Re-engineering the project procurement process through concurrent engineering

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RE-ENGINEERING THE PROJECT PROCUREMENT PROCESS
THROUGH CONCURRENT ENGINEERING

JOHN BOWRON

A thesis submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy of Loughborough University

April 2002
ABSTRACT

The construction industry in the United Kingdom is a multi-billion pound business that contributes, on average 10% of the UK Gross Domestic Product (GDP). However, it is seen by many to be underachieving in terms of service delivery and investment opportunities. Projects are frequently late and over budget much to the disappointment of those involved in the industry and especially clients. Many investigations have been commissioned and resulting reports have suggested improvements in the way the industry is organised.

Procurement of construction projects in the main are undertaken using methods that support fragmentation and adversarial relationships. However, with the introduction of partnering and prime contracting some improvements have been made. Procurement of a construction project begins with the strategies developed during briefing and is only complete when the facility is handed over to the client, some contract strategies allow for the facility to be completed once it is in operation, has been maintained and eventually is demolished. Costings and programmes are then related to life-cycle issues and aspects such as maintenance have to be taken into account during the facility development stages.

The adoption of Concurrent Engineering (CE) is seen to offer the construction industry a way forward. Having been adopted extensively by manufacturing in its product development stages a similar adoption by the construction industry would go some way to achieving the 30% improvement in real terms suggested by Latham [1994] and Egan [1998].

The research described in the thesis aims to develop a new procurement method for the delivery of construction projects. The approach adopted was to identify current methods of procurement and the problems associated with each method. Then using Concurrent Engineering as a basis, a new procurement model was
developed that offered potential improvements in the construction process between the stages of Clients Briefing and Detailed Design. The resulting model was evaluated through the application of CE principles into the process and by the presentation and discussion of the method with a number of industry participants, followed by the completion and assessment of a questionnaire.

The model was shown to fulfil the principles of CE and could be adopted into construction. It offers a new approach to procurement which in turn would save costs and time and potentially improve the quality of the final construction product.

Keywords: procurement, concurrent engineering, IDEF0 models, construction.
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Finally, I would like to thank my family, especially my wife Veronica and our two daughters Anne-Marie and Gemma, who have given up their time with me to let me realise my dream to complete this work.
Dedication

I would like to dedicate this work to my wife Veronica, who has supported me throughout this project. Without her tireless motivation, encouragement, patience and dedication this thesis would never have been prepared.

I would also dedicate it to our two daughters Anne-Marie and Gemma who have supported me continually.

Finally, for the glory of God who has given me everything.
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CHAPTER ONE

INTRODUCTION

This chapter introduces the research project, the industrial context and the potential improvements to be made to the construction industry. The aim and objectives of the research project are outlined and the approach to each area of research is detailed alongside the reasons for the adoption. Finally the structure of the thesis is outlined.

1.1 Background to the Research

This section outlines the background to the research in terms of the status of the UK construction industry and improvements proposed by Latham [1994] and Egan [1998]. It also outlines the potential for Concurrent Engineering to be used in improving the output of the Construction Industry, resulting in an increase in benefits for the businesses of clients, consultants and construction companies alike. Current procurement strategies used in the construction industry are discussed and how they could be improved by the use of a new procurement method based on Concurrent Engineering.

1.1.1 Construction Industry – Current Status

The Latham [1994] and Egan [1998] reports regarding the UK Construction Industry describe the current status of the industry and outline how it can be improved to give clients greater satisfaction and to improve company profitability. The industry had a £58 billion turnover in 1998 employing over 1.4 million people [Egan 1998], which represents approximately 10% of the UK Gross Domestic Product (GDP).
The construction industry is seen by many stakeholders to be failing its clients with projects that are frequently delivered over budget, late and with quality problems. Clients view the construction industry as being inefficient compared with other industries. The industry fails to meet the requirements of modern competitive international business, rarely providing best value [Egan 1998]. The City, as an investor in both projects and individual construction companies, sees the industry as a poor investment where the business is high risk with low margins, resulting in few long term shareholders. The industry is also seen to have too little re-investment in its own businesses through research and training [Egan 1998].

The construction industry is also considered as highly fragmented, with over 163,000 registered companies with the majority having less than 8 employees [Egan 1998]. This can have a serious effect on the industry’s ability to reduce costs and improve product quality.

In summary clients are looking for better value, although they themselves need to look beyond accepting the lowest tender price. On the other hand the construction companies are looking for improved profits to sustain the industry’s future.

Over the last five years, many government sponsored studies and initiatives have highlighted the need for changes aimed at improving the efficiency and competitiveness of the UK construction industry. With clients demanding reduced costs, reduced project duration and improved quality, an important aspect of the construction process that needs to be improved is project procurement. Current methods of project procurement in the UK construction industry offer potential clients many options towards developing their project to a successful completion.
A survey of the industry [Bowron 1998] shows that current methods of procurement are not meeting client's requirements particularly in terms of cost, programme and product quality.

1.1.2 Construction Industry – Procurement
There are currently four main methods of procuring construction projects in the UK. A recent survey [Bowron 1998] found that traditional (40%) Design and Build (20%), Management Contracting (10%) and long term negotiated contracts (10%) were the main methods used. Emerging methods such as PFI and Prime Contracting made up less than 10% of projects. Many of these methods are confrontational in their very nature and do not offer the potential of working together efficiently as a team alongside a client and consultant. This can result in fragmentation within the project team with unclear responsibilities for each part of the team.

One of the concerns of a project team is that a project is generally a non-repetitive venture which involves a virtual team of participants [Smith 1995, Anumba & Evbuomwan 1997] to complete complex processes, where each of the sub-teams are focused on their own individual part of the project. For example the consultant focuses on the design, the contractor on the construction and the client on the costs and programme. However, the overall project delivery process follows a similar pattern in each project and it is only in the product details where changes occur.

It is against the above background that this thesis investigates the scope for a new procurement method that is based on the principles of Concurrent Engineering which have been used successfully in the manufacturing industry.
1.1.3 Concurrent Engineering

Concurrent Engineering (CE) has been used by manufacturing industry in both the UK and USA as a means of re-engineering their processes [Syan 1994 and Salamone 1995] and to gain competitive advantage over emerging far-eastern companies. CE is defined as a systematic approach to the integrated, concurrent design of products of their related processes including manufacture and support [Winner et al 1988]. The aims of CE match the current needs of the construction industry in improvement terms. CE has been developed through the late 1900s following the Second World War and the changing business practices of companies as they developed and grew.

The use of CE in the Construction Industry offers the potential for the improvement required by clients, investors and the industry as a whole.

1.2 Research Aim and Objectives

The overall aim of the research project is to develop a new procurement method for construction projects based on Concurrent Engineering principles. Specifically, the project’s objectives are to:-

a) Review methods of project procurement in current use in the UK. This area of research was to identify the common methods in use and to identify the strengths and weaknesses of each method.

b) Review the use of Concurrent Engineering (CE) in construction and other industries. This was to establish the principles of Concurrent Engineering and to determine whether the process of procurement was similar in the construction and manufacturing industries.
c) Review current modelling methods available and to select the most appropriate method to develop a new procurement model for construction in the UK.

d) Develop a new procurement process model and evaluate it against CE principles and with industry practitioners to confirm the potential benefits.

1.3 Research Methodology

The research was undertaken using a variety of methods to meet the requirements of the research objectives. These are outlined in this section and, where appropriate, detailed further in the corresponding chapters.

1.3.1 Review of Existing Procurement Methods

The review of existing procurement methods used a combination of literature review and an industry survey administered to a random sample of organisations involved with the construction industry. These methods were adopted in order to identify the main procurement methods in use in the UK and then to determine the views of industry as to the status of procurement methods.

The industry survey was used to confirm the problems facing the industry and to gain a wider understanding on the use of each procurement method, the individual party's involvement and the extent and depth of problems faced by clients in delivering successful projects.

1.3.2 Review of Concurrent Engineering

The literature review process was similarly used to establish the current status of Concurrent Engineering, its aims, objectives and principles and its use in the manufacturing industry and the potential for its use in the construction industry. The review also identified many examples where the principles had been adopted

1.3.3 Development of the New Model
The requirements of a new model using Concurrent Engineering were established from an existing high level framework [Evbuomwan & Anumba 1996]. The new model was developed using the IDEF0 modelling technique which allows individual tasks to be broken down to their lowest levels and to assess the inputs, outputs, mechanisms and constraints that act on each task. The IDEF0 modelling technique was chosen following a review of process modelling methods.

1.3.4 Evaluation of the New Model
Once the model had been developed it was important to assess the viability and potential improvements that the new procurement model made to construction. This was achieved by assessing the extent to which the CE principles outlined in Chapter Two had been adopted in the new model. This was supplemented by a presentation to a number of industry practitioners who completed an evaluation questionnaire. The responses to the questionnaire were analysed to establish how the new process improved the construction project delivery process.

The evaluation method for review was chosen to obtain a rapid assessment of the model and also to ensure that the responses were from people currently involved in the industry and with extensive knowledge and experience of the problems associated with the industry.
1.4 Scope of the Research
The scope of the research is limited to construction procurement in the UK. The part of the overall construction development process was considered, with procurement falling between project definition and detailed design both of which have been subject to other studies [Kamara et al 2000 and Waskett 1999].

1.5 Research Significance
The research is considered to be of strategic importance to the industry following reports into the efficiency and potential improvement required in construction [Latham 1994, Egan 1998]. Procurement has considerable influence on most aspects of the project delivery process. Thus any improvement on existing methods would impact on all parties to a construction project.

1.6 Structure of the Thesis
Chapter One (Introduction) gives an introduction to the thesis by describing the issues and the subject (project procurement). The background to the research is shown to have a significant impact on the construction industry through the current thinking on improvements to the industry. The aims, objectives and methodology of the research programme are outlined.

Chapter Two (Concurrent Engineering in Construction) presents the current status of the construction industry, describes the principles of concurrent engineering and how they can benefit the construction industry.

Chapter Three (Evaluation of Existing Construction Procurement Methods) describes the different methods of procurement which are used in the construction industry. The methods are compared with procurement in the manufacturing industry and the limitations of current methods are outlined. The existing methods
of procurement are compared with the principles of CE and the requirements for a new method are outlined.

Chapter Four (Industry Perspectives on Procurement Methods) presents the industry survey conducted to obtain the views of construction practitioners. The survey used a random sample of practitioners falling into the categories of client, consultant and contractor.

Chapter Five (Process modelling techniques) compares the different modelling methods that could be utilised to prepare a new procurement model. The analysis shows the potential benefits of each method and then proposes IDEF0 modelling as the most appropriate to suit the required task.

Chapter Six (New Procurement Method) details the new method using the IDEF0 modelling technique. The method commences with the high level model of asset development which shows the position of procurement within the whole asset development process. The procurement aspect is drilled down to a level where individual tasks are identified.

Chapter Seven (Evaluation of New Procurement Model) assesses the new procurement method against current procurement methods and the principles of CE. The comparison outlines the potential benefits in adopting the new method. The chapter then details the method of independent evaluation of the new model by a presentation to a number of industry practitioners followed by the completion of an evaluation questionnaire. The results of the evaluation and the subsequent review of the results are described and then the chapter continues to show where further improvements can be made to the proposed procurement model that will benefit the construction industry.
Chapter Eight (Summary and Conclusions) summarises the results of the research compared with the initial aims and objectives. The benefits of the new methods are discussed complemented with areas where improvements can be made. Recommendations are made for further research.
CHAPTER TWO

CONCURRENT ENGINEERING IN CONSTRUCTION

2.1 Introduction

Traditionally construction projects are generally non-repetitive ventures, which involve complex processes to harness the resources of people, materials and equipment to build a facility. The resources are often fragmented and involve adversarial contracts where parties have their own vested interest [Egan 1998, Latham 1994]. This has led to engineering projects exceeding both timescales and agreed costs, to the dissatisfaction of clients.

This chapter examines the overall status of the construction industry in the UK, its current problems and outlines the industry's attempts to improve its status. The current problems with the industry have been recognised in several recently issued reports [Latham 1994, Egan 1998]. The reports recognise the need for a different approach to the development of construction projects and suggest, amongst other items, the adoption of processes similar to those used in the manufacturing industry. Concurrent Engineering (CE) is a method that has been used in product development in the manufacturing industry to great benefit of working on a level playing field with Far-Eastern companies. The principles and goals of CE are then reviewed showing how CE has been used to improve the processes in the manufacturing sector in both the UK and USA. This is developed further to identify how CE could be adopted for use both within Construction and, specifically how the construction procurement process can be improved based on CE principles.
Concurrent engineering which is commonly used in the manufacturing industry offers the potential to improve collaboration between parties to a project, focusing on the clients needs and delivering projects with improved quality and reduced delivery times and capital cost [Anumba & Evbuomwan 1997].

2.2 The Construction Industry
The construction industry in the UK is a £58 billion per annum industry employing over 1.4 million people [Egan 1998]. The industry serves many clients including:

- Services Organisations (e.g. Power, Water Authorities, Gas, Telecoms)
- Infrastructure (e.g. roads, railways, airports)
- Commercial (e.g. offices, shops, industrial)
- House Building

Construction projects vary in scale and complexity depending on the client and vary in extent from the design and installation of for example, a single length of drain through to complex multi-functional facilities such as laboratories, offices, airports and tunnels. There are many deliverables within the process such as project scope, design drawings, fabricated steel, constructed facility, all of which are usually developed to meet the needs of the project for a client in terms of cost, time and technical quality.

The construction industry is seen as under-achieving in terms of the delivery of products and is seen as a poor investment for the financial institutions [Latham 1994, Egan 1998]. Many attempts have been made to improve the industry and to integrate parties though different approaches such as Partnering [Crowley 1995, Duncombe 1997, Uher 1995] and Prime Contracting [HM Treasury – 2000(a)] alongside the adoption of new tools and techniques such as Total Quality Management, Quality Function Deployment.
A project, whatever size or complexity is usually executed through a collection of interrelated tasks or sub-projects performed by a group of people who interact together to cause irreversible change [Smith 1995]. In most cases the system used to produce the facility follows a common pattern and comprises a series of activities often referred to as a "project model."

Several process models exist for construction procurement depending upon the method of procurement e.g. Traditional, Design and Build, PFI etc. A generic process model proposed by Anumba & Evbuomwan [1997] for construction projects comprises a ten stage process and covers the full life-cycle of facility from initiation to disposal and is shown in Figure 2.1 below.

![Project Model Diagram](image)

Fig. 2.1 Project Process Model [Anumba & Evbuomwan 1997]
The process is focused on the product and can be separated into four key stages:

- Appraisal – stages 1 – 3
- Implementation – stages 4 – 7
- Utilisation – stages 8 – 9
- Disposal – stage 10.

The appraisal stages consists of the early development activities associated with the clients briefing through the conceptual analysis and onto outline schematics which primarily define the project for later detailed development. The Implementation stages take the schematics and carry out the detailed design and construction for the client. The third key stage comprises the activities associated with the client’s utilisation of the facility. Finally the facility is disposed of by demolition or by onward transfer onto a new owner.

Other process models exist, for example the Process Protocol which comprises the phases for the development and concentrates between ‘Demonstrating the need’ up to ‘Operation and Maintenance’ – the phases are shown below [http://pp2.dct.Salford.ac.uk/ppguide/phase.htm]:

- Phase Zero - Demonstrating the Need
- Phase One - Conception of Need
- Phase Two - Outline Feasibility
- Phase Three - Substantive Feasibility Study and Outline Financial Authority
- Phase Four - Outline Conceptual Design
- Phase Five - Full Conceptual Design
- Phase Six - Co-ordinated Design, Procurement and Full Financial Authority
- Phase Seven - Production Information
Phase Eight - Construction
Phase Nine - Operation and Maintenance.

The Protocol initially appears to focus around the area of feasibility and design (up to six stages) ensuring that a review is carried out by a senior management team at a gate between each phase. The Process Protocol is still under development by Salford University, although a substantial part of the development work has been completed.

Holti et al – [1999(a)] has also developed a new project process model to support Prime Contracting; this is discussed further in Chapter Three.

During each stage of any process the risks and uncertainties associated with the design and construction of the facility are gradually reduced until the facility is constructed and handed over. Also there are many different actors carrying out tasks that reduce the commercial risks, some belong to the client, others to design consultants and others to contractors. Key decisions which have a major impact on cost and programme occur at the early stages, often before many of the actors are currently involved. This is represented graphically in Figure 2.2.

The Figure clearly shows the benefits of making key decisions early in a project. The cost of making a decision is clearly low at the earlier stages, however the longer it is left in a project’s programme the greater the impact of the decision.
Possibilities of Reducing Cost

Accumulated Amount of Investment

Sanction

Decision Steps

Preplanning Planning Design & Construct Equipment Installation of Equipment

Fig 2.2 – Project Decision Timetable [Based on Smith 1995]

Similarly the impact of a project’s development programme on its viability is shown by the typical investment curve in Figure 2.3. If a project is delivered early the profitability for the client is increased by an early return on investment and secondary benefits by the reduction in cost of borrowing. Current contract strategy usually provides for penalty clauses and liquidated damages if the programme is delayed related to the impact on the client’s business.
In many cases the current processes of contract delivery do not encourage teamwork from individual parties to a contract and none meet all of the requirements and principles of CE. Procurement of a facility is frequently overlooked at the briefing stage of a project leading to an impact on the design, and construction costs and programme. The process and detail associated with a project are frequently not considered until the latter stages, therefore allowing design, material selection and construction to be developed by individual parties and passed "over the wall" in a sequential manner [Salamone, 1995] to the party completing the following activity. This attitude encourages fragmentation throughout the project development process which in itself compounds problems in terms of the delivery of the final product.

Fig 2.3 – Project Investment Curve [Based on Smith 1995]
Similarly, for the consultant or the contractor, currently the focus of their company is on their own relationship with the client and the development of their own product e.g. a consultant's product is seen as a set of calculations and drawings that allow a contractor to build the required facility. Similarly the contractor's product is to convert the design drawings into a constructed facility. Therefore activities are frequently carried out sequentially and are not integrated. Frequently the individual parties blame each other for inadequacies in their own performance.

Concurrent Engineering has been widely used by the Manufacturing industry in their approach to product development. This has been seen as essential for the UK and USA manufacturing industry to survive against stiff Far-Eastern competition.

2.3 Concurrent Engineering – Principles and Goals
2.3.1 History of Concurrent Engineering
Concurrent Engineering (CE) evolved prior to the Second World War where new manufactured products were being developed on accelerated programmes [Salamone 1995]. These products were designed by multi-functional teams, including participants from design, marketing, process design and manufacturing.

The Second World War brought about new methods of design and manufacture due to the great need to increase production and develop products quickly and with continual high quality that meet the customer's needs. The post-war manufacturing industry retained the customer focus for products but gradually the large companies evolved into large bureaucracies as demand exceeded supply, product development started to suffer, and the design process reverted to a series of sequential operations. The process retained its strong functional identity without considering the consequences of the individual actions. This led to organisations having an "over the wall" approach to product development as shown in Figure 2.4 overleaf.
The diagram clearly shows the client expectations; however, once the product development team has individually developed their part of the product the final product does not meet with the clients requirements. In this case only the marketing department have direct access to the client and each individual group compromises the product without reference to the original concept. Having completed their own part of the product development they pass their individual product onto the next department.

With increasing competition from emerging Far-East countries in the 1960s and 70s, manufacturing industry in the US and UK needed to change their business philosophy to survive. Also with the development in improved communication technology during the later years of the 1980s and through the 1990s, it was recognised that the market place was fast becoming globally orientated with
customers who were sophisticated but also fragmented in location. Also product development teams were equally being located upon distant shores where resources were cheaper.

Many key manufacturing companies adopted CE as a way forward to ensure that their products gained competitive advantage by being first to the market place. This required substantial re-engineering of their organisations with personnel becoming "product focused" and with all parties including the customers being integral to the product development process. The resulting process is shown below in Figure 2.5 for a team focused on the final product.

![THE DIFFERENCE](image)

Fig. 2.5 – Product Focused Team Approach
The picture shows common access to the client so that all parts of the team have access to the requirements of the product at the same time. The development team can then clearly all focus on delivering the requirements with the client advising on the direction to take where problems occur. Each team member is focused on the final product and not their own individual aspect.

2.3.2 Principles of Concurrent Engineering

In addition to the achievement of concurrency in the process outlined above Prasad [1996] identifies seven key principles to be adopted by a team in a concurrently engineered project. These are:

- Parallel Work groups
- Parallel Product Decomposition
- Concurrent Resource Scheduling
- Concurrent Processing of Tasks
- The minimisation of Interfaces
- Transparent Communications
- Quick Processing

CE is defined as a systematic approach to the integrated, concurrent design of products and their related processes including manufacture and support. This approach is intended to cause developers from the outset to consider all elements of the product life-cycle from concept through to disposal, including quality, cost, schedule and user requirements [Winner et al 1988]. The benefits in the adoption of CE are well publicised [Backhouse & Brooke 1996, Prasad 1996, Salamone 1995, Winner et al 1988] and include:

- A reduction in timescale of the product development process.
- Increased collaboration between companies and especially suppliers at the early stages of a project.
- Increased customer focus.
A reduction in re-work caused by poor communication and misunderstanding.

Increased capacity of output from all parties involved in the process.

The seven key CE principles [Prasad 1996] are described below:

- **Parallel Workgroups** – this describes the ‘time overlap’ of either work groups or activities where each group within a multi-functional team brings their specialised knowledge to the project. In manufacturing these teams are known as the ‘Product Development Teams’ who work alongside each other on different products.

- **Parallel Product Decomposition** – this principle views the product realisation process as a part of the total life-cycle of the product and then overlaps the parts of the process to recreate the whole. If a decomposed activity is dependent on others, then it is likely to be a sequential operation, therefore the length of the overlap between activities is directly related to their dependency. Interdependent tasks usually take longer to complete due to the transfer of information between parties.

- **Concurrent Resource Scheduling** – this involves scheduling the decomposed activities allowing them to be performed in parallel. Once the activities are scheduled and inter-relationships are identified, it is possible, by using techniques such as optimal scheduling, IDEF0 backward scheduling and team-based project management, to set up milestones and plan the product and process development routes. With resources such as teams, task and time a work breakdown structure (WBS) can then be defined.

- **Concurrent Processing of Tasks** – Whilst the key to any project is to manage time effectively, in CE this means that routing and queuing of activities are
optimised in terms of group distribution and information build up. In CE activities are staggered rather than carried out sequentially.

- **Minimising Interfaces** – during a CE based project, it is essential that interfaces are minimised. Interfaces increase the time taken to share information, respond and develop the design manufacturing. There are three major areas where interfaces need to be minimised these are:
  - Product Interfaces;
  - Process Interfaces;
  - Computer Interfaces;

- **Transparent Communication** – this is where the critical information is identified and it is ensured that participants receive it at the allotted time.

- **Quick processing** – This principle assessed the completion of individual activities as fast as possible using tools or design aids.

Prasad [1996] suggests that approximately 80% of a product's development costs are made by decisions achieved in the first 20% of effort. This supports the graph shown in fig 2.3 for the construction industry. Prasad [1996] identifies eight other goals and objectives that need to be met to enable CE to be fully adopted.

- Early Problem Discovery
- Early Decision Making
- Work Structuring
- Teamwork Affinity
- Knowledge Leverage
- Common Understanding
- Ownership and Constancy of Purpose
The goals and objectives are defined as follows [Prasad 1996]:

**Early Problem Discovery** – problems that are discovered early in the engineering process are much easier to solve than those discovered later. The impact to the overall process is therefore minimised and the solution in place before production expenditure is committed.

**Early Decision Making** – With earlier problem discovery the window of opportunity to resolve problems is much wider than those discovered once the design has been frozen and is matured. It is similarly expressed that early decisions need to be lasting throughout the development process; therefore each problem needs to be rigorously assessed.

**Work Structuring** – work is structured so that multiple tasks can be performed independently by resource teams or computers.

**Teamwork Affinity** – this ensures that individual disciplines, whilst producing an optimum design in their own field, will produce similar results for the combined team ensuring that the overall product design is optimised.

**Knowledge leverage** – this is where each individual party involved in a project uses their own product knowledge to improve the overall project and give added value to the client.

**Common Understanding** – teams work better when they have common goals and understandings of how each party achieves the individual parts.
Ownership – Teams work better towards the development of excellence where they have a shared ownership in the product and are empowered to make decisions that aid the development of the product.

Constancy of Purpose – Most individual business units have a natural tendency to make their own departments look good, even though this may be opposite to the overall goals for a specific product. It is important therefore within a corporate structure that all departments work towards a common set of goals ensuring constancy of purpose. This requires a change of thinking within individual groups.

These goals and objectives usually require a step change in the business methods of an organisation and are usually supported by a change in attitude by personnel within these organisations. External influences, such as profitability, level of business, etc., can also have a major impact on a business and heavily influence proposed company internal changes.

This could include the use of computer software, knowledge-based systems or databases, or by building flexibility into the design process to reduce the complexity of downstream activities.

The benefits of adopting the CE principles can be measured in terms of reductions in timescale and therefore cost with a similar improvement in product quality. The next section reviews how CE could be adopted in construction to bring about the changes required to improve the industry.
2.4 Adoption of Concurrent Engineering in Construction

The adoption of CE in the construction industry can be represented in hierarchical format comprising goals, objectives, strategies, tools and techniques for construction with each subsequent level supporting the higher levels.

The high level goals for a product-focused project team should be:

- A fully satisfied customer
- A competitive business

For a single investment these goals are achieved through objectives such as achieving a product on time, on cost and with the requisite product quality. A multi-project environment, however, would (over time) expect a reduction in relative time and cost with a corresponding increase in product quality. To achieve these objectives strategies such as integrated multi-disciplinary teams, early consideration of life cycle issues, etc, could be used facilitated by CE tools and suitable techniques such as CAD and Quality Function Deployment (QFD).

2.4.1 Conceptual Framework for CE in Construction

A conceptual framework for the implementation of CE in construction is illustrated in fig 6.3. It is based on the Concurrent life-cycle design and Construction (CLDC) model [Evbuomwan & Anumba 1996] which was designed to facilitate the integration of all parties involved in a project. It comprises, in a similar manner to a CE framework, different levels of design stages, tools and techniques and finally databases. Procurement, although not a specific single stage, occurs throughout the design and construction stages of a project.

The framework shows six specific stages from client requirements processing through to Construction Planning. Design for life-cycle costing is included as a
design tool or technique based upon knowledge bases such as codes of practice and standards, construction process database.

The stages are developed into a new design and build process model [Evbuomwan & Anumba 1995] and shown below in Figure 2.6

![Figure 2.6 Concurrent Life-Cycle and Construction Model](Evbuomwan & Anumba 1995)

2.4.2 Adoption of CE principles
The adoption of the CE principles identified in section 2.3.2 and those of Prasad [1996] has the potential to improve the construction process. Egan [1998] frequently discusses teamwork, Common Understanding, ownership, constancy of purpose, which the lack of in construction projects cause many of the problems associated with the industry.
With the adoption of the key principles such as parallel workgroups, parallel product decomposition, concurrent task processing and resource scheduling the focus of the product development team will change to achieving the final product rather than the individual products of each party.

2.5 Procurement in Construction

When looking at the current status of procurement, many forms are used to implement the design work associated with a project. However, contract strategy is frequently decided once the outline of a project is already established and in some cases after a design is complete. This tends to result in inadequate consideration of detailed issues until they occur; this can impact on the costs and programme of the works.

In the model identified by Evbuomwan & Anumba [1996] it is important that procurement is considered across all stages starting with setting the strategy during the briefing stages and only being complete at the handover stage. Each of the contracting parties should be included at the earliest point in the programme. This is in line with CE principles and also supports Egan [1998] in the view that the product team should be integrated. However, clients in adopting this approach may feel that the competitive edge is lost and may question whether the product purchased represents value for money. The new model will aim to retain the competitive edge of other procurement methods.

If the strategy is developed at an early stage and an open book policy is adopted during negotiations these areas of concern would be mitigated.
2.6 Summary

The chapter has shown how CE has developed in the manufacturing industry and the benefits associated with the adoption of the method. The chapter has shown some of the difficulties facing the construction industry in the UK. The aims and principles of CE are detailed as defined by Prasad [1996] and the chapter shows the potential that exists for the construction industry if the principles are adopted. The chapter concludes that a new method of construction project procurement should be developed using CE principles to utilise the benefits of a product focused team approach to the development of projects. This is seen as offering a potential saving in terms of cost and programme and offers a way of meeting targets for improvement as identified by Egan [1998].

The following chapters seek to confirm these views by reviewing in depth the differing types of project procurement in common use today. The views of the industry are then represented in Chapter Four where a survey was undertaken to highlight concerns from industry participants.
CHAPTER THREE

CONSTRUCTION PROCUREMENT METHODS

3.1 Introduction
This chapter describes the different methods of project procurement that are utilised in the UK construction industry by clients to develop new assets. Procurement methods in manufacturing are also discussed and the limitations of existing construction procurement methods from a Concurrent Engineering (CE) perspective are outlined.

3.2 Current Methods of Procurement
There are many methods by which clients procure new assets, some are simple requisitions set against a drawing or a performance specification, whereas others involve complex bidding and review procedures to determine the most cost effective contractor. The methods most frequently adopted by the industry are as follows:

- Traditional
- Design and Build
- Construction Management
- Partnering
- PFI or Build Own Operation Transfer (BOOT)
- Prime Contracting
- Long Term Negotiated Contracts
Each method has its own benefits and drawbacks depending on the quality of information available at contract award, confidence in cost estimate, risks associated with project and the timescale available for bidding, design and construction. With each construction project there are a minimum of four parties directly involved with the process. These are the Client, Design Consultants, Contractor and Material Suppliers, each party having a different level of involvement and at different stages in the process. The following pages describe each method of procurement, including the contractual relationships, personnel involved, advantages and disadvantages.

3.2.1 Traditional
This method was developed after the industrial revolution from “separate trade contracting” [Smith 1995]. In this method, the client usually has two separate contracts, the first with a consultant to carry out the design work for the facility and the second is with a main contractor to convert the design into the facility on site [Smith 1995]. The main contractor in turn lets sub-contracts for material suppliers and specialist work in which the company has little expertise. Other members of the team could include geotechnical consultants, environmental consultants and quantity surveyors depending on the scope and extent of the works.

The consultant’s team is frequently led by an architect [Smith 1995] and sometimes by the lead engineering discipline or alternatively an independent project manager. The design team will include architects, civil and structural engineers and services engineers and, whilst the project manager will be involved throughout the process, other members of the team may have a short involvement dependent upon the project programme. The consultant’s team usually prepares the contract documents to allow competitive tenders to be received from a number of contractors.
The contract documents usually prepared by the consultant and issued on behalf of the client, include specifications, form of contract, scope of work, terms and conditions, outline programme with the commercial offer taking the form of a fixed price and being measured as a lump sum, bill of quantities or schedule of rates. With a lump sum the contractor has to measure the quantities detailed in the design and take the quantity risk, whereas with a bill of quantities the quantities are usually prepared by a quantity surveyor for pricing and the quantity risk is transferred to the client.

The construction team would usually include in-house labour resources that are already part of the contractor’s team which are complemented by specialist sub-contractors (e.g. concrete supplier or piling sub-contractor). Some of the larger UK contractors have these resources in-house as separate divisions and, on major projects, concrete is frequently mixed on site.

For a typical traditional contract the contractual relationships are shown graphically below [Pilcher 1992, Smith 1995]

```
CLIENT

CONSULTANT
(Design Team)

CONTRACTOR
(Construction Team)

SPECIALIST SUB-CONTRACTORS
```

Fig 3.1 Contract Relationships – Traditional Procurement

[Pilcher 1992, Smith 1995]
Responsibilities are clear with the design consultant being responsible for the design output and the contractor responsible for the construction work. However, there can be frequent discussion between the different parties especially where programme and delivery of design is concerned and the interfaces between the three key parties. Once the client confirms the contracts, the respective design and construction activities are performed by the respective parties independently and in a sequential manner. An outline flow chart of the process is detailed on the following page with the respective timing of involvement for the different parties.
**Process**

- **Concept Design**
  - Greater than original Budget
- **Estimate**
  - Meets Original Budget
- **Detailed Design**
- **Preparation of Tender Documents**
  - Greater than original budget
- **Issue Tender Documents**
- **Prepare Tender Bid**
  - Review Bid
  - Meets original budget
- **Appoint Main Contractor**
- **Appoint Suppliers And Specialists**
- **Build Facility**
- **Handover**

**Key Actors**

- Client / Design Team
- Client
- Design Team
- Client / Design Team
- Design Team
- Contractor
- Client
- Client
- Main Contractor
- Contractor/Suppliers & Sub-contractors
- Client/Contractor

Fig 3.2 – Flow Chart – Traditional Procurement
The benefits of the traditional approach are well documented [Pilcher 1992, Rowlinson 1999] and include:-

- Competitive Pricing
- High quality
- Clear lines of accountability
- High quality of end product
- Sharing of Risks

Similarly the disadvantages are also well documented [Egan 1998, Latham 1994, Pilcher 1992, Rowlinson 1999, Smith 1995] and include:-

- Many organisational interfaces with independent contracts.
- Duration of project is long due to sequential process.
- Low level of buildability due to late involvement of contractors and material suppliers.
- Contractual relationships are frequently adversarial.

3.2.2 Design and Build

This method of project procurement was developed to give clients a single point of contact for both the design and construction. The contractual organisation for this method is shown in figure 3.3 below and allows the responsibility for all aspects of the project to be taken by a single company with a single contract between the client and the design and build contractor [Akintoye 1994, Pilcher 1992, Smith 1995, Rowlinson 1999].

The contractor receives the tender document in the same manner as the traditional method, but, it usually takes the form of a performance specification with site location drawings, material specifications and sometimes preferred configurations. The appointed consultant or in-house design team prepares an outline design which meets the client's requirements prior to the contractor estimating the work,
identifying timescales and submitting a firm price to the client. Frequently this occurs without reward for the individual contractor’s team as the tender lists can be up to seven or eight contractors with only one contractor being successful. This results in a large investment in engineering resource without any of the submitted schemes necessarily meeting the client’s requirements.

![Diagram of Contractual Relationship in Design and Build Procurement]

**Fig. 3.3 – Contractual Relationship in Design and Build Procurement**

[Pilcher 1992, Smith 1995]

The contractor will probably choose the most cost-effective scheme that enhances his/her own profitability. Once the main design and build contract is won, the successful consultant completes the detailed design based on the submitted scheme. A flowchart of the process is shown on the following page. Generally the initial process is carried out in a sequential manner with only the post-contract design work being carried out in parallel and overlapped with construction activities. This in turn puts pressure on the consultant to perform their duties in time to meet the overall programme.

One of the key benefits of this approach is that the client can review the contractors’ offers in terms of cost and technical approach; therefore, each
submission offers the client a variety of schemes to adopt as the final solution. Frequently during negotiations, the client utilises the best from each scheme and persuades the successful contractor to enhance their own scheme.

An extension of this method is the turnkey contract [Smith 1995], where a contractor provides the necessary design and construction works against a performance specification. Once the project is complete the client “turns the key” to operate the facility. This approach is extensively used in the process industry where the performance specification may be, for example, to produce X tonnes of product, Y MW of electricity or Z m$^3$ of gas. This method uses the expertise of the contractor in the respective fields, however the client remains remote and many problems are often caused by the interfaces between the new and existing facilities such as service supplies, land issues and delivery of the product. The contractor’s team is focused on the design and development of their specific product and efficiencies are made through on-going research and development into improving the product for a number of clients.
Fig. 3.4 – Outline Flow Chart for Design and Build Procurement

- Single point responsibility
- Design and construction teams are integrated
- Reduced project times can be achieved
- Competition is on price and end product

The disadvantages include [HM Treasury 1999, Rowlinson 1999, Smith 1995]

- Changes can be expensive
- Tender process is expensive
- Client’s quality control is minimised
- The process requires a detailed brief initially and a well documented procedure for the review of tenders

### 3.2.3 Management Contracting

This method of procurement was developed for situations where client organisations have limited design and construction experience and the client forms a contract with an independent management contractor to manage the project on his/her behalf. There are two discrete types that fall into the category of management contracting; these are management contracting and construction management [Bennet 1985, Pilcher 1992, Rowlinson 1999, Smith 1995].

In the management contracting approach, the main contractor is usually excluded from carrying out any of the design or construction work and takes on works contractors and sub-contractors to execute the project. The client usually has a separate contract with a consultant to design the works. The contractual relationships are somewhat similar to the traditional method as shown overleaf:
In the second method of management contracting, namely construction management, the Management Contractor provides an independent service of managing the site works. The client has a direct contractual relationship with the works contractor and design consultant [Pilcher 1992]. Under this contract the Management Contractor is delegated specific authorities and responsibilities. The contractual arrangement is shown below:

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Fig. 3.5 – Contractual Relationship in Management Contracting

[Pilcher 1992, Smith 1995]

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Fig. 3.6 – Contractual Relationships in Construction Management
One of the problems associated with this type of approach is the conflict that the management contractor faces by the lack of commercial responsibility for the project despite having to motivate and control costs and timescales for the delivery of the project on site. Secondly, because of the independence of contracts, responsibilities frequently fall between the many parties involved.

Usually, the management contractor is appointed at an early stage in the life-cycle of the project and becomes an integral member of the client’s team [Pilcher 1992]. The management contractor issues discrete work packages for individual aspects of the project. The construction process is outlined below and follows a similar sequential pattern to the traditional method of procurement.
Fig. 3.7 – Outline Flowchart for Management Contracting
The main benefits of management contracting include [Rowlinson 1999, Smith 1995]:

- Early construction start
- Shorter project timescales
- Flexibility for late changes
- Strong organisation
- High levels of buildability and competition for work packages

There are many drawbacks including [Rowlinson 1999, Smith 1995]:

- Additional project management costs.
- Final price of project unknown until final work package issued.
- Assignment of liability is complicated
- Increased risk for client.

3.2.4 Private Finance Initiative (PFI) or Build Own Operate Transfer (BOOT)

PFI is a method of procurement which is becoming increasingly popular in the UK especially for large infrastructure projects [Smith 1995]. This strategy was developed from turnkey contracting in the process industry where the contractor remains responsible for operations for a predefined period to prove the facility and to train operatives [Smith 1995]. The organisational structure for this type of contract is shown overleaf and involves all parties, from investors through to users, in the development of the facility.
The main concession contract is between the Principal client and the Promoter and can be made by either a speculative bid on behalf of the Promoter or invited bids on behalf of the principal. The promoter then becomes responsible for the whole project from financing to the construction and operation of a facility. The individual team members bring their skills together to develop and manage the facility over fixed concession period. Payments are usually made by the Principal or users over the same period. Separate contracts are arranged with the other team members to carry out their specific duties.

The advantages of this approach are:

- All Stakeholders involved
- Full life cycle aspects covered early
- Final costs & programme set at an early stage

The disadvantages are:

- Decision making slow process
- Responsibilities difficult to separate between companies.
- Inflexibility to change
Once selected there is little competition

3.2.5 Partnering

This is a management approach rather than a form of procurement, which is aimed at collaboration rather than confrontation. The approach can be used for all forms of procurement because it works on the basis that competition ends as soon as a bid is accepted and a contract signed [Bennett 1985, Crowley 1995, Duncombe 1997, Uher 1995]. The approach involves all stakeholders who can impact on the quality, programme or cost of a project. This includes clients, designers, contractors, suppliers and may extend to include outside agencies. The current use in construction is limited to small levels but it is becoming increasingly popular as a means to reduce project costs and programmes [Crowley 1995, Duncombe 1997, Uher 1995]. Partnering can be project specific but is generally based on a long term commitment or Framework Agreement, between two or more organisations in achieving common project objectives. It is important for the process to develop trust, commitment, interdependence, co-operation, communication and joint problem-solving whilst maintaining a focus on the final product.

The advantages of this approach are:

➢ Based on team approach & inter support rather than adversarial relationships.
➢ The strengths of each individual company are pooled for the common good of the project.
➢ Project costs and programmes are finalised at an early stage.
➢ High Levels of Buildability incorporated in design.
➢ Project timescales are minimized.

The disadvantages of this approach are:

➢ Difficult to adopt for single projects.
➢ Commercial competitiveness lost.
Liabilities difficult to identify

Initial innovation can be lost once participants become familiar with each other.

Client always looks for minimum cost rather than best value.

Increased organizational costs – contractor and consultants can face a risk of increased costs which they are unable to recover.

Little incentive to develop people

3.2.6 Prime Contracting

This process is a recent innovation following publications regarding the state of the construction industry and has been developed by the UK Treasury for use in public sector contracts. In this process, a Prime Contractor is appointed by a Client to be responsible for integrating the work of the construction supply chain [HM Treasury 1999(a), Holti et al 1999(a) – (c)]. The Prime Contractor is required to pre-qualify and then carry out a value analysis to determine the final users' needs. Once the needs are developed into a project brief, which the client approves, the Prime Contractor develops and costs the potential design solution. He/she then determines the best value option, develops the design and prepares a Guaranteed Minimum Price (GMP). This is agreed by all parties which includes provisions for the sharing of savings that are offered in the design development.

The GMP is refined once the detailed design and construction works are completed and handed back to the client.

At this stage the Prime Contractor monitors the operation of the facility and carries out any maintenance or remedial works. An outline flowchart of the process is shown in Fig 3.9.
The above process is not sufficiently detailed as development is taking place in conjunction with several trial projects. It is specifically designed for clients who have a long-term workload and can establish, manage and improve the quality of the finished construction product and its processes throughout the term of the contract. The use of the process is in its infancy, however the process has been trialled on several projects for the UK Government.
The findings have been published [Holti et al 1999(b) – (c)] and are summarised below in relation to the various phases of a project:

**Concept Phase**

- Designs have been produced which meet the functional specification to a high standard.
- Predicted life costs show approximately 10% savings.
- Prime Contractors have organised their supply clusters and have laid foundations for long term relationships with suppliers.
- A rigorous approach to Value Engineering has been adopted.
- The pilot projects have set up the systems to achieve further progress and improvement.
- Savings in capital cost have not been achieved; however, the foundations have been laid for future reductions.
- Existing practices within the industry have hampered the development of the process and need future improvement.

**Detailed Design, Preconstruction and Early Construction Phases**

In addition to the above findings the trial projects have found the following:-

- The Client’s brief was based upon an output or statement of requirements; this offered improved collaboration between Sponsors, Prime Contractors and Suppliers and has potential for the future.
- The design consultants were both project-based and supplier-based; it was found to be crucial that the division of labour be clearly identified alongside the clear identification of interfaces for each supplier.
- The Prime Contractor should set clear objectives and boundaries for suppliers.
- Prime Contractors need to be able to manage and integrate different kinds of design inputs.
Prime Contractors need to work with suppliers to manage costs based upon the on-site costs rather than previous experience of performance of lump sum contracts. Clearly the process appears to show an improvement in collaboration between the parties involved in a project, however the full benefits are still to be realised and will take a substantial investment in resources by all parties to improve the current situation.

3.3 Limitations of Current Methods

The limitations of the industry and the impact of current procurement methods have been widely publicised. Both Latham [1994] and Egan [1998] state that clients are dissatisfied with the products that are developed on their behalf. Egan summarises the concerns as follows:

- The industry as a whole is under-achieving with low profitability especially to sustain healthy development;
- Clients equate price with cost and do not differentiate between best value and lowest price;
- Projects are seen as unpredictable in terms of delivery;
- The industry is fragmented with over 163,000 construction companies in the UK.

Current methods of procurement have a major impact on the state of the industry by their approach to project delivery and in particular:

- Procurement occurs across the development process from briefing to construction;
- Determines the relationships between parties involved in the process;
- Risks are apportioned between the parties involved in the process;
- Contract terms are identified including payment, insurance, etc.
3.3.1 Traditional
This approach fails due to its many organisational interfaces with independent contracts which lead to fragmentation and confrontational contracts. The process is usually carried out in a sequential manner, therefore offering little opportunity for reducing timescales. With the late involvement of the contractor and material suppliers buildability issues are frequently ignored until it is too late.

3.3.2 Design and Build
This approach fails because the tender process is expensive therefore the product development team looks for the cheapest capital cost solution to allow them to win the project and frequently the client’s quality control is minimised and changes become expensive in terms of cost and programme delays.

3.3.3 Management Contracting
Similar to the traditional approach and in addition further interfaces and therefore costs are introduced with the final price being unknown until the final contract package is issued.

3.4 Procurement in a CE Framework
The concept of concurrent engineering can be represented by a hierarchy comprising goals, objectives, strategies, tools and techniques for construction. Working from the top down, the high level goals of members of any project team are:

1) A fully satisfied customer.
2) A competitive business.

For a single investment these goals are achieved through objectives such as achieving a product on time and on cost with the requisite product quality.
A multi-project environment, however, would over time expect a reduction in relative time and cost [HM Treasury 1999(a)] and an increase in the product quality. To achieve these objectives strategies such as integrated multi-disciplinary teams, early consideration of life cycle issues, etc., could be used facilitated by concurrent engineering tools and the adoption of techniques such as CAD and Quality Function Deployment. Other techniques such as Total Quality Management (TQM) have similar goals, their strategies look at changes within existing processes and aim to “Get it right first time” to achieve their goals.

3.4.1 Conceptual Framework for CE in Construction
A conceptual model for the implementation of concurrent engineering in construction is illustrated in Figure 2.6. It is based on the Concurrent Life-Cycle Design and Construction (CLDC) model [Evbuomwan & Anumba 1995, Kamara et al 1997] which was designed to facilitate the integration of all parties involved in a project. It comprises, in a similar manner to a CE framework, three levels of design stages, tools and techniques and finally databases. Procurement, although not a specific single stage, occurs throughout the design and construction stages of a project.

3.4.2 Requirements for Procurement in a CE framework
Procurement of the design and construction of a facility are at the core of any project. They constitute the interpretation and conversion of the Clients requirements into a finished product (the facility). Procurement in a CE framework, through the use of the previously reviewed principles, goals and objectives in Chapter Two, [Anumba & Evbuomwan 1997, Egan 1998, Kamara et al 1999, Prasad B 1996,] should facilitate the following requirements:

- Different parties to work concurrently with dependency being minimised.
The early consideration of all life-cycle issues impacting on the facility.
The integration of all parties at an early stage in the project.
Focus on the client’s requirements.
Continuous improvement in the product development process.
The minimisation of interfaces.
The minimisation of cost and timescale.
Continuous improvement in the product.
Paralleling of activities.
Transparent Communications.

This suggests that all parties involved in a project should focus on the final product (i.e. the facility) rather than the individual priorities of each party. To achieve concurrency requires the integration, at an early stage, of all parties involved in a project, from clients to suppliers. Procurement should therefore

- Allow companies to successfully carry out their business;
- Involve all parties and individuals producing something as part of the project;
- Agree targets for the achievement of cost, timescale and product quality;
- Maintain focus on the end product;
- Add value to all parties involved;
- Minimise tender costs;
- Maintain a competitive edge on price;

The focus on procurement in any project should therefore begin at the early stages of a project such as the requirements processing and not be complete until the final product is handed back to the client.

3.5 Applicability of Current Procurement Methods to a CE Environment
The requirements detailed in 3.4.2 for a CE procurement method are compared with current procurement methods in table 3.1 overleaf. Specific areas where
current procurement methods meet these CE requirements are then discussed. It is
evident that whilst many of the procurement methods meet some of the
requirements, none of the methods meets all of the requirements. The figures
quoted are based on a critical review and qualitative analysis of the features of
these procurement methods against the requirements of a CE environment.

Table 3.1 –Comparison of Existing Procurement Methods against the
Requirements of CE

<table>
<thead>
<tr>
<th>CE Requirement</th>
<th>Traditional</th>
<th>Design &amp; Build</th>
<th>Management Contracting</th>
<th>Partnering</th>
<th>PFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consideration of Life-Cycle issues</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Integration of all parties at early stages of project</td>
<td>0</td>
<td>M</td>
<td>0</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Focus on Client's Requirements</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Continuous Process Improvement</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Minimisation of Interfaces</td>
<td>0</td>
<td>L</td>
<td>0</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Minimisation of Capital Cost</td>
<td>L</td>
<td>0</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Minimisation of Timescale</td>
<td>0</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Continuous Product Improvement</td>
<td>0</td>
<td>L</td>
<td>0</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

Key  0 = None, L = Low (score 1), M= Medium (score 3), H= High (score 5)
3.5.1 Consideration of life-cycle issues

The only procurement method that allows for detailed consideration of life-cycle issues such as maintenance replacements and improvements is the Private Finance Initiative (PFI). This is due to the long-term concession contract and payment terms which are a key part of PFI [Smith 1995]. Team members need to take these issues into account to determine longer term costs and availability of the facility to perform its duty. Other procurement methods retain a specific defects liability period [Smith 1995] and therefore rely on the quality of the constructed works. Once the period is complete the client could incur substantial maintenance costs due to failure of the asset to perform to the expected standard.

3.5.2 Integration of all Parties

Partnering, prime contracting and PFI make an attempt to integrate all parties to a project. However, this frequently occurs after a design is completed and a contract to build is placed [Smith 1995, Rowlinson 1999]. This fails to capture the experience of a construction contractor in the design phase, as they only have to build what has already been designed. The design and build method integrates the design and construction teams at both the initial and final stages of design. However the client still remains remote from the team.

3.5.3 Focus on Client’s Requirements

Most procurement methods tend to focus on the delivery of the overall end project required. However, the methods tend to focus on providing a solution to the client rather than a detailed assessment of the problem or the client’s requirements. The requirements of detailed technical quality, cost and timescale are frequently overlooked with projects being delivered late, over budget and with poor workmanship. Furthermore, there are inadequate mechanisms to maintain
traceability of client requirements to design decisions and/or track them throughout the life-cycle of the facility/project.

The focus on the client’s requirements should start at the earliest stages and should be integrated throughout the project delivery process [Kamara et al. 1999].

3.5.4 Continuous Process Improvement

Currently there is little motivation for continuous improvement of the project delivery process in most methods of procurement. This is due to the individual nature of projects and each individual company having its own agenda within a project. The ownership of each part of a project is outside of a central organisation and relies on individual companies and their performance. For example, at the design stage the emphasis is placed on an economic design rather than improving the process of the construction stage.

3.5.5 Minimisation of Interfaces

Within any construction project there are four key groups of players; these are the client, designers, constructors and material suppliers. In most current procurement methods the interfaces are generally managed in an adversarial manner, as the disparate disciplines often represent different organisations who do not necessarily share the same goals. Design and Build, Partnering and PFI go some way towards minimising interfaces by integrating team members into a consortium with shared objectives.

3.5.6 Minimisation of Cost

All clients would like their project to be completed at the minimum cost. However, the construction industry is a risky business where uncertainties occur on a regular basis. To enable a client’s business to operate profitably it is important that both capital and maintenance costs can be accurately forecast and minimised. However, on the other hand a contractor requires to maximise his/her
own profitability to meet their own shareholders' needs; this can be frequently achieved through claims rather than operating in a more efficient manner. The current procurement methods only offer marginal incentives to contractors to minimise costs and maintain the quality of product. Partnering and PFI arrangements often have better built-in incentives than the other approaches.

3.5.7 Minimisation of Timescale

Current procurement methods only offer limited scope to reduce project timescales. The potential impact for earlier delivery is that a client can improve his/her own profitability as shown in Figure 2.2. A contractor gains little benefit by delivering the end product earlier and probably incurs an increased cost through ineffective working. Thus, in most procurement methods, it is not normally in the contractors' own interest to be early, as long as they meet the agreed handover date and do not suffer penalties for late delivery. With partnering arrangements, where there are agreed incentives for early completion, contractors will seek to deliver early. The same is true of PFI projects, as the project team can start to earn money once the facility is opened.

3.5.8 Continuous Product Improvement

Material suppliers frequently look to improve their product and therefore retain or improve their market share [Backhouse & Brooke 1996, Brooke et al. 1999]. Under most of the current procurement methods each party involved in a project concentrates on his/her own product (e.g. a designer produces the design, a contractor builds the product), each with their own concept of product quality and improvement. There are limited (if any) incentives to improve the quality of the final product along the stages in the product delivery process. Often the reverse occurs, as contractors try to make up for the low tender figures used to win a project. This is not normally a problem with PFI projects, as it is in the
consortium’s interest to produce a high quality product as they will be responsible for the long-term maintenance.

3.5.9 Concurrent Processing
This is a major aspect of CE [Prasad 1996] which involves paralleling the activities of work groups or tasks. Certain tasks are dependent; they rely on the completion of one task before starting the next. Alternatively, others are independent and do not rely on the outputs of other activities [Prasad 1996]. The aim of concurrent processing is to parallel activities and reduce the time overlap. Currently only the PFI, Partnering and Design and Build procurement methods, where the design and construction phases are procured from one organisation/consortium offer scope for some overlap. The other methods generally support the traditional sequential and “over the wall” approach.

It can be seen from the above that current procurement methods have a major impact on the success of a construction project. It is also evident that they do not adequately meet the requirements of a CE environment. What is required is a new procurement model that builds on the best features of the existing approaches in order to more fully support the implementation of concurrent engineering in construction.

The manufacturing industry in the UK and the US faced similar problems and issues during the late 1970’s and adopted CE to improve their profitability and how they develop new products.

3.6 Procurement in Manufacturing
The process of product development in manufacturing is different in construction as the product itself is different. Construction procurement is usually the supply of a single product to a specific client, using the harnessed resources of people,
materials and machines [Backhouse & Brooke 1996], the manufacturing industry is, in the main, a multi-unit supplier to a wide variety of clients. However the product development teams are very similar in both industries.

Both teams have assemblers (assembly line or construction contractor), there are suppliers (components or material suppliers). However in manufacturing the design team is usually integrated with the assemblers into one team; this only occurs in a number of construction procurement methods.

Typical examples of manufactured items include cars, IT products, fridges, cookers etc. In these cases the client is still remote from the process. However, their views are represented through the marketing department who are also part of the product development team and who obtain the end-users views through market research.

For manufacturing, in general, components are brought together from different areas and assembled at a dedicated production line. Some of the major components are produced within the same parent company as the assembler, whereas others are outsourced to companies whose expertise is in a particular field of components. This also mirrors, in many ways, the construction process where there are specialist sub-contractors such as piling, steelwork and concrete suppliers, etc., generally producing their products off site and assembling them at the assembly line which is the construction site.

However, the integrated approach for manufacturing in the UK and USA is a result of re-engineering their processes using Concurrent Engineering (CE) principles.
3.6.1 CE in Manufacturing
There are many examples in the manufacturing industry of companies having used CE to the benefit of their business. Generally the use of CE has been either in the development of a new product or the wholesale change of a company's business processes. At this stage two examples of changes are reviewed and the successes and limitations highlighted.

The first is at Ford Motor Company [Salamone 1995] where the company used CE to develop one of their new engines and realised potential savings in time and cost, together with improved product quality, this is followed by Chipcom [McNamara, 1994] who changed their total product development process. These examples and the key findings identify the synergy between the construction and manufacturing industries, it is clear that CE has had a substantial impact of the viability of the UK and USA manufacturing industry. This has led to an enhanced competitiveness, increased share of the market and improved profit margins for companies who have followed this route.

Several case studies of the successful implementation of CE are presented below and the processes of manufacturing and construction are compared to show the similarities and differences.

3.6.1.1 Ford Motor Company
The case study [Salamone 1995] relates to the development of two new engines complete with transmissions. One was developed using conventional engineering process (DOHC), the second (Zeta) developed using a CE process.

*Double Overhead Cam Engine (DOHC)*
In 1983 Ford had analysed their products and identified that the quality of their power train was not world class. A decision was made to replace their mid-size
range of engines (SOHC) with a double overhead cam and five speed gear-box. Assumptions were made regarding numbers, materials and design of the new product together with the location for manufacture.

At the time of manufacture the tool market was depressed and many of the component manufactures were trying to break into markets in Germany resulting in prices below 1977 prices. In 1984 orders were placed for prototype parts with delivery in September 1985. The orders were then held in May 1984 to review the manufacturing programmes. The first product from the line was due for completion in July 1987 and the critical point for a restart in the programme was November 1984. During this period the designers had modified the engine which led to a provisional increase in output in the production line. The suppliers were unable to proceed until January 1985 approximately two months late and in March 1985 production was switched to the UK. Despite this the tools were delivered on programme in November 1985.

The engine programme remained due to considerable efforts, however at the stage of prototype testing (March 1987) it was decided that problems with product quality would prevent the engines being available for sale. The solution took over a year to implement leaving a huge investment in resources (plant and people) idle.

A similar fate had befallen the transmission part of the power train where design parameters for the components meant that components were difficult to manufacture. Personal relationships between engineers and suppliers became strained with each adopting stand off positions leading to increased delays. The Zeta engine had a different approach when in 1983 Ford in Europe looked for the pre-sourcing of components for new designs of cylinder heads and blocks. This meant that sources for full volume production facilities had to be identified whilst
the design was a twinkle in a designer’s eye. The selected foundries were able to programme potential production schedules without either queuing or competitive tendering. This reduced the potential lead time by half and identified that similar changes in procurement could realise benefits in the provision of other components.

The European design office was designated “the centre of responsibility” with the potential manufacture taking place globally. The European engine manufacture department were similarly appointed responsible for the development of the production processes. The inaugural meeting for the production in 1986 brought together Ford and its component suppliers and identified the task force leader.

The key deliverables for the team were to develop an engine which was best in class in terms of quality, with a minimum production cost and investment and a production start date of mid-1991. The collaboration with suppliers before financial authorisation went against “the rules” and needed development of a new agreement.

The collaboration led to first hand experience of each party’s production facilities, which some of the personnel had never previously witnessed. The team still followed a traditional approach through the development stages but carried out tasks in collaboration. Communications were simple and a core team met regularly even though they were based in different locations. Reporting into the company’s management was minimised by the issue of the core team’s minutes of meeting.

The benefits of the Zeta engine was that potential cost reductions reached £6 million with further collaboration and the avoidance of changes that led to higher savings. The DOHC was late, missed the market opportunity and was overspent
by approximately £28 million with similar problems for suppliers leading to a total loss in profits of up to £60 million. In comparison the changes to the Zeta engine were less than 5% and the engine was delivered on programme.

The key findings for Ford were:

- Careful selection of team members at the earliest opportunity.
- Early participation of suppliers before the financial approval to proceed with the project.
- Focus on quality of product by validation of each component.
- Producers involved in prototyping to allow further process development.
- New processes validated at prototype stage.
- Team approach to product development
- Concurrent product and process design
- Sharing of information should be open
- Personal attitudes more important than pc hardware for communications.

*Chipcom*

In late 1991 Chipcom set about looking at improving its product development process. It faced limiting resources against a background of rapid growth. The team identified that the implementation of CE would affect the whole company and looked to build on their existing systems and procedures [McNamara 1994]. They adopted the term PACT - “Partnerships for Achieving Champion Teamwork” to best describe what they wanted to achieve.

The original product development process was a six phased process, the six stages being - Investigation, Definition, Design, Verification, Introduction and Production, which were carried out as sequential operations. At the end of each operation there was a review gateway to assess that the product still retained its focus on the original concept. A model framework was issued for all development
groups to maintain consistency within the business. The development team was multi-functional and was accountable for the delivery of the product.

The process was simple but fairly rigid and this was its downfall because there was a resistance to change even if the changes would improve the product. Individual responsibilities became clouded especially when crossing between the boundaries of different departments.

The reasons for change were the changing market place and Chipcom's desire to become a major player in their chosen market, SMARTHUB. This, in turn, required products to be brought to market within reduced timescales. The operation of the business meant that whilst growth was required, it was acknowledged that staff numbers would remain static. Therefore the company looked to CE to make its processes more efficient and at a meeting of key people in the organisation in 1991 identified 150 ideas about CE. These were grouped and the top five categories were:

- Time to Market
- Team Process
- Vision
- Respect
- Customer

The existing sequential operation was identified as one of the firm's major shortcomings. The team felt that the original process had served the business well and that many aspects could be re-used in a CE environment. The themes for development were:

- Ownership of the product;
- Dedication to the customer;
- Project Management skills;
- Team membership and leadership.
The use of the PACT process converted the original sequential six stage process into a three phase process with sequential and parallel activities. The new three phase process consisted of Investigation, Definition and Development. Stages one and two remained sequential with a review gateway at the end of each stage. The development stage had a number of sequential and parallel sub-activities.

The investigation stage consists of looking at internal business requirements and external customer requirements. The output at this stage is a plan which is presented to the corporate management team to gain approval and move to the definition stage. At the definition stage a business plan is developed which identifies the product and its related support effort. At the gateway at the end of this stage the corporate management team allocate the full funds for the development of the product until it is released to the market. The development stage comprises all the previous stages rolled into one with the activities performed in parallel.

A year after the adoption of CE, Chipcom were measuring the improvement in key areas such as Customer Satisfaction, People, Product Delivery and Financial Health and were at the stage where everybody within the organisation had recognised the improvement that CE could make to the business.

The lessons learnt from the two cases presented reinforce the need for the adoption of CE in any industry to be underpinned by an appropriate procurement process/method. These are being taken on board in the development of an appropriate model for construction (presented in the next chapter).

3.7 Proposed Procurement Method
Clearly the previous table and specific examples show that current construction procurement methods do not meet all of the needs of CE.
New methods such as Partnering [Bennett & Jayes 1998, Uher 1995], PFI [Cooper et al 1998] and Prime Contracting [HM Treasury 1999(d)] can enhance any of the traditional methods by increasing collaboration and involvement of parties within a project. The development of a suitable framework for procurement within a CE framework requires the consideration of the following aspects:

- Early involvement of all parties into a project allowing each to use their individual skills for the benefit of the facility [Prasad 1996, Anumba & Evbuomwan 1997, Kamara et al 1997]. Interfaces between parties should be minimised and should allow for concurrent processing [Prasad 1996, Anumba & Evbuomwan 1997].
- Focus on the client’s requirements as defined in the brief including key performance indicators in terms of cost, timescale and product quality [Anumba & Evbuomwan 1997, Kamara et al 1999].
- Life-cycle issues should be considered as part of the briefing of the project [Kamara et al 1999].
- Contract terms should benefit all parties especially where improvements in timescale, product quality and cost are required [Bennett & Jayes 1998, Uher 1995].
- Tasks should be broken down to their lowest level and the overlaps minimised so that tasks are completed in parallel [Prasad 1996].
- The framework should allow for the continuous improvement in both the process and the final product [Prasad 1996].

3.7.1 Methodology for procurement in a CE context

Procurement as a process starts at the briefing stage and is only completed once a constructed facility is complete [Kamara et al 1997]. Currently, whatever method is used the five key parts of procurement in construction are:
➢ Prepare Tender Package (Client and Advisors)
➢ Prepare Tender Offer (Contractor)
➢ Review Tender Offer (Client and Advisors).
➢ Design (Consultant)
➢ Construction (Contractor)

Amendments to the existing processes could be made so as to achieve savings in costs with improvements in quality. However, a step change in the philosophy of construction projects will serve to improve the final product.

The new methodology will use CE and be based broadly on manufacturing and housing methods of business. A preliminary outline, which will be used as the basis for the development of the new process is shown overleaf and will require a step change that a contract group or contractor identifies the need and becomes the initial client during the development phase.
The process would meet the needs of procurement in a CE Framework by

- All parties would be integrated at the earliest possible stage
- Focus on the client would be maintained.
- Interfaces would be removed and the remaining parties would be part of one organisation.
Life-cycle issues become important as they have an impact on the profitability of the final product.

Activity dependency will be minimised allowing a reduction in overall product development time.

Communications will be transparent as all parties will be part of the same organisation.

Continuous improvement in the product and process would be achieved through regular reviews and retained by the contractor, organisation or team.

Further work is now required to produce the key stages into individual tasks and activities that are based on high level goals and objectives. The activities will then be modelled using IDEF0 modelling techniques which show the inputs, outputs, controls and mechanisms of each task, allowing the process to be rationalised and the flow of information between parties to be routed such that delays are minimised. The new process is aimed at meeting the needs of a CE framework and achieving reductions in cost and timescale through the collaboration of all parties to a construction contract.

3.8 Summary

This chapter has identified the most common methods of procurement that are used in the UK construction industry. The contract relationships and outline flow charts for each of the methods are shown in the figures in this chapter. The potential benefits of adopting a procurement method using CE aims and principles are described and compared with the existing procurement methods. This clearly shows that there are benefits to be made by the adoption of CE and developing a new procurement model. Finally the requirements of a new model are outlined against a proposed flowchart for the new model.
CHAPTER FOUR

INDUSTRY PERSPECTIVES ON PROCUREMENT METHODS

4.1 Introduction
This chapter presents the information obtained from an industry survey that set out to establish the views from different perspectives of participants within the construction industry on procurement. It starts with an overview of research techniques outlining the strategy for this part of the work and the methods for ensuring that the data collection and interpretation are valid. It then gives the background to the survey including the design of the questionnaire. The chapter then reviews the results obtained, in particularly with regard to general questions, involvement of personnel, procurement selection criteria and the current level of satisfaction within the construction industry.

The industry survey was primarily aimed at obtaining knowledge of the problems from within the industry, specifically about existing procurement processes. Several methods were considered including case studies, interviews, common meetings and questionnaires.

4.2 Research Methods
This are many ways of determining and interpreting data [Saunders et al 1997], however, Helberg [1995] defines the core value of statistical methodology as “its ability to assist one in making inferences about a large group (a population) based on observations of a smaller subset of that group (a sample).”

Helberg [1995] goes on to state that “in order for this to work correctly a couple of things have to be true, namely the sample must be similar to the population and aspects of the measured variables must conform to assumptions underlying the
statistical procedures.” Graham [2000] also suggests that the information that is
gathered is influenced both by its environment and is a historical representation.
This section reviews the options for obtaining data and outlines the strategy for the
survey confirming how the survey was designed to ensure that the data obtained
was representative for the industry.

4.2.1 Survey Options
There are two key types of research namely quantitative or qualitative research.
The quantitative approach is based upon predictions of events on the basis of
research, whereas the qualitative approach encourages a broader interpretation of
the possibilities, assumptions and values that underline the work [Graham 2000].
Within each type there are several different methods available to obtain data.

Once the data is obtained the interpretations can be completed using either
deductive or inductive reasoning [Saunders et al 1997, Graham 2000]. Saunders et
al [1997] detail the major differences between the two approaches, although
deductive reasoning is generally used for the interpretation of quantitative data
whereas inductive reasoning is used for quantitative data.

Graham [2000] goes on to say that method selection should be based on what is
most likely to satisfy the research objectives rather than the best method available
and that the method is likely to be constrained by the available resources. Both
Graham [2000], Saunders et al. [1995], and Mays [2000] support the notion of
triangulation wherever possible in an attempt to reduce bias, increase validity and
reveal a more comprehensive picture.

Saunders et al [1995] suggest six research techniques are available, these are:

- Experiment
- Survey
4.2.1.1. Experiment
An experiment is a classical research method that is frequently used in sciences. It requires a selection of samples from known populations and assesses the measurement on a small number of variables by the introduction of planned change.

4.2.1.2. Survey
Surveys allow for the collection of a large amount of data using the minimum of resources, based usually on questionnaires, the data received is usually standardised. Saunders et al [1995] detail the attributes of a survey and questionnaire and the different methods of approach.

4.2.1.3. Case Study
This is defined as the “development of detailed, intensive knowledge about a single or small number of related cases” [Robson 1993]. It offers a method of determining greater reason for a particular result. The data collection is more intensive and combines several techniques such as survey, interview, etc.

4.2.1.4 Grounded Theory
This is used to build theories from a collection of data. The data leads to a generation of predictions that are tested in further observations [Saunders et al 1995].
4.2.1.5 Ethnography
This is used extensively in anthropology, the purpose being to interpret the social world of the sample inhabits in the way in which they interpret it [Saunders et al 1995].

4.2.1.6 Action Research
First used in 1946, it has three common themes, namely:
- The management of change
- Involvement between practitioners and researchers.
- Implications beyond the project.

Clearly some of the techniques are more appropriate than others, the proposed research strategy is discussed in section 4.2.5, where the study timetable and resource availability are discussed further culminating in the selection of a strategy that meets the needs of the data collection required.

4.2.2 Bias
Miles and Huberman [1994] describe bias as “seeing what we want to see, misperception, mis-interpretation and making too much of ambiguous data.” Helberg [1995] suggests that two forms of bias exist, firstly representative sampling and secondly statistical assumptions. With the first form of bias it is imperative that the sample taken is representative of the target population. In terms of this study, the construction industry is the whole population; therefore, the sample should reflect the industry. The survey sample was taken from three different generic groups e.g. clients, consultants and contractors with similar numbers of groups and different sizes of organisation, so that a cross-section of groups across the industry that are involved in procurement were represented. The second form of bias relates to the statistical assumptions the data collection makes about the problem.
For example, requests for data may assume that the recipient has knowledge of the problems of the construction industry.

Graham [2000] suggests that "academic research is not necessarily negated by bias. However, the researcher must demonstrate awareness of the sources of bias, reduce it and account for the impact of that remaining. The bias and assumptions of this part of the research are dealt with in Section 4.2.6.

4.2.3 Sample set
As discussed in Section 4.2.2 it is important that the data set used for the research is reflective of the population, in this respect, the construction industry. The sample therefore was designed to cover the key organisations within the industry namely clients, consultants and contractors taking into account the various sizes of the organisations. The data set was to be equally split between the three groups as there is little evidence of the actual split between the groups within the industry. By the selection of this data set it was hoped that any bias from a data set perspective would be removed.

4.2.4 Reliability and Validity
Reliability of data can be confirmed by whether the same results will be obtained on different occasions. Threats to reliability can be in four different forms. These are [Robson 1993]:

- **Subject Error** – This could produce unreliable results by how recipients understand the data and how their individual circumstances and understanding are reflected in the data.

- **Subject Bias** – The responses from the sample could produce unreliable results depending upon the respondents' views and the held views of their employers. Therefore anonymity should be maintained.
- **Observer Error** – This could occur from the potential for different approaches to data collection. The data collection method needs to remain constant throughout the process.

- **Observer Bias** – This could occur by the interpretations of data by the researcher.

Validity is concerned with whether the findings are about what they appear to be about [Saunders et al 1995]. Robson [1993] details the threats to validity as:

- **History** – relates to the impact of timing of research
- **Testing** – relates to the potential to disadvantage respondents
- Instrumentation – relates to the impact caused by potential changes instructed between the collection of data from two samples.
- **Mortality** – refers to respondents dropping out of studies.
- Maturation – this relates again to the timing of the data collection and the impact of events.
- **Ambiguity about Casual Direction** – this relates to the interpretation of the cause of a result when there are differing variables.

These areas will be addressed in respect of the data collection in Sections 4.2.6 and 4.2.7 once the specific research strategy is selected.

### 4.2.5 Research Strategy

The key objectives of the research data collection were as follows:

- Confirm the issues previously identified by Latham [1994] and Egan [1998];
- Establish the involvement of generic groups in a project process from each organisation’s perspective;
- Confirm the type of procurement methods in common use by participants in the industry;
- Obtain a range of views across different organisations within the construction industry;
- Identify problem areas relating to procurement in the industry;
- Establish details pertaining to procurement in the industry in terms of timing and selection criteria.

From the methods detailed in Section 4.2 it is clear that many of these are not appropriate to this stage of data collection, for example:

- The observation of how the social world that the sample inhabits and the way they interpret it will not meet the aims of the research and would require substantial resources.
- Similarly the case study, whilst being technically appropriate, would require a substantial time to develop, interrogate and prepare results as compared with a survey. It would also not cover a wide spectrum of industry as a survey would.
- Grounded Theory - the proposed data collection would not form the basis of a theory, therefore this method is discounted.
- Experiments are also discounted as they are used for the introduction of planned change of one or more variables. Clearly, this is not part of the proposed use of the data collected.

In the light of the above a questionnaire survey was determined as the most appropriate strategy for the following reasons:

- It can reach a broad and random audience – the questionnaire could be sent to a list of respondents in various industry groups.
- It can be anonymous – this was felt to be important so that participants did not need to identify their organisations.
• Short impact for participants – the aim was to minimise disruption to the participants' daily routine. It was estimated that the questionnaire would take approximately 15-20 minutes to complete.

• Ease of review with questions being in a similar format therefore ensuring consistency of response.

• The questions could be structured to meet the objectives of the research.

• The data set would be representative of the industry.

• Saunders et al [1995] suggest a 30% return for anonymous postal questionnaires.

• The resources required to obtain data would be minimal in terms of time compared with other methods.

4.2.6 Removal of Bias
As discussed in Section 4.2.2, bias occurs in two areas. The first relates to the sample and it is assumed that the production of a questionnaire which was sent via the post to named organisations randomly chosen from the NCE's Consultant and Contractors file 1997, would ensure that this area of bias was removed.

The second area of bias related to the statistical assumptions: The key assumption is that the individuals who received the questionnaire had knowledge of the construction industry and that they were in a position to answer appropriately. This was overcome by addressing wherever possible the questionnaire to senior individuals within the companies selected.

4.2.7 Reliability and Validity of Data
With reference to the potential for errors in the questionnaire survey the following measures were adopted to minimise these:
The questionnaire was designed to be straightforward and refers to terms that are common to people working in the industry.

A spread of organisations was considered with equal status given to each. This would ensure that each group was equally represented.

In the letter sent to potential respondents, it was confirmed that any responses would be treated in a confidential manner.

As recommended by Helberg [1995], in order to ensure independence the results of the individual responses could be grouped wherever possible, this would also ensure that any peaks in information gathered were smoothed.

The data collected would be historical and it is acknowledged that any possible repeat of similar data may yield different results as the industry is undergoing a period of change. Therefore the study would be a snapshot of views across the industry.

The mechanism for data collection was consistent, using the questionnaire; interpretation was to be straightforward with charts being prepared from collected data.

The questionnaire was reviewed on several occasions during the development stage to ensure syntax was correct and for case of use.

The time for return was set at four weeks so as to minimise mortality.

A stamped addressed envelope was enclosed to facilitate returns.

The key focus for each questionnaire was:

- **Determine the value of work undertaken** – this was to assess the valuation of work and give a spread between large, medium and small projects and determine if the problems occurred at all levels.

- **Determine the involvement of the parties at each project stage** – this was to confirm when each party became involved and when they thought they should be involved.
• Performance Improvement – this area was intended to assess the project deliverables, especially the design and the constructed facility and to establish whether each party, including the client, felt that the client was satisfied with the end product.

It was imperative that a selection of views across all of the main parties to construction projects was obtained; otherwise the survey would not be representative of the industry.

Whilst the overall response rate to the questionnaire was disappointing at 16%, it was felt that this was typical of an anonymous questionnaire [Som, 1973]. However, because the respondents were chosen randomly the sample gave an overall broad representative view from the different parties. A summary of the responses is included in Section 4.4. The consensus view was that there is a level of dissatisfaction with current procurement methods and the involvement and performance of individual disciplines within the process.

4.3 Questionnaire methods
4.3.1 Survey methodology
A four-page questionnaire, in Appendix 1, was mailed to 300 companies involved in the construction industry. The selection was split equally between Clients, Consultants and Contractors. The selection of Consultants and Contractors was based upon a random selection from the 1998 Consultant’s and Contractor’s File published by the New Civil Engineer magazine. The questionnaires were accompanied with a letter, indicating the aim of the study with a time limit for replies. The level of return was 16% of the questionnaires issued, these were split between each group as shown in Table 4.1.
Table 4.1 – Respondents to Questionnaires

<table>
<thead>
<tr>
<th>Group</th>
<th>No Issued</th>
<th>Positive Returns</th>
<th>Negative Returns</th>
<th>Total Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Clients</td>
<td>100</td>
<td>9</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>Consultants</td>
<td>100</td>
<td>11</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Contractors</td>
<td>100</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>TOTALS</td>
<td>300</td>
<td>30</td>
<td>18</td>
<td>48</td>
</tr>
</tbody>
</table>

4.3.2. Questionnaire Design (Located in Appendix 1)

The questionnaires were designed to be similar for the three main groups involved in the construction process namely Clients, Consultants and Contractors, material suppliers were omitted at this stage, as they were considered remote from the main project process.

Each of the questionnaires were split into several key areas being:

Background Information – To determine the value of business, personnel and company involvement. This was to ensure that views from different parties and different levels within the industry were taken into account.

Project Process Models – This section was to determine the commonest methods of procurement in current use in the UK and assess the involvement of different parties at different stages and key activities of the project. The project model utilised for the process was that developed by Anumba & Evbuomwan[1997]. Each individual stage was assessed to determine key criteria from each party
involved with construction and the roles and responsibilities of personnel at the detailed design stage.

Key data about construction planning was also determined especially in respect of contractor selection, the numbers pre-selected and the time taken in reviewing tenders. Key criteria were established to determine the basis of selection.

**Performance & Improvement** – This section was to determine the extent of the delivery of projects and individual aspects to pre-determined client requirements and to determine the areas where improvements in the project procurement process could be made.

The design of each questionnaire was similar using various methods of ranking responses to the questions. These varied from a simple ranking in order of preference through tick boxes and score charts to specific questions that required a specific response.

### 4.4 Findings

The findings from the report are presented here and are separated into several sections in line with the various sections of the questionnaire

#### 4.4.1 Background Information on the Respondents

In each category companies were selected that had a spread of workload, capital programme and numbers of personnel. The respondents in the Client's group represented an annual capital spend in 1997 of £1500 million and included both public and private companies.

The respondents in the Consultant's group represented an annual turnover of £280 million with a spread of projects between £1 million and £50 million. These
projects were carried out with 1100 people in numbers varying between 5 and 550 in these organisations. This gave an average turnover of £255k per person employed.

The respondents in the Contractor's group represented an annual turnover of £4200 million with a spread of projects between £1 million and £50 million. These projects were carried out with 12,000 people in numbers varying between 5 and 5000 in these organisations. This gave an average turnover of £350k per person employed.

Overall the figures for turnover per person employed is within 10% of the 1998 turnover figure of £58 billion for the industry [Egan 1998]

4.4.2 Project Procurement Methods

The different companies in the construction industry operate several methods of project procurement. The graded scoring system shows the relative use of each method by each group and is shown in fig 4.1 below.
This figure shows that the Traditional procurement route is still the preferred method (40%) for all of the groups, with the Design and Build method representing the second most common method (20%). The third most common method varies depending on the group. Clients and Consultants favour the long-term partnership whereas Contractors prefer Management Contracting. The more recent method of Design, Build Finance and Operate (5%) represents a low but increasing proportion of projects. The figures for Design and Build are similar to those quoted by Akintoye's study (Akintoye, 1994).

4.4.3 Involvement of Key Personnel in Projects
There are several key appointments in the life-cycle of a project, these start with the Client who maintains full responsibility for the project, but contracts other parties to be responsible for the design and construction. In the traditional method of procurement the Consultant is usually appointed to carry out the detailed design and the Contractor appointed separately to convert the design into a tangible asset. There are many models adopted for the procurement of projects [Pilcher 1992, Smith 1995], the key stages identified as part of any of these models were based on a traditional approach with design preceding construction.

Stage 1 Requirements Definition
Stage 2 Preliminary/Conceptual Design
Stage 3 Analysis and Detailed Design
Stage 4 Design/Tender Documentation
Stage 5 Construction Planning
Stage 6 Construction
Each of the generic groups was asked to quantify the involvement of when the key generic groups of people become involved so as to establish a perspective of the procurement process from different viewpoints. The views of different groups about the client's involvement were reasonably consistent throughout the process and are shown in Fig. 4.2 below. For Figs 4.2 through to 4.8 these have been developed from the responses to the questionnaires. Each of the individual groups, clients, consultants and contractors were asked to indicate the involvement of each group in the individual project stages.

Each of the responses were then scored, with A equalling 0 points, B equalling 3 points and C equalling 5 points. The scores were then converted into percentages with 100% representing the total involvement throughout the process. Each individual response within a generic group was then combined, in order to remove peaks, to give an overall percentage for each group.

For example take the client's view of the client involvement shown in red in Fig 4.2, each generic group has a view of a clients involvement. The responses from all of the clients are combined and averaged to give percentages as follows:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25%</td>
</tr>
<tr>
<td>2</td>
<td>23%</td>
</tr>
<tr>
<td>3</td>
<td>14%</td>
</tr>
<tr>
<td>4</td>
<td>15%</td>
</tr>
<tr>
<td>5</td>
<td>12%</td>
</tr>
<tr>
<td>6</td>
<td>11%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
</tr>
</tbody>
</table>

The 25% at stage 1 represents the average % scored by all of the clients who responded to the question.
The addition of the % at each stage gives a total project involvement in each case of 100%.

![Involvement of Key Personnel in Project Stages](image)

**Fig. 4.2 Client's Involvement in Project Stages**

In all cases the view was that the client's main contribution is at the front end of a project, reducing through the detailed design and construction planning stages. The contractor's view is that the Client's involvement should be much greater at stage 1 and subsequently reduced through the tender documentation and construction planning stages. In all other cases the parties' view of the client's involvement all fall within a 3% spread.

The Consultants involvement through the construction process is shown in figures 4.3 – 4.7 and is separated into disciplines. The involvement of a project manager is shown in Fig 4.3 and as expected the project manager has a constant involvement at each stage, with the mean value of approximately 17% at each stage and a range about the mean of ± 2.5%. The greatest differences are at stages 2 and 6 where the Client and Contractor's views differ by about 5%. 
Fig. 4.3 - Project Managers Involvement at Project Stages

The bar charts showing the involvement of the architect, structural and services engineers are similar and show their involvement concentrated at stages 3 and 4. The architect in Fig. 4.4 however, is shown to spend more time at stages 1 and 2 than the other disciplines, whereas the engineers in Fig. 4.5 & 4.6 are shown to spend more time during stages 5 and 6 than the Architect. The greatest difference between different group's views in the Architect's bar chart occurs at stages 1, 2 and 6 where the differences are between 5 and 10%. At stage 1 the Consultants group believe the Architects have a greater involvement, compared with the contractor and client who believe the Architect's greatest involvement is at stages 2 and 3 respectively.
The greatest differences shown in Fig 4.5, the Structural Engineer's graph of involvement occurs at stages 1 and 5 where the Client's view is reversed. The clients believe that the structural Engineer has little involvement at such an early stage whereas they believe that the structural engineer has a greater involvement at stage 5, the construction planning.
The views about the Services Engineer are consistent across all parties and show the peak activity during stages 3 and 4. A major difference of opinion is shown to occur between the client and the contractor. The contractors group believe that the services engineer should have a greater involvement at stage 1 Requirements Definition and a lesser involvement at stage 5 Construction Planning. The two bar charts for engineers show a similar pattern at each individual stage.

Fig. 4.6 Services Engineer’s Involvement at Project Stages

The different views about the Quantity Surveyor (QS) show several inconsistencies. All views show a peak at stages 4 and 6, which are the Tender Documentation, and Construction stages, which would be expected. The split between the different groups however shows a big difference especially at stages 3 and 5. The clients and consultants groups show the QS to be involved a lot more at stage 5 than the contractors. Also the clients and contractors groups show the
QS involvement at stage 3 much greater than the consultants group. The view of the QS involvement at Stage 6 varies by about 5% between the three groups.

![Involvement of Key Personnel in Project Stages](image)

Fig. 4.7 Quantity Surveyor's Involvement at Project Stages

The involvement of the contractor shows their key stages are 5 and 6, with very little time spent at the earlier stages, indeed clients did not expect a contractor to become involved until stage 3. The contractors believe that they have a much greater involvement at stages 1 and 2, and that perhaps they have greater experience to offer at the earlier stages. This view is supported by the response to later questions where respondents were asked if they felt that the contractor should be involved earlier. The responses show that contractors, clients and consultants share the same view, that contractors should be involved earlier in the process.
4.4.4 Key Activities During Each Project Stage

The key early stage activities of a project were assessed to determine when these activities actually occurred. The results are shown in Fig 4.9 and correspond to four activities namely, Monies sanctioned, Procurement strategy chosen, Requirements frozen and Design frozen. The graph shows that on many occasions the activities still occur at late stages during a project. For example in many cases the design is not frozen until construction has started, with the corresponding difficulties with late design changes.
Fig 4.9 Occurrence of Key Activities in the Project Process

The graph shows the typical S shaped curve for Construction projects. The average cumulative percentage of design completion is shown in figure 4.10, which shows that nearly 85% of design is completed by stage 4 in the project process. However this still leaves 15% of design to be completed whilst construction has started on site. Whilst it is likely that design being prepared at this stage is probably due for construction at a later stage it still leaves some difficulties if programmes are advanced or site problems occur. It also shows that potential design problems could still occur which could have an impact on early construction activities such as piling, groundwork’s, etc.
4.4.5 Selection of Schemes and Contractors

The method of selection of both potential design schemes and contractors was considered to be a key area with the potential for savings and development. The intention here was to assess the involvement of key personnel in strategic decisions and the key criteria for the selection of a contractor.

For the selection of design schemes at the Conceptional Design stage the decision was generally taken by a team activity (72.5%). The criteria for the selection of the preferred design option varied. The two areas that were consistently higher than others were cost and functionality, which achieved over 80% of the maximum score from both Client and Consultant. The nearest criteria for the design option were location and size, as identified by consultants (79%). All of the other criteria received less than 60% of the maximum available mark.
At the Contractor selection stage the selection criteria were the typical key performance requirements of any tender package. The most consistently high criterion for selection shown in Fig 4.11 was cost at over 95% of the maximum score, which was reasonably consistent across all categories of respondents. The second highest criterion was technical submission, which scored over 60% with the Client and Contractor respondents but only 35% from the consultants. All other criteria achieved less than 50% of the maximum possible score. This is shown in Fig.4.11.

The potential for savings around the tender process is clearly shown when asked about timescale for tenders to be prepared, submitted and analysed. Fig. 4.12 shows the number of tenderers plotted against the number of occurrences. For the contractor the figure represents an estimation of the basis for the number of jobs won, e.g. 1 in 3. The most common number in all cases is 5 tenderers. The
timescales for tenders are shown in figs 4.13 and 4.14 respectively. The contractors group show a greater spread of numbers of tenderers with some contractors being 1 of 7 and others negotiating directly with the client.

![No. of Contractors Invited to Tender](image)

Fig.4.12 – Frequency of Number of Contractors Invited for Tender

The most common timescales for tenders to be returned are 3 weeks from the consultants' and contractors viewpoints whereas the client shows that either 4 or 5 weeks is the most common. The contractor also frequently expects either 5 or greater than 8 weeks. Clearly this will be dependent upon the scale of the project and the quality of the tender documentation.

During the tendering process all of the contractors who replied said that they offered alternative technical solutions to the design in the tender documents received. The contractor's average tender costs during this part of the construction process represent 1% of the tender value. Assuming their turnover is received
from winning construction work then this represents an internal cost of £42 million on an annual turnover of £4200 million.

Fig. 4.13 – Frequency of Weeks allowed for Tender

Opinion on the most common period of time allowed for the valuation of tenders varied with all parties. The most common for clients was 4 weeks, whereas consultants and contractors said it was typically 1 and 3 weeks respectively. The range of figures are also important, with the clients’ varied between 1 and 5 weeks whereas the consultants’ and contractors’ varied between 1-8 in both cases.

4.4.6 Overlap of Project Stages

The questions in this section were designed to determine the level of overlap between the separate stages in the project procurement process. The questions were constructed around the stages up to construction and assessed whether the stages overlapped or were fully integrated, and determine if the process was stepped between stages. The data clearly shows that stages overlap, the level of overlap varying between minor and fully integrated.
On average this would give an overall length of the tender process of seven weeks between the issue of documents and first discussion with contractors, prior to any further negotiating and an order being placed. There was a substantial difference of opinion about re-submission of prices after initial negotiations, where generally the client and consultant, did not allow re-submission, whereas the contractors’ view was that in 90% of cases they were allowed to re-submit prices.

4.4.6 Overlap of Project Stages

The questions in this section were designed to determine the level of overlap between the separate stages in the project procurement process. The questions were concentrated around the stages up to construction and assessed whether the stages overlapped or were fully integrated, and determine if the process was stopped between stages. The data clearly shows that stages overlap, the level of overlap varying between minor and fully integrated.
Table 4.2 – Overlap between Project Stages

<table>
<thead>
<tr>
<th>Stages</th>
<th>Client</th>
<th>Consultant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>Major Overlap</td>
<td>Minor/Major Overlap</td>
</tr>
<tr>
<td>2/3</td>
<td>Minor/Major Overlap</td>
<td>Minor/Major Overlap</td>
</tr>
<tr>
<td>3/4</td>
<td>Major/Fully Integrated</td>
<td>Major/Fully Integrated</td>
</tr>
</tbody>
</table>

4.4.7 Level of Satisfaction with Current Project Processes

The level of satisfaction with the current project processes was assessed numerically and averaged for each group. This is presented in Fig. 4.15; the higher the figure the greater the level of dissatisfaction. The client group was reasonably satisfied except in assessing constructability and consideration of life-cycle issues.

The consultants group were not as satisfied as the clients and the key areas of dissatisfaction were briefing, overall procurement process, cost control and consideration of life-cycle issues. There was a large difference between them and the clients in the area of client involvement. This was also mirrored between the contractors and the clients.

The contractors were the least satisfied group with the current procurement processes and in all aspects were less than satisfied. The areas with the potential for improvement were the level of choice to client, level of client involvement, communications with the project team, overall procurement process, constructability considerations, compliance with clients needs and safety provisions.
The questions asked were to what extent are you satisfied with the following aspects of the project procurement process. They were scored as 1=Highly satisfied, 5 Highly unsatisfied. The areas were as follows:

1. Briefing/Requirements Definition
2. Level of Choice available to the client
3. Level of Client Involvement
4. Communications within the Project Team
5. Level of collaboration between team members
6. Overall Procurement Process
7. Constructability Considerations
8. Time/Achievement of Targets
9. Achievement of Required Quality
10. Cost Control/Achievement of Target
11. Consideration of life-Cycle issues
12. Compliance with Client’s Needs
13. Safety Provisions/Considerations
These findings were also supported with the responses to the questions when asked if the contractor should be involved earlier and if the client should be involved beyond the Client requirements specification stage.

Key performance indicators for projects are also included in respect of time and cost data. The responses are shown in table 4.3 which clearly shows the potential for improvements to be made. The further time period from the start of the project the clearer the definition and the smaller the tolerance on project costs, hence the increase in % of projects on cost.
Table 4.3 - Satisfaction with Key Project Deliverables

<table>
<thead>
<tr>
<th>Do you think contractor should be involved earlier</th>
<th>Client</th>
<th>Consultants</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Projects on time</td>
<td>75% / 25%</td>
<td>72% / 28%</td>
<td>90% / 10%</td>
</tr>
<tr>
<td>% Projects on cost</td>
<td>69%</td>
<td>81%</td>
<td>79%</td>
</tr>
</tbody>
</table>

4.5 Discussion

The discussion is split into the three areas, namely people, process and selection criteria and where potential changes and improvements can be made to the procurement of construction projects. The reason for this selection is that the three areas that can potentially offer some improvement to the industry and were related to concerns expressed by Egan [1998], Latham [1994] and shown to be key factors in the industry survey.

The survey as one of the key aims set out to determine the extent and timing of the involvement of people. The selection of process was to cover the potential to identify current processes in use and to determine performance improvements. The final area of selection criteria encompasses procurement and the actual criteria used in selection and also the process of procurement in terms of time and resources used in the process. These are reflected in the findings of the survey as highlighted in the previous sections and are related to people, the construction procurement process and selection criteria for schemes and contractors.
4.5.1 People

The involvement of the key people within the project process varied between groups and across disciplines. The survey showed that the client is currently involved throughout the project although all parties agree that their efforts are clearly concentrated at stages one and two. The contractors' view of the client differs, in that they feel the client spends a lot more effort at the requirements definition stage and less effort at the tender and construction planning stages. This supports the clients concerns about the project process, where they are dissatisfied that constructability and life-cycle issues are not being adequately addressed. One of the reasons for this is that the contractor is not involved until the latter stages when they have to interface on a daily basis with the client. Also, contractors would probably expect that much of the client's involvement had already taken place in the earlier stages of developing the project. All parties agreed that the client should be involved beyond the requirements definition stage. This is probably due to the need to ensure that the final technical solution met the client's conceptual requirements and to ensure that performance on cost and programme was maintained.

Comparing a traditional approach to project procurement with a Turnkey type of procurement process, the client's involvement is likely to be substantially reduced due to the nature of the roles and responsibilities of each group within the procurement process. The client's involvement would be reduced to ensure performance of the programme and where their current operation interfaces with the new. The contractor's design, construction and performance will usually be guaranteed as part of the contract terms and conditions.

Looking at the consultants' involvement, the views were reasonably consistent and, as one would expect, the consultants' role is considered to be concentrated around the detailed design and tender stages. The consultants group, however,
thought that their involvement was greater in the earlier stages of the project. This could be a mis-interpretation of what comprises the early stages of a project.

The views of all of the groups show that the existing involvement of the contractor is quite low at the early stages in the construction process and concentrated towards the construction planning and construction stages. The bar charts show that the clients' current view is that the contractor has little involvement until the detailed design stage. However, both the client and consultant identify constructability as a major issue and over 75% of all respondents felt that the contractor's involvement started too late in a project.

This can be somewhat overcome by a design and build procurement method where a single contract is placed with a contractor for the design and construction. The tenders are usually based on an outline design and therefore a contractor can influence (to some extent) constructability issues to suit their own methods. However this procurement route is only used in about 20% of all construction projects.

4.5.2 Process
The main form of procurement for construction projects is still the traditional route (>40%) where separate contracts are arranged by the client for design and construction, with the majority of the design being complete before construction tenders are invited. The design and build method is the procurement method that is common with contractors, perhaps the contractors feel that they have greater control and ability to influence the design in favour of their construction methods. The long-term partnership procurement method is increasing in popularity, however this concept can be applied to any of the current procurement methods.
The concept of the method is that once tendering is complete the competitive element of the process is removed and that the parties all work together, focused on the final product.

Looking at the design activities in all methods of construction procurement the graph in Fig 4.10 show that there is still approximately 15% of design being carried out during the construction period. This is more common in the traditional route than other procurement routes, one can expect that the design for the roof or landscaping is usually not required until late in the construction programme. However, one of the tendering contractors may as part of their tender choose to complete the roof as soon as the main structural frame is installed, allowing all remaining internal works to be completed in drier conditions. To a contractor the effort required to complete the roof early would be offset against potential productivity losses due to inclement weather conditions. This example would clearly have an impact on the design and construction programme and shows where the construction process remains fragmented. If the argument is expanded and assuming that the traditional method of procurement is used, with low contractor involvement at the early stages, a contractor may be precluded on merit or alternatively a full redesign may be required. In both cases resources are wasted needlessly.

In many cases the graph in Fig. 4.10 shows that project requirements and design are not frozen until stages 5 and 6, the construction planning and construction stages. This is after the construction tenders have been prepared and submitted to the client or their representatives. This could mean that the detail that tenderers assume and estimate in their bids could be either excessive or under-estimated. The contractors will usually carry out some form of risk assessment against a project and related to areas where they feel there is a potential for increased cost without increased revenue. For example, where quantities are given as part of the
tender process, the risk for the accuracy of the quantities is borne by the client; the contractor will usually recover their monies. However where a lump sum contract is required based on a submitted design, then it is the contractor who bears the risk for accuracy. Including a risk contingency within the overall contract sum usually mitigates the risk.

It was apparent from the responses to the questions, that overlaps between stages frequently occurred and varied between a minor overlap and stages being fully integrated. On some occasions individual companies did not have an overlap at any stage and all of the activities were carried out in a sequential manner. To improve the process and reduce timescales would require all stages to have some overlap. For example, if a project consisted of 6 stages each of 6 weeks duration, the minimum length that the project programme could be completed would be 6 weeks if all of the stages were fully concurrent. However if the stages were totally independent the programme would extend to 36 weeks. The aim for all parties would be to optimise the programme such that the length was minimised without additional costs for acceleration.

4.5.3 Selection Criteria

The clients' selection of the preferred design option, to meet the overall project concept was found to be based primarily on cost, with life span and maintenance being low on the lists for consideration. Yet, in comparison the Figure 4.15 shows that life-cycle and maintenance are high on the client's list of concerns and areas where potential for improvement exists. The selection of the preferred design option was in the majority carried out as a team activity, however a contractor was not involved in the process and the client usually relied on the consultant to technically evaluate tenders.
The graphs show that the clients' selection of a contractor was usually based on cost, the criteria of value for money and technical solutions were low in the client's rankings. Whilst the contractors provided alternative technical solutions, it is unlikely that a complete redesign of a scheme would be carried out at the tender stage or after the tenders had been submitted.

At the tender stage the most common number of tenders for all parties was 5 with on average 1% of the tender value spent by contractors on the tender process. This then represents a total of 5% of tender values for each project, but only the successful contractor will recover their costs. For example, if a £100 million project were considered, with a tender list of 5, the contractors as a group would spend around £5 million on their tender submissions. Around £4 million of this would be wasted, therefore in general terms 4% in each project is wasted effort on behalf of the contractors tendering for a project. Based on the group of contractors who replied, if the number of tenderers was reduced to 3 a 40% saving in tender preparation costs would realise up to £16 million. This would be financial and personnel resources that the contractor saved from the cost of carrying out business. The costs would eventually be passed down to the client in terms of reduced contractor overheads. The client, however, would need to be satisfied that the resulting tender process remained competitive.

The total length of the tender process was found to be on average 7 weeks, which included 4 weeks for the client to evaluate. The shorter the tender period the higher the risk value associated with the tender submitted. The risk value could be based on the result of a commercial decision depending upon a contractor's determination to win a job and not necessarily anything to do with the job in hand.
Looking at the specific questions relating to performance measures in the construction industry it is clear that the whole team feels that the process could be improved.

Firstly looking at cost, the responses from clients show that 41% of projects are delivered over cost. If an average increase of 10% is assumed and using the capital values from earlier sections in the questionnaire, the potential overspend by the 100 clients chosen in the survey could be up to £600 million. This figure changes for consultants and contractors to 18% and 12% respectively. The reason that the % figure is different is likely to be the level and timing of the respective group's involvement. At the time when the latter groups become involved the cost estimate could have increased above the client's original estimate.

Secondly looking at timing, figures show that the industry has a similar chance of delivering projects on time rather than cost. The clients group feel they had a better chance of delivering projects on time than cost whereas for contractors and consultants the opposite is true. There are many reasons for late delivery in a construction project, including, inclement weather, late delivery of information, lack of resources, difficult site conditions. Some are valid reasons more than others and whilst a contractor may promise many things at negotiation stages, clear evaluation of a programme should be completed to ensure plans are workable and capable of being achieved.

The specific question relating to an increased involvement of clients beyond the definition stage had a high level of agreement where on average 95% of respondents agreed.
The specific question relating to an increased involvement for contractors was not as clear with an average of 73% of the clients and consultants agreeing and 90% of contractors agreeing. The low response from the consultants could be due to the fact that they may feel that their own involvement could reduce if a contractor is involved earlier. They may also prefer dealing direct with a client who controls the purse strings for a project, especially if they were involved with one contractor out of five and have no guarantee of a successful project.

For a client their response could be due to the need to have a competitive price. By the involvement of only one contractor they could feel that the competitive edge is lost and that the project could suffer as a consequence.

4.6 Conclusions and recommendations

It is clear from the survey that the industry, whilst being above average in terms of delivery, still has a large potential for improvement. Specifically the survey found the following in respect of data:

- The preferred method of procurement of construction projects is still the traditional method, the design and build method being the second most popular.
- The selection of both design schemes and contractors is primarily based on cost. The use of other key aspects such as constructability, life-cycle issues, programme are low in terms of selection criteria.
- Constructability, life-cycle issues, maintenance are areas where the client is currently disappointed.
- The involvement of key personnel through the stages of a project varies, the key differences were in the involvement client and contractor.
- The contractor is the least happy with the current project procurement process whereas the client is the most satisfied.
Contracts on average spend 1% on tender preparation. This means that for the respondents potentially over £32 million is used by contractors resources due to tendering and not recovered.

Projects have a 7 out of 10 chance of finishing on time and a 6 out of 10 chance of meeting the original budget at the completion of the construction work.

All groups involved in the construction process were agreed that the contractor's involvement at the earlier stages of a project was low. The majority of the respondents also felt that the contractor's involvement at this stage should be increased.

Generally over 15% of the design was being completed when the work was being constructed.

In respect of the survey methodology and responses, whilst the strategy selected was felt to be the most appropriate, it was disappointing to achieve only a 15% return especially when the survey was addressed personally and had an enclosed self addressed envelope. However the responses did cover all groups equally and both small and large companies views were represented. The survey was maintained as anonymous even though some companies were clearly not shy with publicity. The survey was triangulated to some extent in that it confirmed many of the issues raised by Latham[1994] and Egan[1998]. In hindsight the data received could be supplemented by other sources and further investigation, however time limits restricted further survey work.
4.7 Summary

The construction industry survey was undertaken to determine the views of the industry in a number of key areas such as background information, involvement in a project and level of satisfaction with the existing procurement processes. The questionnaire was aimed at a broad audience and intended to be anonymous.

All of these objectives were achieved although the response rate was disappointing at 16% returns. This rate however was felt to be a common figure for the type of questionnaire [Som 1973].

The questionnaire confirmed the following:

➢ Broad value of participants involved in the industry and responding to the questionnaire with varying levels of turnover and size of projects.
➢ The involvement of different parties in the project process varied with each discipline.
➢ The level of satisfaction with the current processes was quite low, all participants expressing views that contractors should be involved much earlier in the process and client’s involvement should continue until handover.

The findings confirm the views of previous reports [Egan 1998, Latham 1994] and can be used as a basis to improve the procurement process in the construction industry. Many of the comments from the survey can be identified alongside the aims and objectives of Concurrent Engineering a shown in section 3. The key to the following chapters is to take the comments, identify the concepts of a new procurement method and develop an outline method based on an acceptable modelling technique.
CHAPTER FIVE

PROCESS MODELLING TECHNIQUES

5.1 Introduction

The need to develop a new model for project procurement in construction has been discussed in previous chapters. There are many types of modelling techniques that are available, some are more appropriate than others for use in the development of the new model. This chapter looks at the variety of techniques available for use in the development of a new model and selects the most appropriate based on criteria set out at the beginning of the chapter.

The main purpose of the research project was to develop a new procurement process model that is based on CE principles. This involves the breaking down of activities to their lowest level and looking at the individual tasks to identify repetition, waste and improved methods of procuring construction projects.

Some modelling techniques focus on individual tasks whereas others concentrate on other areas such as information flow, and the relationships between parties and stakeholders who are involved in a product’s development. This chapter initially identifies the requirements for the selection of a modelling technique that is suitable to represent the construction process. The different modelling techniques are then described in detail, showing how they meet or fail to meet the criteria identified. In addition an assessment of how a model could be developed was undertaken.
It was decided to adopt a computer based model as the appropriate medium in which to develop the model. The reasons for the choice were:

- Ease of change
- Consistency of output.
- Efficient in terms of development
- Easily understood

A paper based model was considered but it was felt that due to the iterations likely to take place through the development process, the type of model would be inefficient in the longer term. In addition the possible development of the model by a review of current models supplemented with a questionnaire/interview was considered but discarded due to the inefficient method of data collection and the method not being structured to meet the needs of the final product.

The software package Visio Technical 4.1 by the Visio Corporation was used as a development tool as the software already had pre installed templates carrying all of the symbols necessary for development of the model.

5.2 Requirements of Modelling Technique for Development of a New Model

This section sets out the requirements for an appropriate modelling technique to be selected. The high level requirements of any modelling technique should be that it is able to represent the construction procurement process and is easily understood. The specific requirements for the type of model are:

- Total Process – The modelling technique should have the ability to show the total process in a single diagram and to be able to identify the key tasks required.
➢ **Visualisation** – The modelling technique should allow the model to be easily understood and the interaction between tasks should be clearly identified.

➢ **Focus on Tasks** – The modelling technique should emphasise tasks to be carried out because construction procurement is generally organised around tasks and their interaction, rather than the flow of information or the role of parties involved. These are secondary elements that allow the tasks to be carried out.

➢ **Allowance for tasks to be run in parallel** – The modelling technique should allow tasks to be carried out at the same time, allowing the overall timescale to be reduced. The model itself is not specifically required to be time related.

➢ **Impact of key influences on Task** – the influences and limitations on each task should be easily represented. Duplication of effort can then be identified and removed from the process. This would also allow for identifying the earliest timescales for the transfer of information.

➢ **Broad and Deep** – The modelling technique should allow for the development of high level diagrams to cover the whole process. Similarly the adopted technique should also be capable of reaching the lowest level of tasks involved in the process.

➢ **Time Related** – the modelling technique should be independent of time, however it should be capable of easy conversion to allow a simple bar chart to be prepared.
With the key attributes for techniques identified, the common techniques are reviewed against the above criteria and the selection of the most suitable technique is made.

5.3 Modelling Techniques
To start to assess the potential improvements to a procurement process would require an analysis of the existing processes and activities to identify areas where there is a potential to improve. Also it would be necessary to look at the total construction process to see if stages could be combined or removed. To carry out the analysis a process model is necessary. There are many popular techniques that could be utilized to model the procurement process e.g. Work Flow modelling, Data Flow modelling, SADT, IDEF0.

5.3.1 Information Engineering
The method was introduced by James Martin in 1970 and was defined as "an interlocking set of formal techniques in which enterprise models, data models and process models are built up in a comprehensive knowledge base and are used to create and maintain data-processing systems [Daae et al. 1999]." The method is used to assess a company's processes as a whole, rather than individual processes within the company. The method examines a business using a top down approach, starting with business goals and developing down to the product delivery in their production systems and aims to "get the right information to the right person at the right time." One of the successful uses was by American Airlines who introduced an integrated system of on-line terminals to book flights.

This technique would be appropriate in the assessment of the total construction project process but would have limited use in a single stage of that process. The method concentrates on information flow between parts of the organisation and uses data flow models as the framework for individual processes.
5.3.2 Stakeholder Analysis

The purpose of this method of process analysis is to identify the key people involved in a process, setting out each person's issues, concerns and information requirements and assessing where these conflict with each other [Oudman et al. 1998]. The technique is based on the work of Ackoff [ ] who claims that "an organisation can only be successful if it interacts in a constructive manner." The method identifies six key exchanges that an organisation needs to concentrate upon. These are Debtors, Consumers, Government, Investors and Lenders, Suppliers and Employees all of whom interact with the "organisation". This is represented diagramatically in fig 5.1.

Fig. 5.1 – Diagram of Stakeholder Analysis [Oudman et al, 1998]

Action 1 between the Corporation and the Debtors is an exchange of money paid now for money received later with debtors.
Action 2 between the Corporation and Consumers is an exchange of goods and services for money.
Action 3 between the Corporation and the Government is an exchange of money for goods, services and regulation.

Action 4 between the Corporation and Investors and Lenders is an exchange of money paid later for money received now.

Action 5 between the Corporation and Suppliers is an exchange of money paid for goods and services.

Action 6 between the Corporation and employees is an exchange of money paid for work completed.

Similar to the Information Engineering method, this method concentrates on an organisation rather than individual processes. However within the construction procurement process all of the above relationships occur and could be used to assess the importance of each stakeholder at the construction stage. The method does not assess the systematic flow of a process and is generally used in the improvement of existing organisations.

5.3.3 Process Flow Charting

This method represents the operation of any system and describes how work is done [Taouil et al 1998, Melan 1992]. A similar technique is the Data Flow Diagrams which describes what work is done.

Process Flow Charting is a graphical representation of a process, its components and the interactions between them. The methods used usually have standard symbols to represent specific actions, for example:
El Represents an operation

◆ Represents a decision point

▲ Represents a controlled storage point

And so on.

For a simple activity such as returning a video tape to a shop, this can be represented simply as shown below:

Fig. 5.2 – Example of Flowcharting
The elder statesman of design tools, it was developed as the computer was developed and is based on using specific symbols for specific activities. The flowchart complements two systems of process analysis. These are the System Development Method and the Object-Orientated System Analysis and Design.

Flowcharts are typically used in sub-processes and in the identification of problems, and during a process the location within the process of data collection, idea generation and selection. The flowcharts also give a logical representation of the flow of tasks and information in a process, identifying decision points or gateways.

Another process analysis method is the Object Modelling Technique (OMT) which use three separate models to describe the "Object", "Dynamics" and the "Functional" aspects of a process. The Data Flow Diagram depicts information flow and the applied transformations showing inputs and outputs.

This method of process analysis could be used to model the construction procurement process. However, the impact of restraints and the mechanisms used to carry out the task are not identified. The method is beneficial by being a graphical representation, but it is difficult to show a hierarchical break down of tasks into sub-tasks.

5.3.4 Knowledge Acquisition and Documentation Structuring (KADS)
This method is used for the development of Knowledge-Based systems. It addresses the process from two viewpoints namely Results and Project Management [Brooking et al. 1998]. The Results perspective is a set of models that looks at different areas of the system and are improved and updated throughout the life-cycle of a project. The Project Management perspective is a generic life-cycle model which is modified to suit a particular project.
KADS originated in 1985 as a small ESPRIT pilot project involving collaboration between four European Countries.

The common KADS model comprises six individual models addressing different aspects including Organisation, Task, Agent, Communication, Expertise and Design. The Organisation model deals with resources of the organisation and how it will change after the new system is introduced. The task model looks at the individual tasks performed by the organisation. The agent model represents the resources that carry out the tasks within the task model. The expertise model defines the capabilities of an agent in respect of the problem-solving capabilities. The communication model identifies the communications that are used to achieve the overall task. The design model is used as a structure for the implementation of the new knowledge-based system.

Each of the models uses a different basic model for its framework e.g. Data Flow Diagrams, State Transition Diagrams, ER Diagrams.

This method investigates aspects of the development of an Expert System. An expert system uses existing knowledge and develops a computer-based system to allow an agent to solve a problem given certain criteria by the system.

5.3.5 Structural Analysis and Design Technique (SADT)
This is a graphical representation of reality for a particular task and consists of a series of interrelated diagrams [Mulder 1998]. Each diagram is either a parent (summary) or child (detail) and could be both, supporting different levels within the same task. The diagrams are linked in a hierarchical manner with clear identification numbers for each sub-activity. There are two types of model, an activity model which represents activities and a data model which represents the data requirements.
Each level in the model is restricted in size to between three and six boxes. In the activity model, each box represents an activity and the lines between represent data passing between the activities. The opposite is the case for the data model.

In the activity model data is included as inputs, outputs, controls or mechanisms as shown below. The activity is a verb phrase, the inputs are shown to the left and are usually data that can be transformed by the activity into an output. The control data are the activity's restraints while the mechanisms are the means of performing an activity.

The data model is similar to the activity model, with the arrows being the activities that generate, control and use the data.

![Diagram of SADT Activity model](image)

This type of model allows activities to be sub-divided into different levels and identifies what needs to be input and what transforms and is output to the next stage. The stages follow a logical sequence to the next stage which allows the sub-activities and full process to be easily represented. One of the limitations of this method is that multiple interactions between activities are difficult to represent. Concurrent activities are also not easily represented, as there is no facility for temporal representation.
5.3.6 Nijssen's Information Analysis Method (NIAM)

Originally developed in 1974 to help formally analyse required information. The method is also called Object Role Modelling and identifies all the activities that lead to the specification of an information system in a company [Schipper et al. 1998]. The deliverable of the analysis is an Information Structure Diagram. There are three stages in the NIAM method. These are firstly modelling the object system, followed by modelling of the information flows and, finally, modelling the information structure.

The first step in modelling the object system is an analysis of the system into activities consisting of a hierarchy of smaller functions. These are then separated into smaller diagrams, activities are placed into boxes and then further subdivided. Once the diagrams are prepared, the next stage is the creation of the routes of information flow between the activities. The Information Flow Diagrams have standard symbols similar to the flowcharting method. These are shown as graphs (one for each activity) showing the relationships between an activity and its connected activities. When information is required to be stored a buffer may be introduced called an information repository.

The third step, which is the key analysis stage, is called modelling the information structure. This shows the structure in the object types and the associations between them. The fact types are called NOLOTS (non-lexical object types) and LOTS (Lexical object types). Where an association exists between them then the fact cannot be reduced without the loss of the information belonging to it. The facts correspond to the lowest level of activities represented at stage one and the associations are the activities belonging to the two facts. Each fact can have several associations aligned to it; for example, a person may have a town, street and postcode. The diagram is then constructed, adapted, implemented and evaluated.
The final information flow diagram for the activity shown in the flowcharting section is represented below in fig. 5.4.

Fig 5.4 NIAM – Information Flow Diagram

This method works on information flow between activities rather than tasks and is associated with the development process by the control of system development activities within an organisation.
The NIAM process initially examines the activities of a process and sub-divides them into the smallest activities, similar to the SADT method. However, the method only shows the associations between facts and not the interaction between activities.

5.3.7 Information Systems Work and Analysis of Change
This method was developed in the early 1970s and again relates to information systems development. The method uses a framework and usually operates at a business model level [Loefs et al. 1998]. The method initially analyses an existing system and focuses on the process, information, behaviour, organisation and problem. The initial task is the object system model, determining the interest groups at each level and setting the aims for future changes. The process involves a five step process which starts with the change analysis, followed by an activity study, information analysis, data system design and finishes with the adaptation of means. These are supported by a series of graphs and structures.

The first stage results in an evaluated plan for both the existing and future situations. The second stage results in multiple options for activity models for an information system which are used in stage three to produce a fully specified set of information models. At this stage the models should be tested by potential users to identify whether the system has any flaws. The fourth stage results in the preparation of a data process model that is used in conjunction with the selected hardware. A means-adapted data system results.

The method may be useful in that it is based upon an existing process that requires changing by the identification of a problem. However, it concentrates on information analysis and information and data flows rather than specific tasks. The method also shows little of the interaction and constraints between activities.
5.3.8 IDEFØ (Integrated Computer Aided Manufacturing Definition Method)

This type of modelling technique is similar to SADT and combined with it form the major part of the toolbox of process techniques [ICAM 1981 & Zgorzelski et al. 1997]. The method is a set of structured techniques for analysing systems of work and provides engineering methods for the development and management of these systems [Wallace et al. 1987]. The IDEFØ methodology is the first step in developing a total process model and represents the functional modelling perspective. IDEFØ however is limited to being an activity model and takes an input to an activity and transforms it by carrying out the activity and creates an output. The output of this technique is a graphical representation of a particular task and consists of a series of interrelated diagrams [Mulder 1998]. Each diagram is either a parent (summary) or child (detail) and could be both, supporting different levels within the same task. The diagrams are linked in a hierarchical manner with clear identification numbers for each sub-activity. Each level in the model is restricted in size to between three and six boxes. In the functional model, each box represents an activity and the lines between represent data passing between the activities. In the functional model, data is included as inputs, outputs, controls or mechanisms as shown below. The activity is a verb phrase, the inputs are shown to the left and are usually data that can be transformed by the activity into an output. The control data are the activity's restraints while the mechanisms are the means of performing an activity.

The process is represented hierarchically with the initial diagram being the level 0 diagram. This in the procurement process would probably represent all of the six stages of the project process as a single procurement activity.

This type of model allows activities to be sub-divided into different levels and identifies what needs to be input and what transforms and is output to the next
stage. The stages follow a logical sequence to the next stage which allows the sub-activities and full process to be easily represented.

One of the limitations of this method is that multiple interactions between activities are difficult to represent. Concurrent activities are also not easily represented, as there is no facility for temporal representation.

Another of the difficulties of this method relates to task ownership, but provided the activity is not assessing the ownership of each activity then it works adequately. However, the technique can be limited by interactions especially where people and companies that are outside of the key business (in construction this may be the Client) are involved.

5.3.9 Transformation Model
The transformation model is a basic model which takes a number of inputs such as materials and facilities etc. and transforms them into outputs [Melan 1992, Walker 1985]. The output is normally of greater value than the inputs. This forms the fundamental basis of all process models and whilst this method could be used in a similar manner to flowcharting it does not show the controls and mechanisms needed to perform an activity. The process is shown diagramatically in Fig 5.5.
Fig. 5.5 – Transformation Process
5.4 Modelling Technique Selection

5.4.1 Review of techniques

Each of the techniques discussed in Section 5.3 are reviewed in Table 5.1 against the criteria set out in Section 5.2.

Table 5.1 – Review of Modelling Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Total Process</th>
<th>Visualisation Focus on Tasks</th>
<th>Parallel Tasks</th>
<th>Impact key Influences on Task in 1 diagram</th>
<th>Broad &amp; Deep</th>
<th>Time Related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Engineering</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Stakeholder Analysis</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Process Flow Charting</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>KADS</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>SADT</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>NIAM</td>
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<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Information Systems Work</td>
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<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>IDEFØ</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
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<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

From the table it is evident that the KADS, SADT and IDEFØ techniques meet almost all of the criteria required from the set out in section 5.2.

KADS disadvantage over SADT and IDEFØ is that six models are developed concurrently which cover aspects other than just tasks. This requires a significantly greater development period and resource requirement over the other two methods. Also the SADT and IDEFØ methods can be utilised to develop existing organisations and methods whereas KADS develops a new organisational model. The organisations operating within the construction industry already exist, the resources and their capabilities are already defined by the business and the
industry institutions. Therefore the KADS method is discounted on the above basis.

The SADT and IDEFØ methods are very similar, the SADT technique develops two models, namely activity and data, the IDEFØ technique starts with the functional model and then sequentially develops the informational and dynamic models. Either of these techniques are considered appropriate for the development of a new model, the detailed analysis of the selection of how IDEFØ meets the initial criteria is completed in the following section.

5.4.2 Selection of Technique

The IDEFØ technique was adopted for the development of the new model due to the need to have:

- **Total Process** – The IDEFØ level 0 and level 1 diagrams show the whole of the construction procurement process to be modelled from receipt of the Clients Requirements through to completion of the Concurrent Detailed Design.

- **Visualisation** – With a hierarchical approach the tasks and their interrelation are clear. The technique produces diagrams that show how tasks are achieved and what is produced from each specific task.

- **Focus on Tasks** – The IDEFØ technique clearly focuses on tasks required to complete the necessary project. Construction is a task led industry that produces design and constructed assets so clearly there is a synergy between the technique and the industry as a whole.
➢ Allowance for tasks to be run in parallel – The IDEF0 technique allows all tasks to be completed in parallel. However to achieve the maximum reduction in timescale a review of all of the tasks are required to check on interdependence and a bar chart prepared to show its effect on a project’s timescale.

➢ Impact of key influences on Task – The IDEF0 technique shows the major influences on a task through the inputs, outputs, controls and mechanisms. However the technique is limited in showing who performs the task. This can also depend on the type of contract and organisations that are involved in a specific project.

➢ Breadth and Depth – As highlighted earlier the IDEF0 technique is broad based in covering the total extent of the procurement process. The technique is also deep in that all tasks are broken down to their lowest levels by using parent and child diagrams.

➢ Time Related – The IDEF0 technique is not a specific time related technique as it only shows the interrelationship of tasks required to perform the work. A separate bar chart or Critical Path Network is required to determine the exact timescale required for a specific project.

➢ Data requirements between tasks shown as inputs and outputs, some of which are internal to the process and others external.

➢ The method of development of the new model mirroring Prasad’s CE principles [Prasad 1996].
> The ability to include feedback loops as a series of outputs and inputs. This is a theme that Egan stipulates as an improvement in the industry [Egan 1998]. The inclusion of these loops integrates the cycle of learning and continuous improvement into the procurement process.

5.5 Summary

This chapter has identified a modelling technique to develop a new procurement model for construction projects using CE principles. The technique was chosen by initially identifying the key requirements from a modelling technique to suit the industry. Several techniques were reviewed against the initial requirements to assess their compliance, then a selection was made based on those requirements. It was determined that the IDEF0 modelling technique was the most appropriate due to its ability in having a visual representation, being able to drill down to the lowest level of tasks and showing the interactions between different levels and identifying the controls and mechanisms that form part of the construction process.

The model is developed in Chapter Six, based on these principles and represented in IDEF0 format, the first task being an overview of the whole process, referred to as a node diagram. This will set the scene for the outline of the model and allow each major activity to be drilled down to its lowest level.
6.1 Introduction

This chapter confirms the key requirements for a new procurement method for construction using CE principles. The requirements are used to develop a new procurement model. The new model is developed using IDEF0 techniques, the reasons for this choice as opposed to other modelling techniques are explored. The model is then developed from an overall project perspective involving four key generic organisations namely the Client, Design Consultant, Contractor and key material suppliers. The model concentrates on project procurement and acknowledges that an integral part of the process is the briefing and the detailed design stages. Both of these stages have been the subject of previous research projects [Kamara et al. 2000, Waskett 1999]

Figure 6.1 shows an outline flowchart for “Project Development” which identifies the major activities within a construction project and the focus of this thesis. The figure shows the key position of procurement within the overall project delivery process. The key input to the procurement process is the Requirements Specification produced as part of the Client’s Requirements Processing Stage. The final output from the procurement process would be the completion of the detailed design. The concurrent detailed design should carry out the work necessary to plan the construction in detail. However, it is acknowledged that the construction stage whilst appearing independent will run in parallel with the detailed design and is an integral part of project procurement.
The above diagram is based upon the process model shown in Fig 2.1. The first three stages comprise the identification of a project and the preparation of a brief, called the solution neutral project specification which represents stage 1 in the process model of Fig 2.1. It also represents stage 1 of the model shown in Fig 2.6 and phases one and two of the Process Protocol.

[http://pp2.dct.sanlford.ac.uk/ppguide/phase.htm].

Stages four to seven in the above diagram represent the procurement stages of a project and the area for the new model. This represents stages two to six in the
model in Fig 2.1, the remaining stages of the model in Fig 2.6 and phases two to seven in the process protocol. The key outputs would be the detailed design and a construction plan for installation. With concurrency of tasks in the new model it is likely that the following activity, construction, will have already commenced prior to the detailed design being completed.

Stage eight in Fig 6.1 is similar in all the models represented, stage seven in Fig 2.1 and phase eight of the Process Protocol. Stage nine above covers stages eight and nine of Fig 2.1 and phase nine of the Process Protocol. Stage ten above covers stage ten of the process diagram in Fig 2.1.

The following sections describe how the IDEF0 method was utilised for the development of the new model and then details the model itself.

6.2 Modelling Approach/Development
6.2.1 Introduction
As described in chapter 5.0 there are many modelling techniques available for the development of a new model. The main purpose of the research project was to develop a new procurement process model that is based on CE principles. This involves the breaking down of activities to their lowest level and looking at the individual tasks to identify repetition, waste and improved methods of procuring construction projects. IDEF0 was selected on the basis of:

- It covered the total process
- Easily visualised
- Model focuses on tasks
- Allows tasks to run in parallel
- Shows the key impacts on tasks
- The technique is both broad and deep
The IDEFO diagrams in the new procurement model was developed over a period of some months being continually reviewed and updated in the process.

The software package Visio Technical 4.1 by the Visio Corporation was used as a development tool as the software already had pre installed templates carrying all of the symbols necessary for development of the model.

6.2.2 Structure of IDEFO

The IDEFO technique, when developed, represents a system through a series of hierarchical diagrams that allows a complex process to be broken down into individual parts [ICAM 1981]. The diagrams consist of boxes and arrows which represent the tasks and their inputs/outputs/mechanisms and controls respectively. The IDEFO represents the whole process by a single box with external interfaces shown by arrows.

This box is decomposed to between three and six functions each of which are then further decomposed as shown in the Figures 6.4 - 6.24.

This allows the detail to be exposed gradually but limits the complexity and triviality of each diagram. Decomposition becomes complete when the level of detail allows the model to be used. Once each node is decomposed it becomes a wholly enclosed function, i.e. the child diagram all fits within its own parent.

The models are numbered sequentially and top-down, for example, node 0 is the high level diagram which is broken down into four diagrams numbered 1.0 to 4.0 each of which have their own child diagrams.
6.2.3 Context of the Model
The model was developed from an overall project perspective giving an overall view from the completion of a design neutral project specification through to the completion of detailed design. It is assumed in the model that the project comprises a building and that three contractors are pre-selected to bid for the works. The model maintains flexibility in that other engineering disciplines can be utilised and that more than three contractors can be utilised, both by the inclusion of further boxes.

6.3 Evolution & Development of New Procurement Model
Clearly the previous chapters and specific examples show that current construction procurement methods do not meet all of the needs of CE. The development of a suitable framework for procurement within a CE framework requires the consideration of the following aspects:-

➢ Early involvement of all parties into a project

➢ Interfaces between parties should be minimised [Prasad 1996, Anumba & Evbuomwan 1997].

➢ Focus on the client’s requirements [Anumba & Evbuomwan 1997, Kamara et al 1999].

➢ Contract terms should benefit all parties [Bennett & Jayes 1998, Uher 1995].

➢ Tasks will be broken down to their lowest level.

➢ Overlaps will be minimised [Prasad, 1996].
The new model will allow for continuous process and product improvement [Prasad, 1996].

6.3.1 Methodology for procurement in a CE context

Procurement as a process starts at the briefing stage and is only completed once a constructed facility is complete [Kamara et al. 1997], and is completed once the facility is handed back to the Client.

Amendments to the existing processes could be made so as to achieve savings in costs with improvements in quality. However, a step change in the development and implementation of construction projects is required to improve the final product to the benefit of the Client and the profitability of businesses working in the industry. The proposed new project procurement method is based on the CE principles goals and objectives detailed in Chapter Three and the requirements detailed in Table 3.1.

This section breaks down and develops the key stages into individual tasks and activities that are based on high level goals and objectives. The activities are then modelled using IDEFO modelling techniques which show the inputs, outputs, controls and mechanisms of each task, allowing the process to be rationalised and the flow of information between parties to be routed such that delays are minimised. The new process is aimed at meeting the needs of a CE framework and achieving reductions in cost and timescale through the collaboration of all parties to a construction contract.

Following the development of the requirements for a generic model, a high level diagram was developed that identified where procurement fitted into the product development process. This is shown in Figure 6.1.
This in general mirrored the design and build model proposed by Anumba & Evbuomwan [1997]. However procurement of a facility covers a series of tasks, therefore the first diagram covers several of the tasks included in Anumba & Evbuomwan's model. This can be regarded as the IDEF0 Level 0 model, shown in Figure 6.2, from which all the other IDEF0 diagrams are derived.

![Fig 6.2 Level 0 Diagram](image)

Also it was necessary to ensure that all of the detailed requirements of the CE principles [Prasad 1996] were to be adopted as described in Chapter Two and listed below:

- Team affinity
- Early problem discover
- Early decision making
- Work structuring
- Knowledge leverage
- Common understanding
- Ownership
Constance of purpose
Parallel workgroups
Parallel product decomposition
Concurrent resource scheduling
Concurrent processing of tasks
Minimising interfaces
Transparent communication
Quick processing

The "Procure Project" was then taken as the Level 0 model, the highest level within the overall process. A node diagram was developed to show how "Procure Project" is broken down into the lower level tasks. This is shown in Fig. 6.3 below:

![Procurement Node Tree](image_url)

Fig. 6.3 Procurement Node Tree
The node diagram was developed further to sub-divide the second level tasks until the tasks reached a level where they could not be developed further.

Once all of the nodes were identified, IDEF0 diagrams were prepared that showed how the tasks were broken down and interrelated by the inputs and outputs. The mechanisms and controls that influenced the outcome of each task were similarly added to the diagrams. Once the diagrams were completed they were reviewed to ensure that each diagram followed a structured approach and that the overall approach and method followed in a logical manner and that the principles of IDEF0 modelling had been utilised to its full potential.

It was felt that during the development of the model some tasks could be developed further than others and a second node diagram was prepared which focused around “Prepare Tenders”. In general terms it was felt that the reduction of tasks should include sufficient detail to enable the method to be outlined, not necessarily to each detailed task. The second node diagram is shown in Figure 6.4 and the subsequent IDEF0 models are shown and described in the following section.
6.3.2 Functional Representation of the Method

From the node diagrams the Level 0 diagram covers the overall procurement process and was shown previously in Fig. 6.2. This diagram shows the inputs, outputs, controls and mechanisms for the total procurement activity. This activity is then broken down further into the key sub-processes involved with the procurement of a facility and shown in the Level 1.0 diagram in fig 6.5 overleaf.
The sub-processes shown in the above diagram are the four key areas of procurement. Figure 6.5 shows all the inputs and outputs required for each key activity and the inter-relationship between these activities. For example for the “Invite Tenders” activity a business plan and neutral design specification are the inputs. The output to this activity is the tender documentation, which becomes the input for the activity “Prepare Tenders”. At this stage, however, the tenderers will already be known and pre-selected. This is shown in the breakdown of the activity “Invite Tenders”.

6.3.2.1 – Procure Project
In this section each of the sub-activities shown in the Level 1.0 diagram is described. The following sections break down each individual sub-activity to the levels to show sufficient detail to allow the concept to be presented and understood.

6.3.2.1.1 Invite Tenders
This sub-activity includes all the activities required to identify key suppliers and prepare and issue tender documents. These activities are led by the client and where necessary a professional support team. The key aim of the sub-process is to develop the neutral project specification into a tender document which can obtain competitive solutions for price, programme and technical quality. The key inputs are the business plan and the solution-neutral design specification, the key output being the tender documentation. The mechanisms are the resources and the controls are timescale, site constraints, and participant’s constraints.

6.3.2.1.2 Prepare Tender
This sub-activity encompasses all the functions carried out by a contractor to respond to the tender document issued. These activities convert the neutral project
specification into an outline solution that can be compared in terms of price, programme and meeting the requirements of the specification. At this time a team including major suppliers and sub-contractors will be established by the consortium leader. The key inputs are the tender documents, the key output being the tender offer and business plan. The mechanisms are the resources, computer software and materials and the controls are the contract, coal constraints, the site constraints, the project brief and timescale.

6.3.2.1.3 Appraise Tenders
This sub-activity includes all the functions associated with the assessment of the tenders supplied by the individual consortiums. The method of appraisal will be devised at the tender invitation stage. The key input is the returned tenders, the key output being an agreed order for the works. The key inputs are the individual tender offers, the key output being an order for the project. The mechanisms are the Clients and Consortiums resources and the controls are the project brief, the site constraints, the timescale and the client’s budget.

6.3.2.1.4 Complete Concurrent Detailed Design
This comprises all the activities associated with the development of the outline design prepared at the “Prepare Tenders” stage and converting it into the completed design. Part of the Concurrent Detailed Design activity will be to plan the construction works. This is an integrated project team activity that starts with a review of all the available project documentation in an attempt to integrate the two separate teams into one organisation. The key inputs are handover of the site, the business plan and an order for the works, the key output being the detailed design. The design and construction teams would be integrated at this stage and therefore the design would be released on a staggered basis to match the construction programme. The mechanism is the resources of the integrated team
while the controls are the contract, the site constraints, the timescale, the budget and the operating and maintenance requirements.

Taking each individual area in order starting with the activity "Invite Tenders" and finishing with the activity "Complete Concurrent Detailed Design" and breaking down the activities into sub-activities and tasks.
6.3.2.2 - Invite Tenders

The invite tenders invitation activity is divided into four key sub-activities. The inputs to the level being the clients Business Plan and the Neutral Project Specification led by the client and its professional advisors the output is a set of tender documents and an agreed supplier list. There are internal inputs and outputs in this area that are not shown on the upper level diagrams. The breakdown is shown in Fig 6.6 on the previous page. From Fig 6.6 the activity "Invite tenders" is sub-divided into the four key sub-activities as follows:

6.3.2.2.1 - Prepare Pre-Selection Criteria

The activity is to develop criteria so as to enable pre-selection of a small number of suitable consortia/key suppliers, say 3 or 4 from a large list of interested parties. The criteria could include relevance to proposed project, commercial viability, team approach, safety record, for example. The key inputs are the client’s business plan and the solution-neutral design specification, the key output being the service requirements and a potential contractor list. The mechanisms are a project champion and the core team resources while the controls are the resource availability, the abilities of the suppliers and the timescale.

6.3.2.2.2 Pre-Select Consortia/Suppliers

This is concurrent with reducing the number of suppliers down to 3 or 4 using the criteria developed in the previous activity. This could include the preparation of a tender invitation notice, receiving letters of interest and using the criteria to prepare a preferred main consortia/supplier list. The key inputs are the service requirements and an overall consortia/suppliers list, with the key output being the reduced consortia/supplier list. The mechanisms are the project champion and the resources of the core team and the controls are the resource availability, the supplier’s abilities and the timescale.
6.3.2.2.3 Prepare Tender Documents
The activity includes all tasks associated with developing a set of tender documents. This would include the development of a specific scope of works, based on the solution-neutral design specification, outline programme, contract terms and material specifications. The documents should also outline the selection criteria that the returned tenders must meet. The key input is the service requirements, the key output being the tender documents. The mechanisms are the project champion and the resources of the core team and the controls the external constraints, the contract, the timescale and the resource ability. The Client’s Core Team is seen as a team of professionals, either out-sourced or within the Client’s organisation, which have sufficient skills and knowledge to act on the Client’s behalf in the execution of the project.

Whilst IDEF0 will not show the timescale relationship, this activity could be carried out in parallel with the two previous activities so as to minimise programme.

6.3.2.2.4 Issue Tender Documents
Includes all activities associated with the transfer of the document from the client to the consortia/suppliers. The key inputs are the tender list and the tender documents, the key output being the tender documents. The mechanisms are the project champion and the resources of the core team and the controls are the resource availability and the contract plan.

The above activities are now taken and then further subdivided into lower level tasks.
Fig 6.7 – Node 1.1 Prepare Pre-Selection Criteria
6.3.2.3 – Prepare Pre-Selection Criteria
Taking the first of the previous activities, namely “Prepare Pre-selection Criteria”, this is subdivided into three activities the input being the solution-neutral design specification, the output being a list of criteria to be used for the pre-selection of suitable consortia/suppliers. This is shown in Fig. 6.7 on the previous page.

6.3.2.3.1 Prepare Technical Criteria
This activity includes all of the tasks associated with preparing the technical criteria for consortia/supplier assessment. This will include criteria for compliance with the specification and the consideration of life-cycle issues. The technical criteria will also include questions relating to experience in the type of proposed project.

6.3.2.3.2 Prepare Commercial Criteria
This activity includes all of the tasks associated with the development of the commercial criteria for the selection of the successful supplier. This will include the potential to ensure compliance with the budget and the mechanisms for payment where improvements are made to the scope.

6.3.2.3.3 Prepare Management Criteria
This includes setting all the criteria associated with how the project will be managed by the consortia/suppliers including reporting, the criteria to be reported, details of the project plan, possible C.V.’s of key potential staff involved in the management of the project, management organisation tree.
Fig. 6.8 – Node 1.2 – Pre-Select Suppliers
6.3.2.4 – Pre-Select Consortia/Suppliers
From the “Invite Tenders” activity, the next activity to be sub-divided is the “Pre-select Consortia/Suppliers”. This activity is subdivided into four activities that allow suppliers to be pre-selected based on the criteria selected in the previous set of activities. These activities are carried out initially by the client and supported by the suppliers. Fig. 6.8 shows the IDEF0 diagram.

6.3.2.4.1 Issue Pre-Selection Document
This includes all of the activities associated with the issue of documentation, including preparation, criteria for basis of selection, selection of suitable mode for communication and physical issue of the documents to the consortia/supplier list. The recipients could be selected from an approved list, a business directory such as Institution of Civil Engineer’s Contractor file, or by the advertisement in the European Journal or other trade magazines.

6.3.2.4.2 Complete Pre-Selection Document – This includes all of the activities associated with the completion, by the consortia/suppliers, of the issued documentation and returning those to the client. The supplier is required to gather information and present it in the pre-selection documentation. Usually this information will be standard documents such as safety policy, organisation chart, turnover, capability statements, staff resumes and will require the minimum of time for completion.

6.3.2.4.3 Review Pre-Selection Document – This includes all activities by the client to review the documentation issued by the consortia/supplier, resulting in the reduced list of suppliers. The client will have a standard proforma that scores each company against the previously set criteria and allows the three/four most suitable supplier to be selected for the actual tender list.
6.3.2.4.4. Select Tenderers – this includes all activities associated with the confirmation that three/four tenderers have been selected from the initial list. Once the tenderers are pre-selected the final contract tender documents can be issued once they are prepared. They are not reliant on the tender list and can therefore be completed whilst the tender list is being prepared, although the IDEFØ model is unable to show this.

6.3.2.5 Prepare Tender Documents
The next activity to be broken down from the “Invite Tenders” activity is the “Prepare Tender Documents”. This includes all activities associated with the client preparing the necessary final tender documents for issue to the selected consortia/suppliers. This activity is broken into four sub-activities which can be carried out in parallel, although not shown in IDEFØ format, provided each area is the subject of a different department. Fig 6.9 shows the IDEFØ diagram.
6.3.2.5.1 Prepare Technical Specification – This covers the preparation of all the associated technical documents such as scope of work, material specification, site plans, soil surveys (if completed), product quality, etc.

6.3.2.5.2 Prepare Contract Terms – This series of activities cover the preparation of terms such as form of contract, payment schedules, contract references, bonds etc. The terms could be either based on a standard set of terms such as ICE 7th Edition, FIDIC or alternatively an individual purpose set of terms could be developed.

6.3.2.5.3 Prepare Outline Programme – This is the preparation of an outline programme with key milestones shown and would include such dates as “Notice to Proceed”, “Start on Site”, “Final Completion.”

6.3.2.5.4 Prepare Commercial Specification – This is all of the activities involved in the preparation of the commercial aspects associated with the contract and could include such items as Bills of Quantities, Schedule of Rates.

This completes the drill down on the key activity “Invite Tenders” and following completion, the tender document is available and has been issued to the preferred consortia/suppliers. The second of the key activities namely “Prepare Tenders” is broken down into its sub-activities and tasks.
6.3.2.6 Prepare Tenders

This principal activity is divided into four key activities and is led by the contractor who develops his/her own project team. The contractor takes the tender documents and issues a tender offer. The breakdown of this activity is shown in Fig 6.10. The key input into these series of activities is the tender documents received from the Client. Whilst the key output is the tender offers from each of the tendering consortia/suppliers. There are some internal inputs and outputs which are required to enable the tender offer to be put together.

From the IDEF0 diagram in Figure 6.10 showing Prepare Tenders the four key sub-activities are:

6.3.2.6.1 Identify and appoint team

The key activity encompasses all the tasks associated with identifying and appointing a team who can develop the tender document into the tender offer. This would include in-house resources such as a project manager; commercial and engineering support staff also out-house resources such as material suppliers, specialist sub-contractors all of whom can contribute to the output of the team. The key inputs are the tender documents, the key output being a potential clarification, a team list and action plan. The mechanisms are the in-house procedures and suppliers resources whilst the controls are the consortia/suppliers business plan, the timescale, the site constraints and the resource availability.

6.3.2.6.2 Develop Conceptual Design

This activity includes all tasks associated with developing an outline design in response to the tender documents. As consortia/suppliers are identified in the previous set of activities their ideas can be included into the proposed design scheme. The key inputs are the team list and action plan, the key output being the
scheme design. The mechanisms are the supplier's resources and computer hardware and software and the controls being the site constraints, the codal constraints, the material constraints and the resource constraints.

6.3.2.6.3 Estimate Cost
This activity includes all the tasks associated with estimating the likely cost of the scheme outlined in the previous activity. At this stage a net cost model should be developed alongside an agreed team contract strategy e.g. profit and risk share, sub-contract etc. The key inputs into this activity are the scheme design and productivity data, whilst the key output is the cost model. The mechanisms are the consortia/supplier's resources and computer hardware and software whilst the controls are the site constraints, the timescale and the business constraints.

6.3.2.6.4 Prepare Offer
This activity includes all of the tasks associated with taking the cost model produced in the previous activity and developing a tender offer, ensuring the selection criteria are all met. This will include an assessment of the contract risks associated with the project and how the risks will be mitigated. The key input is the cost model, the key output being the tender offer. The mechanisms are consortia/supplier's resources and computer hardware and software whilst the controls are the timescale, the resource availability and the business constraints.

Each of these sub-activities are then broken down further, each having their own IDEF0 diagram. The key activity of “Prepare Tenders” is broken right down to its lowest levels of tasks as shown in the node diagram in Fig. 6.4 starting with the activity “Identify and appoint team”.

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Fig. 6.11 Node 2.1 Identify and Appoint Team
6.3.2.7 Identify and Appoint Team

These series of activities are a combination of all the tasks associated with the identification and appointment of the consortia/supplier's team. This is broken down into four tasks as shown on Fig. 6.11.

6.3.2.7.1 Initial Review of Tender Documents

The initial review of tender documents includes all tasks associated with the receipt of documents into the organisation through to the preparation of an initial action plan for the project tender. The key inputs are the tender documents, the key output being the action plan and the project needs. The mechanisms are the supplier's resources and in-house procedures and the controls are the client's needs, the business plan and the timescale.

6.3.2.7.2 Identify Key Team Members

Once the tender documents are reviewed the team members are identified both available within the contractor's organisation and within sub-suppliers. Associated checks on their availabilities will be completed. The key inputs are the project needs and the action plan, the key output being the tender documentation. The mechanisms are the supplier's resources and in-house procedures and the controls are the timescale, the resource availability, the team abilities and the business plan.

6.3.2.7.3 Appoint Team Members

Once the members are identified along with their availabilities it is then possible to appoint them to the project team. The key inputs are the prospective team list, the key output being the team list and a modified action plan. The mechanisms are the suppliers resources and in-house procedures and the controls the resource availability, the timescale and the team abilities.
Fig. 6.12 – Node 2.1.1 – Initial Review Tender Documents
6.3.2.7.4 Detailed Review of Tender Documents
This is all of the tasks associated with a detailed review by the appointed supplier’s team of the submitted tender documents. Led by the supplier’s project champion, the key inputs are the modified action plan and the team list, the key output being the team list and a modified action plan. The mechanisms are the suppliers resources and in-house procedures and the controls Resource availability, the timescale and the resource ability.

These tasks are then broken down even further, starting with Initial Review of Tender Documents and a separate document prepared.

6.3.2.8 Initial Review of Tender Documents
The initial review of tender documents covers all the tasks associated with the receipt of the documents right through to the preparation of an action plan to deal with the tender. The activity is split into smaller tasks as shown in Fig.6.12. Fig.6.12 shows that the IDEFØ diagram is broken down into sub-tasks as follows:

6.3.2.8.1 Receive Documents and Appoint Project Champion
The document will be received into the offices of each of the tenderers offices, the senior management dealing with the tender will carry out an assessment of resources and appoint a proposal champion from their organisation to manage the tender through to issue. The key inputs are the tender documents and a potential resource list, the key output being the tender documents and a letter of appointment. The mechanisms are the supplier’s management resources and the controls are the resource availability, the client’s constraints and business restraints.
6.3.2.8.2 Identify Key Requirements

Once appointed the proposal champion shall carry out a quick overview of the document to identify the key issues about the tender. This would include programme, overall scope, specific risks, ground conditions etc. The aim would be to give the senior management an outline view. The key inputs are the tender documents and a letter of appointment, the key output being a requirement’s report. The mechanisms are the supplier’s project champion and the controls are the timescale, the site limitations, the client’s limitations, the cost limitations and the business limitations.

6.3.2.8.3 Decide to bid/not bid

Based on the key requirements a decision would be made by senior management whether to bid or not to bid. Whilst in most cases, having pre-qualified, the decision would almost certainly to bid sometimes circumstances such as workload, staffing, inappropriate tender/project could affect the contractor’s ability to produce a competitive tender. The key inputs are the requirement’s report and the tender documents, the key output being the project list.

The mechanisms are the supplier’s management resources, the project champion and a weekly review meeting and the controls the business limitations, the timescale and the cost limitations.

6.3.2.8.4 Prepare Initial Action Plan

Once the decision is made to bid, the proposal champion would then identify and develop an initial action plan. The key inputs are the project list, the key output being an action plan. The mechanisms are the project champion and the controls the timescale, the site limitations, the client limitations, the cost limitations and the business limitations.
6.3.2.9 Identify Key Members

This activity deals with all aspects of the identification of the key members of the project team. This will include personnel inside the contractor’s organisation, which may be as assessment of the common resource pool. Similarly resources external to the contractor’s organisation will be identified as this stage. This will include specialist suppliers such as piling contractors, material suppliers, lawyers, etc. Fig.6.13 shows the IDEFØ model for Node 2.1.2 which is simply broken down into two activities, namely identify internal resources and external resources. Other areas are similarly broken down, for example:
6.3.2.10 Detailed Review of Tender Documents

This task incorporates all the sub-tasks associated with a detailed review by the contractor of the tender documents. This can only occur once the members are identified and appointed to the team. This sub-activity will include all tasks associated with the development of an action plan to allow the tender proposal to be prepared.

6.3.2.11 Complete Conceptual Design

This sub-activity includes all of the tasks and sub-tasks that take place in developing a conceptual design solution to submit as part of the tender proposal. The sub-activity is split into 3 tasks, some of which are broken down further into sub-tasks and are shown on Fig. 6.14. As shown in Fig.6.14, the task of Complete Conceptual Design is further sub-divided as detailed below:
Fig. 6.14 – Node 2.2 Complete Conceptual Design
6.3.2.11.1 Identify Possible Solutions
The first task is to identify solutions that meet the client’s tender documents. This task would produce a design brief for 3 – 4 possible solutions, some of which could be developed further, whilst others will be discarded. The key inputs are the tender documents and the action plan, the key outputs being the conceptual design options and the conceptual design brief. The mechanisms are the supplier’s team resources and the consortia/supplier project champion and the controls are the site limitations, the codal constraints, the client’s constraints and the material constraints.

6.3.2.11.2 Develop Possible Solutions
Each of the possible solutions identified in the previous task should be developed further to enable a selection process to be carried out. This consists of the conceptual design process from all disciplines. The output of the task is an outline design that will have sufficient detail to enable basic cost estimates to be prepared and the analysis of costs and benefits to be carried out. The key inputs are the conceptual design options and the conceptual design brief, the key output being the designed sizes and materials. The mechanisms are the consortia/suppliers team resources, the project champion and computer hardware and software and the controls site limitations, the codal constraints, the client’s constraints, the business constraints, the timescale and the material constraints.

6.3.2.11.3 Select Design Options
This task is to select the scheme that meets the client’s requirements identified in the tender documents. This task will be divided into sub-tasks that include the preparation of estimates, the analysis of the costs and benefits of each scheme. The key inputs are the designed sizes and materials, the key output being the preferred scheme design. The mechanisms are the consortia/suppliers resources and the
project champion whilst the controls will be the timescale, the business limitations and the financial budget.

6.3.2.12 Identify Possible Solutions
This task which is part of the previous parent IDEF0 diagram shown in Fig. 6.14 contains all of the sub-tasks required to produce a broad list of possible solutions that meet the Clients tender requirements. The task is divided into sub-tasks as shown in figure 6.15.
6.3.2.12.1 Brainstorming Meeting

The purpose of this meeting is to produce an extensive list of options that meet the client's requirements. At this stage none of the ideas should be discarded and all of the consortia-suppliers team members should have an involvement in the meeting. The input to this task is the tender documents and the team list, the key output being an unlimited set of options.

6.3.2.12.2 Review Outcome

The output of the brainstorming meeting is reviewed at this stage and each solution categorised/prioritised against the client's requirements. At this stage some of the options may be discarded and the best 3 options would be selected for further development.

6.3.2.12.3 Prepare Design Brief

Once the best 3 options are chosen, a conceptual design brief should be prepared to enable the design team to develop the design further and obtain quantities that will allow an outline estimate to be prepared.

6.3.2.13 Develop Possible Solutions

This activity contains all the sub-activities and tasks associated with developing the solutions identified in node 2.2.1. and is shown in Fig. 6.14. The solutions require minimal sizing to enable comparative estimates to be prepared. The activity is divided into four sub-activities and shown in Fig 6.16. These could be extended as required to cover any amount of disciplines.
6.3.2.13.1 Prepare Conceptual Analysis
This sub-activity contains the task associated with the overall concept of the asset. This would include outlining the basic materials to be used. The inputs to this activity include the design brief and the resource list, the key output being a layout with major dimensions.

6.3.2.13.2 Prepare Civil and Structural Design
This sub-activity contains tasks associated with an asset's structure, foundation and façade. Only preliminary sizing is required. The sub-activity should have a conceptual loading diagram showing how the structure performs in resisting loads horizontal and vertical.

6.3.2.13.3 Prepare Architectural Design
This sub-activity contains all the tasks associated with the planned areas, basic dimensioning, material specifications, amenities such as toilets, fire escapes, access, etc. This will also include the visual concept to be adopted.

6.3.2.13.4 Prepare Services Design
This sub-activity contains all the tasks associated with the outline design of services such as heating, lighting, drainage, etc. The output should include sufficient detail to enable a cost estimate to be prepared.
Fig. 6.17 – Node 2.2.2.1 Prepare Conceptual Analysis
6.3.2.14 Prepare Conceptual Analysis

This sub-activity contains all the initial tasks associated with the identification, from the design brief, of key aspects that the client is aiming to achieve in the tender document. Shown in Fig. 6.17 the task is broken down into a series of smaller sub-tasks.

6.3.2.14.1 Identify Form and Materials

This task includes the identification of the potential form and materials to be used on the project and their specification and availability. This would include aspects such as external cladding, internal structure and finishes. The output would be the major dimensions.

6.3.2.14.2 Identify Structural Grid

This task includes the concept of how loads vertical and horizontal are resisted, the centres and locations of grids and the output being a conceptual structural layout showing the locations of the key members for the project.

6.3.2.14.3 Identify Key Areas

This task includes the identification of all key areas within an asset such as office space, toilet areas, corridors, staircases, lifts, service areas, common facilities depending upon the assets use.

6.3.2.14.4 Identify Key Environmental Data

This task includes the identification of key environmental data such as water quality, fuel supplies, ground data, rainfall, temperatures, wind directions, discharge consent levels.
Fig. 6.18 – Node 2.2.3 Select Design Options
6.3.2.15 Select Design Options
Fig. 6.18 shows the break down of the activities associated with the selection of the most appropriate design options.

6.3.2.15.1 Prepare outline cost Estimates
Includes all sub-tasks associated with the preparation of high level cost estimates based on the design options prepared in activity 2.2.2. The output of this task would be a cost estimate for each design option. The maximum variation of the cost estimates at this stage would be ± 20%.

6.3.2.15.2 Analyse Cost/Benefits of Design Options
Includes the activities associated with analysing the cost benefits and other benefits associated with each design solution. The output of this task would be a list of benefits associated with each scheme. This should also include a risk register associated with each scheme.

6.3.2.15.3 Review Analysis and Select Option
Includes all of the activities associated with reviewing the data prepared above and then selection the most appropriate option to develop further. At this stage further reference should be made to the client’s requirements.

6.3.2.16 Estimate Costs
This set of activities is associated with developing the costs for the chosen scheme. This includes an initial review of the selected design option to assess how the estimate of the scheme is to be prepared.
Fig 6.19 – Node 2.3 Estimate Costs
6.3.2.16.1 Review Design
This activity is a summary of all of the activities associated with a review of the selected design option by the estimating team. Undertaken to ensure that all aspects are completed to enable a detailed cost estimate to be prepared. At this stage the risks associated with the individual scheme should be assessed and wherever possible mitigated.

6.3.2.16.2 Identify Cost Parcels
This set of activities comprise the breakdown of the total proposed estimate into separate areas e.g. foundations, structure, services, etc. to provide traceability of the estimate. This enables separate estimates to be provided by each of the individual sub-suppliers into the main consortium.

6.3.2.16.3 Complete Estimate
This set of activities comprise the preparation of the individual estimates including measurement of quantities, pricing of quantities, rates of manpower efficiency and manpower schedules.

6.3.2.16.4 Collate Estimating Data
This activity allows all of the previous activities to be brought together and summarised, either as a standard document (included in Consortium's quality procedures) or as required by the client in their form of tender submission documents.

6.3.2.17 Prepare Offer
These include all of the tasks associated with taking the basic estimate of quantities and producing the offer to the client. This includes the final assessment of risks, margin, contingency that should be included in the price. The four tasks could be carried out in parallel as they are independent of each other.
Fig. 6.20 – Node 2.4 Prepare Offer
6.3.2.17.1 Assess Risks
These are all of the tasks associated with the identification of risks to the consortium from submitting their tender offer. These should include technical risks such as ground conditions, commercial risks such as viability of the client, programme risk, etc. Each of the risks should also have a mitigation set against them and where appropriate a contingency or exclusion included in the tender document.

6.3.2.17.2 Assess Contingency
This is the task that sets the allowance in the final price to cover the risks and potential unforeseen circumstances that could result in a problem for the consortium during the execution phase of the project. Care is needed at this stage not to duplicate the contingencies of each individual member of the consortium.

6.3.2.17.3 Assess Margin
This is the task that sets the appropriate profit margin for the consortium based on the measurements taken, the design completed and the requirements of the individual members of the team. Care is needed at this stage not to duplicate the margins of each individual member of the consortium.

In the assessment of the margin all parties involved in the consortium should be involved and current workload should also be taken into account.

6.3.2.17.4 Collate Offer
This is the task associated with bringing together the final documents the client requires to be submitted. The documents will include technical details, commercial details, manpower forecasts and detailed planning schedule, organisation charts and consortium agreements etc.
6.3.2.18 Appraise Tenders

Fig. 6.21 shows the tasks associated with the tender appraisal process as carried out by the client. The consortia/suppliers are all involved at this stage and are allowed to present their offers.

6.3.2.18.1 Receive Offers

This would be the first stage in the tender appraisal process and would include all tasks associated with receiving the offers through an initial assessment to arranging the most suitable tender to present their offers.

6.3.2.18.2 Present Offers

This would include all activities associated with the short listed consortia supplier's team presenting the details of their respective offers. This will require the client to carry out sequential reviews and will cover a number of meetings.

6.3.2.18.3 Review Offers

Having listened to the presentations this activity would cover all aspects associated with a final review of all documentation received from the consortia/suppliers prior to selecting a successful tenderer.

6.3.2.18.4 Appoint Consortia/Supplier

This part of the process is all of the activities associated with the appointment of a contractor. This will probably encompass a final clarification meeting where the contracts are signed by the respective parties.
6.3.2.19 Present Offers

These are the tasks associated with each consortium team presenting their offers to the client and an offer summary being prepared by the client. At this stage all consortiums should be allowed to present their offer as generally with three companies, each offer will generally be different. The tasks will be carried out sequentially.
6.3.2.19.1 Present Consortium Offer 1 – 3
These are all the tasks associated with the presentation of each offer to the client. Generally this should be in the form of a meeting where each consortium outlines their schemes and the client could ask questions. A series of sub-meetings may be arranged to discuss specific topics such as technical, commercial, etc. At the completion of the review meeting a discussion paper should be prepared which sets out the aspects of the meeting and should be signed by the appropriate persons to signify approval.

6.3.2.19.2 Prepare Offer Summary
Once all of the consortiums have outlined their offers a document should be prepared by the client that summarises the three bids in terms of the criteria set out when preparing the tender documents.

6.3.2.20 Review Offers
This sequence of tasks allows the client and their advisors time to review and then to complete final negotiations prior to the placing of the contract.
Fig. 6.23 – Node 3.3 Review Offers
6.3.2.20.1 Analyse Offers
These are a series of tasks which analyses each offer in detail, scoring against pre-determined weighted criteria set at the initial stages of the tender preparation and against the client’s requirements. For example, a client may require that appearance is the number one criteria for selection and cost the third most important criteria, this should be reflected in the analysis.

6.3.2.20.2 Select Preferred Consortia
Once the results of the offer analysis are completed a preferred consortium could be selected. These activities could be completed almost at financial closure of the offers, however the client may wish to keep their options open and negotiate with all three consortia. Clearly the greater the number of consortium left at this stage the longer the process, however the client may feel the loss of competitive edge may have a detrimental effect on the overall price of the facility.

6.3.2.20.3 Negotiate with Preferred Consortium
These are all of the tasks associated with negotiations to determine the exact contract value for what product. These will involve several meetings between the client, their advisors and the consortium and should be carried out on an open book basis to help build trust between the parties. The outcome of this task should be an agreement between the two parties that sets the stage for the ongoing development of the project.
6.3.2.21 Complete Concurrent Detailed Design
This is the last of the key activities shown in the Level 1.0 IDEF0 diagram. This major function is decomposed into four key activity areas from confirming the successful consortium/supplier design through to the completion of the detailed design.

Whilst the activities are shown independent from areas such as construction these will inevitably overlap to assist in the reduction of the overall project timescale. Fig.6.24 shows how the activity is broken down into its separate sub-activities. The key area is not broken down into lower level tasks as this is subject to another research project [Waskett 1999 ].

6.3.2.21.1 Confirm Supplier Team
This includes all activities associated with the appointment of the key suppliers to the consortium team. This would include confirmation of key items such as price, timescale and technical requirements.

6.3.2.21.2 Review Conceptual Design
Once the consortium team is appointed the client, main supplier, designers and suppliers should meet to review the original conceptual design submitted as per the original tender. This review should also include an assessment of all the assumptions/risks associated with the tender. The output of this activity should be an improved concept design and a team action plan.

6.3.2.21.3 Plan Construction
At this point, before the detailed design is started the key construction activities are planned. This would be to enable suppliers and designers to confirm the methods of execution for the project and highlight any potential improvements that
could be made. All of the key players in the consortium would be involved and the output would be an outline project execution plan.

6.3.2.21.4 Complete Concurrent Detailed Design
This function contains all of the activities associated with the detailed multifunctional design carried out by all design disciplines in parallel. This stage is outside the scope of this thesis, as other researchers have addressed it [Waskett 1999].

6.4 Application of the Method
The proposed procurement model has been outlined in the previous section. The model is currently at a relatively high level and could be expanded to show further detail, however the aim of the research project was to develop a new procurement method, which has been achieved with the model as detailed. The adoption of the proposed model will give a significant improvement to the procurement of projects. The generic model could be adopted for all types of projects, for example, buildings, infrastructure, process facilities, etc. and still allows the flexibility of each consortium and project to be taken into account.

The impact on the existing tender process is that the tendering timescales will probably be extended, which means the cost of tendering would probably increase due to the level of detail being prepared by each consortium. This is balanced by the reduction in the total project timescale and the number of unwarranted design changes, made possible by clearer definition of the client’s requirements, the earlier involvement of downstream participants and the collaborative approach to design development. An additional benefit is that the detailed tendering process will be focused on key suppliers who satisfy the original client’s pre-selection process.
6.5 Summary

The new procurement model has been outlined in this chapter based on the IDEFØ process modelling technique. The model starts at the stage where a neutral project specification is completed and finishes with the completion of the detailed design, prior to construction. Both of these boundary stages are influenced by the procurement stages although they have been excluded from this model. Similarly the stage development of the Concurrent Detail design has been the subject of other research [Waskett, 1999] and is only outlined as part of this model. With the new model planning the construction activities before the detailed concurrent design it allows the overlap between design and construction activities to be minimised to offer clients even greater benefits.

The differences between the existing and new procurement methods start at an early stage in the process by the adoption of the solution neutral project specification for determining the client’s requirements. This is one of the main inputs to the tender documents and then forces the pre-selected consortium to prepare a solution that meets those requirements as the basis of their tender submission. The consortium team is then developed at an early stage, including constructors and material suppliers, which again forces the outline concurrent design to take place with the involvement of those participants who will deliver the final product.

The new model concentrates its efforts where the impact is greatest for the consortia, around the preparation of the tenders. The new model could reduce the effort required by the construction team by the elimination of all but a select number of consortiums to the bid process. This could have a major impact on the costs of business for construction companies, as many companies are currently only one of 8-10 companies bidding for work.
The new model has been broken down to individual tasks that can be carried out in parallel and it is essential to evaluate the model in terms of the CE requirements, Egan’s improvements and against existing procurement methods. This will confirm the potential improvements to the construction process in terms of teamwork, early identification of problems and their solution, concurrent task completion and concurrent resource scheduling etc. It also shows the correlation of the method in terms of the improvements outlined in Egan [1998].
CHAPTER SEVEN

EVALUATION OF NEW PROCUREMENT METHOD

7.1 Introduction

Having developed the new procurement model this chapter assesses the differences and improvements offered by the new procurement method, developed in Chapter Six, against existing procurement methods, Concurrent Engineering principles and the improvements identified by Latham [1994] and Egan [1998]. This process was completed in two stages, the first stage being a study into the implications of the new model against CE principles, current methods of procurement and Egan's recommendations and the second being data obtained from an evaluation session involving a presentation to an audience of industry practitioners and the completion of a questionnaire.

In the previous chapters it was identified that the new model would be successful if it offered improvements to the overall construction process. To achieve a full evaluation it was felt that a comparison with existing procurement methods and against CE principles was the best way of initially testing the improvements. The CE principles [Prasad, 1996] were set out in Chapter Two and in this chapter the new model is assessed against those principles. Similarly the assessment on existing procurement methods is based on Table 3.1 and the improvements that the Egan Task Force [1998] recommended.

7.2 Assessment against CE Principles

Assessing how the new method compares with the CE principles identified by Prasad [1996] and described in Chapter Two, Table 3.1 which shows how the current procurement methods in use in the UK construction industry utilise CE principles is modified based on a subjective assessment, to show the new method
only. Detailed consideration of each of the principles is then listed and the extent to which the new method achieves the principles is described.

![Table 7.1 - Comparison of New Method against CE Requirements](image)

<table>
<thead>
<tr>
<th>CE Requirement</th>
<th>Proposed New Method</th>
<th>Traditional Design &amp; Build</th>
<th>Management Contracting</th>
<th>Partnering</th>
<th>PFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consideration of Life-Cycle issues</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Integration of all parties at early stages of project</td>
<td>H</td>
<td>0</td>
<td>M</td>
<td>0</td>
<td>M</td>
</tr>
<tr>
<td>Focus on Client's Requirements</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Continuous Process Improvement</td>
<td>M</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>M</td>
</tr>
<tr>
<td>Minimisation of Interfaces</td>
<td>H</td>
<td>0</td>
<td>L</td>
<td>0</td>
<td>M</td>
</tr>
<tr>
<td>Minimisation of Capital Cost</td>
<td>M</td>
<td>L</td>
<td>0</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Minimisation of Timescale</td>
<td>M</td>
<td>0</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Continuous Product Improvement</td>
<td>M</td>
<td>0</td>
<td>L</td>
<td>0</td>
<td>L</td>
</tr>
<tr>
<td>Concurrent Processing</td>
<td>H</td>
<td>0</td>
<td>L</td>
<td>0</td>
<td>L</td>
</tr>
</tbody>
</table>

Key  
0 = None, L = Low (Score 1), M = Medium(Score 3), H= High(score 5)

The way in which the model addresses the requirements of CE [Prasad 1996] are discussed further in the following sections.
7.2.1 Consideration of Life-Cycle issues

In the new method Life-cycle issues are considered at the early stages by the client and included in the Neutral Project Specification shown as an input to node 1.1 in Fig. 6.6 (which is a major part of the tender documents). Specific requirements are included to cover important aspects such as durability, ease of maintenance, sustainability, all of which are then assessed as part of the tender process, as shown in Fig. 6.21. This forces all of the potential suppliers to assess Life-Cycle issues and ensure that their tender offer, including Life-Cycle costs are taken into account.

Currently only PFI has the ability to consider Life-Cycle costs by the nature of the contract terms. However with PFI, Life-Cycle costs are not considered by the end client but by the contractor who is developing the facility. This usually results in life-cycle issues being considered during the implementation stages when budgets and design details have been finalised. Also recent Government decisions on PFI have led to potential cost increases for the downstream operations of a PFI contractor [Building April 2002]. With the remaining means of procurement, such as Traditional and Design and Build, and the limitations on the contract terms there is usually little incentive with these methods to either consider or minimise life-cycle costs. In many projects the ongoing maintenance works can result in a more lucrative long term maintenance contract placed by a client towards the end of the development phase of a project.

The consideration of life-cycle issues at an early stage in the project also results in an integrated project team at an early stage, as recommended by Egan [1998]. The project team will consider the longer term implications of maintenance etc., at such an early stage of the project that design decisions can be made with allowance for these issues rather than being considered at too late a stage that the design cannot be changed without substantial cost and programme implications.
It also allows for the down stream processes and people to be more involved and aware of the design, construction and operation of the facility.

The assessment of the tender documents, which includes details of maintenance, durability issues, etc., will force the tenderers to address this key area as part of their submissions. Therefore the selection process will be based on these issues as well as the capital costs for the scheme, allowing the client to select the best long term value for money rather than just the lowest capital cost.

7.2.2 Integration of all parties at early stages of project

The new model integrates personnel at the earliest possible stage in a project's development. The client pre-selects suppliers at an early stage, shown as node 1.2 in Figure 6.6, without the suppliers committing substantial resources early in the tender process. The solution neutral project specifications that are the main focus of the tender documents do not include an outline design. This forces any member of a project team submitting a tender to develop an appropriate consortium to prepare a credible tender that meets the specification and therefore the client's requirements. The members of the consortia will include personnel with the necessary knowledge, experience and products that will meet the specification. The development of the consortia is shown in Figure 6.11 and is initiated by a review by the project champion to ensure that the most appropriate team members are selected for the tender submission. The early development of the team ensures that issues such as design, construction, and maintenance of the facility are considered at a time when decisions have a major impact on the down stream processes, and the submitted tender, but with little impact on the overall cost.

Clearly, the pre-selection criteria need to be clearly set out and the client needs to have a mechanism for grading the tender submissions to ensure the selected tenderers are the best in meeting the criteria for the project.
Only the PFI and design and build modes of procurement can offer the early involvement of parties to a project, however at the tender stage they are only likely to include an outline team that may include some designers and constructors but will exclude key suppliers and asset management planners.

The partnering method of procurement brings the parties together to work as a team, however this usually occurs after the tender selection process has occurred and a contractor is appointed. This leaves little potential for impact on the final product without substantial redesign, with resulting impact on cost and programme. The traditional and management contracting methods are adversarial methods where the design and construction teams are often seen as separate, leaving the client between the two parties.

The Egan improvements are addressed by a committed leadership within the consortia submitting a tender. This can also be stated for the separate parts to the consortia with each company’s management being involved from the start of the tender process. Also Egan recommends that the construction process relies on integrated teams and processes. Clearly this is the case, with a consortium developing a team, shown in Figure 6.11, comprising personnel involved with all aspects of the tender. This benefits all aspects of the project at an early stage, including construction, maintenance, etc. and gives all members of the consortia the opportunity to agree with the final tender submission.

7.2.3 Focus on Client’s Requirements

The key impact on this CE requirement is by the preparation of the solution neutral project specification before any design occurs, which forces the selected consortia to carry out a proportion of the design during the tender process. With the consortia’s project team developed at an early stage in both the tender preparation and concurrent detailed design stages, the team can come together and
review the client’s solution neutral project specification and focus throughout the tender process on those requirements. The focus on the clients requirements are maintained during the selection process by the assessment of each of the consortia’s tenders against the specification and pre-determined criteria. Once the contract is placed, the Clients and consortia team review the successful tender, as shown in Node 4.2 of Figure 6.24, to ensure all of the aspects of the neutral project specification have been covered. This is the opportunity for both the Clients and Consortia’s team to become integrated and therefore work together. The team will become focused as shown in Figure 2.5, with the client involved in the process throughout the project’s development. Once the two teams are integrated the emphasis is maintained on the final product rather than the individual aspects such as design or construction, therefore both teams work to a common goal reducing the adversarial impact of a project. The involvement of a client throughout the process was one area identified from the industry survey in Chapter Four as an improvement required on the existing procurement processes.

With all of the current project procurement methods a certain level of focus is retained on the clients requirements, however when other aspects such as integrated teams are considered, the focus on the client’s requirements are maintained as a single team rather than individually as the design team or the construction team.

The traditional and management contracting procurement strategies by their very nature allow the design to be completed with a strong focus on the clients requirements, however the contractor is interested in constructing the facility whilst maintaining the minimum of standards that are allowed by the client. Without the full involvement of the contractor in the early stages, as shown in the industry survey in Chapter Four, constructability issues are underestimated and frequently remain unresolved until they occur on site, resulting in increased costs.
and extended programmes, one of the major concerns expressed by Latham [1994] and Egan [1998] and also determined in the industry survey in Chapter Four.

One of the key Egan recommendations [1998] is to improve the focus on the client’s requirements. The proposed method achieves this directly in the ways identified above, but it also achieves an improvement by integrating the teams at the earliest possible moment and setting the quality targets as part of the neutral requirements specification.

7.2.4 Continuous Process Improvement

Continuous improvement of the process is achieved in the new model by pooling the resources and expertise of the team members early to work towards meeting the client’s requirements. This is reviewed at an early stage in the tender process as an input into the review meeting after the brainstorming meeting in Figure 6.15 and before a solution is identified that meets the client’s requirements. The early definition of the client’s requirements enables the consortia’s team to do their best to achieve a design solution within the available budget. The collaborative approach also encourages all participants to work together with other members and the client to improve the process and the project. With the introduction of feedback loops integrated into the process, shown in Figures 6.6, 6.22 and 6.24, project information is archived into a document vault, a series of reviews and best practice notes, issued following key stages of the project, ensures a mechanism exists for continuous improvement that allows all participants to benefit.

The responsibility for document retention from a project should generally lie with the successful consortia to complete as they are central to the construction industry and can benefit most from the learning. On an individual project however, the client should have access to the information vault. Other key areas such as tendered costs and programmes will be retained in the client’s own document
vault. Some clients may have a long-term requirement for the information; however, most clients will only have an irregular need to use the industry.

Most of the other methods have little incentive to improve the construction process. This is demonstrated by the lack of substantial change in the industry since the war years. Much discussion regularly occurs in the trade press [NCE, Civil Engineering, Building April 2002] that indicates that many companies still prefer the adversarial method of carrying out business, even following the recommendations from Latham [1994] and Egan [1998]. Egan has also recently published a further interim report on the industry confirming that some improvement has been made in the industry but not anywhere near the figures anticipated. Partnership only offers a potential for improvement by the nature of the mutual support for the individual companies involved in a project. Within a design and build project, and especially a turnkey project the contractor may choose to improve it’s own processes to reduce the overall cost, however it is unlikely that a client will benefit from a reduction in cost or timescale.

This area is another that Egan recommends as a key improvement to the construction industry and goes onto recommend that a project approach is adopted. This is the case with the new model as the full team is integrated at an early stage, with all parties inputting into the improvement and also benefiting from the learning developed as part of the project output. The issues are forced to occur by a need to continuously review and issue best practice notes.

7.2.5 Minimisation of Interfaces

In the new model the key interfaces between parties has changed from the current methods of project procurement as each consortium works as a team rather than individual firms. This is established at an early stage in the process, but includes the client once the successful consortium is chosen. Interface management is also
smoothed by the early involvement of the downstream participants and the concurrency of project stages. This is clearly established also during the latter stages as shown in Figure 6.24, where the construction activities are planned before the detailed design commences. This allows all parties to be involved and plan their activities to suit the final product, the constructed facility. Whilst the exact details have not been considered as part of this research, it is anticipated that each major party, client and consortia, will form a hub for its own activities, with spokes issuing from the centre to their respective teams. There will only be a single interface between the Client and each individual consortium.

Once an order is placed it is anticipated that the two hubs are amalgamated to form a single hub, called the Special Project Vehicle (SPV), as shown in Figure 6.24, with spokes issuing out to every party involved in the project. Therefore the relationships and interfaces are slightly different from the current methods. This offers an improvement over other methods by keeping the interfaces to a minimum and allows that interface to develop through the tender process and to easily develop further once the contract is awarded. The mechanism for bringing the two hubs together is the establishment of the SPV and a joint review meeting shown in Figure 6.24. This could be a virtual team, located in different parts of the world, although some form of formal arrangement will be required to determine and monitor it's success.

One of the great benefits of this approach is that the communications will be speeded up and the decision making process can be instantaneous, especially with modern communication networks such as teleconferencing, e-mail and conference phone calls and with the establishment of daily reviews the waiting for responses is minimised.
In assessing current methods it is clear that interfaces are not minimised, the traditional an management contracting methods for a small project has a minimum of three interfaces, two of which are direct, one indirect and unless the client allows direct communication, the decision making process can become prolonged. Even then, if a commercial decision has to be made following a technical review then this process can frequently cause delays. Partnering and PFI are the only methods that can offer similar benefits, if the process is set up correctly. The design and build method retains two separate communication hubs throughout the project linked through the design and build contractor and the client. This can make the interface difficult as the contractor can have a different view on the project than both the designer and the client. Therefore the interfaces remain in the same state as the traditional methods.

Egan recommends Partnering the Supply Chain and Integrated Processes and teams as a means of improving interfaces. This will be achieved by the new method as discussed above as effectively once the team is fully integrated within the SPV the supply chain for the project is a ‘wheel’ rather than a ‘chain’

7.2.6 Minimisation of Capital Cost

The capital cost of a project is seen as the number one priority in the selection of both schemes and contractors as shown in Chapter Four. The new model forces the client to set their budget for the project as a target cost to be included as part of the tender documents. This then ensures that the tenderers work within this budget and that they take advantage of the early involvement of the downstream participants to minimize cost. The client must set the budget accurately and fairly, but, this could be in several forms, for example, total capital cost, a 25 year total life-cycle cost, or a cost per unit of product produced by the facility. With the budget set there is scope for the participants to the project, including the client, to reach an agreement on how any cost savings against the target cost would be
shared. This serves as an incentive for all members of the consortium to minimise costs, and with the early involvement of all parties in the consortium it is carried out early in the process and not during the latter stages when the budget is close to being exceeded and the construction is partially complete.

This has the advantage over current procurement methods in that the basis of selecting the most appropriate cost is on best scheme for the budget set by the client as a target for the consortia to achieve and by including a mechanism for saving costs. For the traditional, management contracting and design and build methods the lowest tendered cost is selected with little incentive to minimise costs, in fact many contracts are let where contractors minimise their profit margin to win the work, knowing that there will be further profit to be achieved by the extra work to be completed through the construction process. With PFI, because the costs and payments are spread over a predetermined period the effect of cost is probably seen as nominal, however, if a scheme is selected on a determined payment per year and the capital costs are exceeded it is usually the downstream processes that are affected, for example operation or maintenance staff can be minimised. Partnering does make some effort to achieve the same aims, but with the involvement of all parties not occurring until later in the construction process, some of the downstream participants do not have the motivation nor the time to assess reducing costs.

The benefits of adopting this approach is seen as helping to achieve many of Egan’s recommendations such as customer focus, partnering the supply chain, and product development with the incentive on all participants to reduce costs from the budget figure.
7.2.7 Minimisation of Timescale

Two of the key parts in the new model is firstly the setting of the clients' requirements in the solution neutral project specification and secondly the early involvement of downstream participants in the tender stage. This allows the planning of construction activities to minimise dependencies and to maximise concurrency. This is also followed through into the implementation stage, shown in Figure 6.24, where all the participants, including the client and the designers, plan the construction activities before the detailed design commences. This reduces the uncertainty and delays on site in an attempt to clarify requirements or specifications.

With the breakdown of the activities shown in the new process model, the interdependency of activities has been minimised and the activities and tasks overlapped wherever possible.

This has many benefits over the current methods of procurement where high level tasks such as design or construction are seen as totally independent, as in the traditional and management contracting methods. Here a large proportion of design is completed before construction activities are even considered leading to downstream delays in clarification of design intent. Design and build has an advantage over the traditional method in that the design and construction teams are integrated into one team, but the process is still carried out in a series of sequential operations and with the minimum of client improvement. Partnering is carried out in a similar way to the traditional method in that operations are sequential and construction is not planned until the design is completed, therefore there is little effort used to reduce the timing of downstream activities.

In a similar way that minimisation of cost achieves some of the Egan recommendations, the same can be said about the minimisation of timescale.
7.2.8 Continuous Product Improvement

This area is similar to the continuous process improvement with the feedback loops shown in Figures 6.6, 6.22 and 6.24, this forms a mechanism for continuous improvement. It is in the supplier's and the industry's best interests to retain the benefits with the supplier as primarily they are responsible for the product delivery. However, some clients, for example Government, Local Authorities and some larger private sector companies with a long-term investment programme will have a requirement for improvement and therefore will have an interest in the benefits of this approach. It is clear that as well as including feedback loops it is an integral part of the process that these potential improvements are reviewed as part of the process of the next project, as shown in Figure 6.15. With the learning set in the supplier's product and process it ensures that the client with a one-off project also benefits from the improved methods. One of the clear benefits of the product review is that the final product will always improve and therefore provide other benefits in terms of cost and timescale reductions that are real and achievable and also reduced life-cycle costs by the benefit of reduced maintenance.

7.2.9 Concurrent Processing

This area of CE is addressed in the new model by the minimisation of timescales and the early involvement of downstream participants in the process. This allows, at an early stage, the dependencies between activities to be reduced with the full agreement of all participants therefore allowing the concurrent processing of tasks. With the review of construction before detailed design commences shown in Figure 6.24, this forces the project team to allow concurrent processing of design and construction activities, with the design focus aimed primarily at the critical construction activities and not just producing their individual design product for
the construction team to build. This review also ensures that the downstream activities are carried out in parallel where possible again with the agreement of all parties to the contract.

As for the minimisation of timescales, certain tasks are dependent; they rely on the completion of one task before starting the next. Alternatively, others are independent and do not rely on the outputs of other activities. In the new model the tasks are paralleled as much as possible. This is not evident on the IDEFØ model as the representation format does not readily allow timescale to be shown but with the development of a simple bar programme, it is clear that the impact of reducing dependencies has a large potential for the minimisation of project timescale. Individual activities are also carried out concurrently by having a full project team, with the consortium’s team developed at an early stage in the tender process and confirming their involvement once the project team is appointed. This also ensures that when the project moves from the appraisal stage to the implementation stage a seamless joint between the two stages occurs, where the individual sub-teams are led by participants in the tender process.

The advantages over the current methods of procurement are clear to see, the traditional and management contracting methods have a minimum of concurrent processing, the design is completed before the construction is planned leaving little scope for even the concurrent processing of downstream activities. The same can be said of the PFI and Partnering methods, however the Design and Build method will allow some concurrent processing providing the arrangement between the design and construction team is set an early stage in the process, however this is usually carried out with the minimal of involvement of the client.
This area also addresses Egan’s recommendations by forcing the integration of the processes and teams at such an early stage that the downstream benefits will automatically be realised.

7.3 Assessment Using other CE Goals and Objectives

In addition to the detailed CE requirements, Prasad [1996] also suggests that the following goals and objectives are an integral part of a project being developed using CE:

7.3.1 Early Problem Discovery and Decision Making

This is an integral part of the new model as shown in Figure 6.11 by the involvement of all the key players at an early stage in the process. The client’s team is involved in the early stages of tender document preparation, by the production of a design neutral project specification, and the supplier’s team is similarly established at an early stage in the tender preparation stage. Once a consortium receives notification of acceptance, following the pre-selection submission, they can start to assemble their team, prior to receiving the tender documents. During the tender process the consortium teams need to review early, as shown in Figure 6.11 to allow the discovery of any potential issues and, once identified, they can be resolved at an early stage. The benefit of carrying out this activity early in the process is evident in Figure 2.3 which shows that 60% of the possibilities of reducing the project cost occur during the tender process. It is therefore essential that participants of downstream activities are involved at the early stages of a project. Similarly the construction activities are pre-planned before design commences, as shown in Figure 6.24, which allows for any potential downstream problem activities to be addressed at the design stage and not the construction stage.
7.3.2 Work Structuring

This area is improved by the early involvement of both teams allowing tasks to be performed in parallel. As part of the new models development the tasks have been broken down into their basic form therefore reducing the dependency on other tasks. The reduction of dependency between tasks allows tasks to be completed in parallel. With the involvement of the key people at the tender stage the downstream work structure can be thought out at an early stage, as the estimate is prepared and reviewed once an order is placed.

7.3.3 Teamwork Affinity

This is achieved in the new model through the early involvement of all parties in each team, as described in earlier sections. The client's team is formed at an early stage in the process; similarly the supplier's team is established at an early stage. The new model shows that the team has a clear direction and each member of the team focuses on their part of the product development, not as an independent member, but as part of the larger team. This is achieved through the major part of the full team being developed at the tender stage across the broad range of activities allowing the tender to be developed in a collaborative manner. It is only in depth of resources that the team is increased at the implementation stage where the concurrent outline design is developed into the detailed design. This occurs at the establishment of the SPV, the review of the outline design and the planning of the construction activities, as shown in figure 6.24, where time is allowed for the team to develop together. This sets the targets for collaboration teamwork at an early stage in the concurrent detailed design stage process and ensures that all parties to the final contract are involved in the process. Constant review of the progress towards delivery of the final product also allows the team to collaborate as a whole and to develop its own synergy.
7.3.4 Knowledge leverage
In the new model because each discipline is involved at an early stage their expertise can be used effectively to improve the overall project and give added value to the client. With the clear understanding of the clients requirements contained in the design neutral project specification, the pooling of expertise early in the project will result in better informed decision making and a reduction in uncertainties, all of which occurs without the construction activities having commenced.

7.3.4 Common Understanding, Ownership and Constancy of Purpose
This is created in the new model by the early involvement of all parties in the project. It follows that with the clear statement of client requirements at an early stage, followed by a continual focus on them throughout the assessment and concurrent detailed design stages leads to a greater understanding of the product the client requires. Couple this with the joint development of the outline design and tender submission, the consortium team can develop that common understanding and ownership of the product within their own team. This is developed further with the collaboration and integration between the two teams that will occur at the start of the concurrent design stage, shown in Figure 6.24. The review of and focus on the clients requirements throughout the concurrent design stages ensures that characteristics identified above will be continued throughout the implementation stage of a project.

The early involvement of the client’s team allows their own team to develop the design neutral project specification and focus on the final product. This is also achieved by the early selection of a preferred consortium list, ensuring that the numbers of consortia are minimised. The consortium team is established at an early stage in the tender process, including the majority of downstream participants, as shown in Figure 6.11 and the focus at this stage is clearly on the
production of an outline concurrent design, complete with tender submission that meets the client’s requirements in terms of cost, programme and product quality.

Through regular reviews in the tender process, the focus on the principles above and the project goals are retained. The reviews between the client and the consortium allow the ongoing relationship to be established. Once final selection is achieved the review of costs and technical aspects allows the smoothing of the interface between the two key parties.

7.3.6 Parallel Workgroups

This area of CE is addressed in the new model by the minimisation of timescales and the early involvement of downstream participants in the process. This allows, at an early stage, the activities and workgroups to work in parallel by allowing the concurrent processing of tasks. Even during the tender stages the consortium team complete much of their work in parallel, for example, in Figure 6.16, each of the design groups can work in parallel as the outline design solution has already been agreed previously. Similarly during the tender preparation the client’s team also works in parallel with the development of technical, commercial and contract terms and specification. With the review of construction before detailed design commences shown in Figure 6.24, this forces the project team to allow concurrent processing of design and construction activities and therefore parallel workgroups, with the previously agreed design and construction programme being the focus of the project team rather than the design team producing their individual design product for the construction team to build. This review ensures that the downstream activities are carried out in parallel where possible again with the agreement of all parties to the contract.
7.3.7 Parallel Product Decomposition and Resource Scheduling
With the process being developed using IDEF0 modelling, the overall product development process has been decomposed into individual tasks as shown by the node trees in Figures 6.3 and 6.4. The activities and tasks are then completed in parallel by the individual teams within the Clients and Consortium groups of resources wherever possible. It is essential that the requirements for members of the team are identified at an early stage, as shown in Figure 6.10 so that the team is established and working together from the start of the tender process. The activities of the individuals within the product or project development team are then overlapped as shown in Figures 6.16.

7.3.8 Concurrent Processing of Tasks
This area of CE is addressed in the new model by the minimisation of timescales and the early involvement of downstream participants in the process as detailed in section 7.2.9.

7.3.9 Transparent Communication
There is a substantial change in the order of communication within the project team. This is started with the clear and unambiguous statement of the clients requirements contained in the design neutral project specification rather than the reliance of an interpretation on the clients brief given by an Architect or Lead Consultant. Then with the development of a teamworking and collaborative approach to the project development shown in Figures 6.11 and 6.24 the interfaces and communication channels are well established at an early stage in the process and by the use of e-mail, daily teleconferences and faxes the time for communication can be reduced and become transparent. This allows for improved decision making, reducing waiting time and ensuring that the key decisions are dealt with at an early stage of the project. With each group having the key leaders being appointed at an early stage and remaining throughout the project a level of
continuity and control is also established. Proformas and protocols for communication can be similarly established by the client during the tender preparation stage and continued throughout the process that allows the process of communication to be smooth.

7.3.10 Quick Processing
This particular principle has a major impact on the overall process of procurement in terms of reducing project timescales. The clear definition at an early stage and the establishment of the decision making process at an early stage also reduces the time for processing decisions. Once the process has been decomposed to the individual tasks it is clear that the timescale of certain tasks can be reduced by the use of tools and design aids, e.g. estimating databases, design software, 3D product development using CAD, standard designs and/or details. However it is in establishing with all participants an agreed plan of action at an early stage, for example, an agreed outline design, shown in Figure 6.15 allowing the downstream outline possible design solutions, shown in Figure 6.16, to be completed in parallel. This is also continued throughout the new model, when in the concurrent detailed design phase, the construction is planned before the detailed design commences allowing design and construction activities to be processed in parallel and in a quick and deficient manner. This has a substantial benefit when used at the correct stage in the procurement process.

It is clear from the review of the principles above that the new procurement model utilises CE principles in the process especially by the earliest involvement of all parties to a contract. Constant review during the product development allows the focus to be retained on the client’s requirements.
7.4 Egan's Improvements [1998]

7.4.1 Key Improvement Drivers

The key improvement identified by Egan [1998] relate to the improvement in output of the Construction Industry in terms of client satisfaction and commercial profitability of suppliers. The aim in the report was to achieve a 10% reduction in timescale and costs and a reduction in defects by 20% per annum. The five key drivers for change recommended by Egan have been reviewed in the previous sections in terms of the new model, these were:

- Committed Leadership
- Customer Focus
- Integrated Processes and Teams
- Quality Driven Agenda
- Commitment to People

Only the commitment to people has not been directly discussed and is not directly relevant to the development of the new model. However empowering individual team members to be creative and innovative in proposing design solutions rather than being totally dependent upon lowest costs, gives the industry an opportunity to develop personnel to maximise their skills and knowledge. The conditions for employment improve for personnel with the collaborative nature of the working environment. This will indirectly improve the output of the industry in terms of reduced sickness, greater motivation for individuals.

Egan's task team also suggest that the following areas be addressed:

- **Integrated Process Improvements**

  The new model specifically addresses these issues early in the tender preparation by the development of the design neutral project specification, the early involvement of all participants involved in downstream processes and the constant review against the client's requirements.
• Product Development

This is addressed in the early stages of the new model as the client focuses on the assessment and pre-qualification of tenderers which are suitable to complete the project. This ensures that only the most suitable suppliers will be allowed to tender and only those with the necessary experience for the final product, the constructed facility, will become involved in the project. Once the consortia are pre-selected, the client will have a level of confidence that the companies used for the final product to be developed will have the necessary experience needed to implement the project successfully. It also ensures that inexperienced tenderers are excluded before extensive resources are committed. Current experiences by the author, and in the industry survey, of the pre-tender selection process indicates that it is used to identify as many potential suppliers that can be used to drive down the cost of a project, rather than selecting three or four high quality consortia and allowing them to work within the stated budget cost.

• Project Implementation

The new model focuses on project implementation from the onset rather than waiting until the design is ongoing, as in many forms of existing procurement. The new model ensures that the early involvement of key sub-suppliers occurs early in the tender process within the main supplier’s team. In the new model the implementation is considered alongside the design and estimating for the tender sum and the submission becomes a fully integrated solution that meets the client’s requirements.

The key decisions in the implementation process are considered at an early stage of the process and are confirmed just after contract award, thereby reducing overall timescales and ensuring the product can be delivered in terms of quality, timescale and cost.
• Partnering the Supply Chain

The new model allows partnering to occur with the early involvement of suppliers and sub-suppliers in an integrated team. Therefore the scene is set early with the supplier's team to work together. The contract terms and conditions however, need to reflect the common product ownership and any bonuses and shared profitability is reflected as a consortia team rather than supplier and sub-supplier. In the new model this occurs at the time prior to tenders being submitted, shown in Figure 6.20. In the new model the tenders and sub-tenders are open book and clearly show the extent of costs, overheads and profit. To allow the client to realise the benefits, the contracts would have some form of incentive by agreeing a mechanism where the consortia have to work at continuous improvement to gain an additional bonus.

In the implementation stages of a project it is essential that the clients and suppliers team become integrated. In the new model this is achieved by the development of an SPV, where all parties become shareholders of a company that is utilised for the development of a project, and a common review occurring between all parties once a contract is signed, as shown in Figure 6.24. It is essential that the project champions maintain the partnership focus throughout the product development process and that where necessary ongoing reviews occur between all parties.

• Production of components – The new model does not specifically address this issue, but by the early involvement in the supplier's team and by addressing the area at an early point in the implementation stage then an increasing amount of components can be developed off site and erected on site. The site then becomes the assembly line in terms of product development, similar to the manufacturing and house-building industries. This also has
secondary benefits by the potential improvement of safety, by the minimisation of work carried out on site and also will allow an improvement in product quality by greater control of components based offsite.

Egan [1998] also suggests that competitive tendering is replaced by long term relationships. This is acceptable with clients who have a long-term requirement, however most clients of the construction industry are only likely to contract suppliers on an infrequent basis. The new model benefits both types of client by a common process model which can be adopted and ensure that clients receive value for money rather than just the cheapest price. For an individual client, with the early rejection of the majority of potential suppliers, without the huge commitment of suppliers resources, this will ensure that the cost of carrying out construction business will reduce. This will have a longer term benefit for both clients and for construction companies.

Clearly each of the product development teams or consortiums will be focused on the delivery of their product to meet the client's requirements. The focus can be made sharper by the clear establishment of how the tender submissions will be assessed e.g. cost, quality of product, life-cycle issues, etc.

7.5 Summary

An assessment of the new procurement model against the previously identified CE principles [Prasad 1996], the current procurement methods and Egan improvements [1998] show that the new model encompasses all of the requirements, either directly or indirectly.

With the early establishment of the product development teams and the breakdown of activities to a series of independent tasks the principles of CE are clearly adopted. The task can clearly be carried out in parallel allowing a reduction in
timescale for procurement and subsequent downstream activities. With the emphasis on product development and quality the focus of the suppliers team is clearly on the client and their requirements.

Similarly in the assessment against the improvements identified by Egan [1998] the drivers and integrated process development are an integral part of the new model. The focus of the teams through the procurement process is the establishment and development of an agreement between the client and the supplier which forms the basis for all of the downstream activities. At the early stages the two development teams are working independently until the agreement is reached when the two teams lose their independency and become an integrated team and form a Special Project Vehicle (SPV).

The critical assessment of the proposed model using CE principles and goals, as well as Egan principles, demonstrates that it constitutes a significant improvement over existing methods. However, this was a fairly subjective evaluation and it was considered important to evaluate the new approach using an independent panel. The results of this evaluation are the subject of the next section.
7.6 Independent Evaluation of New Method

7.6.1 Introduction

This section is concerned with the evaluation of the new model outlined in Chapter Six. The methods of achieving some feedback from engineering participants are discussed and the reasons outlined for the specific method chosen. The reasons for each question are discussed together with the responses given by the group of people used in the trial. The overall view of the respondents was that the method would improve the procurement process for construction projects and several potential improvements were offered that would likely increase the improvements.

7.6.2 Evaluation Objectives

Once the new procurement model in Chapter Six was completed, it was essential to independently evaluate its appropriateness and the impact on the project procurement process. The initial review was carried out earlier in this chapter by reviewing the new model against the current methods of procurement, CE principles and against the recommendations identified in Egan's report [1998]. This confirmed that the model met each of the three sets of criteria; however, it was essential that an independent evaluation was conducted that would confirm the earlier findings.

The aim of the independent evaluation was therefore to confirm that the new model met the requirements of CE and offered the construction industry the potential to improve.

This was separated into two key objectives:

▶ How well does the new model meet the requirements of CE principles?
▶ Will the new model improve the existing procurement process and therefore improve the output of the construction industry.
It was essential therefore with the objectives set, that the method of evaluation involved the industry and that personnel involved had considerable experience in construction, an understanding of the problems and had some knowledge of CE.

7.6.3 Evaluation Methods
As described in Chapter Four there are a considerable number of methods available for completing an evaluation [Evaluation Associates, 1997 and Learning Technology Dissemination Initiative, 1999, Saunders et al 1995, Helberg 1995, Graham 2000] but in a similar nature to the earlier questionnaire the general aim was to gain broad opinions about the impact of the new method and to highlight areas where further development would improve the process.

The methods considered were:

➤ **Trial Projects or Case Studies**—The method of using trial projects or case study is a method that offers direct and probably the most detailed feedback from projects being progressed, where the benefits of utilising the new method can be directly compared with the current status of the industry. The method requires a substantial resource input due to parallel systems being used on the same project followed by an assessment being made at the end. The timescale of trial projects is quite lengthy and would require several suitable projects from a broad range each with several participants involved e.g. client, consultant, contractor and material suppliers. The major benefit of this method is the extent of the feedback obtained. However, the major drawback for this evaluation is the substantial resources and timescale required.

➤ **Questionnaire**—This method would involve specific questions tailored to suit the needs of the model, CE and the improvements the model offered. The questions would guide the respondents about their understanding of the model and the responses would be easily collated, reviewed and discussed. The questionnaire
approach to be used could be either anonymous, sent via the post, part of a one to one interview, a telephone interview, or part of a structured presentation to an invited audience. The package of information to be sent to the respondents could be substantial and could lead to misunderstanding and would require the respondent to use a substantial amount of their time in completing the questions. Also previous experience [Bowron 1998, Saunders et al 1995, and Som 1973] indicates that the response rate can be quite low.

➢ **Presentation to a Selective Audience with an Evaluation Questionnaire** – This method would be a combination of methods and would utilise a presentation, produced by the author as a way of transferring the knowledge of the model to reach a multiple audience. The participants would then have a time to respond and then share their views through an evaluation questionnaire. The presentation would utilise current IT software packages of a laptop linked into an overhead projector. The audience would need to be broad based from all groups involved in the construction process to ensure an overall view of the industry was obtained.

➢ **Peer Review** – This method is similar to an interview, however, rather than there being a potential misunderstanding, the peer would have a level of knowledge about the subject and therefore could respond on behalf of the industry community. Similar to the questionnaire the extent of time involved would be substantial from both the author and the selected peers; however, the response would be tailored with the peer’s knowledge and experiences.

**7.6.4 Evaluation Procedure Adopted**
The method chosen to obtain views of the new procurement model was a combination of a presentation to a selected audience of engineering practitioners who would then complete an evaluation questionnaire.
This was chosen for the following reasons:

- Knowledge of subject would be up to date and relevant.
- Broad range of views obtained from different companies.
- Quick and directed feedback.
- Minimise disruption to respondents working commitments.

A presentation and questionnaire were prepared (in appendix Two and Three) and a meeting arranged to share the proposed new method of project procurement. In line with the general aims of the evaluation the aim of the presentation and the questionnaire was the following:

**Knowledge Transfer** – There was two aims in this area, namely to transfer information about the new model to the participants. The participants in return would be able to share feedback on the proposed method. This aim would also assess whether participants were aware of procurement issues and CE.

**Receive feedback** – to determine a broad range of views from different companies associated with the construction industry. The feedback was primarily arranged around the evaluation questionnaire which was designed in three sections. The first section was to determine general information about the respondents. The second section was used to determine specific views about the model and its use of CE and the potential improvements it offered the construction industry. The final section allowed the participants to share some general views about the new model.

**Obtain background information** – this was to ensure a broad range of participants were involved and responses gave substantiation to the model.
7.7 Detailed Results

The evaluation questionnaire was designed with three separate sections: the first was on background details of the respondents, including size of organisation and experience in the industry. The second section comprised details pertaining to the model and how it met specific criteria. The third section was aimed at obtaining the views of the respondents on how they felt that improvements could be made to the model. The number of respondents involved with the evaluation was thirteen.

7.7.1 Background Details

The first question was aimed at determining the type of business that respondents were involved with. The responses are summarised in table 7.2.

<table>
<thead>
<tr>
<th>Business Title</th>
<th>No. of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultant</td>
<td>2</td>
</tr>
<tr>
<td>Contractor</td>
<td>7</td>
</tr>
<tr>
<td>Researchers</td>
<td>4</td>
</tr>
</tbody>
</table>

This shows that the sample of people had a heavy bias towards the contracting area and that both the client and materials supplier's business area were not represented. This has had a substantial bearing on the results, with the bias being towards the contractor's viewpoint.

The next two questions in the organisational section were aimed at determining the size of the respondents' organisations in terms of turnover and numbers of people involved. The results from these questions exclude the researchers and are shown in Table 7.3 overleaf.
Table 7.3 – Summary of Organisation Size

<table>
<thead>
<tr>
<th>Average Turnover</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>£640 million</td>
<td>£200 - £1500 million</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Numbers of People</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>3250</td>
<td>200 – 9000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Turnover/Employee</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>£0.44 million per employee</td>
<td>£0.06 million - £1 million</td>
</tr>
</tbody>
</table>

This shows that depth and the range of contracting organisations involved in the evaluation process were broadly based. The average turnover per employee was greater than those used in the industry survey of industry practitioners contained in Chapter Four.

The next two questions in the organisational area were aimed at determining the level of responsibility and years of experience that the respondents had in the construction industry. This was to determine whether the respondents were sufficiently aware of the overall process of the construction industry. The level of responsibility was determined by the respondent’s position in the company, examples included:

- Project Engineer
- Head of Business Systems
- Improvement Manager
- Knowledge Manager
- Group Technical Manager

The number of years of experience in the industry varied between 4 and 30 years with an average of 18.3 years. This indicates that the respondents were reasonably senior and had adequate knowledge of the construction industry to participate in the evaluation.
The questionnaire then focused on the new procurement model and how it met the criteria of CE and how it was a potential improvement to the construction industry.

7.7.2 Evaluation of New Procurement Process Model

The evaluation process comprised a number of individual questions which were scored by each respondent between one and five with one being the lowest score and five being the highest:

**Question 1** – How well do you feel that the new model meets the aims of Concurrent Engineering? The average scored by the respondents was 3.86 which shows a greater than average view that the new model met the aims of CE.

**Question 2** – How well do you feel that the new model integrates the full team? The average score by the respondents was 3.86, which shows that generally the view was above average. There was a single respondent who felt the team was not fully integrated and gave a score of 2.

**Question 3** – How well does the new model promote ownership of the product development process? The average score by the respondents was 3.57, which was above average. Again a single respondent scored 2 feeling that the model did not quite promote ownership of the process.

**Question 4** – How well does the new model promote constancy of purpose for all members involved in the product development process? The average score was 3.57, which showed that the model allowed all members to be focused on the final product.

**Question 5** – Is the model organised to allow tasks to be performed in parallel? The average score was 3.14, which showed an above average opportunity in paralleling tasks.
Question 6 – *Will the use of the model improve a client’s perception of construction project procurement?* The average score for this question was 3.43 and one of the respondents responded positively but commented that “providing the client is intelligent with respect to the process.” This shows that the group as a whole felt that a client’s view of the industry would improve but this could improve further if the clients had knowledge of the process.

Question 7 – *Will the model improve the competitiveness of the construction industry?* The average score for this question was 3.29 with one respondent suggesting that there are too many other factors that impact on competitiveness.

Question 8 – *Will the model promote the early involvement of all team members including material suppliers such that they can impact and improve a project?* The average score for this question was 3.86 which showed high support that the model would promote the early involvement of all; however one respondent did feel the model was poor at promoting early involvement and scored 1, whilst two participants scored this question as 5 (excellent).

Question 9 – *How well will the model reduce interfaces between parties on the project team?* Again this question was aimed at a specific CE requirement and was scored as 2.57, which was slightly below average. One of the respondents commented that the reduction of interfaces depends on cultural issues and individuals.

Question 10 – *How well will the model promote communications between parties on the project team?* Again this question was aimed at a specific CE requirement and was scored as 3.0, which was average with a similar comment added as question 9 by the same person.
Question 11 – How well will the model reduce the overall timescale of projects? This question was aimed as support to question 5 about the paralleling of tasks. The two questions scored exactly the same at 3.14, above average, with a comment by one respondent that there was insufficient information to assess the overall impact.

Question 12 – How well will the new model improve the focus on product quality? The question scored 3.29, which showed an above average view that the focus would improve.

Question 13 – How well will the model allow for individual styles for each contractor to meet the overall product design? The average score for the question was 3.0 which was average.

Question 14 – How well will the model help to reduce project costs? This question scored above average at 3.14. However one respondent requested further information to assist in the decision process.

Question 15 – How well will the model reduce the cost of business for construction contractors? The score averaged at 3.0, above average and one respondent remarked that tender costs might increase.

Question 16 – How well do you think that early consideration of constructability issues are improved? The score average was 3.79 which was better than average. One respondent commented that suppliers need to be willing to allow this to work.

Question 17 – How easy did you understand the new model? This question was introduced to ensure that all participants understood the model as it was presented. The score averaged at 3.86, which showed an above average understanding.
Question 18 – *How useful do you think that the new model would be to the construction team?* This was scored at 3.77, which shows an above average view that the model would help to improve the industry.

Question 19 – *To what extent did you think the new model was an improvement?* – Again this question was aimed at to complement the previous question. This question was scored at 2.57 just below average, which is a reduced score from that recorded in the previous question.

Question 20 – *What is the overall rating for the new model?* This was the third in a series of questions aimed at determining the overall value of the new model and had an average score of 3.43 which suggests that the new model would be beneficial.

7.7.3 General Comments

There were two questions in this section to obtain views from the respondents for potential improvements to the model and also to pick up any additional comments pertaining to the presentation. All of the respondents commented in these areas and are summarised under the relevant questions below:

In what way do you think the model could be improved?

- Include relationships between team members at stages.
- Earlier integration of supply team and let them carry out design and have ownership.
- Different industries have different needs for the conceptual stages dependent upon the “one at” or repeat type of business they are in.
- Show the links between briefing and design – do not use IDEFØ.
- Review the Construction Design and Management element.
- From the brief presentation it is very difficult to offer an opinion.
The second question was for the respondents to include any other comments:

- Cause and Effect are difficult to assess as there are many other factors other than the process e.g. organisation, culture, resistance to change, competency of the “team”, etc.
- It looks similar to the ideas promoted in the Process Protocol but in IDEFO. I have found IDEFO is good as an analysis tool but not for communication where the matrix approach of the Process Protocol is better.
- Need to distinguish between design, technical and cost proposal.
- Model is similar to that currently used in many areas.
- Bidding costs go up due to more design input.
- Model needs to consider if client specifies design or is it an output specification.
- IDEFO modelling of business processes looks similar in many respects to how we do it. Some differences at the detail level where we would have more checks and balances with opportunity to stop/hold the project.
- This model seems to mirror our current processes for PFI, framework and prime contracting.

7.8 Commentary

After reviewing the evaluation questionnaires it is clear that overall the new model is perceived as an improvement on existing procurement methods. This is reflected in the average score of 3.33 across all of the questions and the responses received. There were some highlights and disappointments, which are discussed below.

Firstly the organisation details showed the extent of the respondents experience and the level of both their own positions and the company’s positions within the UK construction industry. The majority of the organisations were contractors from the top ten in the UK construction industry. Two companies offering consultancy services to the industry were
represented, however, two sectors of the supply chain were not represented namely clients and material suppliers. Both of these have a major impact on the construction process and their views are clearly unrepresented in the evaluation. With respect to the company's size, the turnover and manpower varied between a medium and large sized company. The turnover per employee was substantially greater for the medium sized company compared with the larger companies. This could be due to many factors such as the use of contract labour rather than in-house resources. The individuals who completed the questionnaire generally have in excess of 14 years experience in the industry and are in positions where they are involved with the overall construction process.

Secondly looking at the specific questions, these were organised in terms of the overall impact of the new model on the construction industry and its compliance with CE aims and principles. In both cases the overall view was that the model was beneficial to the construction industry and supported CE aims and principles although there were areas where improvements could be made.

With regards to the benefits to the construction industry only the overall improvement to the industry was seen as just being slightly above average. All of the other questions relating to the benefits to the industry were scored at an average value or above. Considering the improvements as being made up from reduced costs, reduced timescales and improved product quality, the specific questions relating to these areas scored between 3.14 and 3.29, which is above, average. A specific comment related directly to the costs of tendering suggesting that they would increase due to the increased design costs. This may be true, but the reduction in costs from clear definition of the client's requirements, the early involvement of downstream participants and the collaborative working in both the tender and detailed design stages would far offset this. In addition a reduction in tender costs could be achieved through reducing the tenderers down to three or four participants. The client reviews a substantial number of potential consortia at a very early stage in the process, without the contractor investing huge resources.
contractor knowing that the list of competition is only three or four for each project will be able to reduce overhead costs accordingly.

On the client’s perception, the respondents felt that their (clients) view would be improved by the use of the model subject to clients being intelligent about the process. In many cases clients are intelligent about the development of their projects, especially those who are heavily dependent upon the industry on a regular basis. Irregular users of the industry would need support in the use of the new model as they would with any process they use for the first time, however with the feedback into the consortium from previous projects the single client will also benefit from the improved processes and products. With regards to the competitiveness of the industry the potential for the model was felt to be above average. However another view was that there are other criteria that affect competitiveness. This view is valid as many soft issues such as personal interaction and company culture can have a significant effect on how a project is completed. Nevertheless if the product development team is integrated at an early stage, as required by the new model, with a common framework this will form the basis for success of the project.

With regard to CE and the aims and principles adopted in the new model it was generally felt by the respondents that the new model supported these aims. Specifically the questions focused around the involvement of the product development team and the paralleling of activities. The respondents felt that the team was well integrated at an early stage in the development process and that the model promoted ownership of the process and constancy of purpose amongst the team members. This is a key CE requirement that allows the focus on the product rather than on the individual companies’ aspirations for the project. In addition the early involvement of contractors and material suppliers allows constructability issues to be considered at an early stage in the development process, thereby saving time, effort and potential design and construction rework.
Many of the specific comments and potential improvements were related to omissions whilst others were about the process. Some comments such as the earlier integration of the supply chain are adequately provided for in the new model and would suggest that some respondents did not fully understand the new model.

Similarly, the link between briefing and design is shown in the model, although the term “Design Neutral Requirements Specification” is used instead of briefing (see Figure 6.6 in Chapter Six).

Some of the respondents suggested that the model was similar to other models. Indeed this is the case to some extent. However, as seen in earlier part of this chapter, the current procurement methods have their drawbacks with none of them fully supporting CE aims and principles. In particular, none of the models are based on a re-engineered briefing process, none of them allows for the tenders to be based on a requirements specification, none of them forces the integration of the team, including contractors and material suppliers at such an early stage, and none of them forces the ongoing client involvement beyond the contract award, all of which are key features of this new model.

7.9 Summary

In this section the new model has been successfully evaluated by a number of industry practitioners with extensive experience of the construction industry. The method chosen was through the combination of a presentation and an evaluation questionnaire.

In general, the respondents supported the new model in terms of benefits to the construction industry and the use of CE aims and principles although there were several areas of concern. In particular the sample of respondents was probably very narrow and the views from two sectors of the construction supply chain were not obtained.
CHAPTER EIGHT

SUMMARY AND CONCLUSIONS

8.1 Introduction
This final chapter reviews the original aims of the research project and assesses how the aims and objectives of the project have been met. The research work is firstly summarised based on the objectives and how they were achieved. The benefits of adopting the new model is discussed followed by the production of a series of conclusions based upon the work produced.

Following this, recommendations are made for further research in terms of procurement and it's interaction with CE and also of how further development of the new procurement model can be undertaken.

8.2 General Summary
The overall aim of the research project reported in this thesis was to develop a new procurement method for construction projects based on Concurrent Engineering principles. The basis of the model was to enable the effective implementation of CE in construction. The reason for the research was that several recent studies had indicated that the industry was failing its clients and also seen as a poor investment by the City. The industry was seen as fragmented and reliant on old methods of project procurement that were adversarial in their nature. Many of the problems can be associated with the compartmentalisation of individual groups within the industry which lead to a lack of consideration of downstream project activities.

The adoption of Concurrent Engineering aims and principles are seen as a mechanism that will allow the industry to realise some of the potential improvements to be made. To achieve concurrency in the construction industry requires a total change in the way projects are procured from clients briefing
through to the detailed design and construction. This thesis described the way in which the new procurement model would assist in achieving these aims. The way in which the project specific objectives were achieved is discussed below:

a) **Review methods of project procurement in current use in the UK.** This area of research was to identify the common procurement methods in use and to identify the strengths and weaknesses of each method. This was completed in Chapter Three where the main methods and their benefits and pitfalls were discussed. The requirements’ of a procurement method utilising CE was identified alongside the potential benefits of adopting a procurement method using CE aims and principles. Examples of the adoption of CE in the manufacturing industry were discussed and showed how a total stepped change was necessary to realise the full CE potential. This clearly showed that there are benefits to be gained by the adoption of CE through developing a new procurement model. Finally the requirements of a new procurement model were outlined. An additional objective was to obtain a cross section of current views on the use of the different procurement methods. This was to establish the level of current use of the different procurement methods and to assess the involvement of each part in the different stages of the project process. Views were also obtained about the success of each method in delivering projects to time, cost and quality constraints. This was completed using a questionnaire which was randomly issued to participants from the industry. The results were discussed in Chapter 4.

The key findings of the survey were:

- The traditional method was still the most popular method of procurement (40%). This was followed by Design and Build (25%), Management Contracting (20%) and Long term contracts (15%).
The emerging more collaborative methods of procurement such as PFI, Partnering and long term contracts represented approximately 25% of all procurement methods.

There is still considerable scope for improvement, with over 30% of projects reported over budget and about 40% of projects running late.

The level of satisfaction with the current processes was quite low, all participants expressing views that contractors should be involved much earlier in the process and client's involvement should continue until handover.

The findings from the survey confirm the views of previous reports [Egan 1998, Latham 1994] and can be used as a basis to improve the procurement process in the construction industry. However the response rate for questionnaire returns was disappointing. The questionnaire was mailed directly to three types of organisations, including a stamped addressed envelope for the return questionnaire. It is likely that timing, understanding of the questionnaire and its subject probably had an adverse effect on the response rate. With the improved levels of e-mails the author would probably consider a modified strategy for the collection of broad based data. The findings of the survey fed directly into the development of the new procurement method where the early involvement of construction personnel and the continued client support were seen as essential requirements for the new model.

b) Review the use of Concurrent Engineering (CE) in construction and other industries to determine any potential synergies between the processes and organisations of other industries with that of the construction industry. This was to review the principles of Concurrent Engineering and to determine whether any lessons could be learnt from the manufacturing sector. This was discussed in Chapter Two and the findings can be summarized as follows:
➢ CE has benefited the manufacturing industry, especially in the procurement of new products.
➢ The construction industry has seen little evidence of the adoption of CE.
➢ There is the potential for the Construction Industry to adopt CE and benefit from its use, especially in the approach to procurement.

The chapter showed how CE has developed in the manufacturing industry and the benefits associated with the adoption of the philosophy. The chapter also reviewed some of the difficulties facing the construction industry in the UK. The chapter showed the potential that exists for the construction industry if the principles are adopted, and concludes that a new method of construction project procurement should be developed using CE principles to facilitate CE implementation in the construction industry.

c) Review current modelling methods available and select the most appropriate method to develop a new procurement model for construction. The main methods were reviewed in Chapter Five and the IDEF0 method was identified as the best method to be utilised for the new model. The technique was chosen by initially identifying the key requirement for a modelling technique to suit the industry. Several techniques were reviewed against the initial requirements to assess their compliance, and then a selection was made based on those requirements. It was determined that the IDEF0 modelling technique was the most appropriate due to its visual representation, being able to drill down to the lowest level of tasks, showing the interactions between different levels and identifying the controls and mechanisms that form part of the process being modelled.
d) **Develop the new model** for a new procurement process and evaluate against CE principles and with current industry practitioners to confirm the potential benefits.

Development of the new procurement model was outlined in Chapter Six based on the IDEFØ process modelling technique. The key elements and findings of the model development were:

- The adoption of a re-engineered briefing document, termed the design neutral requirements specification as the output from the briefing activities and the major input into the tender documents.
- The early selection of a number of competent contractors to tender to develop the project.
- The early involvement in the tender process of construction personnel and material suppliers.
- The development of outline concurrent design solutions involving all parties of the contractor's consortium, including designers and constructors.
- The breakdown of activities to an extent where they are planned together as a team and then executed in parallel.
- The planning of the construction activities prior to the detailed design commencing.
- The development of a Special Project Vehicle (SPV) for the execution of the project, which has the client and consortium members as shareholders, ensuring the focus is maintained on the final product development.
- A reduction in the time taken for decisions based on the use of current communication technologies.

An assessment of the new procurement model against the previously identified CE principles and Egan recommendations was detailed in Chapter Seven and showed that the new model met all of the CE and Egan requirements and especially
showed that adoption of the model would offer improvements over the current procurement methods currently used by the construction industry. In particular the CE principles were fully utilised:

- All parties are integrated at an early stage of the process.
- The client’s requirements are established early and the focus is maintained throughout the process.
- There is a continuous product and process improvement, caused by the collaborative nature of the team.
- Interfaces are minimised
- Capital cost and timescales are minimised
- The activities and tasks are carried out concurrently.

This is all achieved by the early establishment of the product development teams and by the breakdown of activities to a series of independent tasks. The tasks can clearly be carried out in parallel allowing a reduction in timescale for subsequent downstream activities. With the emphasis on product development and quality the focus of the supplier’s team is clearly on the client and their requirements.

In addition the Egan recommendations were established as an integral part of the procurement model, specifically:

- The leadership was committed from an early date by the establishment of Project Champions.
- Customer focus is maintained throughout the model
- The processes and teams were integrated from an early date.
- The establishment of a clear brief will lead to a quality product in terms of meeting the Client’s requirements.
- The commitment to people and their development and well being is a high priority.
Whilst it is acknowledged that the new model achieves the objectives that were set out initially it was agreed that independent views were obtained to confirm the views of the author. The independent study was the subject of the second half of Chapter Seven and comprised obtaining views from independent evaluators against set criteria. This was achieved through a presentation and the completion of an evaluation questionnaire.

In general, the respondents supported the new model in terms of benefits to the construction industry and the use of CE aims and principles although there were several areas of concern. In particular the sample of respondents was probably too narrow and did not include the views of two key sectors of the construction supply chain – clients and materials suppliers. However the model is focused around the key procurement activities that involve contractors, therefore the sample was seen as being a representative of personnel who would use the new model.

8.3 Benefits of New procurement method

The benefits of the new procurement method are detailed in Chapters Six and Seven in that the adoption of the new method will bring about an increased collaboration within the participants of the industry. The main benefits of the new model include:

- Early involvement of all parties allows the early solution of problems, therefore allowing the client to quickly reduce the risks associated with cost and time overruns.

- The integration of a design neutral project specification as the mechanism for determining the client’s requirements ensures that the requirements are defined early and maintained throughout the process.

- The focus on the client’s requirements throughout the process is caused by the integration of the client into the implementation stages.
The selection of the successful consortium is based on the most appropriate scheme to meet the client’s requirements rather than the least cost option. This is achieved by setting the budget cost before the tenders are issued and by the inclusion of the requirements in the tender documentation.

The early involvement and integration of all participants of the project team allows downstream participants to be involved in the outline conceptual design and therefore the downstream processes are integrated into the tender offer.

The establishment of a Special Project Vehicle (SPV), the review of the client’s requirements and the preparation of the construction plan before the concurrent detailed design stage forces the project team to integrate the downstream processes into the design, therefore reducing the potential for increased construction costs, delays and the avoidance of late changes.

The early integration of the project team allows for the design and construction processes to be integrated.

Feedback loops are included in the process that allows a continuous improvement to be achieved. The issue of best practice notes throughout the process will guarantee improvement in a specific project. The maintenance and review of these notes by the contractor before a specific solution is developed will ensure that the learning from previous projects will be transferred to the next.

Many of these improvements complement each other and frequently it is down to the individuals involved in a project and their attitude towards each other throughout a project’s development that enables projects to be successful or a failure.
8.4 Conclusions

The research that is documented in this thesis shows that a new procurement model using Concurrent Engineering principles, if adapted, will improve the delivery of construction projects in terms of reduced capital cost and programme with a corresponding improvement in product quality. This has been shown through the individual chapters in three key areas namely, the limitations of the current methods of construction procurement, the adoption of CE into construction and the development of a new procurement model based on CE principles.

There are many methods of project procurement, each having their own advantages and disadvantages. The most common method of project procurement is still the traditional method, although the more collaborative methods are increasing in popularity. The traditional method is frequently based on adversarial relationships between the client, the consultant and the contractor, all of which is not conducive to effective collaboration. Specifically, current construction procurement methods have been shown to conflict with client’s requirements in terms of the delivery of the final product [Latham 1994, Egan 1998]. A recent survey showed that projects only had a 70% chance of completing on time and a 60% chance of completion within the original budget [Bowron 1998]. The survey went on to confirm that the selection of schemes and successful contractors was primarily based on cost rather than the need to conform to the client’s requirements. Other key aspects such as constructability and maintainability were seen as a low priority in terms of selection criteria, yet this is one of the key areas for improvement identified by Latham [1994] and Egan [1998]. The survey also supported the notion that construction teams were isolated into design and construction areas. The industry is also seen by city investors as a poor investment, with high risks associated with the product and little reward for the risks and efforts undertaken.
The adoption of CE principles into the Construction Industry offers the potential for the improvements identified by Latham [1994] and Egan [1998]. Concurrent Engineering has been adopted by the manufacturing industry and many of the key principles were seen as being of potential benefit to the problems associated with the construction industry [Anumba & Evbuomwan 1997]. The adoption of the principles is seen to offer improvement in many ways but particularly through the early involvement of all personnel involved in the project development process.

A new procurement model has been developed adopting CE principles and offers the construction industry the potential for improving its processes and output to the benefit of all involved in the construction industry. The new model has been shown to adopt the principles of concurrent engineering and therefore offer the construction industry a new approach to project procurement that improve the collaboration of all parties involved in the construction process. One of the key areas of improvement is the adoption of a design neutral requirements specification as the mechanism for identifying the client’s requirements. This remains a central document throughout the process and is reviewed at several stages to ensure that the focus is maintained on the client throughout the process. A second key area is the integration of the downstream participants at an earlier stage than previously adopted in procurement methods. This allows the downstream processes to be fully integrated at an earlier stage in the overall process. The new method can reduce timescales by the reduction in task interdependence. This has been achieved by using the IDEF0 modelling techniques to reduce the tasks to their lowest level and then to parallel the tasks as much as possible. The new method also has the potential to reduce the capital costs of a project by the early definition of the requirements and
the integration of the participants allowing downstream processes to be developed fully before committing to them. This has the benefit of fully understanding each participants needs and therefore reducing the potential for late changes, resulting in cost increases and delays.

8.5 Recommendations for Further Research

The research has been shown to be successful in meeting the objectives that were set at the start of the project. However there are areas that require further work to enable the model to be further developed and successfully adopted by the industry.

The model could be improved in several ways:

- Addressing the issues of the interaction of people, including roles and responsibilities, I.T., and how people communicate in terms of when and how they require information.
- Including the project timescale into the model as IDEFØ has no mechanism for integrating this into the model.
- Integrate further the research work carried out by Kamara et al [1999] into the briefing processes. This will have the benefit of producing a seamless model between briefing and procurement.
- Integrate further the research work carried out by Waskett [1999] into the downstream processes of concurrent detailed design. This again will have the benefit of producing a seamless link between procurement and its downstream processes.
- Allow other participants to review the model, for example, material suppliers such as steel fabricators and clients. This would need to be carried out on an integrated model that included the briefing development process and also the construction processes.
Further research is needed in the procurement processes and especially:

- The integration of a Special Project Vehicle into the project process. This will allow the participants to be further integrated into the process.

- Develop a database that allows clients to set realistic budget figures for their projects at an early stage. This will ensure that clients understanding of the construction industry tenders are improved and that tenders are released with realistic values attached to them.

- Develop contract terms with incentives that are related to best value rather than least cost.

- Confirmation of the findings in the survey, although attitudes and knowledge will have changed from the timing of the survey (1997), therefore it is likely that the results will also have changed.

Finally the new model could be trialled to confirm the benefits that can be achieved by the adoption of the new model. These benefits are seen as both tangible, in terms of reduced costs and timescale and improvements in product quality, and soft benefits such as improved working relationships, attractiveness of the industry for recruitment, improved profitability and therefore greater investment by city investors.
8.6 Closing Comments

The successful adoption of Concurrent Engineering in the construction industry will vastly improve the timing, cost and improve the final quality of the industry's projects. This requires a change in attitudes and practice between all parties during project procurement such that multi-disciplinary teams work towards a common goal. The research documented in this Thesis shows that the adoption of the new CE based procurement model will allow all participants to work together from the very early stages of a project. The model is considered vital to the effective implementation of Concurrent Engineering into the construction industry.
REFERENCES


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Institution of Civil Engineers – Civil Engineering Procedure, Thomas Telford, London 1976.


Materials Laboratory, AF Wright Aeronautical Laboratories, June 1981.


Schipper, A., Leusink, M., van Montfrans, M., Nijessen's Information Analysis Method. –


Taouil– Process Flow Charting. - 


University of Salford, Process Protocol –

APPENDIX 1 - INDUSTRY QUESTIONNAIRES
APPENDIX 2 - EVALUATION PRESENTATION
APPENDIX 3 - EVALUATION QUESTIONNAIRES
APPENDIX 1 - INDUSTRY QUESTIONNAIRES
Text cut off in original
This survey is intended to evaluate the construction project procurement process in the UK construction industry, from the initial idea through to the pre-construction stage. Your answers to this questionnaire will be treated in the strictest confidence and will be used for academic purposes only. Your response will be highly appreciated, Thank You.

1.0 Background Information

What is your primary business sector?

Railway Property Maintenance

Do you have an in-house Project Management capability?

Yes

Please complete the following table to provide further details about your organisation

<table>
<thead>
<tr>
<th>Number of Employees</th>
<th>Turnover Last Year (£)</th>
<th>Capital Programme £m</th>
<th>Average No. of Projects/year</th>
<th>Average no. of Projects in Each value Group/year</th>
</tr>
</thead>
<tbody>
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<td>100</td>
<td>93 94 95 96 97</td>
<td>120</td>
<td>&gt;£50m £10-50m £1-10m &lt;£1m</td>
<td></td>
</tr>
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</table>

10 Project Process

This section relates to the stages in the project process and the involvement of individuals

Organisation

Has your project management group a project process?

Yes

What forms of Construction Procurement Processes are commonly used? (Rank in order of preference, 1 being the most commonly used and state the reasons for the choice)

<table>
<thead>
<tr>
<th>Method</th>
<th>Ranking</th>
<th>Reasons for Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Design and Build</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Long Term Partnership</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Management Contracting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design/Build/Finance/Operate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (Please State)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For the most commonly used procurement method indicate the involvement of the following disciplines at the various project stages. (A = No involvement, B = Minor Involvement, C = Major Involvement)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Client</th>
<th>Project Manager</th>
<th>Architect</th>
<th>Structural Design Engineer</th>
<th>Services Design Engineer</th>
<th>Quantity Surveyor</th>
<th>Contractor</th>
<th>Other (State)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>C</td>
<td>C</td>
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<td>2</td>
<td>C</td>
<td>B</td>
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<td>3</td>
<td>C</td>
<td>B</td>
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<tr>
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<td>5</td>
<td>C</td>
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<td>6</td>
<td>C</td>
<td>B</td>
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<td>B</td>
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<td></td>
</tr>
</tbody>
</table>

Stage 1 = Requirements Definition
Stage 2 = Preliminary/Conceptual Design
Stage 3 = Analysis and Detailed Design
Stage 4 = Design/Tender Documentation
Stage 5 = Construction Planning
Stage 6 = Construction
<table>
<thead>
<tr>
<th>Stages</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Who by</th>
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<tr>
<td>Monies Sanctioned</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Client</td>
<td>Architect</td>
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<tr>
<td>Procurement Strategy Chosen</td>
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<td></td>
<td></td>
<td></td>
<td>Client</td>
<td>Architect</td>
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<tr>
<td>Requirements Frozen</td>
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<td></td>
<td></td>
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<td></td>
<td>Client</td>
<td>Architect</td>
</tr>
<tr>
<td>Design Team Appointed</td>
<td></td>
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<td></td>
<td>Client</td>
<td>Architect</td>
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<tr>
<td>Cost Estimate</td>
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<tr>
<td>Project Programme</td>
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<td>Preferred Scheme Adopted</td>
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<td>Architect</td>
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<tr>
<td>Design Frozen</td>
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<td>Client</td>
<td>Architect</td>
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<tr>
<td>Tender Preparation</td>
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<td></td>
<td>Client</td>
<td>Architect</td>
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<tr>
<td>Contractor Appointed</td>
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<td></td>
<td>Client</td>
<td>Architect</td>
</tr>
<tr>
<td>% Design Complete at each Stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Client</td>
<td>Architect</td>
</tr>
</tbody>
</table>

**Briefing/Requirements Processing**

How are your requirements communicated to the project team? (Tick Box)
- Specifications
- Outline Design
- Briefing Meeting(Orally)
- Other

Who leads the project team at this stage? (Tick Box)
- Client
- Project Manager
- Architect
- Engineers
- Contractor
- QS
- Other

To what extent is Requirements Definition combined with Conceptual design
- No Overlap
- Minor Overlap
- Major Overlap
- Fully Integrated

**Preliminary/Conceptual Design**

When considering Conceptual Design options what criteria are used?
(Grade 1-14 in terms of importance, 1 being most important)

<table>
<thead>
<tr>
<th>Location</th>
<th>Size of Facility</th>
<th>Materials of Construction</th>
<th>Constructability Considerations</th>
<th>Functionality</th>
<th>Appearance</th>
<th>Safety in Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>7</td>
<td>13</td>
<td>8</td>
<td>4</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

**Environmental Impact**

<table>
<thead>
<tr>
<th>Provision of Services (eg power)</th>
<th>Cost</th>
<th>Demolition Or Disposal</th>
<th>Maintenance</th>
<th>Life Span</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>12</td>
<td>1</td>
<td>11</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

Who selects/Recommends the preferred options? (Tick box)
- Architect
- Engineer
- Project Team
- Team Meeting
- Client Selection
- Other

Who ensures that the original requirements are satisfied by the proposed option? (Tick Box)
- Client
- Project Manager
- Architect
- Engineers
- QS
- Other

To what extent is Conceptual Design combined with Detailed Design?
- No Overlap
- Minor Overlap
- Major Overlap
- Fully Integrated

**Analysis, Detailed Design and Design Documentation**

How is detailed design started? (Tick Box)
- Launch Meeting
- Issue of Project Documents
- Place Order
- Instruction/Letter
- Other
### Roles in Analysis and Detailed Design stage (Tick Appropriate Boxes)

<table>
<thead>
<tr>
<th>Roles/Responsibilities</th>
<th>Client</th>
<th>Project Manager</th>
<th>Architect</th>
<th>Design Engineers</th>
<th>Contractor</th>
<th>Quantity Surveyor</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the same People involved As at Stages 1 &amp; 2?</td>
<td>✅</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who Co-ordinates the Project Team?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who Co-ordinates the Design Team?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who ensures the Design meets the Client’s Needs?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who resolves design disputes?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who issues Design for Tender?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✅</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who receives design at this stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who issues design for Construction</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who receives design at this stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✅</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**How is detailed design issued?**
- [ ] Paper Copy
- [ ] Electronically by Disk
- [ ] Electronically by Network (e.g. intranet)
- [ ] Other

**To what extent is Detailed Design integrated with Design/Tender Documentation**
- [ ] No overlap
- [ ] Minor Overlap
- [ ] Major Overlap
- [ ] Fully Integrated

### Construction Planning

**On average how many contractors are selected to tender?**

5

**How long is usually allowed for Contractors to return tender?**

4 Weeks

**Once the tenders are received how long is the contractor selection period?**

4 Weeks

**Are selected tenderers allowed to re-submit their tenders following initial negotiations?**

[ ] Yes [ ] No

**On what basis is the successful contractor selected? (please grade in order of importance, 1 being most Important)**

<table>
<thead>
<tr>
<th>Cost</th>
<th>Programme</th>
<th>Technical Submission</th>
<th>Past Performance</th>
<th>Safety</th>
<th>Commercial Viability</th>
<th>Compliance With Customer’s needs</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

**Performance and Improvement**

**What percentage of Projects are delivered to the original programme?**

75%

**What percentage of Projects are delivered to the original cost estimate?**

65%
What percentage of Projects fully meet your original needs?  

On average, how many design changes occur within each project?  

On average, at what stages do most of the changes occur?

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Changes</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

In what percentage of cases are the changes initiated by:

- The Client 10%  
- The Architect %  
- The Engineers 40%  
- The Contractor 50%  
- The QS %  
- Other %

To what extent are you satisfied with the following aspects of the project procurement process (1 = Highly satisfied, 5 = Highly Unsatisfied)

<table>
<thead>
<tr>
<th>aspect</th>
<th>Score</th>
<th>If Unhappy state how it could be improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Definition</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Role of Choice available to Client</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Role of Client Involvement</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Communications with Project Team</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Role of Collaboration between Members</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>All Procurement Process</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Structability Considerations</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Achievement of Targets</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Achievement of required quality</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Control/Achievement of Target</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Consideration of Life Cycle issues</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Compliance with Client's Needs</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Provisions/Considerations</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Do you think that Contractors should be involved earlier in the project process?

YN

Why?

Do you think the Client should be involved beyond the Client Requirements Specification stage?

YN

Why?

In what way do you think that the project procurement process could be improved?
Industry Survey – Construction Project Procurement Process – Design Consultants

This survey is intended to evaluate the construction project procurement process in the UK construction industry, from the initial idea through to the pre-construction stage. Your answers to this questionnaire will be treated in the strictest confidence and will be used for academic purposes only. Your response will be highly appreciated, Thank You.

1.0 Background Information

1.1 What is your primary business sector?

1.2 Do you have an in-house Project Management capability Y/N

1.3 Please complete the following table to provide further details about your organisation

<table>
<thead>
<tr>
<th>Number of Employees</th>
<th>Turnover Last Year (£)</th>
<th>What % of Business Design</th>
<th>Average No. of Projects/year in Group/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front End Options</td>
<td>Detail design</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.0 Project Process

This section relates to the stages in the project process and the involvement of individuals

2.1 Has your project management group a project process Y/N

2.2 What forms of Construction Procurement Processes are commonly used? (State the top 3 and reasons used)

<table>
<thead>
<tr>
<th>Method</th>
<th>Position</th>
<th>Reasons for Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design and Build</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long Term Partnership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management Contracting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design/Build/Finance/Operate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (Please State)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.3 For the most commonly used procurement method indicate the involvement of the following disciplines at the various project stages.

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Project Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>Project Manager</td>
<td></td>
</tr>
<tr>
<td>Architect</td>
<td></td>
</tr>
<tr>
<td>Structural Design</td>
<td></td>
</tr>
<tr>
<td>Design Engineer</td>
<td></td>
</tr>
</tbody>
</table>

Stage 1 = Requirements Definition
Stage 2 = Preliminary/Conceptual Design
Stage 3 = Analysis and Detailed Design
Stage 4 = Design/Tender Documentation
Stage 5 = Construction Planning
Stage 6 = Construction
2.4 State when the following are carried out and who by (Mark A, B or C as previous question)

<table>
<thead>
<tr>
<th>Items</th>
<th>Stages</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Who by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monies Sanctioned</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procurement Strategy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements Frozen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Team Appointed</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Estimate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Programme</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Scheme Adopted</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Frozen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tender Preparation</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contractor Appointed</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Complete at each Stage(%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**Briefing/Requirements Processing**

2.5 How do you receive the Client’s requirements? (Tick Box)
- [ ] Specifications
- [ ] Scheme Drawings
- [ ] Briefing Meeting(Orally)
- [ ] Other

2.6 Who leads the project team at this stage? (Tick Box)
- [ ] Client
- [ ] Project Manager
- [ ] Architect
- [ ] Engineers
- [ ] Contractor
- [ ] QS
- [ ] Other

2.7 To what extent is the Requirements Definition and Conceptual design stages combined
- [ ] No Overlap
- [ ] Minor Overlap
- [ ] Major Overlap
- [ ] One Activity

**Preliminary/Conceptual Design**

2.8 When considering Conceptual Design options what areas are considered?
(Grade 1-14 in terms of importance)
<table>
<thead>
<tr>
<th>Location</th>
<th>Size of Facility</th>
<th>Materials of Construction</th>
<th>Constructability</th>
<th>Functionality</th>
<th>Appearance</th>
<th>Safety in Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Impact</th>
<th>Provision of Services (e.g., power)</th>
<th>Cost</th>
<th>Demolition Or Disposal</th>
<th>Maintenance</th>
<th>Life Span</th>
<th>Other</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.9 Who selects the preferred options? (Tick box)
- Recommendation of Architect
- Engineer
- Project Team
- Team Meeting
- Client Selection
- Other

2.10 Who ensures that the original requirements are satisfied by the proposed option? (Tick Box)
- Client
- Project Manager
- Architect
- Engineers
- QS
- Other

2.11 To what extent is the Conceptual Design and Detailed Design stages combined?
- No Overlap
- Minor Overlap
- Major Overlap
- One Activity

Analysis, Detailed Design and Design Documentation

3.1 How is detailed design started? (Tick Box)
- Launch Meeting
- Issue of Project Documents
- Place Order
- Instruction/Letter
- Other

3.2 Roles in Analysis and Detailed Design stage (Tick Appropriate Boxes)

<table>
<thead>
<tr>
<th>Roles/Responsibilities</th>
<th>Client</th>
<th>Project Manager</th>
<th>Architect</th>
<th>Design Engineers</th>
<th>Contractor</th>
<th>Quantity Surveyor</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the same People involved As at Stages 1 &amp; 2?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who Coordinates the Project Team?</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Who Coordinates the Design Team?</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who ensures the Design meets the Client's Needs?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who resolves design disputes?</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who issues Design for Tender?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who receives design at this stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.3 How is detailed design issued
☐ Paper Copy ☐ Electronically by Disk ☐ Electronically by Network (e.g. intranet) ☐ Other

3.4 To what extent is the Detailed Design and Design/Tender Documentation stages an integrated activity
☐ No overlap ☐ Minor Overlap ☐ Major Overlap ☐ Single Activity

3.5 Construction Planning

3.5 On average how many contractors are selected to tender

3.6 How long is usually allowed for Contractors to return tender

3.7 Once the tenders are received how long is the contractor selection period

3.8 Are selected tenderers allowed to re-submit their prices

3.9 On what basis is the successful contractor selected? (please grade in order of importance)

<table>
<thead>
<tr>
<th>Cost</th>
<th>Programme</th>
<th>Technical Submission</th>
<th>Past Performance</th>
<th>Safety</th>
<th>Commercial Viability</th>
<th>Compliance With Customer's needs</th>
<th>Other</th>
</tr>
</thead>
</table>

Performance and Improvement

4.1 What percentage of designs are delivered to the original programme?

4.2 What percentage of designs are delivered to the original cost estimate?

4.3 What percentage of designs fully meet the Client's original needs?

4.4 On average, how many design changes occur within each project?

4.5 On average, at what stages do most of the changes occur?

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Changes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.6 In what percentage of cases are the changes initiated by

* The Client           %
* The Architect        %
* The Engineers        %
* The Contractor       %
* The QS               %
* Other                %
To what extent are you satisfied with the following (1 = Highly unsatisfied, 5 = Highly Satisfied)

<table>
<thead>
<tr>
<th>Area</th>
<th>Score</th>
<th>If Unhappy state how it could be improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Briefing/Requirements Definition</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Choice available to Client</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Client Involvement</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Team Communications</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Collaboration between Team Members</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Procurement Process</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Constructability</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Consideration of Life Cycle issues</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Compliance with Client's Needs</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

4.7 Do you think that Contractors should be involved earlier in the project process?

[ ] Yes  [ ] No  [ ] Not Sure

4.8 What would the benefits be of earlier Contractor involvement?

4.9 Do you think the Client should be involved beyond the Client Requirements Specification stage?

[ ] Yes  [ ] No  [ ] Not Sure

4.10 What would the benefits be of continuous Client Involvement?

4.11 In what way do you think that the project procurement process could be improved?
Industry Survey – Construction Project Procurement Process – Contractors

This survey is intended to evaluate the construction project procurement process in the UK construction industry, from the initial idea through to the pre-construction stage. Your answers to this questionnaire will be treated in the strictest confidence and will be used for academic purposes only. Your response will be highly appreciated, Thank You.

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1.1 What is your primary business sector? 

1.2 Do you have an in-house Project Management capability Y/N

1.4 Please complete the following table to provide further details about your organisation

<table>
<thead>
<tr>
<th>Number of Employees</th>
<th>Turnover Last Year (£)</th>
<th>Average No. of Projects/year</th>
<th>Average no. of Projects in Each value Group/year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;£50m</td>
</tr>
</tbody>
</table>

2.0 Project Process

This section relates to the stages in the project process and the involvement of individuals

Organisation

2.1 Has your project management group a project process Y/N

2.12 What forms of Construction Procurement Processes are commonly used? (State the top 3 and reasons used)

<table>
<thead>
<tr>
<th>Method</th>
<th>Position</th>
<th>Reasons for Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design and Build</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long Term Partnership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management Contracting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design/Build/Finance/Operate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>(Please State)</td>
<td></td>
</tr>
</tbody>
</table>

2.13 For the most commonly used procurement method indicate the involvement of the following disciplines at the various project stages.

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Project Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Design Engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stage 1 = Requirements Definition
Stage 2 = Preliminary/Conceptual Design
Stage 3 = Analysis and Detailed Design
Stage 4 = Design/Tender Documentation
Stage 5 = Construction Planning
Stage 6 = Construction
2.14 State when the following are carried out and who by (Mark A, B or C as previous question)

<table>
<thead>
<tr>
<th>Items</th>
<th>Stages</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Who by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monies Sanctioned</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procurement Strategy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements Frozen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Team Appointed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Estimate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Programme</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Scheme Adopted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Frozen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tender Preparation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contractor Appointed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Complete at each Stage(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Briefing/Requirements Processing**

2.15 How are the Client's requirements communicated to you? (Tick Box)
- [ ] Specifications
- [ ] Scheme Drawings
- [ ] Briefing Meeting (Orally)
- [ ] Other

2.16 At what stage do you receive these requirements? (Ring stage no.)
1 2 3 4 5 6

2.17 Who leads the project team at this stage? (Tick Box)
- [ ] Client
- [ ] Project Manager
- [ ] Architect
- [ ] Engineers
- [ ] Contractor
- [ ] QS
- [ ] Other

2.18 Who do you receive the requirements from
- [ ] Client
- [ ] Project Manager
- [ ] Architect
- [ ] Engineers
- [ ] Other

2.19 Once the Client's Requirements are communicated to you, what is your involvement?
- [ ] Lead Project
- [ ] Develop Options
- [ ] Measure for Tender
- [ ] Design
- [ ] Other
Construction Planning

3.6 During the tender period what are the roles/responsibilities of personnel (Tick Appropriate Boxes)

<table>
<thead>
<tr>
<th>Role/Responsibility</th>
<th>Project Manager</th>
<th>Contracts Manager</th>
<th>Design Engineer</th>
<th>Quantity Surveyor</th>
<th>Planner</th>
<th>Foreman</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who leads Your Team</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who is involved In Tender Process</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who is involved during Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who assesses Constructability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who deals with The Client</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who deals with Material suppliers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2 On average how many jobs do you expect to win

1 in

3.3 Do you offer alternate technical solutions in your tender

Y/N

3.4 How much money do you spend in tendering, as % of tender price

___%

3.5 On average how long is allowed for you to tender

________ Weeks

3.6 Once the tenders are issued how long do you wait for a response from the Client

________ Weeks

3.7 Are you allowed to re-submit prices once the original tender is submitted

Y/N

3.8 In your opinion on what basis is the successful contractor selected? (please grade in order of importance)

<table>
<thead>
<tr>
<th>Cost</th>
<th>Programme</th>
<th>Technical Submission</th>
<th>Past Performance</th>
<th>Safety</th>
<th>Commercial Viability</th>
<th>Compliance With Customer's needs</th>
<th>Other</th>
</tr>
</thead>
</table>

Performance and Improvement

4.1 What percentage of Projects are delivered to the original programme?

_______ %

4.2 What percentage of Projects are delivered to the original cost estimate?

_______ %

4.3 What percentage of Projects fully meet the original needs of the Client?

_______ %

4.12 On average, how many design changes occur within each project?

4.13 On average, at what stages do most of the changes occur?

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Changes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.14 In what percentage of cases are the changes initiated by
<table>
<thead>
<tr>
<th>Area</th>
<th>Score</th>
<th>If Unhappy state how it could be Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Briefing/Requirements Definition</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Choice available to Client</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Client Involvement</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Team Communications</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Level of Collaboration between Team Members</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Procurement Process</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Constructability</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Consideration of Life Cycle issues</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Compliance with Client's Needs</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

4.15 Do you think that Contractors should be involved earlier in the project process?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
</tr>
</thead>
</table>

4.16 What would the benefits be of earlier Contractor involvement?

4.17 Do you think the Client should be involved beyond the Client Requirements Specification stage?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
</tr>
</thead>
</table>

4.18 What would the benefits be of continuous Client Involvement?

4.19 In what way do you think that the project procurement process could be improved?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Project Procurement

Introduction

Aims of Today
Introduction

- Aims of Today
- Current Procurement Methods

Introduction

- Aims of Today
- Current Procurement Methods
- CE and Procurement
Introduction

- Aims of Today
- Current Procurement Methods
- CE and Procurement
- New Procurement Model

Introduction

- Aims of Today
- Current Procurement Methods
- CE and Procurement
- New Procurement Model
- Q & A
- Questionnaire
Current Procurement Methods

- Traditional (45%)

Current Procurement Methods

- Traditional (45%)
- Design & Build (30%)
Current Procurement Methods

+ Traditional (45%)
+ Design & Build (30%)
+ Construction Management (20%)

+ Others e.g. Partnering, PFI, Prime Contracting (5%)
Current Procurement Methods

Current Concerns

± Delivery of Service
± Timescale
± Costs
± Product Quality
± Confrontational Contracts
± Best Practice
± Value For Money

Procurement Methods

± The selection has a major impact on a project’s viability
± Across the development process - from briefing to construction
± Determines the relationships between parties involved in the process
± Risks are apportioned
± Contract terms are identified including payment, insurances, etc.
CE and Procurement

- CE used in manufacturing in their Product Development Process
- CE is defined as a systematic approach to the integrated design of products and their related processes including manufacturing and support. This approach is intended to cause the developer from the outset to consider all elements of the life-cycle from conception to disposal.

CE and Procurement

- CE used in manufacturing in their Product Development Process
- Based on key Aims and Principles
CE and Procurement

- CE used in manufacturing in their Product Development Process
- Based on key Aims and Principles
  - ± Reduction in timescales for product development
  - ± Increased collaboration between team members
  - ± Improved customer focus
  - ± Reduction in Rework/Increased productivity
  - ± Better Quality Products

New Procurement Model

- Basis of Model
- Overall Model
New Procurement Model

- IDEF 0 Modelling

Inputs → Constraints → Activity → Outputs

Mechanisms

New Procurement Model

- Overview - Node Diagram

Project Procurement
New Procurement Model

# Node 1 - Invite Tenders

New Procurement Model

# Node 2 - Prepare Tenders
New Procurement Model

* Node 3 - Appraise Tenders

New Procurement Model

* Node 4 - Prepare Concurrent Detailed Design
New Procurement Model

# Node 2.1- Identify & Appoint Team

New Procurement Model

# Node 2.1.1- Initial Review of Tender Documents
New Procurement Model
✦ Node 2.2 - Complete Conceptual Design

New Procurement Model
✦ Node 2.2.1 - Identify Possible Solutions
New Procurement Model

- Node 2.2.2 - Outline Possible Design Solutions

New Procurement Model

- Node 2.2.3 - Select Design Options
New Procurement Model

Node 2.2.2.1 - Prepare Conceptual Analysis

New Procurement Model

Node 3.2 - Present Tenders
New Procurement Model

Node 3.3 - Review Offers

New Procurement Model

Nodes 4.1-4.4

± Subject of another research project
± Key items - Review Original design submission as single product development team
± Plan Construction before detailed design commences
Summary

- Current Procurement Methods

- CE and Procurement
Summary

- Current Procurement Methods
- CE and Procurement
- New Procurement Model

Q & A
EVALUATION OF PROCUREMENT MODEL

The aim of the presentation and questionnaire is to evaluate the proposed process model for procurement in the construction industry. The completion of the questionnaire will follow the presentation of the model.

a) Organisational Details
   i) Name of Organisation ________________________________
   ii) Type of Business Client/Consultant/Contractor/Material Supplier (Circle one business)
   iii) Number of Employees ______
   iv) Annual Turnover ______
   v) Position of Respondent _____________________________
   vi) Respondent’s Experience in Construction Industry ______ years

b) Evaluation of New Procurement Process Model

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Ranking (1 is poor, &amp; 5 is excellent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How well do you feel that the new model meets the aims of Concurrent Engineering?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2</td>
<td>How well do you feel that the new model integrates the full team?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3</td>
<td>How well does the new model promote ownership of the product development process?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4</td>
<td>How well does the new model promote constancy of purpose for all members involved in the product development process?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5</td>
<td>Is the model organised to allow tasks to be performed in parallel?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>6</td>
<td>Will the use of the model improve a client’s perception of construction project procurement?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>7</td>
<td>Will the model improve the competitiveness of the Construction Industry?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>8</td>
<td>Will the model promote the early involvement of all team members including material suppliers such that they can impact and improve a project?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>9</td>
<td>How well will the model reduce interfaces between parties on the project team?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>10</td>
<td>How well will the model promote communications between parties on the project team?</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>No.</td>
<td>Questions</td>
<td>1</td>
</tr>
<tr>
<td>-----</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>11</td>
<td>How well will the model reduce the overall timescale of projects?</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>How well will the new model improve the focus on product quality?</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>How well will the model allow for individual styles for each contractor to meet the overall product design?</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>How well will the model help to reduce project costs?</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>How well will the model reduce the cost of business for construction contractors?</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>How well do you think that early consideration of constructability issues are improved?</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>How easy did you understand the new model?</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>How useful do you think that the new model would be to the construction team?</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>To what extent did you think the new model was an improvement?</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>What is the overall rating for the new model?</td>
<td></td>
</tr>
</tbody>
</table>

**General Comments**

1) In what way do you think the model could be improved?

______________________________________________________________________________

______________________________________________________________________________

2) Any Other Comments

______________________________________________________________________________

______________________________________________________________________________