RIBA, 2007). Phase One was aimed at analysing initial observations with regard to the research objectives developed from the literature review and the focus group with TCC's staff. The results obtained are summarised in the following sub-sections.

4.1.1 Identifying the activities involved in concrete frame procurement process

As part of the preliminary information gathering, a literature review was initially carried out to obtain an insight into procedures and processes implicated during the design phase of the concrete frame procurement process. Therefore, the focus was looking at the process of project procurement, project procurement frameworks, structural frame selection, structural frame materials, and identifying the procurement routes and contract types already in use. The literature on these topics led to a better understanding of project procurement process in the design phase, and provided the researcher with in-depth understanding and knowledge about development and issues in relation to procurement approaches and structural frame options, particularly concrete frames. A paper was also produced from the literature reviewed which aimed to identify the issues and problems pertaining to this procurement-process-product relationship, examine concrete's fitness for the new procurement paths and raise awareness about this subject. This paper was presented in September, 2006 at the Concrete Communication Conference at University College London (UCL) (Haroglu *et al.*, 2006).

Chapter 2 provides details of the literature review undertaken, but the key areas explored are reiterated here.

Research, statistics and anecdotal evidence over the past fifty years in the UK construction industry indicate that it suffers from numerous problems, not least of which is its reputation for not meeting clients' needs (NEDO, 1974; NEDO, 1983; RIBA, 1993). Evidence of this poor performance is shown in a report from the National Audit Office (2005), which concludes that failure to fully implement best practice procurement and project management in central and local government currently costs £2.6bn a year in terms of avoidable capital and operating costs (Rawlinson, 2006b). Furthermore, a study by Bath University revealed that 73% of public contracts in the UK exceeded the tender price, while 70% were delivered late (Brewer, 2006). The increasing complexity of modern structures together with the incorporation of the elements such as sustainability and whole-life value have encouraged the construction industry to consider new procurement approaches as well as the optimal structural solution (Rawlinson, 2006). Moreover, the problem is exacerbated in the construction industry by the insularity of the professions; the separation of design from construction; the uniqueness of projects and the ephemeral nature of the relationships and project organization (Masterman, 2006).

More recent views from the construction industry suggest that new procurement approaches and structural frame options will inevitably be considered by clients and contractors as offering a way of better meeting project objectives (Sullivan, 2006; Rawlinson, 2007). Within this context, the structural frame plays a significant role in projects' success and accounts for a major portion of project costs, directly and indirectly. Of the options available, concrete offers the structural engineer a wide range of material choices and construction forms to choose from to meet design constraints and performance requirements (TCC, 2006). However, like the construction industry as a whole, concrete construction has been criticized for its poor productivity (e.g. Latham, 1994; Egan, 1998), but research and development has helped to improve various aspects of construction (e.g. Gray, 1995; Nolan, 2005) and is continuing. This all means that concrete can help provide the optimum structural solution to the ever-changing demand for building projects. A report from the BRE (Nolan, 2005), which examined innovation in concrete frame construction over the past 10 years states in the concluding comments that concrete frame construction has the potential and the ability to improve upon its current performance in the future.

4.1.2 Focus group – TCC's requirements for the research

The purpose of this event was for the participants to openly discuss the issues needed to be considered during the design phase of the concrete frame procurement process indicating where the opportunities and barriers lie for the sponsoring organisation, in order to promote concrete in the UK framed structure market. The focus group was held in April 2006 with a selection of structural frame specialist staff (7 structural and 2 civil engineers, plus 1 cost consultant) of TCC; and it was facilitated by the researcher. The meeting provided an opportunity both to fit the objectives of the research project with the business objectives of TCC and to interact with the members of TCC that each had a different perspective on procurement process.

As previously stated TCC is an organisation which aims to assist all those involved in design and construction to realise the full potential of concrete. Therefore it was decided that the main purpose of the research project should be to help TCC to develop its marketing plan, by identifying:

→ The target audience – who the key decision makers are on a building project in relation to what frame type to use;

→ Key issues – what the most important issues are to clients and other decision makers involved when choosing the structural frame type of a building project.

4.1.3 Phase summary

Phase One involved a literature review and an internal focus group with reference to Objective 1 (see Table 3.3). The literature review provided the researcher with information about concrete frame procurement process. Secondly, the internal focus group with TCC specialist staff gave a clear understanding of the specific needs of the sponsoring organization which ensured that the research objectives were in line with those of TCC throughout the research. As a result, these activities provided insight to the key areas that should be further investigated in order to help TCC to increase the use of concrete frames in the UK-framed-structures market.

4.2 PHASE TWO – THE PROCESS OF STRUCTURAL FRAME SELECTION

At this phase, the research incorporated a further review of literature, semi-structured interviews and an internal focus group in order to fulfil the research Objective 2 - *Understand the key issues for the structural frame selection process on a building project* (see section 1.2) which had been clearly re-defined as a result of the research undertaken at Phase One. Since the form of structure is normally considered, refined and developed during the early design stages in response to project and/or client requirements (Ballal and Sher, 2003; Soetanto *et al*., 2006b), for this research the term of 'early design' is intended to cover the RIBA Stages C (Concept) and D (Design Development) (RIBA, 2007).

As mentioned in Chapter 2, the choice of frame type was heavily influenced by the issues specific to that project (Bibby, 2006). However it was found that, in addition to project specific factors, there were many other issues influencing frame choice. To date these 'other' issues have not been fully taken into consideration in theories about the choice of structural frame type. It is these 'other' issues which were the focus of this phase of the research. The research undertaken at this phase is described below.

4.2.1 Understanding the structural frame selection process

A further literature review was therefore carried out which the focus was to identify any studies that had exclusively examined the structural frame selection process. Gray (1995) emphasized in the report "In situ Concrete Frames" that the process must be understood so as to achieve improvement and before the process of improvement can commence it is necessary to understand the scope of the issues around it. Although the choice of frame is heavily influenced by the issues specific to that project, there are a number of issues that are commonly considered by project participants when choosing the frame type. The choice of primary structure is generally determined by cost with less regard to functionality and performance characteristics (SCI, 2000). This is further corroborated by Idrus and Newman (2003) who state that frame selection criteria often focus on cost and time requirements and a previous survey by Soetanto *et al.*, (2006b) identified 31 issues perceived to be important in influencing the structural frame decision-making process (see section 2.4.1).

There is abundant literature on structural frame options, concrete frames, procurement options and forms of contractual arrangements, but much less was on the structural frame decision-making process and even less information was obtainable on the relevance of the choice of structural frame type in influencing the concrete frame procurement process during the design phase. It was therefore decided to undertake semi-structured interviews so as to obtain information in relation to the structural frame decision-making process.

The semi-structured interviews were undertaken with structural engineers from selected consultancies to obtain information in relation to the structural frame decision making process. As the profession for whom structural frame design is a core competence, it was considered appropriate to target a small group of these individuals in the first instance to explore a range of questions about structural frame choices. Nine interviews were carried out in total over a two-month period as reported in Paper 1 (Appendix A). The overall aim of the semi-structured interviews was to probe into the construction industry to identify both the decision makers involved and the rationale behind the selection of structural frame for building projects. These interviews were also intended to provide the context and support data for a later postal questionnaire survey (see section 4.3). Each interview was recorded and subsequently transcribed verbatim and analyzed. Four of the nine interviewees strongly believed that the client and the cost consultant determine the choice of frame for a building project. Three interviewees referred to client and project manager being the most influential in selecting the frame. Another two interviewees considered that the decision on the choice of frame is made by the design team led by the structural engineer. Therefore, one of the main outcomes from the interviews was that, cost consultants, project managers and clients were considered to be the most influential people in the structural frame selection process, more so than the structural engineers themselves. Furthermore, although the semi-structured interviews confirmed that the choice of frame is heavily influenced by the issues specific to the particular project in hand, it was possible to identify a list of generic selection criteria for the choice of frame because the engineers were asked to identify what they considered to be the most important generic issues in frame selection, regardless of location or project. So, a list of the key issues relevant to structural frame selection was compiled and the intention thereafter was to collate cost consultants', project managers' and clients' reactions to the validity of these issues, but before that, a facilitated half-day internal focus group with a selection of structural frame specialist staff (one cost consultant, seven structural and civil engineers) was held to refine the wording of the final list of issues, with the aim of using it in a postal questionnaire survey to the aforementioned groups in Phase Three.

4.2.2 Key issues influencing the choice of frame type

The internal focus group was then geared towards facilitating questionnaire development which was subsequently undertaken.

The objectives set for the event were as follows:

- To refine the wording of the final list of key issues associated with the choice of frame type for a building project those were determined as a result of the literature review and semi-structured interviews in order to be used in the questionnaire survey.
- To structure the questionnaire survey.

The focus group was held in January 2007 with a selection of structural frame specialist staff (8 structural and 1 cost consultant) of TCC; and it was facilitated by the author. As a result, the final list of the key issues was refined so as to be used in the questionnaire survey and the questionnaire format was decided, i.e. lay-out, format of the questions, phrases, in order to obtain the required data. It was also decided that the work stages of the RIBA Plan of Work (2007) would be used in the questionnaire survey (see Appendix F) as the stages are the most generic and applicable to the UK construction industry. Hence, for this research the design stage consists of three parts: Stage C (Concept), Stage D (Design Development) and Stage E (Technical Design). As a result, the ten key issues identified are as follows (shown as presented in the survey; Appendix F):

Table 4.1 Key issues influencing the choice of frame type

No	Issues	Explanation
1	Architecture	Aesthetic issues, layout, etc.
2	Building Use/function	Fire resistance, durability, acoustics, Span, Adaptability to later modifications, etc.
3	Cost	Design and Construction Cost
4	Preference	Preference for a particular frame type
5	Programme	Speed of construction
6	Risk	Client needs, the market, expenses, certainty of delivery etc.
7	Site	Site accessibility, ground conditions, height restrictions, party wall agreements.
8	Size of building	Number of floors / m^2
9	Supply chain capability	Flexibility in the layout of services, ease of supply of materials
10	Sustainability	Durability, recylability, environmental impacts, thermal mass, whole life cost, etc.

4.2.3 Phase summary

Having undertaken an additional literature review, semi-structured interviews and a focus group, 10 key issues were identified as being the most important to the structural frame decision-making process, and the questionnaire was structured accordingly. The semi-structured interviews also found that cost consultants, project managers and clients are the most influential people in the structural frame selection process.

4.3 PHASE THREE – EXAMINING THE STRUCTURAL FRAME SELECTION PROCESS

The postal questionnaire survey (see Appendix F) was undertaken during this phase; which was intended to satisfy both Objective 3 – *Develop insights into how important these key issues are to the decision makers identified, when choosing which structural* *frame type to use on building projects* and Objective 4 - *Investigate the views of key decision-makers concerning the roles of project team members involved in choosing the structural frame at each stage in the design process* (see section 1.2). The survey was aimed at three disciplines, namely cost consultants, project managers and clients, since they were identified by structural engineers as most influential in the structural frame selection process[*]. The primary objectives of the questionnaire survey were to:

- present the key issues in order of importance for project team members to consider when choosing an appropriate structural frame for their building projects during the early design phase;
- identify the divergent and convergent opinions of project managers, cost consultants and client on the key issues identified when choosing the structural frame type;
- examine the variations, if any, between what these parties themselves think of the issues and what others perceive their attitudes to be; and
- provide a view of the different professions, decision makers involved in choosing the structural frame at each key step of the design process.

A pilot study was then carried out with a sample of nine people from both industry and academia to test its legibility and speed of completion. As a result of the pilot study, a few alterations were made to the questionnaire and soon afterwards it was

[*] Having already interviewed structural engineers, it was not considered necessary to issue the questionnaire survey to this population. Rather, it was decided to target the other parties because they are not typically given consideration in research on structural frame selection, which could be a major gap in knowledge, if one considers the opinions of the interviewed engineers as representative of reality

distributed amongst construction clients, cost consultants and project managers to meet its objectives.

The individual respondents were selected randomly from a database of professionals held by The Concrete Centre (TCC), the total size of which is around 25,000 names, not all of whom would be able to comment on this subject matter. Analysis of suitability (based on company activity, regardless of size) resulted in 239 postal questionnaires being sent to a sample of selected individuals, working for cost managers, project managers and client bodies, in the public and private sectors. As a result, 70 questionnaires were received in total, giving an overall response rate of 29.3% which is considered sufficient compared with the norm of 20-30% with regard to questionnaire surveys in the construction industry (Akintoye and Fitzgerald, 2000); Cronbach's Alpha coefficient was 0.812, which is also considered acceptable in terms of research reliability. Of the responses received, 20 were from cost consultants, 25 from project managers and 25 from construction clients (see Paper 1, Appendix A). The questionnaire asked respondents to base their answers on their most recent project to start on site. It was found that Design-Build (D&B) is the dominant form of contract, being used by 50% of those people surveyed. A detailed description of the methodology and analysis of questionnaire survey is given in Paper 1 (Appendix A).

To ensure each individual's credibility, the respondents were asked about their influence over the choice of frame for a building project. By their own judgement 44% of the respondents believed they had a great deal of influence over the choice of frame for a building project, 31% of the respondents thought they had some influence. This suggests that the respondents were generally influential in the structural frame selection, and possessed sufficient knowledge in the structural frame decision-making process. Also, senior representatives from three major contractors (with annual turnovers over £500m) were approached to comment on the findings of the survey but this was largely, a “sanity check” to reassure TCC. These respondents indicated that the findings appeared to reflect what they experienced in industry, corroborating the survey results. The survey results are summarized below; a more detailed account, in relation to the survey objectives, is provided in Paper 1 (Appendix A), Paper 2 (Appendix B) and Paper 3 (Appendix C).

4.3.1 Ranking the key issues influencing the choice of frame type

The aim here was to evaluate the views of the respondents to the survey, i.e. cost consultants, project managers and construction clients on the ten key issues and, hence, the structural frame selection process. As stated earlier, the list of issues was developed into a questionnaire which was designed to capture practitioners’ perceptions of the relative importance of each issue at the early design.

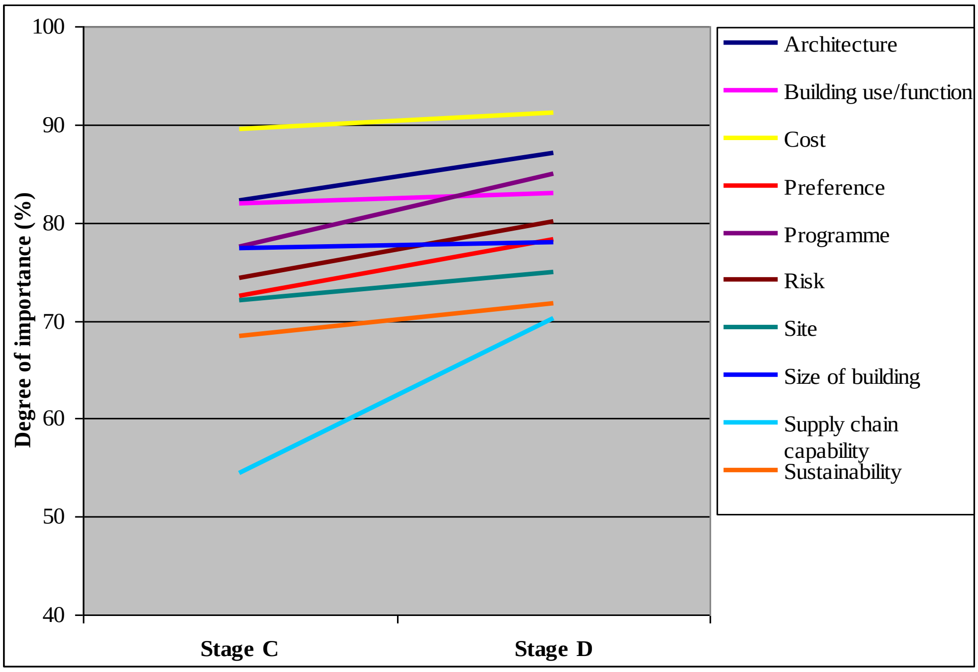

Figure 4.1 Opinions of the respondents of the relative importance of each issue at each stage of ‘early design’

All the project team members discussed the choice of the frame type in terms of what each hopes to gain from the project which means that each participant should be asked to describe what they will require for the project to be a success. There is, however, no precise prescription of what constitutes a successful structural frame selection process, but the findings of this study provide a basis for assessing professional perspectives on structural frame selection. The literature and the findings of the survey confirmed once more that a primary determinant in the structural frame choice is cost, but architecture was also seen to be important. The results revealed that all of the ten issues included in the list were considered to be important, confirming the validity of the criteria as a basis for consideration in structural frame selection. Furthermore, although it can be argued that cost consultants, project managers and clients necessarily understandably have fundamentally different points of view, a Spearman's rho (ρ) test revealed that there was strong agreement amongst the cost consultants, project managers and clients over the significance of the ten key issues affecting the selection of a structural frame for a building project. The ranking of these issues at early design stages could therefore be adopted as the fundamental criteria for assessing and selecting a structural frame for a building project. As a result of these findings, construction practitioners will have the benefit of an understanding the perceptions of the cost consultants, project managers and clients on the key issues which proved to be vital to the structural frame selection process, but further exploration of the linkages between such issues would be a useful addition to this work. A more detailed account regarding above is provided in Paper 1 (Appendix A) and Paper 2 (Appendix B).

4.3.2 Differences in perception

In this part of the analysis, any differences in attitude were examined. This was to provide construction practitioners with an insight into the perceptions of the three groups about the attitudes of each other towards the key issues. There is however, a notable gap between what the three groups themselves think of the key issues and how they perceive one another, particularly the clients. For instance, contrary to the perceptions of cost consultants and project managers about clients, clients pay significant attention to the issue of 'Architecture', whereas they attribute a low importance to 'Building use/function'. The project team should therefore focus on clients' needs and on ways of recognising those needs in order to choose the most appropriate structural frame option. There is a worthwhile study in the area of self- and peer-group perception. As the quote by one of the major contractors commented, anecdotally; *"The benefit would be that if the industry understood the mind of the Client better, we would give a better service."* Paper 1 (Appendix A) provides the survey results, in relation to the differences in perceptions, in more detail.

4.3.3 Key decision makers in the structural frame selection process

Cost consultants, project managers and clients were surveyed in an attempt to better understand their views of the relative influence of each project team member on the choice of frame type. The purpose was to establish the significance and ranking order of the project team members.

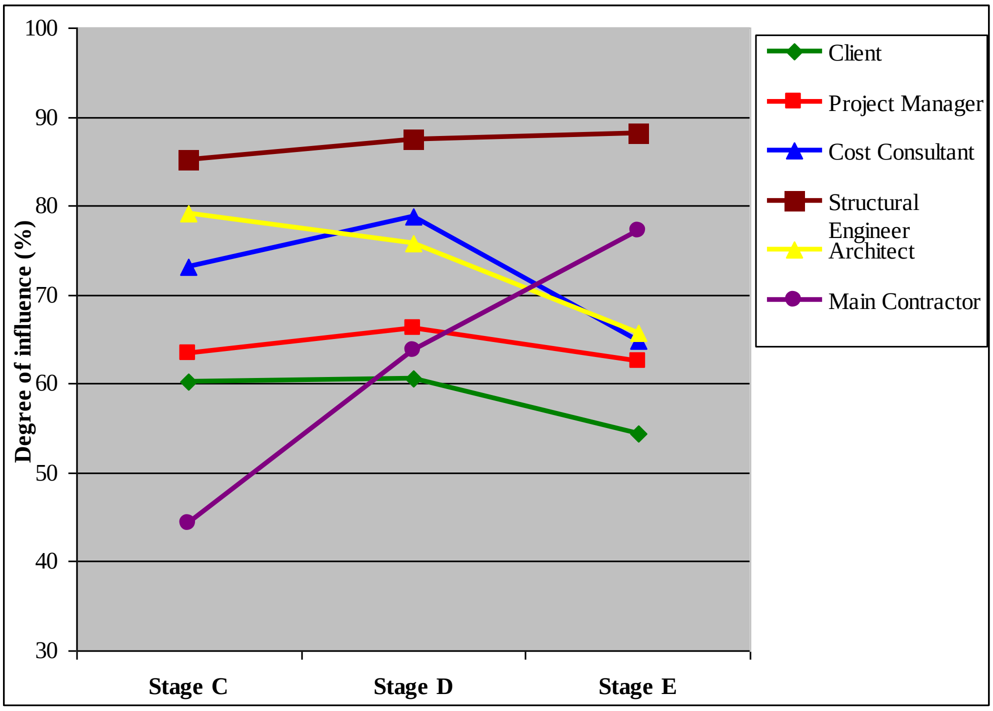

Figure 4.2 Respondents' view of the influence of the project team members at all design stages

As a result of the questionnaire survey, the structural engineer was shown to be the most influential decision-maker in the choice of frame at each stage of design process. This is in contrast to the results of semi-structured interviews carried out with the structural engineers earlier on in this phase of the research. Furthermore, it was found that the contractor's influence is particularly high, as perceived by the respondents, at stages D and E which indicates that contractors could make quite an impact on the choice of frame type for a building project. However, it was not clear whether the main contractor could exert influence to change the frame type or any specifications of a building project after being involved. Hence there was a gap in knowledge about who the key decision maker is and the role of the contractor now appeared to be the next clear area of focus for research. Indeed this was taken forward and formed Phase Four. The survey results, in relation to the rank of decision-makers of the structural frame selection process, are provided in more detail in Paper 3 (Appendix C).

4.3.4 Phase summary

A questionnaire survey was distributed to UK cost consultants, project managers and clients. A total of 70 detailed responses were received and analysed, providing a number of useful insights into the way professionals make choices about structural frame materials. These included: agreement amongst the respondents on the significance of the ten key issues in the structural frame selection process, a notable gap between what the three groups themselves think of the key issues and how they perceive one another and the increasing influence of the main contractor as the design develops. In conclusion, the opinions of the respondents of the relative importance of the ten key issues at each 'early design' stage can give construction practitioners a good indication of the needs and priorities of their clients. This is further supported by the comments from one of the three major contractors approached: *"These trends do appear to reflect opinions I have come across"*. Above all, the ranking of these issues at early design phase could be adopted as the fundamental criteria for assessing and selecting the structural frame type for a building project. In addition, the findings can give construction practitioners an in-depth understanding in the frame industry. For instance, it is evident that Design-Build was predominantly used in the survey projects, 50% of survey projects, and 'Main Contractor' appeared to have a significant input at both stages D and E, which means that main contractors can have a surprisingly influential role in the structural frame decision making process and thus they could be a major audience for TCC in the UK-framed-structures market.

4.4 PHASE FOUR – THE ROLE OF CONTRACTORS IN DESIGN-BUILD PROJECTS

The procurement process plays a significant role in project success and determines the responsibilities of project team members (Rowlinson and McDermott, 1999), so the procurement route can influence the structural frame decision making process and thus to affect the decisions made about the form and material of the structural frame. Therefore, there is good reason to examine its possible influence on choices made in relation to structural frames and thus to fulfil the Objective 5 - *Evaluate the influence of the main contractor in the structural frame decision-making process of building projects, with an emphasis on concrete frames, when using a Design-build procurement route* and Objective 6 - *Provide recommendations to help deliver an improved and efficient concrete frame building project when using a Design-build procurement route.*

With regard to the role of the structural frame, this has been investigated with respect to the ways in which the choice of frame material can meet the client's needs (e.g. Gray, 1995; Soetanto *et al.*, 2006b). There is clear evidence that the selection of an appropriate frame can be critical to the overall success of a building project (SCI, 2000; Soetanto *et al.*, 2006a), whether this is measured in terms of cost, programme or a perceived aspect of quality, such as architectural aesthetics, or even energy performance. Clearly, if the structural frame, which is the skeleton that defines and supports the building, can help deliver improvements in these areas this will represent a tangible benefit to the client in the completed building and, if combined with an appropriate form of contract, could result in further cost and time savings. So the issue which remained unclear and under-researched is the link between the form of contract and the structural frame and specifically the typical level of 'contractual involvement' or influence that the main contractor has on the selection, design or production of the structural frame in a Design-Build project. This warrants consideration in Phase Four in terms of the various types of Design-Build procurement routes, the size of the contractor, the client-main contractor risk relationship, the stage at which the main contractor is involved both informally and contractually, and so a case study approach was selected to investigate these factors on a series of Design-Build projects in the UK. The research in this phase also examined the reasons why clients seem to prefer Design-Build procurement routes. The research is summarised below and a more detailed description is provided in Paper 4 (Appendix D) and Paper 5 (Appendix E).

4.4.1 The research undertaken – case studies

The overall aim of this phase, which the case studies set out to explore, was to investigate the assumption that the main contractor influences major decisions on a Design-Build project, with particular reference to changes to design and/or specification the structural frame. To achieve the research aim (and thereby support or refute that assumption), the following objectives were investigated, in the context of Design-Build (D&B) projects:

- determine the degree and types of involvement that main contractors have within a range of D&B contracts;
- identify the similarities and differences amongst various D&B projects in relation to the degree of contractor involvement;
- identify what changes, if any, are typically made by main contractors to the selection, design, specification or production of a frame;
- draw conclusions about how D&B works best in terms of main contractor involvement;
- make recommendations on degrees of influence that contractors can/should have on the structural frame selection process.

The research objectives were met by undertaking a series of company case studies with UK-based D&B contractors. The results of the questionnaire survey in Phase Three of the research formed the basis for selecting the case study building projects with UK-based D&B contractors. Case studies are recognised as a suitable research approach for this research and four case study building projects of different size and structure were studied using the same case study protocol (see Appendix I) which had been developed around the research objectives and a series of associated research questions. Four building projects were selected (in discussion with the sample of contractors; mixed use, laboratory, hospital, residential) and thus four case studies undertaken using personal interviews with various project team members who had been involved in choosing the structural frame material at the design stages or thereafter. A comparison amongst the four case study projects together with four contractors participated in the study is presented in Table 4.2; for confidentiality, the parties concerned are referred to under the headings of Case studies A, B, C and D. Chapter 3 of the thesis provides the full details of the case study method used together with the process of selecting the four case studies.

Table 4.2 Case study design-build building projects

Case study project	Building type		Regional location	Project value (£m)	Contractor's financial turnover 2008 (£m)	Structural frame type	Tendering arrangement	Project team members interviewed
Case study A	Phase I)	Five residential buildings	South East	45	819.4	In-situ concrete	Single-Stage	Main contractor *(Contractor A)*, Architect, Structural Engineer and Cost Consultant.
	Phase II)	One residential building				In-situ concrete	Two-Stage	
		One office building				Steel		
Case study B	Laboratory building		East Midlands	8	177.5	In-situ concrete	Two-Stage	Main contractor *(Contractor B)*, Architect, Structural Engineer, Project Manager (External) and Client's representative.
Case study C	Hospital		South Yorkshire	4.5	80	Steel	Single-Stage	Main contractor *(Contractor C)*, Architect and Structural Engineer.
Case study D	Mixed-use development		South West	10	2065.4	In-situ concrete	Two-Stage	Main contractor *(Contractor D)*, Architect, Structural Engineer and Client.

4.4.1.1 The use of D&B and contractor involvement

Of all the professionals interviewed, almost all were involved regularly, and in some cases extensively, with D&B procurement. Contractor A stated that nowadays almost all their contracts are D&B; Contractor B said that they currently procure 80% of their projects this way. The key reasons for its use in the four case studies were risk-transfer, cost certainty and single-point responsibility. In all four case studies, D&B was used primarily to shift the risk from client to contractor, as discussed by Akintoye (1994). There is a range of advantages of using Design-Build in order to enhance the implementation of projects (Rawlinson, 1997; Leung, 1999). In the words of Contractor B, *"we are very happy with Design-Build approach, particularly two-stage Design-Build as it allows us to drive and control the design which also means that we control our own destiny".* Contractor A added, *"The advantage of Design-Build for the contractor is that we can manage the process effectively to alter the design if we get involved in the project in good time".*

Although structural engineers seemed to be very influential in case studies A, C and D, it was apparent that the ultimate decision on the frame type lay with the clients, and particularly the more informed clients. However, the Architect and Structural Engineer for Case Study C claimed that contractors can also be very influential if they have the willingness to build in a particular frame type and are motivated to do so. This was corroborated by Client D who asserted that: "*The main contractor can influence the frame choice in Design-Build projects, but it depends on the contractors' involvement in the project*". On the other hand, Contractor C stated that they were in favour of a steel frame because of their broad experience in using steel, whereas the Client D justified their frame material choice by saying *"We know* *concrete well, we know through experience what works and what does not"* (Haroglu *et al.*, 2009 ; see Appendix D). These responses align with the success factors for Design-Build projects (i.e. the contractor's Design-Build knowledge, experience and confidence, and ability to maintain proper documentation) put forward by Songer and Molenaar (1996), Hemlin (1999) and Leung (1999).

All four contractors took over contractually the Design-Build projects at the end of RIBA Stage E and as a result, none of them made any major changes to the Design-Build projects (including the frame choice), but they all exerted some influence on buildability, cost (market prices), construction sequence and methods. That said, Contractor B's involvement appeared to be greater than the others and although Case Studies B and D used two-stage Design-Build, the level of the involvement the Contractors B and D had were not alike which suggests that there may be other factors that control the extent of contractors' involvement in a Design-Build project such as the contractor's size. For instance, Architect D suggested that Contractor D was not proactive, adding: "*The influence of the contractor on a Design-Build project depends on how busy they (contractors) are at the time and how hungry they (contractors) are for work.*" Furthermore, Client D held that "*the involvement of the contractors depends on how quickly the client wants the contractor on site and how much risk the client wants to hold onto*". They went on to say that: "*In general the main contractor's influence in a Design-Build project tends to be related to the size and complexity of the project*". This is echoed in a recent study by Lam *et al.*, (2008) who found that if a Design-Build project is prestigious and has a high value to the contractor, the contractor will naturally put forth extra effort. The findings of the case studies provide interesting outcomes in response to Objective 5 of the research relating to the use of Design-Build and contractor involvement. It is possible to make clear connections between the experiences within the various cases, despite their small number, because there are clear inter-relationships between these four projects. The various issues that appear to determine the nature of the contractor's involvement in Design-Build projects, are represented in Figure 4.3.

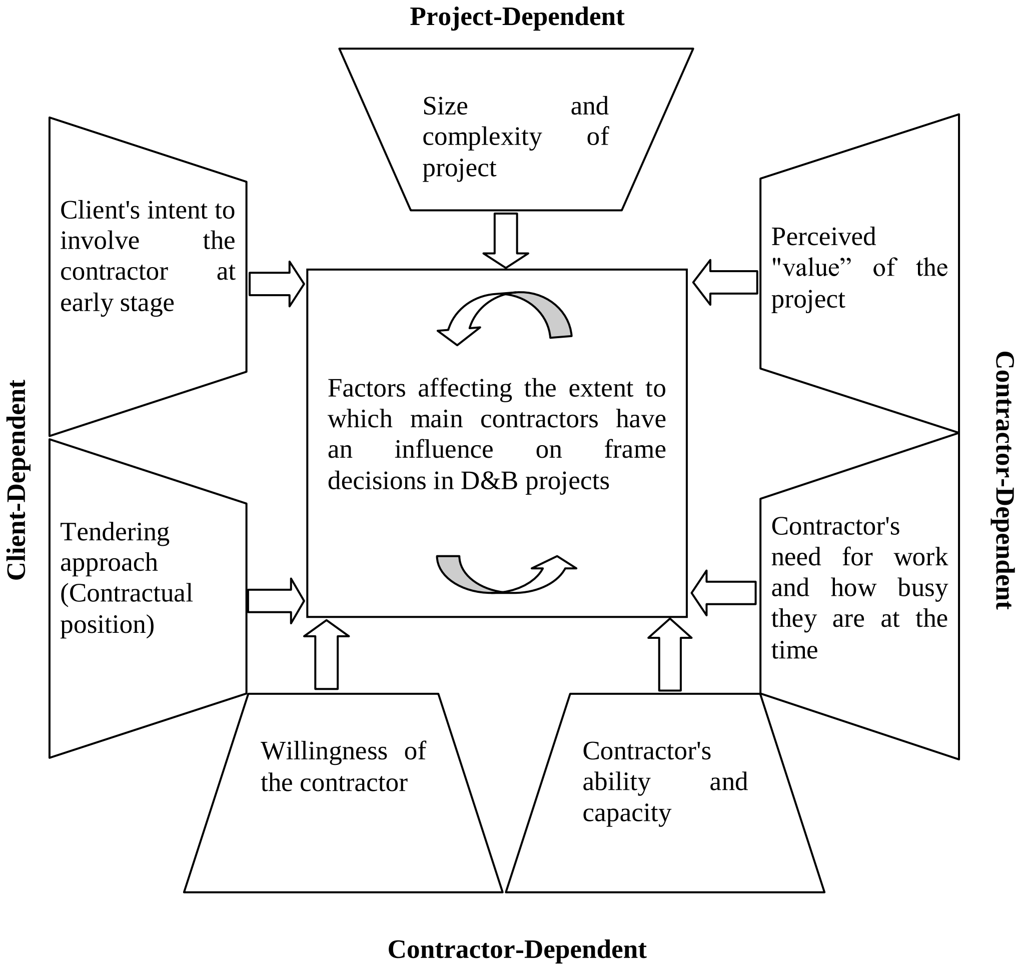

Figure 4.3 Factors affecting the contractor's influence on frame decisions in D&B projects

4.4.1.2 Evaluating the contractors' influence in relation to the structural frame selection process

Each case study project had its own circumstances in terms of what frame material was chosen and which issues influenced this choice. This aligns broadly with findings from Haroglu *et al.*, (2008a) (see Appendix B), which indicated that cost is the most influential issue in the structural frame selection process. However, cost was found not to be the primary issue in the four case study projects.

In the single-stage Design-Build projects, the contractor's influence was not found to be any less than in two-stage Design-Build cases. Early contractor involvement appeared not to happen in practice from the case studies undertaken. Cost Consultant A claimed, from experience in working with contractors for many years, that early contractor involvement is not of any value as the contractors are not very sophisticated in the way they deal with the clients' requirements in terms of cost effectiveness and timeliness. The Client's representative in Case Study B explained that: "*In general what the client tends to do is to have a fairly well-developed scheme design and then to involve the contractor in the detailed design"*. This was evidenced in one single-stage project (Case Study C, hospital) in which Contractor C had no input in to the design process, but later had to change the foundation design to prevent additional costs. This idea is supported by Rawlinson (2008) who says that the readiness of clients to shift away from two-stage tendering indicates a degree of frustration with some aspects of collaborative working and an increase in cost in the second stage, which was corroborated by Client D who complained that two-stage tendering had caused them to exceed their budget. Rawlinson (2006b) goes on to state that the main benefit of two-stage tendering, speed of programme, inevitably comes at the price of some degree of cost premium. Nevertheless, Mosley (2008) notes that properly structured two-stage tendering, using an early conditional contractor appointment, is the best means for the client to control projects and obtain added value from contractors. Leung (1999) also suggests that Design-Build projects perform better if the contractor is allowed to design structures to suit their construction method. With this ‘contractor detailing’ in mind, it appears that the case study contractors only made changes to the frame design, specification or production method as follows:

- Contractor A made a few minor changes, including the concrete specifications (ggbs) and the construction method (slipform construction);
- Contractor B influenced finishes and materials.
- Contractor D influenced the sequence, method of construction and design.

4.4.1.3 Conclusions and recommendations from the case study research

From the case study findings, it is clear that the influential contractor/early contractor involvement can enable the design team to produce better designs in a shorter time with reduced cost which the improvements mentioned in Latham (1994) and Egan (1998) reports could be achieved. Yet early contractor involvement does not happen very often in practice, as in the words of the structural engineer in the Case Study D “*From a designer’s point of view it would be great to have the contractor earlier, however this is not the case for the developers*”. Nevertheless it was found that D&B contractors are generally involved early in the design process under the two-stage tendering. As Rawlinson (2006b) stated that the benefits of the two-stage approach are most likely to be secured when the contractor is proactive in its engagement with the design, buildability and financial aspects of the project. Finally, as revealed in the two of four case studies undertaken in the research, the decisions made on the frame choices of case studies C and D were significantly affected by past experience. To illustrate these key findings on the choice of frame in a Design-Build project and the various actions taken by the contractor, Figure 4.4 (overleaf) attempts to summarise the main outcomes and relate these to RIBA Plan of Work (2007) stages.

From these conclusions it is possible to make some specific recommendations for parties involved in a Design-Build project in order to improve the decision-making process of a building project, particularly concrete frame building projects. The research has demonstrated that early involvement allows the contractor to offer advice on buildability, market conditions and an appropriate supply chain, with the aim of improving buildability and economic feasibility. Clients should be encouraged to involve contractors as early as possible in a Design-Build project to acquire best value from their contractors by allowing them to advise on these issues. This requires contractors to be proactive, willing and able to deal with the client's requirements effectively and efficiently, but this is a problem because contractors may not wish to give such 'free advice' to a client prior to a formal appointment being made. Secondly, it is essential that contractors should influence the structural frame selection process to best suit their construction methods and techniques; this will enable contractors to complete the building successfully saving time and money for themselves and the client. These cases certainly go some way to confirming Mosey's argument (2008) that properly structured two-stage tendering, using an early and conditional contractor appointment, is the best means for clients to control projects and obtain added value from their contractors. That said, clients and other parties should not presume that contractors will always wish to advise on or steer the choice of a structural frame; this will depend on project circumstances as well as contractor motivation to do so. A detailed account of the recommendations is also provided in section 5.5 and Paper 5 (Appendix E).

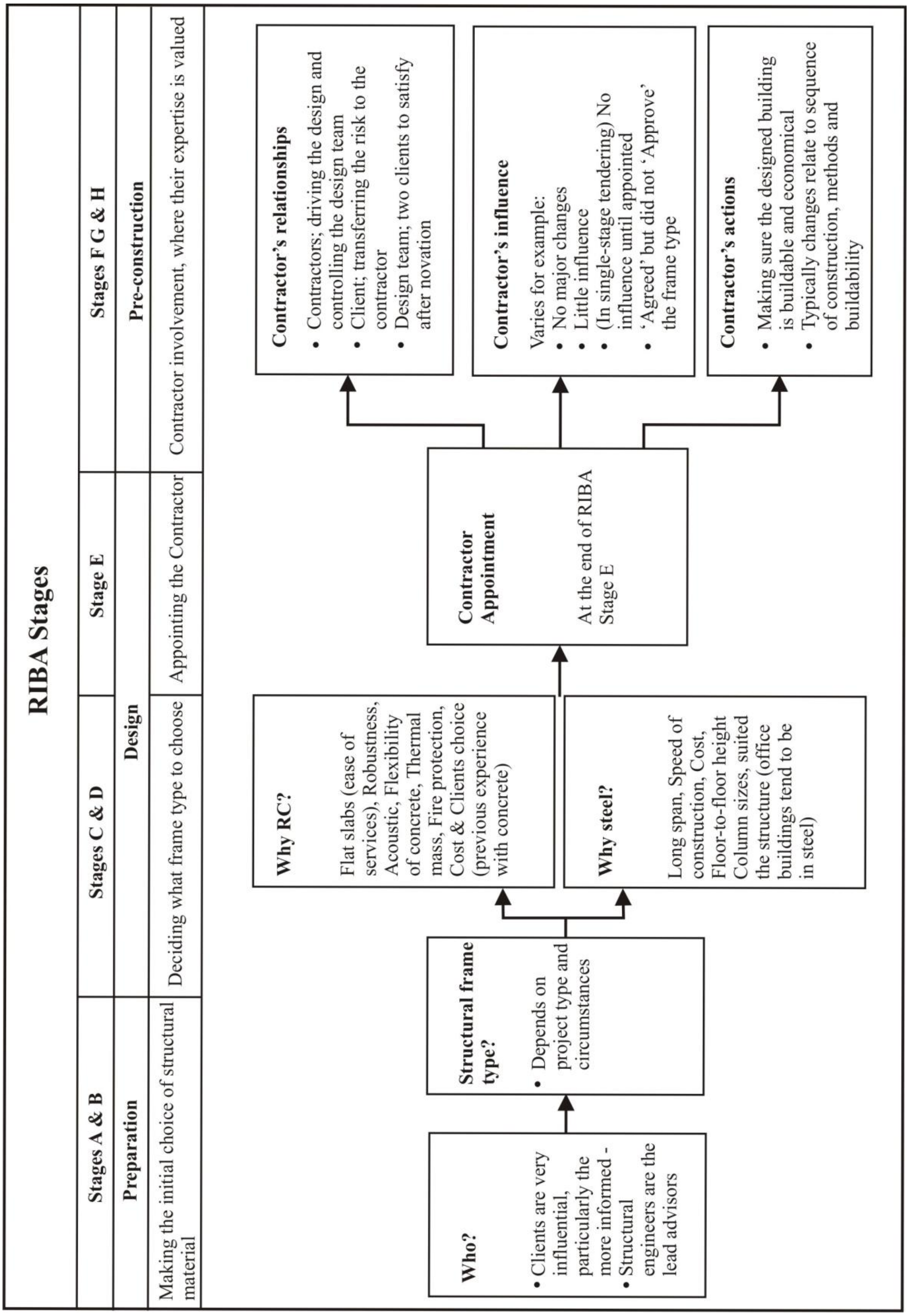

Figure 4.4 Summary of the key findings in relation to the structural frame selection as the D&B project progresses

4.4.2 Phase summary

The main aim of this phase was to assess the influence of the main contractor on a Design-Build project, with particular reference to changes to the design and/or specification of the structural frame. The research also provided recommendations to construction practitioners about how to improve the decision making process for a building project, particularly concrete frame building projects. The four case studies were undertaken to provide an understanding of the role of contractors within UK building projects which were procured using either single-stage or two-stage Design-Build procurement routes. The structural frame selection process was also investigated in the four case study Design-Build projects to establish the extent of the contractors' influence on the selection, design, specification and/or production of a frame. Lastly, recommendations were made as a result of the case studies for an enhanced decision making process of a building project which emphasise the benefits of early contractor involvement.

4.5 SUMMARY

This chapter described the results from the research undertaken. The research used four phases to fulfil the research objectives for the four-year EngD research. Objective 1 was achieved through literature review and a focus group in Phase One in order to gain an in-depth understanding of the concepts of procurement, structural frame decision making process and its relevance to the various stages of the design process, and the benefits of its consideration at the early stages of design. Also during Phase One it was decided as a result of the focus group with TCC's staff that the recognition of the key issues and key decision makers in the structural frame decision making process should be the next step in the research in order to help TCC to promote the concrete frames in the UK-framed-structures market. Phase Two fulfilled Objective 2 by identifying ten key issues as the most important to the structural frame decision-making process through an additional literature review, semi-structured interviews and further focus group. Cost consultants, project managers and clients were also found to be the most influential people in the structural frame selection process as a result of the research in Phase Two.

In Phase Three, a questionnaire survey was then distributed amongst UK cost consultants, project managers and clients to establish the ranking of the key issues affecting the choice of structural frame and to evaluate the influence of project team members in choosing the structural frame material, which fulfilled Objectives 3 and 4. As a result, the ranking of these issues at early design phase could be adopted as the fundamental criteria for assessing and selecting an appropriate structural frame for a building project. Furthermore, Design-Build was found to be the preferred procurement route, with the 'Main Contractor' having a significant input at stages D and E and consequently potential to influence the structural frame decision-making process. Hence, they could be a new target audience for TCC in the UK framed-structures market.

Accordingly the four case studies were undertaken to provide an understanding of the role of contractors within UK building projects in Phase Four with the aim of achieving Objectives 5 and 6. Although it was recognized that main contractors do not generally get involved early in the design process of D&B projects, they were found to be influential over buildability, programme and materials used in all cases, plus were able to provide advice on market prices. However, this was found to be dependent on readiness and ability to affect the design process, size of the project, plus the client's preference/motivation to let them do so. With D&B contracts continuing to be popular in the UK building construction, contractors are expected to be influential in the design process of building projects particularly in projects using two-stage tendering. However, D&B contractors should be well adapted to their key role and should take a proactive approach to other project team members about design, buildability and financial aspects of the projects.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

Chapter 4 reported the results from the research. It presented the key issues used to assess and select the structural frame type for a building project and provided the basis for understanding the relationship between the form of contract and the structural frame by undertaking four case studies of Design-Build building projects. The results then led to recommendations about the benefits of contractor involvement for efficient concrete construction.

The purpose of this chapter is to summarise the key conclusions with reference to the specific research objectives set out in Chapter 1, together with an explanation of the original contribution of the research to current knowledge. Recommendations are then made for the UK construction industry, the concrete industry and TCC, together with some directions for further research.

5.2 REALISATION OF AIM & OBJECTIVES

Prior to the presentation of the specific conclusions in response to each objective, it is appropriate to restate the aim and objectives, and the research problem, presented in Chapter 1 and Chapter 2 respectively. As set out in Chapter 1, it was the aim of this research to:

‘Examine the structural frame decision making process, focusing on concrete frames, and assess to what extent the procurement route adopted can influence the choice of frame for a building project in the UK construction industry’

The research question was formulated and addressed in this research was: *Can the concrete frame procurement process be improved by optimising the structural frame decision making process?*

Recent years have seen almost every sector of the construction industry working to meet the aims of the Latham report. In the UK, both the influential Latham (1994) and Egan (1998) reports identified that improvements designed to reduce budget and timescale and to increase quality would only be achieved if main contractors were involved sufficiently early in the design process and fully understood the needs of the client. In addition, for concrete frame construction Gray (1995) emphasized the need to restructure the roles and scope of the design team to maximise the input from the contractors. Hence, the rise in popularity of procurement routes and forms of contract that permit early contractor involvement (ECI) such as Design-Build within which contractors are involved early to improve supply chain integration. Although Design-Build has been used in the UK construction industry for decades, it gained increased market share from the late 1990s onwards (Ernzen and Schexnayder, 2000; Arditi and Lee, 2003). Indeed, a recent survey of UK project managers, cost consultants and clients (Paper 1, Appendix A) found that Design-Build is the preferred option amongst developers of building projects, ranging from complex, high quality projects to simple buildings. This illustrates a significant change in the UK construction industry, moving away from its conventional, ‘traditional’ procurement systems. So, as a result, one might sensibly presume that most contractors must be getting involved earlier in the design process and thus could be influencing major decisions, such as the selection of a structural frame, although there are still questions about how this affects the risk relationship between client and contractor.

With regard to the role of the structural frame, this has been investigated with respect to the ways in which the choice of frame type and material can meet the client’s needs (e.g. Gray, 1995; Soetanto *et al.*, 2006b). There is clear evidence that the selection of an appropriate frame can be critical to the overall success of a building project (SCI, 2000; Soetanto *et al.*, 2006b), whether this is measured in terms of cost, programme or a perceived aspect of quality, such as architectural aesthetics, or even energy performance. Clearly, if the structural frame, which is the skeleton that defines and supports the building, can help deliver improvements in these areas this will represent a tangible benefit to the client in the completed building and, if combined with an appropriate form of contract, could result in further cost and time savings. However, one issue which was unclear and under-researched is the link between the form of contract and the structural frame (Paper 3, Appendix C) and specifically the typical level of 'contractual involvement' or influence that the main contractor has on the selection, design or production of the structural frame in a Design-Build project. This warranted consideration in terms of the various types of Design-Build procurement routes, the size of the contractor, the client-main contractor risk relationship, the stage at which the main contractor is involved both informally and contractually.

The objectives of the research are reiterated below:

1. To explore the concrete frame procurement process in the design phase.
2. To understand the key issues for the structural frame selection process on a building project.
3. To develop insights into how important these key issues are to the decision makers identified, when choosing which structural frame material to use on building projects.
4. To investigate the views of key decision-makers concerning the roles of project team members involved in choosing the structural frame at each stage in the design process.

5. To evaluate the influence of the main contractor in the structural frame decision-making process of building projects, with an emphasis on concrete frames, when using a Design-build procurement route.
6. To provide recommendations to help deliver an improved and efficient concrete frame building project, when using a Design-build procurement route.

All of these objectives were achieved and a summary of the findings for each objective is discussed in the following section.

5.3 THE KEY FINDINGS OF THE RESEARCH

Findings and specific conclusions that are drawn in response to each objective are explained below.

5.3.1 OBJECTIVE 1

"*Explore the concrete frame procurement process in the design phase*". The purpose was to gain an in-depth understanding of the procedures and processes implicated during the design phase of the concrete frame procurement process, which was achieved through a literature review and an internal focus group. A literature review was undertaken to discover what research was already taking place and to identify where the procurement process of concrete frames could be improved. The findings of the literature review suggested that the choice of frame and the procurement route adopted are fundamental for the successful project outcome (Rowlinson and McDermott, 1999; Soetanto *et al.*, 2006) which pointed towards the importance of early stage of building design where the most important decisions are made, i.e. in determining the choice of structural frame. A building's performance and its value are largely reflected in the quality of decisions taken in the early stages of the project (McGeorge and Palmer, 2002; Kolltveit and Grønhaug, 2004). In addition, more recent views from the construction industry suggest that new procurement approaches and structural frame options will inevitably be considered by clients and contractors as offering a way of better meeting project objectives (Sullivan, 2006; Rawlinson, 2007). Within this context, the structural frame plays a significant role in a project's success and accounts for a major portion of project costs, directly and indirectly (Soetanto *et al.*, 2006b). Furthermore, a focus group was carried out with a selection of structural frame specialist staff of TCC; the objective was to recognise the key areas within the concrete frame procurement process that should be investigated in this research in order to help develop TCC's marketing plan. As a result, it was decided that the key decision-makers and the key issues within the structural frame decision-making process would need to be identified and addressed. Objective 1 confirmed that structural frame selection is of fundamental importance to a building project and the form of structure is normally considered, refined and developed during the early design stages in response to project and/or client requirements (Ballal and Sher, 2003; Soetanto *et al*., 2006b).

5.3.2 OBJECTIVE 2

"*Understand the key issues for the structural frame selection process on a building project*". This was fulfilled through undertaking a further literature review, interviews and another focus group. A further literature review was first carried out to examine the structural frame decision making process. However, only a few publications about the structural frame decision-making process were found and subsequently examined, namely Ballal and Sher (2003), Soetanto *et al*., (2006a) and Soetanto *et al*., (2006b) from which 31 issues were identified as being important in influencing the structural frame decision making process (see Table 2.1). Research was therefore undertaken through interviews with structural engineers to acquire knowledge in relation to the structural frame decision-making process. The findings from this work added to current knowledge obtained from the current literature (see Paper 1:

Appendix A) with respect to the structural frame decision making process, i.e. the recognition of decision makers and a list of ten key issues compiled relevant to structural frame selection. Four of the nine interviewees strongly believed that the client and the cost consultant determine the choice of frame for a building project. Three interviewees referred to client and project manager being the most influential in selecting the frame. Another two interviewees considered that the decision on the choice of frame is made by the design team led by the structural engineer. Therefore, cost consultants, project managers and clients were considered to be the most influential people in the structural frame selection process, more so than the structural engineers themselves. Although the semi-structured interviews found that the choice of frame is heavily influenced by the issues specific to the particular project in hand, the structural engineers identified ten key issues which they considered to be the most important generic issues in frame selection (see Table 4.1). Another focus group with TCC staff was then geared towards improving the wording of the final list of issues, with the aim of using it in a postal questionnaire survey.

5.3.3 OBJECTIVE 3

"*Develop insights into how important these key issues are to the decision makers identified, when choosing which structural frame material to use on building projects*." A questionnaire survey was used to provide views from different professions on structural frame selection with the aim of achieving this objective. It was distributed to 239 UK cost consultants, project managers and construction clients in order to evaluate their views on the ten key issues and, hence, the structural frame selection process. 70 questionnaires were received in total, giving an overall response rate of 29.3%. Paper 1 (Appendix A) and Paper 2 (Appendix B) present the results and analysis of the questionnaire survey in more detail. 'Cost', 'Architecture' and the 'Building use/function' issues were ranked highest in importance by the respondents when choosing the structural frame material. Spearman's rho (ρ) test statistically established the extent to which the three sets of respondents agreed with one another in the ranking of these issues. This revealed that there was considerable agreement and that the degree of agreement was higher than would occur by chance. It can be said that the ranking of the ten issues obtained from this study adequately represents the views of the UK Construction Industry in relation to the structural frame selection process (see Paper 1, Appendix A). As a result of the research, the ranking of these issues at early design stages could be adopted as the fundamental criteria for assessing and selecting a structural frame which is a major contribution to current knowledge to the structural frame decision making process. The rank ordering can give construction practitioners a good indication of the needs and priorities of their clients. However, although the ten issues proved to be considered important by the respondents to the survey, the literature review and the interviews indicated that the selection of the frame is often based on the projects' type and specific circumstances (Bibby, 2006; Soetanto *et al.*, 2006). In addition, the variations, if any, between what the three groups themselves think of the issues and what others perceive their attitudes to be, were also examined and reported. The benefits included an unusually deep understanding of clients' attitudes in relation to the significance of the ten key issues for the choice of primary building structure as well as enabling construction practitioners to resolve some common misconceptions about clients' requirements. The project team should therefore focus on clients' needs and on ways of recognising those needs in order to choose the most appropriate structural frame option (Paper 1, Appendix A).

5.3.4 OBJECTIVE 4

"*Investigate the views of key decision-makers concerning the roles of project team members involved in choosing the structural frame at each stage in the design process*". The questionnaire survey also helped satisfy Objective 4 by providing a number of useful insights into the view of professionals about the decision makers in the structural frame selection process. The survey produced a rank ordering of project team members in relation to the influence they have on the choice of frame type at each stage of design process. Unsurprisingly, the structural engineer was found to be the most influential decision-maker in the choice of frame at each stage of design process. Spearman's rho (ρ) test was again applied to establish the agreement between the three sets of respondents in relation to the rankings of the project team members at each stage. There was a strong agreement amongst the respondents to the survey in terms of the rankings of the project team members (Paper 3, Appendix C). It can be said that the ranking of the six decision makers obtained from the respondents to the survey are representative of the views of the UK construction industry in relation to the structural frame selection process. As a result, the rank ordering at each stage of design process is of direct interest to all those concerned with project teams, structural frame design and selection and effective leadership in decision making. As the design develops, the increasing influence of the structural engineer and the contractor is clear (see Figure 4.2). Contractors were found to have a significant input at RIBA stages D and E (see Paper 3, Appendix C). The increased influence of the contractor could be attributed to the Design-Build route. Objective 4 highlighted that contractors could be highly influential at both stages D and E which means that contractors should be a major audience in the frame market. This is therefore of interest to TCC and warranted specific research in this field in order to find out whether the main contractor could exert influence to change the frame type or any specifications of a building project after being involved. The completion of Objective 4 therefore highlighted the importance attached to the contractors' role in the structural frame decision making process and the potential level of influence during design phase in building projects where there is early contractor involvement. As a result, the role of the contractor appeared to be an appropriate focus for research to see how this area of decision making works in practice.

5.3.5 OBJECTIVE 5

"*Evaluate the influence of the main contractor in the structural frame decision-making process of building projects, with an emphasis on concrete frames, when using a Design-build procurement route*." This objective was fulfilled through a series of case studies in order to investigate the use of Design-Build and contractors' influence on the choice of frame type. It can be inferred from Objective 4 that given the dominant use of Design-Build procurement for the building projects in the UK, the main contractors' influence in the structural frame selection process were to be expected. Four case study building projects of different size and type were studied using personal interviews with project team members who had been involved in choosing the structural frame material at the design stages or thereafter (see Table 4.2). Detailed accounts of the case study findings are provided in Paper 4 (Appendix D) and Paper 5 (Appendix E). The project team members of the four case studies interviewed confirmed that the Design-Build procurement route is used increasingly for building projects in the UK. The structural frame selection process was investigated in the four Design-Build projects to establish the extent of the contractors' influence on the selection, design, specification and/or production of a frame (see Paper 4, Appendix D; Paper 5, Appendix E). The case studies indicated that the more informed clients are much more involved in initiating the choice, evaluating options, deciding on the frame type and also on subsequent changes. It was clear that contractors could be influential in the frame selection process if they had the willingness to build in a particular frame material (provided that the frame selected meets the client's requirements), the motivation to exert their influence on the design team and client, and the capacity to do so. Furthermore, it was clear that (in all but one case), after their appointment, the contractor did make changes to the frame design, specification and/or production method; these changes were aimed at improving buildability and economic feasibility. As a result, Objective 5 demonstrated the significance of the contractor's influence in the structural frame decision-making process by highlighting these key findings on the choice of frame in a Design-Build project and the various actions taken by the contractor (see Figure 4.4). This is of strategic importance to TCC as it should embrace the growing importance of the contractors in making and influencing decisions in the structural frame selection process when promoting concrete in the UK framed structures market.

5.3.6 OBJECTIVE 6

"*Provide recommendations to help deliver an improved and efficient concrete frame building project when using a Design-build procurement route*". Case study research also helped achieve this objective by providing an in-depth understanding of the degree and type of involvement main contractors have within a range of D&B building projects. Contrary to existing knowledge, contractors in the case studies appeared to be fairly satisfied with the Design-Build procurement route and more importantly they seemed to have learned how to manage the construction risk that they inherit from their clients. A range of factors which affect the nature and depth of contractor involvement in a Design-Build project were identified, some of which were common to more than one case study. These included contractor motivation and the nature of the particular building project in hand, e.g. layout, client requirements, ground conditions etc (see Figure 4.3). That said, it was clear that early involvement allowed the contractor to offer advice on buildability, market conditions and an appropriate supply chain. There are clear lessons here for contractors, clients and design teams working on D&B projects. The findings pointed out that contractors can help the client achieve cost and time savings through buildability, material and other improvements, but this advice only emerges when the client and procurement approach facilitates this exchange and the contractor feels sufficiently motivated to make such a contribution (Paper 5, Appendix E). This is of fundamental importance to clients as well as the concrete industry in terms of successful project outcomes because it will provide a justification in getting contractors involved and appointed sufficiently early in the design process. As a result, the findings further reiterated that an influential contractor/early contractor involvement can enable the design team to produce better designs in a shorter time with reduced cost which the improvements, as espoused by Latham (1994) and Egan (1998). This research also corroborates findings by Gray (1995), who stated that input from contractors needed to be maximized in order to optimise the design process for efficient concrete construction.

5.4 CONCLUDING THE RESEARCH QUESTION

From the above section it is now possible to develop a response to the research question defined in section 1.2. The research question addressed in this research is:

Can the concrete frame procurement process be improved by optimising the structural frame decision making process?

The thesis has presented results obtained from focusing on the task to investigate the structural frame decision making process. These results demonstrated the significance of the contractor's influence in the structural frame decision-making process. Therefore it is quite clear that the influential contractors add value to a project by their *early involvement* in design which could result in achieving cost and time savings. This also corroborated findings by Gray (1995), who stated that input from contractors needed to be maximized in order to optimise the design process for efficient concrete construction.

In conclusion, the results obtained provide an important step in answering the research question defined in section 1.2. The research presents how efficient concrete construction can be achieved through early contractor involvement even though more work is required to add a more detailed understanding of the specific benefits of early contractor involvement, and how such involvement works in various procurement approaches.

5.5 CONTRIBUTION TO KNOWLEDGE AND PRACTICE

This section summarises the demonstration of innovation in the application of knowledge to the engineering business environment during the course of this research, which was described in detail in section 5.3.

The research highlights the importance of early design decisions on the construction phase of a building project, particularly the decision on the choice of frame. At present, there appears that the UK construction industry pays relatively little attention to the structural frame decision making process. The research shows that this is a problem because the survey results (such as the ranking of the ten key issues and the investigation of the variations, if any, what cost consultants, project managers and clients themselves think of the issues and what others perceive their attitudes to be) provide evidence of the differences in attitude that construction practitioners have about the needs and priorities of their clients, which is reflected in unclear, confused decision-making on structural frames. This information will help TCC target its marketing effort; it can be used effectively to develop TCC’s marketing strategy to clients by having a better understanding of clients’ attitudes in relation to the significance of the ten key issues for selecting the structural frame of a building project. Furthermore, the survey results show the important influence of the structural engineer and the contractor during the design stages. The results also highlighted the growing use of Design-Build procurement in the UK construction industry.

The applied case study stage of the research investigated whether the main contractor could exert influence to change the frame type or any specifications of a Design-Build project after being involved. These demonstrated the significance of the contractor's influence in the structural frame decision-making process which provided clear lessons for contractors, clients and design teams working on Design-Build projects. For instance, the results showed that contractors can help the client achieve cost and time savings through buildability, material and other improvements, but this advice only emerges when the client and procurement approach facilitates this exchange and the contractor feels sufficiently motivated to make such a contribution.

Finally, the thesis demonstrates that the structural frame decision making process is a vital part of delivering efficiency and quality of building projects. Both the concrete industry and steel industry will benefit from the research contributions.

5.6 LIMITATIONS AND VALIDITY OF THE CONCLUSIONS

This section presented several important considerations regarding limitations and validation of the research results.

Changes in the ranking of the issues at the early design stages could occur as a result of economic changes. The responses to the survey were certainly shaped by the economic climate in which the respondents were operating; indeed, with any survey the results would be affected by the background in which the respondents are operating. The way to establish variability, i.e. what the differences are and how important they may be might be to repeat the same survey, say every five years. In this research repeating the survey was not considered possible because of the time constraints. However, those using the data should be aware of the impact of changes with time which may have happened regarding the ranking of the key issues, e.g. effect of an economic recession.

Good quality research depends on a commitment to testing and increasing the validity as well as the reliability of your research results. The evaluation of research results involves a set of validities, which are described as construct validity, internal validity, external validity, and statistical inference validity (Fellows and Liu, 2003). Construct validity concerns the degree to which the variables, as measured by the research, reflects the hypothesized construct. Internal validity is mainly concerned with causal studies, where an investigator tries to find dependencies between events. External validity (Yin, 1994) is concerned with the problem of whether a study’s findings are possible to generalize to beyond the immediate case study. Statistical inference validity, judged by inference statistical measurements, is high where the sample is a good representation of the population (Fellows and Liu, 2003).

The important issues regarding validity have been addressed during the research work by observing the important aspects mentioned above. The novelty value of the results has been demonstrated both in terms of acceptance of papers to conferences and a journal, but also by clearly building on the existing literature. With regard to the survey, the results revealed that all of the ten issues included in the list were considered to be important, confirming the validity of the criteria as a basis for consideration in structural frame selection. Because of this, and the considerable degree of influence the respondents have on the choice of frame type, the returned sample was considered to be representative of the actual decision-making population. Also, senior representatives from three major contractors (with annual turnovers over £500m) were informally approached to comment on the findings of the survey. These respondents indicated that the findings appeared to reflect what they experienced in industry, thus corroborating the survey results. Furthermore, since the results from case study research presented rest on four case studies, they could be subject to question in terms of reliability (Yin, 1994), but because there were significant differences in the contractors' size as well as the building projects' type and value they can be considered to offer a reasonable representation of the breadth and depth of main contractors' involvement in Design-Build projects.

5.7 INDUSTRIAL IMPLICATIONS

The aim of this section is to provide a brief summary of the impact of the research that has taken place during the EngD programme and how the research findings have had an influence on the way TCC works. It will also provide some indication of implications for the UK construction industry in general.

5.7.1 THE IMPLICATIONS FOR THE SPONSOR

One of the prime aims of TCC is to help all those involved in the design and use of concrete to become knowledgeable about the products and design options available. The expectation from the research was that it would enable TCC to better understand the drivers that affect professionals' specification decision, particularly in structural frame selection (influenced by procurement route), and that they would use the results to focus attention and assist in the delivery of business improvements (marketing strategy) for the concrete and cement industry. In so doing, this research provided an insight into TCC's audience's opinions and perceptions about structural frame decision-making process, specifically by:

- identifying who were the key decision-makers;
- understanding and identifying the issues that would encourage them to choose the structural material; and
- capturing the perceptions of each party towards the key issues and how each party is perceived by the other parties on those issues.

This enabled TCC to identify the need for qualitative research in order to understand attitudes to concrete, the decision-making process of the different stakeholders, concrete's competitors and communication challenges forced by TCC. As a result, TCC commissioned a major research study into the perceptions of concrete during 2008 to be able to make more informed decisions with regard to their interactions with the construction industry. This is the first time that such research has been undertaken in the UK. Its recommendations will not only influence the work and direction of TCC but of the concrete industry as a whole (Hicks et al., 2008; unpublished – commercial in confidence).

Furthermore, it was decided to investigate whether the main contractor influences or actually changes any specifications i.e. structural frame type, on a Design-Build project. The decision was primarily made on the basis of the interest of TCC as it expected to be able to understand more about the area of decision-making process in practice and the reason for this was that it was evident that D&B was used predominantly (50% of surveyed projects). The structural frame selection process was also investigated in the four Design-Build projects to establish the extent of contractors' influence on the selection, design, specification and/or production of a frame. This has resulted in a number of useful conclusions which TCC has taken into consideration in defining its strategy for promoting concrete frames in the UK construction industry. For instance, TCC was made aware of the growing importance of the contractors in making and influencing decisions in the structural frame selection process as a result of the continuous increase in the use of Design-Build projects. Finally, as a result of the research it is also believed that TCC gained benefits from the EngD programme during the 4-year period because it has decided to recruit to a further EngD student at Loughborough University.

5.7.2 THE IMPLICATIONS FOR WIDER INDUSTRY

This research has contributed to knowledge mainly in the areas of structural frame selection processes and the contractors' role in the decision making process of D&B projects in the UK. Specifically, the identification of the ten key issues that are the most important when choosing the frame type of a building and the ranking of these ten issues by cost consultants, project managers and clients for this study, which represents the views of the UK construction industry as supported by three major contractors (see section 4.3). The ranking of these issues at early design phase could therefore be adopted as the fundamental criteria for assessing and selecting the structural frame material for a building project.

Furthermore, in construction, as in any industry, it is crucial that client satisfaction is achieved if an organization is to succeed, or indeed survive. Thus, a key stakeholder is the client, namely the organization or individual who makes the decision to purchase services from the construction industry (Barrett, 2000). Nevertheless, in the light of the research findings the industry does not seem to understand clients' needs as highlighted in both the influential Latham (1994) and Egan (1998) reports. Therefore, it remains to be seen whether the industry will find ways of tackling this problem. However, the rank ordering at each stage can give construction practitioners a good indication of the needs and priorities of their clients – besides which, the findings help to explore and clarify misconceptions the three groups (cost consultants, project managers and clients) have about one another's attitudes towards the structural frame selection process (see Paper 1, Appendix A). The research has also shown that D&B contracts are popular in the UK building construction and contractors are expected to play a more prominent role in the design process of building projects particularly in projects using two-stage tendering and influencing in some way the choice of frame type of a building project. Paper 5 (Appendix E) highlights some areas which should be addressed in order for clients to control projects and obtain added value from their contractors such as early contractor involvement.

5.8 RECOMMENDATIONS FOR INDUSTRY

The research concluded by making a series of recommendations to the UK construction industry as a whole, the concrete industry and TCC on the basis of the work described in this thesis.

5.8.1 The UK Construction Industry

The UK construction industry as a whole should address the misconceptions about the attitudes of project team members in relation to the structural frame decision making process, particularly with respect to construction clients. The best way of doing so would be to improve communication between parties at the design stages and when options are studied such that clients' needs might be better met through the delivery of a better value structural frame. One of the ways might be via greater use of partnering arrangements, as per BRE’s report (2005). Most importantly it should be remembered that client's needs are the top priority. The project team should therefore focus on clients’ needs and on ways of recognising those needs in order to choose the most appropriate structural frame option as there is clear evidence that the selection of an appropriate frame can be critical to the overall success of a building project (SCI, 2000; Soetanto *et al.*, 2006a).

5.8.2 The UK Concrete Industry

The research has shown that early involvement allows the contractor to offer advice on buildability, market conditions and an appropriate supply chain, and these aimed to improve buildability and economic feasibility. The concrete industry should therefore endorse the uptake of new procurement routes which allow for early contractor involvement in order to optimise the design process for efficient concrete construction, as asserted previously by Gray (1995). In so doing, clients should be encouraged to involve contractors as early as possible in a Design-Build project to acquire best value from their contractors by allowing them to advise on buildability and supply chain. This requires contractors to be proactive, willing and able to deal with the client's requirements effectively and efficiently, but this is a problem because contractors may not wish to give such 'free advice' to a client prior to a formal appointment being made. Secondly, it is essential that contractors should influence the structural frame selection process to best suit their construction methods and techniques; this will enable contractors to complete the building successfully saving time and money for themselves and the client. That said, clients and other parties should not presume that contractors will always wish to advise on or steer the choice of a structural frame; this will depend on project circumstances as well as contractor motivation to do so.

5.8.3 The Concrete Centre

The research has indicated that D&B contracts are continuing to be popular in the UK building construction which means that contractors are expected to be increasingly influential in the design process of building projects particularly in projects using two-stage tendering. TCC should therefore embrace the growing importance of the contractors in the structural frame decision making process as the contractors could be the target audience in the UK frame market. It could help by developing new publications or guidance documents to support clients (by helping them understand the ramifications of their choices) and contractors (by providing them with more publications about concrete frame construction).

By analyzing and interpreting the data, areas for further research have been identified and these areas are explained in the following section.

5.9 FURTHER RESEARCH

This section highlights four areas of research that could be investigated further as a result of the research, but were not addressed during the EngD timescale.

Examine the relationships between attitudes and different project stakeholders in relation to the structural frame decision making process; this research has attempted to focus on the perspectives of cost consultants, project managers, and clients with respect to the significance of ten key issues identified as being most important to the structural frame selection process. Future directions may include an extension of this work with other key project stakeholders (e.g. structural engineers and architects), in order to see the degree of importance of the key issues from other different perspectives as well as validating the key issues further, such that they can be used as a sound basis in structural frame selection.

Define clients' requirements for building projects in the UK construction industry; the literature reports poor performance on the part of the UK construction industry, specifically for not meeting clients' needs. In the light of the survey findings the industry still does not seem to fully understand clients' needs, as highlighted in both the influential Latham (1994) and Egan (1998) reports. Further research is therefore required to understand, how does this affect the success or failure of a building project in relation to the structural frame selection process? This would be useful in understanding the clients' requirements such that clients' needs might be better met through the delivery of a better value structural frame.

Articulate the benefits of early contractor involvement; the research found that there are various issues determining the nature of the contractor's involvement in Design-Build projects, i.e. size and complexity of project, willingness of the contractor, etc. Building on these findings, mechanisms to encourage and support early contractor involvement need greater elaboration. In particular further work could be carried out to assess the specific benefits of early contractor involvement, the factors that affect the extent to which contractors get involved with structural frame decision making and the risk relationship between client and contractor.

Determine the connection between structural frame decision making process and the appropriate choice of procurement route; the different forms of procurement available to clients have differing ways of accommodating the structural frame decision making process such that each procurement route assigns a different set of roles to project stakeholders, which inevitably influences their decision-making. To understand the relationships between the structural frame selection process and the appropriate choice of procurement route will require further work.

5.10 SUMMARY

This chapter has shown that all the research objectives set out in Chapter 1 were met by the research undertaken during the four year EngD programme. It described the impact of the research on both the industry and the sponsoring organisation which is seen as the core element of the Engineering Doctorate (EngD) Programme. Recommendations were then made which, if implemented, might enable construction practitioners and clients to enhance the structural frame decision making process, thus to optimise the design process in terms of reduced cost and timescale and increased quality. In addition, it highlighted the need for the areas of further research to support change in the construction industry.

6 REFERENCES

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APPENDIX A (PAPER 1)

Full reference:

Haroglu, H., Glass, J. and Thorpe, T. (2009), A study of professional perspectives on structural frame selection. Construction Management and Economics, Vol. 27, No. 12, pp. 1209-1217.

A study of professional perspectives on structural frame selection

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Abstract: The choice of an appropriate structural frame can contribute to effective short- and long-term performance, and enhance client satisfaction but limited research indicates that the issues taken into account during structural frame selection are not very well understood. With this in mind, a major research programme is reported in the paper including interviews and an industry survey, to examine the attitudes of project managers, cost consultants and construction clients in analyzing the issues they typically consider when choosing the structural frame for a building, and to provide insights about how such decisions are made in practice. Ten key issues were identified as being the most important affecting structural frame selection, but the extent to which different parties considered these and at what stage was found to vary. Also, the variations, between what these parties themselves think of the issues and what others perceive their attitudes to be, were examined. In particular, the results showed that what clients perceive differs considerably from how clients' views are perceived by others. For instance, according to cost consultants and project managers, their clients' preference to regularly select a 'preferred' frame type or material is a far more widespread tendency than clients themselves actually acknowledged.

Key words: Building, Decision Making, Structural Frame, Research.

INTRODUCTION

The choice of the primary structure of a building has a major influence on the value of the building to the client, because it provides a high degree of functionality and future flexibility, and largely determines the speed with which the construction process can be executed (SCI, 2000). Furthermore, frame choice can have a huge impact on both the short- and long-term performance of the completed building. In the short term the frame must give its client the satisfaction of his/her needs, such as construction being completed on time and to budget, it must also satisfy future changes in functional requirements of the building in the long term (Soetanto et al., 2006a). On the other hand, although both the influential Latham (1994) and Egan (1998) reports suggest that the industry should focus on its clients and their expectations, the UK construction industry has never had the best reputation for meeting its clients' expectations. Evidence of this poor performance is shown in a report from the National Audit Office, which concludes that failure to fully implement best practice procurement and project management in central and local government currently costs £2.6bn a year in terms of avoidable capital and operating costs (Rawlinson, 2006).

In this context, interviews, a workshop and a major industry survey in which cost consultants, project managers and clients ranked the key issues used by project team members when selecting structural frames at the early design stage of a building project, were carried out to achieve the results presented in this paper. The results were analysed using Statistical Package for the Social Sciences (SPSS), to establish a ranking of the key issues, as the selection criteria for the structural frame type and material for building projects, by each set of respondents to the survey (i.e. cost consultants, project managers and clients) and to investigate the degree of agreement amongst the three sets of respondents. We know that cost is an important issue, but what else is important is less clear. We also know that each project can be different and the decision on the choice of frame for each project relies heavily on those projects' specific circumstances.

In addition, the best construction practices have little value if the requirements of the client are not clearly understood and managed throughout the project life cycle (Barrett, 2000). Also, the project team members need to understand each others' problems, concerns and weaknesses. So the variations, if any, between what the three groups themselves think of the issues and what others perceive their attitudes to be, were also examined and reported. The benefits included an unusually deep understanding of clients' attitudes in relation to the significance of the ten key issues for the choice of primary building structure as well as enabling construction practitioners to clear up some common misconceptions about clients' requirements.

As a result, the purpose of this study was to understand and depict the views from different professions on the structural frame selection during the early design phase, which is generally understood to be when the structural frame of a building project is commonly selected (Ballal and Sher, 2003). The outcome is greater clarity on the issues that are commonly taken into account and an insight on the relative priority placed on these by the various parties involved.

STRUCTURAL FRAME SELECTION PROCESS

A building's performance and its value are largely reflected in the quality of decisions taken in the early stages of the project (McGeorge and Palmer, 2002; Kolltveit and

Grønhaug, 2004). This is a crucial part of the design process in which the project participants concentrate on project requirements as well as the needs of the client. Structural frame selection is of fundamental importance to a building project and the form of structure is normally considered, refined and developed during the early design stages in response to project and/or client requirements (Ballal and Sher, 2003; Soetanto *et al*., 2006b). The work stages of the RIBA Plan of Work (2007) have been used in this research as the stages are the most generic and applicable to the UK construction industry. Hence, the term 'early design' here is used as a shorthand for RIBA Stages C (Concept) and D (Design Development).

A structural frame is defined as *"the load-bearing assembly of beams, columns and other structural members connected together and to a foundation to make up a structure"* (Blockley, 2005, p.453). Structural frames have an increasingly demanding role to play in modern commercial buildings, with the growth in use of larger clear-span floors and increasing numbers of mixed-use developments with conflicting structural grids. However, this situation appears not to have had a knock-on effect on the selection of the structural frame (Bibby, 2006). Although designers have a wide choice of structural frame materials for buildings, i.e. concrete, steel, timber, masonry etc., these tend to be based on structural steel or reinforced concrete frame types (Soetanto et al., 2007). The choice of a concrete or steel frame is still mainly dependent on the building type and site-specific constraints (Bibby, 2006) and, although the choice of frame is heavily influenced by the issues specific to that project, there are a number of issues that are commonly considered by project participants (Haroglu *et al*., 2008). For instance, Idrus and Newman (2003) state the selection criteria often focus on cost and time requirements and a previous survey by

Soetanto *et al*. (2006b) identified 31 issues perceived to be important in influencing the structural frame decision making process.

The UK has a tradition of in-situ concrete construction and in the past in-situ concrete frame construction dominated the frame market. Concrete has lost significant market share to structural steel in the framed structure market over the past two decades (BRE, 2005). However, changes in the building regulations and in the high price of land favour the use of concrete over steel for high-rise residential construction. These higher land values are dictating higher density developments to generate greater returns. High-rise residential apartment blocks often utilise the concrete frame's additional mass for improved acoustic insulation, improved energy consumption from its increased thermal mass and a high quality finish from exposed concrete (Stefanou, 2004). Also, as the sustainability agenda develops in ever greater importance, concrete and steel construction strive to achieve sustainable design solutions as well as a structurally efficient solution.

Clients are at the core of the process and their needs must be met by the industry (Latham, 1994). The client is the sponsor of the construction process and provides the most important perspective on how the construction industry performs as far as procurement systems are concerned (Rowlinson and McDermott, 1999). According to Masterman (2006), the client is the organization, or individual, who commissions the activities necessary to implement and complete a project in order to satisfy its/his needs and then enters into a contract with the commissioned parties: the client is therefore central to the project. The Building Research Establishment (2005) has suggested that the future direction of research and development in the concrete frame sector must take cognisance of the importance of better understanding the clients' requirements.

With these factors in mind a major research study was undertaken to examine key project stakeholders and their views on the structural frame selection process, the methods used which is described below.

THE RESEARCH APPROACH

Having reviewed the literature from previous studies in this field, it was decided to conduct semi-structured interviews with structural engineers in order to obtain information in relation to the structural frame decision making process. As the profession for whom structural frame design is a core competence, it was considered appropriate to target a small group of these individuals in the first instance to explore a range of questions about structural frame choices. Thus, nine interviews with structural engineers were carried out in total over a two-month period at the interviewees' work places. Each interview was tape recorded and subsequently transcribed verbatim and analyzed. One of the main outcomes was that, cost consultants, project managers and clients were found to be the most influential people in the structural frame selection process, other than structural engineers. Furthermore, although the semi-structured interviews found that the choice of frame is heavily influenced by the issues specific to the particular project in hand, it was possible to identify a list of generic selection criteria for the choice of frame because the engineers were asked to identify what they considered to be the most important generic issues in frame selection, regardless of location or project.

So, a list of the key issues relevant to structural frame selection was compiled and the intention thereafter was to collate cost consultants', project managers' and clients' reactions to the validity of these issues, but before that,,a facilitated half-day internal workshop with a selection of structural frame specialist staff (one cost consultant, seven structural and civil engineers) was held to refine the wording of the final list of issues, with the aim of using it in a postal questionnaire survey to the aforementioned groups. The number of issues was necessarily restricted to ten; this was to reflect the level of importance but also to enable the respondents to provide timely and considerable responses. As a result, the ten key issues identified are as follows (shown as presented in the survey):

- Architecture: aesthetic issues, layout, etc.
- Building use/function: fire resistance, durability, acoustics, span, adaptability to later modifications, etc.
- Cost: design and construction cost
- Preference: preference for a particular frame type or material
- Programme: speed of construction
- Risk: client needs, the market, expenses, certainty of delivery etc.
- Site: site accessibility, ground conditions, height restrictions, party wall agreements.
- Size of building: number of floors / m²
- Supply chain capability: flexibility in the layout of services, ease of supply of materials
- Sustainability: durability, recylability, environmental impacts, thermal mass, whole life cost, etc.

QUESTIONNAIRE SURVEY

The list of selection criteria, as above, was developed into a questionnaire which was designed to capture practitioners' perceptions of the relative importance of each criterion. The postal questionnaire was distributed to cost consultants, project managers and clients, since they were found to be the most influential people in the structural frame selection process, as identified by the structural engineers interviewed earlier.. The respondents were asked to rate the importance of the key issues on a 4-point Likert scale ranging from 0 for ´lowest level´ to 3 for ´highest level´ as by using an odd number of response points, respondents may be tempted to 'opt-out' of answering by selecting the mid-point (Fellows and Liu, 2003). A pilot study was then carried out with a sample of nine people from both industry and academia to test its legibility and speed of completion. As a result of the pilot study, a few alterations were made to the questionnaire and soon afterwards it was distributed amongst construction clients, cost consultants and project managers to establish the significance and rank order of the key issues.

The individual respondents were selected randomly from a database of professionals held by The Concrete Centre (TCC), the total size of which is around 25,000 names, not all of whom would be able to comment on this subject matter. Analysis of suitability (based on company activity, regardless of size) resulted in 239 postal questionnaires being sent to a sample of selected individuals, working for cost managers, project managers and client bodies, in the public and private sectors. As a result, 70 questionnaires were received in total, giving an overall response rate of 29.3% which is considered sufficient compared with the norm of 20-30% with regard to questionnaire surveys in the construction industry (Akintoye and Fitzgerald, 2000);

Cronbach's Alpha coefficient was 0.812, which is also considered acceptable in terms of research reliability.. Of the responses received, 20 were from cost consultants, 25 from project managers and 25 from clients (see Table 1).

Table 1: Breakdown of questionnaire responses and response rate

	Number of Questionnaires		
Respondent group	Distributed	Returned	Response rate %
Cost Consultant	86	20	23.26
Project Manager	74	25	33.78
Client	79	25	31.65
Total	**239**	**70**	**29.29**

To ensure each individual's credibility, the respondents were asked about their influence over the choice of frame for a building project. It was found that 75% of the respondents thought they had a great deal or some influence over the choice of frame for a building project which suggests that the respondents were generally influential in the structural frame selection, and possessed sufficient knowledge in the structural frame decision-making process.

The results revealed that all of the ten issues included in the list were considered to be important, confirming the validity of the criteria as a basis for consideration in structural frame selection. Because of this, and the considerable degree of influence the respondents have on the choice of frame, the returned sample was considered to be representative of the actual decision-making population. The methods applied for the statistical analysis are described next.

ANALYSIS AND STATISTICAL TECHNIQUES

This questionnaire was designed to provide predominantly descriptive data. An ordinal scale was used to obtain data in this survey that the distances between the numbers (ratings) assigned in the Likert scale were not known. Therefore, non-parametric tests were used in the analysis because non-parametric statistical tests are available to treat data which is inherently in ranks (Siegel and Castellan, 1956; Johnson and Bhattacharyya, 1996); the analysis was then carried out on the ranks rather than the actual data. The non-parametric procedures adopted for this study were frequency, severity index analysis, and Spearman's rho (ρ) test.

Frequency analysis was first used to examine the degree of importance for each issue. Severity indices were then calculated by using the frequencies of responses via Equation 1 (Ballal, 2000). The issues were then placed in rank order from 1 to 10. The form of the Equation is as follows:

$$S.I. = [\sum_{i=1}^{i=n} \omega i * fi] * 100\% / n$$

… (1)

Where: S.I. = severity index; fi = frequency of responses; ωi = weight for each rating; n = total number of responses

Since the 4-point Likert scale ranging from 0 for ´lowest level´ to 3 for ´highest level´, was used for the survey in order for the respondents not to be tempted to 'opt-out' of answering by selecting the mid-point, the weight assigned to each rating and is calculated by the following Equation 2 (Ballal, 2000):

ωi = (Rating in scale) / (number of points in a scale)

… (2)

Therefore, $\omega 0 = 0 / 4 = 0$; $\omega 1 = 1 / 4 = 0.25$; $\omega 2$ = No mid-point in the scale; $\omega 3 = 3 / 4 = 0.75$; $\omega 4 = 4 / 4 = 1$

Example: An example of the calculation for the severity index is given below:

Effect of "Sustainability" at Stage C by Client:

	Not imp=0	Of little imp=1	Quite imp=2	Extremely imp=3	Total (n)
Frequencies (fi)	3	3	8	11	25

S.I. = ((3*0+3*0.25+8*0.75+11*1)/65)*100 = 71%

Having calculated the severity indices of each issue for each group, the next step was to conduct a comparative analysis to distinguish between their responses. Since the variables are at the ordinal level, there are two prominent methods for examining the relationship between pairs of ordinal variables namely, *Spearman's rho* (ρ) (or Spearman rank correlation rs) and *Kendall's tau* (τ) – the former being more common in reports of research findings (Brymer and Cramer, 2005). Kendall's tau usually produces slightly smaller correlations, but since Spearman's rho is more commonly used by researchers, it was decided to use it in this case. The Spearman's rho correlation coefficient is produced by using the rank of scores rather than the actual raw data (Brymer and Cramer, 2005; Hinton *et al*., 2004; Kinnear and Gray, 2006). The Statistical Package for the Social Sciences (S.P.S.S.) was used to compute and run these statistical analyses. The next section presents the results of the survey and discusses the major findings that emerge.

RESULTS AND DISCUSSION

RANKING OF THE KEY ISSUES BY EACH GROUP

Tables 2 and 3 display the respondents' view of the degree of influence of the project team members on the choice of frame during the early design stages.

Table 2: Results for each group at RIBA Stage C 'Concept'.

Concept (Stage C of RIBA Stages)						
Key Issues	Cost Consultant		Project Manager		Client	
	S.I %	**Rank**	S.I %	**Rank**	S.I %	**Rank**
Cost	87.5	**1**	91.7	**2**	89.0	**1**
Architecture	81.3	**2**	80.2	**3**	85.0	**2**
Building use/function	77.5	**3**	92.7	**1**	75.0	**6.5**
Site	76.3	**4**	66.3	**8**	74.0	**8**
Size of building	73.7	**5**	75.0	**6**	82.3	**3**
Risk	71.3	**6**	76.0	**5**	75.0	**6.5**
Programme	70.0	**8**	79.3	**4**	82.0	**4**
Preference	70.0	**8**	67.7	**7**	79.0	**5**
Sustainability	70.0	**8**	54.3	**9.5**	71.0	**9**
Supply chain capability	43.8	**10**	54.3	**9.5**	63.0	**10**

Table 3: Results for each group at RIBA Stage D 'Design development'.

Design Development (Stage D of RIBA Stages)						
Key Issues	Cost Consultant		Project Manager		Client	
	S.I %	**Rank**	S.I %	**Rank**	S.I %	**Rank**
Cost	92.1	**1**	85.4	**1**	96.0	**1.5**
Architecture	86.3	**2**	79.0	**4**	96.0	**1.5**
Programme	82.5	**3.5**	82.0	**2**	91.0	**3.5**
Risk	82.5	**3.5**	70.8	**6**	87.0	**6**
Building use/function	80.0	**5**	79.2	**3**	89.0	**5**
Preference	78.8	**6**	65.0	**9**	91.0	**3.5**
Size of building	76.3	**7**	71.7	**5**	85.4	**7**
Site	76.3	**8**	69.8	**7**	79.0	**9**
Sustainability	75.0	**9**	67.7	**8**	73.0	**10**
Supply chain capability	70.0	**10**	59.4	**10**	81.0	**8**

Establishing agreement amongst three groups

To investigate the agreement amongst the three sets of respondents on the ranking of the key issues, Spearman's rho (ρ) test was applied. Spearman's rho (ρ) (or Spearman rank correlation rs) test was computed using the Statistical Package for the Social Sciences (SPSS). The three groups are correlated statistically by applying Spearman Rho test. Table 4 presents all of the Spearman Rho correlations computed, using SPSS.

Table 4: Spearman's Rho (r) test results on the significance of issues between disciplines.

	Correlations		
Stages	Cost Consultant vs. Project Manager	Cost Consultant vs. Client	Project Manager vs. Client
	Correlation Coefficient		
Stage C	0.732*	0.640*	0.707*
Stage D	0.809**	0.884**	0.640*

NB: **, * denotes 'strong' with $p < 0.01$ and 'some' with $p < 0.05$ statistical evidence of significant similarities.

The level of significance was determined by SPSS both at 0.05 and 0.01 levels, which indicated the degree of relationship amongst the three groups. While $p < 0.05$ means that there is less than a 5 per cent chance that there is no relationship between the two rankings, $p < 0.01$ can be accepted at the 99% confidence level, assuring that agreement between the two rankings was much higher than it would occur by chance (Bryman and Cramer, 2005; Fellows and Liu, 2003; Field, 2000). From Table 4 above, all of the correlations written with asterisks did achieve statistical significance at either $p < 0.05$ or $p < 0.01$ which confirmed that there are strong relationships amongst the rankings of three groups, particularly at stage D. It may therefore be concluded that the rankings obtained from the three groups, as given by the severity index analysis, was consensual.

DIFFERENCES IN PERCEPTION

In this part of the analysis, the differences in attitude were examined. Figures 1, 2 and 3 show how strongly each party regards each issue and how strongly that party is regarded by the other parties on those issues. This is to provide construction practitioners with an insight into the perceptions of the three groups about the attitudes of each other towards the key issues.

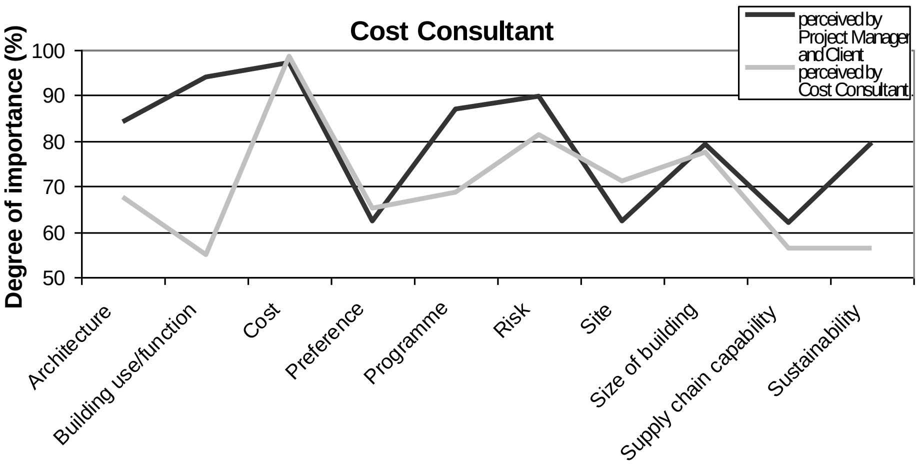

Figure 1. Perceptions of cost consultants

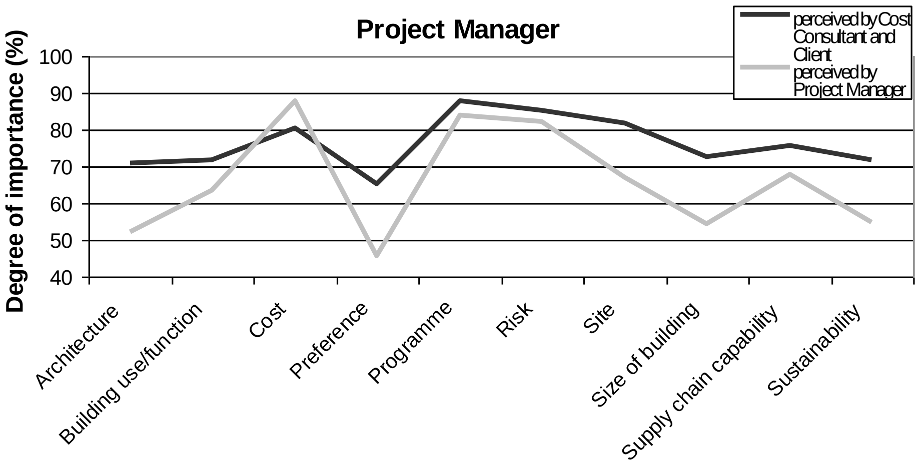

Figure 2. Perceptions of project managers

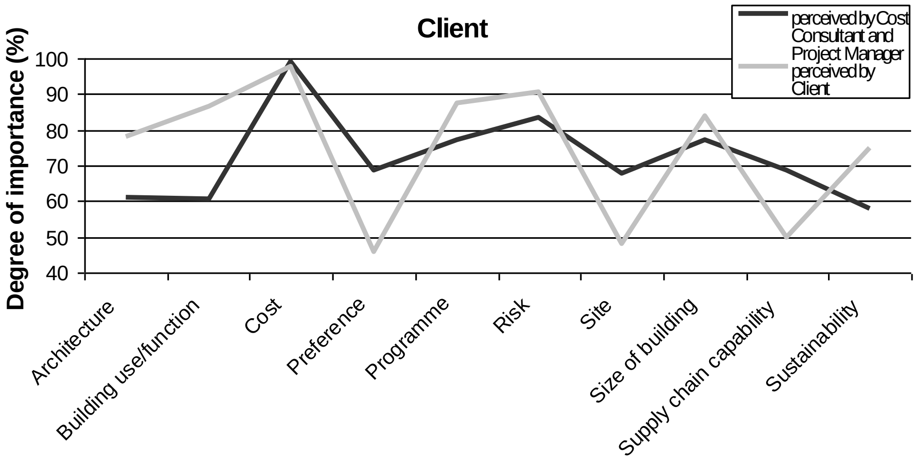

Figure 3. Perceptions of clients

It can reasonably be concluded from the results of the analysis that all of the ten issues identified were of at least some significance to the three sets of respondents. Also, the results of the Spearman's rho (ρ) test suggest that there is a strong consensus amongst the three groups on the rankings of the issues at each stage of early design. However, there appears to be a considerable disparity between what the three groups themselves think of the issues and what others perceive their attitudes to be in relation to the significance of the ten key issues over the structural frame selection process, particularly what 'clients perceive' differs significantly from 'how clients are perceived'.

The Spearman's rho (ρ) test results (see Table 4) confirmed that there was a strong agreement amongst the three groups in terms of the ranking of the key issues. As might be expected, 'Cost' was perceived to be the most important issue by each group of the respondents. Architecture also appeared to be important. Furthermore, although the issues of 'Sustainability' and 'Supply chain capability' were ranked to be the least important issues by each group, the degree of importance assigned to them by each group was sufficient to argue that they are typically taken into account when choosing the structural frame

Despite the strong agreement amongst the three groups in relation to the significance of the issues, their views counter one another in places. The three groups display differences of opinion about ‘Building use/function’, ‘Size of building’ and ‘Preference’ at stage C. For instance, rather surprisingly, clients attributed a lower importance to ‘Building use/function’ than cost consultants and project managers; a situation that warrants further investigation. ‘Size of building’ is another area of difference amongst the three groups at stage C. Cost consultants and project managers do not consider ‘Size of building’ with the same degree of importance as do clients (perhaps because they think this is not of concern to them, but more so to clients and contractors). Yet again it is surprising that clients pay more attention to the importance of ‘Preference’ than the other two groups of the respondents. This indicates that clients are under the impression that making decisions based on familiarity and personal preferences is a common practice. The agreement was even stronger at stage D as regards the correlation coefficients of Spearman test in Table 4. However, ‘Architecture’, and ‘Preference’ are the areas of difference amongst the three groups of the respondents at stage D. Clients unsurprisingly pay far more attention to the importance of ‘Architecture’ than do cost consultants and project managers at stage D. The low rankings of ‘Supply chain capability’ by each group could be attributed to the early design stages, as it may have been thought to be too early to consider on.

On the other hand, regarding the differences in perception of cost consultants shown, it appeared that there is a relative agreement between what cost consultants perceive and how cost consultants are perceived by project managers and clients over the issues of ‘Cost’, ‘Preference’, ‘Size of building’ and ‘Supply chain capability’. However, there are still some major divergences on the issues of ‘Architecture’, ‘Building use/function’, ‘Programme’ and ‘Sustainability’. Interestingly, ‘Architecture’ and ‘Building use/function’ were perceived to be highly important to cost consultants, whereas cost consultants thought not. However, there appears to be some differences in the perceptions of project managers. The main differences are about; ‘Architecture’, ‘Preference’, ‘Site’, ‘Size of building’ and ‘Sustainability’. It is again surprising to see that whilst ‘Site’ was perceived to be one of the most important issues to project managers, yet it was not given the same degree of importance by project managers themselves. Finally, what ‘clients perceive’ differs significantly from ‘how they are perceived’, particularly on the issues of; ‘Architecture’, ‘Building use/function’, ‘Preference’, ‘Site’ and ‘Sustainability’. Taking the issue of “Preference”; cost consultants and project managers claim that clients’ tendency to build in a particular frame material is high – far more than clients acknowledge. More surprisingly, project managers and cost consultants did not feel that ‘Building use/function’ was important for clients as clients did themselves. In summary, the results show clear disparities between how groups see themselves making a decision and how others see them doing so.

As in any research based on a questionnaire survey, this study is of course subject to some biases and limitations. Firstly, with regard to the use of The Concrete Centre’s database; although it may not necessarily represent the whole UK construction industry, it is large (25,000 names), up to date and nationwide. Secondly, since the postal questionnaire was sent through the post from The Concrete Centre to the respondent, it may have been presumed that the main thrust of this survey was about concrete frames, rather than structural frames in general. And finally, the number of the key issues was restricted to ten in order to obtain timely and considerable responses from the respondents. Nonetheless, it can be said that the ranking of the ten issues by the three sets of the respondents for this study does adequately represent the views of the UK construction industry.

Furthermore, in construction, as in any industry, it is crucial that client satisfaction is achieved if an organization is to succeed, or indeed survive. Thus, a key stakeholder is the client, namely the organization or individual who makes the decision to purchase services from the construction industry (Barrett, 2000). Nevertheless, in the light of the survey findings the industry does not seem to understand clients' needs as highlighted in both the influential Latham (1994) and Egan (1998) reports.

Therefore, it remains to be seen whether the industry will find ways of tackling this problem. In addition, although, as the literature and the interviews indicated, the choice of frame is heavily influenced by the issues specific to the project in hand, the ten key issues identified proved to be significantly important during early design, particularly 'Cost' and 'Architecture'. In addition, decisions about the choice of frame must take account of project team members' interests. Thus the rank ordering of the issues by each group can give construction practitioners a good indication of the objectives and priorities of these three groups – besides which, the findings help to explore and clarify misconceptions the three groups have about one another's attitudes towards the structural frame selection process. What it does not do is account for emerging priorities: new issues may increase in relevance or urgency over time; for example, little attention seemed to have been paid by the respondents to refurbishment and retrofitting, but this is a key consideration for some projects. Indeed, it is possible although unlikely that, had the research process commenced with a group other than the structural engineers, other issues may have been highlighted from the outset.

CONCLUSIONS

Selecting the most appropriate structural frame is critical to a project's success. The opportunity to enhance the performance and value of a proposed project is immense during the early design stages (ASCE, 2000; Kolltveit and Grønhaug, 2004). As a result of a literature review, semi-structured interviews and a workshop, ten key issues were recognized as being the most important to the structural frame selection process. A questionnaire survey was then distributed to UK cost consultants, project managers and clients in order to evaluate their views on these ten key issues and, hence, the structural frame selection process. There is, though, no precise prescription of what constitutes a successful structural frame selection process, but the findings of this study provide a basis for assessing professional perspectives on structural frame selection.

The literature and the findings of the survey confirmed once more that a primary determinant in the structural frame choice is cost. All the ten key issues proved to be critical to the choice of frame with regard to the magnitude of their severity indices. Furthermore, although it can be argued that cost consultants, project managers and clients necessarily and properly have fundamentally different points of view, Spearman's rho (ρ) test statistically revealed that there was strong agreement amongst the cost consultants, project managers and clients over the significance of the ten key issues affecting the selection of a structural frame for a building project. The ranking of these issues at early design stages could therefore be adopted as the fundamental criteria for assessing and selecting a structural frame for a building project.

In addition, there is a notable gap between what the three groups themselves think of the key issues and how they perceive one another, particularly the clients. For instance, contrary to the perceptions of cost consultants and project managers about clients, clients pay significant attention to the issue of 'Architecture', whereas they attribute a low importance to 'Building use/function'. The project team should therefore focus on clients' needs and on ways of recognising those needs in order to choose the most appropriate structural frame option.

As a result of these findings, construction practitioners will have the benefit of an understanding the perceptions of the cost consultants, project managers and clients on the key issues which proved to be vital to the structural frame selection process, but further exploration of the linkages between such issues would be a useful addition to this work. Future directions may also include an extension of this work with more project stakeholders (e.g. architects), in order to see the degree of importance of the key issues from other different perspectives as well as validating the key issues further as a sound basis for use in structural frame selection.

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APPENDIX B (PAPER 2)

Full reference:

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Critical Factors Influencing the Choice of Frame Type at Early Design

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Abstract: The design process, as defined by Pahl and Beitz (1988), is the intellectual attempt to meet certain demands in the best possible way. Early design phase is a critical part of a building project and decisions made through this phase lay the foundations for the construction phase. These involve the evaluation of alternative frame types fulfilling key constraints in order to come up with the optimum structural solution. Although the choice of frame is heavily influenced by the factors specific to that project, there are a number of issues that are commonly considered by project participants. These issues were addressed by means of literature review, semi-structured interviews and a workshop, to identify the most important factors in influencing structural frame selection. This paper reports on research which analysed postal questionnaires sent to cost consultants, project managers, and clients and established a ranking of ten issues for each stage of early design. The data collected were tested, using the Statistical Package for the Social Sciences (SPSS) through *frequency* and *Spearman's rho* (ρ) analyses. Ten issues proved to be significant to the structural frame selection process; the statistical tests have established the agreement between cost consultants, clients and project managers in the rankings of these issues. Therefore, the paper concludes that these issues could be adopted as fundamental criteria for assessing and selecting the structural frame type for a building project during the early design phase.

Key words: Early design, structural frame, selection criteria.

1. Introduction

The decision on the selection of a structural frame has profound implications for the future performance of a building project. The choice of a structural frame of a building has a major influence on the value to the client, because it provides a high degree of functionality and future flexibility, and can strongly affect the speed of the construction process (SCI, 2000). Furthermore, the frame choice is the key phenomenon of a building project that has a huge impact on both the short- and long-term performance of the completed building. In the short term the frame must give its client the satisfaction of his/her needs such as construction being completed on time and to budget, it must also satisfy future changes in functional requirements of the building in the long term (Soetanto *et al*, 2006). It is therefore significant to recognize the issues that are the most important when choosing the frame type of a building

In this context, this paper reports on research based on a questionnaire survey which ranked the criteria used by project team members when selecting structural frames. The criteria were compiled based on a thorough review of literature on the structural frame selection process, semi-structured interviews and a workshop. The results were analysed using Statistical Package for the Social Sciences (SPSS), and through *frequency analysis*, confirmed that the ten issues were considered to be important by the respondents. The severity index has been further used to rank the issues for the degree of significance. Lastly, *Spearman's rho* (ρ) analysis has been calculated to establish a measure of agreement between cost consultants, clients and project managers in the rankings of issues at early design phase. The study presents findings of a questionnaire survey to establish a ranking of the criteria at the early design and to investigate the degree of agreement among cost consultants, project managers, and clients with regards to the criteria for choosing a frame for a building project. The aim is to present the key issues in order of importance for project team members to consider when choosing an appropriate structural frame for their building projects during the early design phase.

2. The Process of Structural Frame Selection

A structural frame is typically defined as "the load-bearing assembly of beams, columns and other structural members connected together and to a foundation to make up a structure" (Blockley, 2005). According to Soetanto et al, (2006) the structural frame is the skeleton that defines and holds the whole building together. There is a wide choice of structural frame types for building projects. There are four basic types available: *concrete, steel, timber,* or *masonry.* Although many options are available, these tend to be based on structural steel or reinforced concrete frame types for the simplest buildings (Soetanto et al., 2007). Bibby (2006) indicated that the choice of whether to go for a concrete or steel frame is still mainly dependent on building type and site-specific constraints.

Although the choice of frame is heavily influenced by the factors specific to that project, there are a number of issues that are commonly considered by project participants when choosing the frame type. The choice of primary structure is generally determined by cost with less regard to functionality and performance characteristics (SCI, 2000). This is further corroborated by Idrus and Newman (2003) that frame selection criteria often focus on cost and time requirements. However, the cost model studies published by The Concrete Centre (UK) revealed that the structural frame comprises between 7-12% of the final cost of a building in relation to the type of the building (Ryder, 2007). Therefore, The Concrete Centre (2004) suggests that frame cost should not dictate the choice of frame. Many other factors should also be taken into consideration when selecting the optimum frame solution such as programme, health and safety, environmental performance, etc.

The work stages of the RIBA Plan of Work (2007) are used in this research as the stages are well-known and widely recognized throughout the UK Construction Industry. We can consider that 'early design' covers design development between RIBA Stages C (Concept) and D (Design Development), and is the phase when the structural frame of a building project is usually selected (Ballal and Sher, 2003). Soetanto et al, (2007) point out the major problem of making decisions based on early designs is the subjectivity which individuals bring to the process. However, the level of a building's performance is largely reflected in the quality of decisions taken in the early stages of the project (McGeorge and Palmer, 2002), hence, the importance of decisions made at the initial design stage is significant since succeeding design tasks, analysis and detailed design generally aim at satisfying the constraints imposed during this formative stage (Ballal and Sher, 2003). Kolltveit and Grønhaug (2004) described the early phase as "the process and activities that lead to, and immediately follow, the decision to undertake feasibility studies and to execute the main project". Furthermore, the pressure to improve decisions made at the preliminary design process has increased following calls for cost reductions, timely completions, and zero defects in building projects (Egan, 1998; Latham, 1994).

With these pressures in mind a major research study was undertaken to examine key project stakeholders and their views on the structural frame selection process, the methodology for which is described below.

3. Methodology

A comprehensive literature review was first completed in order to collect the key issues from the previous studies in this field. Semi-structured interviews were then conducted with structural engineers to recognize the key issues. Having listed the key issues identified from both the literature and the semi-structured interview' findings, a facilitated internal workshop with TCC members was intended to generate the final list of ten key issues as being the most important affecting the structural frame selection for a building project with the aim of using them in the postal questionnaire survey. These issues are listed and briefly described in Table 1; the following section describes the methodology used in detail.

Table 1. Key issues influencing the choice of frame type at early design

No	Issues	Explanation
1	Architecture	Aesthetic issues, layout, etc.
2	Building Use/function	Fire resistance, durability, acoustics, Span, Adaptability to later modifications, etc.
3	Cost	Design and Construction Cost
4	Preference	Preference for a particular frame type
5	Programme	Speed of construction
6	Risk	Client needs, the market, expenses, certainty of delivery etc.
7	Site	Site accessibility, ground conditions, height restrictions, party wall agreements.
8	Size of building	Number of floors / m²
9	Supply chain capability	Flexibility in the layout of services, ease of supply of materials
10	Sustainability	Durability, recylability, environmental impacts, thermal mass, whole life cost, etc.

3.1 Interviews

Nine semi-structured interviews were arranged with structural engineers in selected consultancies to retrieve information about structural frame options and how they are evaluated. The core topics discussed during these interviews included: the frame types applied in their projects, influential, criteria used for selecting the frame type, and the rationale behind the preferred frame type of their current project. These interviews were carried out in total over a two-month period at the interviewees' work places, each lasting approximately 30 minutes. Each interview was tape recorded and subsequently transcribed verbatim and analysed. Although the semi-structured interviews found that the choice of frame is heavily influenced by the factors specific to the particular project in hand, a draft, generic list of selection criteria for the choice of frame was developed.

3.2 Internal Workshop

Based on the literature review and the findings from semi-structured interviews, a facilitated half-day workshop with a selection of structural frame specialist staff at The Concrete Centre was held to refine and agree the final list of issues, with the aim of using this in a postal questionnaire survey. The number of issues was necessarily restricted to ten, as shown in Table 1; this was to reflect the level of importance but also to enable the respondents to provide timely responses.

3.3 Questionnaire survey

The list of criteria was then developed into a questionnaire instrument designed to capture practitioners' perceptions of the relative importance of each criterion. The respondents were asked to rate the importance of the criteria on a 4-point Likert scale ranging from 0 for ´lowest level´ to 3 for ´highest level´ as by using an odd number of response points, respondents may be tempted to 'opt-out' of answering by selecting the mid-point (Fellows and Liu, 2003). Having developed the questionnaire, a pilot study was carried out with a sample of nine people from both industry and academia to see how they understand the questions and the response options. Having made a few amendments to the questionnaire as a result of the pilot study, the questionnaire survey was distributed amongst construction clients, cost consultants and project managers to establish the significance and ranking order of the issues identified.

The individual respondents were selected randomly from a database of professional companies held by The Concrete Centre (TCC), regardless of the size of the company. As shown below in Table 2, 239 postal questionnaires were sent to selected names, working for cost managers, project managers and client bodies, in the public and private sectors. As a result, 70 questionnaires were received in total, giving an overall response rate of 29.29% which is considered sufficient enough to meet the research reliability level compared with the norm of 20-30% with regard to questionnaire surveys in the construction industry (Akintoye and Fitzgerald, 2000). Of the responses received, 20 were from cost consultants, 25 from project managers and 25 from clients (Table 2).

Table 2. Questionnaire distribution and response rate

	Number of Questionnaires		
Respondent group	Distributed	Returned	Response rate %
Cost Consultant	86	20	23.26
Project Manager	74	25	33.78
Client	79	25	31.65
Total	**239**	**70**	**29.29**

To ensure each individual's credibility, the respondents were asked about their influence over the choice of frame type for a building project. It was found that 75% of the respondents have a great deal or some influence over the choice of frame type for a building project which suggests that the respondents were generally influential in the structural frame selection, and possessed sufficient knowledge in the structural frame decision-making process.

The results revealed that all of the ten issues included in the list were considered to be important, confirming the validity of the criteria as a basis for consideration in structural frame selection. Because of this, and the considerable degree of influence the respondents have on the choice of frame type, the returned sample was considered to be representative of the actual decision-making population. The next section considers some of the results in detail.

4. Analysis and Results

This questionnaire was designed to provide predominantly descriptive data. An ordinal scale was used to obtain data in this survey that the distances between the numbers (ratings) assigned in the Likert scale were not known. Therefore, non-parametric tests were used in the analysis because non-parametric statistical tests are available to treat data which is inherently in ranks (Siegel and Castellan, 1956; Johnson and Bhattacharyya, 1996); the analysis was then carried out on the ranks rather than the actual data. The non-parametric procedures adopted for this study were frequency, severity index analysis, and Spearman's rho (ρ) test.

First of all, frequency analysis was applied to examine the degree of significance for each issue. The severity index was used to rank the issues for the degree of importance. The results of the frequency analysis and the ranking (severity index) have been based on analyses of all the completed responses. Individuals within these three disciplines provided information based on their own experiences from one of their projects that had recently started on site. However, these experiences were gained from distinct disciplines in the early design phase, so it was essential to conduct a comparative analysis to distinguish between their responses. Since the variables are at the ordinal level, there are two prominent methods for examining the relationship between pairs of ordinal variables namely, *Spearman's rho* (ρ) (or Spearman rank correlation rs) and *Kendall's tau* (τ) – the former being more common in reports of research findings (Brymer and Cramer, 2005). Kendall's tau usually produces slightly smaller correlations, but since Spearman's rho is more commonly used by researchers, it was preferred to be employed in this paper. The Spearman's rho correlation coefficient is produced by using the rank of scores rather than the actual raw data (Brymer and Cramer, 2005; Hinton *et al*., 2004; Kinnear and Gray, 2006). The Statistical Package for the Social Sciences (S.P.S.S.) was used to compute and run these statistical analyses.

4.1 Ranking the key issues: frequency and severity index analysis

This stage of the statistical analysis ranked the issues in order of importance for each stage of early design. In this case, frequency analysis was first carried out to obtain the frequency of the respondents, using the Statistical Package for the Social Sciences (S.P.S.S.). The frequencies of responses were therefore used to calculate severity indices for each issue via Equation 1 (Ballal, 2000):

$$[1] \qquad S.I. = \left[\sum_{i=1}^{i=n} \omega i * fi\right] * 100\,\% \,/\, n$$

Where:

S.I. = severity index $\qquad$ fi = frequency of responses

ωi = weight for each rating $\qquad$ n = total number of responses

Since the 4-point Likert scale ranging from 0 for ´lowest level´ to 3 for ´highest level´, was used for the survey in order for the respondents not to be tempted to 'opt-out' of answering by selecting the mid-point, the weight assigned to each rating and is calculated by the following Equation 2 (Ballal, 2000):

$$[2] \qquad \omega i = (Rating\ in\ scale) / (number\ of\ points\ in\ a\ scale)$$

ω 0 = 0 / 4 = 0 $\qquad$ ω 1 = 1 / 4 = 0.25 $\qquad$ ω 2 = No mid-point in the scale

ω 3 = 3 / 4 = 0.75 $\qquad$ ω 4 = 4 / 4 = 1

Example: An example of the calculation for the severity index is given below:

Effect of "Architecture" at the Stage C:

	Not Important=0	Of little importance=1	Quite important=2	Extremely important=3	Total (n)
Frequencies (fi)	0	6	31	32	69

Severity Index = ((0*0+6*0.25+31*0.75+32*1)/69*100 = 82.25**%**

The issues were then ranked in order of value of severity index, the highest value having a rank of 1, and the lowest value assigned a rank of 10. Tables 3 and 4 present the issues ranked in terms of importance for each of the early design stages. 'Cost' appeared to be the most important issue at both stages.

Table 3. Issues ranked in Concept Design

Concept Design (Stage C of RIBA Stages)							
Key issues or criteria	Frequency of responses for score of				No. of responses	Severity Index %	**SPSS Rank**
	0	1	2	3			
Cost	0	3	20	46	69	89.49	**1**
Architecture	0	6	31	32	69	82.25	**2**
Building use/function	0	9	23	37	69	81.88	**3**
Programme	0	10	31	27	68	77.57	**4**
Size of building	1	8	31	25	65	77.31	**5**
Risk	0	14	29	26	69	74.28	**6**
Preference	3	8	40	18	69	72.46	**7**
Site	1	15	27	25	68	72.06	**8**
Sustainability	5	13	27	23	68	68.38	**9**
Supply chain capability	5	27	23	13	68	54.41	**10**

Table 4. Issues ranked in Design Development

Design Development (Stage D of RIBA Stages)							
Key issues or criteria	Frequency of responses for score of				No. of responses	Severity Index %	**SPSS Rank**
	0	1	2	3			
Cost	1	1	17	49	68	91.18	**1**
Architecture	2	2	22	44	70	87.14	**2**
Programme	2	1	31	36	70	85.00	**3**
Building use/function	2	5	24	38	69	82.97	**4**
Risk	1	8	27	33	69	80.07	**5**
Preference	5	6	23	36	70	78.21	**6**
Size of building	2	6	32	26	66	78.03	**7**
Site	2	11	28	28	69	75.00	**8**
Sustainability	5	11	25	28	69	71.74	**9**
Supply chain capability	3	14	28	24	69	70.29	**10**

4.2 Establishing agreement between project managers, cost consultants and clients

To investigate the agreement between three sets of respondents that is to say cost consultants, project managers and clients on the ranking of the key issues, Spearman's rho (ρ) test was applied. The frequency of responses and severity indices were again calculated for each group to produce a separate ranking of the issues, as shown in Tables 5 and 6.

Table 5. Comparison of severity index and ranking for each group at Concept Design

Key issues / Criteria	Concept Design (Stage C of RIBA Stages)					
	Cost Consultant		Project Manager		Client	
	Severity Index %	**SPSS Rank**	Severity Index %	**SPSS Rank**	Severity Index %	**SPSS Rank**
Cost	87.50	**1**	91.67	**2**	89.00	**1**
Architecture	81.25	**2**	80.21	**3**	85.00	**2**
Building use/function	77.50	**3**	92.71	**1**	75.00	**6.5**
Site	76.25	**4**	66.30	**8**	74.00	**8**
Size of building	73.68	**5**	75.00	**6**	82.29	**3**
Risk	71.25	**6**	76.04	**5**	75.00	**6.5**
Programme	70.00	**8**	79.35	**4**	82.00	**4**
Preference	70.00	**8**	67.71	**7**	79.00	**5**
Sustainability	70.00	**8**	54.35	**9.5**	71.00	**9**
Supply chain capability	43.75	**10**	54.35	**9.5**	63.00	**10**

Table 6. Comparison of severity index and ranking for each group at Design Development

Key issues / Criteria	Design Development (Stage D of RIBA Stages)					
	Cost Consultant		Project Manager		Client	
	Severity Index %	**SPSS Rank**	Severity Index %	**SPSS Rank**	Severity Index %	**SPSS Rank**
Cost	92.11	**1**	85.42	**1**	96.00	**1.5**
Architecture	86.25	**2**	79.00	**4**	96.00	**1.5**
Programme	82.50	**3.5**	82.00	**2**	91.00	**3.5**
Risk	82.50	**3.5**	70.83	**6**	87.00	**6**
Building use/function	80.00	**5**	79.17	**3**	89.00	**5**
Preference	78.75	**6**	65.00	**9**	91.00	**3.5**
Size of building	76.32	**7**	71.74	**5**	85.42	**7**
Site	76.25	**8**	69.79	**7**	79.00	**9**
Sustainability	75.00	**9**	67.71	**8**	73.00	**10**
Supply chain capability	70.00	**10**	59.38	**10**	81.00	**8**

From this, Spearman's rho (ρ) (or Spearman rank correlation r_s) test was computed using the Statistical Package for the Social Sciences (S.P.S.S.). The three groups are correlated statistically by applying Spearman Rho test. Table 7 presents all of the Spearman Rho correlations computed, using SPSS, as shown below.

Table 7. Spearman's Rho (r) test results between the rankings of three groups

Stages of Early Design	Correlations		
	Cost Consultant vs. PM	Cost Consultant vs. Client	PM vs. Client
	Correlation Coefficient		
Concept Design (Stage C)	0.732*	0.640*	0.707*
Design Development (Stage D)	0.809**	0.884**	0.640*

Note: ** , * denotes 'strong' with p < 0.01 and 'some' with p < 0.05 statistical evidence of significant similarities

The level of significance was determined by SPSS both at 0.05 and 0.01 levels, which indicated the degree of relationship amongst the three rankings. While $p < 0.05$ means that there is less than a 5 per cent chance that there is no relationship between the two rankings, $p < 0.01$ can be accepted at the 99% confidence level, assuring that agreement between the two rankings was much higher than it would occur by chance (Bryman and Cramer, 2005; Fellows and Liu, 2003; Field, 2000). From Table 7 above, all of the correlations written with asterisks did achieve statistical significance at either $p < 0.05$ or $p < 0.01$ which confirmed that there are strong relationships amongst the rankings of three groups, particularly at stage D. As a result, it may be concluded that the rankings obtained from the three groups, as given by the severity index analysis, was consensual amongst the respondents.

5. Findings and Discussion

As a result of the frequency and severity index analyses, the ten issues perceived by industry professionals as being the most important in influencing the choice of frame type were ranked in order of importance at each of the early design stages. The Spearman’s rho test established the consensus between the three sets of respondents in relation to the rankings of the issues at each stage.

“Cost”, as anticipated, overrides everything else, indicating that it still dominates structural frame selection. “Architecture” was perceived to be the second most important issue at both stages. ‘Building use/function’ was ranked the third at stage C, indicating the paramount importance of choosing the right type of frame type to suit a given situation. It is plausible that ‘Programme’ rises to be number three at stage D because as the design develops, it becomes a more important consideration. ‘Sustainability’ has a low score which was ranked the second least important issue suggesting that construction practitioners are not taking it seriously. Lastly, the least important issue is ‘Supply chain capability’. However, supply chain capability has significant scores of severity index at the stages C and D, 54.41 and 70.29% consecutively (Tables 3 and 4) which means that it is the least significant only when compared with the other nine key issues.

Table 7 present the Spearman’s rho (ρ) test results which revealed that there was a strong agreement amongst the three groups and the degree of agreement was higher than would have occurred by chance. ‘Cost’ is almost unanimously agreed upon to be the most important issue in the selection of a frame type, apart from stage C where ‘Building use/function’ was ranked highest by project managers. Although the cost consultants, project managers and client were in good agreement with each other with regard to the significance of the ten key issues, their opinions contradict each other in places. The three groups display differences of opinion about ‘Building use/function’, ‘Site’, ‘Size of building’ and ‘Programme’ at stage C. For instance, rather surprisingly, clients do not consider ‘Building use/function’ with the same degree of importance as do cost consultants and project managers, a situation that warrants further investigation. Furthermore, cost consultants pay more attention to the importance of ‘Site’ when compared with project managers and clients. On the other hand, cost consultants attribute less importance to ‘Programme’ than do project managers and clients (perhaps because they think this is not of concern to them, but more so to contractors and project managers). Regarding the Spearman correlation coefficients in Table 7, agreement is stronger at stage D. However, considering the rankings in Table 6, ‘Risk’ and ‘Preference’ are areas of difference amongst the three groups of the respondents, e.g. ‘Risk’ is ranked higher by cost consultants, clients attribute greater importance on ‘Preference’, but project managers perceived ’Preference’ to be the second least important issue. This raises a question of what makes clients think that ‘Preference’ plays an important role in the structural frame decision-making progress.

There are certainly some biases and limitations in this study as in any research based on questionnaire surveys. Firstly, with regard to the use of The Concrete Centre’s database; although it may not necessarily represent the whole UK construction industry, it is large (25000 names), up to date and nationwide. Secondly, the number of key issues was restricted to ten and these may have been interpreted in a different way by the respondents, despite efforts made to re-phrase the issues after the pilot study.

Nevertheless, it can be said that the ranking of the ten issues obtained from this study adequately does represent the views of the UK Construction Industry in relation to the structural frame selection process. Although the ten issues proved to be considerably important by the views of the respondents to the survey, the general agreement from the literature review was that the selection of frame is often based on the projects’ type and specific circumstances (Bibby, 2006). Also, as the literature indicated (SCI, 2000; Idrus and Newman, 2003), 'Cost' was proved once again to be the dominant issue in the structural frame selection process. In addition, client requirements are changing constantly, but they are not communicated to the whole project team resulting in non-conformities and costly changes at the construction phases (Process Protocol, 1998). As clients have become more aware and demanding of the construction industry, they are also becoming less tolerant of the problems and the risks involved in the delivery of major projects (Smith et al., 2004). Therefore, the rank ordering at each stage can give construction practitioners a good indication of the needs and priorities of their clients. Above all, the ranking of these issues at early design phase could be adopted as the fundamental criteria for assessing and selecting the structural frame type for a building project.

6. Conclusions

The early design phase is described in the literature as the process and activities that lead to the decision to execute the main project. Pressure on the industry to improve decisions made at the early design phase, particularly those involving costs and speeds, results in a need for more research in this field. Having undertaken a literature review, semi-structured interviews and a workshop, 10 key issues were identified as being the most important to the structural frame decision-making process. A questionnaire survey was distributed to UK cost consultants, project managers and clients. A total of 70 detailed responses were received and analysed, providing a number of useful insights into the way professionals make choices about structural frame types.

Much of the literature suggested that cost consultants, project managers and clients often have different views about what constitutes success for a building project. However, in this case, the Spearman's rho test statistically revealed that there was strong agreement between three disciplines over the significance of the key issues influencing the choice of a frame type for a building project. Selecting the correct structural framing is crucial to a project's feasibility and success and traditionally, cost is the most influential factor which was confirmed by this research, but architecture was also seen to be important.

It was clear that there were some areas of disagreement between parties, such as sustainability. Aspects such as this are of concern since global issues and regulatory changes are bringing pressure to bear on the construction industry to change its cost-focused attitude. It is clear that the choice of structural frame for a project remains a difficult battle ground for such issues.

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APPENDIX C (PAPER 3)

Full reference:

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Who is the key decision maker in the structural frame selection process?

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Abstract:
Selecting the correct structural frame is crucial to a project's feasibility and success, but this decision can have profound implications for the future performance of a building project. In practice, the eventual choice of a frame may involve various parties including client, project manager, cost consultant, structural engineer, architect, main contractor, etc. This paper presents research findings on the levels of influence of these project team members on the structural frame selection process. It describes the results of a two-year study in which various research methods were undertaken including a state-of-the-art literature review, semi-structured interviews and a postal questionnaire survey. The interviews showed that cost consultants, project managers and clients were found to be the most influential people in the structural frame decision-making process, so a postal questionnaire survey was sent to a sample of UK companies operating in these areas to further examine their priorities and views in detail. The data collected was subsequently analyzed and produced a rank ordering of project team members in relation to the influence they have on the choice of frame type at each stage of design process. In fact, they agreed that the structural engineer was the most influential decision-maker in the structural frame selection process. So, this paper asks the question 'who really is the key decision maker?' The conclusions will be of interest to all those concerned with project teams, structural frame design and selection and effective leadership in decision making.

Keywords: construction, project teams, structural frames, research

1 INTRODUCTION

The framed structure market cuts across several traditionally defined sectors such as residential, education, commercial, health, retail, leisure etc. The UK has a tradition of in-situ concrete construction and in the past in-situ concrete frame construction dominated the frame market. Over the past 20 years concrete has lost significant market share to structural steel in the framed structure market (BRE, 2005). However, concrete's range of structural frame solutions, its thermal efficiency, inherent fire resistance, acoustic and vibration performance, durability and low maintenance ensure that it performs well in a number of UK markets such as commercial and residential buildings (TCC, 2005). Nevertheless, the concrete market has remained steady over the past 18 months, with the exception of reinforcement prices, which are still volatile (Bibby, 2006).

Selecting the correct structural frame is crucial to a project's feasibility and success but this decision on the structural frame type can have profound implications for the future performance of a building project (Soetanto et al, 2006a). Furthermore, the project stakeholders' requirements should be captured and taken into consideration so as to ensure apt decisions in the design stage (Soetanto et al, 2006b). Therefore, we tend to make an assumption that the choice of an appropriate structural system during the design stage will lead to a successful project outcome. It is therefore essential to recognize the decision makers in the structural frame selection process. In practice, the eventual choice of a frame may involve various parties including client, project manager, cost consultant, structural engineer, architect, main contractor, etc. So who is the key person to influence what structural frame type is used, and any changes to the design of building project.

This paper describes the results of a two-year study in which various research methods were used including a state-of-the-art literature review, semi-structured interviews and a postal questionnaire survey. As a result of these interviews, cost consultants, project managers and clients were found to be the most influential people. A postal questionnaire, aimed at these three disciplines, to address the influence of project team members upon choosing appropriate frame type for building projects. The results were analysed using Statistical Package for the Social Sciences (SPSS), and through *frequency analysis*, confirmed that all project members, perceived by these respondents to the survey, have a great deal of influence in the choice of frame type. The severity index has been further used to rank the project team members (decision makers) for the degree of influence they have in the structural frame selection process. Lastly, *Spearman's rho* (ρ) analysis has been calculated to establish a measure of agreement between cost consultants, project managers and clients in the rankings of these decision makers at each stage of design process. The study presents findings of a questionnaire survey to establish a ranking of the decision makers (or project team members) at each stage of the design process and to investigate the degree of agreement among cost consultants, project managers, and clients with regards to the rankings. The aim is to provide a view of the different professions, decision makers involved in choosing the structural frame at each key step of the design process.

2 PROJECT TEAM MEMBERS

Although the precise contractual obligations of the project participants vary with the procurement option adopted, the project participants must carry out certain essential fundamental functions. The project team consists mainly of client, architect, project manager, structural engineer, cost consultant and main (principal) contractor (CIOB, 2002). Each member of the project team is described below:

Client: A client is a person or organisation paying for the services and can be represented by others, such as clients' representative, employer's agent, project manager, etc. Their chief interest would be to satisfy themselves that the contractor(s) were performing in accordance with the contract and to make sure they are meeting their obligations to pay all monies certified for payments to the consultants and the contractor(s) (CIOB, 2002).

Architect and Structural Engineer: The architect is in charge of the architectural issues, whereas the engineer is concerned with more technical issues. The design should be developed with the involvement of both sides: architect and engineer. There are different driving forces: technical for the engineer whose main aim is to make things "work" without compromising the architects' concept. The architect deals with the appearance of the structure which needs to be true to the concept and fit the context and use (Larsen and Tyas, 2003).

Project manager: Construction and development projects involve the coordinated actions of many different professionals and specialists to achieve defined objectives. The task of project management is to bring the professionals and specialists into the project team at the right time to enable them to make their possible contribution, efficiently. Effective management requires a project manager to add significant and specific value to the process of delivering the project. The value added to the project by project management is unique: no other process or method can add similar value, either qualitatively or quantitatively. The project manager in the main has a role which is principally that of monitoring the performance of the main contractor and the progress of the works (CIOB, 2002).

Cost Consultant (quantity surveyor): The cost consultant has responsibility to advise on building cost and estimating, which can have two distinct roles (Morrison, 1984):

- Part of the design team for cost advice but not management of budget.
- Appointed separately by the client as a cost consultant.

Main contractor: The principal management contractor has a duty to (CIOB, 2002):

- Mobilize all labour, subcontractors, materials, equipment and plant in order to execute the construction works in accordance with the contract documents.
- Ensure the works are carried out in a safe manner
- Indemnifying those working on site and members of the public against the consequences of any injury resulting from the works.

The extent to which the above-mentioned roles are likely to influence the choice of frame type for a building project depends on various matters such as the procurement route adopted, existing attitudes within the organisations involved, type of the building project, project value etc. Nevertheless, a study by Haroglu *et al*. (2008) identified several issues perceived to be the most important to the structural frame decision-making process and established an agreement between cost consultants, project managers and clients over the significance of these issues influencing the choice of a frame type for a building project. Therefore, it is also important to appreciate the common approach adopted by the members of a typical building project to the structural frame selection process. As a result, this paper examines project team members' influence on the choice of frame type at each stage of the design process.

3 DATA COLLECTION

Although a few research studies have been carried out in this field, a state-of-the-art literature review was first completed in order to understand the process in which the structural frame is normally selected as well as identifying the decision makers in this process. Semi-structured interviews were then conducted with structural engineers to determine the most influential people in the structural frame selection process with the intention of capturing their perceptions in the postal questionnaire survey.

The work stages of the RIBA Plan of Work (2007) are used in this research as the stages are well-known and widely recognized throughout the UK construction industry. We can therefore acknowledge that the design stage consists of three parts: Stage C (Concept), Stage D (Design Development) and Stage E (Technical Design).

3.1 SEMI-STRUCTURED INTERVIEWS

Nine interviews were arranged with structural engineers in selected consultancies to retrieve information about structural frame options and by whom they are evaluated. The core topics discussed during these interviews included: the frame types applied in their projects, influential people in selecting the frame type, and the rationale behind the preferred frame type of their current project. Consequently, cost consultants, project managers and clients were found to be the most influential people in the structural frame decision-making process. These interviews were carried out in total over a two-month period at the interviewees' work places, each lasting approximately

30 minutes. Each interview was tape recorded and subsequently transcribed verbatim and analysed.

3.2 QUESTIONNAIRE SURVEY

As a result of the interviews, cost consultants, project managers and clients were surveyed in an attempt to better understand their views of the relative influence of each project team member on the choice of frame type. The respondents were asked to rate the influence of the project team members on a 4-point Likert scale ranging from 0 for ´lowest level´ to 3 for ´highest level´ as by using an odd number of response points, respondents may be tempted to ‘opt-out’ of answering by selecting the mid-point (Fellows and Liu, 2003). Having developed the questionnaire, a pilot study was carried out with a sample of nine people from both industry and academia to see how they understand the questions and the response options. Having made a few alterations to the questionnaire as a result of the pilot study, the questionnaire survey was distributed amongst cost consultants, project managers and construction clients to establish the significance and ranking order of the project team members.

The individual respondents were selected randomly from a database of professional companies held by The Concrete Centre (TCC), irrespective of the size of the company. As shown below in Table 1, 239 postal questionnaires were sent to selected names, working for cost managers, project managers and client bodies, in the public and private sectors. As a result, 70 questionnaires were received in total, giving an overall response rate of 29.29% which is considered sufficient enough to meet the research reliability level compared with the norm of 20-30% with regard to questionnaire surveys in the construction industry (Akintoye and Fitzgerald, 2000). Of the responses received, 20 were from cost consultants, 25 from project managers and 25 from clients (Table 2).

Table 1. Questionnaire distribution and response rate

Respondent group	Number of Questionnaires		Response rate %
	Distributed	Returned	
Cost Consultant	86	20	23.26
Project Manager	74	25	33.78
Client	79	25	31.65
Total	239	70	29.29

The respondents were also asked about their influence over the choice of frame type for a building project in order to appreciate the value of each individual's response to this survey. Below Figure 1 shows that 44% of the respondents had a great deal of influence over the choice of frame type for a building project whereas only 9% had none, which suggests that the respondents were generally influential in the structural frame selection, and possessed an immense understanding in the structural frame selection process.

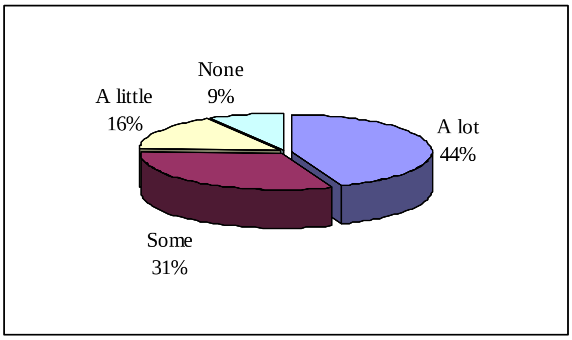

Figure 1. The influence of the respondents on the choice of frame type

The results confirmed that all of the project team members included in the survey were considered to be influential, proving the validity of the decision makers of a typical building project as a basis for consideration in the choice of frame type. Because of this, and the considerable degree of influence the respondents have on the choice of frame type, the returned sample was considered to be representative of the actual decision-making population. The next section illustrates some of the results in detail.

4 ANALYSIS AND RESULTS

The questionnaire was designed to provide predominantly descriptive data. An ordinal scale was used to rank the responses in this survey that there was no indication of distance between scaled points or commonality of scale perceptions in the Likert scale by respondents. It essentially provided a hierarchical ordering. Therefore, non-parametric tests were used in the analysis because non-parametric statistical tests are available to treat data which is inherently in ranks (Siegel and Castellan, 1956; Johnson and Bhattacharyya, 1996); the analysis was then carried out on the ranks rather than the actual data. The non-parametric procedures adopted for this study were frequency, severity index analysis, and Spearman's rho (ρ) test.

First of all, frequency analysis was applied to examine the degree of influence for each project team member. The severity index was used to rank the project team members for the degree of influence. The results of the frequency analysis and the ranking (severity index) have been based on analyses of all the completed responses. Individuals within these three disciplines were asked to provide information based on their own experiences from one of their projects that had recently started on site. However, these experiences were gained from distinct disciplines at each part of design stage, so it was essential to conduct a comparative analysis to distinguish between their responses. Since the variables are at the ordinal level, there are two prominent methods for examining the relationship between pairs of ordinal variables namely, *Spearman's rho* (ρ) (or Spearman rank correlation rs) and *Kendall's tau* (τ) – the former being more common in reports of research findings (Brymer and Cramer, 2005). Kendall's tau usually produces slightly smaller correlations, but since Spearman's rho is more commonly used by researchers, it was decided to be applied in this case. The Spearman's rho correlation coefficient is produced by using the rank of scores rather than the actual raw data (Brymer and Cramer, 2005; Hinton *et al.*, 2004; Kinnear and Gray, 2006). The Statistical Package for the Social Sciences (S.P.S.S.) was used to compute and run these statistical analyses.

4.1 RANKING THE PROJECT TEAM MEMBERS: FREQUENCY AND SEVERITY INDEX ANALYSIS

This stage of the statistical analysis ranked the project team members in order of influence for each part of design process. In this case, frequency analysis was first carried out to obtain the frequency of the respondents, using the Statistical Package for the Social Sciences (S.P.S.S.). The frequencies of responses were therefore used to calculate severity indices for each project team member via Equation 1 (Ballal, 2000):

$$\text{S.I.} = [\sum_{i=1}^{i=n} \omega i * fi] * 100\% / \text{n} \qquad (1)$$

Where: S.I. = severity index; fi = frequency of responses; ωi = weight for each rating; n = total number of responses

Since the 4-point Likert scale ranging from 0 for ´lowest level´ to 3 for ´highest level´, was used for the survey in order for the respondents not to be tempted to 'opt-out' of answering by selecting the mid-point, the weight assigned to each rating and is calculated by the following Equation 2 (Ballal, 2000):

$$\omega i = \text{(Rating in scale) / (number of points in a scale)} \qquad (2)$$

Therefore, $\omega 0 = 0 / 4 = 0$; $\omega 1 = 1 / 4 = 0.25$; $\omega 2$ = No mid-point in the scale; $\omega 3 = 3 / 4 = 0.75$; $\omega 4 = 4 / 4 = 1$

Example: An example of the calculation for the severity index is given below:

Influence of "Architect" at the Stage D:

	Not imp=0	Of little imp=1	Quite imp=2	Extremely imp=3	Total (n)
Frequencies (fi)	0	11	30	24	65

S.I. = ((0*0+11*0.25+30*0.75+24*1)/65)*100 = 75.77%

The project team members were then ranked in order of value of severity index, the highest value having a rank of 1, and the lowest value assigned a rank of 6. Tables 2, 3 and 4 present the project team members ranked in terms of influence for each stage of the design process. In addition to that, Figure 2 displays the respondents’ view of the degree of influence of the project team members on the choice of frame type during the design process.

Table 2. Issues ranked in Concept Design

Concept (Stage C of RIBA)							
Project Team Members	Frequency of responses for score of				No. of responses	Severity Index %	SPSS Rank
	0	1	2	3			
Structural Engineer	1	6	17	42	66	85.23	1
Architect	0	9	28	29	66	79.17	2
Cost Consultant	2	13	25	27	67	73.13	3
Project Manager	1	19	31	12	63	63.49	4
Client	4	22	20	18	64	60.16	5
Main Contractor	21	14	19	11	65	44.23	6

Table 3. Issues ranked in Design Development

Design Development (Stage D of RIBA)							
Project Team Members	Frequency of responses for score of				No. of responses	Severity Index %	SPSS Rank
	0	1	2	3			
Structural Engineer	0	6	15	45	66	87.50	1
Cost Consultant	1	8	29	29	67	78.73	2
Architect	0	11	30	24	65	75.77	3
Project Manager	2	17	26	18	63	66.27	4
Main Contractor	10	9	27	19	65	63.85	5
Client	5	18	27	14	64	60.55	6

Table 4. Issues ranked in Technical Design

Technical Design (Stage E of RIBA)							
Project Team Members	Frequency of responses for score of				No. of responses	Severity Index %	SPSS Rank
	0	1	2	3			
Structural Engineer	0	3	22	40	65	88.08	1
Main Contractor	4	10	14	38	66	77.27	2
Architect	5	14	26	19	64	65.63	3
Cost Consultant	4	17	26	19	66	64.77	4
Project Manager	3	18	27	14	62	62.50	5
Client	6	24	19	14	63	54.37	6

Figure 2 shows the opinions of the respondents of the level of influence that the project team members have on the choice of frame type at the three stages of design process. ‘Structural Engineer’ appeared to be the most influential at all stages. Note the increasing influence of the ‘Structural Engineer’ and especially the ‘Main Contractor’, with the influence of the other members decreasing.

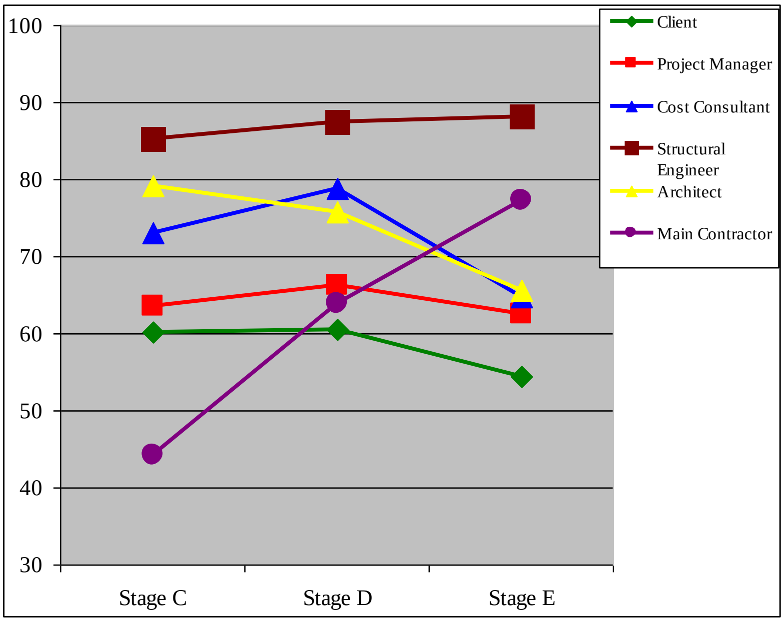

Figure 2. Respondents' view of the influence of the project team members at all design stages

4.2 INVESTIGATING AGREEMENT: SPEARMAN'S RHO (ρ) TEST

To examine the agreement, if there is any, between three disciplines on the ranking of the project team members in relation to the influence they have in the structural frame selection process, Spearman's rho (ρ) test was employed. The frequency of responses and severity indices were again computed for each group to generate a separate ranking of the project team members, as shown in Tables 5, 6 and 7. Additionally, the Figures 3, 4 and 5 were used to display the results of the analyses for the readers of this paper to assimilate more readily.

Table 5. Comparison of severity index and ranking for each group at Concept Design

Project Team Members	Concept (Stage C of RIBA)					
	Cost Consultant		Project Manager		Client	
	S.I %	SPSS Rank	S.I %	SPSS Rank	S.I %	SPSS Rank
Cost Consultant	84.21	1	65.22	3	72.00	3
Structural Engineer	83.82	2.5	86.46	1	85.00	1
Architect	83.82	2.5	78.13	2	77.00	2
Project Manager	66.18	4	60.87	4.5	64.13	4
Client	58.82	5	60.87	4.5	60.42	5
Main Contractor	35.29	6	34.78	6	59.00	6

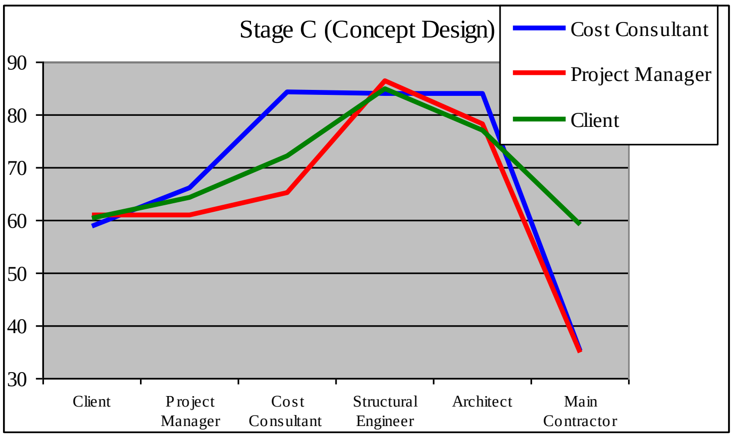

Figure 3. The views of the three sets of respondents on the degree of influence the project team members have at stage C

Table 6. Comparison of severity index and ranking for each group at Design Development

Project Team Members	Design Development (Stage D of RIBA)					
	Cost Consultant		Project Manager		Client	
	S.I %	SPSS Rank	S.I %	SPSS Rank	S.I %	SPSS Rank
Structural Engineer	83.82	1	87.50	1	90.00	1
Cost Consultant	81.58	2	73.91	2	81.00	2
Architect	80.88	3	72.83	3	75.00	4
Project Manager	61.76	4	66.30	4	69.57	5
Main Contractor	60.29	5	51.09	6	78.00	3
Client	55.88	6	59.78	5	64.58	6

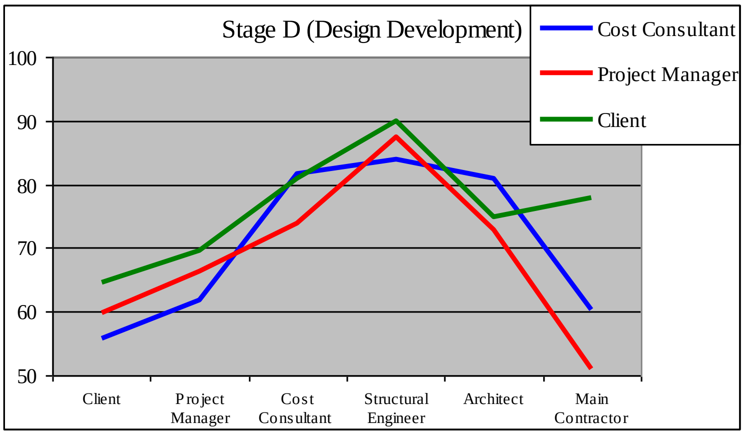

Figure 4. The views of the three sets of respondents on the degree of influence the project team members have at stage D

Table 7. Comparison of severity index and ranking for each group at Technical Design

Project Team Members	Technical Design (Stage E of RIBA)					
	Cost Consultant		Project Manager		Client	
	S.I %	SPSS Rank	S.I %	SPSS Rank	S.I %	SPSS Rank
Structural Engineer	86.76	1	91.30	1	86.00	2
Cost Consultant	73.68	2	57.95	5	64.00	4
Main Contractor	72.06	3	70.83	2	87.00	1
Project Manager	64.71	4	62.50	4	60.87	5
Architect	61.76	5	63.64	3	70.00	3
Client	50.00	6	52.27	6	59.38	6

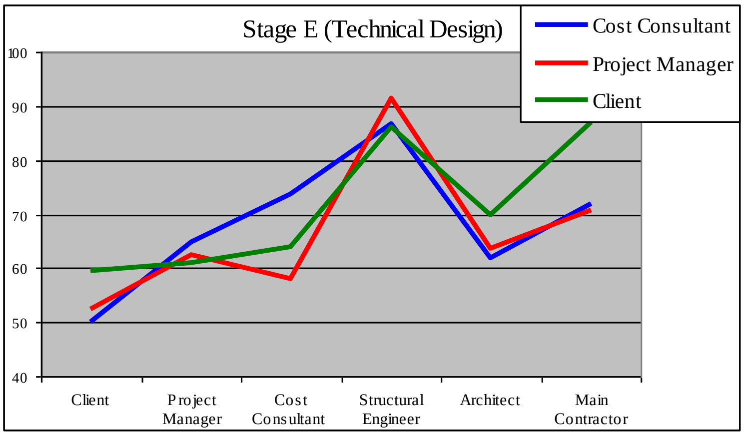

Figure 5. The views of the three sets of respondents on the degree of influence the project team members have at stage E

As a result of this, Spearman's rho (ρ) (or Spearman rank correlation rs) test was computed using the Statistical Package for the Social Sciences (S.P.S.S.). The three groups are compared statistically by applying Spearman Rho test. Table 8 presents all of the Spearman Rho correlations computed, using SPSS, as shown below.

Table 8. Spearman's Rho (r) test results between the rankings of three groups

Design Stages of RIBA	Correlations		
	Cost Consultant vs. Project Manager	Cost Consultant vs. Client	Project Manager vs. Client
	Correlation Coefficient		
Stage C	0.794	0.812*	0.986**
Stage D	0.943**	0.829*	0.657
Stage E	0.600	0.600	0.886*

Note: **, * denotes 'strong' with $p < 0.01$ and 'some' with $p < 0.05$ statistical evidence of significant similarities

The level of significance was set by SPSS both at 0.05 and 0.01 levels, which indicated the degree of relationship amongst the three rankings. $p < 0.05$ means that there is less than a 5 per cent chance that there is no relationship between the two rankings, whereas $p < 0.01$ means that there is less than a 1 percent chance, and can be accepted at the 99% confidence level (Bryman and Cramer, 2005; Fellows and Liu, 2003; Field, 2000). From Table 8, most of the correlations written with asterisks did achieve statistical significance at either $p < 0.05$ or $p < 0.01$ which confirmed that there are strong relationships amongst the rankings of three groups, assuring that agreements amongst the three rankings was much higher than it would occur by chance. As a result, it may be concluded that the rankings obtained from the three groups, as given by the severity index analysis, was consensual amongst the respondents.

5 FINDINGS AND DISCUSSION

With regard to the results of frequency and severity index analyses, all of the project team members were ranked by the respondents to the survey in order of influence they have at each stage of the design process. The Spearman's rho test was then applied to establish the consensus between the three sets of respondents in relation to the rankings of the project team members at each stage.

As the design develops, note the increasing influence of the structural engineer and especially the contractor, with the influence of the other members decreasing, as shown in Figure 2. It is evident that 'Structural Engineers' influence was perceived to be far more than the other project team members at all times during the design process. However, the structural engineers interviewed indicated that they were not the most influential party in the choice of frame type, citing cost consultants, project managers and clients as more influential. This may be because structural engineers are not aware of their influence, or because they do not want to pronounce that they are powerful in the structural frame selection process. On the other hand, 'Clients' were perceived to be unexpectedly the least influential decision-maker for the duration of design process in general. 'Architect' and 'Cost Consultant' were perceived to be very influential during stages C and D when the structural frame of a building project is generally selected (Ballal and Sher, 2003). In addition, regarding the magnitude of the severity indices, there appears to be a relatively large gap separating the 'Structural Engineer', 'Architect' and 'Cost Consultant' as the top three decision makers from the rest at the stages C and D, as shown in Tables 2 and 3. 'Project Manager's influence is highest at stage D where it was ranked the fourth by the respondents which indicates that 'Project Manager' is not considered with the same degree of influence as are 'Structural Engineer', 'Architect' and 'Cost Consultant'. In addition, 'Main Contractors' influence rises to be number two at stage E. However, it may well be too late for the main contractor to influence the choice of frame type at this stage.

From the results of the Spearman's rho (ρ) test, there appeared to be a significant agreement in the rankings of project team members amongst the three groups and the degree of agreement was higher than would have occurred by chance, as shown in Table 8. The degree of agreement amongst the three groups is higher at stages C and D than it is at stage E as regards the correlations written with asterisks in Table 8. 'Structural Engineer' is generally agreed upon to be the most influential decision-maker in the selection of a frame type. Although the cost consultants, project managers and client were in good agreement with each other in relation to the degree of influence of the decision makers (or project team members), they differ in some places, particularly the degree of influence of 'Main Contractor' at stages D and E. 'Main Contractor' was considered to be very influential by clients in the structural frame selection process at stages D and E, whereas cost consultants and project managers did not consider 'Main Contractor' very influential at stage D (it was ranked the least influential decision-maker by project managers). A possible reason for this is that contractor involvement in a building project at stage D is perceived to be higher or more effective by clients than it is in reality. In addition, not surprisingly whilst

'Cost Consultant' was considered to be the second most influential at stage E by cost consultants, it was ranked by project managers and clients to be the fifth and fourth respectively.

As in any research based on a questionnaire survey, this study is subject to some biases and limitations. Firstly, with regard to the use of The Concrete Centre's database; although it may not necessarily represent the whole UK construction industry, it is large (25,000 names), up to date and nationwide. Secondly, since the postal questionnaire was sent through the post from The Concrete Centre to the respondent, it may have been presumed that the main thrust of this survey was about concrete frames rather than structural frames in general.

None-the-less, it can be said that the ranking of the six decision makers obtained from the respondents to the survey are representative of the views of the UK construction industry in relation to the structural frame selection process. Since selecting the correct structural frame is crucial to a project's feasibility and success, the assumption made earlier on in this paper was that the choice of an appropriate structural system will lead to a successful project outcome. The rank ordering at each stage of design process can therefore be of much interest to all those concerned with project teams, structural frame design and selection and effective leadership in decision making. Above all, the findings can give useful insights into the frame industry. For instance, it is evident that 'Main Contractor' appeared to have a significant input at both stages D and E which means that contractors should be a major audience in the frame market.

6. CONCLUSION

The decision on the choice of frame has significant short- and long-term implications for the building's function and its client's needs (Soetanto et al., 2007). Having undertaken a literature review and semi-structured interviews, cost consultants, project managers and clients were found to be the most influential decision makers in the selection of structural frame process. So this study asked these people the question 'who really was the key decision maker?' through a postal questionnaire survey. The respondents to the survey were requested to base their answers on one of their projects that had recently started on site. So, as project participants moved through the design stages, their influence was evaluated by the respondents. A total of 70 detailed responses were received and analyzed, providing a number of useful insights into the view of professionals about the decision makers in the structural frame selection process.

As a result of the questionnaire survey, the structural engineer was evidently found to be the most influential decision-maker in the choice of frame at each stage of design process. This is an outstanding contrast to the results of semi-structured interviews carried out with the structural engineers earlier on in this research. Further research in this field might examine how the key decision makers in the choice of frame for a building project vary by sector, project value, type of procurement route, etc. Furthermore, it was found that the contractor's influence is particularly high, as perceived by the respondents, at stages D and E which indicates that contractors could make quite an impact on the choice of frame type for a building project.

In conclusion there were some areas of disagreement amongst the three sets of respondents, such as the main contractor. This warrants specific research in this field. It is not known yet whether the main contractor could exert influence to change the frame type or any specifications of a building project after being involved. Hence there confirms to be a gap in knowledge about who the key decision maker is and while this paper has offered some key insights, the role of the contractor now appears to be next area of focus for research, particularly if we are seeking a clear model for how this area of decision making works in practice.

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APPENDIX D (PAPER 4)

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EVALUATING THE MAIN CONTRACTOR'S INFLUENCE WITHIN THE CONCRETE FRAME CONSTRUCTION DECISION MAKING PROCESS

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Abstract: *The UK has a tradition of in-situ concrete construction and in the past in-situ concrete frame construction dominated the structural (skeletal) frame market. Despite concrete's range of structural frame solutions (i.e. its thermal efficiency, inherent fire resistance, acoustic and vibration performance, durability and low maintenance), it lost significant market share to structural steel in the framed structure market in the UK in the late 20th century, although it still performs well in commercial and residential applications today. A four-year research programme was initiated by Loughborough University and The Concrete Centre to investigate the key drivers and barriers in the concrete frame procurement process as it is a generally under-researched area with the specific aim of identifying ways in which the process could be improved.*

To begin with, the research investigated typical structural frame selection processes through a state-of-the-art literature review, semi-structured interviews and a postal questionnaire survey. One of the main findings was that the design & build procurement approach was used for about 50% of UK construction projects. This illustrated the significance of the contractor's potential influence in the structural frame decision-making process and so the subsequent stage of the research examined the role of contractors in detail; for example, whether the main contractor could exert influence to change the frame type or any specifications of a building project as a result of the design & build procurement route being used.

This paper reports major new findings on the main contractors' influence over the structural frame selection process and will therefore be of interest to designers, contractors and clients/customers.

1 INTRODUCTION

In the UK in-situ concrete frame construction dominated the structural (skeletal) frame market for many years. Concrete's inherent benefits such as fire resistance, sound insulation, robustness and minimum vibration are widely recognised as are its thermal mass and high quality finish. Cost model studies add cost-effective construction and sustainability to this list. These qualities provide a wide range of framing options to suit projects' needs[1]. However industry reports[2] have revealed that concrete lost significant market share to structural steel in the framed structure market in the UK in the 1980s and 1990s, although it still appears to perform well in commercial and residential applications. Among the various industry responses to this change in the structural frame market, a four-year research programme initiated by Loughborough University and The Concrete Centre has investigated key drivers and barriers in the concrete frame procurement process. This process plays a significant role in project success and determines the responsibilities of project team members[3], so there is good reason to examine its influence on structural frames. The research initially investigated the frame selection process through a state-of-the-art literature review, semi-structured interviews and a postal questionnaire survey. One of the key findings was that Design-Build procurement was used for about 50% of UK construction projects, indicating that the contractor can potentially exert significant influence in the structural frame decision-making process. The subsequent research phase investigated whether the main contractor influences or actually changes any such specifications (i.e. structural frame or material types) on a Design-Build project, which is reported here.

2 BACKGROUND REVIEW

Both the influential Latham[4] and Egan[5] reports identified that improvements to reduce budget and timescale and increase quality would only be achieved if main contractors were involved sufficiently early in the process and fully understood the needs of the Client. Hence, there has been a rise in popularity of procurement routes and forms of contract that permit early contractor involvement (ECI) such as Design-Build within which contractors are involved early (and ideally appointed formally) to improve supply chain integration. Although some confusion exists amongst inexperienced clients, the term Design-Build (D&B) has almost been unanimously interpreted and defined as[6]:

"An arrangement where one contracting organisation takes sole responsibility, normally on a lump sum fixed price basis, for the bespoke design and construction of a client's project."

Although D&B has been used in the UK construction industry for decades, it has gained increased market share in the past ten years[7]. D&B arguably places more responsibility and liability on to the contractor than any form of procurement[8, 9]. Its benefits include single point responsibility, availability of the contractor's knowledge of 'buildability' and standardisation of the construction process[8].

However, it also has a number of disadvantages one of which is the poor quality of design[10], the main reason being that architects seem to have less control over design than they would in a traditional approach[11]. Also, the advantages of competition may not be passed onto the client when using D&B[9, 12]. The principal variants of the D&B (integrated) procurement systems are[6]; Novated D&B; Package deals; Develop and construct; and, Turnkey. A variety of tender and contractor arrangements are adopted including Single-Stage (Competitive) and Negotiated Tendering, along with the more innovative Two-Stage Tendering and Partnering arrangements.

The role of the structural frame in meeting client's needs has been investigated[13, 14]; there is clear evidence that the selection of an appropriate frame type can be critical to the success of a project[14, 15], whether this is measured in terms of cost, programme or a perceived aspect of quality, such as architectural aesthetics, or even energy performance. If the structural frame can deliver improvements in these areas this represents a tangible benefit to the client and, if combined with an appropriate form of contract, could result in further cost and time savings. However, there is pressure on project teams to make early decisions on structural form, which could be either advantageous or injurious to short term out-turn measures and long term performance benefits such as energy consumption. This issue[16] (and specifically the influence that the main contractor has on the selection, design or production of the structural frame in a D&B project) remains unclear and under-researched. In particular, it warrants consideration in terms of tendering arrangements in D&B procurement, size of the contractor, client-main contractor risk relationship, and the stage at which the main contractor is involved both informally and contractually.

3 ADOPTED APPROACH – FOUR CASE STUDY D&B PROJECTS

The main aim was to investigate whether the main contractor influences or actually changes any specifications, i.e. structural frame type, on a D&B project. It has been suggested that D&B is the dominant form of contract and that structural frames can contribute to the success of a building[11]. With the main contractor clearly taking significant, and earlier, responsibility for a building project within D&B, then it is reasonable to propose the following research hypothesis:

- Design-Build procurement routes are the most popular form of contract used in the UK construction industry, so as a result main contractors must be influential in the subsequent structural frame decision-making process and may, in some cases, change the specification of a frame.

To achieve the aim (and thereby support or refute the hypothesis), a series of case studies were undertaken based on projects with UK-based D&B contractors. Case studies are appropriate when the phenomenon under study has not been investigated within its context[17, 18]. Due to the diversity of company size and structure, an exploratory case study design based on multiple cases with single units of analysis has been adopted for the research[17].

Four construction contracting companies of different sizes and structures were studied using the same protocol developed around the research hypothesis and a series of associated questions. A shortlist of target companies for the case studies was produced from the results of a questionnaire survey[11], within which respondents had volunteered specific building projects for consideration in this stage of the research. These 23 companies represented a cross-section of UK contractors by size and the type of procurement routes used because they are small-medium and large contractors (categories which account for more than 90%[25] of construction contracts by turnover per annum, have been involved in D&B projects recently and were willing to participate in the study; four cases emerged from this. The objective was to collate views of the various project team members who were involved in the design stages or thereafter. So interviews were held with a range of professional groups including, but not necessarily limited to; main contractor, structural engineer, architect and cost consultant. For confidentiality the parties concerned are referred to as Contractors A, B, C and D. There were significant differences in the contractors' size (number of employees and financial turnover). The types of building projects examined were also different, plus Contractor A and Contractor C were appointed through single-stage competitive tendering, whereas Contractors B and D were employed using two-stage tendering arrangement in the D&B projects. The four contractors together with the D&B projects they were involved are therefore deemed to present a realistic sample. Data were collected through semi-structured interviews along with the researcher observations, documentation and records during interviews. The data (content) analysis involved exploring the themes and patterns revealed in the interviews to draw similarities and differences within and cross-case analyses. Also, the process of analysis involved continually revisiting the data and reviewing the categorisation of data until the researcher was sure that the themes and categories used to summarise and describe the findings were a truthful and accurate reflection of the data.

4 MAIN CASE STUDY FINDINGS

This section presents the findings of case studies conducted to examine the main contractors' influence on a D&B project. Because of the extent of the data collected from the case study interviews, only key findings are discussed here.

4.1 Case study A

This development project consisted of seven buildings, six residential buildings with retail units on the ground floor and one office building. Initially five residential buildings were designed and subsequently tendered through single-stage tendering.

The other two buildings (residential and office buildings) were procured using two-stage tendering when Contractor A had already started on site. The project team members interviewed for this case study were: Contractor A, Architect, Structural Engineer and Cost Consultant. Although Contractor A claimed that they got involved at Stage D of the RIBA Plan of Work[19] in the first five building projects, they were not contractually appointed until the end of Stage E. As a result, Contractor A prompted a few minor changes in the project including the concrete specifications (using ggbs) and the construction method (slipform construction). Contractor A claimed to be influential in selecting the frame type of office building in which they were involved *"right from the start of the project"* which was confirmed by the Architect and Structural engineer who said that Contractor A did influence the frame choice of the office building as well as buildability. Contractor A approved the frame choice of residential buildings, but added that *"We would not want to challenge the frame type of the residential buildings selected by the design team"*, explaining why the Structural Engineer thought that the involvement of Contractor A was of limited value because the choices were already made by the time they came on board. Indeed, the contractor conceded that even if they had challenged the team, the frame type may not have been changed anyway.

4.2 Case study B

This was a laboratory building with in-situ concrete frame flat slabs, procured through two-stage tendering. The project team members interviewed for this case study included: Contractor B, Architect, Structural Engineer, Project Manager (External) and Client's representative. Contractor B became involved in the project from RIBA Stage C onwards but contractually took over the project after Stage E. Contractor B did not make any major change during the design process, rather they influenced finishes, materials used, and gave useful advice on market prices. The Client's representative stated that Contractor B's involvement did help the project team members to work together as a team, to resolve problems before the work started on site. The external project manager also believed that Contractor B had a positive influence and made an accurate market assessment. Contractor B said that their early involvement helped them get appropriate sub-contractors saying *"The envelope of the building was originally designed to have dual curve which was proven extremely expensive so the design team (architect, structural engineer, services engineer, etc.) chose to go for a single curve which was a lot cheaper than dual curve. We used our supply chain. We had key packages and we knew the workload"*. Contractor B claimed that the frame choice was dictated by the client as it was an environmentally friendly building and concrete was one of the key features of this solution, so the contractor wanted to retain it. The decision to use concrete was made by the design team including Architect, Structural Engineer and Cost consultant fairly early on in the design process.

4.3 Case study C

A three-storey steel frame hospital building which was procured through single-stage D&B; the project team members interviewed were; Main contractor (Contractor C), Architect and Structural Engineer. Contractor C was appointed at the end of RIBA Stage E and reportedly did not have any influence in the design process until the contract was placed, but thereafter, tried to make the design more buildable and economical (e.g. changing the foundation design due to difficult ground conditions). The Structural Engineer chose the frame type for the project. However, the Architect indicated that if Contractor C had wanted to use a particular frame type to better meet the client's requirements, they could have changed this. The Structural Engineer claimed to be the most influential project team member in selecting the frame type; however he did add that typically main contractors could be very influential if they wanted to build in a particular frame type. Contractor C stated that they were in favour of a steel frame because of their broad experience in using steel and that a three-storey building was too small to build in concrete.

4.4 Case study D

This was an in-situ concrete frame residential block with retail units on the ground floor. It was procured through two-stage D&B, but competitively tendered at RIBA Stage C. The project team members interviewed were: Contractor D, Architect, Structural Engineer and Client. Although it used two-stage tendering, Contractor D was not involved early in this project. The client indicated that it was a straightforward building so they did not have to get the contractor involved. Contractor D had little influence in developing the design as there was little scope to change anything, but the Client noted that Contractor D did influence the sequence, method of construction and design of the structural frame, and took control of the design by using their own supply chain. Contractor D was informally involved during Stage D and knew that they were the preferred contractor, so they refined their costs somewhat. Interestingly the client added *"I am not a fan of two-stage D&B as we ended up spending more money"* and also asserted that they would go for single-stage D&B in the future. The interviewees explained that the Structural Engineer had the biggest influence in the choice of frame type, adding that three construction methods were investigated to meet the client's criteria. Reinforced concrete flat slab construction was considered the most cost effective solution; the client stating that *"We know concrete well, we know through experience what works and what does not"*. However, they did express that a main contractor can influence the frame type, but this would depend entirely on the size and complexity of the project. Contractor D suggested a steel frame for the project in lieu of concrete for the reasons of speed, certainty and sustainability issues, plus they had far more experience in steel than concrete. Both the Architect and Contractor D pointed out that the choice of reinforced concrete flat slab was by agreement rather than by approval.

5 DISCUSSION

According to the main contractors interviewed, they get involved in a substantial number of D&B projects. This corroborates the evidence from literature[11] that D&B procurement is used extensively. In the words of Contractor B, *"we are very happy with D&B approach, particularly two-stage D&B as it allows us to drive and control the design which also means that we control our own destiny".* Contractor A added, *"The advantage of D&B for the contractor is that we can manage the process effectively to alter the design if we get involved in the project in good time".* Although it was recognized that main contractors do not generally get involved early in the design process of D&B projects, they were found to be influential over buildability, programme and materials used in all cases, plus were able to provide advice on market prices. However, this was found to be dependent on readiness and ability to affect the design process, size of the project, plus the client's preference/motivation to let them do so. Although D&B contractors are generally involved early in the design process under the two-stage tendering, this does not have an effect on the degree of influence they have on the choice of frame type. The benefits of the two-stage approach are most likely to be secured when the contractor is proactive in its engagement with the design, buildability and financial aspects of the project[20]. These cases confirm that properly structured two-stage tendering, using an early conditional contractor appointment, is the best means for clients to control projects and obtain added value from their contractors[21]. Finally, as revealed in two cases, decisions made on the frame choices of case studies C and D were affected significantly by past experience. Therefore, it can be deduced that when D&B contracts are used, previous experience in frame types and working relationships between project team members may be critical with regard to the selection, design or production of a frame.

6 CONCLUSIONS

With D&B contracts continuing to be popular in the UK building construction and most of the rest of the world, contractors are expected to play a more prominent role in the design process of building projects particularly in projects using two-stage tendering and influencing in some way the choice of frame type of a building project. This paper has shown with the help of case studies, some new insights into the influence of main contractors on D&B building projects. From the case study findings, it is clear that contractors can help the client achieve cost and time savings through buildability, material and other improvements, but this advice only emerges when the client and procurement approach facilitates this exchange and the contractor feels sufficiently motivated to make such a contribution. There are clear lessons here for contractors, clients and design teams working on D&B projects.

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APPENDIX E (PAPER 5)

Full reference:

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Powerless or powerful? How contractors influence major construction decisions in Design-Build projects

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Abstract:

Purpose: The steady increase in the use of Design-Build in the UK suggests that contractors have a growing level of influence and responsibility in construction decisions within building projects including, but not limited to, major elements such as the structural frame. However, the relationship between procurement approach and structural frame decision-making remains under-researched. This research sets out to examine the factors affecting contractors' influence in Design-Build projects.

Design/methodology/approach: A case study approach has been adopted to understand whether or not such a link exists and to achieve a deeper appreciation of the role of the contractor in Design-Build decision-making by examining four building projects in which four different contract scenarios were employed.

Findings: In the cases investigated, the choice of Design-Build was made largely to transfer risk to the contractor who then delivered the completed building for a pre-agreed price. However, the contractor's ultimate level of influence on structural frame selection and specification depended on his willingness and ability. Where the contractor chose to influence the process and/or take specific actions (such as changing the design or specification), this was because there was a desire, ability and capacity to do so.

Research limitations/implications: Findings are based on four cases, so caution should be exercised in extrapolating the results too widely.

Originality/value: Clients and their agents may presume that contractors will influence and/or steer the structural frame decision-making process, but in practice this may not always be the case.

Key words: contractor, Design-Build, procurement, structural frame.

1 Introduction

In the UK, both the influential Latham (1994) and Egan (1998) reports identified that improvements designed to reduce budget and timescale and to increase quality would only be achieved if main contractors were involved sufficiently early in the design process and fully understood the needs of the client. Hence, there has been a rise in popularity of procurement routes and forms of contract that permit early contractor involvement (ECI) such as Design-Build within which contractors are involved early to improve supply chain integration. Although Design-Build has been used in the UK construction industry for decades, it gained increased market share in the late 1990s onwards (Ernzen and Schexnayder, 2000; Arditi and Lee, 2003). Indeed, a recent survey of UK project managers, cost consultants and clients by Haroglu et al. (2009) found that Design-Build is the preferred option amongst developers of building projects, ranging from complex, high quality projects to simple buildings. This illustrates a significant change in the UK construction industry, moving away from its conventional, ‘traditional’ procurement systems. So, as a result, one might sensibly presume that most contractors must be getting involved earlier in the design process and thus could be influencing major decisions, such as the selection of a structural frame, although there are question marks about how this affects the risk relationship between client and contractor.

With regard to the role of the structural frame, this has been investigated with respect to the ways in which the choice of frame type and material can meet the client’s needs (e.g. RPEG, 1995; Soetanto et al, 2006). There is clear evidence that the selection of an appropriate frame can be critical to the overall success of a building project (SCI, 2000; Soetanto et al, 2006), whether this is measured in terms of cost, programme or a perceived aspect of quality, such as architectural aesthetics, or even energy performance. Clearly, if the structural frame, which is the skeleton that defines and supports the building, can help deliver improvements in these areas this will represent a tangible benefit to the client in the completed building and, if combined with an appropriate form of contract, could result in further cost and time savings.

This is an area which remains unclear and under-researched. The link between the form of contract and the structural frame (Haroglu et al., 2008b) and specifically the typical level of ‘contractual involvement’ or influence that the main contractor has on the selection, design or production of the structural frame in a Design-Build project requires attention. But there are many factors to consider: various types of Design-Build procurement routes, the size of the contractor, the client-main contractor risk relationship, the stage at which the main contractor is involved both informally and contractually (i.e. appointed). It was considered that the factors could be best examined through a series of case studies. The research has also examined the reasons why clients seem to prefer Design-Build procurement routes.

As a result, the findings from four case study building projects are presented. An understanding of Design-Build procurement in current use is followed by the description of the research aim and objectives, together with the research methodology adopted. A summary of key findings is discussed and analysed in relation to other related studies. Finally, conclusions and recommendations are made including the fact that there may be an important misconception of the part of the client about the degree of influence that a contractor may choose to exert in a given project.

2 The Design-Build Approach

Design-Build (D&B) is a form of procurement system in which the main contractor is responsible for both design and construction to deliver a building to the satisfaction of the client (Akintoye and Fitzgerald, 1995; Lam et al. 2008). Although some confusion exists amongst inexperienced clients, the term Design-Build has almost been unanimously interpreted and defined as (Masterman, 2006, p.67):

> *"An arrangement where one contracting organisation takes sole responsibility, normally on a lump sum fixed price basis, for the bespoke design and construction of a client's project."*

Design-Build arguably places more responsibility and liability on to the contractor than any form of procurement (Akintoye, 1994; Peace and Bennett, 2005). The key benefits include single point responsibility, availability of the contractor's knowledge of 'buildability' and the standardisation of the construction process (Franks, 1990; Janssens, 1991; Akintoye, 1994; Turner, 1995). Furthermore, according to Peace and Bennett (2005), compared to a traditional approach, Design-Build projects based on a minimal statement are completed 40% faster, while those based on an outline design are completed 25% faster. Also, Design-Build projects are much more likely to be completed on time and are reportedly 15% cheaper than equivalent traditional projects. However, the Design-Build method also has a number of disadvantages, one of which is the poor quality of design (Franks, 1990; NJCC, 1995). The main reason for this may be that architects have less control over the design process than they would in a traditional approach, as they often become novated to the contractor in the latter (production design) stages. Finally, the advantages of competition (i.e.

competitive tendering) may not be passed onto the client when using Design-Build (Rowlinson, 1999; Peace and Bennett, 2005).

The principal variants of Design-Build (integrated) procurement systems are described according to Masterman (2006) as follows;

- Novated Design-Build;
- Package deals;
- Develop and construct; and,
- Turnkey.

In addition, a variety of tender and contractor arrangements can be adopted including Single-Stage (Competitive) and Negotiated Tendering, along with the more innovative Two-Stage Tendering and Partnering arrangements. Single-stage and Two-stage tendering arrangements are the most common forms adopted on Design-Build projects in the UK construction industry. The adoption of two-stage tendering on Design-Build projects is beneficial in terms of the balance between client control over design development and the eventual transfer of design responsibility to the contractor. However, one key drawback is that the preferred contractors' role in design development will strengthen its negotiating position, enabling it to drive a particularly hard bargain in the closing stages of the second-stage tender (Rawlinson, 2006). On the other hand, single-stage competitive tendering provides the client with an early contractual commitment on price and the contractor is not given an opportunity to revisit this. However, second-stage tendering helps the contractor to understand the design. In adopting the single-stage route, the client sacrifices some opportunity for interface with the contractor's supply chain and is heavily reliant on the quality of their initial statement of design intent and specification to achieve expected quality standards on site (Rawlinson, 2008).

Design-Build procurement is now the most prevalent form of procurement according to a recent survey of project managers, cost consultants and clients (Haroglu et al, 2009). Much research has been undertaken to examine the attributes, efficiency and applicability of Design-Build procurement route as well as the construction industry's perceptions of it (Janssens, 1991; Akintoye, 1994; Akintoye and Fitzgerald, 1995; Chau et al, 1996). That said, it is not the intention of this study to review these characteristics of the Design-Build procurement method. The essence of this research is to provide a clear understanding of the role which contractors currently play within Design-Build building projects in the UK vis-à-vis frames. The next section describes the aims and objectives of the case study research in more detail.

3 Research aims and objectives

The literature suggests that Design-Build is the dominant form of contract and also that structural frames can contribute to the success of a building. Since Design-Build is the most popular form of contract used in the UK construction industry, it would seem reasonable to make the assumption that main contractors must be influential in the structural frame decision-making process and may, in some cases, change the specification of a frame to better suit project circumstances (e.g. to enhance buildability or reduce risk).

So, the main aim of this research was to investigate whether or not the main contractor influences major decisions on a Design-Build project, with particular reference to changes to design and/or specification of the structural frame. To achieve this, the following research objectives were identified, in the context of Design-Build projects:

- determine the degree and types of involvement that main contractors have within a range of Design-Build contracts;
- identify the similarities and differences amongst various Design-Build projects in relation to the degree of contractor involvement;
- identify what changes, if any, are typically made by main contractors to the selection, design, specification or production of a frame;
- draw conclusions about how Design-Build works best in terms of main contractor involvement;
- make recommendations on degrees of influence that contractors can/should have on the structural frame selection process.

4 Research approach

The research objectives were met by undertaking a series of company case studies with UK-based Design-Build contractors. Case study is the method of choice when the phenomenon under study has not been investigated within its context (Yin, 2003; Fellows and Liu, 2003). Case study methods allow investigators to retain the holistic and meaningful characteristics of real-life events – such as individual life cycles, organizational and managerial processes, neighborhood change, international relations, and the maturation of industries (Yin, 2003). Most studies look for what is common and pervasive, whereas the intent of the case study may not be generalization but rather to understand the particulars of that case in its complexity (Key, 1997). However, a common criticism of case study methodology is that its dependence on a single case renders it incapable of providing a generalizing conclusion (Tellis, 1997). To mitigate this problem, Hamel et al. (1993) and Yin (1994) argue that the goal of the study should establish the parameters, and then should be applied throughout the research. Thus, even a single case could be considered satisfactory as long as it fulfilled its established objectives.

Due to the diversity of company size and structure, an exploratory case study design based on multiple cases with single units of analysis was therefore adopted for this research, in accordance with guidance offered by Yin (2003). Multiple cases need to be employed to ensure that the results present a breadth and depth of main contractors' involvement in Design-Build projects. Four case study building projects of different size and structure were studied using the same case study protocol which had been developed around the research objectives and a series of associated research questions. A shortlist of possible target companies for the case studies was produced from the results of a previous questionnaire survey (see Haroglu et al. 2009), within which respondents had volunteered specific building projects for consideration. Those 23 companies represented a cross-section of UK contractors by size and the type of procurement routes; they were small-medium and large contractors (categories which account for more than 90% of construction contracts by turnover per annum), had been involved in a Design-Build project recently and were willing to participate.

In this study, four building projects were selected (in discussion with the sample of contractors) and four case studies undertaken using personal interviews with project team members who had been involved in choosing the structural frame material at the design stages or thereafter. A comparison between the four case study projects is presented in Table 1, based on contractor's size and project details; for confidentiality, the parties concerned are referred to under the headings of Case studies A, B, C and D.

Table 1 Case study design-build building projects

Case study project	Building type		Regional location	Project value (£m)	Contractor's financial turnover 2008 (£m)	Structural frame type	Tendering arrangement	Project team members interviewed
Case study A	Phase I)	Five residential buildings	South East	45	819.4	In-situ concrete	Single-Stage	Main contractor *(Contractor A)*, Architect, Structural Engineer and Cost Consultant.
	Phase II)	One residential building				In-situ concrete	Two-Stage	
		One office building				Steel		
Case study B	Laboratory building		East Midlands	8	177.5	In-situ concrete	Two-Stage	Main contractor *(Contractor B)*, Architect, Structural Engineer, Project Manager (External) and Client's representative.
Case study C	Hospital		South Yorkshire	4.5	80	Steel	Single-Stage	Main contractor *(Contractor C)*, Architect and Structural Engineer.
Case study D	Mixed-use development		South West	10	2065.4	In-situ concrete	Two-Stage	Main contractor *(Contractor D)*, Architect, Structural Engineer and Client.

As shown in Table 1, there were significant differences in the contractors' size as well as in the building projects' type; the cases also differ markedly in terms of project value, from £4.5 million to £45 million. This diversity was an intentional aspect of the research design because it helped reduce possible bias. The four contractors together with the Design-Build projects in which they were involved, are therefore considered to offer a reasonable representation of the breadth and depth of main contractors' involvement in Design-Build projects.

The primary form of data collection for the case studies was semi-structured interviews, supplemented with documentation, records and observations where available and as appropriate. Interviews are one of the main sources of case study information (Tellis, 1997); these were semi-structured, individual, personal interviews using a number of key and supplementary questions. Interviews vary in their nature, they can be: structured, semi-structured and unstructured; the major differences lie in the constraints placed on the respondent and the interviewer (Fellows and Liu, 2003). The structured interview does not provide sufficient scope to probe ideas further, as the questions set are quite tightly defined (Hancock, 1998). Also, group interviews may be considered one possibility, but it can be difficult to coordinate people's diaries. On the other hand, semi-structured interviews can yield a variety of kinds of information; even within one interview you could (Drever, 1995):

- Gather factual information about people's circumstances
- Collect statements of their preferences and opinions
- Explore in some depth their experiences, motivations, and reasoning.

In line with the overall aim of this research, the focus of the interviews was on any changes that had occurred to the frame design, specification or production method as a result of the informal involvement and the subsequent contractual appointment of the main contractor to the project. So, individual interviews were held with a range of professional groups including, but not necessarily limited to; main contractor, structural engineer, architect, cost consultant and client. In all cases, a letter was sent, or telephone call made to each selected individual outlining the research and inviting them to participate. A participation information sheet was sent to interviewees after access was granted. The interviews lasted between thirty minutes to one hour, depending on the interviewees' situation, and were tape recorded and transcribed verbatim for later analysis.

Typically, data analysis in a research project involves summarizing the mass of data collected and presenting the results in a way that communicates the most important features (Hancock, 1998). The preferable approach is to consider, evaluate and plan the analysis in a similar way to planning the whole research project (Fellows and Liu, 2003). Yin (1994) encourages researchers to make every effort to produce an analysis of the highest quality; hence he introduced the following principles:

- Show that the analysis relies on all the relevant evidence;
- Include all major rival interpretations in the analysis;
- Address the most significant aspect of the case study;
- Use the researcher's prior, expert knowledge to further the analysis.

Stake (1995) favours coding the data and identifying issues more clearly at the analysis stage, but coding qualitative data requires different techniques. The qualitative researcher has no system for pre-coding so needs a method of identifying and coding items of data which appear in the text of a transcript so that all the items of data in one interview can be compared with data collected from other interviewees (Hancock, 1998). This qualitative content analysis is a procedure for the categorisation of verbal or behavioural data, for purposes of classification, summarisation and tabulation; the emphasis is on determining the meaning of the data (Hancock, 1998; Fellows and Liu, 2003).

In this research, data analysis involved exploring themes and patterns revealed in the interviews to draw similarities and differences within and between cases, i.e. cross-case analyses. The data were then given coded allocations, based on key themes that emerged from the interviews, to categorise and group 'respondents' from whom the data had been obtained, so that a comparison of case studies was made effectively and thoroughly (Fellows and Liu, 2003). The process involved continually revisiting the data and reviewing its categorisation until the researcher was sure that the themes and categories used were a truthful and accurate reflection of the data (Hancock, 1998). In this study every effort was made to avoid bias (e.g. through the use of leading questions) that might have unduly influenced the outcomes. A summary of the key findings is presented in the following section.

5 The key findings

This section presents the key findings from four case studies conducted to examine the role of the contractor in the Design-Build decision-making process; it is not possible to fully document the detailed accounts of the interviews, so the following account is drawn from a synthesis report of the 'raw' interview data. The results are discussed under the theme headings derived from the data analysis; for all themes, a comparison was made within and between the cases. Where appropriate, direct quotes are used from particular interviewees. Refer to Table 1 for further details of building type, contractor size, contract type, frame type and interviewees contacted.

5.1 The rationale for using Design-Build

Participants in case study A (residential) cited the following reasons for using Design-Build: passing over the risk to main contractor, fixed lump-sum price and having the flow of information handled by a single body. This was echoed in Case Study B: the laboratory client was very experienced and was said to always use Design-Build, choosing to do so in this case to transfer the risk to the contractor. In Case Study C, Contractor C and Structural Engineer C said that the client wanted to transfer the risk, whereas Architect C claimed that it offered better cash flow for the client as Client C did not have to pay fees to the design team until the contract had been let. The Structural Engineer C also added that a lump-sum price was another reason for choosing Design-Build for the hospital. In Case Study D (mixed use), all project members interviewed agreed that risk was one of the important reasons for using Design-Build. Architect D and Structural Engineer D claimed that Design-Build was essentially used to move the risk away from the client. Contractor D added that the prime motives were, specifically, less responsibility for client in terms of co-ordination and having a lump-sum price. Client D summed it up nicely by stating that: "*cost certainty and risk transfer were the reasons for using Design-Build. However if we were to prioritise, then the primary reason would be cost certainty*".

5.2 The rationale behind the choice of the frame type

The basis upon which the frame type for each project was selected varied from project to project, which is entirely understandable as the building types ranged from residential to laboratory and hospital buildings.

The reasons for choosing the frame type in Case Study A varied among the project team members interviewed. Structural Engineer A stated that a concrete frame was chosen for the residential buildings because of cost issues and the use of flat slabs (to minimise storey height). Contractor A was satisfied with this choice, adding that: "*For residential buildings acoustics is everything*"; this was echoed by Cost Consultant A who also cited concrete's benefits in fire integrity, ease of services across flat slab and robustness. In Case Study B (laboratory), concrete was also selected, predominantly because of the thermal mass (seen as environmentally friendly). Other common reasons given by project team members were: the use of flat slabs, acoustics and flexibility. In addition, Client B's representative pointed out that the concrete frame was more economical than steel.

For the mixed use development, Structural Engineer D explained that three frame types were investigated to meet the client's key criteria, which included: column locations that coordinated with retail and apartment layouts, adequate acoustic mass, ease of construction, minimal structural zone/floor to ceiling heights. The three construction methods considered were: reinforced concrete flat slab structure, in-situ reinforced concrete beams and precast concrete planks, steel beams and in-situ concrete topping. Structural Engineer D said that a concrete flat slab has the advantage of least structural depth and is cost effective if column centres are not wide.

The soffit is flat, allowing simple services distribution and simplicity in the detailing of ceilings, but careful arrangement of columns is necessary to eliminate transfer structures. The inherent flexibility means that irregular column positions are more easily achievable, plus the inherent fire resistance and density of the concrete limits sound transmission between residential units. This strong case for concrete was supported by Cost Consultant D, who said it was the most cost effective solution. Finally, Client D made the firm statement that *"We know concrete well, we know through experience what works and what does not"*.

For the office building in Case Study A, a steel frame was chosen because it offered long span and required a greater floor-to-floor height. Contractor A chose steel for the office buildings for speed and a slight cost saving over concrete for the client. Cost Consultant A explained that they needed a clear span with 14-15m and could get an economical solution only by using steel, adding: "*With concrete flat slabs we would have had relatively thick floors and [for] spanning 15m [concrete] was not ever suggested by the structural engineer at all"*. According to the interviewees in Case Study C, speed was the main reason why steel was used as it was a very tight programme. Also, the column sizes were smaller in steel frame than in concrete, which preserved more rentable floor space for the client. Contractor C thought that a three-storey building was simply too small for a concrete frame.

5.3 Who is influential in the structural frame selection process?

The interviewees were asked to give their views on which project team members were influential in choosing the structural frame type for each case study project. There were found to be some important variations between the cases, in terms of who exerted leadership and how decision-making processes were handled.

In Case Study A every project team member (except for the Architect) interviewed thought they were the most influential party in the frame selection process. Structural Engineer A stated that they were by far the most influential body, whereas Cost Consultant A also claimed to choose the frame type, but in collaboration with the client. Contractor A claimed to be influential in selecting the frame type for the office building *"right from the start of the project"* which was confirmed by Architect A and the Structural Engineer, who also mentioned the contractor's influence on its buildability. In the case of the residential buildings, Contractor A approved of the frame choice, but added that *"We would not want to challenge the frame type of the residential buildings selected by the design team";* perhaps, because the choice had been made by the time they were appointed, Structural Engineer A thought that the involvement of the contractor was of limited value. Indeed, the contractor conceded that even if they had challenged the team, the frame type may not have been changed anyway.

In Case Study B, the decision to use concrete was apparently a joint decision between several project team members (including the architect, structural engineer and cost consultant) fairly early on in the design process, before Contractor B was involved. Nevertheless, Contractor B claimed that the frame choice for the laboratory was dictated by the client as it was an environmentally friendly building and concrete was one of the key features of this solution, so the contractor wanted to retain it.

In Case Study C, the project team members all confirmed that it was the structural engineer who had chosen the frame type. Contractor C stated that they were in favour of a steel frame because of their broad experience in using steel and the size of the project, being just three storeys. Architect C said that the contractor could have been influential, but Structural Engineer C claimed that contractors can be very influential only if they have the willingness to build in a particular frame type.

Likewise, in Case Study D the structural engineer had the biggest influence in the choice of frame type, but Client D asserted that the final decision was theirs. Contractor D had apparently suggested a steel frame (for reasons of speed, cost certainty and sustainability issues, plus they had far more experience in steel than concrete), so it is no surprise that both the Architect and Contractor D pointed out that the choice of reinforced concrete flat slab was by agreement, rather than by approval. Finally, the client suggested that a main contractor can influence the frame type when there is a need for early contractor involvement, but this would depend entirely on the size and complexity of the project.

5.4 Involvement of the main contractor and actions taken

The degree and type of involvement that each main contractor had in the case study projects is described here, together with any changes made by the contractor, such as changes to design, specification or production of the structural frame. Again, it appears that there were some significant differences in approach.

As stated by the project team members interviewed in Case Study A, although Contractor A claimed that they got involved in the first five building projects at Stage D of the RIBA Plan of Work (2007), they were not contractually appointed until the end of Stage E. Thereafter, Contractor A prompted a few minor changes including the concrete specifications (using ggbs) and the method of construction (using slipform construction for cores). For the final two buildings in this case, Contractor A was involved from the beginning, although not contractually; during this time, Contractor A asserted that they had a major impact in the structural frame selection process, which was corroborated by Structural Engineer A.

Similarly, Contractor B became involved in the laboratory project from RIBA Stage C, but contractually took over after Stage E. According to the interviewees, Contractor B did not make any major changes during the design process, rather they influenced finishes, materials used, and gave useful advice on market prices. Indeed, the Client's representative and the external project manager stated that Contractor B's involvement helped the project team work together and resolve problems before work started on site. Early involvement helped Contractor B organise sub-contractors: *"The envelope of the building was originally designed to have a dual curve which was extremely expensive so the design team (architect, structural engineer, services engineer, etc.) chose to go for a single curve which was a lot cheaper. We used our supply chain. We had key packages and we knew the workload"*. Contractor B explained that "*Two-stage was the right route for this project as there was a lot of involvement in cost planning to get it on budget"*.

Although two-stage tendering was also used in Case Study D, Contractor D was not involved early (informal discussions during Stage D did however allow the contractor to refine costs somewhat). Client D indicated that it was a straightforward building so they felt they did not have to get the contractor involved early and Structural Engineer

D stated that most of the design had been developed by the time Contractor D was appointed (so they had little influence in developing the design and there was little scope for them to change anything). Client D did point out however that the contractor influenced the sequence, method of construction and design of the structural frame, plus they took control of the design by using their own supply chain. Interestingly the client added *"I am not a fan of two-stage Design-Build as we ended up spending more money"* and asserted that they would go for single-stage Design Build in the future.

Contractor C was appointed at the end of RIBA Stage E, but reportedly did not have any influence until the contract was placed. Thereafter, Contractor C tried to make the design more buildable and economical for the client "*Quality is also paramount and using cheaper materials does not necessarily mean that it would undermine the quality*". In addition, Structural Engineer C said that the foundation design was changed due to difficult ground conditions.

6 Discussion

The use of Design-Build and contractor involvement

Of all the professionals interviewed, almost all were involved regularly, and in some cases extensively, with Design-Build procurement. Contractor A stated that nowadays almost all their contracts are Design-Build; Contractor B said that they currently do 80% of their projects this way. In all four case studies, Design-Build was used primarily to shift the risk from client to contractor, as asserted by Akintoye (1994). The other key reasons for its use were cost certainty and single-point responsibility.

Although structural engineers seemed to be very influential in case studies A, C and D, it was apparent that the ultimate decision on the frame type lay with the clients, and particularly the more informed clients. However, the Architect and Structural Engineer for Case Study C claimed that contractors can also be very influential if they have the willingness to build in a particular frame type and motivation to do so. This was corroborated by Client D who asserted that: "*The main contractor can influence the frame choice in Design-Build projects, but it depends on the contractors' involvement in the project*". These responses align with success factors for Design-Build projects (i.e. the contractor's Design-Build knowledge, experience and confidence, and ability to maintain proper documentation) put forward by Songer and Molenaar (1996), Hemlin (1999) and Leung (1999).

All four contractors took over contractually the Design-Build projects at the end of RIBA Stage E and as a result, none of them made any major changes to the Design-Build projects (including the frame choice), but they all exerted some influence on buildability, cost (market prices), construction sequence and methods. That said, Contractor B's involvement appeared to be greater than the others and although Case Studies B and D used two-stage Design-Build, the level of the involvement the Contractors B and D had were not alike which suggests that there may be other factors that control the extent of contractors' involvement in a Design-Build project such as the contractor's size. For instance, Architect D suggested that Contractor D was not proactive, adding: "*The influence of the contractor on a Design-Build project depends on how busy they (contractors) are at the time and how hungry they (contractors) are for work.*" Furthermore, Client D held that "*the involvement of the contractors depends on how quickly the client wants the contractor on site and how much risk the client wants to hold onto*". They went on to say that: "*In general the main contractor's influence in a Design-Build project tends to be related to the size and* *complexity of the project*". This is echoed in a recent study by Lam et al. (2008) who found that if a Design-Build project is prestigious and has a high value to the contractor, the contractor will naturally put forth extra effort.

So, the findings of the case studies provide interesting outcomes in response to the research objectives relating to the use of Design-Build and contractor involvement. It is now possible to make clear connections between the experiences within the various cases, despite their small number, because there are clear inter-relationships between these four projects. It is possible to summarise the various issues that appear to determine the nature of the contractor's involvement in Design-Build projects, and these are represented in Figure 1.

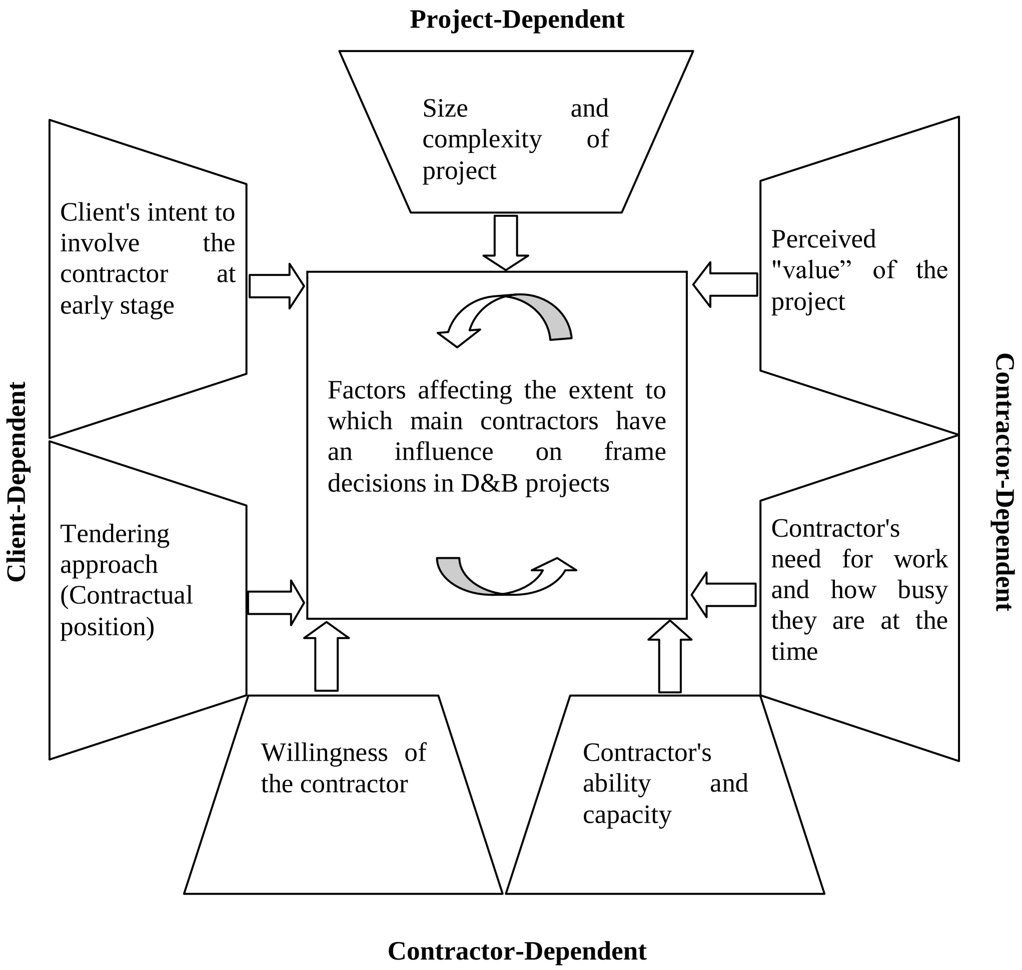

Figure 1 Factors affecting the contractor's influence on frame decisions in D&B projects

Contractors' influence on the choice of frame type

Each case study project had its own circumstances in terms of what frame type was chosen and which factors influenced this choice. Although this statement aligns broadly with findings from Haroglu et al. (2008a), which indicated that cost is the most influential factor in the structural frame selection process, this was found to be not the primary issue in the four case study projects.

In the single-stage Design-Build projects, the contractor's influence was not found to be any less than in two-stage Design-Build cases. Early contractor involvement appears not to happen very often in practice. Cost Consultant A claimed, from experience in working with contractors for many years, that early contractor involvement is not of any value as the contractors are not very sophisticated in the way they deal with the clients' requirements in terms of cost effectiveness and timeliness. The Client's representative in Case Study B explained that: "*In general what the client tends to do is to have a fairly well-developed scheme design and then to involve the contractor in the detailed design."* This was evidenced in one single-stage project (Case Study C, hospital) in which Contractor C did not have any input in the design process, but later had to change the foundation design to prevent additional costs.

This idea is supported by Rawlinson (2008) who says that the readiness of clients to shift away from two-stage tendering indicates a degree of frustration with some aspects of collaborative working and an increase in cost in the second stage, which was corroborated by Client D who complained that two-stage tendering had caused them to exceed their budget. Rawlinson (2006) goes on to state that the main benefit of two-stage tendering, speed of programme, inevitably comes at the price of some degree of cost premium. Nevertheless, Mosley (2008) notes that properly structured two-stage tendering, using an early conditional contractor appointment, is the best means for the client to control projects and obtain added value from contractors. Leung (1999) also suggests that Design-Build projects perform better if the contractor is allowed to design structures to suit their construction method. With this ‘contractor detailing’ in mind, it appears that the case study contractors only made changes to the frame design, specification or production method as follows:

- Contractor A made a few minor changes, including the concrete specifications (ggbs) and the construction method (slipform construction);
- Contractor B influenced finishes and materials.
- Contractor D influenced the sequence, method of construction and design.

To illustrate these key findings on the choice of frame in a Design-Build project and the various actions taken by the contractor, Figure 2 attempts to summarise the main outcomes and relate these to RIBA Plan of Work (2007) stages.

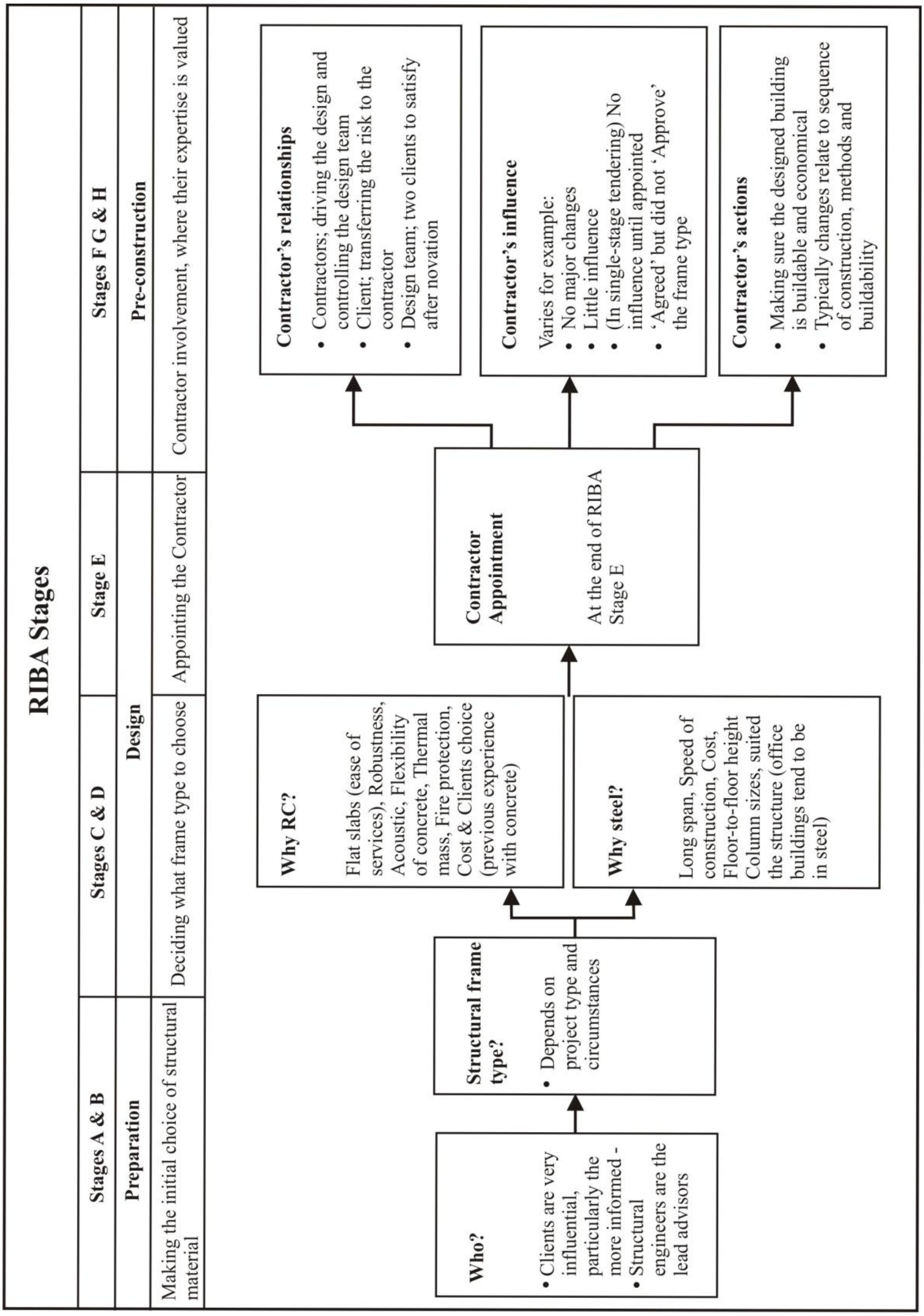

Figure 2 Summary of the key findings in relation to the structural frame selection as the D&B project progresses

7 Conclusions and recommendations

The central aim of the research was to determine whether or not the main contractor influences major decisions on a Design-Build project, with particular reference to changes design and/or specification the structural frame. The four case studies helped provide an understanding of the role of contractors within UK building projects which were procured using either single-stage or two-stage Design-Build procurement routes. The structural frame selection process was also investigated in the four Design-Build projects to establish the extent of the contractors' influence on the selection, design, specification and/or production of a frame.

The project team members of the four case studies interviewed confirmed that the Design-Build procurement route is used increasingly for building projects in the UK. Contrary to popular belief, contractors in the case studies appeared to be fairly satisfied with the Design-Build procurement route and more importantly they seem to have learned how to manage the construction risk that they inherit from their clients. A range of factors which affect the nature and depth of contractor involvement in a Design-Build project were identified, some of which were common to more than one case study. These included contractor motivation and the nature of the particular building project in hand, e.g. layout, client requirements, ground conditions etc. That said, it was clear that early involvement allowed the contractor to offer advice on buildability, market conditions and an appropriate supply chain.

With regard to the structural frame, the case studies indicated that the more informed clients are much more involved in initiating the choice, evaluating options, deciding on the frame type and also on subsequent changes. It was clear that contractors could be influential in the frame selection process if they had the willingness to build in a particular frame type (provided that the frame type selected meets the client's requirements), the motivation to exert their influence on the design team and client, and the capacity to do so. Furthermore, it was clear that in all but one case that after their appointment, the contractor did make changes to the frame design, specification and/or production method; these changes aimed to improve buildability and economic feasibility.

From these conclusions it is possible to make some specific recommendations for parties involved in a Design-Build project. First, Clients should be encouraged to involve contractors as early as possible in a Design-Build project to acquire best value from their contractors by allowing them to advise on buildability and supply chain. This requires contractors to be proactive, willing and able to deal with the client's requirements effectively and efficiently, but this is a problem because contractors may not wish to give such 'free advice' to a client prior to a formal appointment being made. Secondly, it is essential that contractors should influence the structural frame selection process to best suit their construction methods and techniques; this will enable contractors to complete the building successfully saving time and money for themselves and the client. That said, clients and other parties should not presume that contractors will always wish to advise on or steer the choice of a structural frame; this will depend on project circumstances as well as contractor motivation to do so. These cases certainly go some way to confirming Mosey's argument (2008) that properly structured two-stage tendering, using an early, conditional contractor appointment, is the best means for clients to control projects and obtain added value from their contractors.

As with all research, this study is not comprehensive. It is not possible to generalise from these four case studies and individual interviews undertaken may not be representative of the corporate body. However, it is hoped that the findings presented provide a useful insight into the nature of Design-Build projects in the UK. In particular there is scope for further research on the specific benefits of early contractor involvement, the factors that affect the extent to which contractors get involved with structural frame decision making and the risk relationship between client and contractor.

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APPENDIX F   QUESTIONNAIRE SURVEY

SELECTING A STRUCTURAL FRAME
2007 Industry Research Questionnaire

This questionnaire is part of an ongoing Engineering Doctorate research project based in the Centre for Collaborative and Innovative Construction Engineering at Loughborough University. The aim of this survey is to assess the factors that people typically consider when choosing the structural frame for a multi-storey building and should result in a better understanding of how such decisions are made in practice.

Your input to this survey is much appreciated, but in the event of any queries, contact details can be found at the end of this document and in the cover letter. Thank you very much for your time and assistance – it is much appreciated.

Please ☑ as appropriate for multiple sections

SECTION 1: Background Information

Your name: ………………………………….. Name of Employer: ………………………………………..

Your position……………………………..… Department:…………………………………….………….

Telephone: ………………………………… Email: ……………………………………………………….

1a. Approximate number of company employees:……………………………………………………..

1b. Please state the approximate annual turnover for your company.

☐ Less than £1m ☐ £1-4m ☐ £5-9m ☐ £10-19m
☐ £20-49m ☐ £50-99m ☐ £100-499m ☐ Over£500m

1c. Please indicate your professional affiliation or current role

☐ Architect ☐ Client ☐ Contractor/Builder
☐ Project Manager ☐ Cost Consultant ☐ Structural Engineer
☐ Other [PLEASE SPECIFY]………………………………………………

1d. What types of projects do you typically work on? (Please answer parts I, II and III).

I. ☐ Residential / Housing ☐ Commercial ☐ Industrial
☐ Other [PLEASE SPECIFY]…………………………………………………………………
II. ☐ New ☐ Renovation/refurbishment
III. ☐ Private ☐ Public

1e. How much influence do you typically have on the choice of frame type for a building?

☐ A lot ☐ Some ☐ A little ☐ None

SECTION 2: Project Information

Please complete the following questions *__based on one of your projects that has recently started on site__*. This will enable us to better interpret people's responses.

The project's name (or project number)**:**…………………………………………………………………….…

The project type:

□ Residential / Housing □ Commercial □ Industrial □ Other [PLEASE SPECIFY]……………

The procurement type:

□ Traditional □ Management Contracting □ Construction Management
□ Design build □ Two-stage tendering □ Other [PLEASE SPECIFY]……

2a.The table below lists a range of issues which may be discussed during the selection of a structural frame. We would like your views on the __relative importance of each issue at each of the four project stages shown, *for your project*__ (you may also add further issues if you wish).

For __each__ project stage, enter any score between 0 and 3, which you think best represents the importance of __each__ issue, where:

0 = Not important 1 = Of little importance 2 = Quite important 3 = Extremely important

ISSUES		PROCUREMENT PROCESS (RIBA Stages)			
		Stage A/B	**Stage C**	**Stage D**	**Stage E/F/G/H**
		Feasibility	Conceptual Design *(Multiple frame options)*	Scheme Design *(Frame option selected)*	Detailed Design / Tender action
1	Architecture (Aesthetic issues, layout, etc.)				
2	Building use/function				
3	Cost (Design and/or construction)				
4	Preference for a particular frame type				
5	Programme - speed of construction				
6	Risk (client needs/the market/expenditure)				
7	Site (access, ground conditions, etc.)				
8	Size of building (m^2 / number of floors)				
9	Supply chain capability				
10	Sustainability				
Other:……………………………………					
Other:……………………………………					

2b.The table below lists a range of issues which may be discussed during the selection of a structural frame. We would like your views on the <u>relative importance of each issue for each of the project team members shown *for your project*</u> (please add any further issues you wrote in Question 2a.)

For <u>each</u> role listed, enter any score between 0 and 3, which you think best represents the importance of <u>each</u> issue to that person, where:

0 = Not important   1 = Of little importance   2 = Quite important   3 = Extremely important

ISSUES		People's roles on your project					
		Client	Project Manager	Cost Consultant	Structural Engineer	Architect	Main Contractor
1	Architecture (Aesthetic issues, layout, etc.)						
2	Building use/function						
3	Cost (Design and/or construction)						
4	Preference for a particular frame type						
5	Programme - speed of construction						
6	Risk (client needs/market/expenditure)						
7	Site (access, ground conditions, etc.)						
8	Size of building (m^2 / number of floors)						
9	Supply chain capability						
10	Sustainability						
Other:……………………………………							
Other:……………………………………							

2c.The table below lists the same people who are typically involved in the same four project stages. In this section, we would like your views on the level of influence that they have on the selection of a structural frame. Consider each person listed below in relation to *your project*.

For each stage, enter any score between 0 and 3, which you think best represents that person's overall level of influence, where:

0 = Not influential 1 = Of little influence 2 = Quite influential 3 = Extremely influential

People	**PROCUREMENT PROCESS (RIBA Stages)**			
	Stage A/B	**Stage C**	**Stage D**	**Stage E/F/G/H**
	Feasibility	Conceptual Design *(Multiple frame options)*	Scheme Design *(Single frame option)*	Detailed Design / Tender action
Client				
Project Manager				
Cost Consultant				
Structural Engineer				
Architect				
Main Contractor				

SECTION 3: Future Research

We will be carrying out interviews with selected respondents in the future and would like you to consider taking part.

3a. Would you be willing to share examples of good practice to be used as case studies for this research? ☐ Yes ☐ No

3b. Would you like to receive a summary of the results of this survey? ☐ Yes ☐ No

If you answered YES, please ensure your contact details are entered on page one of this questionnaire.

Please check if you have completed the contact details on page 1 of the survey and return the questionnaire in the self-addressed envelope provided

Thank You Very Much for your Time and Assistance

Contact details:

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APPENDIX G INTERVIEW SCHEDULE

Interview Schedule: 'Procurement Process in the Concrete Frames'

This interview forms part of the research for an engineering doctorate project investigating the improvement of the concrete frame procurement process. The aim of the interview is to identify the knowledge in the area of procurement and contract strategies within the construction industry, and to identify the rationale behind the selection of frame option as well as the procurement route and contract type. The focus is looking at project working methodologies, and identifying the procurement and contract types already in use.

1. Background Information

This section will be used to collect the general data on the project that the interviewees currently work as well as already worked.

Prompt 1: What are the typical types of projects you work on?

☐ Civil Engineering ☐ Offices ☐ Health
☐ Housing ☐ Education ☐ Industrial

Prompt 2: What is the current project you work on?

I. Project name:

II. Project type

☐ Civil Engineering ☐ Offices ☐ Health
☐ Housing ☐ Education ☐ Industrial

III. Procurement type

☐ Traditional ☐ Management Contracting
☐ Design build ☐ Construction Management
☐ Other

IV. Company Project Value – Total Project Value:

V. Types of Contract

☐ JCT ☐ ICE
☐ NCE ☐ Other

VI. Forms of Contract

☐ Price-based ☐ Cost-based ☐ Other

VII. Phases of the building process in which your company participates on this project:

☐ Client brief
☐ Conceptual design
☐ Scheme design
☐ Detailed design
☐ Site Mobilisation
☐ Construction
☐ Maintenance

VIII. How many other companies involved in this project:
(Contractors, sub-contractor, suppliers, consultants (site), consultants (HQ), other)

2. Frame Options

This section will be used to evaluate the options and the decisions with respect to the structural frame options on construction projects.

Prompt 3: What kind of frame options do you typically apply?

☐ Concrete ☐ Steel ☐ Timber ☐ Other

Prompt 4: Have these options changed over the past years?

Prompt 5: Why did you use this type of structural frame for your current project?

3. Procurement and Contract Strategies

This section will be used to assess the use of procurement routes/contract types on construction projects particularly concrete frame projects.

Prompt 6: What type of procurement routes do you typically employ?

☐ Traditional
☐ Design build
☐ Other
☐ Management Contracting
☐ Construction Management

Prompt 7: Have these types changed over the past years?

Prompt 8: Do you think if there is any particular procurement route/approach is suitable or problematic for concrete frames?

Prompt 9: Why did you use these procurement route and contract form for your current project?

4. Further comments

Prompt 10: Is there anything else you want to say about 'the selection of structural frame and procurement/contract option', that I haven't asked you?

APPENDIX H FOCUS GROUP (WORKSHOP)

Workshop Agenda: Monday 22 January 2007

10:00 Start of meeting/briefing

Welcome and introductions.

10:05 Background information

The facilitator will give a presentation about progress made during the research and some early conclusions from a recent programme of interviews. The plan for the future research will also be explained and there will be time for Q&A/discussion.

10:25 Introduction of workshop

The facilitator will give a brief explanation of what we will be doing and what we hope to achieve.

10:30 Task 1: The choice of frame - making the issues list

Participants will be divided into two groups, each dealing with the same issues, but using different flipcharts. A number of issues have been identified as important when choosing the frame type of a building – these have been written on post-it notes. Each post-it note represents only one issue and is attached to a flip chart-sheet (each group has the same set of issues). Each group will be asked to select ten issues from the post-it notes or they can add other issues they think are important by writing on a fresh post-it note.

Having done this, participants will write an explanation of why those 10 were selected on the flip chart.

11:15 Coffee break / review the list

11:30 Task 1: Plenary Session – Justification

There will be an opportunity for each group to explain their ten issues together with the rationale behind the selection and for the rest of the participants to ask questions. The facilitator will invite discussion as appropriate.

11.45 Task1: Add-on

Each group will be given a final opportunity to add any issues (up to three) which they feel are missing (on a new sheet) and the facilitator will draw the task to a close.

12:00 Task 2: Questionnaire try-out

As part of the development of a questionnaire survey, participants will be given three models (formats) for a particular question. Feedback on the ease and speed of completion will be requested.

12:30 Close of workshop and lunch

APPENDIX I CASE STUDY PROTOCOL

The contractor's influence on structural frame design within D&B projects: case studies from the UK

Draft case study protocol

1 Background

Both the influential Latham (1994) and Egan (1998) reports identified that improvements designed to reduce budget and timescale and to increase quality would only be achieved if main contractors were involved sufficiently early in the design process and fully understood the needs of the Client. Hence, the rise in popularity of procurement routes and forms of contract that permit early contractor involvement (ECI) such as design-build within which contractors are involved early to increase the level of supply chain integration. Although some confusion exists amongst inexperienced clients, the term design-build has almost been unanimously interpreted and defined as (Masterman, 2006, p. 67):

"An arrangement where one contracting organisation takes sole responsibility, normally on a lump sum fixed price basis, for the bespoke design and construction of a client's project."

Design-Build arguably places more responsibility and liability on to the contractor than any form of procurement (Akintoye, 1994; Peace and Bennett, 2005). The key benefits include single point responsibility, availability of the contractor's knowledge of 'buildability' and the standardisation of the construction process (Franks, 1990; Janssens, 1991; Akintoye, 1994; Turner, 1995). Furthermore, according to Peace and Bennett (2005), design-build projects based on a minimal statement are completed 40% faster, while those based on an outline design are completed 25% faster than the projects using a traditional approach. Also, design-build projects are much more likely to be completed on time an are reportedly 15% cheaper than equivalent traditional projects. However, the Design-Build method also has a number of disadvantages. One of the major drawbacks of using the design-build procurement approach is the poor quality of design (Franks, 1990; NJCC, 1995). The main reason for this may be that architects seem to have less control over the design process than they would in a traditional approach (Haroglu et al., forthcoming). Also, the advantages of competition may not be passed onto the client when using design-build (Rowlinson, 1999; Peace and Bennett, 2005).

The principal variants of the design-build (integrated) procurement systems are described according to Masterman (2006) as follows;

- Novated design and build;
- Package deals;
- Develop and construct; and,
- Turnkey.

In a recent survey of project managers, cost consultants and clients, Haroglu et al (forthcoming) discovered that the design-build procurement route was the most popular form of contract used in the UK construction industry.

In addition to changes within contracts, the role of the structural frame in meeting the client's needs has also been investigated (e.g. RPEG, 1995; Soetanto et al, 2006) and there is clear evidence in the literature that the selection of an appropriate frame type can be critical to the overall success of a building project (SCI, 2000; Soetanto et al, 2006), whether this is measured in terms of cost, programme or a perceived aspect of quality, such as architectural aesthetics, or even energy performance. Clearly, if the structural frame can help deliver improvements in these areas this will represent a tangible benefit to the client in the completed building and, if combined with an appropriate form of contract, could result in further cost and time savings.

However, one issue which remains unclear and under-researched is the link between the form of contract and the structural frame (Haroglu et al., 2008) and specifically the typical level of "contractual involvement" or influence that the main contractor has on the selection, design or production of the structural frame in a design-build project. This warrants consideration in terms of the various types of design-build procurement routes, the size of the contractor, the client-main contractor risk relationship, the stage at which the main contractor is involved both informally and contractually, and so a case study approach has been selected to investigate these factors on a series of design-build projects in the UK. The next section describes the aims and objectives for the case studies.

2 Research Aim, objectives and hypothesis

The main aim of this research is to investigate whether the main contractor influences or actually changes any specifications i.e. structural frame type, on a Design-Build project. It has been suggested from both the findings of Haroglu et al's (forthcoming) and a review of literature that design-build is the dominant form of contract and also that structural frames can contribute to the success of a building. With the main contractor clearly taking significant, and earlier, responsibility for a building project within Design-Build, then it is reasonable to propose the following research hypothesis:

- Design-Build procurement routes are the most popular form of contract used in the UK construction industry, so as a result main contractors must be influential in the structural frame decision-making process and may in some cases change the specification of a frame.

To achieve the research aim (and thereby support or refute the hypothesis), the following objectives need to be investigated in the context of Design-Build projects:

- determine the degree and types of involvement that main contractors have within a range of Design-Build contracts;
- identify the similarities and differences amongst various sizes of contractors in relation to the degree of their involvement;
- identify what changes, if any, are typically made by main contractors to the selection, design or production of a frame;
- investigate how and why these changes were made – what were the drivers and barriers to such changes;
- draw conclusions on how design-build works best in terms of main contractor involvement;

- make recommendations on how much influence main contractors can/should have on the structural frame selection process.

These objectives can be divided into a series of **Research questions:**

A: Preparatory questions:

- Which construction companies are the most representative of the construction industry?
- Which of these are most representative of the design-build projects in the UK construction industry?

B: Case-specific research questions:

- At which stage does each main contractor get involved in design-build project, i.e. concept design, scheme design and detailed design?
- Who was the key person to influence on what material is used, and on any changes as the project progresses?
- How influential was each main contractor in the design decision-making process?
- To what extent was each main contractor involved in the structural frame selection process?
- What were the main issues that needed to be considered during the structural frame selection process?
- What would the main contractor's preference be for the frame type of their projects, typically and also in this case?
- What changes are typically made by the main contractor?
- How were these changes decided?
- When were they made?
- How were they made?
- Who was involved?
- How effective were they?
- What would they do differently now?

C: Overall research questions:

- What similarities were there?
- What differences were there?
- What worked best?
- What could have worked better?
- What went wrong?
- Were there any critical success factors?
- Was Design-Build advantageous to the main contractor, client and other project team members?
- What are the disadvantages of Design-Build in general?
- What conclusions can be drawn and recommendations made?

3 Research method

These objectives will be met by undertaking a series of company case studies with UK-based Design-Build contractors;

"Case studies are used when the researcher intends to support his/her argument by an in-depth analysis of a person, a group of persons, an organisation or a particular project" (Naoum, 2007; p. 45).

The case study is the method of choice when the phenomenon under study has not been investigated within its context (Yin, 2003; Fellows and Liu, 2003). One advantage of the case study method is that it may be possible to make generalizations but may not be possible to reject existing generalizations (Casley and Lury, 1982). Case study methods allows investigators to retain the holistic and meaningful characteristics of real-life events – such as individual life cycles, organizational and managerial processes, neighborhood change, international relations, and the maturation of industries. (Yin, 2003). Most studies look for what is common and pervasive, whereas the intent of the case study may not be generalization but rather to understand the particulars of that case in its complexity (Key, 1997). A common criticism of case study methodology is that its dependence on a single case renders it incapable of providing a generalizing conclusion (Tellis, 1997). However, Hamel et al. (1993) and Yin (1994) argued that the goal of the study should establish the parameters, and then should be applied to all research. Thus, even a single case could be considered satisfactory as long as it fulfilled the established objectives.

Yin (2003) asserts that case study research can be based on a (2 X 3) typology design, i.e. single- or multiple cases mapped with an exploratory, descriptive or explanatory study. Whilst a single case study needs only to focus on one case, in multiple-case studies, cases should be selected so that they replicate each other or one predictably different (systematic). Stake (1995) and Yin (1994) identified at least six sources of evidence in case studies. These are as follows:

- Documents
- Archival records
- Interviews
- Direct observation
- Participant-observation
- Physical artifacts

Due to the diversity of company size and structure, an exploratory case study design based on **multiple cases with single units of analysis** has therefore been adopted for the research in accordance with the guidance offered by Yin (2003). That is, four construction contracting companies of different size and structure will be studied using the same case study protocol. Personal, face to face interviews with selected individuals will provide the primary source of data, supplemented with documentation, records and observations where available and as appropriate. The results of the individual cases will then be combined in a cross-case report, from which lessons will be identified and recommendations made.

4 Preparatory stage

A shortlist of possible target companies for the case studies was produced from the results of a questionnaire survey (Haroglu et al, forthcoming), within which respondents had volunteered specific building projects for consideration in this stage of the research.

These 23 companies represent a cross-section of UK contractors by size and the type of procurement routes used because they are small-medium and large contractors (categories which account for more than 90% based on ranking in Contractors File 2008 of New Civil Engineer NCE) of construction contracts by turnover per annum, have been involved in a design & build project recently and were willing to participate in the study. Multiple cases need to be employed to ensure that the results present a breadth and depth of main contractors' involvement in design-build projects. In this study, four contractors were selected and four case studies undertaken using personal interviews with various project team members who were involved from the design-build projects.

The objective here is to collate the views of the various project team members who have been involved in choosing the structural frame material at the design stages or thereafter. So the interviews will be held with a range of professional groups including, but not necessarily limited to; **main contractor, structural engineer, architect and cost consultant** in order to collate a broad range of perspectives covering different aspects of the structural frame selection process. Interviews will be held with the related people (project team members) or their representatives, probably on an individual basis, but in some cases in a group depending on the interviewees' preferences. In all cases, a letter will be sent, or telephone call made to each selected individual outlining the research and inviting them to participate.

5 Interviews

Interviews are one of the main sources of case study information (Tellis, 1997). The interviews will be semi-structured using a number of key and supplementary questions. The choice of interviews as the primary source of data was determined by consideration of the scope and depth required for this case study research. Furthermore, interviews vary in their nature, they can be: structured, semi-structured and unstructured; the major differences lie in the constraints placed on the respondent and the interviewer (Fellows and Liu, 2003). The structured interview does not provide sufficient scope to probe ideas further, as the questions are set quite tightly defined (Hancock, 1998). Also, group interviews may be considered one possibility, but perhaps difficult to coordinate people's diaries. On the other hand, semi-structured interviews can yield a variety of kinds of information; even within one interview you could (Drever, 1995):

- Gather factual information about people's circumstances
- Collect statements of their preferences and opinions
- Explore in some depth their experiences, motivations, and reasoning.

The term 'semi-structured' means that the interviewer sets up a general structure by deciding in advance what ground is to be covered and what main questions are to be asked. This leaves the detailed structure to be worked out during the interview (Fellows and Liu, 2003).

In line with the overall aim of this research, the focus of the interviews will be on any changes that have occurred to the frame design, specification or production method after the "contractual involvement" of the main contractor in the project.

5.1 Interview questions

The interviews will cover the following broad topics:

I. The nature of the main contractor's involvement in the design process when using D&B
II. Structural frame selection process
III. Advantages and disadvantages of Design-Build

Key interview questions:

I. Main Contractor involvement in the design process when using Design-Build

- Was main contractor involved early enough in the project?
- What changes have been made by the main contractor after being involved in the project?
- How much influence did main contractor have on the project after being involved in the design process?
- Was early contractor involvement in the project valuable?
- What do you think about ECI in general?

II. Structural frame selection process

- When, how and why the structural frame type was chosen?
- Was the decision entirely dependent on the project variables as to what materials they used?
- What other issues were considered when choosing the structural frame type of the project?
- Who was the most influential body in choosing the structural frame type of the project?
- Was the selected structural frame type right? What structural frame type would you prefer now?
- What would you do differently now?
- Do you have a preference for a particular structural frame type? And Why?

III. Advantages and disadvantages of Design-Build

- What were the reasons of using Design-Build?
- Was Design-Build beneficial to the project in general?
- Was Design-Build advantageous to you?
- What are the shortcomings of using Design-Build in most cases?

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