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**THE APPLICATION  
OF  
CONCURRENT ENGINEERING PHILOSOPHY  
TO THE CONSTRUCTION INDUSTRY**

**by**

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**A Doctoral Thesis**

**Submitted in partial fulfilment of the requirements**

**for the award of**

**Doctor of Philosophy of the Loughborough University**

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## **DEDICATION**

To my wife Nor Hayati, and my three children Iman Hayat, Muhammad Idzham and Iman Sofea for their love and support.

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## ABSTRACT

The research explores the rationale of applying Concurrent Engineering (CE) philosophy to the construction industry. CE was considered based on its successful implementation in other industries. In the manufacturing industry it is used to overcome problems similar in nature to those of the construction industry, resulting from the practice of the traditional 'over the wall' processes in product design and manufacturing (construction). During the initial stage, the research evaluated current problems faced by the industry, such as the high degree of fragmentation of industry structure and work processes, adversarial relationships among project participants, lack of communication, etc., and its effort to achieve improvement. The research also investigated the theoretical background of CE philosophy, its application in other industries especially in manufacturing, the rationale for its application to construction, and current practices within the construction industry similar to those encompassed within the CE philosophy. CE consists of several basic principles, of which the teamwork was the main focus of this research and is used as the main strategy to achieve CE implementation for construction industry.

By using both quantitative and qualitative evaluation, the research determined that there was no evidence to support that CE has been practised in construction as a complete process, as it has in other industries. The research also established a number of factors that support and inhibit collaborative teamwork in construction, and rank them according to their relative importance. The rankings indicate the priorities for the industry in order to achieve collaborative working, which is critical to CE implementation. The main output of the research was the establishment of 'guidelines' for implementing a Cross Functional Project Team (CFPT), i.e. the cross functional teamwork concept based on CE principles, forming the main strategy to implement CE in construction. The 'guidelines' were developed based on the consensus opinion of industry experts using the Delphi study technique. The findings from case studies were used to validate these 'guidelines'. The research also developed a tool known as the 'Matrix Measurement Guidelines - Toward CE in Construction' (MMG-TCEiC) to help the industry to map the process toward achieving a collaborative teamwork concept based on CE environments within construction projects.

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# CHAPTER ONE

## INTRODUCTION

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### 1.1 Introduction

In the client's satisfaction survey report published by Construction Clients Forum (Ridout, 1999) it was found that 58 percent of the respondents had experienced delays in their project. In the same survey 32 percent of the respondents claimed that the project exceeded the contract budget. With respect to the quality, only 10 percent indicated that they had a defect free project, while 32 percent indicated that the project was delayed by defects. The above survey results presented here are just examples of concern over the performance of the construction industry. The need to improve construction industry performance has been a common agenda in numerous reports and conferences. The same concern has also been expressed in Construction Task Force Report (Egan 1998). This report argued that too many construction clients were dissatisfied with overall performance. It also set the target of reducing construction cost and time by 10 percent annually and reducing defects by 20 percent per year. A further recommendation made was on the need to make the construction process to be more explicit and transparent to the industry and clients.

Latham (1994) set the target of 30 percent real cost reduction by the year 2000. This reflected the inefficiency of the construction project. Gray (1996) in 'Value for Money' argues that UK's workers are as productive as any other workers elsewhere but quotes from Horner et al. (1989) that lapses in productivity arise from task complexity and organisational failure. He also comments on the delay of information flow to the supply chains within construction project in UK compared to Japan and US. He argued that in the UK, 70 percent of information is supplied to the suppliers after the project has commenced. This practice indirectly affected the processes at the site. Lynn (1996) quoted from Sir John Egan's views in his article which described the construction industry as not only inefficient but also "deaf" to how it has fallen behind its competitors.



In a wider context, the construction industry has also been associated with many other weaknesses. The highly competitive nature and specialisation of the industry has failed to provide the platform for close co-operation among project participants. Each of the participants has their own agenda and objective toward the project (Nam and Tatum 1992, Bedelian 1996). Each of the participants involved has absolute loyalty to their group and not to the ultimate client. They will try to minimise the risk of being wrong, therefore finger pointing and assigning blame is a familiar practice in construction (Williams, 1995). The adversarial nature of the relationships among the project participants has been commonly quoted by researchers such as Hinze and Tracey (1994), Tarricone (1992), Harding (1996) and Puddicombe (1997). Albanese (1994) reported that from the research survey carried out on 60 large construction firms, 20 out of 28 responses received agreed that “*owner-contractor working relations can be best described as adversarial and uncooperative*”. He also said that the design/construction process is characterised by adversarial working relationship among owners, designers and constructors. A similar image of the UK construction industry has also been indicated in other literature including Latham (1994), NEDO (1988), and CIPS (1994). A study measuring mutual confidence between three parties' i.e. the clients, contractors and professionals in UK construction industry by Munns (1996), found lower levels of trust shown toward contractors and the clients. He concluded that this indicated a potential source of future conflicts.

One of the main reasons believed to be the cause of the inefficiency of the industry today results from the traditional way of delivering the construction project. The construction industry involves a large number of participants in projects that are usually complex. This complexity has increased significantly over the past decades and likely to continue to do so into next century (Froese and Waugh, 1991). Due to this complexity, the industry developed the traditional approach of dividing the project into smaller tasks and assigning it to the project specialist, the architect, the engineer and the contractor as a means of addressing the complexity of the process (Fisher and Froese, 1996). The most significant result of this division of functional tasks is the separation of design and construction. Kostoff (1977) claimed that the idea of separating the function of design and the construction function account for the functional specialisation in response to the increasing complexity of the industry. According to Latham (1994) this

traditional approach is the route with which the UK's construction industry is most familiar. However, he asserts that the traditional approach is where many of the problems emerged through lack of co-ordination between design and construction. Egan (1998) also criticised the traditional process, which is based on a fragmented structure and referred to the separated process as inefficient and promoting a confrontational culture. Another related problem is poor communication. This situation arises from the fragmented nature of the industry and results in inefficiency in the project delivery process (Howard et al., 1989).

As a response to the weakness and inefficiency associated with the traditional practices in delivering construction projects, several efforts have been undertaken within the industry to overcome the persistent problems despite the continuous popularity of the traditional system. These efforts to improve the industry include: using alternative forms of procurement like design and build; project management contracts; partnering approach; improving the relationships within the supply chain; and increasing reliance on information technology to improve project communication. Consistent with needs of the construction industry and its clients, this research is dedicated towards investigating the potential of applying an alternative approach to delivering the construction project. The research focuses on the aspect of improving the construction process by the concept of collaborative teamwork within a CE environment.

## **1.2 Research background**

It is argued that any effort to improve the traditional way of delivering a construction project will be more effective if it is able to address the key issues related to the fragmentation of the work process. This can be achieved by:

1. changing the existing serial and fragmented construction process into an integrated and simultaneous approach;
2. improving the current concept of collaborative teamwork from the existing practice by creating more opportunity for cross functional project information sharing;

3. creating the platform to enable the team members to have enhanced roles that can contribute to the design and to have their requirements considered in the design process; and
4. enabling the clients requirements to be addressed by the team.

The background of this research emanates from these fundamental issues. Other industries such as manufacturing have initiated changes in their industry by addressing these four fundamental issues. The importance of these issues has also been discussed in all major reports within construction industry. Egan (1998) recognised the need to make radical changes to conventional processes through which the construction projects being currently delivered. He also identified the importance of setting the objectives and targets consistent with the client's perceptions and the importance of developing the integrated team. Gray (1996) advocated the use of integrated design and process in his report 'Value for Money' as a strategy to achieve better value for construction. Latham (1994) strongly emphasised the need to broaden the design team to include non-traditional designers members like sub-contractors, specialist contractors, service engineers and public health consultants. Consistent with the need to address these fundamental issues, this research proposes that the construction industry should implement the 'Concurrent Engineering' (CE) philosophy as an alternative approach to the existing traditional practices within the industry.

CE is a management philosophy originated from manufacturing (Smith 1997). A detailed description of the CE philosophy and the rationale of its implementation in construction are presented in Chapter three. As an introduction, CE is defined here according to Winner et. al (1988) 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 the developers, from the outset, to consider all elements of the product life cycle from concept through disposal, including quality, cost, schedule, and user requirements”*

CE comprises of the following basic elements as quoted by Smith (1997) from Jo et. al (1993):

- *the increased consideration of manufacturing process in product design;*
- *the formation of cross functional team to accomplish the development process;*
- *the focus on customers during the development process; and*
- *the use of lead time as a source of competitive advantage.*

Even though the term 'Concurrent Engineering' is less familiar in construction the industry has inadvertently already become familiar with some elements that are parallel with CE philosophy, especially within recent major innovative projects. However there is no evidence to support the notion that CE has been fully implemented within construction as in other industries such as manufacturing. The concept relating to the application of CE in construction has generated some interest in recent literature. However, unlike that in manufacturing communities, the discussions are still very limited.

In the existing literature, the discussions on CE implementation to construction fall into two major key areas. First, the literature on the potential and opportunity of CE implementation in construction for example Love and Gunasegran (1997), Kamara and Anumba (1997), Kamara et. al (1997), Houvila et al. (1997), Baxendale et al (1997), and De La Garza et. al (1994). The other area of discussion relates to the topic of using Information Technology (IT) to support data integration in CE environments within construction are e.g. Hannus et al. (1997) and Amor and Clift (1997). The research on CE application to construction also mainly focus on developing appropriate process modelling methodologies and using IT to integrate data in CE environment. Examples of such research effort include CONCUR (Los and Storer 1997) and ToCEE (Amor and Clift 1997). Kamara (1999) studies the implementation of CE to construction by focusing on the client requirements. To date, most of the literature published in the effort to study the viability of implementing CE to construction is not fully supported by data but simply expresses from the theoretical point of view the importance of CE to construction.

The issue of the importance of CE to construction had been expressed either directly or indirectly within the literature and reports. Kamara et al. (1997) describe the goals and objectives of CE as very appropriate to the construction industry in meeting the challenges that the industry currently faces. De La Garza et al. (1994) advocate that CE has the potential to "*reoptimise, reenergise, and refuel*" construction industry. Egan (1998) recognised CE as one of the techniques from other industries for improving efficiency and quality. Latham (1994) also indirectly implied the importance of CE to construction when he stressed the important roles of the multidisciplinary team and the integrated design process, two of the important issues that are addressed by CE philosophy. Evboumwan and Anumba (1997) signify the need for the integration of major key players in multi-disciplinary team for any construction project to meet the challenge of today's competitive climates. They further propose that to achieve these, requires a major paradigm shift within the industry.

### **1.3 Research aim and objectives**

The main aim of the research was to propose the application of Concurrent Engineering (CE) philosophy to the construction industry by using a collaborative teamwork approach.

The following objectives were set within the scope of this research:

1. To investigate the practice of work process and teamworking within current construction projects.
2. To identify the concepts and philosophy of CE.
3. To identify the methodology of CE implementation in other industries.
4. To identify the benefits and problems faced by organisations when implementing CE.
5. To assess the rationale and the potential benefits of implementing CE to construction.

6. To assess the presence in construction of elements that are parallel to CE and that are being practised within the current construction project and evaluate their level of achievement.
7. To establish the guidelines for the industry to form the cross functional project team (CFPT), i.e. the collaborative teamwork based on CE principles as an approach to achieve CE implementation in construction.
8. To develop a tool which can help the industry to map the process of the construction project towards achieving the CE environments.

#### **1.4 Research methodology**

The research employed both qualitative and quantitative methods. Creswell (1994) defined qualitative study as *"an inquiry process of understanding social and human problem based on building a complex, holistic picture, formed with words, reporting detail views of informants, and conducted in a natural setting"*. He defines quantitative study as an inquiry based on *"testing a theory composed of variables, measured with numbers, and analysed with statistical procedures in order to determine whether the predictive generalisations of the theory hold true"*. However it was not the aim of the research to adopt any single approach between the two. The research also adopted the triangulation strategy to investigate convergence among different sources of information. Fellows and Liu (1997) described triangulation as a process of applying two or more research methods to investigate the same thing. The method adapted in this research is also guided by the approaches used by the previous researchers in this similar construction management organisational related field of research.

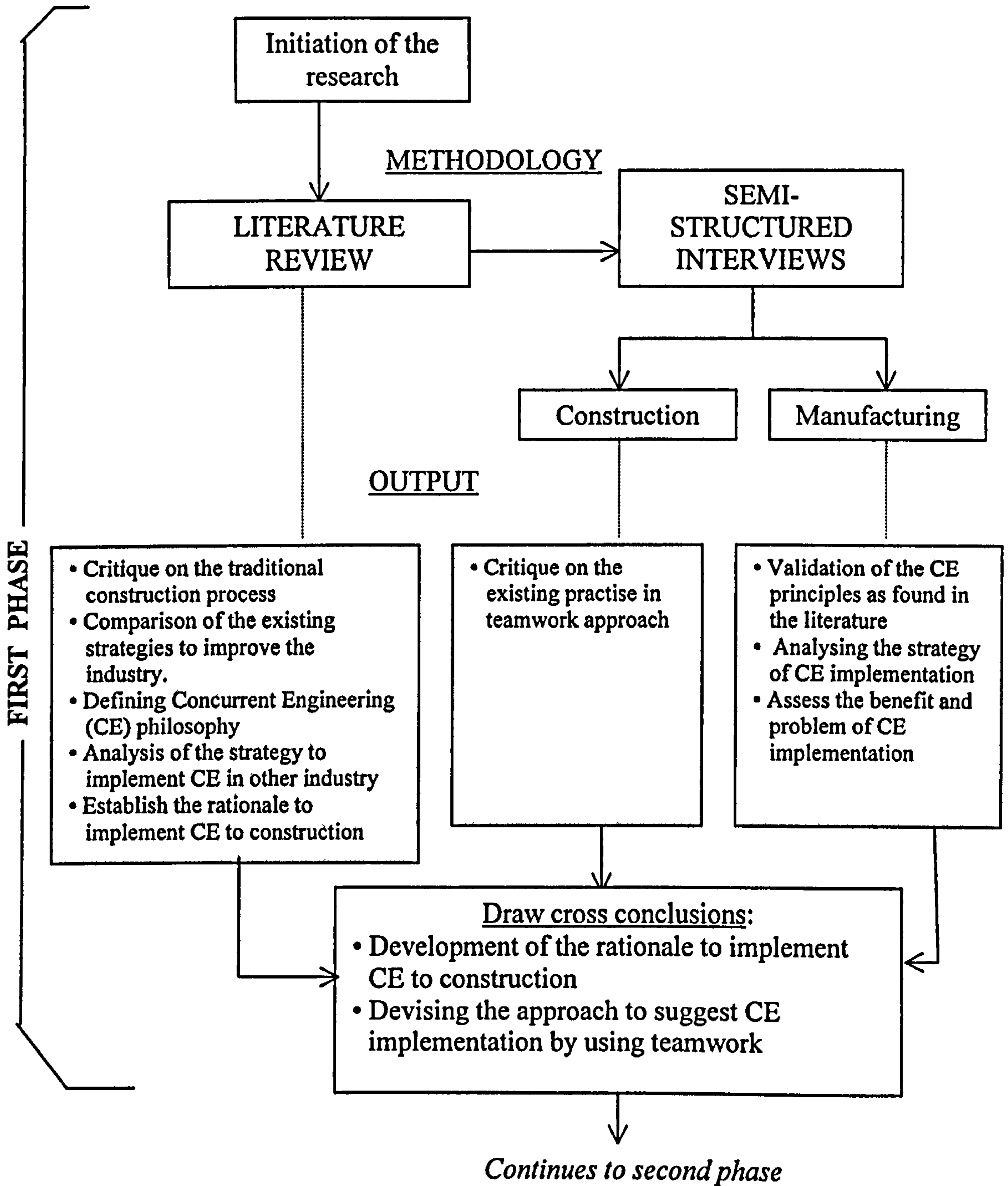
The process to understand the relationship and applicability of CE to construction needs to be resolved carefully. Therefore, the research was developed through several stages. During the first stage the research the agenda demanded a better understanding of research issues and the underlying theories relating to them. The methodologies used in this stage were the literature review and the semi-structured interviews. The source of

data for the literature reviews generated from multiple sources such as: journals and books from construction and manufacturing areas; theses search; Internet; media articles; and conference proceedings. The semi-structured interviews were carried out with the personnel from construction and manufacturing industries. The discussion on the interviews is presented in chapter six.

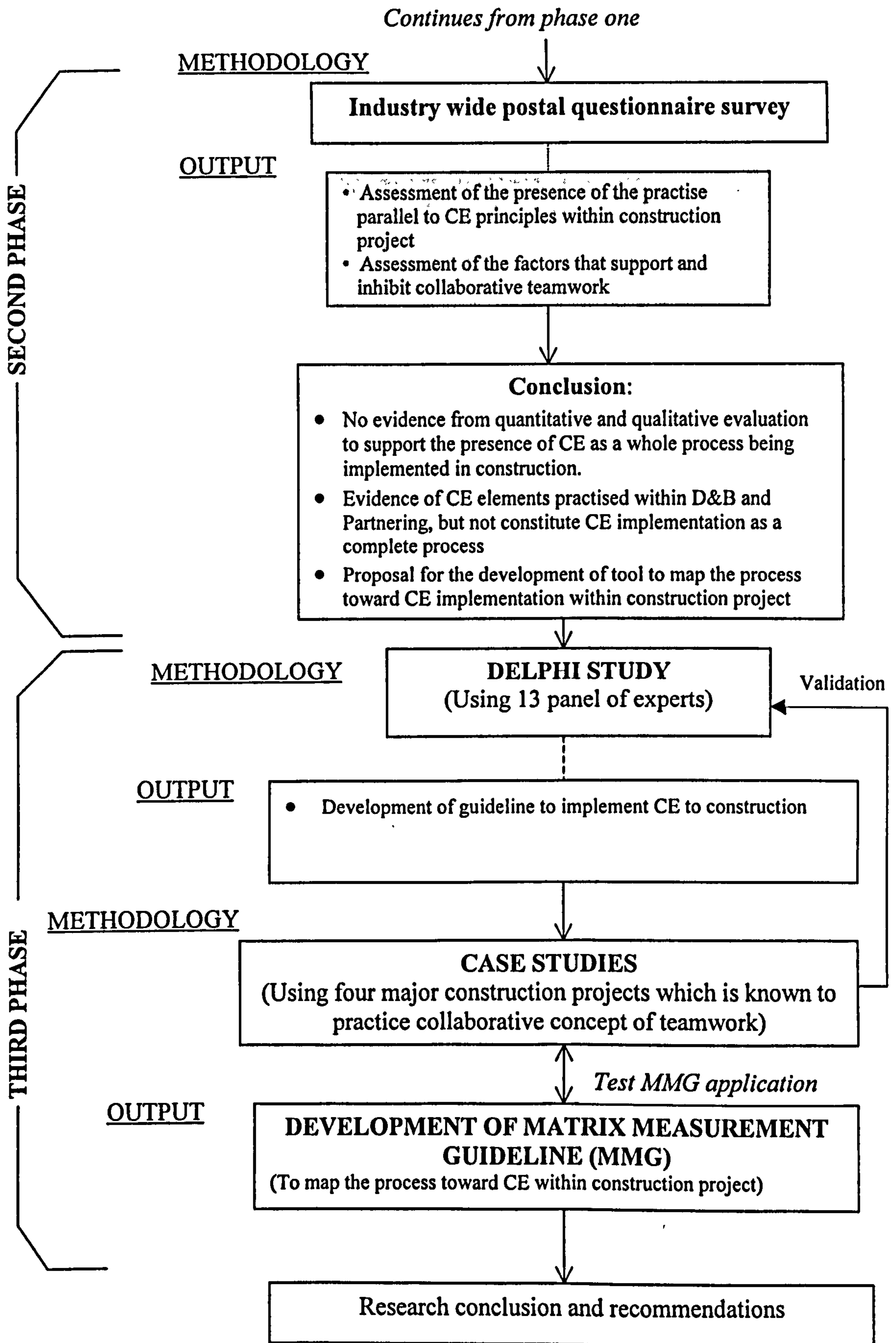
In the second stage, the research focused on testing the findings that had been developed earlier. To achieve this, quantitative data was collected using postal questionnaires survey methods. One hundred and sixty questionnaire forms were sent to the contractors' and consultants' organisations within United Kingdom. The detail discussion of the questionnaire survey results is presented in chapter six. The data collected were analysed using appropriate statistical methods. The findings from this stage of research set the foundation for the development of the guidelines to implement CE to construction.

The third stage involved an evaluation of the proposal to implement CE in construction. The research established guidelines toward the formation of the collaborative teamwork concept in construction and the supporting tool for the industry to map the process toward achieving CE environment. The main source of data to develop the 'guidelines' was acquired with a specific focus group of thirteen experts, which are known in this research as 'the panel of experts'. The panellists are the individuals, with experience and knowledge in various fields of UK construction industry. The methodology used in this process was an adapted Delphi Technique. The detailed description of this technique is explained in chapter seven. The guidelines developed in this research were validated using the case studies. The development of the supporting tool known as Matrix Measurement Guideline-Toward CE in Construction (MMG-TCEiC) was developed based on the data gathered from the previous stages and tested using case studies on four major construction projects. Discussion on the MMG-TCEiC and case studies are made in chapter eight. Figure 1.1 shows the overview of research process through each stage, the methodology used and the nature of data collected.

# Research Process







**Figure 1.1 Research process**

## **1.5 Summary of research achievements**

The research explored the potential of applying Concurrent Engineering (CE) philosophy to construction. The CE philosophy offers an alternative approach of how to deliver the construction project with respect to collaborative teamwork, work process and an orientation towards the customer. These are undoubtedly the most important aspects of improvement that the industry is currently struggling to achieve. This research has undertaken the preliminary work to justify the requirement and rationale for CE implementation and to evaluate the presence of CE elements within a construction environment. This research has established evidence and facts about the following aspects:

- Qualitative evidence of traditional construction process and the current state of art on how collaborative teamwork is achieved within construction industry, and the factors that support and inhibit its achievement.
- The evaluation of the philosophy of CE and its practical implementation within manufacturing industry.
- The profile of involvement of contractors in project design development and the comparison of the level of involvement between contractors sub-groups using traditional contract and D&B, as well as the sub-contractors and those using partnering approach.
- Comparison of the experiences of the contractors, sub-contractors and consultants as well as those using partnering approach towards project exposure, authority, and communication.
- The ranking of factors that promote collaborative teamwork and the comparison of the ranking between contractors and consultants groups.
- The ranking of factors that inhibit collaborative teamwork and the comparisons of the rankings between contractor and consultant groups.

Further research effort focus on formulating the strategy to implement CE to construction and develop a tool to map the process toward CE within the construction project has also been produced. These all represent important contributions to the construction industry. Each of these will be briefly discussed here.

### **Guidelines to implement CE to construction**

The guidelines developed take into consideration the need to adapt CE practice and become consistent with the construction industry environments. The main parameters of the guidelines proposed encapsulated the following aspects:

- a) The inclusion of the team members at various stage of design development
- b) Team characteristics
- c) Team leadership
- d) Clients role
- e) Team roles in project design development
- f) Leadership in project design
- g) Design development decision process
- h) Project information sharing
  - Type of information needed to be made available for key members
  - Type of IT tools to support project information sharing
- i) Strategy to achieve team formation at the outset of the project
- j) Organisational structure to support project teams
- k) Physical working environments to support team integration
- l) IT leadership requirements

### **Development of Matrix Measurement Guideline**

"Matrix Measurement Guideline - Toward CE in Construction " (MMG-TCEC) is the tool developed in this research to help the industry to map the process of achieving CE. This tool has been developed to suit current construction industry practice. This tool has

been tested through case studies of four major construction projects. By using this tool to map their current achievement toward CE, organisations can develop a strategy to improve their achievement on the next project by focusing on areas that require more attention.

## **1.6 Organisation of the thesis**

The thesis is organised in nine chapters. A brief summary of each chapter is provided here:

**Chapter one** introduces the background of the research, its aim and objectives. It also discusses the methodology used, the contribution of the research and finally how the entire thesis has been organised.

**Chapter two** presents an overview of the construction industry. It reviews the industry background and the challenges faced. The practice of the traditional construction process and its related issues are also addressed and discusses on current efforts to improve industry performance.

**Chapter three** focuses on the discussion of the philosophy Concurrent Engineering (CE). A definition of CE is provided and its major elements discussed in detail. The concept of the Cross Functional Team (CFT) is introduced and elaborated. The discussion continues with the experience in CE implementation by other industries especially manufacturing. The benefits and the problems in CE implementation are presented.

**Chapter four** focuses on discussion that relates CE to construction. The argument to rationalise CE philosophy to construction is presented. Comparison is made between the traditional construction work process to the concurrent process according to CE principles. The importance of Cross Functional Team as a strategy to implement CE to construction is explained. The chapter also discusses the presence of the elements that are parallel to CE that are currently practised within construction industry.

**Chapter five** elaborates in detail on aspects of the design and administration of the data collection in this research. This includes the literature search, industry interviews, industry wide questionnaire survey, Delphi studies, and case studies.

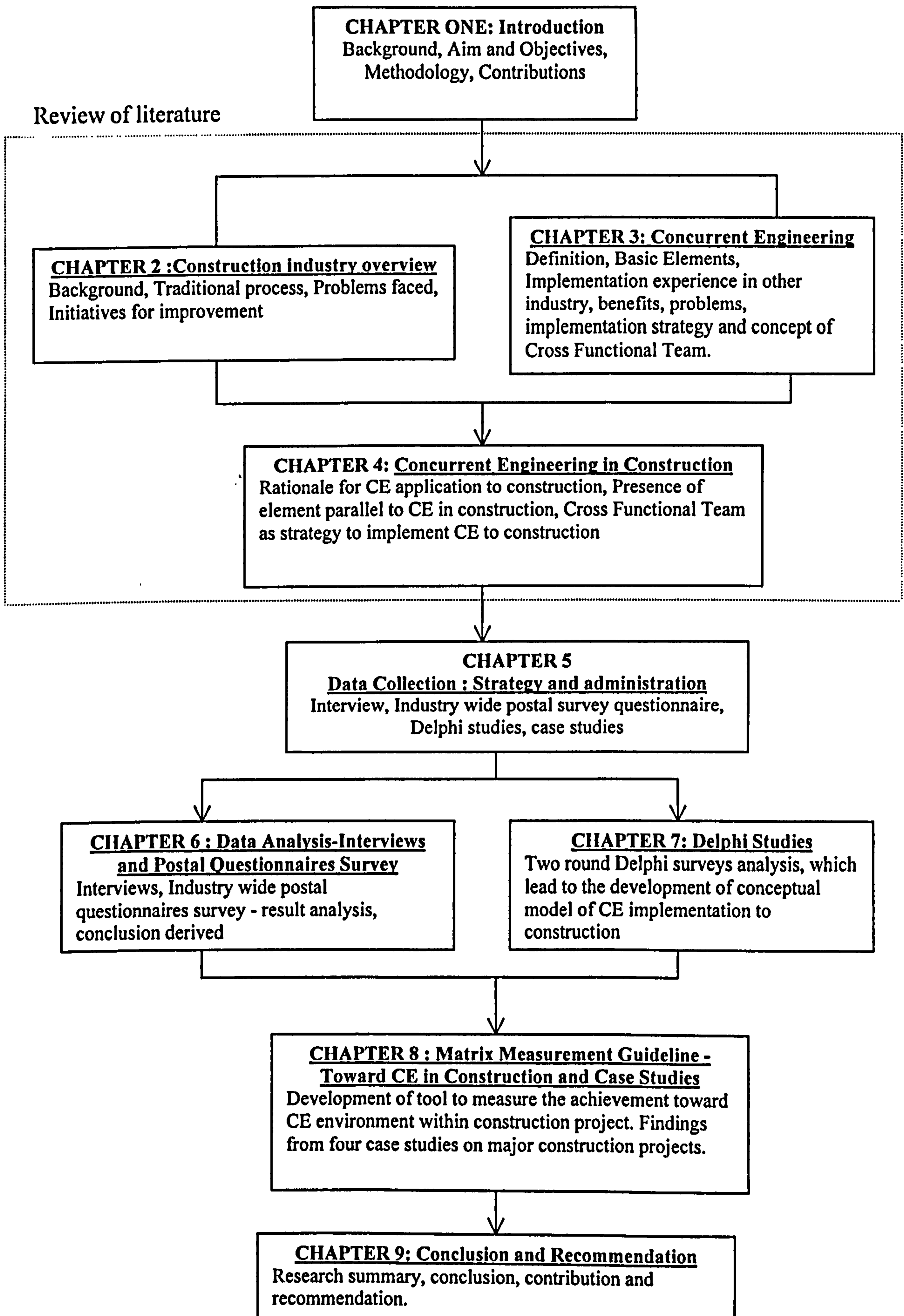
**Chapter six** analyses the data gathered from the industry interviews and industry wide postal questionnaire survey. The findings, and the conclusions derived from the data are reported.

**Chapters seven** analyses in detail the findings from the Delphi study and discusses the development of the guidelines to implement CE to construction.

**Chapter eight** presents the development of the Matrix Measurement Guideline - Toward CE in Construction (MMG-TCEC). Also discussed the findings from case studies.

**Chapter nine** concludes the results of the research. Discussions are made on the contribution of the research and then recommendations are made for future research.

Figure 1.2 shows the flow the chapters of this thesis.



**Figure 1.2 Thesis outline**

## CHAPTER TWO

### CONSTRUCTION INDUSTRY OVERVIEW

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#### 2.1 Introduction

This chapter presents an overview of the construction industry. The main focus of the chapter is 'the traditional construction process' which dominates current industry practice in organising and delivering the construction projects. Various issues pertaining to 'the traditional construction process' such as: its definition; process model; and its limitations and various problems associated to it are explored. The chapter also discusses various efforts within construction industry to improve the industry performance together with their limitations.

#### 2.2 Background

Construction industry is an important sector in any developed country economy. In UK construction represents eight percent of gross domestic product (GDP) (Latham 1994). The growth of construction industry depends greatly on wider economic performance. If the economy is strong, there will be a strong demand for construction projects. Demand will fall otherwise during a general recession period. Construction projects vary from small refurbishment work to large, billion pound projects like the Channel Tunnel (Harvey and Ashworth, 1993). The industry is characterised by a large number of participants and has a highly fragmented structure. The major stakeholders of the industry represent different organisations including large public listed companies, which may employ more than a thousand workers. Many small companies are self-employed workers or companies who employ two workers. These organisations also represent different trades. They may be categorised as follows: consultants; contractors; sub-contractors; project managers; suppliers; and specialists.

An important sectors in national economy, the UK construction industry has been criticised for its performance for the past decades. A series of reports have reflected

such concerns. These include the Emmerson Report (Emmerson, 1962), Banwell Report (Banwell, 1964), The Wood Report (Wood, 1975), Latham Report (Latham, 1994) and Egan Report (Egan, 1998). Numerous academic papers have discussed the issues related to the problems faced by construction industry either in UK and other countries. These issues already been mentioned in chapter one, will be elaborated here. In response to criticism and with the desire to develop improved work methods within the industry, various alternative approaches from the traditional way of delivering the project have been developed by the industry. Most of these centre on developing alternative procurement approaches or improving the business relationship among project participants.

There is no doubt that the construction industry has gained much benefit from such initiatives. However the central issue now is the extent these initiatives have resolved the problems faced so far? Will the improvement measures adopted within the industry so far treat the roots of the problem or just the symptoms. Recent reports like Egan (1998) and the results of surveys within industry do not convince us that considerable improvement has been achieved. Cox and Townsend (1997) quoting from Harding (1996) claim that there is growing evidence that the problems of fragmented, self-interested and adversarial culture of the industry still persist. Therefore the effort to search for solutions to cure the industry 'illness' is still an ongoing process. In this research it is recognised that the root of the problems faced by the construction industry today is related to the traditional construction process. The following sections will explore this issue in greater detail.

## **2.3 Traditional construction process**

### **2.3.1 Definition**

There is no specific definition given to the term "traditional construction process" in the literature. However it can be literally understood as the common practice inherited from the long established custom of delivering the construction project. The word 'traditional' is often associated with the common practices in construction such as procurement, work process or project organisation. Terms like "traditional method of procurement"



(Harvey and Ashworth, 1993), "traditional project" (Ashworth, 1996), "traditional contract" (Fisk, 1992) and "traditional organisation of construction" (Halpin and Woodhead, 1980) are often used in the text to describe the normal standard practice in organising and procuring the project. Latham (1994) used the term "traditional construction" in his report to describe the project which involved well established and normal techniques of design and construction. He further stated that this traditional way also involved the use of Standard Forms of Contract such as JCT 80 or ICE 5th and 6th. Egan (1998) used the term "conventional construction process" to describe the process which is sequential and largely separated process of planning, design and construction. In American the term design/bid/build (Konchar and Sanvido, 1998) or design/award/build (Groton and Smith, 1998) is used to describe the traditional way of procuring projects. Williams (1995) applied the term 'traditional' to express a similar concept of fragmentation of work process in construction project when he compared the traditional process with the fast track design and build process. Larson (1997) applied the term 'traditional' to describe the nature of win-lose adversarial relationship and compared it with the partnering approach.

The way the term 'traditional' appears in the literature has two implications. First it is used to describe the custom methodology of organising and procuring the project, and second this methodology has inherent problems associated to it. For the purpose of this thesis the term traditional construction process is defined as, "the methodology of procuring (delivering) the construction project based on the fragmentation of work process, which is normally carried out in a sequential manner".

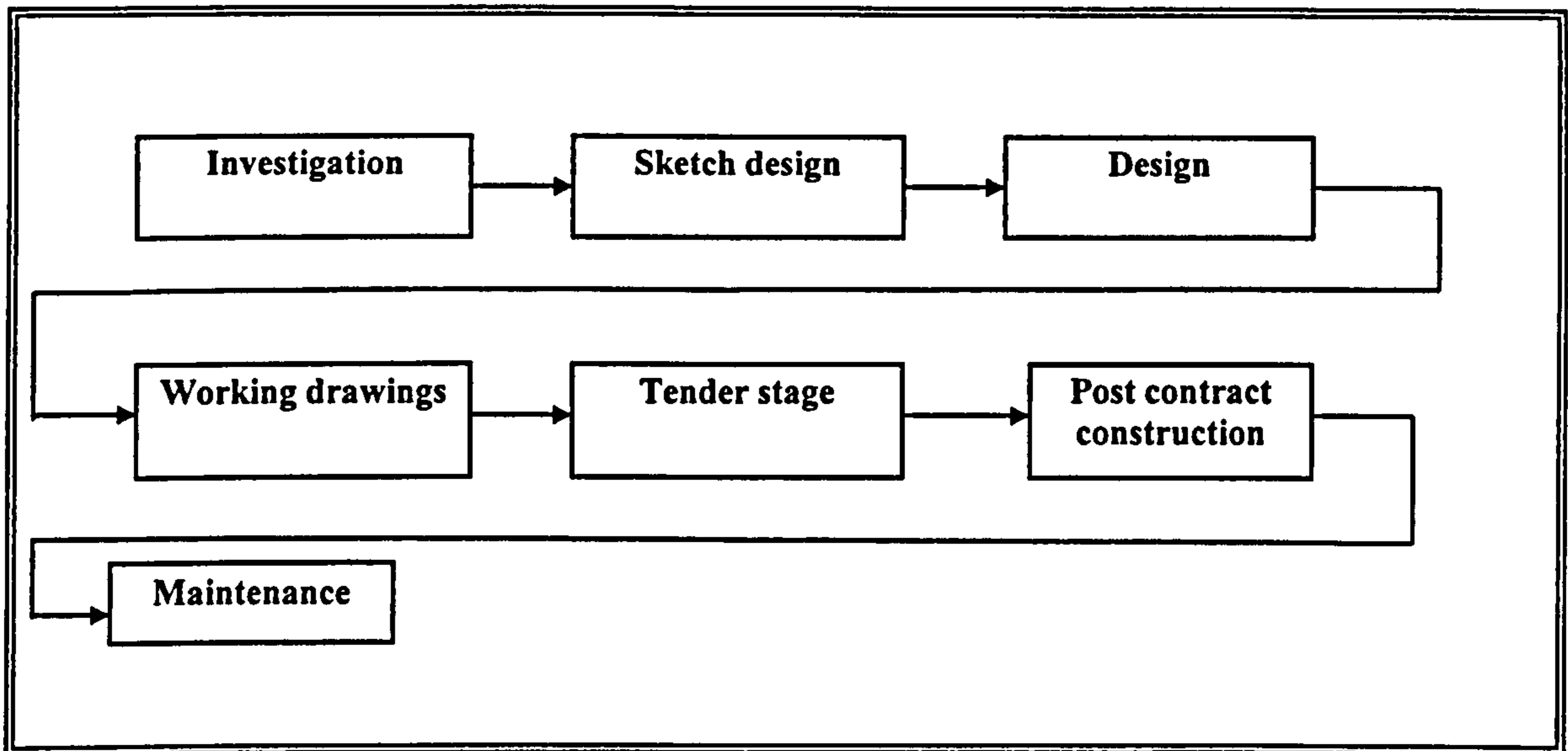
### **2.3.2 Historical background of UK construction process**

The background of UK construction industry can be formally traced back to the middle of 13th century with the establishment of craft guilds (Dunican, 1984). The evolution of the construction process started with the single point of control of design and construction by a leader known as mastermason (Jergeas 1989). As the time passed, new developments put constraints on the guilds system. These developments included: the invention of new construction materials such as brick and Portland cement; change of building legislation system which require the use of brick and stone after the incident

of great fire of London; and industrial revolution in 18th century. These developments resulted in an increase of the complexities and greater requirements for projects (Jergeas 1989). To meet these challenges new fields of craftsmanship and design personnel developed. The building craftsman become an entrepreneur who controlled the smaller enterprises from appropriate guilds such as plumbing, carpentry and bricklaying. This practice is similar to the modern concept of sub-contracting to deliver the project. The period of 1780-1820 marks the change in the procurement system with the development of the method of Gross Tendering (Dunican, 1984). In this system the general contractor tendered the cost of entire project and would be responsible to manage, and organise the entire workforce to deliver the project. According to Jergeas (1989) the emergence of the role of consultant resulted from the process of separation of the specialist designing sub-contractors. This need developed from the complexity of the design requirement after the invention of Portland cement. This separation of the design and construction function has become the significant identity of the "traditional way" for delivering the project up to the present day. The fragmentation of the construction process proliferates as the project complexity increases. The fragmentation was complemented by the use of the traditional contract form.

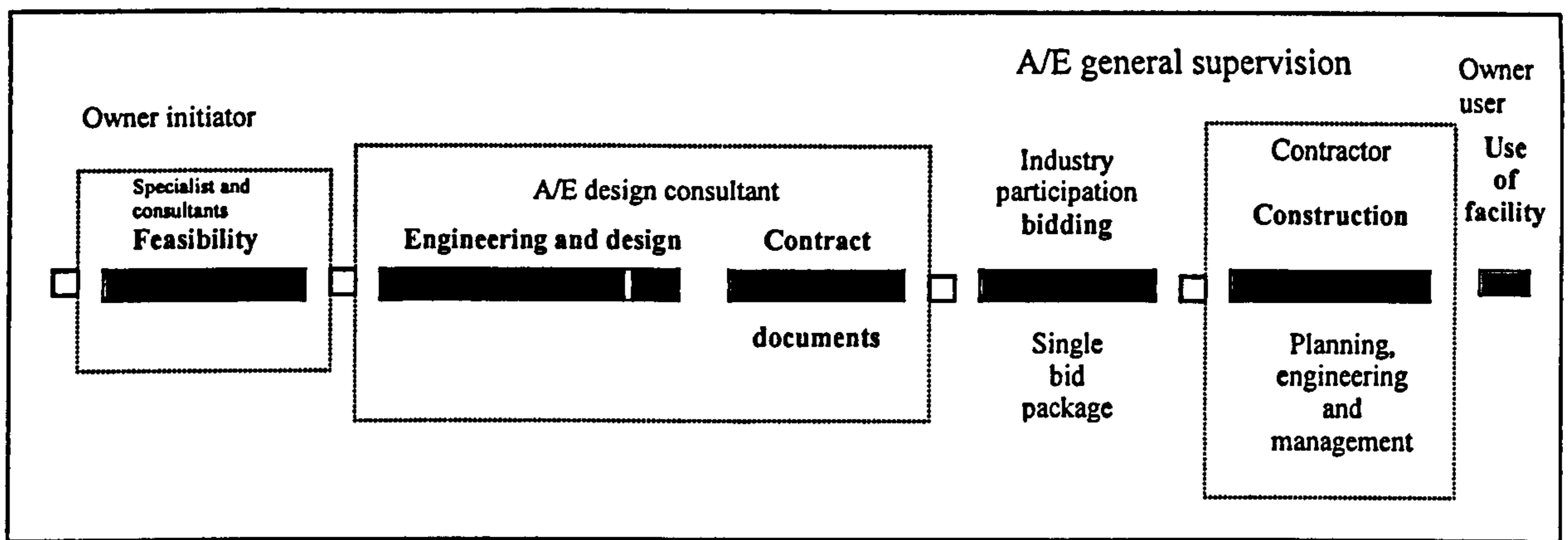
### 2.3.3 Traditional construction process

There is no one model of the construction process. In UK's construction industry the most commonly referred model is the RIBA plan of work (Ashworth 1996). The typical phases of linear construction process based on RIBA plan of work is as shown in figure 2.1. The architect and engineer will do the conceptualisation and design. The planner and estimator (quantity surveyor) will estimate the cost, do the financial planning and prepare project schedule. The constructor (contractors) will undertake the construction work and the client is responsible for the maintenance function. The entire process is control by the standard hierarchical management methods.



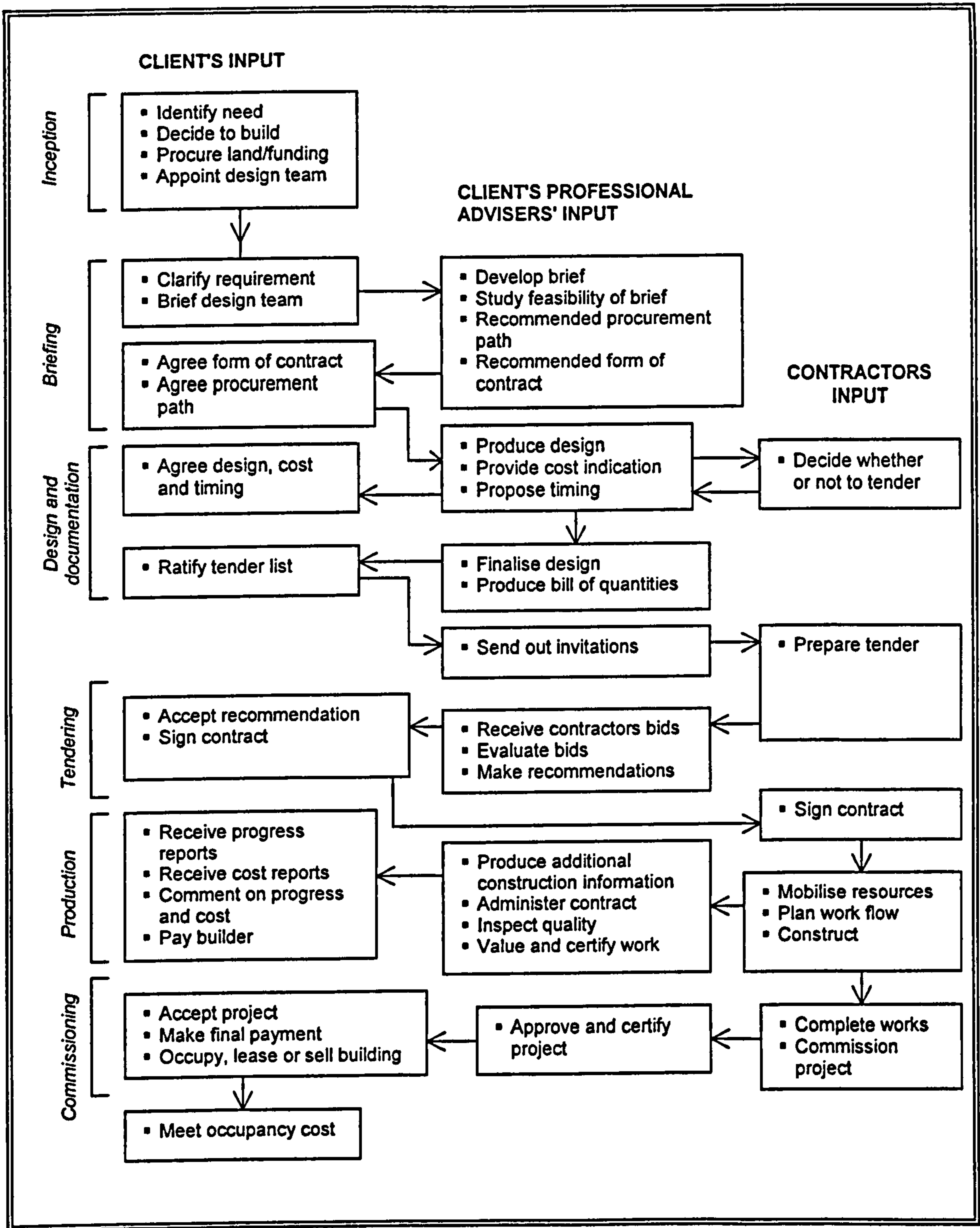
**Figure 2.1 RIBA construction process (Adapted from Ashworth 1996)**

✱ The project development process is divided into two general phases: pre-contract and post contract. The pre-contract activities are: client briefing; investigation; sketch design; designs; working drawing; and tendering stage. Upon completion of the tendering procedure, the project will follow with construction phase and maintenance of the facilities. The whole development process (project life cycle) of the project is executed in a sequential manner throughout the entire project life cycle. The construction process model to show how construction work being organised based on the linear relationship of each phase of project task has been the dominant practice of the construction industry management text until now. Halpin and Woodhead (1980) present one of such example as shown in figure 2.2., whereby each phase cannot proceed without the full completion of its proceeding phase.



**Figure 2.2 Traditional organisational of construction (Halpin and Woodhead 1980)**

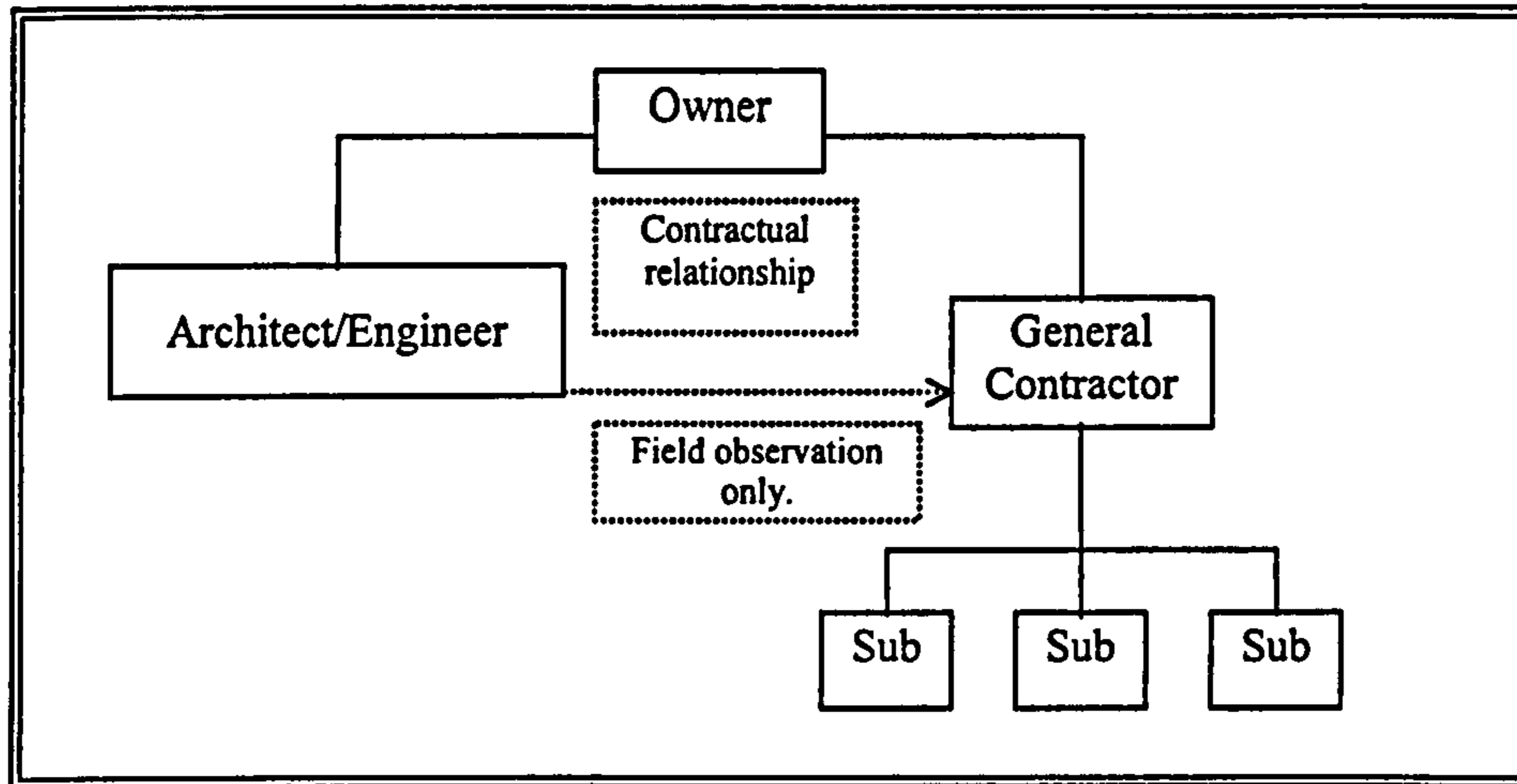
Kwakye (1997) equally presents a model of traditional sequence of activities in construction as shown in figure 2.3. He does not only presents the sequence of phases, but also details of the inter-relationships between the major parties in each phase.



**Figure 2.3 Traditional sequence of activities in construction project (Kwakye 1997)**

In general the major participants of construction process consist of the client, design consultants and the contractors. The Aqua Group (1996) states that the building team is made up of the design team and construction team. The design team consist of the: employer; project manager; planning supervisor; architect; quantity surveyor; structural

engineer; building services engineers; and nominated sub-contractor. While the construction team consist of: contractor (or principal contractor); site agent (or foreman, described in the contract as the person in charge); nominated sub-contractors and domestic sub-contractors; and clerk of works (which is appointed by the employer). Fisk (1992) shows the typical traditional relationship in the project as in figure 2.4.



**Figure 2.4 Traditional construction contract relationship (Fisk 1992)**

This relationship is fragmented further as each of these participants has their own sub-groups. For example the contractors normally have contractual relationship with sub-contractors and suppliers. Clients may have separate relationships with project advisors such as managers to look after their interest while the consultants may sub-contract their designing responsibilities to the other consulting firms. The complexity of the relationship between the project participants in a project will grow up as the project become larger. In the traditional system, these participants of the project must cooperate together and their commitment toward the project is manifested by the separate contractual arrangements. Together they join the project team at different stages of the project life cycle. The 'team' participation starts with the owner engaging the service of the design consultant and then follows by the constructor during the post contract stage. The team members are expected to share common project goals. The traditional arrangement of project procurement system (project delivery system) has often been

credited for providing the greatest amount of competition, which results the lowest cost (Miles, 1996).

## **2.4 Problems associated with the traditional construction process**

Despite the benefits that the industry gains from implementing the traditional construction process in delivering project there are also many problems associated with this approach. The problems and weaknesses that are commonly associated with the traditional system are discussed here:

### **2.4.1 Fragmentation of the industry**

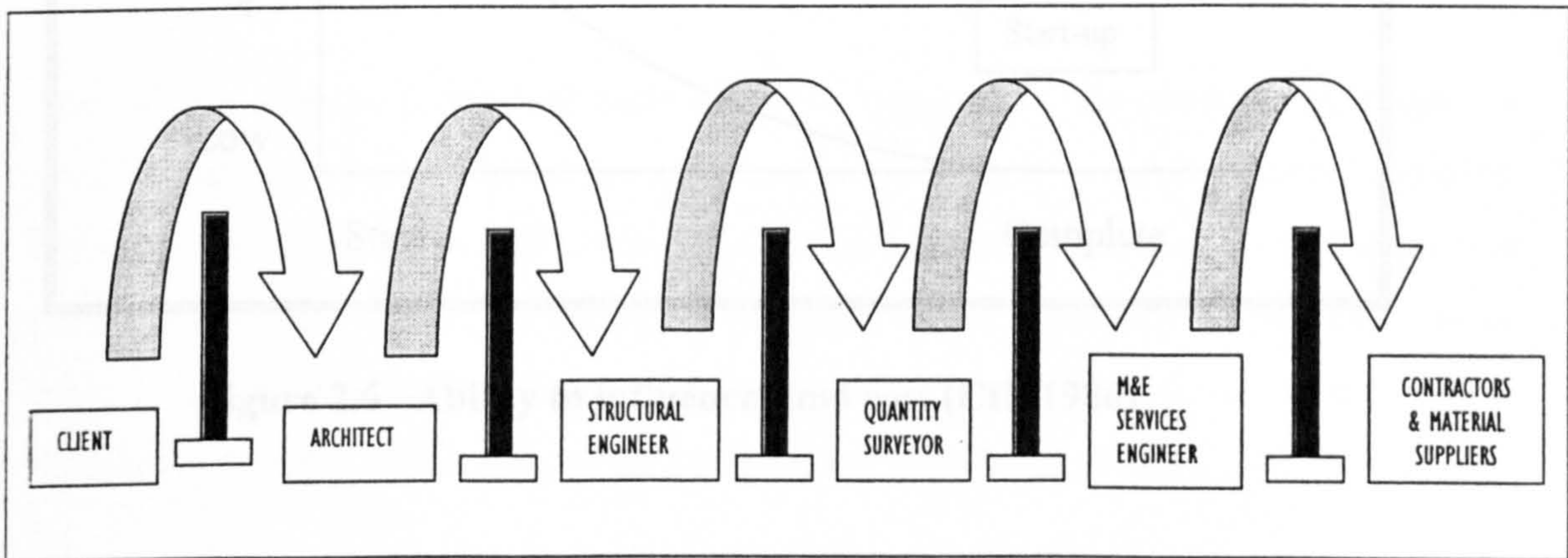
The issue of the fragmentation within construction industry resulting from the traditional construction process can be viewed from two aspects. First is the fragmentation of the process, which divides the work process. The most significant division is in the separation of the design and construction phase. Second is the fragmentation of the industry structure itself. Each of this issue is discussed separately here.

#### **2.4.1.1 Fragmentation of the process**

The separation of the design and construction process is the most important feature of the traditional construction process. The separating of these two important phases of the project development is not only the practice of construction but also a common approach in the traditional manufacturing process. Within manufacturing the concept of separating the design and manufacturing process has been developed based on the "division of labour" theory developed by Frederick Taylor (Donnelly et al. 1992). The assumption made by Taylor was that each task in a job is separable and independent. This theory further developed by Henry Ford in the mass production of automobile (Crowley 1996). However in late 1970's this approach was considered inappropriate. Unlike construction, manufacturing industry was very quick to respond to the need for

change by adopting the alternative approaches in design and production management philosophy.

The practice of separating the design and construction process has resulted in many setbacks to the industry performance. Sir Harold Banwell (1964) commented "*In no other important industry is the responsibility for design so far removed from the responsibility of construction*". The separation of the design and construction function has resulted in the "*institutionalised, functionally separated, project structure that affected all stages of the design-construct process and is still the dominant form today*" (Puddicombe, 1977). Wood (1975) claimed that the traditional separation of design and construction diminished the advantage of contractor capability to contribute at the design stage. He further commented that the inclusion of contractors within the traditional method of procurement is too late for practical use of their advice and experience toward design development. Evboumwan and Anumba (1996) make the analogy of "over-the-wall" process to describe this fragmented process approach. This concept is presented in figure 2.5.



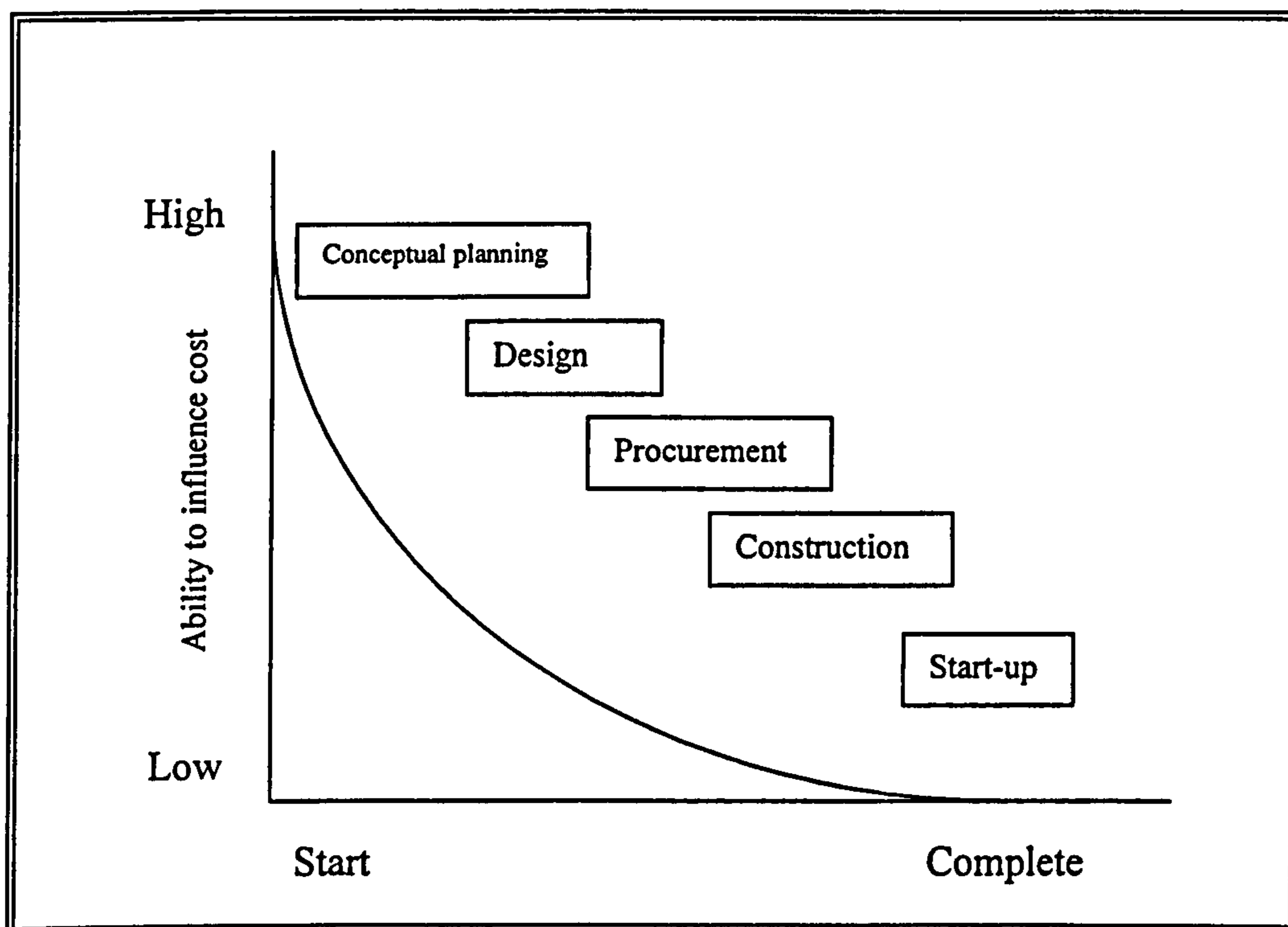
**Figure 2.5 Over the wall process (Evboumwan and Anumba 1996)**

Syan (1994) also uses the same analogy to describe the same traditional manufacturing process. In this process each completed process will be tossed over the 'imaginary wall' to the other functional group within the linear process line for further action to complete the whole task. In this system if any error is detected, the task will be tossed backward



over the imaginary wall for rectification. The whole process is iterative and time and cost ineffective.

The design phase is considered critical because the decisions made at this stage have high a degree of influence toward the eventual project cost. Such concept are presented in the figure 2.6 by Albano and Suh (1992) which they quoted from CII (1986). ✓



**Figure 2.6 Ability to influence final cost (CII, 1986)**

Design defects will escalate construction cost. However the difficulties will not end there because it may take litigation to determine the cause and who shall pay for the additional cost incurred (Sweeney 1998). The exclusion of the constructors at this stage is not the only concern. It is also considered critical to have the input of other key project members like the main suppliers, main sub-contractors and specialist subcontractors within the design development phase.

#### **2.4.1.2 Fragmentation of industry structure**

The impact of the separation between the designer and the constructor has gone beyond the limit of the separation of the functional departments. Construction is currently dealing with separate companies of a divergent culture. Any effort to bring this functional group together would result in culture clash and give negative impact to the project (CMC 1991). The fragmentation of the traditional construction process influences the way in which the industry is being structured today. A high degree of fragmentation is often considered to be the nature of the construction industry (De La Garza et al. 1994, Baumal 1997, Krippaehne et. al, 1992). As an example of the magnitude of the fragmentation in construction, the new Pittsburgh (USA) International Airport construction involved 2,400 contractors, sub-contractors, fabricators, suppliers, and vendors (Moorcroft 1993) while 125 firms were involved in the Mall of America project in Minneapolis (Cosgrove, 1991). According to Latham (1994) in UK there were approximately 200,000 contracting firms of which 95,000 are private individuals or one person firms. Cox and Townsend (1997) contend that many main contractors do not take the work directly and there is a greater use of labour only sub-contractors. This type of sub-contractors normally has little or no training to undertake specific work.

The existence of the diversified trade expertise required for the construction project is well recognised especially as construction projects are becoming more complex. However the way the co-ordination is achieved effects the efficiency of the process (Gray 1996). The fragmented nature of industry requires a platform to pull together all project participants from various organisations. Love et al. (1998) argue that this is difficult to achieve within the current traditional procurement system.

#### **2.4.2 Adversarial culture**

Cox and Townsend (1997) emphasise that the current industry structure has many potential point for conflicts when each participants try to pass on the risk to others within the work. Mendelsohn (1998) described the diversification of the goals of the designers and builder as: *"The designer wants a functional design that reflects his philosophy and the builder wants a buildable product within reasonable risk*

*limitations.* Krippaehne et al. (1992) stated that the various parties that participate in a construction are potentially confrontational with different individuals, goals and objectives: "*What the owner wants in a project may be very different to what the designers intent is, or the motivation of the constructors.*"

Conlin et al. (1996) claim that construction industry in the UK has in recent years, becoming highly adversarial. They supported their claim by quoting Newey (1992) finding's that show a 100 percent increase in litigation in the period of 1973 to 1980 and increase around 15% per annum in the period of 1980 to 1989. In their research on the relationship between construction procurement strategies and construction contract disputes which was conducted on 21 completed project, they concluded that the traditional procured projects have the higher number of disputes which were related to the: group conflicts; payments and budgets problems; project delay; and negligence. Equally design and build projects tended to retain a higher number of conflicts in the cases related to the quality and administration issues.

### **2.4.3 Lack of communication**

Another issue that has been widely recognised as a major problem faced by construction industry is related to the poor communication. This situation arises from the fragmented nature of the industry and results in inefficiency in the project delivery process (Howard et al. 1989). Luiten et al. (1997) described how the communication between the project participants did not evolve at an equal pace and has thus resulted in 'islands of knowledge' of information. Reinschmidt et. al (1991) describe how the separation of function and phased process has impeded communications, obstructed understanding, led to claims and litigation, and contributed to the fragmentation of the industry. Evbouman and Anumba (1996) assert that the key disadvantage of this traditional practice is the inadequate communication between each of the players involved in the project. This can result in: loss of information about design intent; fragmentation of design data; and difficulties in maintaining data consistency. Love et al. (1998) also claim that the traditional method of delivering the project hinders effective communication and understanding between participants. Konchar and Sanvido (1998) reinforce the argument of poor communication achieved within the traditional project delivery system when they argue that interaction between the specialists within

the project is extremely low particularly during the design phase thus leading to: inefficient design; increased error and disputes; higher cost; and ultimately longer schedules.

#### **2.4.4 Breakdown in supply chain**

Supply chain is defined by Christopher (1992) as *"the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hand of the ultimate consumer"*. Agapiou et al. (1998) argue that in construction the communication system established within the supply chain is being influenced by the fragmented structure and the extremely competitive nature of the industry. Within this system the relationship between contractors and suppliers is characterised by the need to secure the lowest price for the material. The flow of essential information between the relevant parties is very limited. Due to this limitation most of the decision within the supply chain is made on the ad-hoc basis rather than systematically. According to Agapiou et al. (1998) this can lead to two problems. First some of the materials are purchased just before they are required and this can result in delay or interruption to schedule. The second problem is dealing with the material procured in large quantity without complying with the actual production requirements at site can lead to the problem of transporting them to site, stocking and wastage. Gray (1996) claims that the fragmentation impedes the opportunity for the industry to generate additional value within production process. The study by the CII (1999) of owner, contractor and supplier relationships states that strategic procurement items which include complex engineered equipment and systems that are essential for project performance are frequently designed, manufactured and delivered by suppliers who are outside the traditional circle of co-operation of and contractors.

Construct I.T (1997) suggests that by using IT, it could strengthen the communication links and support collaborative work, electronic trading and effective communication between the parties in the construction process. GroupWare system, Internet, and EDI are considered important tools to support the communication requirements in the construction supply chain system. However using IT alone is inadequate to improve the

communication within the supply chain. There is also a need to recognise the role and capability of the suppliers to contribute to the construction process. This must be compounded with the effort to restructure the existing organisation structure so that it can support collaborative teamwork environment for all parties involved within the supply chain.

#### **2.4.5 Lack of focus to client**

One of the misconceptions in the traditional construction process is that if clients accept design and construction as two separate independent functions, this will raise the quality of the work (Williams, 1995). However this idea prevents co-operation and teamwork and is therefore not in the client's best interest. Clients normally get less than the optimal design solution in this working environment where constructors and other key project members are separated from the design function and denied the opportunity to give valuable input during the design phase.

### **2.5 Improving the Industry**

#### **2.5.1 Introduction**

The last few decades have witnessed an important change in the production industry across the globe. The philosophy of mass production has shifted to a new paradigm and production philosophy. The focus in production is now directed towards fulfilling the customer preference for a better quality and greater value for product. Competition has become more intensified. The best example is in the automobile and electronic industries where the American and the European manufacturers have had to face the market challenge from their Japanese counterparts. Apart from the quality and versatility of the product it has also become essential to reduce the lead-time to market the product to gain the market niche. Towill (1997) describes this wave of change as a revolution, which has resulted in many enterprises changing their business process. In

this revolution new ideas and management philosophy have been embraced to replace the traditional paradigm of a product driven and functionally organised work process.

These waves of change inevitably also have some influence on the construction industry even though the change may not be as dramatic as in other industries. This phenomenon may be explained by the nature of the construction industry itself, which is characterised, by highly competitive environment, low profit margin, dealing with one-off type projects and inconsistent demand. Within this environment the industry has developed a cautious attitude toward adapting to any the new way of working. The movement urging the industry to reconsider its adherence to the traditional inefficient way of delivering construction projects is not a new effort. Awareness of the need for the construction industry to refocus its process toward achieving a more collaborative environment especially in the aspect of integrating the design and construction function is shared both within and out with the industry. This is reflected in the theme of most construction related reports such as Banwell Report (Banwell, 1964), Wood Report (Wood, 1975), Faster Building for Industry (NEDO, 1983), Latham (Latham, 1994), CRINE Report (1994) and Egan (1998). The industry has responded by offering alternative ways to procuring the project. However the quest for improvement continues as the industry strives to achieve the fundamental changes which can deliver the greater efficiency in the work process, achieving better collaboration of project participants and to realign the focus to client requirements. These requirements are seen as the major challenge that the industry faces today. There are many factors that motivate the industry toward the effort to improve the current performance. These include:

- the inefficiency of the traditional work process;
- the need to be more competitive locally and globally;
- increased use of IT tools to support more efficient communication;
- technological advancement in construction method;
- increased role of downstream project participants toward project design requirements; and
- to improve profit margin by increasing work efficiency.

In the UK the effort to improve the industry is being driven by the initiatives of the public and private agencies as well as construction and client organisations. The academic research community in the collaboration with the industry has also played important roles in analysing the current industry achievement, benchmarking and developing new concepts for applications. Examples of some of such effort are:

1. BAA leading roles in redefining the work process and improving the relation with supply chain in their airport development project (Duncombe, 1997)
2. Construct I.T.- Centre of Excellence - the industry led network of major clients, consultants, contractors, suppliers, IT communications companies and universities set-up to promote IT research in the UK construction (Construct I.T. 1997).
3. Design Build Foundation - A forum to promote and improve integration of design and construction to deliver customer satisfaction through single source of responsibility (DBF 1997).
4. Construction Best Practice Programme - A programme funded by DETR and steered jointly by government and Construction Industry Board. The programme aim to identify current best practice and raise awareness of its importance and ensure appropriate advisory and mentoring services to be made available (CBPP 1998).
5. Process Protocol (Pp) - A joint research effort by universities and industrial partners in developing a Generic Design and Construction Process Protocol (Pp). Pp is a common set of definitions and formats that serve as a basis to enable a wide range of organisations in construction project to work together seamlessly (Kagioglou et al. 1998).

A literature review of the main approaches to improving industry performance can be categorised into several major themes:

- using an alternative procurement approach;
- using a partnering approach;

- buildability or constructability programme;
- integration of the design and construction process; and
- applying new management philosophy originated from other industry.

Each of these themes will be discussed in the following section with respect to their theoretical background, application and an analysis of how each approach could fundamentally impact the traditional construction process.

### **2.5.2 Using an alternative procurement approach**

The traditional approach in procuring the project still largely dominates UK construction industry. The call for reconsideration of this approach began to develop since the early 1960's. According to Harvey and Ashworth (1993) the catalysts for the changes are:

- i) *Government intervention through committees such as Banwell Reports.*
- ii) *Pressure group being formed to create beneficial change for their members, most notably the British Property Federation.*
- iii) *International comparisons, particularly with USA and Japan, and influence of Single European market in 1992.*
- iv) *The apparent failure of construction to satisfy the perceived needs of its customers, particularly in the way in which it organises and executes its projects.*
- v) *Influence of educational developments and research.*
- vi) *The response, particularly in times of slumps in the industry, toward greater efficiency.*
- vii) *Changes in the ways in which technologies are used and attitudes amongst the professions.*
- viii) *The clients' desire for single responsibility.*

The main variation of the approaches that has been practised within the industry currently includes the design and build (D&B) and project management. There are more than 30 contract forms available in UK and most of them developed within the scope of



these three procurement approaches. The difference in these forms of contract lies within the interpretation of the individual clauses and the various agencies that developed them (Ashworth 1996). One of the procurement approaches that has the capability to provide the platform to integrate design and construction function is the design and build. Discussion on design and build procurement presented in the next section.

### **2.5.3 Design and build (D&B)**

Design and build (D&B) is the industry solution for the client who wishes to transfer the design and construction liability to one organisation. D&B has gained the popularity in US (Konchar and Sanvido 1998) as well as the UK. The Design Build contract is defined as a procurement system in which an owner enters into an agreement with a single firm to produce all planning, design, and construction with his own in-house capabilities (Fisk 1992, Turner 1995). Therefore in this system the communication barrier that exist between the designer and constructor team can be eliminated and the integration of the design and construction team can be practically realised. The advantage of this system is that it provides a single reference point for the client. The system is also able to eliminate the tension between designer and contractor since both members are supposed to come from single organisation. D&B can accelerate project delivery time but to achieve this would require additional management staff, additional pre-planning activities and greater co-ordination among team personnel (Retherford, 1998). However Groton and Smith (1998) argue that it is wrong to assume that D&B contractors will protect the owner interest. In this system the owner can lose the 'checks and balances' created with the typical contractor/architect arrangement. Quality assurance can also be an issue (Mulvey, 1998). The owner will not get independent advice on project problems and progress. Furthermore the idea of single point of reference only means that the client has single point of reference for the management of the project, it does not necessarily guarantee that the designer and the contractors must come from the same organisation. In performing the task the main D&B contractor may subcontract portions or the whole of the design or construction task to other companies (Konchar and Sanvido, 1998). D&B does not guarantee immunity for the owner from design defects (Sweeney, 1988). A current development in the D&B system is to

introduce the concept known as bridging. In this system the owner will appoint an independent project manager to look after his interest in the project (Mulvey, 1998). Despite these, D&B has much potential to offer the industry to overcome the shortcomings of the traditional construction process. D&B is one the best platform to achieve the integration of the designer and the contractor within the project and earn the benefits such as minimising administration bureaucracy and reduce project life cycle time. If properly planned, a certain degree of concurrency in execution of the project tasks can be achieved since the designer and the contractors are working in non-adversarial environment. There is research evidence to support that D&B has outperformed other procurement approaches in the project achievement of cost and time. Table 2.1 shows the analysis of the comparative study by Kochar and Sanvido (1998) and Reading D&B Forum between D&B and traditional (Design/bid/build) and construction management procurement rates for unit cost, construction speed, delivery speed, cost growth and schedule growth parameters. The actual study was more comprehensive and reported in Kochar and Sanvido (1998).

**Table 2.1 Comparisons of the Design and Build performance with other procurement approach (Kochar and Sanvido 1998).**

Multivariate model	U.S.			R <sup>2</sup>	Reading DB forum: DB versus DBB (%)	R <sup>2</sup>
	DB versus CMR (%)	CMR versus DBB	DB versus DBB (%)			
Unit cost	4.5 less	1.5 less	6 less	99	13 less	51
Construction speed	7 faster	6 faster	12 faster	89	12 faster	90
Delivery speed	23 faster	13 faster	33 faster	87	30 faster	80
Cost growth	12.6 less	7.8 more	5.2 less	24	NA	NA
Schedule growth	2.2 less	9.2 less	11.4 less	24	NA	NA

Note: DB = design/build; DBB = design/bid/build; CMR=construction management at risk; NA=not applicable

#### 2.5.4 Fast Track system

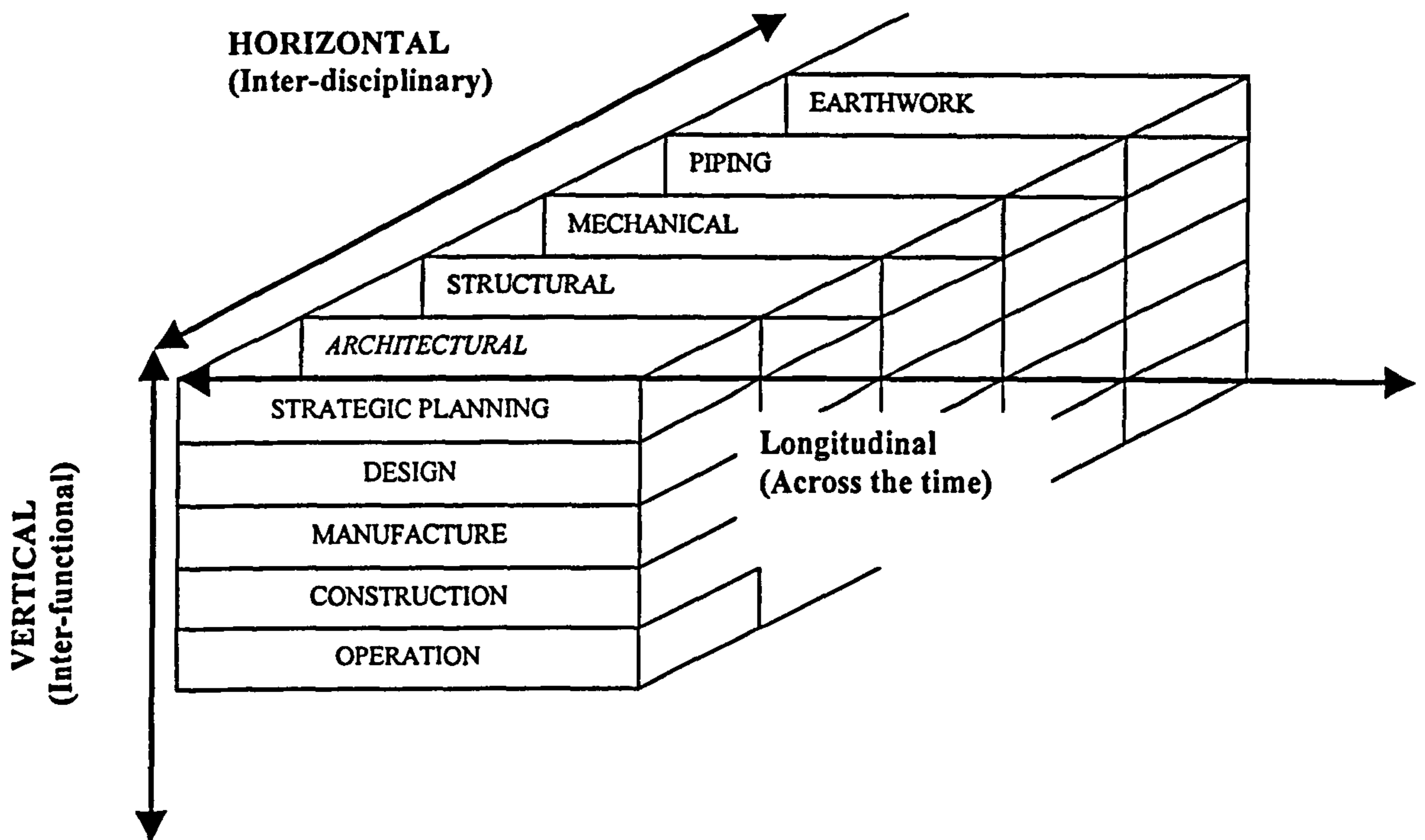
Fast track system is a management technique that is being practised within construction industry with the objective to reduce overall construction time. This is achieved through the integration of work procedure and process (Ashworth 1996). In this system, initial construction will begin before actual facilities design work is finalised (Hendrickson and Au, 1987). Williams (1995) suggest that fast track project should take less than 70% of the time it takes to undertake traditional projects. He further stated that for a fast track technique to be successful better communication, trust and demand for teamwork are essential. All participants, clients, contractors, engineers, suppliers must work together, need to be thoroughly familiar with the scope of work. Any changes made to the completed design work can be a hindrance in achieving the desired time saving.

Houvilla et al., (1997) argue that fast track is a practical oriented approach without solid conceptual or theoretical basis and rarely used in construction. The benefit of time saving gained by using this approach is always offset by the additional cost, normally incurred in the fast track project (Harvey and Ashworth, 1993). Ashworth (1996) argues

that despite Fast Track System's ability to shorten the project time, this might be at the expense of the other facet of cost and performance. He further argues that those aspects may be very inferior to those achieved by the use of traditional methods of procurement.. Williams (1995) states that one of the major disadvantages of this system is the lack of the opportunity to optimise the design solution. Fast track can support process change and concurrency in the accomplishment of project tasks but the prime aim is the time reduction.

### 2.5.5 Integration

Nam and Tatum (1992) argue that the major factor that contributes to the failures of the conventional construction process can be attributed to incongruent goals and the consequences of divergent behaviour by the participants in a project team. Puddicombe (1997) wrote that this condition has been labelled by the prominent industry researchers as "disintegration". Tatum (1990) suggests that integration as a method to link the traditionally discrete phases of design and construction and this can be achieved through the application of information technology. The term integration is defined by Fergusson and Teicholz (1996) as: *"the flow of knowledge and information in three dimension: vertically (between industry function), horizontally (between discipline or trades), and longitudinally (through time), by organisational (humanware) and technical (software and hardware) modes of co-ordination.* Howard (1994) defined integration within the context of construction industry as: *"the representation of management and communication of information (data and knowledge) throughout the life cycle of facility planning, design construction and management"*. Figure 2.7 shows the conceptual representation of the three dimensions of the integration process.



**Figure 2.7 Three Dimension of integration (Adapted from Fergusson and Teicholz, 1996)**

Currently there are also many other initiatives being undertaken within the construction industry to support a higher level of data integration between different organisations for more efficient communication system and to achieve greater concurrency in project implementation. Such efforts attempt to rationalise the construction process to support greater flow of information, which ultimately aims to provide a platform for greater information sharing ability among project participants. Examples of discussions on project information integration and modelling for construction can be found in the works of: Fisher and Froese (1996) on characteristics of shared project models; Reinschmidt et al. (1991) on integration of engineering design and construction; Froese (1996) on model of construction process information; and Luiten and Tolman (1997) on automating communication in construction. Nam and Tatum (1992) argue that the use of information technology alone is insufficient. Puddicombe (1997) suggests that organisational integration is critical in order to achieve the objective of information integration. Partnering is an example of the integration process between the organisation and trades. One of the common IT tool

that is used to support organisational integration is the GroupWare. In one of the projects employed as a case study for this research it was observed that the project team was heavily reliant on Lotus Notes GroupWare system to support communication and data integration among the partnering members.

### 2.5.6 Partnering

The partnering approach has generated considerable attention in construction industry recently. It is not a procurement approach but rather a means of transforming hostile, adversarial owner-contractor relationship into more collaborative team (Larson, 1997). The term partnering has been defined from the various perspectives viewed by authors. In general, the following definition of partnering by Construction Industry Institute (CII) has been cited by many authors such as Matthews et al (1996), Crowley and Karim (1995), Wilson et al. (1995), Cook and Hancher (1990): *"a long term commitment between two or more organisations for the purpose of achieving specific business objectives by maximising the effectiveness of each participant's resources. This requires changing the traditional relationship to a shared culture to organisational boundaries."*

Sometimes terms such as 'teambuilding' are being used instead to express the same process of bringing people together in the project with the joint objective for developing a common mission statement of shared goals; building and development of trust and commitment; and resolving conflicts (Albanese 1994). CBPP (1998) describes partnering as innovative approaches in managing the relationship between organisations in construction, which intends to go beyond the traditional relationship. The concept of partnering was inspired from the manufacturing industry where the product assemblers normally establish a long-term supply relationship with key first-tier component suppliers. According to CBPP (1998) there are three types of partnering approach as being practised in the construction industry. They are:

- i) Long term agreement between clients and contractors.
- ii) Long term agreement between main contractors and members of their supply chain.

iii) Post-contract project-specific partnering.

Some of the benefits from partnering to construction industry as studied by Matthews (1996) include:

- reduction of exposure to litigation by enhancing communication among all parties;
- better time and cost control of the project;
- increased opportunity for a financially successful project because of non-adversarial win-win attitude;
- more efficient communication; and
- improved decision making.

Many anecdotal accounts of projects that have experienced successful partnering have been reported especially by major construction companies. An example is provided by the construction of expansion to a new business building project for Marks and Spencer in Chester (CBPP, 1988). The acclaimed benefits from the partnering programme, which involved four major companies were:

- outturn cost could be fixed when only 5 weeks into the project;
- defect free building, on time and within budget; and
- open communication, trust and co-operation at all level resulted in speed and efficiency in construction.

A study conducted by Larson (1997) to examine the relationship between certain partnering activities and project success, found that specific partnering elements like establishing problem solving procedures and provision for continuous improvement were linked to cost control and meeting schedule. He also claims that partnering activities were positively related to satisfying customer needs, avoiding expensive litigation, and overall results. According to him the findings from his study supported the arguments by the partnering advocates that partnering can contribute to more productive, collaborative working relationship between owners and contractors. However, he argues that partnering is a complex and dynamic process which is more

than handshake. Therefore it requires understanding as to how different elements and activities interact to influence project success. In another study Larson and Drexler (1997) identify the barriers to project partnering. The study used an open ended mail questionnaire with 187 respondents. The main results from the content analysis of the responses identified the following barriers:

1. Failure to build true relationship of trust.
2. Many people with an instinctive suspicion of the other party due to past experience.
3. Difficulties to get rid of old habit ('Old habits die hard').
4. Too much reliance on legal protection and /advantages or loopholes in documents.
5. Synchronising goals in a big organisation or when numerous sub-contractors used.
6. Low bid method of awarding projects.
7. Failure to use plan.
8. Unfamiliarity or misunderstanding of partnering concept by upper management.
9. Failure to "walk the talk".

The concept of partnering is business oriented. What is achieved in the project is strictly governed by individual experience and the ability to plan and control the partnering process to ensure that each party involved adheres to their initial commitment. It is argued here that partnering is good for the major organisation if it is formed between regular group members. For the industry as a whole, where a majority of its key players comprise small companies who undertake sub-contracting of the works, the partnering process is not easy to achieve. Moreover partnering does not have any specific principles rather than those developed by mutual understanding and agreement. It is not a solid conceptual approach that has universally accepted principles with very clear guidelines. Love et al. (1988) argue that cultural and behaviour barrier might impede the benefits of partnering. Partnering cannot be fully realised if implemented within the existing traditional procurement approach.

### **2.5.7 Buildability (Constructability) programme**

Another approach taken by the industry in the effort to overcome the shortcoming of the traditional construction process is by employing the constructability programme.



Constructability (also known as buildability) is a concept that has been developed in recognition of the inherent shortcomings and limitations of the traditional owner-designer-contractor relationship. The major feature of the constructability concept is the infusion of construction knowledge and experience into activities preceding construction so that it will result in efficient site operations (O'Connor et al. 1987). Earlier research on the constructability concept was conducted by Construction Industry Research and Information Association (CIRIA) in the 70's (Skibniewski et al. 1997). CIRIA's definition of constructability is *"the extent to which the design of building (or other structure) facilitates ease of construction, subject to the overall requirements for the completed (structure)"*. The Construction Management Committee (CMC 1991) of the ASCE Construction Division defines constructability program as *"the application of disciplined, systematic optimisation of the construction related aspects of a project during the planning, design, procurement, construction, test, and start-up phases by knowledgeable, experienced construction personnel who are part of a project team"*.

Francis et. al (1996) cite that the earlier studies found that the lack of integration of construction knowledge into design process hindered the ability to construct. Also the traditional contractual procedures that separate design from construction process was seen as a major factors hindering constructability. The study carried out by Tatum (1987) describes the benefits from constructability improvements to include decreased construction scope, decreased construction difficulty and improve construction methods and technology. The work on constructability in UK was narrowly focussed by highlighting the techniques and details, with emphasis on productivity by design rationalisation (CIRIA 1983, Griffith 1985, Gray 1983).

On reviewing the achievement of constructability program Mendelsohn (1997) raised the issue of it applicability. He commented that for the constructability review plan to be effective, generally it is necessary to first complete the plan up to a certain level sometimes up to 90%. He proposed a revised constructability process that would consider the inclusion of the construction expertise before any design is put to paper. Another important issue that needs to be considered is who supplies the actual expertise involved in the constructability process apart from the contractor? Suppliers, major sub-contractors and the specialists are also important group of team members that should be considered important stakeholders in design development process. Their role

should extend beyond merely revising a near complete design or just strictly narrowed to the technical aspect of construction only. Furthermore, it is argued here that the implementation of buildability programme needs to be established on a proper platform. Participation in the buildability process should be those who will be involved in the implementation of the design. The current traditional process, is one of the critical factors that may hinder the implementation of constructability programme. Fisher and Tatum (1997) suggest that constructability knowledge should be formalised and made available in the appropriate form. The use of IT is considered to be one of the appropriate forms to support the implementation of constructability implementation.

### **2.5.8 New management philosophies**

Over the past two decades many new management philosophies have emerged. Some of these have revolutionised the manufacturing industry. These new philosophies have mainly embraced on the concept of satisfying the increasing need of customers for better quality and value. Highly competitive and volatile markets today also demand the competing enterprise to offer their services or products within highly constrained time scales if they want to secure their position in the market. Hammer (1990) stated that as companies change their focus from producer to customer, *“the watchword of the new decade are innovation and speed, service and quality”*. Under these constraints, many enterprises have embraced new customer oriented management philosophies to improve their performance and efficiency.

A review of the construction management literature shows the growing trend for applying the concept of the new management philosophies adapted from other industries to construction. Among the new concepts that have been introduced for construction are:

- Business Process Reengineering (BPR)
- Lean Construction
- Concurrent Engineering (CE)
- Computer Integrated Manufacturing (CIM)

However the research findings indicate that the construction industry is very slow in adopting and applying these theories in construction (Betts et al. 1997). Many reasons have been associated with this phenomenon. The most common reason for the delay to accept the new paradigms is a belief of uniqueness of the industry (Kwak et al.,1995). However Koskela (1992) indicated that the trend to perceive the uniqueness of the industry is a psychological need common to other industries as well. Another reason that is often quoted is the high degree of fragmentation of the industry (De La Garza et al., 1994). This has resulted in the intense competition because of the large number of specialised firms in this industry which in turn forces the companies to avoid risk and adhere to the industry norm whenever possible (Mohan, 1990). Oglesby et al. (1989) point out that construction firm owners are not aware of the economic payoff to be derived from the appropriate use of modern management systems and not willing to meet the additional cost that might be incurred from the change.

Some of the major new management philosophies are discussed in the following section. (The detail discussion of the CE philosophy is presented in chapter 3.)

#### **2.5.8.1 Business Process Reengineering**

Business process reengineering (BPR) sometimes referred to as process reengineering or just 'reengineering' is a concept popularised by Micheal Hammer (1990). It was first presented as an argument for an alternative rationale in the application of IT to transform the organisation rather than just a mere automation (Betts et al, 1997). The term reengineering is defined by Hammer and Champy (1993) as: *"fundamental rethinking and radical redesign of business process to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed"*.

The essential theme of BPR as discussed by Edwards and Peppard (1994) lies upon the following principles:

- focus upon stakeholder;

- integrates functional specialisation of organisation;
- redesign the process;
- use of information technology as an enabler for change; and
- the critical roles of human resources.

BPR is general philosophy of changing the organisational structure and business process. It is developed on the basis of the model of a stationary organisation. Mohamed (1997) points out that the application of BPR is exclusively an 'in-house' operation, which experience minimum dependence and interference from external factors. Therefore to realise its application in construction industry to re-engineer the construction process requires an approach that encapsulates other concept such as Concurrent Engineering or Lean Production (Love et al, 1997).

#### **2.5.8.2 Lean Production**

The Lean Production is a system developed over a 20 years period by Toyota Motor Company in Japan and popularised by Wormack et al. (1990). The basic philosophy of this system is to maximise profits by minimising waste. Lean Production philosophy is regarded as a generalisation of various partial approaches to production such as Just in Time (JIT), Total Quality Management (TQM), Time Based Competition, Process Re-design, World Class Manufacturing and Concurrent Engineering (Koskela 1997, Schonberger 1990, Plossl 1991). The basic aim of Lean Production philosophy is to avoid waste of time, money, equipment, etc. (Shingo 1992). Melles (1997) argues that Lean Production does not really include new principles of management technique. He states that the basic idea of applying Lean Production to construction is simply by elimination of waste and non-productive task. Since the Lean Production philosophy is generic in nature it is difficult to single out a specific application of it to construction as a whole process. One of the interesting argument of Lean Production application to construction is made by Crowley (1996):

*"Many companies involved in construction particularly specialist subcontractors already regard themselves as lean. Having cut costs to*

*the bone, they feel that there is no more fat left to trim. Some have restructured downsized and outsourced choosing to concentrate on their preferred core business. And yet they are not achieving the profits margins seen in manufacturing."*

Such arguments reflect the idea that applying lean philosophy to construction requires a systematic management and production approach that must involve the whole process and participants. Sub-contractors and suppliers must be included in such a system rather than being instructed to deliver output especially under the traditional procurement approach.

## **2.6 Summary**

In this chapter the construction industry has been explored with respect to: its historical background in UK; current state of art of its traditional process; and the development that is taking place to improve the industry performance due to the shortcomings of the traditional construction process. The nature of the construction industry today either in UK and many countries is described in the literature as highly fragmented and characterised by adversarial relationship between the project participants. This phenomenon leads to further problems such as: inefficiency of the work process; highly competitive nature; breakdown of communication within the supply chain; lack of focus toward customer; and poor project performance in term of time quality and cost. The traditional construction process, which has been developed upon this fragmented industry structure and process is considered as the root of these problems.

In response to this limitation of the traditional construction process several effort have been made within the industry to improve its performance by: using alternative procurement approaches like design and build; adoption of integration strategy like partnering; and promoting new management philosophies like CE, BPR and Lean Production. There is also effort to promote the use of the IT tools to enhance project communication with the aim to achieve better collaboration within the industry. In evaluating the effectiveness of these efforts, there are two important issues that need to be addressed. First, how acceptable are these changes to the industry, which had been

confined for decades within the 'traditional' culture? Second, is the strategy recommended (or already being practised) adequately capable of solving the fundamental issues of the traditional construction process which has been considered as the root the problem that the industry is facing now? The lesson learned from the effectiveness of the present experience to transform the industry traditional practice toward a new paradigm of non-adversarial and working under integrated process system can guide us toward developing a better strategy to be proposed for the industry.

Design and build procurement system and partnering approach have been accredited as a viable approach that is proven to improve project performance. Their application has gained some momentum recently. Other new management philosophies like BPR and Lean construction are still striving to gain the acceptance, probably because the lack clarity and understanding of their concept which seem to be so generic in nature. Various levels of information technology tools are being utilised by the industry to support project communication even though the industry is still plagued by the belief that they are costly to implement.

In analysing the existing industry scenario and the effectiveness of the effort taken to improve the industry performance the following facts has been established:

- The limitation of the traditional construction process is well established.
- There is a desire within the industry to accept changes but this is happening in a very prudent manner.
- Any initiative to reform the industry traditional practices need to have the capabilities to change the two facet of the traditional paradigm i.e.; separation of work processes and isolation of the team member into unrelated functional groups. This can be achieved by elimination of the barrier that separate work process and promotion of collaborative teamwork culture within the project.

- The practice of D&B procurement approach within the industry shows evidence that the construction project can be procured using a collaborative teamwork approach. Even though the ultimate aim of D&B system is to provide single source responsibility to the client, some degree of collaborative working especially between designer and constructor can be achieved when working under the same management.
- The acceptance of partnering approach within construction industry is another evidence of the desire of the industry toward collaborative teamwork approach and it can be practically implemented.
- Despite these evidences that support the view that projects using D&B or partnering exhibit better performance compared to the traditional approach, but there are still limitations in term of their capabilities to support process change. This is because their implementations are still being influenced by the traditional culture of construction process.
- The use of IT is gaining acceptance within the construction industry. However, IT alone is inadequate to support process change if there is no organisational change taking place to create the need for more information exchange between the project players within the collaborative environment.

In analysing the limitation of the current effort to improve the industry raised above the following issues become apparent:

- There is a need for further research agenda to consider alternative measures to improve the industry performance.
- This effort must take into consideration of the limitation of the existing strategy in promoting collaborative teamwork and changing the work process.
- Any new strategy to change the traditional construction process must not be built upon the traditional platform of project delivery system.

- However it is important to consider the approach which the industry is already familiar with to be incorporated in the new strategy.
- The familiarity of the D&B concept, partnering and some of the application of IT tools to support project communication can provide a good basis for the introduction of the new strategy.

The analysis of the industry background and current initiatives as well as the limitation that exist within the current approaches to improve the industry's performance provides a good insight of the actual requirements needed to develop a new strategy. These findings also support the research agenda to introduce the adoption of Concurrent Engineering (CE) philosophy to construction. The detail aspects of CE philosophy will be explored in the next chapter (chapter 3). CE is a well established management philosophy and its development was dictated by the need to change the practice in the traditional manufacturing process. Therefore considering the limitation of the current approaches, CE seems to be the most appropriate strategy to be explored and rationalised for its application within a construction industry environment.



## CHAPTER THREE

### CONCURRENT ENGINEERING PHILOSOPHY

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#### 3.1 Introduction

Concurrent Engineering (CE) is one of the new emerging management philosophies that have a strong potential to be applied to construction. The importance of CE philosophy is that it prescribes how to realign the traditional way of work processes based on a fragmented and sequential product development system into a new paradigm of integrated life-cycle process using a multidisciplinary teamwork approach. This chapter evaluates in detail aspects of CE philosophy from the manufacturing industry perspective, where CE was originally developed. The rationale of applying CE to construction will be discussed in the next chapter (chapter 4).

The first part of this chapter explains the theoretical background of CE, the rationale for its development and its principles. Comparison is made between the traditional manufacturing process and concurrent process to develop better understanding of the differences in approach used in the CE concept in organising the work process. Then each principle that makes-up CE will be explored. A particular focus in the discussion of the CE principles will be the concept of Cross Functional Teams (CFT), the teamwork approach based on CE philosophy requirement. This is vital, as CFT is the backbone of CE implementation. The latter part of this chapter explores the experience in CE implementation by manufacturing organisations. An assessment will be made on the strategy used to implement CE, the challenge in implementing CE, the benefit gains, as well as the problems faced. The lessons learned from CE implementation in manufacturing will be used later to provide useful guidelines that can support the formulation of a research agenda on CE implementation in construction.

## **3.2 Background of CE development**

### **3.2.1 Background**

Concurrent engineering (CE) is a relatively new term being applied to the engineering design philosophy (Smith, 1997). It is also commonly known as Simultaneous Engineering or Parallel Engineering. There are also other names that are associated with CE such as: Concurrent Design; Life Cycle Engineering; Design for Manufacture, and Unified Life Cycle Engineering (Dowlatshahi, 1994).

The principal idea behind the development of CE is to reduce the product development time (Prasad, 1995a). However Stalk and Webber (1993) argue that shortening development lead time is in itself not the only goal. It has to be combined with other competitive advantages such as better customer orientation; improved product quality; and lower development cost. All these goals have a strong relationship with a shorter development lead-time. The strategic objective of CE is to integrate the development and production management and replace the traditional departmental specific division of labour, which was invented by Taylor (Krause and Ochs, 1992). This integration process must be coupled with the integration of human expertise and knowledge through the platform of collaborative teamwork and sometimes supported by information technology (IT) tools. Applying this concept to any organisation means all the project life cycle requirements must be considered early in the design development phase. This will enable to reduce length of iterative loops in design cycle and minimise error and rework (Reidsema and Szczerbicki, 1998). Gerwin and Susman (1996) describe CE as the radical breakthrough of the traditional practice in manufacturing. It challenges the traditional product development process, functionally based organisation structures and the concentration of decision-making authority in management. CE has been practised by many manufacturing organisations today as a way of working in a highly volatile and competitive market. The implementation of CE in other industries has been acknowledged to: improve quality; reduce time to market; provide greater customer satisfaction; minimise waste; and increase product reliability (Zangwill, 1992).

### **3.2.2 Rationale for CE development**

The emergence of CE philosophy resulted from the dilemma in manufacturing communities to search for a more effective and innovative approaches in product design and manufacturing (Dowlatshahi, 1994). The changing nature of technology and market led to the situation whereby the individual product life cycles were rapidly shortened (Backhouse and Brookes, 1996). By late 1970's and early 1980's demand for frequent design changes grew as the Japanese competitors were able to develop faster. This situation exerted the pressure on western world manufacturers to review their conventional approach in product development. Liker et al.(1996) argue that the use of the traditional process is no longer appropriate. As the market demand for new product increases and there is an urgent need to shorten product life cycle. Organisations are forced to reorganise their structure and approach to enable them to remain competitive. The conventional product development and manufacturing process system involving highly bureaucratic, functional structures inhibit the degree of co-ordination and natural interdependence required by complex systems. The traditional system also uses a sequential process with low interdependence between the designer and manufacturer. This consumes time before the product matures and is well understood. It requires long periods of iteration of redesign and production. This view is supported by Hauptman and Hirji (1996). They contend that the traditional product development has been rendered inadequate and obsolete. Ayres (1991) argues that the traditional system tends to permit (even encourage) an excessive number of errors and defects in the product, resulting in the unnecessary downstream cost of inspection, repair, and rework. The traditional system of work has proved too slow and non-adaptive as market opportunities shifted from standardised items to what has recently been termed as "mass customisation" (Smith and Reinertsen, 1991). Hull et al. (1996) state that in many cases, large, mechanistic bureaucracies have had to reinvent themselves by adopting new product development paradigms such as CE, or lose market share to speedier, lower cost competitors.

CE seems to have the antidote for the limitation and inflexibility of the traditional mass production system. Miller (1993) describes CE as an absolutely necessary business process and paradigm shift that is capable of delivering against today's business requirement. It is also considered as a precursor to world class manufacturing

environment and capable of responding to high quality, speed and cost requirements. Yoshimura (1996) describes CE as an effective and powerful methodological philosophy for obtaining the most satisfying product design from an integrated global viewpoint. Hauptman and Hirji (1996) claim that it is evidence from the academic research and popular press that CE has been widely adopted by companies and has been successfully diffusing throughout the industry.

### **3.2.3 Historical background of CE**

Smith (1997) argues that CE is not totally a radically new set of ideas. Many aspects of CE principles have been mentioned in past literature, however, the total realisation of CE as a whole concept was only made in the late 1970's. Table 3.1 presents some of the statements concordant to the CE principles made as far back in 1930's which have been quoted by Smith (1997).

**Table 3.1 Awareness toward the important of factors that are parallel to CE in the past (Smith, 1997)**

<b>CE PRINCIPLES</b>	<b>AUTHOR</b>	<b>STATEMENT</b>
Need for integrating with other functions	Purdey (1947)	<i>"Co-operation [between product design and manufacturing engineering organisations] appear to me an essential for best results. It should begin in the early stages of product design and continue as long as the product being produced."</i>
Use of multifunctional teamwork strategy to accomplish integration	Thompson (1945)	<i>"Close co-operation with the production department during the development of design is essential if the maximum degree of productivity efficiency is to be obtained. In fact, it is considered good practice to have one or more production planners stationed within the engineering department, to work with the designers and approve each drawing for adaptability to production and feasibility of manufacture."</i>
Including voice of customer in the design process	Brady (1931)	<i>"Machine designers, and engineers responsible for the engineering development of many kinds of metal products should have awakened to their responsibilities in putting sales appeals into their product long before they did."</i>
Lead time	Fernstrom et al. (1935)	<i>"Life quickened [around the turn of century] and complexities developed at such pace that the problem of making product design cope properly with changing conditions now involves the complete depiction and development of a product from the original idea to the point of use."</i>

Jo. et al. (1993) state that automobile industry pioneers such as Henry Ford to some extent practised the philosophy of what is known today as concurrent engineering. The Japanese applied the concept of CE in their manufacturing industry without even using the term name. Tomiyama (1995) asserts that CE is the American interpretation and

implementation of Japanese manufacturing practices regarding communication, organisational and technological aspects. Syan (1994) also agrees that CE is not a new concept. He argues that successful manufacturing managers have practised it, but no one has paid much attention to apply it in a systematic way. Smith (1997) suggests possible reasons why CE has not been adopted earlier despite the awareness of its importance. These reasons are outlined below:

- i. There is a greater need for the co-operation between the product development and manufacturing process within the current process than in the past.
- ii. The current changes in technology made CE both more possible and necessary.
- iii. The lower cost of communication and other enabling technologies encourage a more cross-functional co-operation behaviour.
- iv. The practice of using functionally separated organisations in the past makes the implementation of CE difficult.
- v. Engineers have been under trained in product development.
- vi. The different nature of strategic environment in the past compared to the existing standard (for example the level of competition and client acceptance in the past may not warrant CE implementation).

### **3.3 Defining Concurrent Engineering**

There are many definitions of CE that can be found in the literature but most of them are similar. The term “Concurrent Engineering” was originally devised by Institute for Defense Analysis (IDA), a working group set up by US Defence Advanced Research Project Agency (DARPA) in their Report R-138 (Winner et al., 1988). The IDA definition of CE is the most widely accepted by the manufacturing community as follows:

*“Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle*

*from concept through disposal, including quality, cost, schedule, and user requirements".*

Apart from IDA's definition there are also various other definitions that can be found in the literature. According to Prasad (1995a) CE definitions in the contemporary literature are more encompassing and reflect a range of expectations from modest productivity improvement to complete push button type automation. One example of a comprehensive definition of CE is made by Cleetus (1996): *"CE is a systematic approach to integrated product development that emphasises responsiveness to customer expectation and embodies team values of co-operation, trust sharing in such a manner that decision making proceeds with large intervals of parallel working by all life cycle perspectives synchronised by comparatively brief exchanges to produce consensus"*.

Another broader view of CE is made by Darr and Birmingham (1994) who state: *"CE is an approach to product development that integrates a company's overall knowledge, resources, and experience as early as possible in the design cycle (for example, considering manufacturing and servicing at the start of the design process)"*. Turino (1992) defines CE from the management strategy point of view as follows: *"CE is a goal-directed effort, where "ownership" is assigned mutually among the entire group on the "total job to be completed, not just "pieces" of it, with the understanding that the team is empowered to make major design decisions along the way"*. Hartley (1992) broadened the CE definition by involving the concerns of design, production, purchasing, finance and marketing, and also by tying in lead times with improved quality and lower costs. Creese and Moore (1990) define CE from the strategic benefit of it as *"a management philosophy dedicated to the improvement of customer satisfaction through improved quality, reduced costs and faster product development"*. Gould (1992) defined it from the broader perspective of CE philosophy and commented, *"CE is about the top-down implementation of a management philosophy using an open approach to organisation management and quality system."* The emphasis on financial consideration was given by Adachi et al. (1995) when they wrote *"the final objective of concurrent engineering is to enhance profitability by cutting time-to-market of new products and building a smooth development process."*

Another dimension of CE interpretation give specific emphasis on the environment creates by it that supports the application of information technology tools. One of such CE definition offered by U.S. National Research Council as *"a design environment in which computer-added design technology is used to access and improved the quality of a product, not only during the active design phase but through its entire life-cycle"* (Ellis, 1992).

The writer has analysed the recurrence of the elements pertaining to CE that exist in the various CE definitions and the result is tabulated in table 3.2.

**Table 3.2 Recurrence theme in CE definitions**

<b>RECURRENT ELEMENT APPEAR IN CE DEFINITION</b>	<b>WHO QOUTES IT?</b>
Concurrent design and product development process	Winner et.al 1988, Knight and Jackson 1989, Wallace 1990, Ruding 1990, Eversheim 1990, Lawon and Miller 1992, Stephanon and Spiegl 1992, Cleetus 1992.
Shorten lead time in the product development process	Knight and Jackson 1989, Yamazoe, 1990, Eversheim 1990, Adachi et al 1995, Barkan 1988, Evans 1988, Stauffer 1988, Winner et. al 1988,
Use of teamwork (team environment) from outset stage and cross functionality nature of the team.	Walklet 1989, Yamazoe, 1990, Wallace 1990, Schonwald, 1990, Eversheim 1990, Lawson and Miller 1992, Cleetus 1992, Turino 1992.
Consideration of downstream (e.g. manufacturing) issue during upstream (e.g. design) phase	Winner et.al 1988, Stephanon and Spiegl 1992, Kannapan and Marshek 1992, Darr and Birmingham 1994.
Emphasise response to customer expectation	Yamazoe, 1990, Wallace 1990, Cleetus 1992, Creese and Moore 1990.



### **3.4 Fundamental element of CE**

There are many ways to present the component of CE elements featured in the literature. For example Prasad (1995a) presents eight principles of CE as follows:

- Early problem discovery
- Early decision making
- Work structuring
- Teamwork affinity
- Knowledge leveraging
- Common understanding
- Ownership (Team ownership of the products)
- Constancy of purpose (Consistency of goals between different departments represented in the team)

Kamara et al. (1997) describe principles of CE from their study consisting of the following theme:

- The need for organisational support to implement business process change to facilitate CE working practices.
- Use of multi-disciplinary teams.
- Upfront consideration of life-cycle issues to facilitates early problem discovery and decision making.
- Concurrent or parallel processing whenever possible.
- Use of IT to support timely and accurate information flow.
- Integration of technology and tools.
- Continuous process improvement.
- Continuous focus on the customer.

For the purpose of this thesis the basic elements of CE made by Smith (1997) will be used as a basis for the analysis . A wider discussion will be presented on the concept of cross functional teams because of its importance to CE implementation. The four principles described by Smith (1997) are as follows:

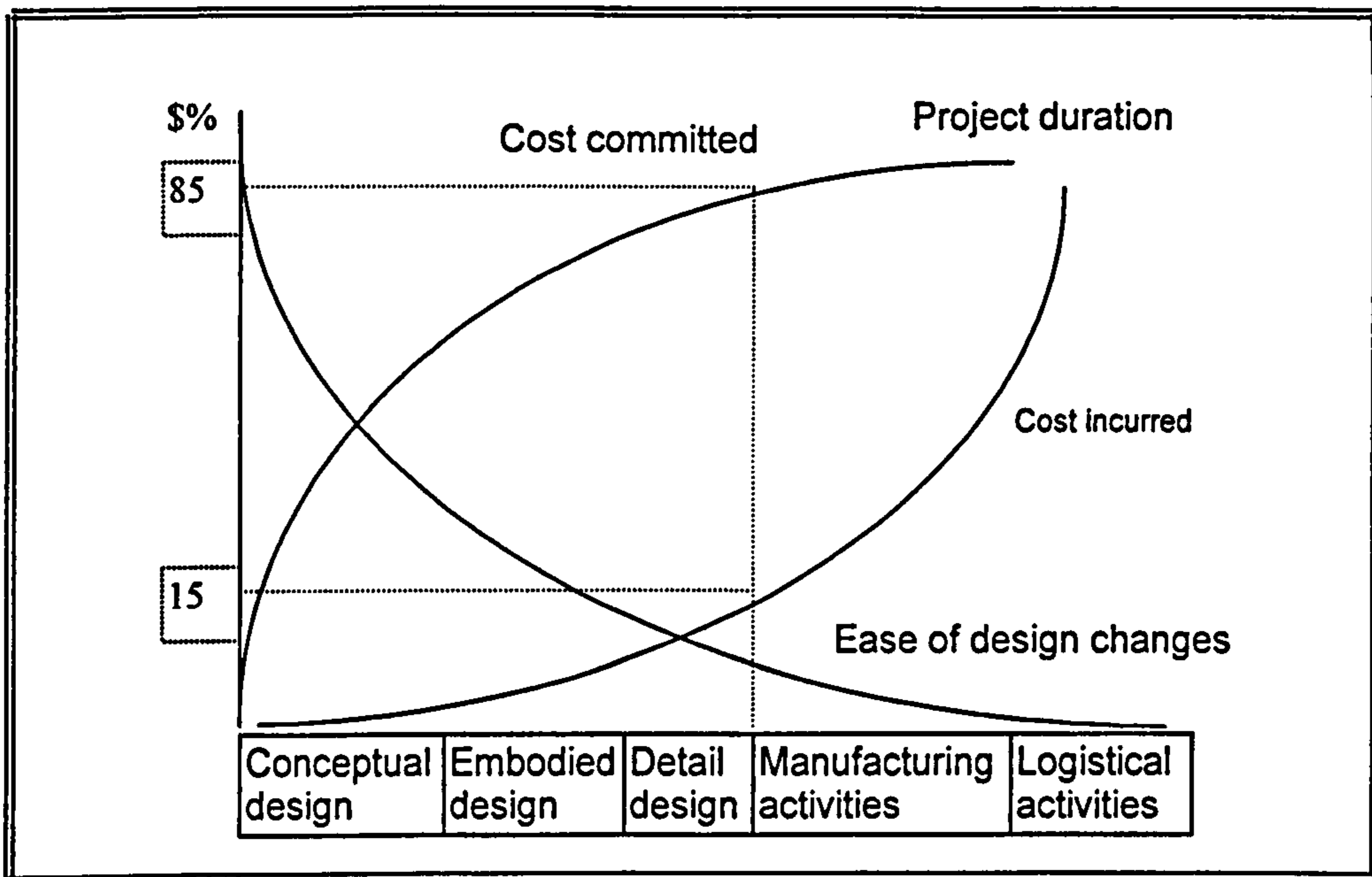
- Consideration of downstream requirement during the design development
- The use of cross functional teamwork
- Consideration of the customer requirements in the product development
- Use of lead time as source of competitive advantage

These four principles are fairly typical and adequately represent all aspect of CE that are commonly described by other authors in the literature.

### **3.4.1 Consideration of downstream requirement during the design development**

One of the important features of the CE approach is the consideration given to the life cycle requirement during the design development phase. Early consideration of this aspect is critical because it helps the developer to understand the actual downstream requirements and incorporate them in the design. This is also critical to avoid the high cost of rework and the adverse effect due to design error. It is estimated that the cost of repair increases logarithmically as orders place later in the product life cycle (Siegal, 1991). A study conducted by Computer Aided manufacturing International (CAM-I) on the distribution of the total cost incurred for the new product development concluded that while 5-8% of the cost are incurred during concept and engineering phase, but those two activities committed or accounted for a 'lock in' 80% of the total cost of the product (Ragatz et al., 1997).

Figure 3.1 shows the projection of the cost committed, cost incurred and the ease of design changes throughout the project life cycle. Table 3.3 summarises findings which show the importance of early consideration of the downstream requirement during design phase.



**Figure 3.1 The influence of design in determining the downstream project cost. (Dowlatshasi, 1994)**

**Table 3.3 The importance of early consideration of downstream requirements**

	Statement	Quoted by
1	80% of final production cost of 2000 component determined at the design stage in a study at Rolls Royce.	Corbett (1986)
2	It is estimated by Ford Motor Company that 70% of all production savings among the four manufacturing elements of design, material, labour and overhead, stem from improvements in design.	Cohodas (1988)
3	A study revealed that product design is responsible for 5% of a product's cost but it can determine 75% of all manufacturing costs and 80% of a product's quality performance.	Huthwaite (1988)
4	A study shows that 70% of the life cycle cost of a product is determined at the design stage.	Nevins and Whitney (1989)
5	It is believed that 40% of all quality problems can be traced to poor design.	Dixon and Duffey, (1990).
6	As much as 70 -80% of manufacturing productivity can be determined at the design stage.	Suh (1990)

### 3.4.2 The formation of 'Cross Functional Team' (CFT)

#### 3.4.2.1 The importance of the teamwork in CE

The teamwork concept based upon CE principles is normally referred to as the Cross Functional Team (CFT). There are also other common names used in the literature to identify the team such as: Multifunctional Team; Multidisciplinary Team; Concurrent Engineering Team; and Product Development Team. Cleetus (1992) use the term 'Tiger team' to express the same concept as CFT. Their description of the tiger team is *"a team comprising experts from different disciplines working together on high-priority projects, pooling their requirements, procedures, constraints, and solutions."* Dowlatshahi (1994) defines CFT as: *"temporary partnership between design and manufacturing engineers that results in a resolution of a particular design and manufacturing concerns"*. The writer argues that this definition may not accurately represent the ideal collaborative concept of CE because it ignores the inclusion of the external stakeholders like key suppliers.

The formation of the team is crucial for effective implementation of CE (Belson and Nicleson 1992). Owen (1992) states that CE is structured around multifunctional teams that bring specialised knowledge necessary for the programme. Krause and Ochs (1992) regard the formation of the team as the first step of CE implementation, which work as a synchronisation institute. Swink et al. (1996) support this view by suggesting that team provides the primary integration in CE programs. Prasad (1995a) describes the team capabilities to produce results greater than individual team member effort as the cornerstone of any CE organisation. The importance of teamwork in starting CE initiatives is also illustrated by the remark made by Roy Wheller of Hewlett Packard when asked: *"What tool does an engineer need to get started in CE?" Wheller's answer was: "Pencil, paper, some intelligence, and willingness to work with peers in other functional areas to get the job done"* (Watson, 1991)

Zirger and Hartley (1996) outline the importance of the cross functional team in the implementation of CE concepts as follows: to facilitate the communication of product requirements and constraints among functional groups; facilitate early problem identification; promote better cross functional co-ordination; and facilitate faster

decision making. The teamwork concepts embraced by CE principles require organisational and culture changes. It is the departure from the traditional over the wall design and manufacturing concept whereby the functional member within the same project work in a near isolation environment with congruent goals toward project.

#### **3.4.2.2 Important features of CFT**

One of the important features of CFT is that the team is normally formed at the outset of the project and this enables team members to better understand the strength and weakness of various technical and market alternatives and to be able to make a better decision (Eisenhardt, 1989). Another important feature of the team in CE environment is the authority and flexibility given to the team to make essential development decision. Gerwin and Moffat (1997) state that team autonomy is an essential characteristic of CFT engaged in CE. They conducted a study on 53 cross functional development teams in 14 firms in the US and concluded that withdrawing autonomy is negatively correlated with both task and process aspects of team performance. Prasad (1995a) also supports the claim that autonomy is essential for the CE team. He suggests that the team also must be empowered to give them the freedom and authority, to get the job done right the first time. One way to realise this objective is to use the concept of the virtual organisation whereby the co-ordination and interaction of the team members can be achieved through the use of modern communication technology. Kimura (1994) suggests that the teamwork based on a 'virtual company' concept in the situation where the core company has only limited staff.

#### **3.4.2.3 Communication in CE environment**

Successful implementation of CE relies heavily on functional integration, information sharing and collaborative problem solving among all participants. Effective communication is one of the most important ingredients to support CE. Accurate up to date information must be readily available to enable team members to make correct design decisions (Harding, 1996). CE design environment requires high degree of interdependency among the activities. According to Zirger and Hartley (1996) early

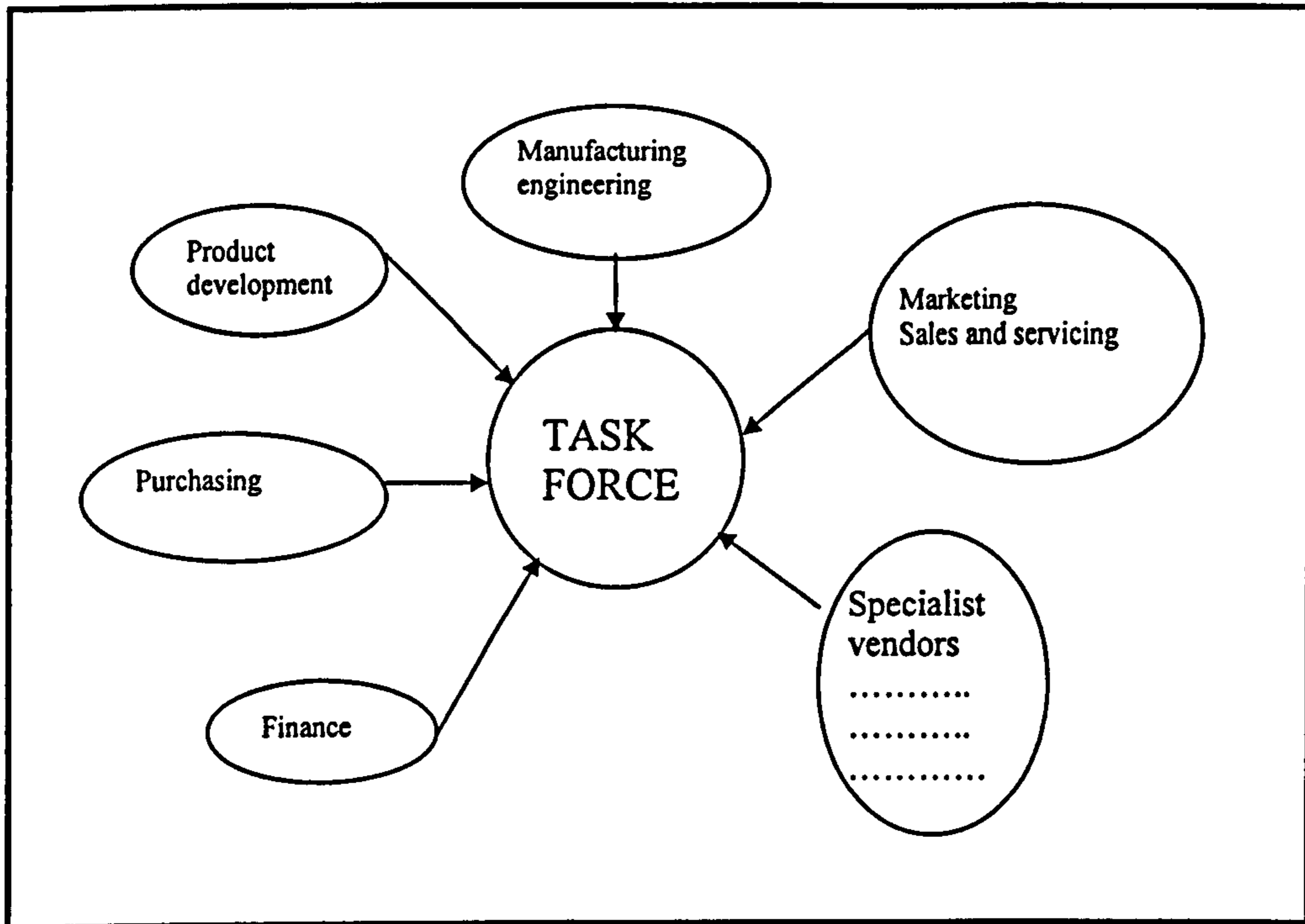
information sharing among functional groups enables the development team to identify and address potential problems during concept design, thus reducing time consuming redesign efforts. Therefore it is crucial to have a communication system which has the ability to co-ordinate and synchronise communication among the designers (Pasley and Roddis, 1994). The importance of communication issues in CE environment is also expressed by numerous publications in CE literature, and focus on information processing and modelling perspectives. Various tools which are considered important to support communication in CE includes: CAD, CAM, computer support co-operative work (CSCW), distributed information systems, group decision support systems (GDSS), expert systems, multimedia, and communication network (King and Majchrzak (1996).

Effective communications become more critical as team members are distributed over different sites. In this situation the used of computer based communication which support exchanges of various form of data format such as textual, graphic and visual can be very useful. If co-location of the team is impossible then the concept of 'virtual co-location can be adopted as an alternative solution.

#### **3.4.2.4 Components of the team**

Team members are selected for their ability to contribute to the design of the product and processes (Pennell et al., 1989). The members of the team normally comprise of experts from various functional departments formed to work on the specific project, and stay together throughout the development of the product (Smith, 1997). The participation of the team members is not to be limited to one member within a particular organisation. It can also include outsiders such as trade partners, sub-contractors, suppliers and client. The study conducted by Ragatz et al. (1997) on 60 companies from Michigan State University Global Procurement and Supply Chain Electronic Benchmarking identifies that the participation of suppliers in the New Product Development (NPD) team provided the greatest distinction between most and least successful integration effort.

Figure 3.2 illustrates the minimum components of the multidisciplinary team task force proposed by Syan (1994).



**Figure 3.2 Minimum component of CFT (Syan, 1994)**

### 3.4.2.5 Team responsibility

In the CE concept, a member of the CFT normally has a dual responsibility and accountability; i.e. toward the team and individual functional group. The responsibility of the team includes development of the project plan and schedule, agreement upon the project specification and budget. This requires a high degree of co-operation and understanding toward overall project goals among project members.

The involvement of the team members in the design development process is very critical in CE. Miller (1993) describes the design process in CE as the integration of execution of business and technical requirement at the same time. Hauptman and Hirji (1996) emphasize that CE by nature requires visibility of design parameters and mutual

consideration of all decisions in a collaborative environment to resolve conflicts. The concept of synchronisation of concurrent task in CE requires all the different enterprise wide functions have to bring their recommendation, restrictions, and interests at the different product life cycle simultaneously (Krause and Ochs, 1992). Yoshimura (1996) describes that the approached of gathering project wide and more comprehensive viewpoint results in optimal design solution due to due to wider viewpoint and linked relationship of many factors of design and production.

#### **3.4.2.6 Benefits of the team**

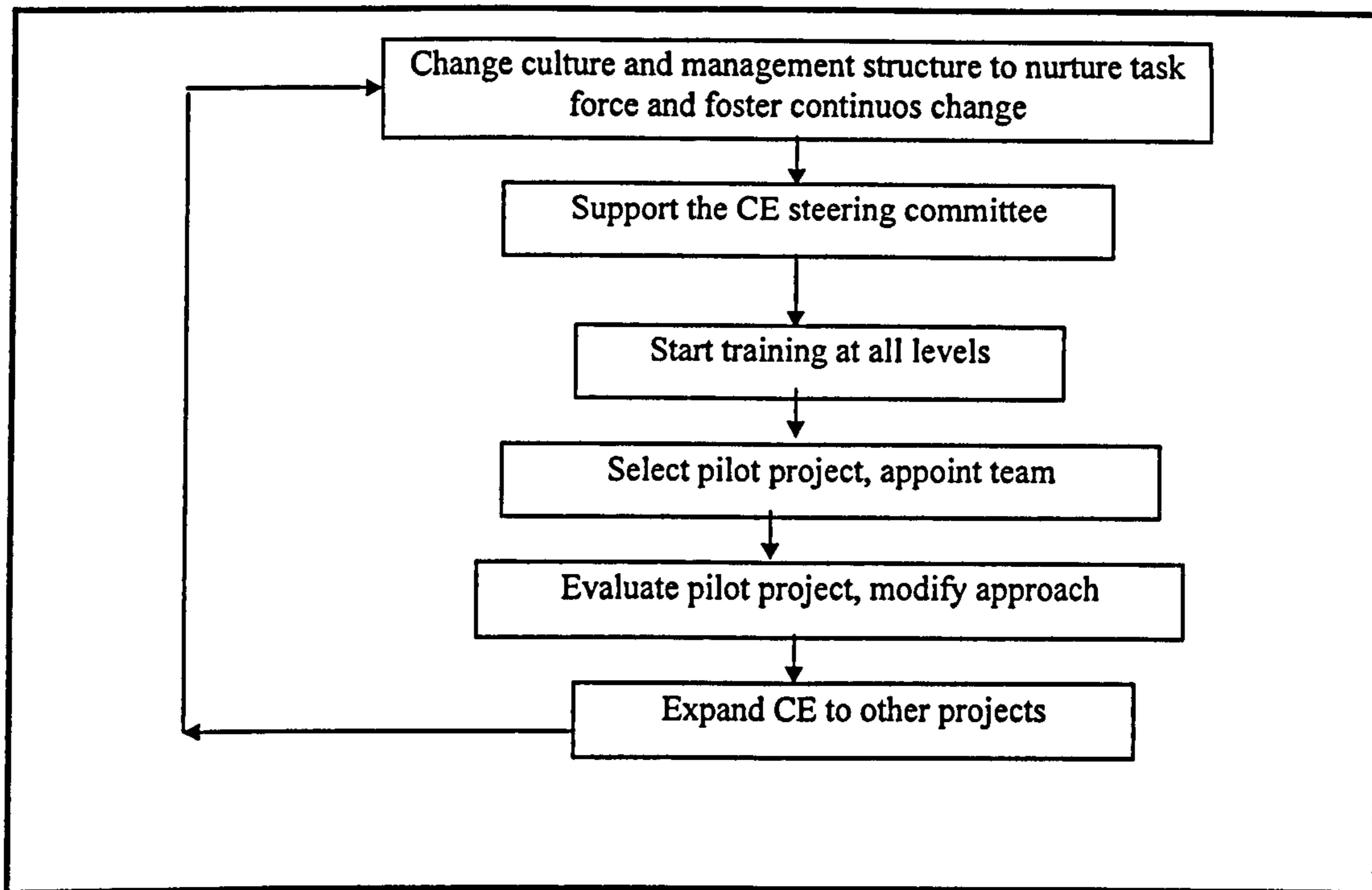
There are numerous case studies on the significant benefits gained from the successful use of teamwork approaches. The use of a team which consists of members from key functional groups like marketing, engineering and manufacturing has been widely recognised as an important factor leading to the reduction of the development cycle time (Bower and Hout 1988, Smith and Reinertsen 1991, Stalk and Hout 1990, Susman and Dean 1992, Wheelright and Clark 1992). Henke et al. (1993) claim that the team provides the following main benefits:

- The shortcomings of hierarchical structures are overcome by the ability of the team to cut across traditional vertical lines of authority.
- Decision making is decentralised.
- Hierarchical information overload is reduced at higher level.
- Higher quality decisions can have a significantly greater potential of occurring than with individual decision.

#### **3.4.3 Establishing CFT and support structure**

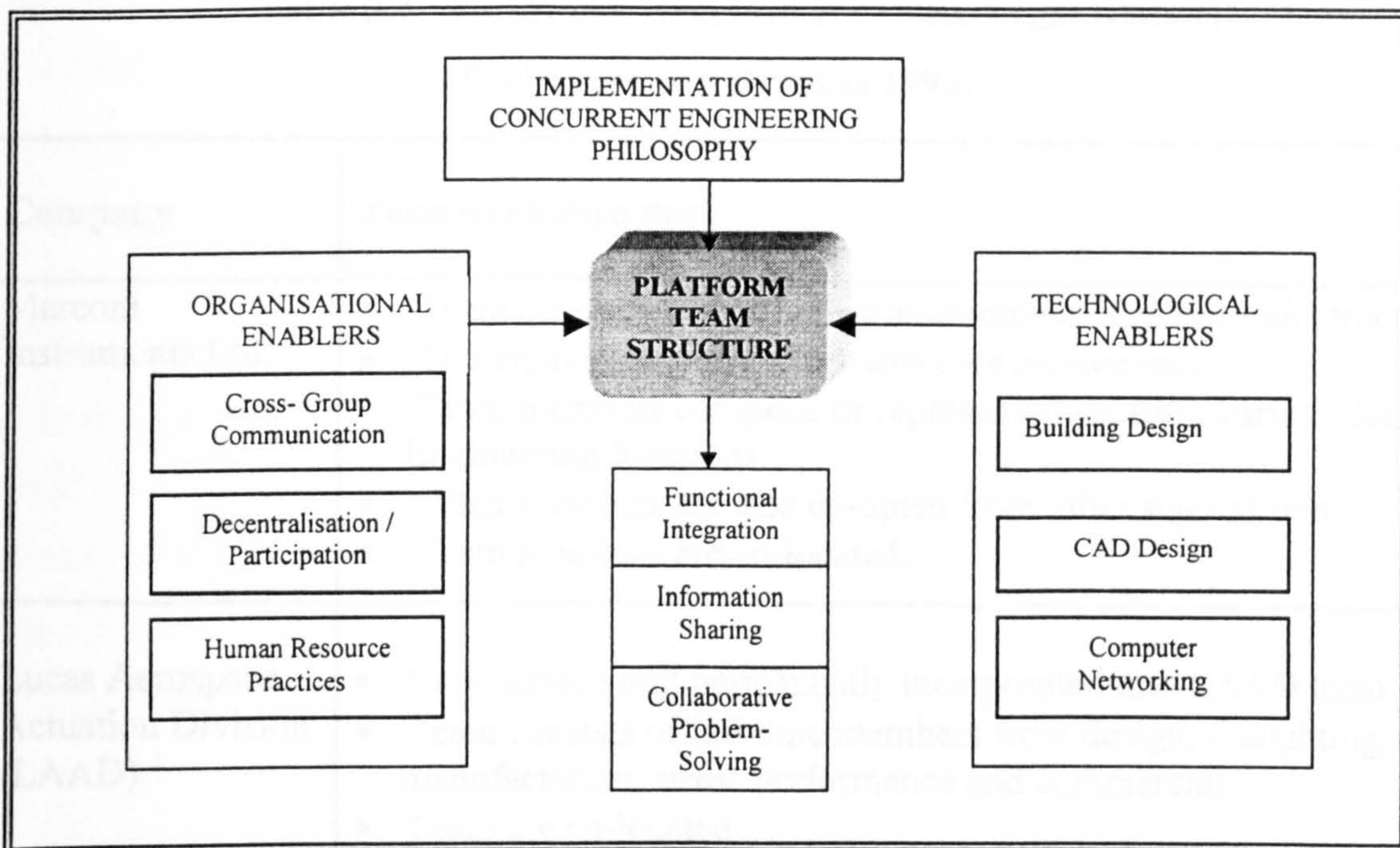
The first step in CE implementation is to set up an organisational structure to support the teamwork. This has to be carefully implemented stage by stage. Syan (1994) suggests six steps of CE implementation as shown in figure 3.3.





**Figure 3.3 Steps to implement CE (Syan, 1994)**

Hadad (1996) offers the conceptual model for CE implementation as shown in figure 3.4. According to her, the central mechanism for CE implementation is the establishment of product focussed CFT. The team operation is to be supported by organisational and technological enablers.



**Figure 3.4 Conceptual model to support CE Cross Functional Team in CE implementation (Hadad, 1996)**

There is no single approach of teamwork concept that fits all types of organisation. It has to be reviewed based on the individual organisation requirement. Different CE solutions are required for different companies to fit their own environment needs (Backhouse and Brookes, 1996). Dowlashashi (1994) suggests that teams may exist in the following forms:

- a temporary partnership which results in a resolution of a particular design/manufacture concern;
- an ad-hoc structure which usually takes a large project over a longer life span like introduction of new product; and
- a permanent or standing department which oversees and nurtures the overall product development aspects of an organisation.

Backhouse and Brookes (1996) present observations made from case studies of how teamwork structure is being developed in various organisations (table 3.4).

**Table 3.4 Teamwork structure at various organisations  
(Backhouse and Brookes 1996)**

<b>Company</b>	<b>Teamwork Structure</b>
Marconi Instruments Ltd.	<ul style="list-style-type: none"> <li>• Team operates within highly autonomous business unit structure.</li> <li>• The organisation still maintains core service unit.</li> <li>• Team members comprise of representatives from various design and Engineering functions.</li> <li>• Other members are also co-opted from other support unit.</li> <li>• Team members are co-located.</li> </ul>
Lucas Aerospace Actuation Division (LAAD)	<ul style="list-style-type: none"> <li>• Core service unit permanently incorporated into LAAD team</li> <li>• Team consists of full time members from design, draughting, manufacturing, stress performance and commercial</li> <li>• Team are co-located</li> </ul>
Instron Ltd.	<ul style="list-style-type: none"> <li>• Maintain identifiable functional unit</li> <li>• Team created across the functional team</li> </ul>
Design to Distribution Ltd. (D2D)	<ul style="list-style-type: none"> <li>• Heavyweight teams superimposed on functional structure</li> <li>• Extensive use of communication technology and a project team developed on virtual team basis.</li> <li>• Team members comprise from manufacturing, mechanical design, firmware, hardware, software designer and test engineer.</li> </ul>
Rolls-Royce	<ul style="list-style-type: none"> <li>• Full time , autonomous team</li> <li>• Very large team often in the order of 100 people</li> <li>• Membership comprises from design and development engineers and manufacturing and purchasing representatives.</li> <li>• Team also supported by other specialists</li> </ul>

#### **3.4.4 Focus on customer requirement during the development process**

The consideration toward capturing the customer requirements in the development process is another important aspect of CE philosophy. There are two approaches observed in the literature how customer needs may be captured in the development process. First by their inclusion in the cross functional team which had been a common

strategy. Secondly using a specific tool known as 'Quality Function Deployment (QFD) in which one of its objectives is to improve customer satisfaction (Menon et al.,1994). Akao (1990) defines QFD as a method for developing design quality aimed at satisfying customer requirements by translating their demand into design targets and major quality assurance points to be used throughout the production phase. Sullivan (1986) viewed QFD as an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, and sales. In QFD, all operations are driven by the 'voice of the customer', QFD therefore represents a change from manufacturing process quality control to product-development quality control (Kamara, 1999). A detailed study on client requirements processing in CE environment for design and construction process, which incorporate the QFD tools can be referred in Kamara (1999).

In the process of capturing customer requirements it should be realised that customers also vary in their degree of sophistication (Maddux and Souder, 1993). Some customers expressed their requirement correctly, whilst others are likely to provide insufficiently defined needs. Therefore, client's requirements must be carefully considered.

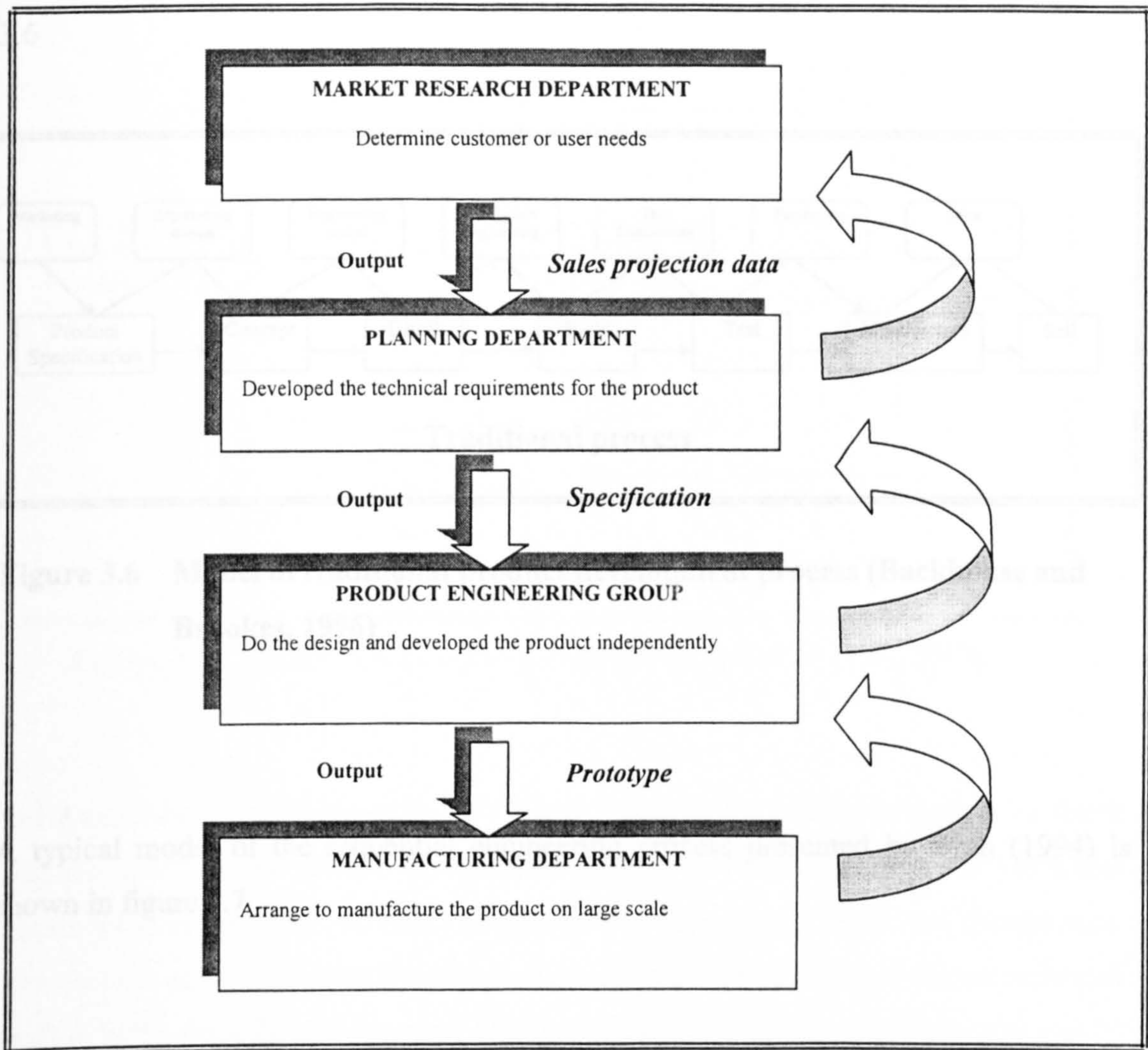
### **3.5 Comparison of the traditional process with CE**

To understand the underlying principles of CE, Backhouse and Brookes (1996) suggest that we must examine the difference between the traditional (or conventional) approach in the product development life cycle with the CE approach. By comparing these two approaches one can get a better understanding of the rationale behind CE development and its objectives.

#### **3.5.1 The traditional product development system**

The main tenet of the traditional product development and production process is the concept of 'division of labour' and the assumption that each of the tasks is independent and separable. It is also based on the assumption that control of information flow is the

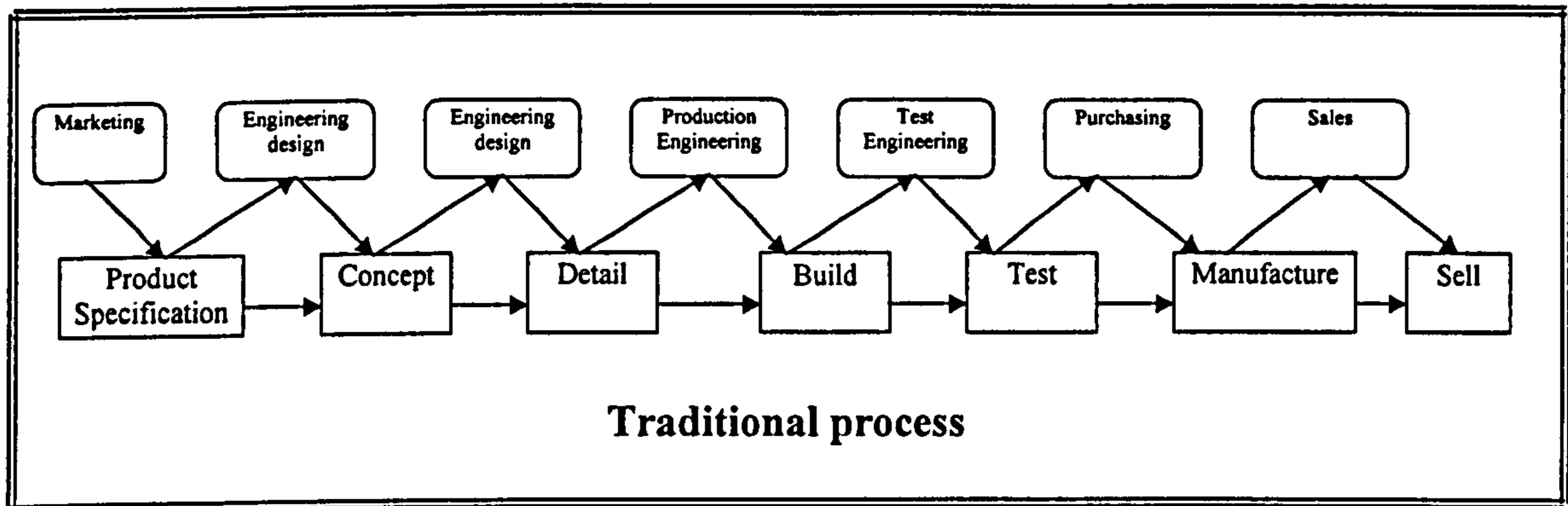
key component to success (Prasad, 1995b). These assumptions lead to the formation of the rigid, and hierarchical, types of organisation structure to command and control both the people and the process in this system (Crowley, 1996). The tasks are carried out in a sequential manner. Therefore this approach is also commonly known as 'sequential' or 'serial' process. The traditional approach is also sometimes referred to as the 'over the wall engineering system' (Syan, 1994). In this system, each stage of production development process independently performed by a specialist skilled workforce representing a functionally known department. The advantages of the traditional system is that it has cheaper initial design cost and it is well practised. The typical department or functional group in product development and their responsibilities described by Prasad (1995a) is graphically presented here for clarity in figure 3.5



**Figure 3.5 Typical functional department in product development**  
(Prasad, 1995a)

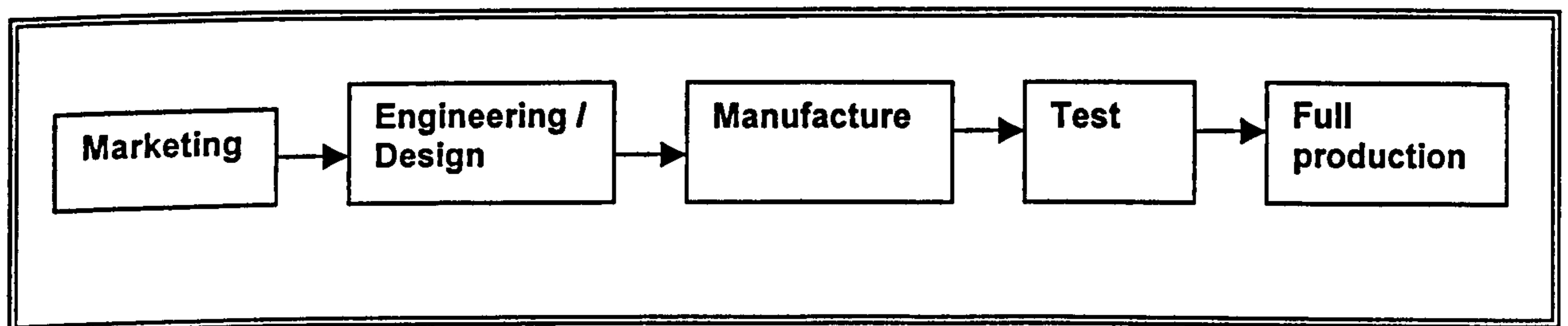
In the traditional process, once each task is completed, it will be passed over the 'wall' to another functional department for another sequence of action. This process will continue and follow through each phase in a linear or sequential manner throughout the life cycle of the product. If there is any error, feedback for modification required, the task will be passed backward. For example the manufacturing department will have to pass back the design work to the designer for another consideration or improvement based on their requirements. The communication between each functional department is very limited and normally made through proper channels such as standard engineering change orders (Jo et al. 1993). A model of the traditional linear or sequential product

development process presented by Backhouse and Brookes (1996) is shown in figure 3.6



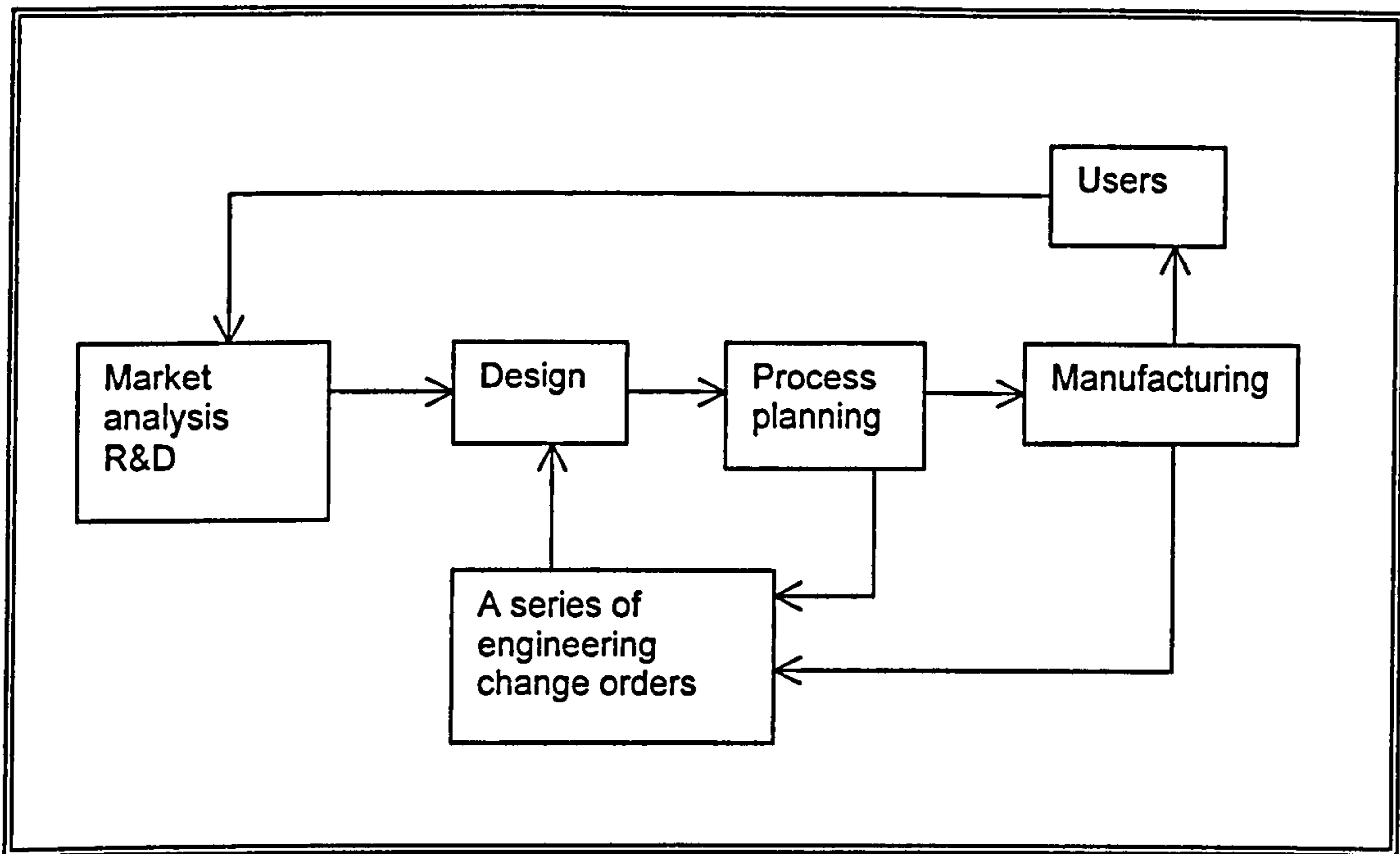
**Figure 3.6 Model of traditional product development process (Backhouse and Brookes, 1996)**

A typical model of the sequential engineering process presented by Syan (1994) is shown in figure 3.7



**Figure 3.7 Model of sequential engineering process (Syan, 1994)**

Jo et al (1993) present the following model to describe the sequential development cycle (figure 3.8).



**Figure 3.8 Model of sequential development cycle (Jo et al., 1993)**

Riedel and Pawar (1991) assert that the disadvantage of the traditional process is that it takes a longer time for product development. They argue that the whole process in this system is too bureaucratic. Conflict of interest develops among functional departments. There is also communication breakdown develops between functional departments and result in difficulties the development of better solution for design. This may also results in late and costly request for modification of design. Design team is normally insulated from market and external pressures and innovation tend to be stifled. This phenomenon may lead to the failure to understand customer requirements (Prasad, 1995a).

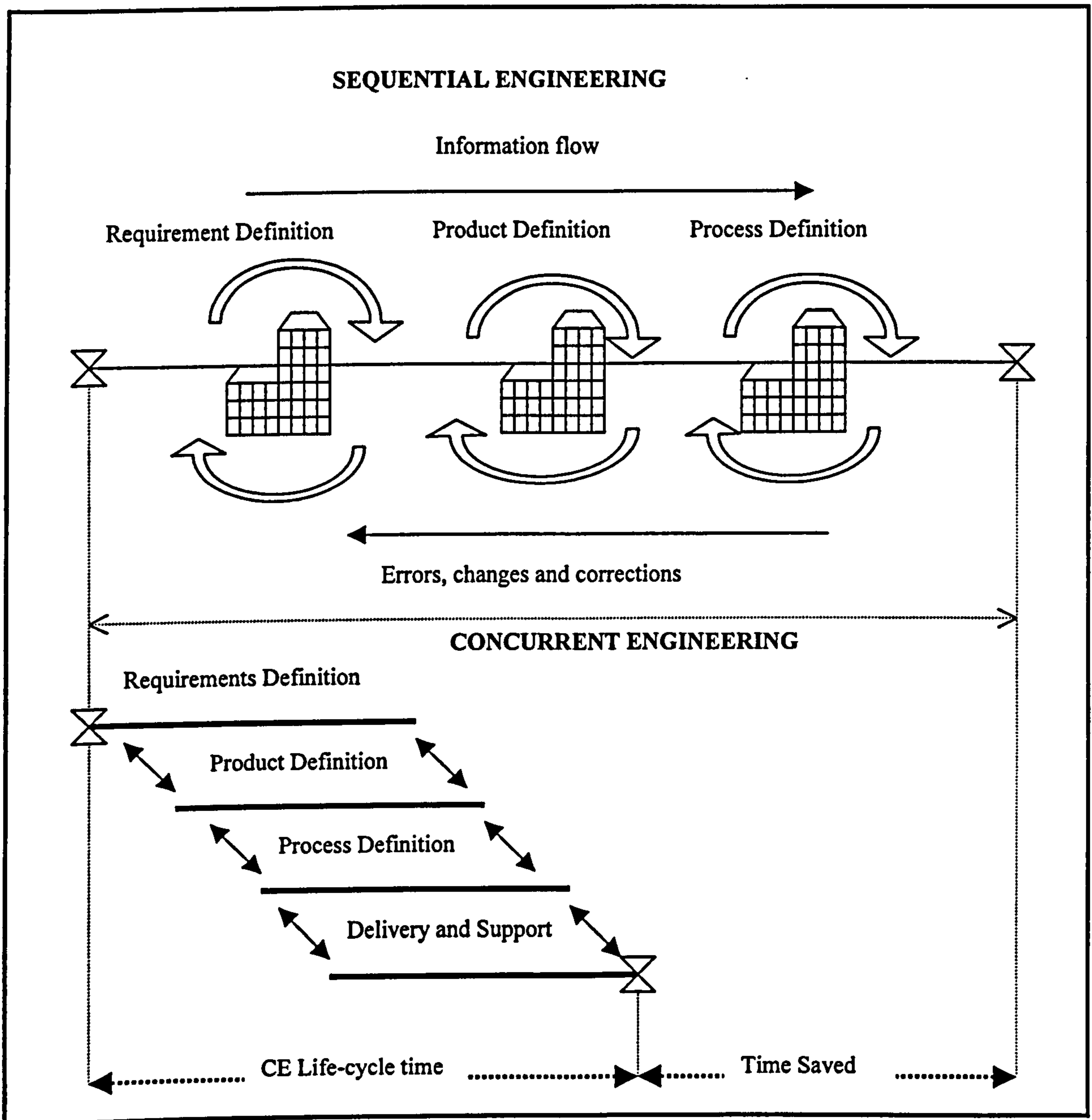
Even though the typical linear or sequential process model may look simple and straightforward Prasad (1995a) argues that rarely does a product developed in this system go to production in one shot. He states that the major shortcoming of this system is it is based on the premise that a new phase can only start after the preceding phase is completed and signed off. Normally a significant portion of manufacturing cost (50%-80%) would already be committed during the design without getting appropriate input from the manufacturing engineer. According to Prasad (1995a) the major problem encountered by manufacturing engineers in this system is that the design solution is not always suitable for production. There were problem with the unavailability of adequate manufacturing equipment to suit the design requirement and problems with parts



assembly. Problem also developed due to the inability to utilise the existing production equipment, tooling, automatic assembly, etc. Tight tolerance in the design could also lead to extra work and high scrap generation.

### **3.5.2 Concurrent or parallel process**

Contrary to the serial process, CE embraces a different approach to product development system. The basic ingredient of CE is that all aspects of the product life cycle should be considered as early as possible during design. The key idea that has been developed for the implementation of CE is the use of the team (Swink et al., 1996). The term 'concurrent' implies two important meanings. First it indicates the simultaneity in considering all life cycle requirement in the product and manufacturing process during the design development. Secondly, the life cycle requirement being considered simultaneously at outset, enables the task to be overlapped to some degree because it might not be necessary to wait for the whole preceding task to be wholly completed before the proceeding task can start. This difference between the traditional serial approach and the concurrent approach is shown in figure 3.9.



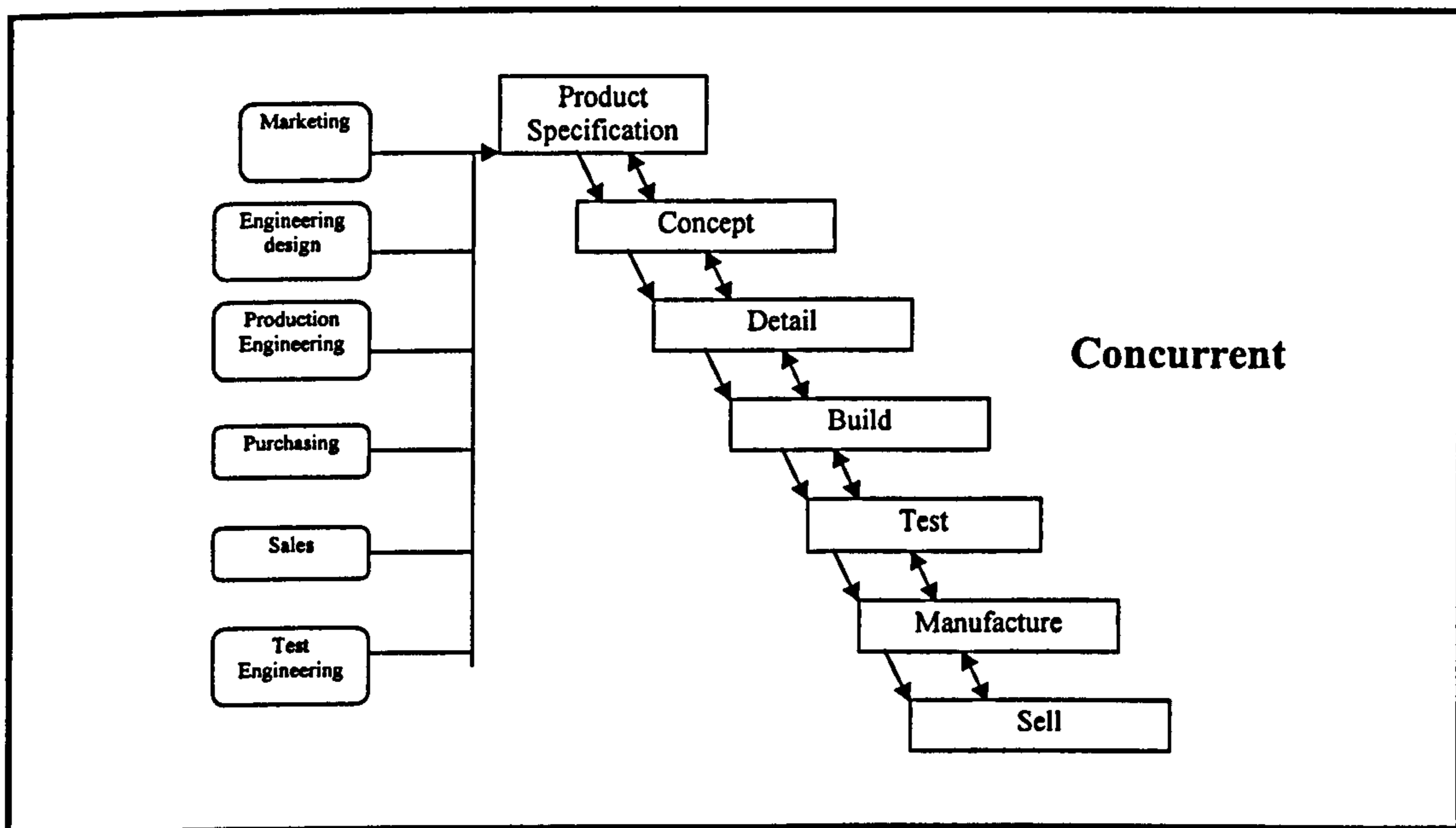
**Figure 3.9 Comparison of the Sequential Engineering and CE (Prasad, 1995b)**

The main differences between the traditional serial approach and the CE approach are twofold. First, CE enables the concurrency or overlapping accomplishment of the task which in the traditional serial approach is difficult to achieve. Secondly, consideration of downstream requirements is made during the upstream stage. This is possible because CE approach requires the removal of the 'imaginary wall' that exist between the upstream and the downstream functional group. Typical CE practice brings designer

and manufacturing engineer physically and organisationally closer in order to accelerate the development task.

In the CE concept the representatives of the various functional groups are required to work together in a team that is commonly referred in CE terms as the cross functional or multi-functional team. This is a major breakthrough compared to the traditional system whereby each functional group performed their task in almost near isolation. The formation of the team is made from the outset stage of the project.

Backhouse and Brookes (1996) also presented a model to illustrate the CE concept as shown in figure 3.10.



**Figure 3.10 Conceptual model of CE (Backhouse and Brookes, 1996)**

### 3.6 Evidence of CE Success

Concurrent engineering has gained a wide acceptance in manufacturing, especially in automobile industry. CE has been developed based on solid conceptual grounds rather than just a general business philosophy. It is well documented as a philosophy for improving productivity through a systematic approach to design (Brown et al., 1996). Evans (1993) claims that some positive results have been attained by many companies

that have substantially poor CE implementation and this demonstrates robustness of CE. The emergence of CE is based upon the interpretation of Japanese best practice in manufacturing. Japanese practices are often heralded as models of CE (Liker et al., 1996). This alone has already been an important case to consider CE implementation. Apart from that the implementation of CE can be coupled with various production management supporting tools which are known for their usefulness such as: Quality Function Deployment (QFD), Just In Time (JIT), Total Quality Management (TQM), Taguchi, Kanban, etc. CE can be viewed as coming out to the scene at the right time and right place. CE is the much sought after solution of the western world to face the market challenge of the 21<sup>st</sup> century to be more efficient in product development process. Many corporate organisations have already initiated educational programs on the philosophical shifts to CE (Jo et.al, 1994). Much of the success of CE is acknowledged through several factors such as teamwork, reduction in cost, improved quality and reduction in product development time. In the US automotive industry the integration of design and manufacture process due to the implementation of CE has resulted in major paradigm shift in the way the firms are organised and operate (Ettlie and Stoll, 1990).

Backhouse and Brookes (1996) report on the success story from Rover and Chrysler in their publication. Tony Gilroy, Land Rover's chief executive dedicated the success of their four wheel drive vehicle, Discovery to the use of CE in improving their performance of the product introduction process. Chrysler also shared the same success story in implementing CE for their new product of mid range saloon car, the Neon which helped them to recover from record quarter year losses in 1990. In a qualitative case study by Hadad (1996) of an automotive firm on their implementation of CE concept for their new products (a large sedan and a small sedan car) she concluded that the achievements of the firm were as follows:

- reduction over one year in the product life cycle for the large sedan (first production under CE teamwork platform);
- lesser production life cycle time for the smaller sedan car;
- initial popularity of the sedan helped the company to set record earning; and
- company suppliers strategy yielded \$260 million savings in 1993.

The benefit of implementing CE can also be realised through the psychological impact to the organisation. Dowladshasi (1994) quoted from Ettlle and Stoll (1990) who reported the success enjoyed by Cadillac, a division of General Motor Corporations in the implementation of CE through teamwork. They embarked on improvement of operation through continuous training, exchange of information and departmental dialogue. This resulted in teamwork and two-way communication channel group decision, resulting in product improvement and knowledge sharing. Table 3.5 summarises the findings from the literature by Lettice (1995) of the benefits gained by some of the organisations from CE implementation within the time, cost and quality parameters.

**Table 3.5 Summary of the benefits gains by some companies from CE implementation (Lettice 1995).**

<b>Company</b>	<b>Quality</b>	<b>Cost</b>	<b>Time</b>
Aerojet Ordnance	400% yield improvements on munitions program (Pennel & Winner 1989)	-	-
Dere & Company	66% reduction in number of inspectors. (Pennel & Winner 1989)	Reduced product development costs by 30%. Scrap rework cost reduced by 60%. (Pennel & Winner 1989)	60% savings in development time (Zangwill, 1993)
IBM	Fewer engineering changes; guaranteed producibility and testability (Zangwill, 1993)	Reduced direct labour cost in system assembly by 50% (Pennel & Winner 1989)	40% reduction in electronic design cycle (Zangwill, 1993)
Hewlett Packard Instrument Division	Product failure rate reduced by 60%; scrap and rework reduced by 75% (Zangwill, 1993)	Inventory reductions of 62% (Pennel & Winner 1989). Product field failure rate reduced by 60%, scrap and rework reduced by 75% (Zangwill, 1993).	Reduced development cycle time by 35% (Zangwill, 1993).
Boeing Ballastic Systems Division	Floor inspection ration decrease by 66%; material shortages reduced from 12% to 0; and 99% defect free operation (Zangwill 1993)	Reduced labour rates by \$28/hour, cost saving of 30% to 40% (Zangwill, 1993)	Part and materials lead time reduced by 30%; one part of design analysis reduced by over 90% (Zangwill, 1993)
Northrop	Number of engineering changes reduced by 45%. Defects reduced by 35% (Zangwill, 1993)	30% saving on bid on a major product (Zangwill, 1993)	Part and assembly schedule reduced by 50% on two major subassemblies; span time reduced by 60% (Zangwill, 1993)

### **3.7 Problems in implementing CE**

Implementing CE requires a radical change in organisation culture (Evans, 1993). It is a departure from the traditional practice to a new way of working. The process requires considerable commitment from top management down to the bottom of the organisation structure. It also requires understanding of new principles of working especially the concept of teamwork and sharing of information throughout the organisation. Therefore problems in implementing CE philosophy are inevitable especially when dealing with

the psychological aspects of human beings. The case study by Hadad (1996) observed some of the difficulties in the implementation of CE. Some of her observations were: overwork and stress among design technicians; a claim of lack of recognition for their contribution; limited manufacturing experience of engineering managers; internal skill shortages because too few experts are spread across too many teams; and conflicts between team requirements and functional requirements.

Evans (1993) reported on the common failures to the successful implementation of CE. He presented his observations based on his direct experience in consultation work on CE implementation and also from the direct input of a CE user forum. His observations on the common failure modes were:

- i. Lack of support from middle management.
- ii. Poor vision by the target group.
- iii. Lack of CE experience.
- iv. Inadequate support from senior management.
- v. Lack of functional group co-operation.
- vi. Poorly organised multidisciplinary team.
- vii. Culture paralysis - difficulties to understand the fact that change of management culture has to take place to give way for CE implementation.
- viii. Too many tools to support CE are available and cause confusion and massive delay to select the appropriate one instead of going for the basic necessary tool.
- ix. Middle management 'hijack' of the resources being used for CE (e.g. member of the team).
- x. Lack of clear responsibility given to the team members.
- xi. Companies' lack of confidence of CE due to the initial shortcomings in CE implementation.

Maddux and Souder (1993) divide the barriers to the implementation of CE into two categories i.e. the technical barrier and the organisational barrier. The major technical barriers according to Maddux and Souder (1993) relate to the lack of preparation to implement CE. Among the examples given are: lack of facilities; lack of supporting technologies (e.g. CAD/CAM); and lack of knowledge on CE process.

One of the major barriers is inadequate organisational climate to adopt the new CE environment. These included problems with the lack of support from top management to support CE implementation. Under the traditional approach, each functional group is normally well established for their capability to perform (deliver) a specific functional task. However, within a CE environment the elimination of this functional boundary is essential to pave the way for the cross-functional integration. In such a situation it is common for the traditionally established functional group manager tend to be protective of their group and thus impede the integration process under the CE climate. The functional group also fear of losing their creativity when their members were required to work in an open system along with other groups. In one of the interviews conducted in this research (reported in chapter six) it was found that one of the organisation that implemented CE still maintained a small group of functional divisions along with the CFT to ensure that they can still maintain the excellency of their individual contribution to design. Other problems that contribute to failure of CE implementation are due to the lack of customer involvement in the design process.

A more specific problem related to the CE implementation was studied by King and Majchrzak (1996). They identified the problem of the effectiveness of using of various enabling technologies such as CAD, CAM, GDSS, expert systems and communication networks used to support CE multidisciplinary design environments. Based on their observations they concluded that the assumptions made by CE tool developer communities were likely to inhibit CE tools from successfully enabling the CE process. This is because most of the IT tools developed does not give adequate consideration to the human aspect in using the tool in a new CE environment. Kusiak and Park (1990) look into the problem in the implementing CE in a large scale and sophisticated product design environment. They concluded that in such cases difficulties will arise in managing the team and suggest a clustering system of numerous design tasks.

### **3.8 Summary**

This chapter exposed some of the important characteristics of CE from the perspective of the manufacturing industry. From the literature reviewed, it is clear that there are agreements among the authors regarding the definition of the concept of CE



philosophy. Despite the many definitions offered in the literature, most of them expressed the same principles of CE and concur to the following fundamental elements:

- Consideration of all life-cycle requirements in the design development phase
- Use of multi-functional teamwork
- Focus on customer requirements
- Use of lead time as source of competitive advantage

The following remarks summarise the important aspects of CE:

- CE is a well-established management philosophy. It is being adopted within manufacturing industry in the area of new product development. Its reliability has been tested and proven beneficial to manufacturing.
- CE has helped the manufacturing industry to face the challenge of reducing product development time and the demand for better quality, value and cheaper cost of the product.
- CE is a customer oriented management philosophy. This is an important feature that make CE suitable for adoption.
- The most important aspect of CE is the exigency for process change from the traditional sequential approach to the concurrent or simultaneous process. This is one of the most important qualities that differentiate CE from other approaches. CE can be considered as one of the interpretation of Business Process Re-engineering paradigm.
- Another important feature of CE is the utilisation of the collaborative teamwork concept. The establishment of teamwork concept is very critical especially in the effort to reorganise the fragmented nature of an industry such as construction. The nature of the teamwork concept promoted by CE has its own characteristic that makes it different from the typical teamwork approach normally used in the traditional process.
- The main differences of the CE teamwork approach are as follows:
  - The team is commonly known as cross functional or multifunctional team (CFT)
  - The team is formed at the outset

- The members comprise a wider range of participation, and include the customer and suppliers.
  - CFT are given the flexibility and authority to make important project design decision.
  - Team members are given the role and opportunity to make contributions to the design development thus promoting the sense of commitment and ownership toward the design. Such teamwork environment also encourages innovation in product development.
  - CFT emphasises on cross functionality communication and shared common project goals.
  - CFT can exist in a real or virtual environment.
- CE approach can be coupled with other array of tools like TQM, JIT, Lean Manufacturing, etc.

The experience from the implementation of CE in the manufacturing industry fuelled this research with many insights of the strategy used. Among the important facts analysed are:

- Principally CE is easy to implement and very flexible. It has a very clear concept that can be well understood. The main requirements are willingness to share information and working as a team.
- To implement CE requires culture change in work practices. This implies abandoning the traditional sequential work process where necessary and removal of functional boundaries to give way to a concurrent process. It also requires commitment to share information across the functional boundaries and sharing common goals.
- Formation of the team is used as an important strategy to implement CE. However there are many different approaches or platforms used to support the teams either in a virtual or real environment.

- CE is very flexible and its adoption must be customised to suit individual organisational needs. Different organisation may require different CE solutions.
- Many organisations use IT to support CFT communication within CE environment.
- CE culture requires recognition of the roles of team members in the design development process. This includes the external stakeholder like the suppliers and clients.

The main benefits gained from implementing CE are:

- Reduction of development time
- Promotion of teamwork environment
- Change in work processes
- Improvement in overall quality and value of the product
- Improvement in the focus on customer requirements

All those benefits are also equally important to construction as well. Construction also shares the same concern on the limitation of the traditional approach as experienced by manufacturing. Therefore it is critical for the industry to consider the potential of applying CE to construction as it has been proven successful in manufacturing. The justification of the rationale of CE implementation to construction will be made in the next chapter.

## CHAPTER 4

### APPLYING CE TO CONSTRUCTION

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#### 4.1 Introduction

The main theme of this chapter is to review existing applications in construction and explore the potential for applying Concurrent Engineering to the construction industry. In chapter three CE was explored from the manufacturing industry perspective and helped to establish the potential for applying it to construction. The rationale for the application of CE to construction derives from the similarity of the basic construction/manufacturing process as well as the nature of the problem faced by both industries, as a result of the traditional approach practised in its work process. Both of these similarities will be explored in greater detail in this chapter. Each of the important CE elements will be discussed together with their relevance from a construction industry perspective. Then the current developments in construction industry towards the implement of CE will be presented. Many aspects of CE are not actually new to construction. Some of the current practices within construction that is parallel to CE will be used as a basis to introduce CE in this industry. The chapter will also look into the perceived benefits and the potential problems if implementing CE to construction. Lastly, a formulation of agenda for further research effort will be made on the basis of the information gathered.

#### 4.2 Background

CE is a widely accepted design management philosophy in several industries especially in manufacturing. However, despite the claim made by Love and Gunasekaran (1997), there is no research evidence to support that it has been fully applied in construction to the same extent as in other industries. The topic of the application of CE and its fundamental elements to construction has generated some interest in recent research literature such as De La Garza et al. (1994), Baxendale et al. (1996), Evbuomwan and Anumba (1996), Houvilla et al. (1997), Love et al., (1998) and Kamara (1999). The main focus of the discussion can be categorised in two key areas, the application

specific CE tools and modelling technique to support data integration in a CE environment and the managerial perspective of CE implementation as a complete process. However the literature relating to construction application is far more limited compared to those in manufacturing. This reflects the infant stage of the CE in this industry. This research described in this thesis is oriented toward the investigation of the issues related to the organisational aspects of implementing CE in construction.

Even though CE is relatively a new philosophy to construction it must be recognised that some aspects parallel to its elements are actually already being practised in construction especially within the Design and Build (D&B) procurement and partnering approach. Concurrent engineering is seen to be a feasible option that can be adapted by construction industry. This is based on its acceptance in other industries especially in manufacturing and also due to the similarity of process systems in other industries to construction (Houvilla et al. 1997, Kamara et al. 1997).

The success achieved in the automobile industry provides a special appeal to construction to consider the adoption of CE. A comparison between construction and manufacturing industries justifies the notion that the difference between the two industries is not a major factor to prevent construction from adopting and practising CE. Such a comparison will be made in the following section. The main motivation for the consideration of CE adoption to construction stems from the need to overcome the problems associated with the traditional construction process. (This has been discussed in chapter two).

Kamara et al. (1997) argue that improvements in productivity through the use of CE in manufacturing provide a basis for similar improvements in construction considering the similarities between the construction and manufacturing processes. Furthermore, the changing environment within construction industry, which demands for more value from the construction product as well as the fragmented nature of the construction industry provide the opportunity for the consideration of CE implementation. The goals and principles of concurrent engineering are appropriate to the challenges that face the construction industry.

Koskela and Houvilla (1997) view that CE as an approach that can eliminate waste in construction. Baxendale et al. (1996) suggest that CE is a viable approach to realise Latham's call for the teamwork approach in construction. They argue that construction currently lacks a single management system to handle multi-disciplinary teamwork. Evbuomwan and Anumba (1997) argue that today's climate of competition demands the integration of all key players in the construction project and CE is capable of creating such teamwork which would enable concurrent design practices within a multidisciplinary construction project team. They suggest that to implement CE in construction the following important issues need to be addressed:

1. The need to focus on the customer/owner/client.
2. The need to integrate the activities of the various functional disciplines involved in the project.
3. The need to carry out competitive benchmarking of design and construction practices and processes.
4. The need to focus on the quality, cost and delivery of projects
5. The need to concurrently developed the design of the project along with the fabrication, construction and erection processes.
6. The need to establish strategic relationships with materials and component suppliers and sub-contractors.
7. The need to integrate CAD and other design tools for concurrent engineering;
8. The need to use modern project management techniques to enable paralleling and overlapping of the design and construction activities.
9. The need to integrate and commonalize of design knowledge, data and information.
10. The need to use of new materials and technologies.
11. The need for effective use of computer hardware and software.

De La Garza et al. (1994) also considered CE as suitable for application to construction. They argue that CE can be used as a strategy to capitalise the existence of the highly fragmented and specialised nature of the industry to generate diversity of knowledge in the design development. Evbuomwan and Anumba (1996) state that CE can be used to integrate all functional disciplines within construction and proposed construction to use D&B as a model to implement CE.

### **4.3 Comparison between manufacturing and construction industry**

Manufacturing industry is known for its leading role in adopting new management principles and techniques like: Concurrent Engineering; Lean Manufacturing; Just In Time (JIT); Computer Integrated Manufacturing and many others. Intense competition in the market, sophistication of the customer and advances in engineering and information technology are among the major factors already identified in chapter three that motivate the industry to abandon the traditional practice in manufacturing process. It is also recognised in chapter two that construction is very slow to adopt these changes that is taking place in manufacturing. Many reasons contribute to these phenomena. Crowley (1996) states that experience from the CIMsteel Project (1994) indicated that many parties involved in construction are very reluctant to consider themselves as part of a manufacturing process. Construction is viewed as different from manufacturing, therefore it is difficult for the industry to adapt to the principles and techniques that are being developed in manufacturing.

Historically both industries developed as craft-based industries. However manufacturing has transformed to mass production which places greater reliance on technology than human skill. Initially both of the industries used the traditional system of product development. But at the end of 1970's and in the early 1980's the traditional approach was no longer considered appropriate to enable manufacturing to accommodate the growing pressure in market demand especially from the intrusion of the Japanese manufacturers. To remain competitive against the foreign manufacturers the industry adopted a new production management paradigm which emphasised on customer satisfaction and integration of the work process. Construction on the other hand, still relies on the traditional way of work process for the project. Many reasons contribute to this phenomenon. The most important one is the belief that construction is different from manufacturing. This is true to some extent, but what limits construction from adapting to the changes that are already being taken place in manufacturing? To understand this issue better let us analyse the differences and similarities that exist between construction and manufacturing (Crowley 1996, Sanvido and Medeiros 1990, Ireland 1992):

The major differences are:

1. The nature of the construction project (product) is mostly one of a kind, and project based. The construction product is largely custom made compared to multi-unit production in manufacturing.
2. Construction products are normally built at the site whilst manufactured products are typically made in a facility and transported to their customer. Therefore it is easier to control the manufacturing process environment in comparison to construction's.
3. The location of manufacturing process equipment, material paths, and the physical work area remain fairly constant throughout the production of one product. The construction work face changes as each component product is installed in place. This requires that process equipment, (e.g., concrete forms), and material handling equipment, (e.g., cranes), move as the work area changes.
4. Construction products are generally more complex and involve heavier assemblies.
5. Production volumes are typically smaller in the construction industry. There is a more "one-of-a-kind" production each time. (Examples of construction mass production are: production of concrete or lumber components; small batch production-prefabrication of reinforcing steel, while the whole site is an assembly of components.)
6. Unlike manufacturing, the competition from foreign companies may not be very crucial for most small to medium construction companies that dominate the industry either in UK or elsewhere. But intense competitions occur within the industry locally.
7. Compared to manufacturing, the construction industry faces the problem of very low profit margins.



Apart from the differences between construction and manufacturing, there are also many similarities between them. Amongst these are:

1. The manufacturing and construction industries both produce engineered products that provide a service to the user
2. Both construction and manufacturing use a similar systematic process to develop the final product, which involve planning, design development and manufacturing process and operational and maintenance considerations.
3. Both industries rely on sub-contractors and suppliers and the intense competition in their respective markets.
4. The construction process and manufacturing process involve the repetitive nature of assembly.
5. Both industries face large fluctuations in demand.
6. Like manufacturing, construction also faces increasing demand from the client (or customer in manufacturing) for a better value for the money.

In analysing the above points, it is obvious that there are apparent differences between construction and manufacturing industry. However, the similarities are strong and significant especially in terms of work process. Therefore, it is argued that the difference is more towards the technical aspect rather than the basic fundamental operation and management of the process. Indeed some of the technology innovated in manufacturing, like the use of 3D CAD tools, is being widely used in construction today. Therefore, there is no reason why construction cannot adopt some of the management principles that are being developed in manufacturing as long as construction is willing to abandon the traditional practices in work process where necessary. This is because most of these new principles are not intended to be applied on the traditional work process foundation.

Sanvido and Medeiros (1990) argue that both industries also experience some similar types of problems in some areas. One of those areas is related to the high cost of correcting design errors and including late changes in the design. Both industries also have a vast number of duplication of information in the same project, however only a small amount of these information are being shared across the project. The process of transferring the information from design to construction/manufacturing is very inefficient. Usually there is also lack of available information on planning. All these problems are related to the traditional system and manufacturing has put significant effort to overcome them by adopting CE philosophy. This is coupled by the utilisation of other tools to support CE like CIM, JIT, TQM, Quality Function Deployment (QFD) and many others.

The similarity of construction and manufacturing outweigh the differences between the two and it is rational enough to consider the adoption of CE, which is a management philosophy rather than technical tools, to construction. What is more important is for the construction industry to develop an appropriate strategy to adapt CE to suit the construction environment.

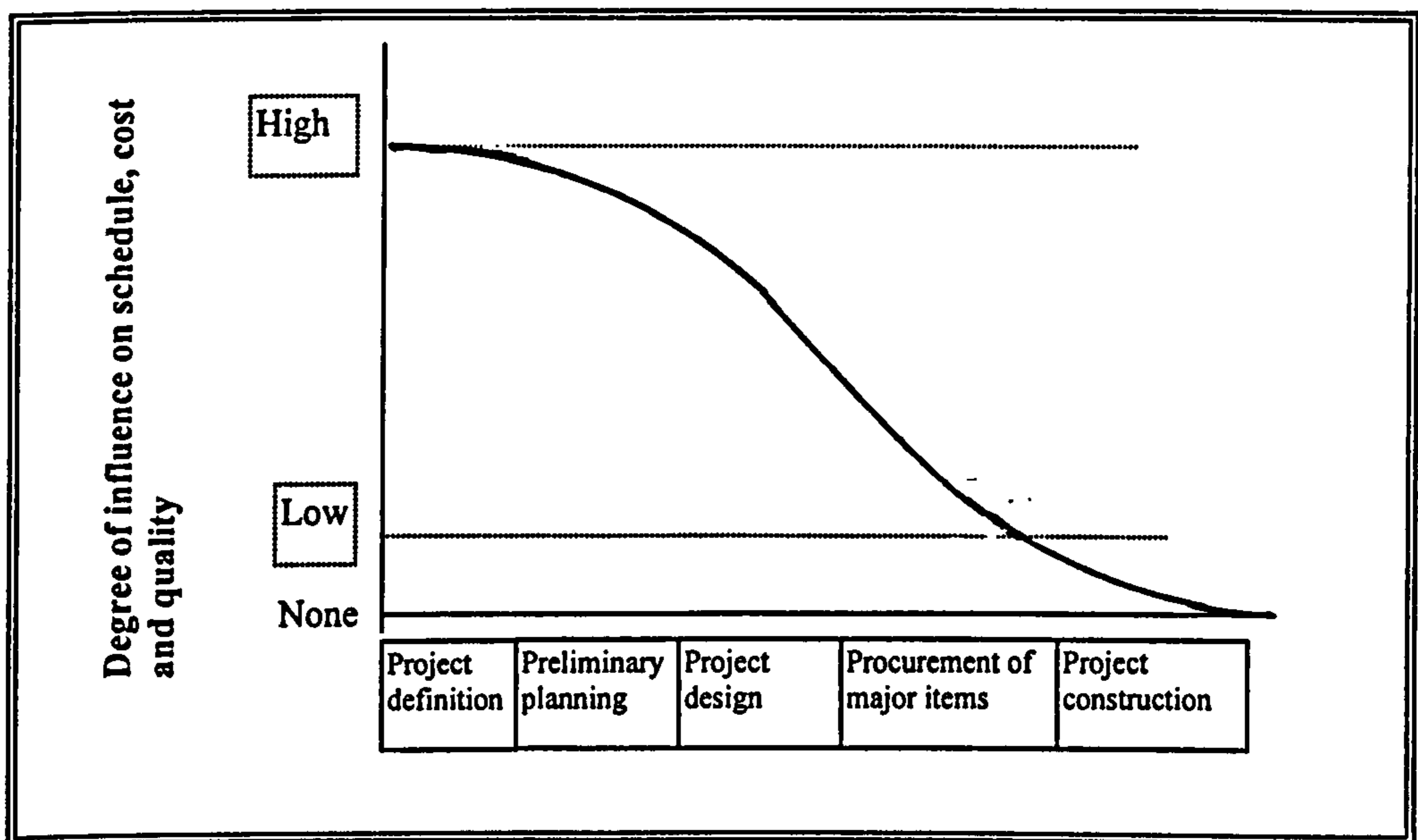
#### **4.4 Applying the important themes of CE to construction**

The basic elements of CE which have been discussed in the previous chapter are now presented here again but within the context of construction industry.

##### **4.4.1 Consideration of project life cycle requirements in the design process**

In chapter two many models of traditional construction process and the parties involved have been presented (figure 2.1, 2.2 and 2.3). In the simplest form the construction process can be divided into two major phases; pre-contract and post contract. Pre-contract activities include: briefing; feasibility; sketch design; design; tendering; and post contract include construction and maintenance of facilities (Ashworth 1996). Applying CE principle to construction means that all the project life-cycle requirements such as: planning; construction; end user requirements; maintenance requirements;

constraints by major suppliers, sub-contractors, and specialists contractor need to be simultaneously (concurrently) considered during the design development phase. Input from the functional expertise from all the various organisations in the project has to be considered in the design from outset. The rationale used by manufacturing industry in recognising the importance of the design phase in influencing the project cost, quality and efficiency is equally applicable to construction. Peurifoy and Ledbetter (1985) state that the degree of the influence on cost over the duration of construction process is not constant throughout the life cycle. The influence is higher at early stage of the project and diminishes as the development progress as shown in figure 4.1.



**Figure 4.1 Degree of influence on schedule, cost and quality  
Peurifoy and Ledbetter, 1985)**

However, as discussed in chapter two, the traditional construction process is developed based upon the separation of the design and construction functions. Therefore, consideration of the downstream requirement cannot be fully realised during the design phase because of the lack of participation from the constructors and other parties. Due to this constraint it is common for the construction project to experience the design related problems in the later stage of the project. The implementation of CE cannot be realised if the traditional work process persists.

## **4.4.2 Teamwork**

### **4.4.2.1 Introduction**

The use of teamwork is a common feature approach in today's management practice. It is also a common practice to organise a project team prior to the execution of the construction project. However the basic feature of the teamwork is different from one application to another. The following sections will discuss on the common aspect of teamwork from the general perspective prior to the discussion of the application of the teamwork concept based on CE philosophy to construction.

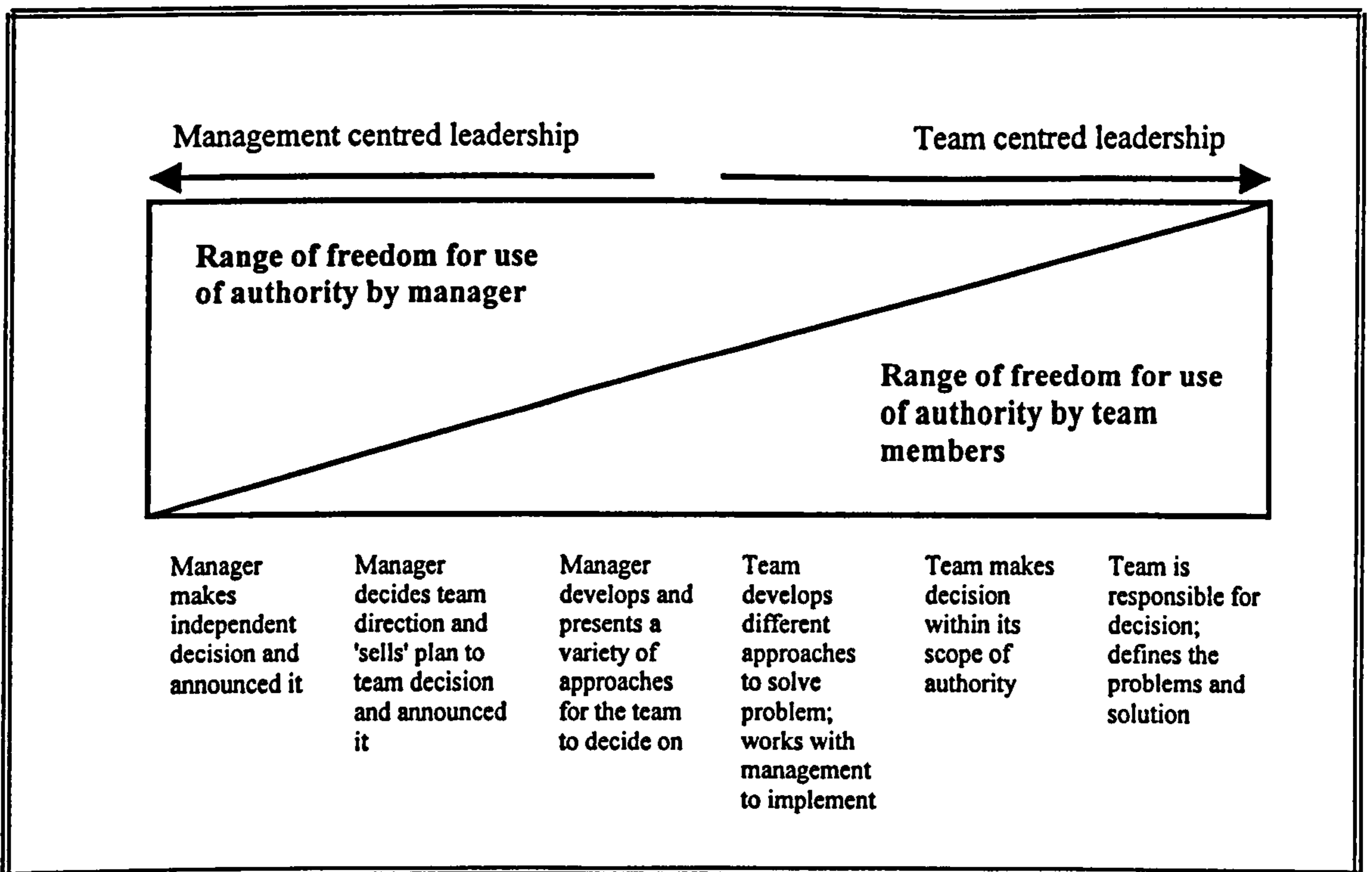
### **4.4.2.2 The general concept of teamwork - Background and definition**

There is no significant difference between the term 'team' or 'group'. Both terms imply the same meaning and are used interchangeably in the literature. However there are several features that differentiate each application of teamwork or groupwork in any organisation. The basic presumption of team is that the whole is greater than the sum of parts, so the team can produce more than individual effort taken alone (Mendelsohn, 1998).

Donnelly et al. (1992) define workgroup as *"a collection of employees (managerial or non managerial) who share certain norms and who strive to satisfy to satisfy their needs through the attainment of the group goals.* Katzenbach and Smith (1993) define team as: *"a small number of people with complementary skills who are committed to a common purpose, performance goals and approach for which they hold themselves mutually accountable"*. Larson and LaFasto (1989) definition of team is *"a team has two or more people: it has specific performance objective or recognisable goal to be attained; co-ordination of activity among the members of the team is required for the attainment of the team goal of objective"*.

Handy (1985) states that groups vary from formal (such as workgroup, a project team, a board) to informal (such as the luncheon group, ah hoc meeting or discussion). Donnelly et al. (1992) categorised the different type of team as follows: interest group; friendship

group; committees; quality circles; action-oriented group; and self manage groups. Ray and Bronstein (1995) argue that the term 'team' despite being commonly used often gets abused. Neumann et al. (1995) support this argument and claim that the used of the word 'teamwork' is confusing because it had been applied to every grouping of individuals in an organisation regardless of how that group actually work. Ray and Bronstein (1995) differentiate the concept of 'true team' from the 'traditional team'. According to them, the traditional work group is highly leader dependent, led by a manager who is responsible for goal setting, decision making, making job assignment, performance appraisals and in many places hiring and firing team members. The nature of the work that this 'traditional team' deals with fragmented into many different parts and no one person except the manager sees the entire process. The 'true team' have the ability to determine their own planning and decision for the whole process, respond quickly to customer requirements while being able to reduce time dramatically. Oliva (1992) in the earlier literature developed the same concept of differentiating the team characteristics by virtue of the management influence. His concept is presented in figure 4.2.



**Figure 4.2 The spectrum of teamwork authority (Oliva 1992)**

#### **4.4.2.3 The importance of the team**

The main purpose of team formation is fairly clear and commonly found in the literature i.e: to motivate people and get better commitment toward achieving common goals. This also helps people to achieve a better working life. Major purposes of organising a team as stated by Handy (1985) are:

- i. For the distribution of work
- ii. For the management and control of work
- iii. For problem solving and decision making
- iv. For information processing
- v. For information and idea collection
- vi. For testing and ratifying decision
- vii. For co-ordination and liaison
- viii. For increased commitment and involvement
- ix. For negotiation or conflict resolution
- x. For inquest or inquiry into the past

Neumann et al. (1995) assert that teamwork has been considered a viable alternative to the principle of 'Taylorism', or 'scientific management'. Back in 1950's to 1970's workgroup or team were used as a means of returning the autonomy and controls to workers involved in automated production. However the focus in using teamwork is currently shifted toward achieving improved performance in cost, quality and innovation as well. The significant area of the application of workgroup has taken place in post-war Japan. Fulmer (1992), quoted from Rosabeth Moss Kanter (1989) the editor of Harvard Review asserted that the team is the competitive weapon in 1990's. Donnelly et. (1992) all describe "*teams, partnerships, ownership, and cohesiveness are what more and more employees are asking today*". According to Fleming and Koppleman (1997) the move to implement a new concept of using the 'integrated team' as an approach in product development has been adopted by many industrial giants like Chrysler, DuPont, Eastman Kodak, Eli Lilly, General Motors, Hewlett-Packard and Xerox. Even though the name of the teamwork concept used by those enterprises are not the same, but they have a similar principle: all teams include the requirements that multiple functional disciplines join together to work toward a common objective.

#### **4.4.2.4 Team building**

The process of building a team requires consideration from various aspects ranging from the human and psychological aspect, to the physical resources requirement to support the team. Donnelly et al. (1992) state that workgroup have similar characteristics to formal organisations. They outlined four phase process which point out some characteristic and attitudes inherent in group development:

1. Mutual acceptance - accepting each other.
2. Decision making - open communication concerning the job rule.
3. Motivation - better to co-operate than to compete, emphasis on group solidarity.
4. Control- members contributing according to their skill and ability, exercise sanction to ensure members behave 'according to 'group' norms.

A study of over 40 teams by (Oliva 1992) found the following common characteristics to build a team as shown in table 4.1:

**Table 4.1 Common characteristic to build a team (Oliva 1992)**

1. Create a common vision of what the project will create or accomplish
2. Developed and approve a set of rules for the team to use, during the very first team meeting
3. Assign or have each person select one area of expertise for which they will be responsible
4. Decide how the team will make its own decision and the limits stated by management
5. Jump into project at running speed
6. Communicates with people outside the team to publicise the team progress, resources required and project achievement
7. Grow smaller - most successful team have a small core group: up 8 to 15 people. Others can be associated with the team through their representative in the core group
8. Be close to each other,. Team should be co-located
9. Use technology to eliminate the delays cause by time, distance and language between customers and vendors.
10. Reward the team

#### **4.4.2.5 Basic characteristic of the team**

The basic nature of the team is to enable its members to work in a unit to accomplish challenging goals. There are many studies conducted to investigate the important characteristics of the team. Parker (1990) suggest a list of characteristics of an effective team from the general perspective as follows:

- 1 Clear purpose
2. Informal climate
3. Participation all members in discussion
4. Effective listening
5. Civilised disagreement
6. Consensus decision



7. Open communication
8. Clear roles and work assignment
9. Shared leadership
10. External relationship - developing key outside relationship
11. Style diversity - broad spectrum of team player types
12. Self assessment

Larson and La Fasto (1989) identified eight characteristics, or properties of effectively functioning teams as follows:

1. a clear, elevating goals;
2. a results-driven structure;
3. competent members;
4. unified commitment;
5. a collaborative climate;
6. standards of excellence;
7. external support and recognition; and
8. principled leadership.

Fleming and Koppleman (1997) stressed on the importance of the management commitment to support the project team. The top management commitment to support the team must seriously extend beyond the official declaration of the team formation. The organisation must provide the team with: adequate budget; a published charter establishing the teams; adequate authority to influence important decision prevalent to the project goals and personnel matters; and empowerment to make their own decision.

#### **4.4.2.6 Applying CE teamwork concept to construction**

Teamwork is the backbone of CE (Jo. et al 1993). The formation of the team concept is an important feature that characterises the relationship between various participants within construction project. However the degree of the relationship among the members of the team in the traditional construction project is different from the teamwork concept of cross functional team (CFT) as proposed in CE philosophy. In general the

project team concept in the traditional construction process involves owner and/or his representatives, designers and contractors engaged in a temporary organisation for the purpose of executing the project task and guided by the requirements of the contract. Cherns and Bryant (1988) refer to a construction project team as a temporary multi organisation (TMO) due to the temporary nature of the team existence. The term 'project team' may also be used by the individual organisation participating in the project to represent their group. For the purpose of this thesis, the general concept of teamwork is defined as: *"individuals or groups representing various organisations in the construction project drawn temporarily together for the purpose of co-ordinating the project task"*.

The main objectives of the formation of the team for a construction project are to facilitate the communication and the co-ordination of works among the members. Communication is normally achieved in a very formal way. Each of the members has their own specific responsibility toward the project and the client. Contribution to other functional requirements outside their defined role is minimal. This is manifested by the rigid hierarchical organisational structure commonly used. However, a flatter organisation structure that supports more open communication between functional teams is required to support the project team used in the design build procurement or partnering concept as claimed by an organisations interviewed. This is reported in much more detail in the case study (chapter 8). The major difference between the teamwork concept in CE compared to the traditional teamwork concept for a construction project lies within the following factors:

- the removal of functional boundaries;
  - the formation of the team from is made from the inception stage of the project;
  - the main objective of the formation of the team is to enable the members to contribute in the design stage;
  - team members may comprise of a wider range of members to include the client, major sub-contractors and major suppliers;
  - the team is normally given adequate authority to make important design decisions;
- and

- the team support process changes from the traditionally design then build approach to more flexible concurrent (overlapping) development of project task.

The following example indicates some of the project team aspects based on CE implemented in manufacturing:

The characteristics of teamwork concept used by Chrysler and Boeing (Backhouse and Brookes, 1996) include:

- Bringing together people from all of the functions (various engineering functions together with marketing, sales and purchasing) involved in product development into what it termed 'platform teams'.
- Teams co-operating in every stage of the product's development from conception through to delivery.
- Personnel within the teams working concurrently by ensuring that their particular knowledge was taken into account by other members of the team at the first opportunity.
- Manufacturing (production) engineers were involved from the earliest stages of the design

Based on the observations made in the literature the writer argues that the teamwork concept based on CE principles has not been fully implemented in construction. The behaviour of the team participants is determined by the type of the procurement approach adopted (Chen and Mead 1997). Therefore for the construction industry to practice teamwork concept based on CE principles, an appropriate amendment toward the existing procurement system has to be made. Gordon (1994) argues that the traditional procurement appears to induce "adversarial relationship and lack of teamwork". The use of the teamwork concept with the design-build system may look to bear some resemblance to CE teamwork concept in the sense that it includes the design and construction team from the inception of the project. However the design build team may (or not) represent the interest of a particular organisation only. In contrast participation in CE by the team normally represents the interest of a wider range of project participants including the customer and suppliers. The partnering teamwork

concept is another approach that had been taken up by the construction industry and bears many characteristics of CE team. Moore et al. (1992) state that the primary advantage of partnering is that it recognises the objectives of all parties and therefore creates synergy for project success. However the author argues that the ability of the partnering approach to develop a teamwork concept parallel to CE principles depends on several factors. Among the factors are: who are in the partnering parties; the real objectives of partnering (because it is intended to pursue a business goal); the involvement of the clients in the partnership; and the type of procurement approach used to deliver the project.

The importance of the teamwork in CE implementation in manufacturing industry is very significant. The writer argues that construction should take the same position by considering the use of CFT concept as a strategic approach to implement CE. There is very limited discussion in the literature to review the character of the teamwork needed to implement CE in construction.

The most important factor in the formation of the team to support CE in construction is that it must be able to support process change. The writer argues that the existing traditional teamwork concept adopted in construction industry is only suitable to support the traditional framework of sequential process system. In a CE environment the formation of the team must involve all the major stakeholders. In construction this includes; the owner; the designer; constructor (contractor); sub-contractor; customers; and suppliers. All these parties must work as a team. The initial stage of the formation of the team must be at the outset of the project, although it is recognised that the team will be extended and change as the project progresses.

The role of each participant must be recognised and also their contribution toward the project design development. The contractor, or their subcontractors, material and equipment suppliers who have knowledge on the constructability aspect of the project and material usage must be recognised for their role to influence or review the design. In CE, they will be given the role to contribute during the conceptual and detail design phase of the project. This will be achieved within the multifunctional concurrent team. Design will be a team effort. This is a major departure from present practice whereby the designer (architect and engineers) “own” the design. This is also contrary to the

traditional practice of the designer “throwing over the wall” the completed package of design work to the contractor for construction. No barrier between the designers and constructors should be allowed to exist in CE practice.

#### **4.4.3 Lead time**

The reduction of lead time in manufacturing is important to enable the product to reach market as soon as possible. In construction, reducing development time is equally important. Most projects have the urgency to be completed in the planned time so that the return from investment can be reaped as soon as possible. Therefore the objective of CE to reduce product development time is very appropriate in construction industry scenario as well. In CE, reduction of development time is achieved by simultaneously considering all life cycle requirements in design development. This strategy leads to reduction of the unnecessary time needed to rectify design error and rework. It is also enables parallel accomplishment of project task because of early involvement of team members and the ability to share more project information across the functional boundaries. In the construction industry the overlapping of project development task is frequently achieved through the 'fast track'. The discussion on the fast track system and its limitation has been presented in chapter 2.

#### **4.4.4 Focus on the customer requirements**

The common approach normally used in CE to capture customer requirements is by their inclusion in the project team and use of techniques such as Quality Function Deployment (QFD). In a manufacturing environment understanding customer requirements is the most important aspect to ensure the acceptability of the product. The importance of addressing customer requirements was the critical factor in the achievement of Rover in their four wheel drive model the 'Discovery'. *"The success of the four wheel model of discovery was not simply based on its novelty but on high quality product design derived from clear view of customer requirement "* (Backhouse and Brookes, 1996). The tradition of addressing clients' requirements is quite different in construction industry. Clients' priority in their requirement towards the construction

project varies from the need to have a good quality end product, at the most competitive price and fastest time of project delivery by sacrificing some aspect of the design and quality (Ashworth, 1996). The initial client requirements in the construction project are addressed at the briefing stage. Clients will be involved in the project team throughout the project life cycle. But due to the complexities of the construction project and the limitation client's experience, their need is not always properly addressed. It is a normal practice in construction for a client to appoint another party such as a manager to look after their interest in the project. It is also normal in the traditional construction practice for the design consultant to represent the client's interest in the project. However, the writer argues that since the construction team is isolated from the design process, the client will be deprived from getting an optimal design solution and cost due to their lack of input.

Kamara et al. (1997) state that if the client's requirement is properly processed, it can facilitate concurrent working. Client's requirement must be thoroughly understood and analysed to ensure they are made clear and unambiguous. In his research, Kamara (1999) determined that:

- there must be a formal framework to process clients requirements;
- such framework should provide effective procedures and techniques for precise establishment of client requirements;
- the requirements must be traceability and easily correlated during the development process;
- the requirements must be analysed and prioritise to avoid conflict; and
- the requirements processing should facilitates design creativity and integration into product development process.

He argues that the current mechanisms for processing client's requirements in construction industry i.e. the briefing process do not satisfy CE approach. Table 4.2 above summarises the comparison between current briefing practices and the CE approach made by Kamara (1999).

**Table 4.2 Current briefing practice and requirements processing in a CE context (Kamara, 1999)**

<b>REQUIREMENTS PROCESSING IN CE</b>	<b>CURRENT BRIEFING PRACTICE</b>
The requirement for a formal methodology:	Although formal guidelines such as the RIBA plan of work and checklists are usually followed the process of translating requirements into technical specifications is mostly not based on any formal methodology, but on subjective judgement based on the training, orientation and experience of the designer.
The requirement for precision and clarity:	Insufficient time is allocated to the briefing process (Latham-1994). Therefore insufficient time to precisely define analyse and prioritise clients' requirements in a way that will provide the clarity and unambiguity required to facilitate concurrent working. The use of the design process to evolve and develop the brief no doubt is responsible for this.
The requirement for traceability and correlation	The practice of recording decisions and changes to requirements on paper as corrections to drawings could make it difficult for requirements to be traced and correlated especially for large and complex project. There is also no formal or structured process to correlate requirements to see if there are any conflicts or dependencies.
The requirement for rigorous analysis and prioritisation	Although experts clients use techniques such as value engineering to prioritise analysis and prioritise their requirements, the analysis and prioritisation of requirements is mostly done subjectively. Furthermore there is usually no formal procedure to analyse the requirements.
Facilitating design creativity and integration into the product development process:	Briefing is part of the design process and many creative and award-winning designs have been developed using current briefing practices. However clients requirements are not rigorously analysed and translated into a solution-neutral format that will enhance design creativity. The processing of requirements in tandem with the design process might inhibit a proper understanding of the problem that design is to solve.
Computer-based	Current briefing practice in the construction industry' is mostly paper-based and the use of IT cannot be described as a widespread The weakest area is in the translation of the client's business needs into a workable solution (Construct IT 1996)

#### **4.5 The benefits of applying CE to construction**

There are many potential benefits that can be reaped by construction industry if it implement CE. Currently construction has already gain the benefit from implementing some of the element that are parallel to CE through design and build procurement approach, fast track system and partnering approach. But the benefit gained through these partial or 'unintentional' approaches toward CE is limited. This can be greatly amplified if it is applied as a whole process as in manufacturing. The argument of the limitation of those approaches has been presented in chapter two. Furthermore their development is not intended to achieve the same objective as delineated in CE philosophy.

The most important benefit from the application of CE to construction lies within the capability of the CE philosophy to support process change. Construction has suffered from the setback of traditional practices, which has resulted in many problems. Therefore, there is an urgent need for the industry to realign the traditional way of delivering the project with respect to the work process and the teamwork structure. Like the experience in manufacturing, implementing CE requires an organisation to abandon the traditional practice of work process and adversarial way of working. Fragmentation and specialisation is a natural phenomenon in construction. But applying CE principles will help to tear down the invisible wall that separate these fragmented functional organisation (groups) and pull them together into a solid collaborative team sharing the same project goals and objectives. All the different expertise from various functional groups will enjoy the opportunity to contribute their input and queries toward design development. Another important benefit of applying CE to construction is the ability to reduce lead-time in product development. Project delay is a very common in construction therefore the industry should consider adopting CE as strategy to minimise the problem.

De La Garza et al. (1994) reported the result of a study on CE implementation in Europe and the outcome shows the following achievement: 30%-42% reduction in manufacturing cost; 75% reduction in scrap and rework; 35%-60% reduction in time to develop an artifact; 30%-87% reduction in defects; and 30%-60% increase in saving. This study although not carried out on construction presents the idea of the array of



benefits that construction can expect from CE implementation. Egbuomwan and Anumba (1998) suggest that by applying CE will have the following benefits to construction. Implementing CE will enable the establishment of formal framework to identify client's requirement at outset. CE will help to reduce error, rework, and duplication of work that normally incurred in the conventional (traditional) procedure. This will result in: shortening lead times; reducing cost and project delays; drastically reduce claims and dispute; and saving project cost. CE also enhances teamworking and group dynamics with better co-ordination of the efforts of team members. Apart from that the application of CE also ensures concurrent design and construction in an integrated project model and will improve the technical capability of the project team through the enhanced knowledge base, and better informed design decisions. CE also supports early conflict resolution and ensuring the incorporation of buildability, safety and risk analyses at an early stage. The implementation of CE in construction also provides a suitable framework to utilise IT tools to improve the industry efficiency in the cross functional communication and information sharing.

#### **4.6 Inhibitors in CE implementation to construction**

The inhibitors towards the implementation of CE in other industries especially manufacturing are well documented in the literature and have been discussed in chapter three. Such information is not directly available in construction literature. Therefore any discussion on the potential inhibitors to the implementation of CE must be based upon the perception and generalisation of the expected industry reaction towards accepting changes and deviation from its normal process. The author perceive the following inhibitors implementing CE to construction:

1. Psychological impact of fear to change and unwillingness to accept the risk associated to it.
2. Fear of losing power to control and domination over the project design and planning phase by the traditional project manager or designer.
3. Lack of knowledge of concurrent engineering concepts and practice.
4. Fear of lack of budget to support the use of IT tools especially in the small project.
5. Concern over the legal implications resulted from CE implementation.

Another inhibitor that might impede efforts to introduce CE to construction is due to the persistence attitude of the industry in accepting any changes from its traditional practice in delivery of project. Many reasons have been associated to this phenomenon. The most common reason is a belief of uniqueness of industry (Kwak et al.,1995). However, Koskela (1992) indicated that the trend to perceive the uniqueness of the industry is more of psychological need common to any other industries as well. Another reason that is also commonly quoted is the high degree of fragmentation of the industry (De La Garza et al., 1994). This has resulted in the intense competition because of the large number of specialised firms in this industry and force the companies to avoid risk and adhere to the industry norm whenever possible (Mohan, 1990). Oglesby et al. (1989) point out that construction firm owners are not aware of the economic payoff to be derived from the appropriate use of modern management systems and not willing to meet the additional cost that might incurred from the change.

#### **4.7 A methodology for applying CE to construction**

Applying CE to construction requires a major breakthrough in its traditional culture. Baxendale et al. (1996) argue that CE is not easy to implement. They proposed that it must be tried by major clients first. Dearsley and Lettice (1997) relate the findings of their exploratory study to identify the managerial and organisational factors that contribute to successful implementation of CE to construction. They propose three important factors to implement CE:

- clear understanding by senior management of what implementing CE entails;
- the use of change agents like CE steering committees; and
- the use of pilot studies prior to the full implementation of CE.

Kamara et al. (1997) argue that CE implementation in construction cannot be the wholesale copy from manufacturing. This view is supported by Dearsley and Lettice (1997) who state that the blind adoption of current manufacturing practice within construction could lead to problems. They identify that the main challenge that the construction industry will have to face to implement CE is to break down the barrier of

the professional organisations and obliterate the traditional practice of separating design and construction. Then it is also important to consider how to effectively integrate while maintaining the identity of each member in a multi-functional organisation. They make recommendations as to how to implement CE by:

- building on current practice and trends like fast tracking and the use of project teams;
- the formation of alliances and partnerships;
- effective processing of clients requirement; and
- action based research with industry participation.

Houvila et al. (1997) look at the application of CE to construction by conceptualising the lean production concept with specific focus on the objective to eliminate the non-productive tasks in the process. They further proposed that CE objectives can be achieved in construction by: reducing the share of activities that not directly contribute to conversion; conceptualising CE with Lean Construction and aggressively reducing uncertainty in the early phase of engineering project.

According to Carter (1992), CE can be applied to any organisation by balancing the following three important concepts:

1. The organisation structure must be able to support the development team which should operate as a single entity.
2. An efficient communication structure is required to support free and speedy information exchange between team members.
3. An analysis of the product development life cycle should be carried out during the conception and design stages.

Love and Gunasekaran (1997) offer a generic view as to how CE can be implemented to construction by the identification of the associated downstream aspects of design and construction processes; the reduction or elimination of non-value adding activities; and the used of multi-disciplinary team.

The views of these experts may be summarised as follows:

Existing literature does not specifically identify a clear approach to how CE can be implemented in construction, but rather offers a general perception based on the experience from other industries. It is accepted that the use of teamwork is the most important strategy to implement CE but it is not clear how a teamwork structure based on CE principles could be adopted within existing procurement practice. Some proposals have been made in the literature to support the use of the existing procurement systems like design and build or by using partnering approach to implement CE. Evbuomwan and Anumba (1996) suggest if construction can overcome the deficiency of the current practice in D&B as shown in table 4.2, it can be used as a model to implement CE.

**Table 4.3 Limitation of the current Design and Build procurement approach (Evbuomwan and Anumba, 1996)**

- Clients incur extra costs in retaining a set of consultants at the early stages of the project.
- The outline design which forms the basis of tenders is based on the initial consultants interpretation of client requirements - this may be distorted and could mislead the tendering consortia.
- The outline design inhibits the ingenuity and creativity of the tendering consortia by limiting them to the initial consultants' vision of the desired facility.
- There is a significant amount of rework and duplication inherent in existing procedures, particularly where the initial consultants are not novated to the successful contractor.
- The expertise of the successful consortium is not fully exploited in the most influential stage of the design process -conceptual and preliminary design
- Delays often arise due to the initial time spent developing the outline design, time spent by the successful consortium in clarifying client requirements and liaising with the initial consultants and time spent seeking approval for alternative materials and design changes.
- There is great potential for disputes and claims at the construction stage due to the client's requirements not being well-defined at the early stages. These problems often relate to cost, quality and performance requirements
- Quality, value for money and client satisfaction are not guaranteed by existing procedures.

Evbuomwan and Anumba (1997) suggest the following key issues that must be address to implement CE in construction. The issues are:

1. The need to focus on the customer/owner/client.
2. The need to integrate the activities of the various functional disciplines involved in the project.
3. Carrying out competitive benchmarking of design and construction practices and processes.

4. Focussing on the quality, cost and delivery of projects.
5. Concurrently developing the design of the project along with the fabrication, construction and erection processes.
6. Establishing strategic relationships with materials and component suppliers and sub-contractors.
7. Integration of CAD and other design tools for concurrent engineering.
8. Use of modern project management techniques to enable paralleling and overlapping of the design and construction activities.
9. Integration and commonalization of design knowledge, data and information;
10. The use of new materials and technologies;
11. The effective use of computer hardware and software.

Currently there are claims that some organisations have adopted practices parallel to CE. They are mainly in the UK petrochemical industry. Anumba et al. (1997) present three case histories on the collaborative relationship in the construction of petrochemical industries facilities. They suggest that the experience can be used to show the way forward to support CE implementation in construction (Table 4.4, 4.5 and 4.6).

**Table 4.4 Case history 1 : The Andrew Alliance (Anumba et al. 1997)**

**Case History One**

**THE ANDREW ALLIANCE**

***The objective of the alliance:***

The Andrew Alliance is between British Petroleum (BP) as client and seven main contractors. The objective of the alliance is to deliver the Andrew facilities at a target cost of £373 million, fully operational on schedule and with design and operational safety cases accepted by the Health and Safety Executive of the UK.

***The strategy adopted included the following:***

- The involvement of alliance partners right from the beginning. This ensured that the whole life-cycle of the project was considered very early in the process, especially in preparing the estimate for the completion and operation of the Andrew facilities.
- A single alliance agreement between the contractors and BP which aligned them financially to the overall success of the project. In addition to this, each contractor individually signed a works contract with BP. The decomposition and assignment of tasks to each contractor made parallel scheduling and concurrency in operations possible.
- The use of an integrated management team (IMT) made up of the BP project manager (as chair) and the project managers of the main contractors in the alliance.
- The use of electronic data interchange across alliance members and with suppliers, and information systems which facilitated the transfer and exchange of data during project execution. These systems also provided comprehensive, user-friendly data banks to support operations and maintenance throughout the life-cycle of the oil field.

***The result (benefit) of this alliance included :***

- cost savings of about £70 million
- The commissioning of the project took just 3 weeks instead of the usual 3-4 months.

**Table 4.5 Case history 2 : The Britannia Topsides Alliance (Anumba et al., 1997)**

<p style="text-align: center;"><b>CASE HISTORY TWO</b> <b>The Britannia Topsides Alliance</b> (Ongoing at the time of research)</p> <p><b>Description of the alliance:</b> Alliance between a group of operators (a seven company consortium) and six main contractors. The oil companies operate as Britannia Operator Limited (BOL), a company formed to provide a single focus for field and operations. The Britannia development consists of drilling, production and accommodation platform, and a subsea well centre together with offtake pipelines to enable production to commence in October 1998. The alliance between the seven companies is aimed at reducing the capital expenditure (Capex) figure of £390 million and future operating expenditure. Its scope covers management, design, procurement, fabrication, installation and hook-up and commissioning.</p> <p><b>Some features of this alliance include the following:</b></p> <ul style="list-style-type: none"><li>• The modeling of the entire structural aspect of the integrated deck using the PDMS software;</li><li>• The transfer of drawings electronically to enhance communication between various activities which are usually carried out in different locations;</li><li>• The decomposition of activities among the different partners to facilitate parallel scheduling and concurrency in operations.</li></ul>
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**Table 4.6 Case history 3 : Conoco Jupiter Project (Anumba et al., 1997)**

<p style="text-align: center;"><b>CASE HISTORY THREE</b> <b><u>CONOCO JUPITER PROJECT</u></b></p> <p><b>Description of the alliance:</b> This is an alliance project for the design, fabrication and installation of a Well-head Platform. The cost of £25 million (\$40 million) for the equipment and structure included a £2 million (about \$3 million) design contract. The parties in the alliance were the client, design and project management consultants, fabricators, and installation contractors.</p> <p><b>The characteristics, benefits and lessons learnt as a result of this alliance included the following:</b></p> <ul style="list-style-type: none"><li>• Design input by all parties and close collaborative working between them (especially between the designers and fabricators). This was facilitated by the use of the Plant Design Management System (PDMS) for all piping and structural drawing with DXF as the electronic data exchange protocol.</li><li>• Video conferencing was also used for communication between the designers and fabricators.</li><li>• Although the travel budget was higher than expected, cost savings of up to £5 million were made. This was shared between the partners in accordance with an agreed 'risk and reward' strategy.</li><li>• The overall project duration was also reduced by 3-4 months due to a six-month overlap between design and construction.</li><li>• The use of a fully integrated project schedule facilitates greater co-ordination between the parties involved. The use of similar CAD systems, a common project model or neutral interfaces such as DXF are vital for effective collaborative working.</li></ul>
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Duncombe (1997) describes BAA effort to implement practices parallel to CE through their partnering effort with their supplier. BAA owns and operates seven airports within the UK of which Heathrow, at 56m passengers per annum and with over 90 airlines, is the world's busiest international airport. As a major client organisation BAA spend about £500 million annually on airport expansion and improvement programme. Among the important practices by BAA that are claimed to be parallel to CE are:

- A disciplined and consistent approach to projects.
- Clear project gateways.
- Greater predictability in terms of cost and programme.
- A common vocabulary.
- The introduction of design standard and standard components.
- A foundation upon which to improve.
- To complete design and to thoroughly pre-plan the fabrication and construction process before starting construction.
- Work with the suppliers as an integrated team committed to the progressive integration of design, fabrication and construction; to be sure that every part fits and is properly engineered.
- Used of dedicated team which are :
  - Collocated
  - Use GroupWare system (Lotus Notes) to support project communication
  - Team are formed early
  - Supplier are paid for their involvement
  - Team members were chosen to provide right skill and attitude required by the project
- Maximised the use of standard components and off site fabrication.
- Great emphasis was placed on the desire to pre-plan all off and on site activities.
- Supply Chain Management involved working with key suppliers to identify value improvements and cost savings within their supply chain.

There is also evidence gathered in the case study (chapter 8) to support the practice in partnering approach within the major construction project which are parallel to many CE elements.

## **4.8 Summary**

The literature review on CE application to construction does not provide clear evidence to support the argument that CE has been fully implemented as in other industries such as manufacturing. However there is evidence that construction is already implementing some elements which parallel CE through various platforms particularly: design and build procurement approach; partnering approach; and formation of alliances. There is also no single model based on actual implementation that can be adopted by the industry as an example of CE implementation in construction. CE is still at infancy stage in construction and opportunity is wide open for the researches to study various aspect related to its implementation to construction.

The conclusions that can be derived from literature relatively to the proposal to implement CE to construction are:

1. There is a desire within construction industry to adopt new management philosophies and tools from other industry to overcome the inadequacy of the traditional approach.
2. The approaches that are currently taken by the construction industry to improve its performance are mainly gearing toward achieving a better collaboration among project participants in the project. However these effort does not really align toward changing the traditional work process.
3. The motivation for the industry to consider the adoption of CE are:
  - The need to overcome the inadequacy of the traditional work process
  - Sophistication of the client
  - Availability of the cheaper IT tools to support cross functional communication and information sharing
  - Intense pressure to improve efficiency due to the very low profit margin
  - Similarity between construction and manufacturing especially with the basic work process system and problem faced when using the traditional approach
  - Congruence of goals between CE and construction industry need

- Lack of single management system to support collaborative teamwork environment.
  - The use of teamwork even though different from CE cross functional teamwork (CFT) approach in CE, is a common approach use to pursue construction project. Therefore this is a very critical foundation to pursue CE.
4. In pursuing the objective to implement CE the important issues needed to be addressed by construction industry are:
- The platform to support teamwork formation
  - A mechanism to integrate design and construction process
  - The need to realign the focus toward encapsulating the customer/client requirements in the projects
  - Improving the strategic relationship with 'external' stakeholder of the project mainly the major suppliers and sub-contractors.
  - Determination of the appropriate IT tools to support: project communication; information sharing; and project data integration to suit the budget constraint and temporary nature of the construction project
5. A comparison between the construction industry and the manufacturing industry revealed that:
- The difference between construction and manufacturing mainly lies within the technological aspect, but the fundamental aspect of work process still remain the same
  - Both industries share common problems due to limitations resulting from the practice of the traditional work process
  - Therefore there no reason why construction cannot adapted to incorporate the management philosophy of CE which has been developed and applied within manufacturing industry
6. The important elements of CE that have been analysed for their relevancy to construction are:

*Consideration of the project life cycle requirements within the design phase:*

- A very relevant issue to construction because principally construction exhibits the same trend of influence with respect to the higher cost committed for the project during the design development phase.
- Failure to observe this principle resulted with the same consequences as in manufacturing product development such as: requirement for unnecessary error and rework; costly repair; design inefficiency; delay and escalation of project cost.

*Teamwork:*

- Teamwork is a common feature in delivering construction project even though the concept is not the same as in CE practice.
- Cross Functional Teamwork (CFT) concept as proposed by CE philosophy is very appropriate to integrate the fragmented industry structure.
- It is also very important to facilitate effective communication and eliminate the functional barriers that exist within construction project.
- Indeed much of the efforts to improve the industry currently are directed toward improving the collaboration among the project team members.
- Construction has already exhibit in the recent major project that the industry is capable to work in collaborative environment.
- The main mechanism used by the industry currently to achieve collaborative teamwork environment is through D&B, partnering and alliances.

*Focus on client requirements:*

- Critical factor in construction because of the limitation of the current briefing practice.

- currently lack of appropriate mechanism to implement it effectively

*Lead time:*

- A very important principle when applied to construction because of the common problem that the industry faced is delay in the completion of the project.
  - Like in manufacturing there are also construction products that need to be marketed as soon as possible.
  - If the product is not to be placed in open market, otherwise the client would also like to occupy the facility constructed as soon as possible because of the large amount of the investment made on construction project.
  - Construction project is normally built to support other economic activities. Therefore completion according to the planned schedule is very important.
7. The perceived benefits from implementing CE to construction are:
- CE support process change
  - As an alternative approach to replace the traditional construction practice
  - Reduce project development time
  - Provide a framework for the collaborative teamwork structure
  - Provide a formal framework to encapsulate clients and end users requirement in the design
  - Provide opportunity for all project team members to contribute valuable knowledge and experience in the design
  - Promote sense of common ownership toward design
  - Improve quality of the final design
  - Minimise unnecessary error and rework in the project
  - Enable the industry to capitalise the current fragmentation nature
  - Enable the industry to fully utilise the available IT tools as the need for cross functional communication arise

**8. The expected inhibitors to implement CE in construction are:**

- Psychological fear of losing power by designers if other team members are given opportunity to participate in the design process.**
- Lack of exposure to CE concept and practice.**
- Low profit margin and intense competition within the industry are still critical barriers that force the industry to develop over cautious attitude in accepting any changes from the current work process.**
- The persistence of the traditional procurement approach that dominate the industry.**
- The belief that the industry is unique and different from others so that adoption of work practices from other industries inappropriate.**
- Legal issue that may arise in new collaborative working environment based on CE principles.**

**9. There is no research evidence to support CE has been implemented to construction a complete process. However some practice parallel to CE elements has already taken place within the industry. The following strategies which are gathered in the literature are consider important component to support the adoption of CE to construction:**

- The use of teamwork approach as the main strategy**
- CE adoption must no be the wholesome copy from other industry. There is a need to customise it to suit the construction industry environment**
- It is important to address the organisational issue prior to the implementation of CE to construction to ensure its acceptance**
- The use of steering committee to develop appropriate policy to implement CE**
- CE adoption must be test first with the major clients**
- The traditional procurement does not harmonise with the CE implementation**
- Adequate communication structure must exist to support teamwork**
- Existing practice like D&B and partnering can be used as a basis for way forward to implement CE.**

- There is a need to develop a strategic relationship with the clients, subcontractors and suppliers to facilitate CE implementation

10. The lesson learned from the industry experience in implementing the CE related elements especially in collaborative teamwork approach are:

- Capitalising the concept of partnering and alliance as the main strategy to achieve collaborative teamwork environment
- Early formation of the team
- Use of integrated management team
- Use of GroupWare system and other individual tool like video conferencing, common database, Electronic Data Exchange (EDI) and Email to support teamwork communication
- Use of dedicated team for a particular project task
- Carefully planned the project task and allocation of task among team members to achieve concurrency in project

As a final conclusion from the literature review, the following key issues are regarded as important and will be used as a foundation to develop further agenda and investigation:

1. The assumption that CE has not been fully realised in construction industry needs to be supported by research data. It is important to ensure that the implementation of CE to construction is made as a complete process and not partial adoption of some of its elements. This is important to ensure that construction industry will be able to reap full benefit from CE implementation.
2. The literature search also revealed that some elements that are parallel to CE are already being practised within D&B and partnering/alliances projects. This finding needs to be investigated further by this research to determine whether they represent a complete CE implementation or not. It is also important to address such an issue because they can be used as a platform to implement CE if many elements of CE are already familiar within such practices.

The claim that practices that is parallel to CE in construction also lead to confusion with regard to the status of its actual implementation. This phenomenon led the research to develop a tool to assist the industry to map the process toward implementing CE within construction project. This tool must be developed based on actual principles of CE philosophy and the experience in manufacturing industry and validated against the major construction project that exhibits high degree of experience in collaborative teamwork.

3. The use of the teamwork based on CE principles has been an important strategy to achieve CE implementation in other industries. This led the research to consider the adoption of the same strategy in construction because:

- Teamwork is a familiar concept in construction even though the practice is not consistent with CE principles.
- Reorganising the 'new way' of teamworking based on CE principles also mean reorganising the traditional approach in project team in construction. This is a very is a critical approach toward achieving CE implementation in construction. The use of teamwork concept as proposed in CE provide the platform for the multi-functional firms within fragmented construction industry structure to work together under CE environment.
- Currently there is lack of effort in research to investigate the potential of using teamwork strategy to achieve CE implementation in construction. Therefore it is critical for this research to develop a suitable framework to support the formation of 'collaborative teamwork concept based on CE principles as a model for the industry to implement CE to construction.
- There is a need to customise the implementation of CE to suit the actual need and application. Therefore it also important for the research to evaluate the factors that are related to the collaborative teamwork within the current practice so that it can be used as a basis to develop the teamwork base on CE principles. To



support this research also need to establish the industry opinion on the factors that support and inhibit teamwork.

As a way forward to address the above issues, this research adopted the following research approach as shown in table 4.7

**Table 4.7 The strategy adopted as a way forward in this research.**

	<b>KEY RESEARCH ISSUE</b>	<b>RESEARCH STRATEGY</b>
1.	To determine the existence of the practices within the construction industry similar to those encompassed within the CE philosophy, especially within D&B and partnering.	<p>Considering the nature of the issues need to be investigated within the wider context of industry, the research adopted two stage of study as follows:</p> <ol style="list-style-type: none"> <li>1. Industry interview - to explore the issue further from the industry practitioner</li> <li>2. Using industry wide postal questionnaire survey so that larger population of construction industry practitioners can be surveyed for their responses.</li> </ol> <p>Chapter 6 dedicate to discuss the findings from the industry interviews and industry wide postal questionnaire survey</p>
2.	To determine the current state of art of collaborative team work within construction project	
3.	To determine the factors that support and inhibit collaborative teamwork	
4.	To develop the framework to implement collaborative teamwork concept based on CE principles to construction	<p>The issue needs to be investigated in a more focus and comprehensive manner. The research decided to use Delphi study to address this issue. This is because the technique provide the platform for the research to elicit construction industry expert opinions in several round before conclusion is made to develop guidelines for the formation of collaborative teamwork based on CE principles to construction. Chapter seven dedicates the discussion on Delphi study outcomes.</p>
5.	To develop the tool to map the process toward CE environment in construction	<p>The issue relates to the actual practice in industry. Therefore, the appropriate way forward to develop 'Matrix Measurement Guideline' (MMG) is by using the findings from research such as literature review and interviews. The MMG developed will be tested using case studies. This will be discussed in chapter eight.</p>

## **CHAPTER FIVE**

### **DATA COLLECTION**

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#### **5.1 Introduction**

This chapter describes in detail the overall data collection strategy and administration for the research. Different methodologies were employed to generate qualitative and quantitative data at different stages of the research. These methodologies were: literature review; interview; single stage postal questionnaire survey; Delphi (Inspired) method; and case study analysis. The objective of each methodology used, type of data generated and the rationale for its adoption is discussed here. Different types of data collected are also used to support the triangulation approach used this research. Altogether there were: seven interviews; one hundred sixty postal questionnaire surveys sent; and two rounds of Delphi studies conducted using a panel of thirteen experts representing various sectors of construction industry's; and four detailed case studies conducted in the research. The detail analysis of the findings for each of these methodologies will be made in the following chapters.

#### **5.2 The aim and objectives of data collection**

The main aim of the data collection was to enable the research to:

1. Develop theoretical background on the current state of art of the construction industry practice with respect to the collaborative teamworking and work process;
2. Determine the existence of the practice which are parallel to Concurrent Engineering principle within the industry;
3. Establish a framework comprising of the variables that are related to CE implementation in construction which suit construction industry environment; and

4. Develop a measurement tool to serve a guideline for the industry toward implementing CE environment within construction projects.

To achieve this aim the research has adopted the following strategy to generate the desired qualitative and quantitative data:

Methodology 1: Literature review

Methodology 2: Interview

Methodology 3 : Industry wide postal questionnaire survey

Methodology 4 : Delphi (inspired) study

Methodology 5 : Case study

### **5.3 Description of the methodology used**

The following sections describe the specific objective of each methodology used, their background and rationale for their adoption in this research.

#### **5.3.1 Literature review**

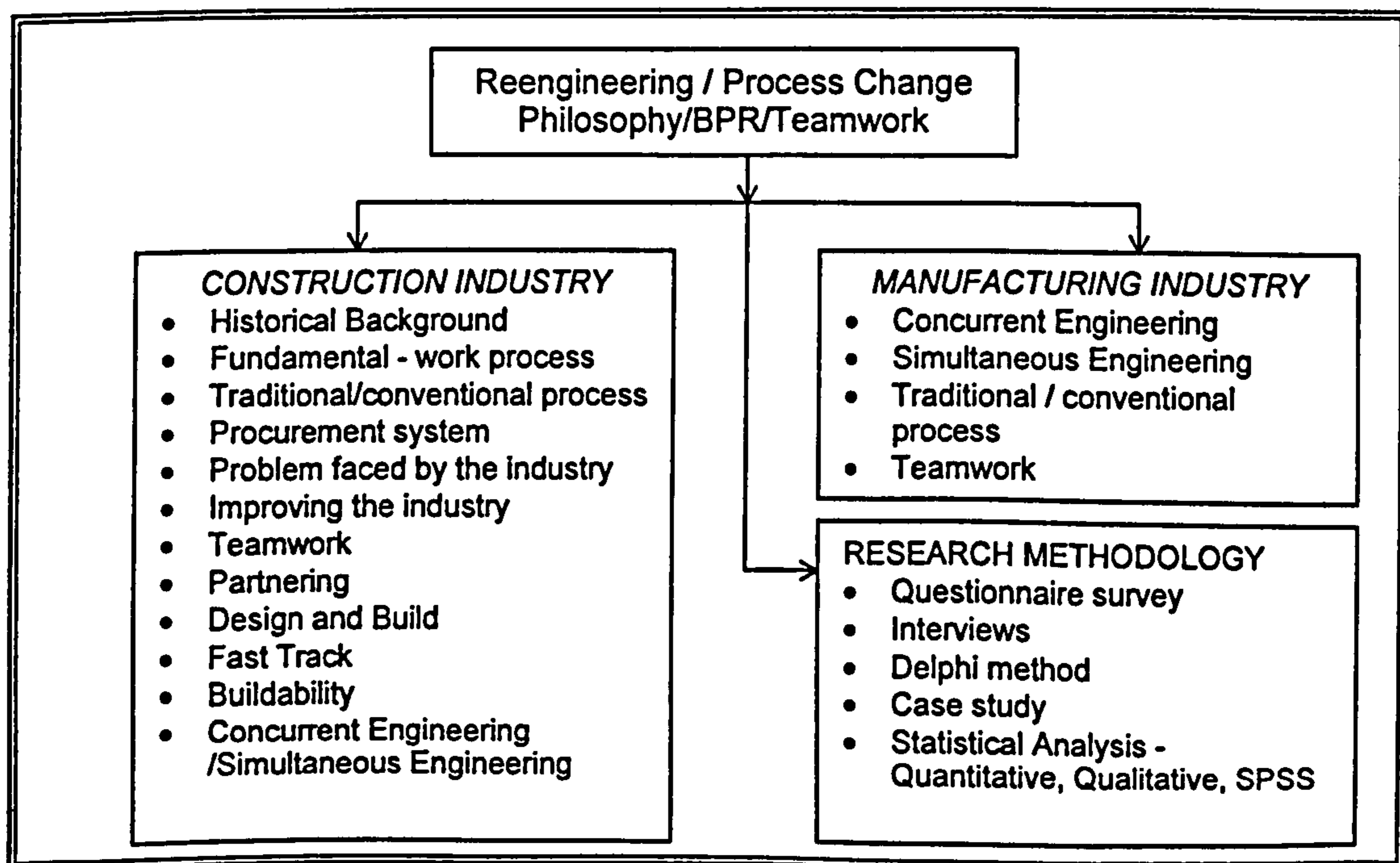
The literature search in this research covers broad spectrum of material from construction and manufacturing industry source. The scope of research relates to both construction and manufacturing industry and it is a relatively new issue in construction.

The specific objectives of literature search were:

- to evaluate the construction industry background with respect to industry; component, structure and work process;
- evaluate the problems faced by the industry and its major cause;
- to evaluate the strategy used by the industry to overcome the problems;
- to establish the theoretical background of CE and its application in manufacturing industry;
- to evaluate the rationale of adoption of CE to construction;

- to establish the perceive factors that may support or inhibit CE implementation to construction;
- to evaluate the propose strategy to implement CE to construction; and
- to evaluate the practise which are parallel to CE concept and construction industry.

The initial stage of the research involved a wide spectrum of topics, which relate to the concept of re-engineering paradigm. This is considered as the basic foundation of the research initiative in reviewing the current practice in the traditional construction process. Then the research focuses specifically on the adoption of the Concurrent Engineering (CE) philosophy as the main strategy to support the process change of the traditional construction process. Since CE is a concept initiated from manufacturing, therefore the material collected for this research was not only covered within the construction industry domain, but also related to the manufacturing industry. CE is a 'foreign' subject to construction, therefore other material which is indirectly related to the research topic needed to be investigated. The main keywords used in the literature survey are shown in Figure 5.1. (The actual keyword searches were more extensive and derived from these major keywords).



**Figure 5.1 Main keyword used in the research**

The sources of the material for the literature came from:

1. Loughborough University Pilkington Library - OPAC, CD-ROM, Index to Theses, etc.
2. Internet Database (BIDS, OCLC First Search)
3. Media articles
4. Internet (World wide web) search
5. Individual organisation brochure and publication

### **5.3.2 Interviews**

#### **5.3.2.1 General guidelines**

The preliminary stage of this research relied upon general observations of the issues relevant to the research to develop a general understanding and to support the findings from the literature. For this purpose (whereby the spectrum of the investigation is still wide open) it was appropriate to obtain qualitative type of data which can be easily generated from a method like face to face interview. According to Hughes (1996) the advantages of interviews among others are: it creates the opportunity for the interviewer to have face to face encounter with informants; the capability to obtain large amount of expansive and contextual data quickly; facilitates access for immediate follow-up data collection for clarification and omissions; and data collection can be made in natural setting. On the other hand, the interview methodology also has some weaknesses associated to it. According to Hughes (1996) amongst the weaknesses of the interview are: data are open to misinterpretation due to cultural difference; difficult to replicate; dependent on honesty of those providing data; and dependent to on the ability of the researchers to be resourceful, systematic and honest to control bias.

Three common major categories of interviews described by Fellows and Liu (1997) are:

1. structured;
2. semi structured; and
3. unstructured.

However Patton (1980) describe the different categories of interview as follows:

1. Informal conversational interview
2. Interview guide approach
3. Standardised open end interview
4. Close quantitative interview

His categorisation of the above approaches based on the principle of 'continuum of formality' as describe by Grebenik and Moser (1962). The two ends of the continuum is the informal conversational interview and the closed quantitative interview. In the informal conversational interview the question normally asked in the natural course and no predetermination of questions, topic and wording. On the other hand the closed quantitative interview use the predetermined the question and response category.

In this research the semi-structured interview method as described in Fellows and Liu (1997) was adopted. In this method, the interview the topic was specified in advance but the wording used and the order of the question varied on each occasion to suit the interviewees' experience and contentment of the issue presented.

### **5.3.2.2 Interview process in the research**

Six different interviews sessions ware undertaken in this initial stage of the research All the respondents were the senior management personnel or project managers of various organisations representing construction enterprise and manufacturing. Each of the interviewee was involved in different type of collaborative teamwork structure in their organisation. The teamwork concept was used as the central issue of discussion with the interviewees from construction industry because the concept is more familiar and can generate more information needed. It is also an important concept that is parallel to CE element. However, in the interviews with members of manufacturing industry, the concept of Cross Functional Team relate to CE principles was used directly as the terminology was well understood.

### **5.3.2.3 Objective of interviews**

The interviews had dual set of objectives. First, the objective of the interviews with the construction industry personnel were:

- to observe the general characteristic of the teamwork approach that are being practised within the construction project; and
- to compare teamwork concept as practised by industry with the concept of cross functional team based on CE approach.

Second, the objective of the interview with the manufacturing organisation that are implementing CE were:

- to study the general approach used to implement CE;
- to observe the motivation factors and problems in the implementation of CE;
- to validate the general principles of CE as found in the literature with the principles understood and practised within the organisation;
- to assess general issues raised from the implementation of CE; and
- to get the opinion from other industry CE practitioner how CE can be implemented to construction.

All of the above issues raised in the interviews are important to this research because they give the basic idea from the practical point of view on the nature of the collaborative teamwork being achieved across organisations and comparison with the CFT concept in CE. By studying the approach in the collaborative teamwork help to develop the idea of their characteristics and relevancy to CE practice. The interviews with the CE practitioners from manufacturing industry set a benchmark to compare the different concept of collaborative teamwork that are being practised within the organisation that are practising CE and not. The result of the interviews was used as guideline to develop the industry wide questionnaire survey in the later stage.

#### **5.3.2.4 Questioning strategy during interview**

In any interview, it is critically important to observe fundamental issue that may influence the whole process to minimise bias in the information provided. Three condition necessary according to Fellows and Liu (1997) are:

- accessibility to the interviewee of the information required;
- cognition - interviewee's understanding of what is required; and
- motivation for the interviewee to answer the question accurately.

Fellows and Liu (1997) also quoted from Atkinson (1967) suggesting three types of question that an interviewer should observe during the interview session categorise as:

- factual;
- knowledge; or
- opinion.

It is important to be aware that opinion is normally a more sensitive category and factual is the least one. Therefore the most important approach in the interview is to simulate the relaxed environment where the interviewee feel the freedom to response and discuss the given topic. The use of the term concurrent engineering was intentionally avoided from being used with the respondent from construction industries because such terminology was considered quite new to this industry. Instead only the important elements of CE were being incorporated within the questions asked.

All the questions given were open-ended type. Prior to the interview session, adequate preparation was made to review the background of the interviewee and this was used to simulate the discussion. The general outlines of the question that needed to be asked were also prepared in advance but not necessarily followed in a strict order. Appendix 1 shows the general guidelines of semi-structured interview questionnaire with construction industry while appendix 2 shows the guidelines of such interview with manufacturing industry. The typical procedure in the interview session is as follows:



### *i. Introduction*

Normally the interview started with brief introduction providing self-identification of the interviewer, and the purpose of the interview, as well as the objective of the study. Then the interviewee was also given the opportunity to describe his position, his organisation background and main area of business. The format of the interview was then agreed with the interviewees.

### *ii. Questioning*

Hughes (1996) used the term 'uneven conversation' to describe this stage because the rule to follow at this stage is the interviewer should spend more time to listen and it is not a session for conversational exchange of view (Howard and Peters 1990). The procedure follows here are:

- Put forward an open ended question (Experience from the exercise shows some interviewee prefer to describe about their experience on the given topic at the beginning then follows by a more detail questioning session for whatever issue left out. Some would prefer to answer the question accordingly from the beginning).
- Care is taken to ensure that the question is well understood and make any necessary clarification as needed.
- Recording the response.
- Request for clarification of the response.
- Repeating the process by presenting the next intended question.

### *iii. Ending the interview*

At the end of the session normally a brief conclusion is made to summarise the whole issue discussed. Then followed by offering the gratitude to the interviewee for the co-operation given.

### **5.3.3 Industry wide postal questionnaire**

#### **5.3.3.1 Respondents and data**

The second stage of data collection of this research was by using postal questionnaire survey. A total of 160 questionnaires were mailed to respondents in UK. 80 questionnaires sent to the contractors and another 80 were sent to the consultants. The source of the names of the contractors is obtained from the New Civil Engineer Contractors' File published in July 1997 (NCE 1997). It is one of the most comprehensive and up to date listing of major Civil Engineering and Building firms in UK, which have a turnover of at least £20 million in the latest financial year. The list of the consultant firms selected to participate in this survey selected from the 'Consultant Engineer 500' (1997). Only the firms with the turnover exceeding than £1 million are selected. Total overall rate of response of the survey is 31.8 percent recorded. The detailed analysis of the questionnaire survey result is presented in chapter six of the thesis. This section focuses on the theoretical aspect of using the questionnaire technique and discussion of its development.

The postal questionnaire survey used in this research aimed to collect the quantitative and qualitative data from the UK construction industry contractors and consultants' organisations on aspects related to collaborative teamwork. The sample of the questionnaire is presented in the appendix 4 of the thesis. Contractors and the consultants are the two most important stakeholders in any construction project. The nature of the data collected in the survey was based on the respondents' experience in the recent projects.

The research recognised the importance of other members of a project team mainly the client, end user, major sub contractors, specialist sub contractors and suppliers. But in the traditionally dominated construction process system of UK construction industry contractors and the consultants are normally take the leading management role of project planning, design and construction. Furthermore the nature of the diversity of the construction clients organisation and the nature of their business which is normally non-related to construction industry make it difficult to establish the right personnel who has a directly experience in the construction project to participate in the survey.

### **5.3.3.2 Objectives**

The main objectives of this questionnaire survey were to establish the following:

- to evaluate industry experience toward collaborative teamwork in the construction project;
- to evaluate the presence of the practice of CE or elements in which are parallel to its philosophy current construction practice by:
  - establish the profile of involvement of the contractor in the project design development process; and
  - evaluating the experience of the respondents toward various attributes related to collaborative teamwork based on CE practice within construction project.
- to assess the ranking of the factors that :
  - support collaborative teamwork;
  - inhibit collaborative teamwork

### **5.3.3.3 General guidelines of questionnaire development**

The postal questionnaire survey is categorised as one of the impersonal survey method (Nachimas and Nachimas 1976). According to them, the main advantage of this system are it is cheaper than personal interview. It also reduces biasing errors that might result from the personal characteristics of interviewers and from variability in their skills. The methodology is useful when questions require quick response. Larger amount of question can be incorporated and respondents have flexible time to response, without any necessary appointment. According to (Nachimas and Nachimas 1976) the disadvantage of the mail questionnaire is that it is difficult to get adequate rate of response (normally about 20-40% only). It can be used only when the questions are simple and straightforward enough to be comprehended with the help of the printed instructions and definitions. The answers in the questionnaire survey have to be accepted, as final. There is no opportunity to probe beyond the given answer, to clarify ambiguous answers. Another disadvantages of questionnaire survey is the researcher cannot be sure that the right person completes the questionnaire; an individual other

than the intended respondent may complete it. According to Moser and Kalton (1971) in the questionnaire survey the respondent can see all the questions before answering any one of them, so the various answers cannot be regarded as independent.

There are many guidelines available for the preparation of the questionnaire. One such guide is that produced by Loughborough University computing services unit (Hunt 1995). Among the key areas given in the guideline are: to define the objective survey; to decide how to collect replies; to run a pilot survey; when writing questions to avoid open ended questions, to keep answers mutually exclusive; to be concise etc. Thomas (1996) also provides additional useful guideline in administration of postal questionnaire. He suggestions include the following points: use instructions and questions which are clearly and unambiguously expressed in simple language; make clear who is asking for information, for what purpose and who will have access to the information; and make clear to each respondent exactly what he is expected to do by way of completing and returning the document.

The postal questionnaire strategy was adopted in this research because this approach matched the purpose of the research need. The use of postal questionnaire method has more flexibility to incorporate such extensive inquiry and allow them to be simplified but yet maintain the level of clarity to the respondents. The typical data collected using questionnaire survey are normally quantitative nature even though the qualitative one can be incorporated as well. The use of quantitative data enables the appropriate statistical technique to be employed in the analysis to support the decision making in the research. It is an effective methodology and suited the budget and time constraint of this research.

The development of the questionnaire involved many stages of reviewing before the final production. It was an iterative process. Three construction industry experts were used to check the initial question included and a series of corrections made toward improving the clarity of wording used the general approach of the presentation. A cover letter explaining the purpose of the survey accompanied every questionnaire sent along with a self addressed return envelope. The respondents were also given the opportunity of receiving the general analysis of the survey by indicating this in the questionnaires survey form.

The questionnaire layout is as follows:

1. Introduction - describes the purpose of the questionnaire, its central theme and the content, and contact address of the researcher.
2. General information - which require the respondents to describe brief background of their organisation, their position and experience. Other identities such as name of the company, address and respondents identity are requested on optional basis.
3. Section A - evaluation on the project background that being referred by the respondents in term of: the type of procurement used; functional role; profile of involvement in project design development phase; and how co-ordination of the project being achieved. Throughout the Section A, the respondents only required to make selection by ticking in the appropriate box. The basic idea of using the 'tick reply' technique was to develop the psychological feeling of easiness to complete the questionnaire in the initial stage without scarifying the quality the data needed for the research. At the end of section A nine short statements related to the respondents experience toward collaborative working in their recent project were given and the respondents were required to indicate their responses on the given Likert scale ranking from one to five.
4. Section B and Section C used the same technique of using the Likert scale for the respondent to response toward the factors that support and inhibit collaborative teamwork.

Principally the basic idea in the development of the questionnaire was to maintain the simplicity and clarity of the question and the required effort to response. However this has been achieved without scarifying the quality of the question and the response.

#### 5.3.3.4 Data analysis

The detail analysis of the questionnaire survey data is presented in chapter six. This section aim to describe in brief the two major statistic used in data analysis apart from the frequency analysis. Those two statistics were the Mann Whitney U Test and Spearman Rank Correlation.

##### 5.3.3.4.1 The Mann-Whitney U Test

The Mann-Whitney U Test is a non-parametric statistic that can be used to test whether two independent groups have been drawn from the same population provided ordinal measurement has been achieved (Siegel 1957, Hamburg 1970). It is in the category of the rank sum tests (Fellows and Liu, 1997).

The basic procedure of conducting the test is by merging the data and ranking them in ascending order. In the event of ties ranking, the average of the ties ranking is used Siegel (1957). The basic comparison of the two samples of the data is achieved by comparing their mean ranking of the data. The U value computed from the following expression is used to determine whether the difference of the mean ranking of the two samples is significant to the specified confidence level:

if U statistic was defined in term of  $R_1$  then :

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

Or alternatively if the U statistic was defined in term of  $R_2$  then one may use the following expression:

$$U = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - R_2$$

Where:

$n_1$  is the number of observation in sample number 1 (the smaller sample of the two)

*n<sub>2</sub> is the number of observation in sample number 2 (the bigger sample of the two)*

*R<sub>1</sub> is the sum of the ranks of the items in sample number 1*

*R<sub>2</sub> is the sum of the ranks of the items in sample number 2*

In this research the statistical package of SPSS for Windows version 7.5 was used to help the computation of the mean rank and U value. The determination of the *Critical U* was made by using the value given in the relevant table (i.e. the table of critical value of U in the Mann-Whitney Test) provided by Siegel (1957). A detail description of the Mann-Whitney U Test is provided in Siegel (1957) and Hamburg (1987).

#### **5.3.3.4.2 Spearman rank correlation coefficient: r<sub>s</sub> (rho)**

The Spearman rank Correlation coefficient test is used to determine the association between the two set of data when only ordinal data are available (Anderson et al., 1990). It is a statistic based on ranks and requires at least an ordinal scale so that the objects or variables under study may be ranked in two ordered series (Siegel 1957).

The basic expression for computing the r<sub>s</sub> value is given by Anderson et al. (1990) and Hamburg (1987) as follows:

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}$$

Where: *n = number of items being ranked*

*d = difference between the ranks for the paired observations*

The actual computation and determination of whether the difference between the two sets of ranking is statistically significant at certain significant level is more complicated. It is described in detailed in Siegel (1957). For this research SPSS for Windows version 7.5 was used to aid the computation.

## 5.3.4 Delphi study

### 5.3.4.1 Introduction

'Delphi' is a name given to the technique that supports group communication. Woundeberg (1991) describes Delphi as the best known qualitative, structured, indirect interaction future method in use today. It is a technique for eliciting the opinion of group of people normally known as panel of experts (Helmer 1983, Dalkey 1969). Donnelly et al. (1992) describe Delphi as:

*"the technique involves the solicitation and comparison of anonymous judgements on the topic of interest through a set of sequential questionnaires that are interspersed with summarised information and feedback and opinions from earlier responses"*.

The Delphi technique was created by Olaf Helmer and Norman Dalkey in 1953 at RAND corporation. Initially the aim for Delphi creation was to address future military issues. However this technique become popular a decade later for technological forecasting and corporate planning (Helmer, 1983). The main aim of Delphi study is to generate a reliable and creative exploration of ideas for decision making. It is argued that decisions made by the group are more reliable than those made by an individual (Johnson and King, 1988). The basic underlying principles of Delphi technique are (Helmer 1983):

- Using structured questioning (normally achieve through questionnaire);
- Iteration process of questioning and feedback through several rounds;
- Controlled feedback on analysis of the results from the previous round (responses) given to the panellists.
- New issues are added as required based on feedback and critique from the panellists; and
- Anonymity of responses throughout the process to ensure freedom to express opinion from wider group.



Armstrong (1989) describes three characteristics of Delphi as: anonymity; statistical analysis; and feedback of reasoning. He states that RAND Corporation found that anonymity was the critical success factor in Delphi technique. If the team of experts is put together naturally there will be some individuals with more experience and more respected for their achievement than others. This will definitely be a problem in generating opinion in the team. The younger and less experienced individuals may be reluctant to challenge the opinion of better known experts.

Delphi is also a suitable technique to replace the normal face to face meeting because it is a method that emphasises privacy of expressing ideas (Rowe et al., 1991). Using Delphi technique help to remove the bias effects on consensus decision from certain individual influence in the group. It is also a cheaper way to gather the expert opinion without having to call everybody for the meeting and without having to worry about their schedule and appointment.

According to Lang (1998) the Delphi procedure consists of the following stage:

1. Subject matter is circulated to the participants to comment the issue
2. The material is then synthesised by co-ordinator and distributed in questionnaire format.
3. Questionnaire redistributes with feedback to participants about the previous round analysis to enable participants to reconsider their opinions.
4. The process is repeated until finally a certain level of consensus or stability is reached.

Ziglio (1996) asserts that the first stage of Delphi is very crucial because if the panellist do not understand the aim of the study they may not be able answer appropriately, become frustrated and lose interest. Statistical tool is often used in Delphi to analyse the data generated from the responses of the panellists.

#### **5.3.4.2 Different types of Delphi technique**

Ever since its invention, the Delphi technique has undergone various processes of modification by its users and led to the formation of various forms of Delphi 'inspired' method. Linstone and Turoff (1975) divide Delphi broadly into two categories: The first one is known as the 'conventional' Delphi and the newer one is known as the Delphi Conference or Real Time Delphi. The difference between the two is the original one uses the manual 'pencil and paper' approach in the process while the later ones use computer programme. However both types use a similar basic iterative process of questioning and feedback to allow the panellists anonymously refine their responses. Another type of Delphi categorisation offered by Van Dijk (1990) and Woudenberg (1991). Their categorisations are: Conventional Delphi; Policy Delphi; and Decision Delphi. Policy Delphi does not aim for consensus rather than developing strongest possible different opposing views on resolution of an issue. Decision Delphi aims to find resolution among the opinion generated by a diverse group of people.

#### **5.3.4.3 The environment that suits the application of the Delphi technique**

Linstone and Turoff (1975) argue that even though Delphi has been labelled as a forecasting procedure it has been applied in many other varieties of purposes such as in: planning process; gathering information; developing causal relationship; exploring different option; and exposing priorities. Some of the examples of the applications are: gathering current and historical data not accurately known and available; exploring urban and planning options; putting together the structure of a model; developing causal relationships in complex economic social and phenomena; and exposing priorities of personal values and social goals.

Linstone and Turoff (1975) also provide a comprehensive list of situations where it would be best to employ the Delphi technique:

1. *If the problem does not lend itself to precise analytical techniques but can benefit from subjective judgements on a collective basis.*

2. *If the individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise.*
3. *If more individuals are needed than can effectively interact in a face-to-face exchange.*
4. *If time and cost make frequent group meetings infeasible.*
5. *If the efficiency of face to face meeting can be increased by a supplemental groups communication process.*
6. *If disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured.*
7. *If the heterogeneity for the participants must be preserved to assure validity of the results i.e. avoidance of domination by quantity or by strength of personality ('bandwagon effect').*

Martino (1976) suggests that Delphi technique is best suited to make forecasts in fields that are poorly structured. He added Delphi also useful technique in fields that are too new to have adequate historical data for the use of other methods. Ziglio (1996) suggests the application of Delphi to solve the problem that does not lend itself to precise analytical techniques but can benefit from subjective judgements on collective basis. Delphi is also considered as a suitable method to solve the problem that has no monitored history nor adequate information on its present and future development; and in addressing problem that requires the exploration and assessment of numerous issues connected with various policies options. Some of the examples of Delphi application can be referred in Adler and Ziglio (1996).

#### **5.3.4.4 Consensus opinion**

The concept of consensus opinion may vary from each Delphi application. In some Delphi applications like Policy Delphi, the use of consensus opinion is not important at all (Lang, 1998). There is no specific rule in the literature that can be used as a standard rule to determine how to reach consensus opinion. This phenomenon is regarded as appropriate situation considering the nature of Delphi application, which suits many different environments and different type of data generated in each situation. The writer

argues that different types of statistical approach may be needed to analyse the different types of data generated in different Delphi applications. Therefore the decision rules to determine the consensus opinion may also vary according to the individual types of data. To support this argument the reference is made to the general guideline of several methods that can be used to determine the consensus level given by Lang (1998):

1. The use of median of response
2. The spread of inter quartile range as degree of consensus
3. Respondents made self-appraisal as to their competence in giving response. The answer from those who grade their competency level as high are used as a median rather than group as a whole

#### **5.3.4.5 Delphi panellists**

The term panellist in Delphi is referred to the group of expert selected to participate in Delphi process. The selection of appropriate person is very critical because this can maximise the quality of the response and the credibility of the result of study to wider audience (Bijl, 1992). There is no specific rule to determine the qualification requirements for the selection of the appropriate person to be a panellist. However the general guidelines in the literature show that the panellist should be a person that have reasonable familiarity and experience with the subject matter of study (Rowe et al. 1991 and Masser and Fooley 1987).

In terms of the number of panellists required for each application Ziglio (1996) states that it should vary according to application. He suggests a size of ten to fifteen person of a homogenous group of expert can yield good results from a Delphi study. In one of the example application of Delphi study reported by Goldsmith (1996) used 121 panellist. In the Delphi study reported by Niero and Robertson (1996), 31 panellists contributed throughout the study. Turoff and Hiltz (1996) stated that the normal size of the group is 30-100 individuals.

### **5.3.5 Application of Delphi technique for the research**

#### **5.3.5.1 Introduction**

The Delphi technique adopted in this research is based on the conventional Delphi approach. However adaptations were made to ensure continuity of involvement and feedback from the panellists over the time period. This required some limitations to be applied. The number of rounds used in the actual Delphi questioning process was kept to the minimum stated in the literature i.e. two round only (Lang, 1998). The number of experts used was thirteen. The initial intention was to continue the study up to three rounds but considering that the level of consensus opinion reach in the analysis of the second round (chapter 7), there was no necessity to continue the study. Furthermore slower rate of return of the response due to time constraints of the panellists signified the research of the potential delay that might incurred if the Delphi round progressed further. It is essential to state that these factors do not violate the basic principles of the Delphi study such as iteration of process of questionings, controlled feedback, and anonymity of responses. It is more appropriate to address the Delphi study used in this research as a Delphi 'inspired' method due to limitation mentioned above. However as a matter of simplicity the term Delphi Study will be used to addressed the Delphi 'inspired' method used in this research. The Delphi study carried out in this research was complemented (supported) by the earlier findings of the industry wide postal questionnaire survey. This is justified here because the entire research effort focus on the same subject matter and draw responses from the same population i.e. respondents within UK construction industry domain. Most of the respondents in the postal questionnaire survey were also those in the category of individual that posses a reasonable skill and knowledge of the construction industry. Therefore the initial stage of exploration of ideas that is commonly done in Delphi study is considered partly achieved within the earlier stage of the questionnaire survey.

#### **5.3.5.2 The rationale for the adoption of the Delphi technique for the research**

Delphi was adopted in this research because of the nature of the study and the appropriateness of this method. The study involved a subject matter that has not yet

been implemented in construction. There are no historical data available to be used to develop a model of collaborative teamwork based on CE principles and to support CE implementation to construction. The issue of implementation of CE to construction is a subjective one. The problem does not lend itself to any precise analytical techniques. Therefore the use of Delphi method based on the subjective judgement of the group of experts was appropriate to address this issue. Furthermore, there are also many other related issues such as the impact on the current procurement systems and the use of appropriate IT tools that need to be included to support the formation of collaborative teamwork to construction. The use of the Delphi panellists with diverse experience and area of expertise in construction industry to evaluate such issues ensured that these topics could be suitably addressed. The Delphi technique was also an efficient and economical method in soliciting the expert opinion and arriving at group consensus on the issues in this study. The method provided an 'anonymity of response'. This is an important principle for this type of research whereby the subject matter is still new. Respondents might be reluctant to lend their opinion any issue, which is new to them, if the discussion is being carried out in open forum. The anonymous environment gave the respondents the freedom to express their opinion independently.

#### **5.3.5.3 The Delphi process**

The Delphi study in this research closely adopted the standard process of conventional previously described. The process was as follows:

##### ***Step 1: Determination the aims and objectives of the Delphi study***

This was the most important step that guided the development of the Delphi questionnaire. The main aim of the Delphi study in this research was generate the consensus opinion of the industry experts to develop the guideline for the formation of the 'cross functional project team' (CFPT) i.e. the collaborative teamwork based on CE principles for construction industry. The formation of the CFPT has been identified in the earlier stage of the research as one of the approach to achieve CE implementation to construction.

The initial stage of data inquiry had also identified the issues relevant to the collaborative in construction. These issues included: the current state of art of the collaborative teamwork experience within construction project; the factors that can support and inhibit its implementation in construction; and the characteristics of Cross Functional Team (CFT) based on CE principles as practised in other industry.

In the Delphi study, the main objectives were :

1. To evaluate the basic component and characteristic of Cross Functional Project Team (CFPT).
2. To assess supportive tool and mechanism to achieve the formation of CFPT.
3. To evaluate the implication of such formation to current construction industry environment.

The detail description of these objectives is presented in appendix 5 of the thesis.

### ***Step 2: Selection of the panellists***

There were thirteen panellists represent various groups of expertise used in this Delphi study. These were chosen from a range of, professions, backgrounds and expertise.

These categories included:

- Architect
- Planner
- Design Engineer
- Contractor
- Academic (Construction Management and IT specialist)
- Specialist contractor/ Supplier
- Senior Project manager
- Quantity Surveyor
- Consultant

Panellists were initially approached to get their agreement to participate in the process. This was an important step to ensure that they will have the commitment to participate

throughout the Delphi process. The participation of each the panellist was purely on voluntary basis.

### ***Step 3: Development of Delphi questionnaire***

The design of the questionnaire in this Delphi study took into account the research into the preparation of and the findings from the earlier stage of data inquiry using postal questionnaire survey. The subject matter in the Delphi survey document was more focused and aimed at experts. The focus in the postal questionnaire survey was more general and of exploratory nature. The findings from the earlier stage postal questionnaire indicated the current state of art of the collaborative working experience in UK construction industry and also the establishment of the ranking of the factors that support and inhibit teamwork. These findings were used as a basis to develop the Delphi study questionnaire.

This study involved two round of the survey. The main structure of the questionnaire consist of:

- Cover letter
- Brief introduction of the study which described the basic principles of Concurrent Engineering (CE) and the basic concept of cross functional teamwork based on CE philosophy
- A description of the Delphi technique and the adopted process in this study
- An assurance of confidentiality
- Instructions for the panellist how to complete the questionnaire
- For the Second Round Delphi (SRD), document of the analysis of the First Round Delphi (FRD) results was included for the panellist to review

Every questionnaire that was sent to a panellist was coded to enable the co-ordinator to identify the respondent. For the Second Round Delphi (SRD) each questionnaire sent was developed individually for each panellist because it had to include the panellist previous vote beside the analysis of the results from the previous 'voting' process. (The



term vote is commonly used in the Delphi process to denote the panellist choice of response in the questionnaire. The result of the analysis from the previous voting process is a common result for all panellists. Adequate instruction was given at each section of the question in the questionnaire. The example of the FRD and SRD is exhibit in the appendix 6 and 7 of this thesis. The detail analysis of the FRD and SRD surveys is discussed in chapter seven.

The main consideration in designing Delphi questionnaire was to facilitate the process of analysing the responses later. It is also critically important to ensure the clarity of the questionnaire and simplicity to response to ensure the effectiveness of the responses and maintaining the panellist interest in the Delphi process. Prior to the final adoption of the Delphi questionnaire, it was reviewed with two construction industry experts. Their critiques and comments were reviewed and where appropriate the questionnaire amended prior to final release.

The nature of the inquiry in this Delphi study was more comprehensive and detailed compared to the postal questionnaire survey. In FRD panellist were expected to give at least fifty seven responses. This did not include the additional responses for the close-ended questions. The categorisation of the type of questions in FRD were:

- Closed ended type
  - agreement/disagreement or rating on given Likert scale - 51 questions.
  - Multiple choice (ticking the box) - 6 questions
- Open ended - 3 questions

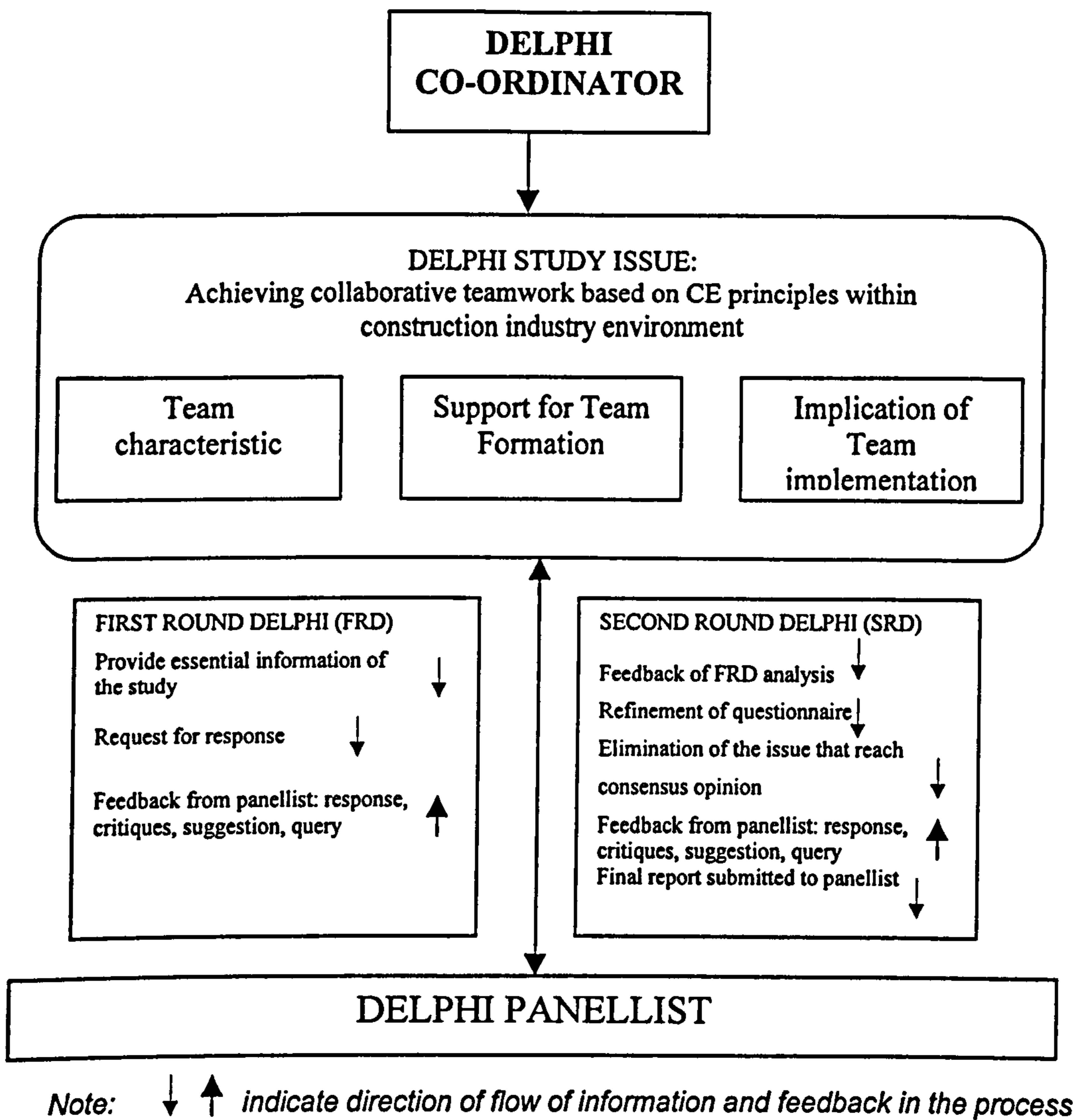
#### ***Step 4 : Analysis of the responses, feedback and development of SRD***

Upon the completion of the FRD process, the responses were analysed using the appropriate statistical method. In the SRD survey necessary adjustment were made to the questionnaire by: amending the existing questions where necessary; addition of the new questions; and deletion of the questions on issues that already reach the 'consensus' level.

The main objective in analysing the Delphi survey was to determine whether each issue presented had reached a consensus of opinion. If a particular issue had reached the consensus level, it will not be pursued again in the SRD. However this concept did not apply to every issue presented, especially for the open-ended questions. For this type of question a content analysis technique was used. In most cases simple descriptive statistical method using frequency analysis was employed. A consensus level of 75 percent was adopted in this Delphi study. As indicated earlier (section 5.3.4.4), there is no clear guideline to be adopted of how to determine the consensus level in a Delphi study. The use of 75 percent limit as consensus gave the co-ordinator the ground to screen which issue need to be pursue further in SRD and which one should be abandon because they have already reach the consensus.

All panellists were given the opportunity to express their comment, disagreement and suggestions to every issue presented in the questionnaire. The contact number of the co-ordinator was also given for the panellist to contact if any further explanation required. Face to face interview with one the panellist member was also conducted after FRD to review his general opinion on the FRD Delphi questionnaire. Appendix 8 and 9 exhibit the analysis of the Delphi study results which were provided to every panellist after each round of the Delphi studies. Appendix 10 shows the executive summary of Delphi study submitted to the panellist.

Figure 5.2 summarises the FRD and SRD process:



**Figure 5.2 Delphi (inspired) process used in this research**

#### **5.3.5.4 Major output from Delphi study**

The rate of response from the FRD survey was one hundred percent. The SRD recorded an 84.6 percent response. The detail analysis of the Delphi survey is presented in chapter seven. The main output from the Delphi study was used as a basis to develop the guidelines to form CFPT in construction industry. The detail discussion of this guideline is made in chapter seven.

### **5.3.6 Case Study**

The final parts of the data collection in this research use the case study methodology. Using case study is a common methodology employed by the researcher in construction management area. Examples of the use of case study as part of the research methodology are Nesan (1997) and Jergeas (1989). According to Fellows and Liu (1997) the importance of case study is that it helps to carry out the in-depth investigation of particular instances within the research subject.

The case study employed in this research aim to validate the guidelines to implement CE developed from the Delphi studies. The case studies also being used to test the application of Matrix Measurement Tool-Toward CE in Construction (MMG-TCEiC). MMG-TCEiC is a tool developed in this research to map the process toward achieving CE environment. Detail discussion of MMG-TCEiC development is made in chapter eight. To achieve this aim the case study was conducted on four major projects that were known practising the concept of collaborative teamwork that were close to CE principles. In all case studies, in-depth interviews on all aspect of their practice in collaborative teamwork being conducted. The interview normally take several hours and involved one or more senior management personnel who were directly involved in the teamwork. Apart from the interviews, various material supplied by the organisation were taken back for further review. All the case study was conducted at site and follow-up was made where necessary using telephone. The detail discussion of the case study output is made in chapter eight. Appendix 4 shows the general guideline for the 'key issues to be raised' in the case study to guide the investigation.

## **5.4 Summary**

This chapter has described the theoretical background of methodology used for data collection in this research together with the rational for their adoption. The methodologies used were:

- Literature review

- Interview
- Industry wide postal questionnaire survey
- Delphi (inspired) Method
- Case study

Each methodology was used to suit the requirements of each stage of the research. The earlier stages of the research required a general scoping study of the research topic and the literature review and interviews with construction and manufacturing industry personal achieved the objectives of exploring the subject in greater detail. They also helped the research to identify the specific issues that need to be investigated further. One such issue was the focus on collaborative teamwork concept based on CE principles. The later stage of the methodology applied emphasis on the validation of the detail aspect of the research scope and thus the use of the Delphi methodology served this purpose.

The findings from each part of the research were used to contribute to the development of the next stage of the study and to confirm the findings by a 'triangulation' approach that ensured each issue was fully explored and confirmed. The detail analysis of the data generated from the methodologies adopted is discussed in the chapters six to eight where the main findings of the research are identified.

## **CHAPTER SIX**

### **DATA ANALYSIS - INTERVIEWS AND QUESTIONNAIRE SURVEY**

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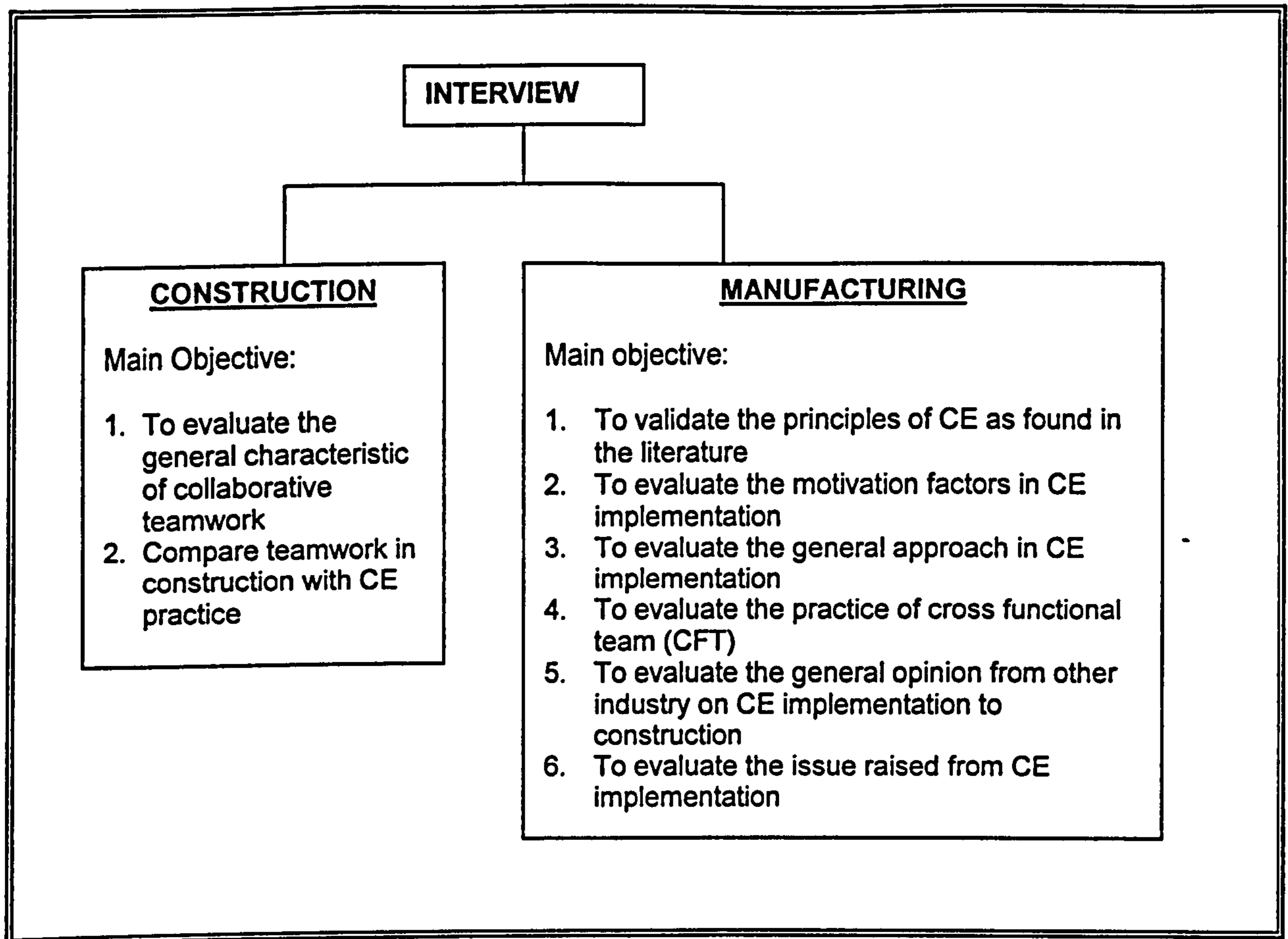
#### **6.1 Introduction**

This chapter analyses in detail data from industry face to face interviews and the industry wide postal questionnaire survey. Qualitative data gathered in the interviews reinforced the findings from the literature search and developed better understanding of the research topic. Face to face interviews were conducted with personnel from both the construction and manufacturing industries. 'Qualitative content analysis' method (Fellows and Liu 1997) was used to analyse the responses from these interviews.

The findings from the interviews were used to support the development of the industry wide postal questionnaire survey. This survey focused on aspects of collaborative teamwork environments. Various aspects related to a collaborative teamwork environment based on Concurrent Engineering (CE) principles were incorporated in the questionnaire and tested within the construction industry's respondents. Various statistical methods including frequency analysis, Spearman Rank Correlation Coefficient, and Mann-Whitney U Test were used in the analyses, and the major findings discussed in detail.

#### **6.2 Face to face interview**

The theoretical background of the interview method and the main objectives of using it in this research have been explained in chapters one and five. This chapter reports the analysis of the findings. Content analysis approach was used to analyse the responses from each interviewee. A summary of the objectives is presented here again for review in figure 6.1.



**Figure 6.1 Summary of the objectives of face to face interviews**

### **6.3 Interviews with construction industry personnel**

There were four separate face to face interviews with personnel within construction industry conducted in the research. All of the interviewees were experienced practitioners in construction industry. Two of them were senior project managers, one a project manager and a planner. The interviews used a semi-structured approach. (Detail of the methodology is explained in chapter five). All the interviews were carried out at different times and places. The set of questions to be asked were prepared as a guideline prior to the interview session which normally lasted around one hour. Appendix 1 and appendix 2 shows the sample of guidelines of the questionnaires used in the semi-structured interviews with the personnel from construction and manufacturing industries. However during the actual session, a different sequence of presenting the questions was used to allow more flexibility in the discussion. In general the questions presented in the interviews fell into these common themes:

- Theme I: Concept of teamwork as understood and experienced by interviewees**
- Theme II: Description of teamwork experience by the interviewees**
- Theme III: The benefits and the problems of teamwork**
- Theme IV: How information sharing may be managed in teamwork**

Each of the above themes is briefly discussed here to describe their importance and relationship to the research interest. The responses from the interviews then follow.

### **6.3.1 Theme I: Concept of teamwork as understood by interviewees**

The main objective of the questions presented within this theme was to explore interviewees' opinion on the concept of teamwork based on their observation and personal experience in construction industry projects. The responses of the interviewees are summarised below:

1. Teamwork is a buzzword being adopted by construction industry without really understanding its real meaning or rules associated to it.
2. Teamwork is suitable for big projects and requires serious consideration before applying it.
3. Teamwork is efficient but not always effective.
4. In construction a 'natural team' always forms at site level.
5. Before the concept of teamwork is applied it needs some consideration of several factors like level of construction activities and understanding of client requirements.
6. The client should take the leadership role in teamwork.
7. The teamwork concept can be successful if the team is physically co-located.
8. The best person to lead the team is the best person! The person should be known to others.
9. The partnering concept is not a viable approach to achieve teamwork because it has a weak link in chain.
10. Teamwork may be defined as an approach of bringing the client and the contractor together from the early stage of the project. Partnering is one of the ways to achieve it.



The interviews clearly identify that there is a lack of common definition of the concept of teamwork in construction industry today. It is being practiced by the industry without actually knowing what the 'rules' associated to it. Clearly there is a need for a consistent definition for teamwork to avoid misunderstandings.

### **6.3.2 Theme 2: Description of teamwork experience by the interviewees**

These questions involved the description of the teamwork features as experienced by the interviewees. The context of the discussion involved the description of the teamwork characteristic with respect to the team leadership, membership, team roles and organisational structure. The responses provide the research with the insight of the industry's current experience in teamwork. These experiences are observed for their affinity with CE teamwork concept. A detailed response was given for each interviewee.

#### **6.3.2.1 Interviewee #1:**

Teamwork builds around the Design and Build (D&B) system. However the respondent stated that D&B, despite being claimed to promote teamwork, was in reality not always adequately beneficial to the project owner and cannot consider being a general solution to promote teamwork concept in construction.

#### **6.3.2.2 Interviewee #2**

The concept of teamwork practised sought to deliver the project by using clustering system. Examples of the clustering units were: architecture group; structure design group; and M&E group. These individual functional units were 'clustering' around the 'core team' and were collectively identified as the project teamwork. The main features of the teamwork in this system were:

1. Each cluster unit representing the functional team within the project had their own leader which reported direct to project manager.
2. Each cluster surrounding the 'core team' was represented by key project members formed the basis of the teamwork.
3. Core team members were responsible for the co-ordination and commercial aspects of the project.
4. The project team was brought together from the start of the project and started off with the brainstorming session.
5. The project manager had the responsibilities to co-ordinate the project team to meet the project requirements.
6. The relation with the external entities such as suppliers and the client organisation was realised through the 'extended teamwork' concept. (The project was not in favour of partnering concept).

### **6.3.2.3 Interviewee #3**

The project teamwork concept described was developed within the scope of main contractor control capacity and exhibited the following features:

1. All the expertise located in the team starting from the design development phase on day 1 of the 2 years project period with some autonomy to make business decision.
2. The team also involved their subcontractors.
3. The teamwork practised was motivated by the need to do the job in a more efficient way and flexible environment practice within the contractor's firm.
4. The team was co-located. The physical layout to promote team interaction and communication support was critical as well as adopting the flexible structure.
5. No special training was given to the team members.
6. The teamwork environment created encouraged the members to display their expertise and challenge the way the work was undertaken.

#### **6.3.2.4 Interviewee #4**

The teamwork concept has been developed based on the implementation of the partnering approach and using design and build procurement for the project. The main characteristics of the teamwork were:

1. The team consists of the: clients; main contractors (which was the design-build contractors); all sub-contractors; trade specialist; and suppliers.
2. The client led the team.
3. Co-ordination was achieved through a 'core team committee' comprising key project representatives and clients
4. A decision had been made to use a flatter organisation structure to support open communication.
5. Some degree of the concurrency of the performance of the project task has been achieved within this teamwork approach due to the involvement of the building contractors during the design stage of the project.

The interviewee claimed that the teamwork approach was adopted because of the 'right price' of the project. The teamwork was achieved through Design and Build with Management procurement and supported by partnering approach.

#### **6.3.3 Theme III: The benefits and the problems of teamwork**

The benefits and problems related to teamwork based on the interviewees' experience helped to guide the research with aspect to the opportunities and inhibitors in the adoption of the concept of collaborative teamwork in construction.

##### **6.3.3.1 The benefits of teamwork**

The benefits of the teamwork as claimed by the interviewees based on their experienced were:

1. Improved communication and project team spirit.

2. Improved overlapping of the work.
3. Improved project time.
4. Satisfaction of project's client due to the enhanced communication and attention given by the project team to their project need.
5. The specialist trade sub-contractors were able to contribute to the design team.
6. Teamwork assisted the client to make the decisions.
7. Enabled the overall budget to be put together.
8. Develop opportunities to test the overall plan.
9. Provided an opportunity to get job right the first time as contractor involved early.

### **6.3.3.2 Problems in teamwork experience**

The interviewees' claimed that the problems that they had experienced in teamwork were mainly related to the human factors. They also indicated that the traditional mentality of trying to protect 'individual group' interest within the project team as another major problems that they had experienced.

### **6.3.4 Theme #4: How is information sharing being managed in the teamwork**

The openness in information sharing among team members is an important feature in CE environment. This question enabled the researcher to assess how information sharing was achieved within the project team in construction industry. The responses were:

1. A limited use of IT tools was reported from the teamwork experience by interviewee #2 to support team communication. These included using email and shared project databases.
2. Interviewee #3 also indicated that a limited IT tools used to support the team communication. The project benefited from the ISDN link connected at the site which enabled them to share common design information through electronic medium.

3. Interviewee #4 claimed that only a basic IT tools being used to support communication for the project such as telephone and fax. The application of the computer based communication tools was limited due to the interest and the knowledge of the team members. Essential project information was disseminated by the regular circulation of project report at site and head office

## **6.4 Interviews with manufacturing industry**

### **6.4.1 Introduction**

The research identified two major manufacturing organisations in UK for interviews. Both of the organisations were known to have already implemented CE in their new product development process. All the personnel interviewed were at the level of senior manager or director. All interviewees were familiar with the principles of CE and were directly responsible for new product development programmes within their organisations. In one of the sessions, the interview was conducted with three senior personnel at the same time. The objectives of these interviews carried out with the personnel from manufacturing industry were different from the construction interviews. The objectives were:

1. To evaluate the motivation of CE implementation
2. To evaluate the general approach used to implement CE
3. To evaluate the implementation of the cross functional team (CFT) concept
4. To observe the motivation factors and problems in implementation of CE
5. To validate the principles of CE as found in the literature with the principles understood and practised within the organisation
6. To assess general issues raised from CE implementation
7. To get opinion from other industry practitioner of the potential of applying CE to construction

The interviews involved two different organisations from two different sectors in manufacturing (identified as organisation #1 and organisation #2 here). The nature of

the products of these two organisations were also different, i.e. military aircraft and automobile. The findings from the interviews are therefore presented individually.

## **6.4.2 Findings of interviews with Organisation #1**

### **6.4.2.1 Motivation for CE implementation**

The main motivational factor for organisation #1 to adopt CE was driven by the need to produce more effective product and to excel in the market. In the past the organisation used the traditional approach in their product design development and had difficulties to take advantage from technical elegant solution by individual functional team to make more profit. Therefore CE was being implemented by the organisation with the following objectives:

1. To reduce lead time in product development.
2. To integrate the project team.
3. To focus on the customer requirement.
4. To achieve product balance and optimum solution.
5. To achieve the 'fit the purpose' quality.
6. To optimise the 'overall production' not only the individual component.

### **6.4.2.2 General approach used to implement CE**

The main strategy used by the organisation #1 to implement CE was by the formation of the 'cross functional team'. The application of CE was initially launched within the new product development only.

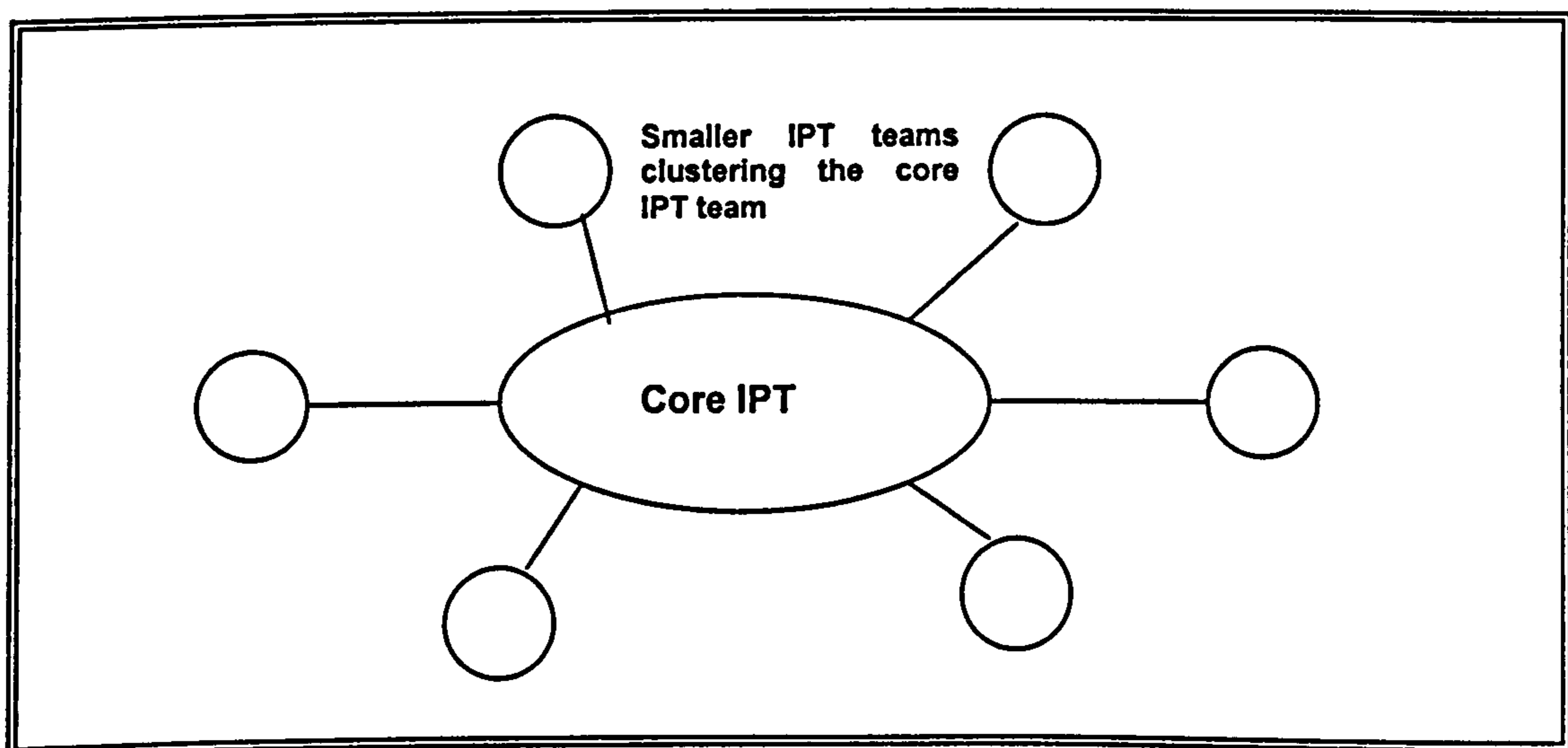
The main features of the team formed were:

### Team identity

The cross functional team formed within the organisation #1 was better known as Integrated Product Development (IPT) team. (Other specific team also formed in the process but due to confidentiality nature of the information as requested by the interviewees, it will not be reported here).

### Team Structure

For a new project mission a core team including expertise from various functions across project development life cycle is being formed. The members of the core team are permanent. Surrounding the core team are smaller IPT teams. The interviewees indicate that these teams are similar to the concept of cross-functional teams. The conceptual model showing how the smaller IPT teams clustering around the core team is shown in figure 6.2.



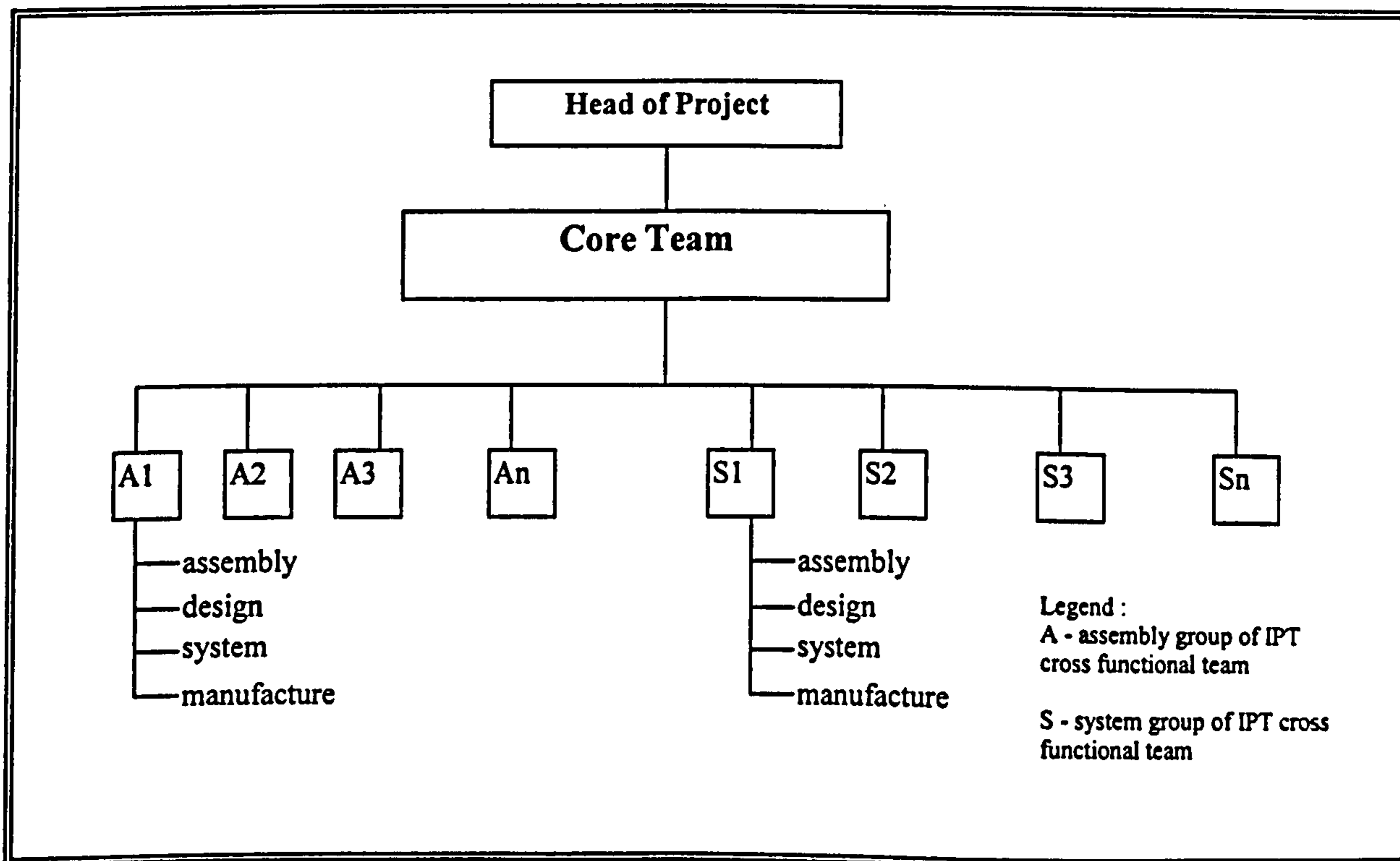
**Figure 6.2 - Integrated Project Team (IPT) concept used by organisation #1**

The members of the core team are experts from the various functional groups at various phases of project life cycle. Smaller IPT teams are structured to represent each specific function of the project (figure 6.3). The number of cross functional representatives in each IPT team varies depending on the actual needs of the different functions and the project phase. The core team members, which consist of the senior personnel will co-

ordinate all the smaller IPT team (cross functional team) that cluster around the core team throughout the life cycle of the project.

*IPT team breakdown structure*

The criteria for the formation of the IPT teams is based on two major features i.e. the anatomy of the product to be developed i.e. the military aircraft and the product development cycle. The aircraft product breakdown comprised two major elements; the assembly breakdown (the aircraft structural element) and the systems breakdown (e.g. fuel system, communication system, electrical system, etc.). The product development life cycle comprised of design and manufacturing phase. Therefore in each IPT team will consist of the participants from these various functions; Assembly, System; Design; Manufacturing. The conceptual model of the IPT organisation is shown in figure 6.3



**Figure 6.3 IPT organisational structure at organisation #1**



### Teamwork (cross functional team) characteristics

The main features of IPT (cross functional team) formed by the organisation #1 were characterised by the balanced representation of the members from the functional groups in making the decision in product design development. The team used consensus approach in making the decision. The team was formed at outset, co-located in a common place and shared common project goals. Despite having many smaller IPT groups, but adequate measure has been taken to ensure that these groups were able to share project information across the functional boundaries.

### Participation of the suppliers and client

At the time of the interview, the direct participation of the supplier in IPT team had not been fully implemented. However the organisation seriously engaged in partnership program with their key suppliers.

### Authority of the team

The interviewees indicated that the team was given sufficient authority to make decisions for their product. The organisation had developed a system known as “maturity/risk gates” to aid in decision making. The interviewees expressed their confidence that the quality of the decisions were better when made with the team.

#### **6.4.2.3 General issues raised from CE implementation**

The interviewees also mentioned problems related to the hierarchical culture mentality whereby people are very careful of the given authority to make decision. They quoted examples of such question as “What can I do?” or “What information do I need?” as still being dominant in some of the team members thinking. Other related problems quoted were the role of ‘decision broker’ in the team. The team leader had to be given the authority to facilitate the decision-making and co-ordinate the team members.

#### **6.4.2.4 The use of IT to support team communication**

IT was considered as a very important feature to support the teamwork. The team relied on the used of the digital representation of the product model accessible by team members. 'Remote site real time access system' to product information was used to support the team communication. The organisation was at the time of this research developing a communication tool to enable more efficient communication within the team.

#### **6.4.2.5 Validation the principles of CE as found in the literature with the principles understood and practised within the organisation**

A set of principles of CE generated from literature was presented to the interviewees with some explanation. Then they were asked whether they agree or not that those principles represented the concurrent engineering concept as understood and implemented by their organisation. The major principles presented are: increased consideration of manufacturing process in production design; formation of cross functional team; focus on customer during product development process; and use of lead time as source of competitive advantage.

The interviewees expressed their agreement on all the four principles and other similar related principles by quoting the word "absolutely, without any doubt". In addition they added that the aspect of achieving the highest quality through total product concept and realistic goal to achieve superb product is also major feature of CE principles as implemented by their organisation. They commented that, with respect to implementing CE in construction there is not much difference between construction process to manufacturing and obviously CE is a viable concept for construction.

### **6.4.3 Findings of interviews with organisation #2**

#### **6.4.3.1 Motivation for CE implementation**

The motivational factors that drive the organisation to implement CE developed from the need to realign the traditional work process. This desire was an influence from the research work by MIT team on production philosophies of car manufacturers in Japan as described in by Wormack et al. (1990). The organisation was also motivated by the need to meet stiff competition from Japanese car manufacturers.

#### **6.4.3.2 General approach to implement CE**

Organisation #2 represents a leading company in car manufacturing industry. Car manufacturers were recognised as the pioneer in the implementation of CE in western world. Organisation #2 also used teamwork as the main strategy to implement CE. According to the interviewee, the design and manufacturing of the product was previously organised by dividing the expertise into various functional groups of that represent each component of the product. The design and manufacturing was based on 'over the wall' concept. With the implementation of CE principles these functional group (the core group of the component) had been broken down and members are distributed to the various groups that represent each different complete build unit of the product.

#### **Teamwork (cross functional team) characteristics**

The team component consists of all expertise represent from various functional groups working together in a single dedicated team for a single product line. There were many different cross functional teams existed within the organisations. Each 'complete' team is dedicated to a specific product (i.e. model of the car) and assigned with the 'ownership' of responsibility for their input to the product. Team members are being co-located throughout the life cycle of the product and report to the same management.

The teams were given the flexibility to develop their product based on the input from the various functional group representatives. To maintain excellence in research and development for each component, a certain number of expertise was retained in each functional group but not for the product development purposes.

#### **6.4.3.3 General issue raised from CE implementation**

The respondent reviewed his experienced in the implementation CE as a transition from the traditional process within his organisation especially on the reformation of the teamwork concept. One of the main issues raised from the implementation of CE was related to the loyalty of members to the team and the functional groups that they represent. Other major challenge faced in implementing CE was in the process of deploying everybody out of the functional group while recognising the need to develop the superiority in the technological competencies of the individual functional component in manufacturing. There was logistic problems due to the need to build the 'duplicating' team centre for each team. This is because each of the team developed the same kind of product even though of different models.

The claimed benefit from the implementation of CE by the organisation were: able to integrate the design and manufacturing effort; able to reduce the overall product development life cycle by compressing the schedule; and the ability to execute the task concurrently wherever permitted. The implementation of CE also results in the improvement of the quality of the product.

#### **6.4.3.4 Use of IT and other tool to support team**

The used of IT was considered very important to support the teamwork communication. The interviewee described some aspects of the GroupWare system used to support communication system not only for the team but also the entire organisation. The organisation relies heavily on CAD, CAM and 3D modelling tools to support team information sharing process. It was also recorded during the interview that the

organisation has engaged the application of various other tools to support the implementation of CE like quality function deployment technique.

#### **6.4.3.5 Validation of CE principles**

As in the previous interview, the set of principles of CE generated from literature was presented to the interviewee. The interviewee was asked whether or not he agreed that those principles represented the concurrent engineering concept as understood and implemented within his organisation. The interviewee expressed his agreement on all the four principles presented (i.e. the same principles presented to the organisation #1) that they represented CE principles as understood and practised by them.

#### **6.4.3.6 Opinion of CE application to construction**

The respondent strongly indicated that there is no reason why CE cannot be applied to construction. The respondent quoted that automobile and aerospace industry are probably the most complex industries but yet still able to depart from past traditional practice in manufacturing philosophy to CE. Thus there is every opportunity for construction to learn from their experience.

### **6.5 Summary from the interviews**

#### ***Construction industry organisations***

There are several different approaches that have been practised within construction industry to realise the concept of collaborative teamwork within the construction project today. The analysis of the experiences of the respondents indicates that some aspects of collaborative teamwork environment may be achieved within construction project today through the various platforms such as:

1. Using design and build procurement approach
2. Using partnering approach
3. Combination of both D&B and partnering approach
4. The initiative main contractor to create the collaborative teamwork environment
5. The initiative of the client to create the collaborative teamwork environment

However it cannot be verified from the interviews the actual limit of the achievement in teamwork so that they can be used as a basis for comparison with each other. The interviews also identified the argument that there is a lack of common definition of the concept of teamwork in construction industry. It is being practised by the industry without actually knowing what the 'rules' associated with it.

These findings support the earlier suggestion on the implementation of collaborative teamwork concept based on CE principles to construction industry. This is because collaborative teamwork based on CE are guided by a common principles. These findings also suggest to the research the need for further investigation to evaluate the advantages and the limitations that exist within the design and build and partnering approach to procurement. Another important issue developed from the evaluation of the interviews is the need to develop a measurement tool as a guideline to determine the limit of achievement in collaborative teamwork based on certain guided principles such as CE.

The second category of the findings from the interviews relates to the general characteristics of the teamwork as practised on the projects. From these projects it was established that:

- The client was favoured to assume the role of teamwork leadership
- Partnering approach is both favoured and criticised for its role in support teamwork within construction
- Collocation of the team in a common place is considered important to support teamwork in construction
- The analysis shown that there was a limited use of IT tools to support team communication in construction project reviewed

- Some of the important features of teamwork environment in construction industry exhibited from the analysis are:
  - Clustering the smaller functional group unit around the core team
  - Bringing the team members early into the project
  - Collocation of the team members
  - Inclusion of the sub-contractors and suppliers into the team
  - Involvement of the contractors in the design process (reported in D&B experience)

The above findings provided the research with the insights of on the common features of teamworking that are practical and can be implemented within construction industry environment.

Some of the main benefits from the current teamwork experience by the respondents were:

- Improve of the communication and project team spirit.
- Improved project time.
- Improve clients' satisfaction.
- Inclusion of sub-contractors and suppliers in the team facilitates early decision making.
- Facilitate involvement of the contractors in the design process.

These findings gave a strong indication that construction industry is also inclined toward achieving the same benefits in teamwork as those being achieved within other industry that implement CE principles. It also gave indication that some elements that are parallel to CE might have already been practised within construction industry environment. Therefore it is very important for the research to identify the presence of CE practice within construction industry further. This was investigated further in the questionnaire survey.

### ***Manufacturing industry interviews***

The analysis of the responses from the manufacturing industry revealed the practical approach of CE implementation within their organisation. Some of the important features revealed are:

- The rationale for CE adoption given in the interview are similar with those commonly found in the literature such as:
  - The need to improve product development time
  - To meet the challenge from tougher market competition
  - To improve product quality
  - To meet customer requirement
- To realise CE implementation two important features have been observed, first use of the teamwork as a main strategy and second abandonment of the traditional 'over the wall engineering' practice.
- The common features of teamwork identified from the interview are:
  - Form at outset
  - Sharing information among functional across functional boundaries
  - Comprises of representative from various functional group expertise
  - Team are collocated
  - Team report to the same management
  - Team members make contribution to design development process
  - Team members have 'ownership' over the product
  - Team given the flexibility to make design decision
- IT has been extensively used to support the team information sharing. This is considered critical for both case interviews considering the high level of technological nature of the product manufactured by both organisations.
- Both organisations interviewed also confirmed the benefits gained from CE implementation to include:
  - Reduction of the overall product development time



- More elegant solution achieved for the product design
  - Cost efficiency
  - Promote teamwork spirit
  - Provide better satisfaction to the customer (client)
- The basic elements of CE as determined from the literature has been confirm in both interviews to represent the CE principles as understood and practised by them.
  - With respect to the potential of implementing CE to construction all the personnel interviewed agreed that it is a viable concept to be implement to construction.

### ***Directions for the next stage of the research***

The conclusions derived from the analysis of the interviews and the contribution of the to the direction of work for the next stage of this research were:

1. Construction industry is already moving toward encapsulating the concept of collaborative teamwork
2. The main platforms currently used to achieve collaborative teamwork within construction are D&B and partnering, even though there was also initiative by individual project using traditional platform to embrace the concept of collaborative teamwork
3. Even though it can be generally felt that some elements of CE have been implemented within current construction projects, further investigation is required to determine whether they really represent actual CE implementation as a whole process, as in other industries.
4. The major drawback of the collaborative teamwork environment observed in the interviews from the current practice in the construction industry compared to CE environment is :

- The implementation of teamwork environment in construction is made without referring to any guided principles like in CE environment
- Generally the collaborative teamwork in construction aims to co-ordinate the work rather than to get all the participants to contribute toward design solution
- Only 'preferred' team members involved in any partnering concession
- Client requirements are not necessarily addressed within current teamwork environment especially within D&B procurement approach

5. The findings from the interviews helped the research to progress further in the following ways:

- Guide the research to focus on the D&B and partnering approach in the analysis of the questionnaire to verify further the presence of CE elements in both practices.
- The evaluation of the characteristic of teamwork based on CE practices in manufacturing industries (which also conform to those found in the literature search) led the research to use them as a basis of developing CE teamwork environment in construction in the Delphi study. They were also used as a benchmark to measure the attainment of CE environment in MMG-TCEiC. In the questionnaire survey they were used as a guide to determine the presence of CE practice in the analysis.

## **6.6 The industry wide postal questionnaire survey**

### **6.6.1 Introduction**

This section reports the analysis of the data gathered from the industry wide postal questionnaire survey. The questionnaire was designed to evaluate further the presence of CE practice within the construction industry and to identify the factors that support and inhibit collaborative teamwork. The initial approach used was to evaluate the profile of the respondents' involvement in the project design development phase.

Further assessment was made on the respondents' experience in the collaborative teamwork environment of the construction project. The focus was on the factors considered consistent with the CE practice. These factors have been determined from the literature search and the interviews with CE practitioners in manufacturing industry.

The questionnaire survey ranks the factors that support and inhibit teamwork. These important factors further support the research work. The findings of the analysis from this chapter were used to develop the Delphi questionnaire survey in the next stage of the research. Appropriate statistical tools using frequency analysis method, Mann Whitney U Test and Spearman Correlation Test were used to analyse the data. The SPSS version 7.5 for Windows statistical package was used to aid the computation.

It is very important to note that the term 'Concurrent Engineering' (CE) was not used in any part of the questionnaire. This strategy was taken because the term 'CE' is rarely known in construction industry. The experience of the researcher during the industry interviews showed that the interviewees from the construction industry were not familiar with the term 'CE' and its introduction although generating curiosity, also created some confusion. Therefore it was important to avoid its usage in the questionnaire to minimise any possibility of confusion and any bias in their responses.

The detail description of the questionnaire development was presented in chapter five. The sample of the industry wide questionnaire is presented in appendix 5.

This chapter is presented in accordance to the sequence of the questions in the survey document. The main sections of the data analysis are as follows:

1. The analysis on general information of the respondents;
2. The analysis of the profile of involvement of the respondent's organisation in the design development phase of project life cycle;
3. The analysis of the respondents' experience in the previous project with respect to the level of project communication; the level of awareness toward project goals; and the level of project authority and flexibility; and

4. The analysis of the level of agreement of the different groups of the respondents toward the factors that support and inhibit formation of collaborative teamwork environment.

#### **6.6.2 General Information on the respondents**

The industry wide mail survey yield a total of 51 responses from the total of 160 questionnaire forms sent (a response rate of 31.8 percent). The respondents were selected from the Consultant Engineers 500 (1997) and Contractors' File (NCE 1997) as per the criteria for the selection of the respondents was discussed in chapter five. 160 questionnaire forms were mailed to the two major target groups, contractors and the consultants. Fifty one respondents provided complete answers, one was incomplete. The breakdown of the respondents based on their major groups and their sub-groups is shown in table 6.1.

**Table 6.1 Breakdown of respondents group**

MAJOR GROUP	NO. OF RESPONSE	BREAKDOWN OF RESPONDENTS SUB-GROUP BASED ON TYPE OF PROCUREMENT USED IN THE PROJECT	NO.
(1) Contractor	32	<u>Traditional Contract</u> Main-contractor - 11 Sub-contractor - 3 Traditional contract with partnering - 3	17
		Design-build contract	10
		<u>Others:</u> Project Management -3 Did not clearly indicate procurement method - 2	5
(2) Consultant	16	Traditional contract	11
		Design and build contract	5
(3) Others	3	Client Designer led contractor Project manager	1 1 1
Total			51

Two major sub-groups are used in the analysis, contractors and consultants (table 6.1). Any respondents that do not belong to either group were ignored in the analysis. The criteria used to analyse the responses of each sub-group were based upon the type of procurement system that the respondents used in their last project.

### 6.6.3 Respondents' background

The respondents' construction industry experience is shown in table 6.2. 90 percent of the respondents had 15 or more years experience. Table 6.3 shows the respondents' position in their organisation.

**Table 6.2 : Respondents' experience**

Experience in years	Percentage of the respondents
0 - 10	4%
11 - 20	34% (Note: 28% between 15-20)
21 - 30	48%
Above 30	14%
Total	100%

**Table 6.3 Respondents' position**

Respondents' Position	Frequency	Percentage
Senior manager/ Manager	23	45.1
Chief Engineer	3	5.9
Contract manager	5	9.8
Director/ Assistant director	13	25.5
Others (partner, QS, associates)	7	13.7
TOTAL	51	100

#### **6.6.4 Respondents' sub-group**

Two major divisions of groups used in the questionnaire survey analysis were the contractors and the consultants (table 6.1). They were further divided into the sub-groups represent the type of procurement used in their last project. In the questionnaire the respondents were instructed to respond based on their experience on the last project they were involved. A special sub-groups of 'sub-contractor' and 'traditional contractor with partnering' were also being used in the analysis. No such sub-groups existed for the consultant within the sample collected. Any respondents that did not belong to either group were ignored in the analyses.

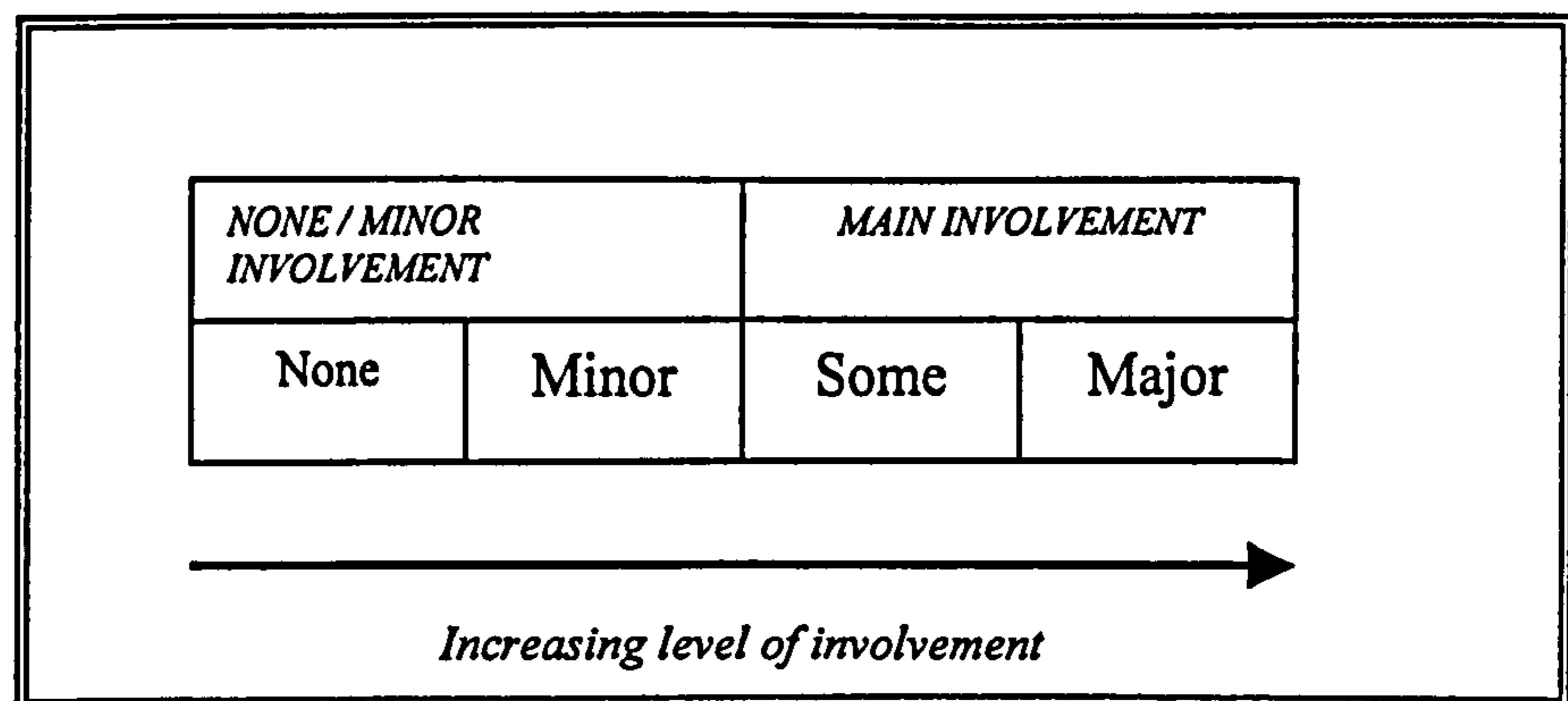
#### **6.6.5 Analysis of the profile of involvement of the respondents (contractor's group) in the design development phase**

##### **6.6.5.1 Introduction**

The analysis on the profile of involvement of the respondents in the design development phase was used in the research as one of the indicators to observe the presence of the practice parallel to CE within construction project based on the responses from the questionnaire survey. The most important aspect of the analysis was to compare the different profiles of involvement for the respondents' sub-group using the design and build contract with the traditional contract sub-group. However only the involvement of the contractors was considered in the analysis as they belong to the non-designers group of project participants. Theoretically, it has been established from the literature review and interviews with CE practitioners that in CE environment the involvement of key projects team members are normally made at outset of the project with significant roles in making contribution toward design development process.

In the design of the questionnaire, the RIBA plan of work (Ashworth 1996) was used to describe the typical phases in the pre-construction stage. The respondents were required to indicate the level of their involvement at every stage indicated in the questionnaire by doing simple ticking in the provided space. The level of their involvement is being measured using four discrete ordinal scales as shown in figure 6.4. Each scale: 'none';

'minor'; 'some'; and 'major' indicates different level or degree of involvement in ascending order as shown in figure 6.4.



**Figure 6.4** Ordinal scale used to evaluate the level of involvement of the respondent in the project life cycle

The following steps were undertaken to develop the profile of involvement in the design process for contractors' group of the respondents:

- i) The frequency of the responses for each ordinal scale as shown in figure 6.4 above were being calculated.
- ii) The frequency of the response for 'some' and 'major' scale were being added together
- iii) The summation of (ii) divided by the total responses for all ordinal scale to determine the proportion of the responses that belong to the 'main involvement' category.
- iv) The same procedure was repeated for each activity in the design development stage. The graph was plotted to show the 'profile of involvement in the design development process' for each sub-group of the contractors.

The discussion on the 'profile of involvement in the design development' for contractors' sub-groups and comparisons between them are presented here:



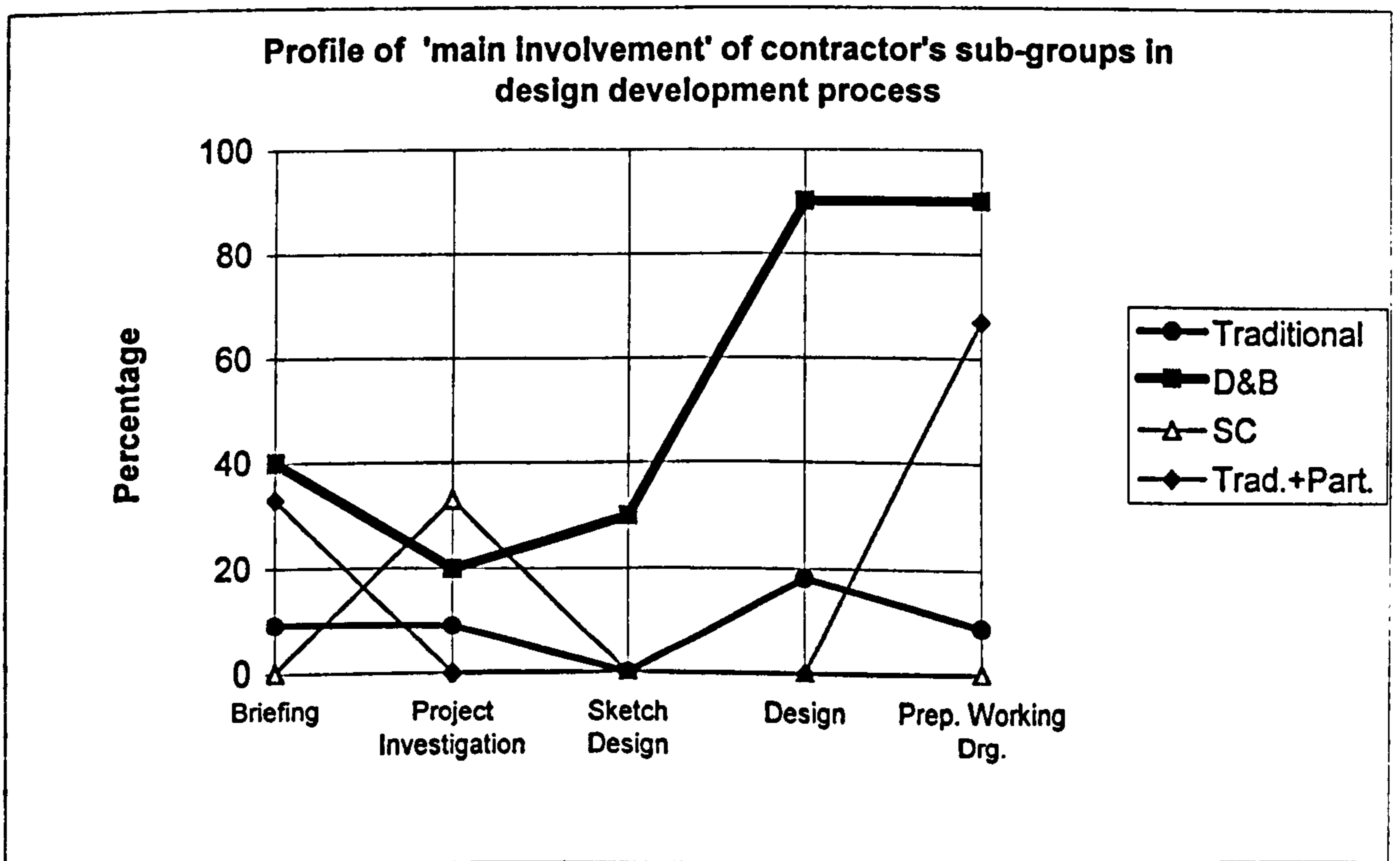
### 6.6.5.2 Profile of involvement of contractors in the design development phase

The frequency analysis which shows the profile of contractors 'main' involvement in the project life cycle is shown in table 6.4

**Table 6.4 Contractor's 'main involvement' in the design development process**

ACTIVITIES CONTRIBUTED TO DESIGN DEVELOPMENT	CONTRACTORS' SUB-GROUP			
	Trad.	D&B	SC	Part.
Briefing	9.09	40	0	33
Project Investigation	9.09	20	33	0
Sketch Design	0	30	0	0
Design	18.18	90	0	0
Preparation of Work. Drawing	9.09	90	0	67

Figure 6.5 shows the graphical representation the profile of involvement of the contractor's sub-groups in the design development process.



**Figure 6.5 Contractor's profile of 'main involvement' in design development process**

The analysis of the involvement of the contractors group in the design development phase shows that the traditional sub-group (either with or without partnering approach) as well as the sub-contractors did not really have significant involvement (less than twenty percent) in making contribution to the design development phase. Those using the D&B procurement approach show some significant involvement particularly in the design stage. However the involvement in the earlier design development stage (briefing, project investigation and sketch design) for all groups were particularly low (less than 40 percent). A comparison using Spearman correlation statistical test was made to observe the relationship between the profile of involvement of the D&B group to the traditional group.

Hypothesis testing at 5 percent significance level executed as follows:

$H_0$  = no significant agreement between the profile of involvement of the groups of respondents

$H_1$  = there is significant agreement between the profile of involvement of the groups of the respondents

The result of the test and the Spearman  $r_s$  (rho) value is shown in table 6.5. It was determined from the test that differences between the profile of the involvement of the D&B and traditional group was significance at 95 percent confidence level, 1 tail test. The Spearman  $r_s$  (rho) value was 0.54 showing a moderate strength of positive relationship between the two groups' profile. No statistical test conducted to compare the data obtained for the sub-contractor and partnering group as the number of the respondents for each group is too small (3 each).

**Table 6.5 Bivariate correlation analysis for 'profile of involvement' in the design development phase of contractor's D&B and Traditional sub-groups**

Bivariate correlation analysis	Spearman $r_s$ (rho)	Significance value	Hypothesis testing: (at 95% confidence level)
D&B and Traditional contractor's sub-groups involvement	0.54	0.312	$p > 0.05$ , Accept $H_0$ , there is significance difference D&B and Traditional level of involvement

If the criteria of involvement in the design development is being considered as an indication to reflect the presence of practice parallel to CE in construction, the finding from the analysis is unlikely to support that this has been successfully achieved even within design and build and partnering approach. However the findings support that the use of design and build procurement approach outperformed the achievement of those using the traditional contract for this aspect

## 6.6.6 The respondents' experience towards important elements related to teamwork

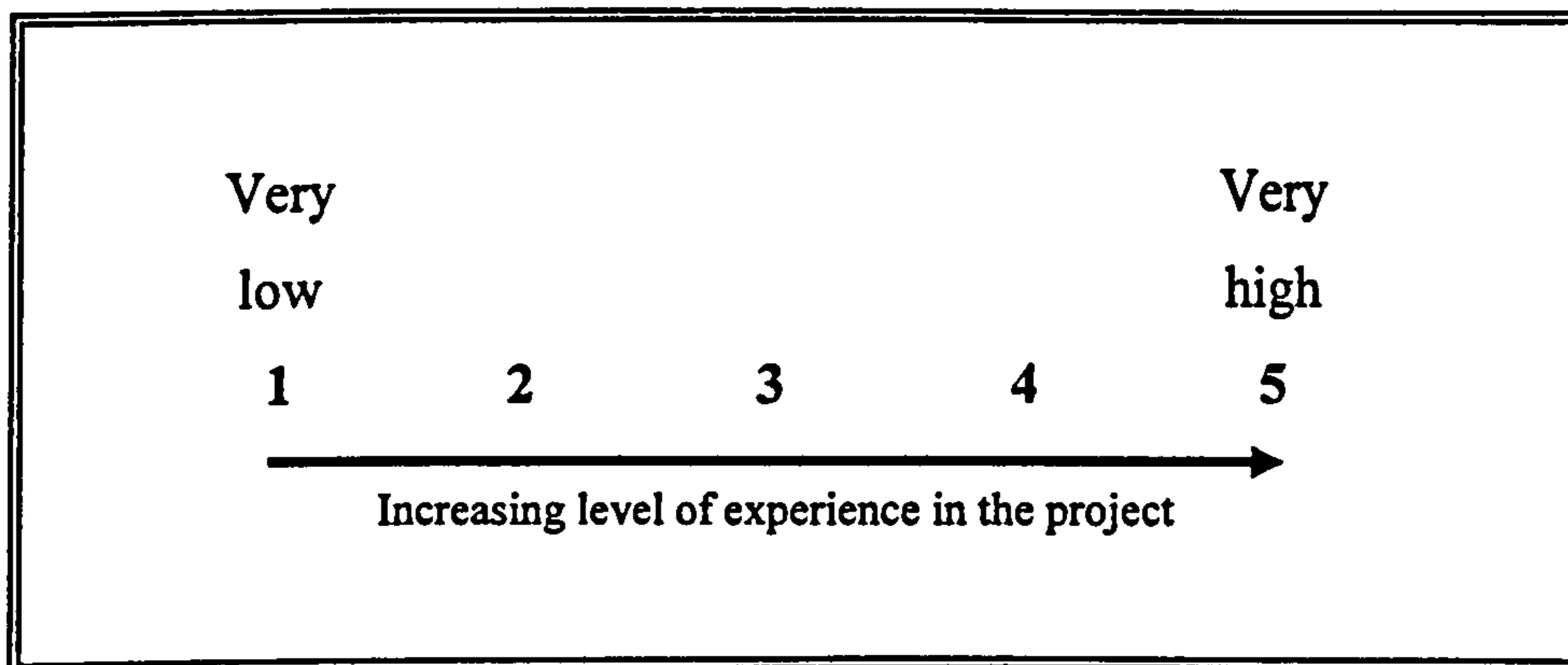
### 6.6.6.1 Introduction

The questionnaire aimed to explore further the aspect of the respondent's involvement in the project with respect to the factors relevant to a collaborative teamwork environment. In question 6 section A of the questionnaire, the survey assesses the respondents' experienced on the various attributes, which were considered important in the CE collaborative teamwork environment. The attributes used in the questionnaire were based on the findings from the literature review on CE and interviews with the CE practitioners. These attributes are shown in table 6.6.

**Table 6.6 Important attributes related to collaborative teamwork assessed in the questionnaire survey**

<u>Category I</u>	<u>Category II</u>	<u>Category III</u>
<ul style="list-style-type: none"> <li>• <i>Project communication</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Project exposure</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Project authority</i></li> </ul>
<ol style="list-style-type: none"> <li>1. Communication between the functional group</li> <li>2. Information sharing between functional group</li> <li>3. Direct communication with clients</li> </ol>	<ol style="list-style-type: none"> <li>4. Clear understanding of the overall project goal</li> <li>5. Understanding of other functional task in the project</li> </ol>	<ol style="list-style-type: none"> <li>6. Flexibility to express ideas to improve project design outside normal control</li> <li>7. Project authority given to make decisions that affected other project task.</li> <li>8. Ability to respond to problems outside functional area</li> </ol>

To evaluate the level of the experience of the respondent toward the given attributes, the Likert scale of five discrete ordinal level of agreement was used as shown in figure 6.6



**Figure 6.6 Ordinal scale used to observe the level of agreement toward the important attributes related to collaborative teamwork experience**

The division of the sub-groups to analyse the survey data used the same criteria as in the previous analysis (section 6.6.5). However this analysis includes the consultant's groups. As in the previous analysis, only the respondents that clearly indicated the usage of traditional or design and build contract are being considered. The result was analysed using frequency analysis and Mann Whitney U test. Brief description of the Mann Whitney U Test statistic was presented in chapter 5. Detail description of the theoretical background and test procedure using Mann U Whitney statistic can be referred in Siegel (1956), and Hamburg (1970).

In the frequency analysis, only the proportions of the responses that belong to the 'high level of experience' category were used as a basis for comparison for different sub-groups experience. The 'high level of experience' is being identified here representing the level of agreement on Likert scale that are greater than 3 (i.e. 4 and 5). The similar approach being adopted by Nesan (1989) for the similar context of data analysis.

The Mann Whitney U test was used to check whether the difference of experience by different sub-groups toward the same attribute in the questionnaire is statistically

significance at 95 percent confidence level ( $\alpha = 0.05$ ). Comparison was made to observe the different sub-groups' experience toward the all eight attributes by using the actual response (i.e. the actual level of individual agreement in each sub-group) recorded. The actual level of each respondent agreement was used for Mann Whitney U Test because by using such data, the total number of respondents for each sub-groups (i.e.  $n_1$  and  $n_2$ ) can be verified for computation and thus gave us a more reliable result. This cannot be achieved if the computation is based on the value of the percentage of proportion of 'high level' agreement for each sub-group. For the Mann Whitney U test the following rules of hypothesis testing was used:

Null Hypothesis ( $H_0$ ) = There is no different of experience observed between the two sub-groups

Alternative hypothesis ( $H_1$ ) = There is a significant difference of experience observed for the two sub-groups observed

To establish a confidence level of 95 percent (or 5 percent significance level) a one tail test was used as a basis for acceptance or rejection of null statistics. The critical U value ( $U_{cr}$ ) used in this analysis is taken from the relevant tables given in Siegel (1956). Null hypothesis is rejected when the computed value of U is equal or smaller than U critical ( $U_{cr}$ ). This procedure is described in Siegel 1956. The following sections will discuss in detail the analysis of the responses of the survey:

#### **6.6.6.2 Respondents' experience in 'project communication attributes'**

These aspects were analysed for both contractors and consultants.

##### **6.6.6.2.1 Contractor's experience**

Table 6.7 tabulates the result of the proportion (in percentage) of the responses indicating high level of experience of the contractor's sub-group toward the aspect of project communication.

**Table 6.7 Contractors experience in project communication and information sharing**

Contractors sub groups		Traditional	Sub-con.	D&B	Partnering
Ref	Attributes:	(Percentage (%) scored >3)			
1.	Communication between the functional group	63.6	33.3	80	66.7
2.	Information sharing between the functional group	18.2	0	60	66.7
3.	Direct communication with the client	45.5	33.3	60	66.7
Average score >3		42.43	22	66.7	66.7

**Table 6.8 Mann Whitney U Test to compare the experience level of Contractor's Traditional and D&B sub-group toward communication factors**

Ref.	Attributes	Mean Rank		U	Decision Critical U=31 (at $\alpha = 0.05$ ) one tail
		Traditional	D&B		
1.	Communication between the functional group	9.27	12.90	36	Accept $H_0$ .
2.	Information sharing between the functional group	9.00	13.20	33	Accept $H_0$ .
3.	Direct communication with the client	10.05	12.05	44.5	Accept $H_0$ .

The results show that contractors' groups that used the design and build procurement and those engaged with partnering approach have a higher proportion of responses (>3) in all three attributes presented in the questionnaire. This result give the indication that those procurement systems that have an element of teamwork such as D&B or using partnering approach may provide a better environment for the communication process in the project. The traditional contract group has a very low score (18.2 percent) in the area of information sharing. However the overall result shows that level of project communication was not very satisfactory for all groups. The results highlight the 'isolated' nature of sub-contractors participation in a project. As a sub-group they recorded the lowest percentage in all aspects of the communication attributes.

The comparison using Mann Whitney U test using the actual individual responses in the survey, shows that even though the D&B sub-group indicate higher level achievement compared to the traditional group but this different is not statistically significance at 95 percent confidence level in all three attributes.

#### 6.6.6.2.2 Consultant's experience

Table 6.9 shows the results of the consultant's group. Table 6.10 shows the Mann Whitney U test analysis comparing the score of the consultant's traditional and D&B groups.

**Table 6.9 Consultants experience in project communication and information sharing**

Consultants' sub groups		Traditional	D&B
Ref.	Attributes:	(percentage of responses scored > 3)	
1.	Communication between the functional group	55	60
2.	Information sharing between the functional group	64	40
3.	Direct communication with the client	55	60
Average		58	53.3

**Table 6.10 Mann Whitney U Test to compare the experience level of Consultant's Traditional and D&B sub-group toward communication factors**

Ref.	Attributes	Mean Rank		U	Decision Critical U=12 (at $\alpha = 0.05$ ), one tail.
		Traditional	D&B		
1.	Communication between the functional group	8.45	8.60	27	Accept H <sub>0</sub> .
2.	Information sharing between the functional group	9.32	6.70	18.5	Accept H <sub>0</sub> .
3.	Direct communication with the client	8.5	8.5	27.5	Accept H <sub>0</sub> .

The analysis of the result for the consultant sub-groups exhibit different pattern of 'high level experience' toward project communication attributes compared to the contractor's sub-groups' experience. The consultant's traditional group had a marginally 'higher average' score compared to the D&B group. The Mann-Whitney U test confirmed that there is no significance different between the score of the two groups within 95% confidence level.

#### **6.6.6.3 Respondents' experience in 'project exposure's attributes'**

The category of project exposure assessed the level of understanding towards project goals and other functional tasks. These two aspects are considered an important requirement or 'catalyst' to enable the project team members to develop a clear objective in their involvement in the collaborative teamwork. Sharing common project goals and understanding of the other functional roles is an important criterion in CE environment. The total percentage of the responses that indicate they have experience high level of experience (score greater than 3 on the agreement scale) for both the contractor's and the consultant's sub-groups are presented table 6.11.



**Table 6.11 Level of respondents' experience in project exposure**

Ref.	Respondents' group	Contractors				Consultants	
		(Percentage scored >3)					
	Attributes:	Trad.	SC	D&B	Part.	Trad.	D&B
4.	Clear understanding of overall project goals.	36.7	0	80	67	72.7	60
5.	Understanding of other functional tasks in the project.	27.3	0	60	67	72.7	60
	<b>Average score &gt;3</b>	<b>32</b>	<b>0</b>	<b>70</b>	<b>67</b>	<b>72.7</b>	<b>60</b>

#### 6.6.6.3.1 Contractor's experience

The analysis shows that sub-contractors sub-groups did not indicate that they had any high level experienced in both attributes related to project exposure. Contractors using the traditional contract also indicate a low score for both attributes with the average score at 32 percent only. Contrary to this, the level of experience of contractors using either the D&B form of procurement or used partnering approach was much higher at 70 percent and 67 percent. These finding was confirmed by using the Mann-Whitney U statistic test in which the D&B group exhibits higher level of experience toward project exposure attributes and this is statistically significance within 95 percent confidence level (table 6.12).

**Table 6.12 Mann Whitney U Test to compare the experience level of Contractor's Traditional and D&B sub-group toward project exposure**

Ref.	Attributes	Mean Rank		U	Decision Critical U=31 (at $\alpha = 0.05$ ), one tail.
		Traditional	D&B		
4.	Clear understanding of overall project goals.	7.95	14.35	21.5	Reject $H_0$ .
5.	Understanding of other functional tasks in the project.	8.77	13.45	30.05	Reject $H_0$ .

#### 6.6.6.3.2 Consultant's experience

The analysis for the consultants' groups reflected the same trend as in the experience of the consultant group in the project communication category. Table 6.11 shows that the average high level of experience for the consultant's sub-group using the traditional form of contract were higher than the D&B group. However the analysis using the Mann Whitney U test (table 6.13) indicated that the difference experience of the two groups is not significance at a 95 percent confidence level.

**Table 6.13 Mann Whitney U Test to compare the experience level of Consultant's Traditional and D&B sub-group toward project exposure's attributes**

Ref.	Attributes	Mean Rank		U	Decision Critical U=12 (at $\alpha = 0.05$ ), one tail.
		Traditional	D&B		
4.	Clear understanding of overall project goals.	9.27	6.80	19.5	Accept $H_0$
5.	Understanding of other functional tasks in the project.	8.45	8.60	27	Accept $H_0$

**6.6.6.4 Respondents' experience in 'level of flexibility and project authority' attributes**

The level of the authority and the flexibility to express idea is one of the important requirements to support collaborative teamwork environment based on CE. Three attributes that are related to this category were presented in the questionnaire. Table 6.14 shows the results of the frequency analysis of 'high level experience' for all sub-groups belong to contractor's sub-groups and consultant's sub-groups for all three attributes within the category of the level of flexibility and project authority. Table 6.15 shows the Mann Whitney U Test results.

**Table 6.14 Level of respondents experienced in the project (level of project authority and flexibility)**

Ref.	Attribute	Contractors				Consultants	
		Trad.	SC	D&B	Part.	Trad.	D&B
6.	Flexibility to express ideas to improve project design outside normal control	63.6	33.3	60	100	81.8	60
7.	Project authority given to make decisions that affected other project tasks.	27.3	33.3	90	66.7	63.6	40
8.	Ability to responds to problem outside functional area	9.1	0	50	66.7	36.4	20
	<b>Average %</b>	<b>33.3</b>	<b>22.2</b>	<b>66.7</b>	<b>77.8</b>	<b>60.6</b>	<b>40</b>

**6.6.6.4.1 Contractor's experience (level of project authority and flexibility)**

The analysis of the response shows that sub-contractors using the traditional contract have the lowest score in 'high level of experience' level of project authority and flexibility in all the three attributes with an average percentage of 22 percent. The traditional contractor using the partnering approach indicated a highest overall score in the frequency analysis compared to the other sub-groups. The contractor's traditional sub-group indicated that they had a slightly higher experience compared to the D&B group with respect to the flexibility to express ideas to improve project design outside normal control. However the difference is quite marginal. The Mann Whitney U test analysis using the individual response confirmed that this difference is not statistically significance at 95% confidence level. On the other hand, the D&B sub-group clearly indicated that they have higher level of experience in the other two attributes in this category. Moreover, the difference is statistically significant at 95% confidence level when tested using the individual responses.

**Table 6.15 Mann Whitney U Test to compare the experience level of Contractors' traditional and D&B sub-groups in level of flexibility and project authority attributes.**

Ref.	Attributes	Mean Rank		U	Decision Critical U=31 (at $\alpha = 0.05$ ), one tail.
		Traditional	D&B		
6.	Flexibility to express ideas to improve project design outside normal control	10.41	11.65	48.5	Accept $H_0$
7.	Project authority given to make decisions that affected other project task.	7.55	14.80	17	Reject $H_0$
8.	Ability to responds to problem outside functional area	7.86	14.45	20.5	Reject $H_0$

#### 6.6.6.4.2 Consultant's experience (level of flexibility and project authority)

The analysis shows that the traditional sub-group of consultant had a higher high level experience in all attributes within the category of project authority and flexibility compared to their counterpart in the D&B sub-group. However the analysis using the Mann Whitney U Test indicated that none of this finding is significance at 95% confidence level as shown in table 6.16.

**Table 6.16 Mann Whitney U Test to compare the experience level of Consultant's Traditional and D&B sub-group toward level of flexibility and project authority attributes.**

Ref.	Attributes	Mean Rank		U	Decision Critical U=12 (at $\alpha = 0.05$ ), one tail.
		Traditional	D&B		
6.	Flexibility to express ideas to improve project design outside normal control	9.05	7.30	21.5	Accept H <sub>0</sub>
7.	Project authority given to make decisions that affected other project task.	9.55	6.20	16	Accept H <sub>0</sub>
8.	Ability to responds to problem outside functional area	9.59	6.10	15.5	Accept H <sub>0</sub>

#### 6.6.6.5 Respondents' experience in 'adversarial relationship in the project'

The adversarial nature of construction is a common characteristic frequently being associated to construction industry. This was tested in this questionnaire. The level of experience (high level, score >3 on agreement scale) is presented in table 6.17

**Table 6.17 Respondents experiencing a high level of adversarial relationship amongst project team members**

Attribute	Contractors				Consultants	
	Trad.	SC	D&B	Part.	Trad.	D&B
Level of adversarial relationship existed amongst the project team members.	36.36	33	0	0	0	20

### 6.6.6.5.1 Contractor's experience

It is interestingly to note here that, from this analysis, the incidence of a 'high level' of adversarial nature relationship is quite low. However the results of the frequency analysis supports that D&B and partnering approach have less 'high level of experience' of adversarial relationship in the project compared to the traditional sub-group. However the analysis using the using Mann-Whitney U statistic (table 6.18) for the traditional and D&B sub-groups determined that different results obtained for the two groups is not significance at 95 percent confidence level.

**Table 6.18 Mann Whitney U Test statistic to compare the level of experience in adversarial relationship between the traditional and D&B contractor's sub-groups.**

Attributes	Mean Rank		U	Decision Critical U=31 (at $\alpha = 0.05$ )
	Traditional	D&B		
Level of adversarial relationship existed amongst the project team members.	12.50	9.35	38.5	Accept $H_0$

### 6.6.6.5.2 Consultant's experience

None of the consultants within the traditional group indicated that they have any high level of experienced of adversarial relationships in their previous project. However 20 percent of the responses from the D&B sub-group indicated otherwise. The analysis of the actual responses using Mann Whitney U Test shows that the differences of the experience of the consultant's traditional sub-group and D&B sub-group (table 6.19) is not statistically significant at the 95 percent confidence level.

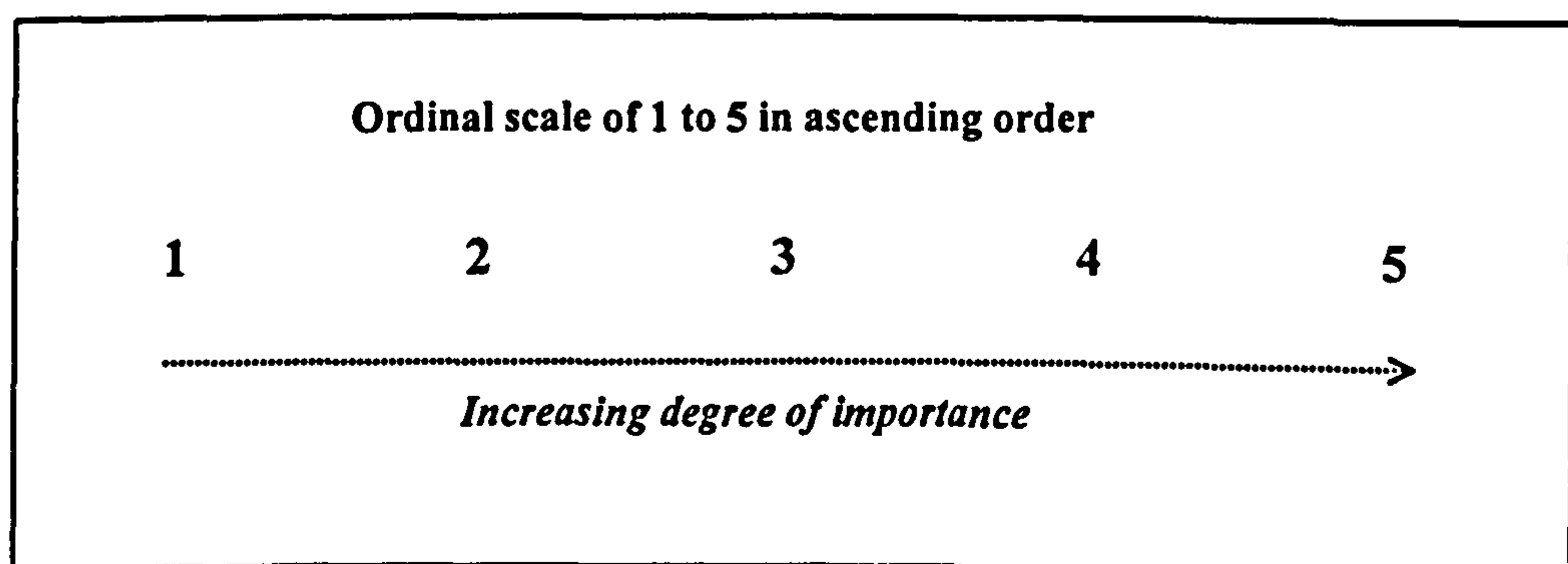
**Table 6.19 Mann Whitney U Test statistic to compare the level of experience in adversarial relationship between the traditional and D&B consultant's sub-groups.**

Attributes	Mean Rank		U	Decision Critical U=12 (at $\alpha = 0.05$ )
	Traditional	D&B		
Level of adversarial relationship existed amongst the project team members.	7.64	10.40	18	Accept $H_0$

### 6.6.7 Environment that supports and inhibits collaboration within team

#### 6.6.7.1 Introduction

Section B of the questionnaire was design with the objectives to pool the respondent's opinion on the factors that promote and inhibit collaborative teamwork environment. The sections divided into two parts, question 1 to evaluate the factors that promote collaborative teamwork and question 2 to evaluate the factors that result in the barriers. A Likert's scale of five ordinal measures of agreement (from 1 to 5) toward the importance of each factor presented was used in the questionnaire (figure 6.7).



**Figure 6.7 Five ordinal measures of agreement on Likert scale**

Each scale represents the following rating:

1 = unimportant

2 = fairly important



- 3 = important
- 4 = very important
- 5 = critically important

The main approach used to analyse the data generated from the responses was by using the 'Relative Indices' (RI) technique. RI computes the strength of 'indices of agreement' for each factor. This technique using RI has been used by Nesan (1997), Holt et al. (1996), and Shash (1993) in the same context of application. The computation of RI is given by the following formulae:

$$RI = \frac{\sum (1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5)}{5(n_1 + n_2 + n_3 + n_4 + n_5)}$$

Where:

*RI* - Relative Indices

$n_1, n_2, n_3, n_4$  and  $n_5$  - number of responding indices.

The computation of RI using this formulae yield the value of RI ranging from 0.2 to 1, where 0.2 represent the minimum strength and 1 the maximum strength (Holt et al.1996).

The basic rule use to develop the ranking was based on value of the Relative Indices (RI) and median score for each factor. The ranking was made in descending order from the top. The factor with the highest RI value topped the ranking. Wherever there is ties between the factors, the median score is used to resolve the ties. In such cases of ties score (i.e. same value of RI) the factor that has the higher median will be rank in the higher order. The ranking of the important factors which promote and inhibit collaborative teamwork environment was done for the sample represent the contractors' and the consultants' group. 32 responses are being used for the contractors' group while 16 for the consultants. The Spearman's Rank Correlation Coefficient,  $r_s$  (rho), is used to observe the correlation of the ranking by the two different groups and their significance

at 95% confidence level is determined. Brief discussion of the Spearman's rank Correlation Coefficient method was presented in chapter 5, but the detail discussion of the statistic can be referred to Siegel (1956).

The following section presents the detail analysis for question 1 and 2 of section B of the questionnaire.

#### **6.6.7.2 Ranking of factors that promote a collaborative teamwork environment**

Nine factors that promote collaborative teamwork were presented in the questionnaire document. These factors were established from the information gathered from various sources such as literature search and industrial interviews with construction and manufacturing industry personnel. Table 6.20 shows the detail result of the survey for the contractors' and the consultants' group as well as the combined ranking.

**Table 6.20 Ranking by the respondents toward the factors that promote collaborative teamwork**

Factors	Overall		Contractor		Consultant	
	R.I	Rank	R.I	Rank	R.I	Rank
Availability of key information (design information, schedules, etc.) to all team members.	0.898	1	0.897	1	0.900	2
Addressing the client's requirements as a team.	0.889	2	0.877	2	0.913	1
Early consideration of construction and operational problems	0.830	3	0.852	3	0.788	3
Assigning adequate authority to key project participants to impact design decisions.	0.796	4	0.813	4	0.763	6
The inclusion of team members from various functions within the project team.	0.770	5	0.768	5	0.775	4
Ability of all team members to perform project tasks concurrently.	0.751	6	0.738	6	0.775	4
Initiative from the client.	0.681	7	0.716	8	0.613	7
Improving existing procurement systems to support the formation of a united project team.	0.677	8	0.729	7	0.575	8
Provision of information technology to minimise communication barriers.	0.536	9	0.535	9	0.538	9

Three different rankings were established. First, based on the result of contractors group, second the ranking based on consultants opinion and third the overall respondents opinion which combined the consultant and contractors respondent. Each of these rankings were developed individually. Spearman Correlation (Siegel 1956) test was carried out to check the degree of correlation between the rankings by the contractors and the consultant group. The result of the test is shown in table 6.21 below. Hypothesis testing at 5 percent significance level executed as follows:

$H_0$  = no significant agreement between the ranking of the groups of respondents

$H_1$  = there is significant agreement between the ranking of the groups of respondents

The result of hypothesis testing is shown in table 6.21

**Table 6.21 Hypothesis testing using Spearman  $r_s$  (rho) to observe the correlation of different groups' rankings on factors that support collaborative teamwork**

Bivariate correlation analysis of ranking	Spearman $r_s$ (rho)	Significance value	Hypothesis testing: (at 5% confidence level, 1 tail)
1. Contractors' and consultants' ranking	0.91	0.001	$p < 0.05$ , reject $H_0$ , no significance difference in the rankings.
2. All respondents and contractors' ranking	0.98	0.001	$p < 0.05$ , reject $H_0$ , no significance difference in rankings.
3. All respondents and consultants' ranking	0.93	0.001	$p < 0.05$ , reject $H_0$ , no significance difference in rankings.

The test indicated that there is a strong agreement between the rankings established for the contractors' group and the consultants' group ( $r_s=0.91$ ). There are also very strong agreement between the rankings of all respondents and contractors ( $r_s=0.98$ ) and with the consultants ( $r_s=0.93$ ). The entire test have the significance value of 0.001 thus confirmed that there were no significance difference between the rankings amongst the respondents within 95 percent confidence level limit adopted in this research.

The overall ranking shows that the 'top ranking factors' to promote a collaborative teamwork environment in construction should emphasised on the 'openness' concept in project information sharing and synergism in the addressing the client's requirements. There is also a high level of agreement (third rank) on the need for the early consideration of construction and operational problem. Ranking no. 4 and no.5 indicate that teamwork should be given adequate authority to impact design decision and the nature composition of the team that reflect multi-functionality of team members.

At the bottom of the ranking, provision of information technology to minimise communication barriers has not been regarded as the critical factors. This ranking was unanimously agreed by both the contractors and the consultants group ranking. This is quite unexpected considering the efforts within the industry to promote the use of information technology tools to improve project communication. This phenomenon could be explained by the cost incurred and the amount of technological knowledge required for the industry to engage with sophisticated information technology tools. This view was also supported by the opinions gathered during industry interviews earlier. However it would be very misleading to assume that IT had no significance role to support collaborative teamwork. The appropriate interpretation from this ranking is to assume that IT still regarded as important (by considering the its relative index score of 0.536 on the scale ranges from 0.2 to 1). However relatively, it may not be as critical as other factors presented above.

#### **6.6.7.3 Ranking of factors that are barrier to collaborative teamwork environment**

Question 1 of part B is dedicated to evaluate the opinion of the respondents on the factors that are considered as barriers to collaborative teamwork. Fourteen factors were introduced in the questionnaire and the respondents required to rate all those factors accordingly using the Likert scale given as in question 1. Those factors have been developed based on the same sources as mention earlier (section 6.6.7.2). The result of the analysis is shown in table 6.22. The ranking for all the three categories of groups: all respondents; contractors; and consultants were established based on the relative index value computed for each factor. The same procedure for to establish the ranking as in the preceding section was adopted here.

**Table 6.22 Ranking by the respondents group to the factors that inhibit teamwork**

Factors that Inhibit collaborative teamwork environment.	Overall Respondents		Contractors		Consultants	
	R.I	Rank	R.I	Rank	R.I	Rank
Lack of clear direction toward project goals.	0.85	1	0.838	2	0.875	3
Lack of mutual trust between project participants.	0.842	2	0.831	3	0.863	4
Lack of willingness to share project information	0.829	3	0.844	1	0.800	5
Diverse goals amongst project participants	0.821	4	0.788	4	0.888	1
Lack of the client support for the teamwork approach.	0.800	5	0.756	6	0.888	1
Lack of commitment due to cost constraints.	0.767	6	0.775	5	0.750	7
Lack of a single management system to support interaction between team members.	0.758	7	0.744	7	0.788	6
The traditional adversarial nature of construction.	0.692	8	0.700	8	0.675	8
Fear of a power struggle between different groups.	0.642	9	0.644	9	0.638	10
The issue of who is going to lead the team.	0.638	10	0.638	10	0.638	10
Lack of knowledge of other functional areas.	0.617	11	0.613	11	0.625	12
Difficulty in quantifying the benefits of working in close collaboration.	0.617	11	0.594	12	0.663	9
Existing traditional contract systems.	0.542	13	0.575	13	0.475	13
The temporary nature of the project.	0.429	14	0.425	14	0.438	14

As in the preceding section, appropriate statistical analysis was used to evaluate the correlation factors and their significance value to determine if any significance difference exist between the rankings for the groups. The detail result of the statistical test using Spearman correlation coefficient,  $r_s$  ( $\rho$ ) is tabulated in table 6.23. The finding indicated that there were a very close correlation existed between the three sets of rankings. The  $r_s$  ( $\rho$ ) coefficient between the contractors' and consultants' ranking is 0.86 with significance value of 0.001 at 95 percent confidence level. The  $r_s$  ( $\rho$ ) value for relationship between the rankings of all respondents group with the contractors is

0.98 and with the consultants is 0.91 with significance value of 0.001 at 95 percent confidence level for both. Therefore, the null hypothesis that there is no significance relationship between those rankings is rejected. For the purpose of further evaluation, the ranking computed for all respondents' group will be used.

**Table 6.23 Hypothesis testing using Spearman  $r_s$  (rho) to observe the correlation of different groups' rankings on factors that inhibit collaborative teamwork**

<b>Bivariate correlation analysis of ranking</b>	<b>Spearman <math>r_s</math> (rho)</b>	<b>Significance value</b>	<b>Hypothesis testing: (at 5% confidence level, 1 tail)</b>
1. Contractors' and consultants' ranking	0.86	0.001	$p < 0.05$ , reject $H_0$ , accept $H_1 =$ no significance difference in the rankings.
2. All respondents and contractors' ranking	0.98	0.001	$p < 0.05$ , reject $H_0$ , accept $H_1 =$ no significance difference in rankings.
3. All respondents and consultants' ranking	0.91	0.001	$p < 0.05$ , reject $H_0$ , accept $H_1 =$ no significance difference in rankings.

The top five ranking factors in the overall respondents' ranking are related to the understanding of project goals, mutual trust, client support, and willingness to share information. These factors are the basic foundation to the development of the collaborative teamwork environment. These issues represent the priority for the industry to overcome. The factor related to the lack of willingness to share project information has also been rank in top position (third ranking). It was rated as the top factors by the contractors group. Trust between the project team members is also closely related to the readiness to share the information for mutual benefits. The diverse goals amongst the project participants is also resulted from the lack of a system to support the interaction between team members, a factor which had been positioned at the seventh rank but with high RI of 0.758. A lack of client support (R.I. = 0.8) which

ranks at number 5, is also considered as important factors that inhibit teamwork. Clients, who normally considered having the 'supreme' authority in the project should have taken more role to influence the formation of effective project team.

The temporary nature of the project, which is commonly being quoted as one of the unique features of the construction industry, was considered as the least important factor in the ranking (RI=0.429). The same ranking for this factor was obtained for the contractors' and consultants' groups. This is important point to support the effort within construction industry to look into the teamwork practice of other industry even though they are based on a more permanent nature project type like in manufacturing industry. The existing traditional contract system has been rated as second from bottom (RI=0.54). Relatively the RI for this factor reflects its importance as well.

#### **6.6.8 Summary from the questionnaire survey**

##### **1. Contractors involvement in the design development process**

The evaluation indicated that:

- a. Contractors belong to D&B group have higher level of profile of involvement compared to the other groups (traditional, sub-contractor, and traditional with partnering).
- b. However D&B group did not indicate significant participation in the earlier phase of the process to contribute to the design solution i.e. during briefing, project investigation and sketch design.
- c. There is no justification to conclude that D&B, or those involved in partnering support involvement in design development phase compared to other group.

##### **Respondent's experience on the factors that are relevant to CE collaborative teamwork environment within three categories of attributes:**

**Category I** - Project communication

**Category II**- Project exposure

**Category III**- Project authority



### *For contractors*

For contractor's group D&B and partnering has indicated that they have relatively higher level of experience toward all three major categories of attributes presented compared to the traditional sub-group and sub-contractor's sub-group. Contractor's sub-contractors group is the group that have least experience all three categories of attributes. Despite the high level experience of contractor's D&B group, their average score is within the range of 67 -70 percent only. However the statistical test to determine whether the D&B sub-group have a significantly higher level of experience than the traditional sub-group in every attributes presented was not well justified. In most case the differences is not significant at 95% confidence level. -

### *For Consultants*

The traditional consultant's sub-group indicated that they have higher experience in all three categories of attributes compared to the D&B group. But most of these differences are not statistically significance at 95% confidence level.

### *Level of adversarial in the project*

Both contractor and consultant indicate low experience in adversarial relationship in the project. For contractor the traditional group and sub-contractor indicated higher level of experience in adversarial relationship compared to D&B and partnering. An opposite score was recorded for consultants, whereby the D&B group indicated that they had a higher experience of adversarial relationships than the traditional group.

### *Overall conclusion from the assessment:*

The assessment on the experience toward attributes related to collaborative teamwork environment in the project in relation to the existence of CE elements in construction at present (based on the available research data) are:

- The findings from the evaluation of the contractors' involvement in the design development phase suggests that D&B is more likely to be able to support a collaborative teamwork environment.

- Likewise, an analysis of other important factors (respondents' experience on factors that are relevant to CE collaborative teamwork) also suggests that it is more likely to be successful under D&B projects, but only for contractors.
- The D&B procurement approach is probably the best platform to support the collaborative teamwork environment in construction currently, but the research data do not strongly support that many elements of collaborative teamwork consistent with CE environment are present within the current D&B practice.
- The data available for the sub-groups that use traditional procurement approach with partnering was too small for meaningful statistical comparison with other groups' findings. However as a matter of getting some indication, the use of the partnering approach indicated that they may have more potential to support collaborative teamwork compared to the purely traditional group.
- The conclusion that can be derived from the analysis is unlikely to support that many elements of collaborative teamwork consistent with CE environment present within the current practice either in the traditional procurement approach or design and build.
- However, the practice of D&B and Partnering should be an appropriate platform to support the initiation of the implementation of CE in construction

*Ranking of factors that support and inhibit collaborative teamwork*

The ranking established from the survey for the factors that support collaborative teamwork is in the following order:

1. Availability of key information (design information, schedules, etc.) to all team members.
2. Addressing the client's requirements as a team.
3. Early consideration of construction and operational problems

4. Assigning adequate authority to key project participants to impact design decisions.
5. The inclusion of team members from various functions within the project team.
6. Ability of all team members to perform project tasks concurrently.
7. Initiative from the client.
8. Improving existing procurement systems to support the formation of a united project team.
9. Provision of information technology to minimise communication barriers.

The ranking established from the survey for the factors for that inhibit collaborative teamwork environment is in the following order:

1. Lack of clear direction toward project goals.
2. Lack of mutual trust between project participants.
3. Lack of willingness to share project information
4. Diverse goals amongst project participants
5. Lack of the client support for the teamwork approach.
6. Lack of commitment due to cost constraints.
7. Lack of a single management system to support interaction between team members.
8. The traditional adversarial nature of construction.
9. Fear of a power struggle between different groups.
10. The issue of who is going to lead the team.
11. Lack of knowledge of other functional areas.
12. Difficulty in quantifying the benefits of working in close collaboration.
13. Existing traditional contract systems.
14. The temporary nature of the project.

The main conclusions that can be derived from these rankings toward the development of the collaborative teamwork environment (in which all the factors related to CE principles) are:

1. There is a need to make the key project information available to all parties.

2. There is a need to ensure that all project team members to share common project goals.
3. Client needs must be addressed as team.
4. The team must be vested with adequate power and authority to make important design decisions.
5. Team members must comprise of all functional group within the project.
6. The inclusion of the team members must be made early to enable consideration to be made for the construction and operational problem in the design development.
7. Client has an important role to support collaborative teamwork.

Other related conclusion that can be made which are considered less critical are:

1. Information Technology tools are considered important but they are not top priority. It is more critical to address human and organisational issue first to support collaborative teamwork.
2. Temporary nature of the project should not be considered as inhibitor for construction industry to develop collaborative teamwork.

## **6.7 Overall summary - Interview and questionnaire survey**

From the analysis of the data from face to face interview and postal questionnaire survey, the research concluded that :

- CE has not been practised as a complete process as in other industry in construction industry yet
- There is 'indication' to support that some elements parallel to CE are already being practiced in construction industry especially within design and build procurement.
- There is a strong desire within the industry to support the formation of collaborative teamwork environment consistent with CE philosophy.

The data available from the ranking provide the research with foundation to develop the framework for the Delphi study and the development of MMG-TCEiC in the following phase of the research effort.

## **CHAPTER SEVEN**

### **THE DELPHI STUDY**

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#### **7.1 Introduction**

This research has determined that there is no evidence to support that CE has been fully implemented in construction. Therefore one of the aim of this research is to propose an appropriate framework for the industry to support CE implementation within UK construction industry. It has also been determined that the use of collaborative teamwork based on CE's Cross Functional Team (CFT) is considered as the strategic approach to achieve CE implementation. However, to rationalise the implementation of CE to construction, the research established the relevant importance of the related criteria, and validate those criteria with industry. To achieve this, the research has adopted the Delphi (inspired) technique as methodology to elicit the consensus opinion of the industry experts to review the various issues related to CE implementation to construction.

The related issues that have been considered in this study are:

- The organisational issue of the teamwork and its characteristic such as team membership and leadership;
- The various impacts resulting from the formation of collaborative teamwork based on CE principles (Cross Functional Project Team (CFPT)); and
- The appropriate IT tools to support CFPT.

Two rounds of Delphi study were conducted using 13 panellists representing various fields of UK construction industry experts. The results from the application of this technique, (which has been identified as 'Delphi Study' in this research), to formulate the guidelines for the implementation of CE within UK construction industry through the formation of Cross Functional Project Team (CFPT). The theoretical aspects of the Delphi method and general process of how to conduct the Delphi study was discussed

in chapter five. This chapter focuses on the analysis of the results generated from the studies.

## 7.2 Panellists and co-ordinator

Thirteen panellist members selected to participate in this study. None of them had less than 10 years industry experience. The professional background of the panellists and their experience in construction industry is shown in table 7.1. To maintain the anonymity of the panellists each of them was assigned with a reference number. This coding system was important especially in reporting the analysis of each round result.

**Table 7.1 Brief description of the Delphi Study panellists**

<b>No.</b>	<b>Reference Code</b>	<b>Industry sector represented</b>	<b>Number of years experience</b>
1.	101	Consultant - Architect	25
2.	102	Contractor - Regional planner	20
3.	103	Designer - Engineering	30
4.	104	D & B Contractor - Co-ordinator	10
5.	105	Academician - Construction management/ Computer expert	15
6.	106	Contractor - Design manager	45
7.	107	Academician - Construction management/ Computer expert	18
8.	108	Specialist supplier	27
9.	109	Project manager	10
10.	110	Consultant - Quantity surveyor	40
11.	111	Consultant	43
12.	112	Owner/ Developer	15
13.	113	Engineering manager	35

Thirteen panellists participated in the First Round Delphi (FRD) exercise and all of them responded to the FRD questionnaire. In the second round Delphi exercise 11 panellists responded by returning the questionnaire sent to them while one panellist (reference number 105) indicated through electronic mail that he was satisfied with the first round results. One panellist (reference number 113) did not respond in the second

round Delphi questionnaire and cannot be contacted. The co-ordinator for this Delphi study was the writer.

### **7.3 Delphi questionnaire development**

The Delphi study in this research involved two rounds of questioning and feedback. The two level of Delphi studies were identified as:

1. First Round Delphi (FRD); and
2. Second Round Delphi (SRD).

The SRD was an extended version of the FRD. A copy of FRD and SRD questionnaires is presented in appendix 6 and appendix 7 of this thesis. The development of the Delphi study questionnaire was guided by the findings from the literature search, interviews with the CE practitioners and the findings from the industry wide postal questionnaire survey. The main theme of this Delphi Study was to evaluate the relevant factors associated to the formation of CFPT within the existing construction industry environment. All the panellists were informed about the basic principles of CE and the concept of Cross Functional Team. Contact numbers, email account and departmental address was given to the panellist for them to reach the co-ordinator for them to clarify on issues throughout the Delphi study period.

The presentation of the issues in the Delphi Study questionnaire was divided into three major sections. These sections and the issues presented to the panellists are presented here:

- Section A:** Evaluation of the organisational related issues of teamwork formation.
- Section B:** Evaluation of the issue related to the team roles and responsibility and required level of changes from current practice to implement CE.
- Section C:** Evaluation of the issue of IT to support CFPT communication.

The following sections present the detail analysis of the results of the Delphi study. They are presented in the same order as in the Delphi questionnaires.

## 7.4 Data Analysis: SECTION A

### 7.4.1 Organisational issue related to the formation of Cross Functional Project Team (CFPT)

The main objective of this question was to determine the component of the CFPT and other attributes related to it as shown in figure 7.1.

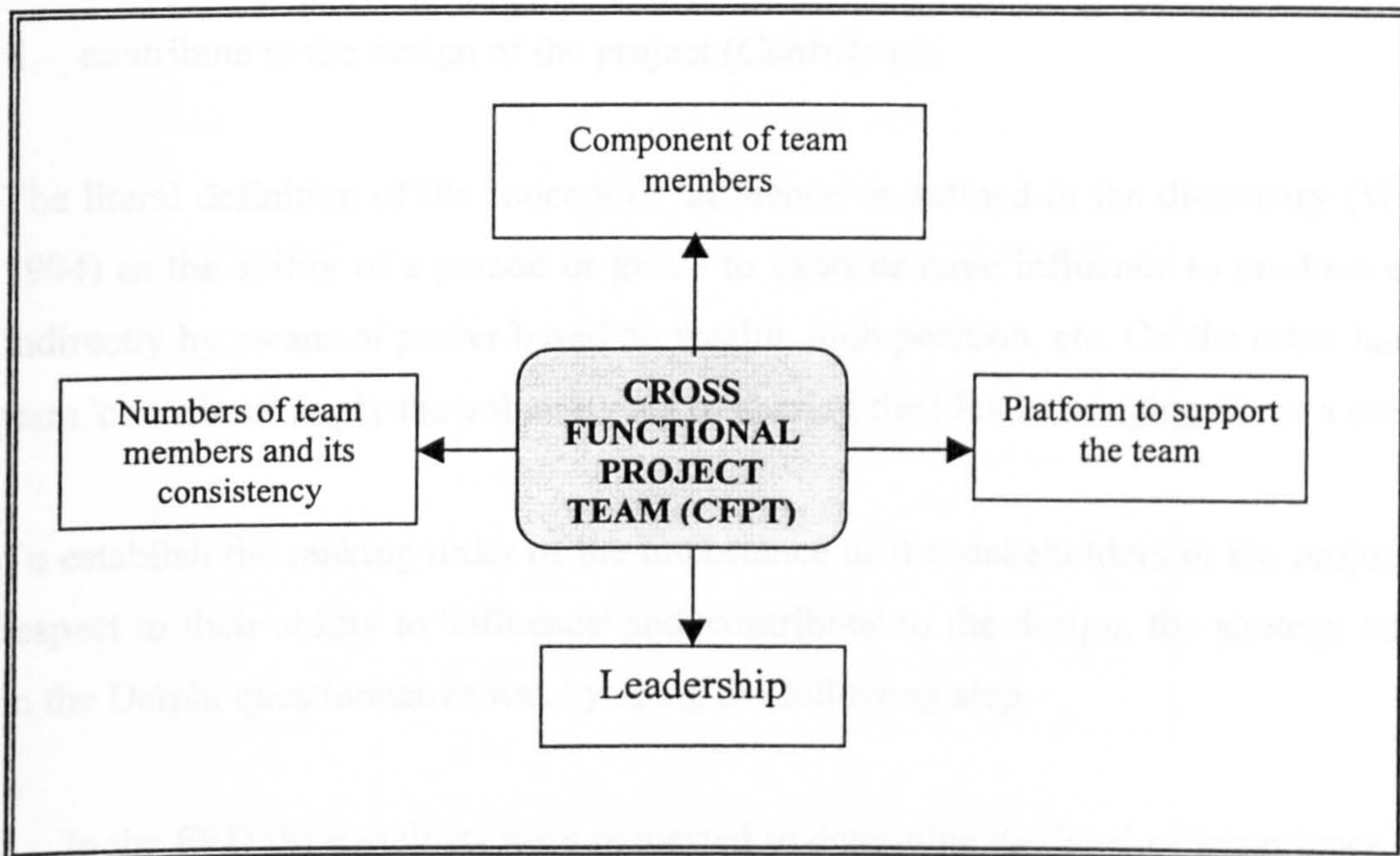


Figure 7.1 Main attributes of CFPT

### 7.4.2 Component of CFPT

The main objective of exploring this issue is to determine the list of the priorities of stakeholders that is to be included in the CFPT. The assumption made in the Delphi study was, that in a construction scenario the preliminary stage where the design is still at conceptual level only those parties that have ability to 'influence' the formulation of the design will be more likely to be included in the team. Inclusion of other team members can be made at later stage. However to ensure that the process of the inclusion of team members consistence with CE's practice, the intake process should be



completed prior to the commencement of the sketch design. This is to ensure that all key team members will have opportunity for their requirements to be considered in the design and also for them to make any appropriate contribution.

In the Delphi questionnaire related to the composition of the team the first objective is to identify the list of the project stakeholders that the panellist considered importance to the project with respect to their:

- i. ability to influence project design (*Influence*); and
- ii. contribute to the design of the project (*Contribute*).

The literal definition of the concept of 'influence' is defined in the dictionary (Webster 1994) as the ability of a person or group to exert or have influence to produce effects indirectly by means of power based on wealth, high position, etc. On the other hand the term 'contribute' imply the voluntary act of sharing the idea in bringing about a result.

To establish the ranking order of the importance of the stakeholders in the project with respect to their ability to 'influence' and 'contribute' to the design, the strategy adopted in the Delphi questionnaires was by using the following step:

1. In the FRD the panellists were requested to determine the level of importance of the given list of stakeholders. The rating is done using the Likert scale of 5 ordinal levels of importance in ascending order from 1 to 5.
2. The result of the FRD was first analysed using frequency analysis method.
3. Based on the result of the frequency analysis, the Relative Indices (RI) value was computed for each stakeholders. The 'Relative Indices' (RI) for each stakeholders was computed using the procedure described in chapter 6.
4. Based on the RI value, a ranking of the stakeholders according to their 'level of importance to 'influence' and to 'contribute' to the design' was established. These rankings is shown in table 7.2 and 7.3

5. In SRD, the rankings established based on RI values were given to each panellist and they were requested to verify them or re-rank the table if they wished.
6. Based on the SRD outcome, the rankings were finalised. The final analysis of the result was calculated by using the 'mean rank' technique by averaging the ranking for each stakeholders by all panellist. The same technique of finding the mean of rank was used by (Schmenner, 1997). The result of this final ranking is shown in table 7.4 and 7.5.

**Table 7.2 FRD : R.I. for stakeholders that can influence project design**

<b>Ranking</b>	<b>Relative Index</b>	<b>Stakeholders</b>
1	0.86	Client
1	0.86	End user / (customer)
3	0.85	Architects
4	0.75	Engineers
5	0.66	Main contractors
6	0.60	Service contractors
7	0.58	Surveyors
8	0.57	Financiers
9	0.54	Contractors
10	0.49	Suppliers

**Table 7.3 FRD : R.I. for stakeholders that can contribute to project design**

Ranking	Relative index	Stakeholders
1	0.89	Architects
2	0.83	Engineers
3	0.74	Main contractors
4	0.66	Sub- contractors
5	0.65	Client
6	0.60	Service contractors
7	0.58	End user (customer)
8	0.52	Suppliers
9	0.51	Surveyors
10	0.37	Financiers

**Table 7.4 Final ranking of the stakeholder that are able to influence project design**

Ranking	No. of response	Mean Rank	STAKEHOLDER
1	11	1.00	Client
1	11	1.27	End user (Customer)
3	11	3.09	Architects
4	11	4.00	Engineers
5	11	5.09	Main contractors
6	11	6.18	Service contractors
7	11	7.18	Surveyors
8	11	7.45	Financiers
9	11	8.73	Sub- contractors
10	11	10.00	Suppliers

**Table 7.5 Final ranking of the stakeholder that are able to contribute to project design**

Ranking	No. of response	Mean Rank	STAKEHOLDER
1	11	1.09	Architects
2	11	2.00	Engineers
3	11	3.45	Main- contractors
4	11	4.27	Sub- contractors
5	11	5.55	Client
6	11	5.82	Service Contractors
7	11	6.55	end user(customer)
8	11	6.82	Suppliers
9	11	8.00	Surveyors
10	11	9.82	Financiers

#### 7.4.2.1 The interpretation of the result of the ranking

The rankings developed in this Delphi study propound the following key issues:

1. The level of input that the stakeholders can contribute to the project can be categorise according to their roles in the project; and
2. Therefore, while recognising the importance of the requirement to include all team members from outset, but it is also suggested that the inclusion of the members into the project team can be prioritised.

The ranking of the stakeholders than can *influence* the project design established the list of the priorities of the stakeholders that to be included in the initial stage of the project design development. The choice of the client and the end-user in the top two positions indicate the importance of their role in influencing the project design. In the current construction practice it is rare to include the 'voice' of the end user within the project. In CE practice the end user requirements can be captured using tools like Quality Function

Deployment (QFD). Other important stakeholders that need to be considered for inclusion in the initial stage of the project design development process are the architect, the engineers, and the main contractors. The inclusion of the sub-contractors and suppliers are not considered critical at this stage.

The second ranking deals with the list of the stakeholder that can contribute in the design process. This ranking guide the teamwork for the further intake of the CFPT members as the design evolve further from conceptual to sketch and detail design stage. If their inclusion in the team were not considered in the conceptual stage, then those project stakeholders inclusions shall be considered important at this stage.

According the Delphi panellists, the important stakeholders at this stage are: the architect; engineers; main-contractors; and sub-contractors. The placing of the suppliers in the 8th ranked is unexpected considering their ability to support the design process. This is probably because in construction the suppliers service are normally engaged by the contractors and their interest may be considered covered by contractors. In CE, this is considered inappropriate because the main suppliers requirement need to be represent in the project as much as the main contractor.

#### **7.4.3 Maximum number of representatives for each functional group**

The panellists were asked to determine the maximum number of the persons that should be available to represent each functional group within a cross functional team to ensure that it will efficiently represents the interests of all parties involved. The consensus respond to the question is presented in table 7.6.

**Table 7.6 Analysis of the maximum number of representative for each functional group**

No.	Alternative choices for number of representative for each functional group	No. of response	Percent	Decision
i.	Strictly one representative for each functional group.	2	15.4%	
ii.	Depends on the role of the group, some may have more than one representative.	11	84.6%	<i>Consensus</i>
iii.	More than one representative for each group but of equal numbers	0	0.0%	
iv.	Others	0	0.0%	
	<b>TOTAL</b>	<b>13</b>	<b>100%</b>	

The panellist decided (84.6%) that there should not be any limit of representative for one group. This result indicates that in some functional area more than one representative may be required to represent their interest in the team.

Another issue presented to the panellist was related to the consistency of the number of team members throughout the project life cycle. The panellist decided that there should be flexibility in term of the total number of membership of the team. This result is shown in table 7.7.

**Table 7.7 Analysis of the alternative choices for consistency of number of team members**

	Alternative choices for consistency of number of team members	No. of responses	Percent (%)	Decision
i.	Remain the same throughout the project life cycle	0	0%	<i>Consensus</i>
ii.	Change in number depending on the project phase	13	100%	
iii.	Others, please specify	0	0%	
	<b>TOTAL</b>	<b>13</b>	<b>100%</b>	

#### 7.4.4 Team Leadership

Leadership is an important criterion for the collaborative team. The consensus decision reached from the Delphi studies for this issue was the CFPT should be lead by a designated project manager. The result of the voting is shown in table 7.8

**Table 7.8 Analysis of the choices of most appropriate party to lead the team**

	<i>The most appropriate party to lead the team</i>	Result Percent. (%)	Decision
i.	Clients or their representatives	7.7%	
ii.	A designated project manager	84.6%	<i>Consensus</i>
iii.	Designers	0.0%	
iv.	Engineers	0.0%	
	Others as suggested by panellist):		
v.	Person with adequate skill and capability	7.7%	
	<b>TOTAL</b>	0.0%	

#### 7.4.5 Factors that client can contribute to teamwork

In the First Round Delphi (FRD) study the panellists were also asked to write factors that they consider the client can contribute towards the teamwork. The responses from this open-ended question are presented in table 7.9. The major categories of the responses are:

- Clients related factors
- Adequate preparation at outset
- Good management/ attitude/roles of client
- Fairness in the procurement system
- Clear project goal and direction

- Good communication system
- Adequate funding for contingency
- Realistic project goal

**Table 7.9 Content analysis result for clients contribution to teamwork**

<p><b>CLIENTS RELATED FACTOR</b></p> <ul style="list-style-type: none"> <li>▪ By being a team member, at all times not only when advantageous</li> <li>▪ Clients must clear about their objectives</li> <li>▪ He must be involved in the decision making during the progress of the project</li> <li>▪ He must not require variations</li> <li>▪ The client should limit the changes once the design phase being completed</li> <li>▪ Client must recognise the consequences of their actions</li> <li>▪ Avoid too much innovation</li> <li>▪ Used standard products</li> </ul>	<p><b>ADEQUATE PREPARATION AT OUTSET</b></p> <ul style="list-style-type: none"> <li>▪ Clearly define the brief with end users before instructing design team</li> <li>▪ Picking a QS who can estimate accurately is critical</li> <li>▪ Clearly identify the relative importance of time cost, and quality for project at outset.</li> <li>▪ Sort out very clearly what is required with the end user and alter as little as possible during the design period (the client brief.)</li> <li>▪ Set out his requirement from on-set of project</li> <li>▪ Simply by ensuring that as much work is done before starting the construction process</li> </ul>	<p><b>GOOD MANAGEMENT/ ATTITUDE/ROLES OF CLIENT</b></p> <ul style="list-style-type: none"> <li>▪ Appoint the most appropriate and competent professional team and contractors</li> <li>▪ Emphasis on quality rather than fee bid.</li> <li>▪ Holding people agreed to the specs</li> <li>▪ Monitor that his requirement is maintained</li> <li>▪ Appoint a single client representative with authority to make decisions.</li> <li>▪ Make timely decisions during design period</li> <li>▪ Listen to professional advice</li> <li>▪ Be involved in all key pre-design stages</li> <li>▪ The client is the main driver</li> <li>▪ Client will do well by being educated</li> <li>▪ Take the best professional advice and become involved.</li> <li>▪ Established clear decision making routines, so that all parties know what can be made and at what level and which have to be refereed upwards</li> <li>▪ Established a comprehensive cost control mechanism that cost each stage of the design and works so that there are no surprises.</li> <li>▪ Have clearly understood objectives and well develop brief at the outset and keep changes to a minimum.</li> </ul>
<p><b>FAIRNESS IN THE PROCUREMENT SYSTEM</b></p> <ul style="list-style-type: none"> <li>▪ Removing unfair and uneven penalties toward various</li> <li>▪ i.e damages against contractors but no penalties to design team</li> <li>▪ Payments penalties should be equal distance between each parties and the clients should be the same</li> </ul>	<p><b>MISCELLANEOUS:</b></p> <p><b>GOOD COMMUNICATION SYSTEM</b></p> <ul style="list-style-type: none"> <li>▪ Communication is efficient and clear</li> </ul>	
<p><b>CLEAR PROJECT GOAL AND DIRECTION</b></p> <ul style="list-style-type: none"> <li>▪ Build a team so that all are aiming for the same goal so that all are in a win-win situation.</li> </ul>	<p><b>ADEQUATE FUNDING FOR CONTIGENCY</b></p> <ul style="list-style-type: none"> <li>▪ Always have contingency fund for changes and unforeseen</li> </ul> <p><b>REALISTIC PROJECT GOAL</b></p> <ul style="list-style-type: none"> <li>▪ Ensure his requirement is realistic</li> <li>▪ Ensure the requirement pursued by the team is his requirement</li> </ul>	



#### **7.4.6 Important factors to overcome the lack of mutual trust in construction industry**

Question 7 of part A requested the panellist to give their opinions on the factors that they consider important to overcome the problem of 'lack of mutual trust' in construction industry. This is also an open-ended type of question. The content analysis result of the responses are presented in table 7.10. The major categories of the responses are:

- Establish long term relationship
- Common project goal
- Establish long term relationship
- Education and training
- Improved communication
- Competitive nature of the industry
- Factors related to the human nature
- Experience factor
- Grouping together for work and socialising
- Avoid special personal relationship of client with one party
- Clearly identify risk
- Partnering

**Table 7.10 Content analysis of the open ended question on the factors to overcome lack of mutual trust**

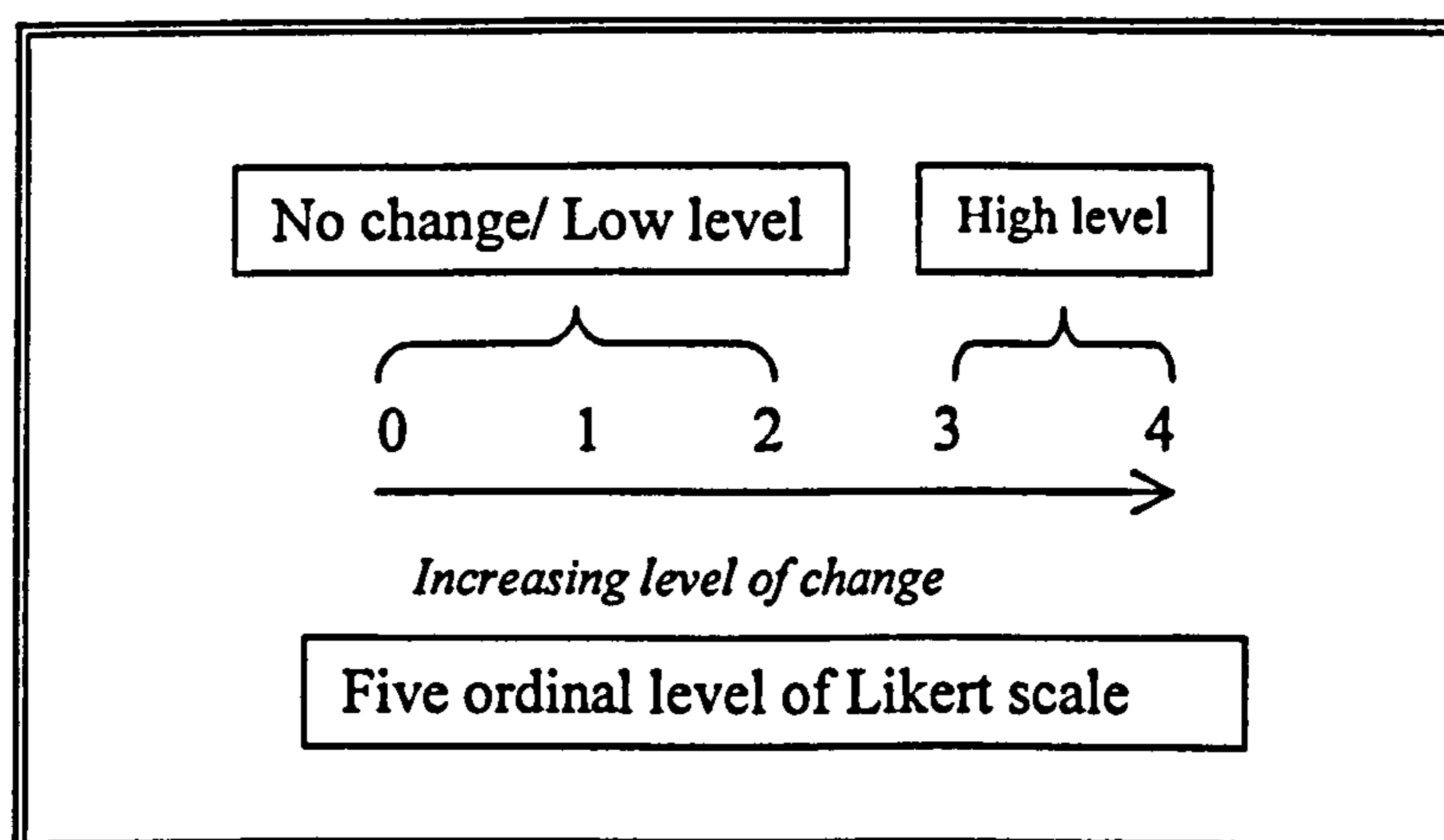
<p><b>Common project goal</b></p> <ul style="list-style-type: none"> <li>▪ Aiming for common goal would help</li> </ul> <p><b>Establish long term relationship</b></p> <ul style="list-style-type: none"> <li>▪ Long term relationship could help</li> <li>▪ Encourage the same team to work together on successive project</li> </ul> <p><b>Education and training</b></p> <ul style="list-style-type: none"> <li>▪ Multi-disciplinary training of construction professionals.</li> </ul> <p><b>Improved communication</b></p> <ul style="list-style-type: none"> <li>▪ Better communications</li> </ul> <p><b>Competitive nature of the industry</b></p> <ul style="list-style-type: none"> <li>▪ Competitive nature of the industry, contractors do not have enough margin in the tender process</li> <li>▪ Distrust occurs because contractors are seek to recover their cost</li> </ul>	<p><b>Factors related to the human nature</b></p> <ul style="list-style-type: none"> <li>▪ Human nature has much to answer</li> <li>▪ Cultural issue</li> </ul> <p><b>Experience factor</b></p> <ul style="list-style-type: none"> <li>▪ Only experience or openness and honesty will engender mutual trust</li> </ul> <p><b>Grouping together for work and socialising</b></p> <ul style="list-style-type: none"> <li>▪ Bring all team members together at start and regularly thereafter for open project related decisions and social functions</li> <li>▪ Getting used to living together will solve the problems.</li> </ul>	<p><b>Avoid special personal relationship of client with one party</b></p> <ul style="list-style-type: none"> <li>▪ Avoid private client/QS relationship.</li> </ul> <p><b>Clearly identify risk</b></p> <ul style="list-style-type: none"> <li>▪ Must clearly identified the risk and cost</li> <li>▪ Clients and their advisors must be informed judgement about contractors before tender</li> </ul> <p><b>Partnering</b></p> <ul style="list-style-type: none"> <li>▪ Partnering, joint working seminars, and social function can greatly assist</li> <li>▪ Bringing the whole team together under one roof and working alongside</li> <li>▪ More partnering type contract and less competitive tendering</li> <li>▪ Partnership is a way forward</li> </ul>
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## 7.5 Data analysis: SECTION B

Section B of the Delphi study questionnaire evaluates the various factors that are considered important to support the formation of the CFPT in accordance to the CE principles within construction industry environment. The analysis of each of the questions is presented here.

### 7.5.1 Expected level of changes to support CFPT implementation

To realise the formation of CFPT according to CE principles within the current construction industry environment requires some changes within the current practices. Several issues related to the client factors, team members factors, and existing procurement system and process have been presented to the panellist for evaluation. A Likert scale of five discrete ordinal level of agreement from 0 to 4 was used in the questionnaire. The analysis to determine the consensus level of opinion divided the panellist's voting into two sections of 'high level' of change expected and 'No change'/'Low level' as shown in figure 7.2



**Figure 7.2** Categorisation of 'High' and 'Low' level of changes on Likert scale

The analysis of result for question 1 in section B of the Delphi questionnaires survey is shown in table 7.11

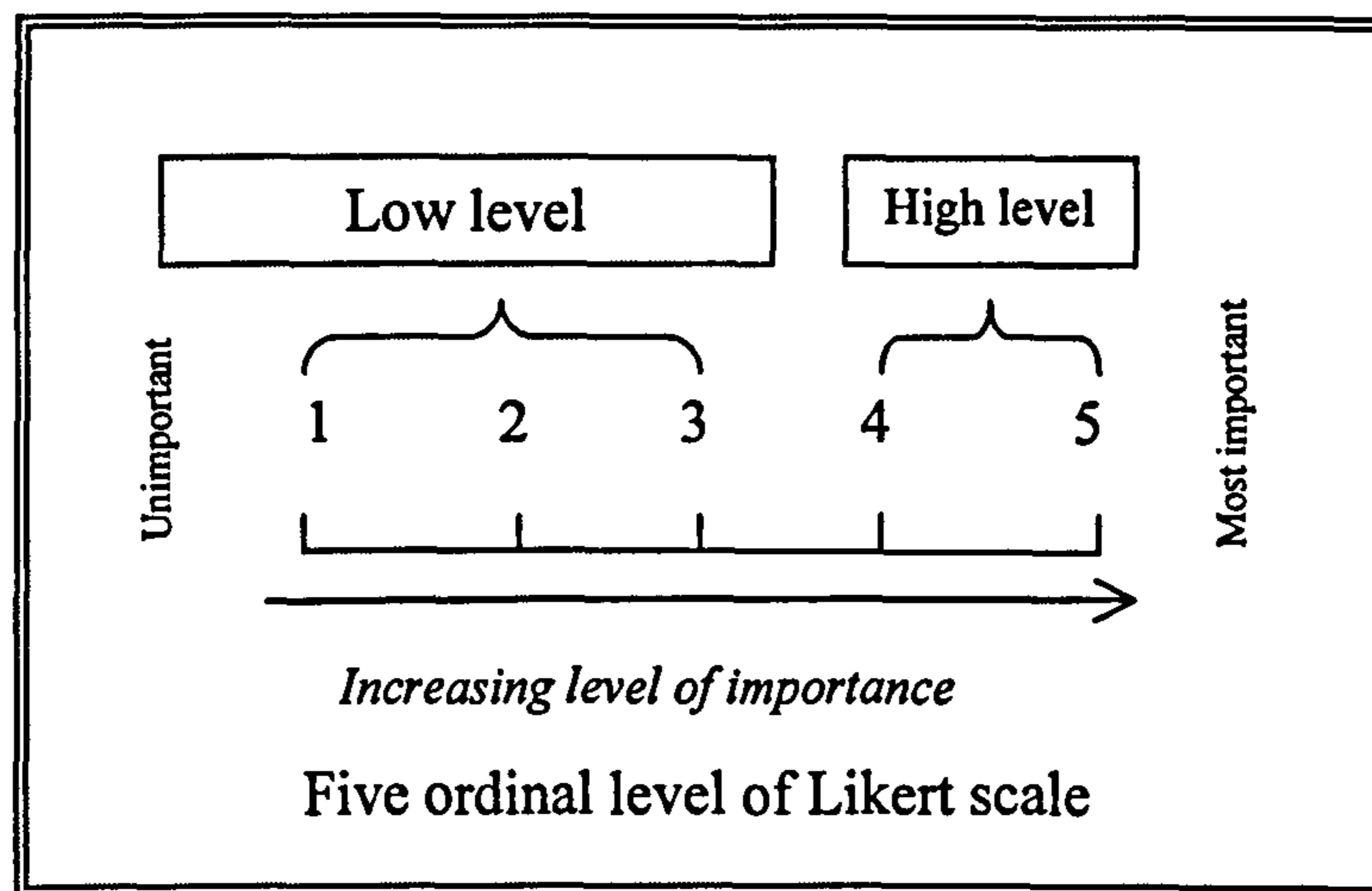
**Table 7.11 Level of changes expected from the formation of the CFPT in construction industry**

	Factors	Total score (%)		Delphi decision
		Low level (score <3)	High level (score ≥3)	
a.	Existing traditional procurement system.	23.1	76.9	Consensus
b.	Existing traditional process.	23.1	76.9	Consensus
c.	Relationship between the various functional groups in the project.	23.1	76.9	Consensus
d.	Role of the client in project leadership	15.4	84.6	Consensus
e.	Initiative of the client in supporting the teamwork.	23.1	76.9	Consensus
f.	Allowance for special provision in the contract to support teamwork approach as mentioned above.	33.3	66.7	No consensus
g.	Adoption of special criteria to select team member.	16.7	83.3	Consensus
h.	Collocation of project team members into a common office	10.0%	90.0%	Consensus

Most of the issues presented received consensus agreement from the panellists that a high level of change should be expected within those issues (table 7.11) to realise the formation of CFPT . Only one issue related to the 'use of the specific provision in the contract' did not received consensus opinion of the panellist. This indicated that using a partial approach such as partly changing some aspect of contract provision is inadequate to support formation of CFPT.

### **7.5.2 The level of importance of various factors related to teamwork requirement**

Question 2 of section B evaluated the panellists' opinion on the importance of the issues related to team authority and flexibility and the requirement of project information for the CFPT. A Likert scale of five discrete ordinal level of importance (from 1 to 5) as shown in figure 7.3 was used for panellist to rate. Their total score was divided into two categories as shown in figure 7.3. 'High level' of score was accounted for total proportion in percentage of the panellists rating of 4 and 5 on Likert scale.



**Figure 7.3** Categorisation of 'High' and 'Low' level of 'importance' on Likert scale

The result of the Delphi study on the issues related to the level of importance of various factors related to teamwork requirement is presented in table 7.12.

**Table 7.12 Issue related to the CFPT requirement**

	Delphi issues	Total score (%)		Delphi decision
		Low level (score ≤3)	High level (score >3)	
a.	The team must be given the power to override an individual functional group's decision.	50	50	No consensus
b.	The team must be given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members.	15.4	84.6	Consensus
c.	Team members must be given adequate authority and flexibility to contribute and to review the design throughout its development phase.	7.7	92.3	Consensus
d.	Final adoption of the design for the project must be made upon the consensus decisions of team members.	46.2	53.8	No Consensus
e.	The team must be provided with the adequate information relating to:	7.7	92.3	Consensus
	i) project planning the end users' requirements			
	ii) project scheduling			
	iii) basic design requirements			
	iv) project cost			
	v) the duties and responsibilities of other team members			
	vi) the project priorities			
	Vii) the client's requirements			
Viii) The end user's requirements				
f.	Final adoption of the design by the designers will take into account input from other team members but not necessarily require unanimous agreement decision of the team members.	30	70	No consensus
g.	The need for the project to accommodate a new physical working environment such as sharing common offices.	10	90	Consensus
h.	Attitudes toward sharing common project information must be change from the current attitude when working in the traditional project environment.	0	90	Consensus
i.	The quantity surveyor (estimator) for the project must cost alternatives as design proceeds.	0	90	Consensus

The analysis showed that the consensus agreement of the panellists on most of the issues presented (table 7.12). Three issues that did not achieve consensus agreement after the SRD were (a), (d) and (f). Issue (a) related to the authority of the team to override individual functional group decision. This suggests that a 'soft' approach is needed in the initial stage in giving the authority to the CFPT within current environment. This view is further strengthened with the finding from (d) and (f). In (d) panellist less agreeable to the idea of giving the CFPT full authority toward to adopt final design solution. In (f) even though the score lacked of consensus opinion the score recorded (70 percent) suggested that it was a better solution than (d) in managing the design process issue for the team.

### **7.5.3 Level of changes required to support formation of CFPT at outset**

Formation of CFPT at the outset of the project is not a common approach in construction. Some changes are expected to take place to support this way of working. Four related issues were presented to the panellist in the Delphi study for them to determine level of changes that may take place. A Likert scale using five ordinal measurements as shown in figure 7.2 was used. Similar approach of analysis to determine the consensus level as in the question 1 (section 7.5.1) was adopted. The result is shown in table 7.13

**Table 7.13 Level of agreement on the issues related from the formation of the CFPT at outset**

	Delphi issues	Total score (%)		Delphi decision
		Low level (score <3)	High level (score ≥3)	
a.	Changes must be made to the 'traditional' procurement System.	15.4	84.6	Consensus
b.	The participants to a project will need educating and training in collaborative working.	15.4	84.6	Consensus
c.	The client must be willing to pay additional costs for the appointment of all team members at the start of the project.	23.1	76.9	Consensus
d.	The client will be required to input additional resources to manage and co-ordinate the project team.	69.2	30.8	No consensus

All the issues presented except issue (d) received the consensus opinion of the panellists. The panellist did not consider that the formation of the CFPT at outset requires the client to input additional resources to manage and co-ordinate the project team.

#### **7.5.4 Mechanism that can be used to support to achieve the formation of CFPT at outset**

There are many optional mechanisms that can be used to support the formation of CFPT at outset. Some of these were evaluated in the Delphi study. The panellists were requested to rate their level of importance for each of the mechanism presented using Likert scale of five ordinal scales as shown in the figure 7.3. A similar approach of analysis to determine the consensus level as in the question 2 (section 7.5.2) was adopted. The result is tabulated in table 7.14.



**Table 7.14 Mechanism to achieve the formation of the CFPT at outset**

	Delphi issues	Total score (%)		Delphi decision
		Low level (score $\leq 3$ )	High level (score $>3$ )	
a.	Initiative from clients.	15.4	84.6	Consensus
b.	Initiative from parties approached by the clients To develop the project.	15.4	84.6	Consensus
c.	Initiative from regulatory agencies.	91.7	8.3	Consensus
d.	Use of procurement system	38.5	61.5	No consensus
e.	Initiative from industry group	40	60	No consensus

The panellist agreed that initiative from client and the parties approached by the client are the important mechanism to support the formation of CFPT from outset. Panellist consensually vote that the initiative from regulatory agencies not a viable approach to support formation of CFPT at outset. They also cannot reach consensus agreement to consider the use of the procurement system and initiative from industry group to support formation of CFPT at outset.

### 7.5.5 The framework to support CFPT

The Delphi study also evaluated the appropriate framework that can be used to support the formation of CFPT within a construction industry environment. The findings from the panellist's opinion are presented in table 7.15

**Table 7.15 : The framework to support CFPT**

	<b>Type of framework to support the CFPT in construction industry environment</b>	<b>Percentage of vote (%)</b>	<b>Decision</b>
a.	Matrix form of organisation.	0	No consensus opinion on the issue
b.	A core 'cross functional project team' surrounding by smaller functional teams.	69.2	
c.	Virtual organisation' form of 'cross functional project team' in which co-ordination and communication rely on information technology.	23.1	
d.	No specific form can be defined because it depends on the individual project's requirement as in other industries.	7.7	
e.	Others, please specify:	0	

The analysis of the responses from the panellists shows that there is no consensus agreement on any particular approach that should be adopted. This finding indicated that the framework to support the formation of CFPT in construction should be a flexible option to suit individual requirements of project.

#### **7.5 6 The barriers to support the formation of the team from outset**

Question 6 of section B used the open-ended type of question to generate panellists opinion on the factors that inhibit the formation of team at outset of the project. The responses given by the panellists are displayed in table 7.16. They are divided into three major groups :

1. Lack of understanding of the approach and confidence in the project.
2. Perceived problem.
3. Issue related to the traditional 'adversarial relationship' issue.

**Table 7.16 SECTION B (Q6) : FACTORS THAT INHIBIT FORMATION OF THE TEAM FROM OUTSET OF THE PROJECT**

LACK OF UNDERSTANDING OF THE APPROACH AND CONFIDENCE IN THE PROJECT	PERCEIVED PROBLEM	TRADITIONAL 'ADVERSARIAL' RELATIONSHIP ISSUE
<p><i>Lack of understanding and confidence in the approach</i></p> <ul style="list-style-type: none"> <li>• Perceived benefit in proving improve design quality and financial reform</li> <li>• Clients must understands the benefits of early involvement of other members of the team.</li> <li>• Few example of team working in this way, clients likely to be unenthusiastic to adopt untried methods</li> </ul> <p><i>Lack of confidence in the project</i></p> <ul style="list-style-type: none"> <li>• Availability of team members</li> <li>• Certainty that the project will go ahead</li> <li>• Most projects never get off ground</li> <li>• Long term commitment of team members (especially when skill are in short supply- team members moving to another employers</li> </ul>	<ul style="list-style-type: none"> <li>• Cost of involving the team members with little input at initial stages.</li> <li>• Severe limitation of fund in the early stages</li> <li>• The long gestation period of many project</li> <li>• Liability for designers decision</li> <li>• Procurements issue</li> <li>• Potential lost of competitive edge in the future work</li> <li>• lack of trust time!</li> <li>• Lack of common standards e.g. It systems</li> <li>• The need for client to choose the team trusting that fair and reasonable terms that can be later negotiated when the project is adequately defined</li> <li>• Traditional approaches to the contracts</li> <li>• The unwillingness of the e.g. Architects to embrace other parties in the design process</li> <li>• Reluctance of designers to accept views of the team</li> <li>• Not all team members being at the same level of training /education in team working</li> <li>• Lack of training</li> </ul>	<ul style="list-style-type: none"> <li>• Cultural problem</li> <li>• People attitude</li> <li>• Professional jealousy between consultants/contractors and contractors/SC/suppliers</li> <li>• Lack of trust</li> <li>• The detached position taken by client and his reliance upon professional team</li> <li>• Clients commitments</li> <li>• Traditional clients</li> <li>• Tendency to keep project secret.</li> <li>• Entrenched attitude of potential participants</li> <li>• Communications</li> <li>• Unwillingness to share information with others</li> <li>• Litigious nature of the industry</li> <li>• Professional pride</li> </ul>

## **7.6 Data Analysis: SECTION C**

Section C of the Delphi questionnaires evaluated the information technology requirements to support the communication for the CFPT. The analysis of the Delphi questionnaires for this section is presented here.

### **7.6.1 Analysis of the level of change require to enable key information to be made available for CFPT member**

To enable the CFPT to operate more efficiently there is need to make sure that key project information to be made available to the members. However sharing information across the functional boundaries is not a common practice in construction. To achieve this there is a need for some changes to be taken place within certain aspects of the industry practice. Some of these factors were presented for the Delphi panellist consideration to determine the level of changes expected. The ordinal scale used for rating, and the analysis to determine the consensus level of opinion of the panellist follow the same approach as in section 7.5.1. The results of the Delphi studies on this issue are presented in table 7.17.

**Table 7.17 Change from current practice requirement toward adoption of IT to support CFPT formation and related issues**

	Delphi issues	Total score		Decision
		<3	≥3	
b.	Changes in the industry culture.	7.7%	92.3%	Consensus
c.	Changes to the existing procurement systems.	23.1%	76.9%	Consensus
d.	Changes in information technology commonly used on a construction project (telephone, fax, E-mail, etc.).	30.8%	69.2%	No consensus
e.	New criteria for selection of project team members.	46.2%	53.8%	No consensus
f.	The attitude of the project team (Team members are expected to be more open in their attitude towards the used of information technology tools.	7.7%	69.2%	No consensus
g.	Leadership in IT use for the project. (The management team for the project should lead the promotion of the use of information technology within the project)	10.0%	90.0%	Consensus
h.	The way the project is managed must exhibit greater reliance on the use of IT.	55.6%	44.4%	No consensus

Note: Question (a) has been dropped for SRD.

From the analysis of the result the panellists had determined that the following factors require a high level of change: (b) the industry culture; (c) existing procurement system; and (g) leadership in IT. Other factors presented that did not received consensus opinion for high level of change include: (d) changes in the technology currently used; (e) criteria for team members selection; (f) attitude of team members; and the way IT is managed in projects (h).

## 7.6 2 Information technology tools to support CFPT

The Delphi study also evaluated the application of the common information technology tools to support CFPT communication. The tools are shown in table 7.18 along with the result of the assessment of the panellists. To procedure for rating the important level of

each tool and assessment of the consensus agreement of panellist use the same approach as in section 7.5.2. The result of the assessment is shown in table 7.18.

**Table 7.18 Information technology tool to support teamwork**

	Delphi issues	Total score (%)		Delphi decision
		Low level (score $\leq 3$ )	High level (score $>3$ )	
a.	Personal information systems (e.g. word processor, spreadsheet, databases, desktop publishing, presentation applications)	61.5%	38.5%	No consensus
b.	Workgroup information systems (e.g. E-mail, video conferencing, workgroup decision support system, workgroup databases etc.)	23.1%	76.9%	Consensus
c.	Enterprise information systems (e.g. EDI, interdepartmental management information system, inter enterprise systems integration)	53.8%	46.2%	No consensus
d(i).	Shared project database	0.0%	100.0%	Consensus
d(ii).	Electronics meeting (not to replace) traditional	60.0%	40.0%	No consensus
d(iii)	Electronic data and voice mail	20.0%	80.0%	Consensus
d(iv)	Electronic team scheduling	33.3%	66.7%	No consensus
d(v)	Video conferencing	50.0%	50.0%	No consensus
d(vi)	Shared electronic project model	50.0%	50.0%	No consensus

The panellists strongly agreed (100 percent) that shared databases (d(ii)) as highly important tool that should be used. They also considered workgroup information system (b) and electronic data and voice mail (d(iii)) as highly important to support the team. The findings from this result serve as an important guideline for the research to determine which type of IT tools that are considered important to support CFPT within current construction environment. On the human aspect, the findings strongly support that it is very important for construction industry to change the attitude in accepting IT

to support project communication. The increased use of IT tool will create more opportunity for more open communication and increase the ability to share common project information such as sharing common project database.

### 7.6.3 The appointment of the information manager

The full application of information technology to support CFT will require expert assistance to manage and regulate the users. The consensus agreement of the panellist support the idea to appoint the information manager for the team. The result is shown in table 7.19.

**Table 7.19 Level of agreement on the appointment of the information manager**

	<b>Level of agreement on the appointment of the information manager</b>	<b>Percentage (%)</b>	<b>Total</b>	<b>Decision</b>
	Strongly agree	38.5	(Strongly Agree + Agree) 77%	Consensus
	Agree	38.5		
	Neutral	15.3	Neutral: 5.3%	
	Disagree	7.7	(Disagree + Strongly disagree) 7.7%	
	Strongly disagree	0		

## 7.7 Development of the guidelines to support the formation of CFPT to construction

Based on the consensus decision of the panellist on the issue presented in the Delphi study, the research has developed a set of guidelines that can be used to support the formation of CFPT within construction industry environment as an effort to achieve CE implementation to construction. Table 7.20 presents the summary of the process toward the development of the guidelines to support the formation of CFPT based on

the findings from Delphi studies. This guideline was further validated with the findings of case studies in chapter eight. Finally guided by the overall findings of the research, the specific guidelines developed from the Delphi study will be further complemented by the establishment of the 'General guidelines'. The summary of the 'overall' guidelines to support the formation of the CFPT in construction as a process toward implementing CE philosophy to construction is presented in chapter eight. Figure 7.4. illustrated the overall process toward the development of these guidelines.



**Table 7.20 : Development of Guidelines for the formation of CFPT from the Delphi studies**

Item No.	KEY ISSUE IN CFPT	MAIN SSSUE PRESENTED TO THE PANNELLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
1.	<p><b>Team component</b></p>	<p>a. Who should be in the team?                      b. How to prioritise the inclusion of team members into the team in stages throughout the design development process?</p>	<p>Rankings established for the stakeholders that :</p> <ul style="list-style-type: none"> <li>- can influence project design; and</li> <li>- have the ability to contribute to the design</li> </ul> <p>Based on those rankings special criteria adopted to prioritise the intake of the team members at different stages of the design development process.</p>	<p>1. The top priority of the members to be included in the briefing process can be based on the rankings* of the stakeholders that can influence the design.</p> <p>2. The top priorities of the members to be included in the later stage of the design (i.e. before commencement of the sketch design stage) can be based on the rankings* of stakeholders that can contribute to the design (if they are not already included earlier.)</p> <p><i>Note: * Rankings are provided in page 241</i></p>
2.	<p><b>Number of representative for each functional group in CFPT</b></p>	<p>How many members should represent each functional group?</p>	<p>Depending on the role of the functional group, some may have more than one representative</p>	<p>There should be flexibility in term of the number of representative from each functional group in the CFPT depending on their roles.</p>
3.	<p><b>Consistency of team members</b></p>	<p>Should the number of the CFPT members remain constant or flexible in the project life cycle?</p>	<p>Change in number depending on the project phase</p>	<p>The number of the team members should not be fixed. It should be varied from one stage of the project life-cycle to the another.</p>
4.	<p><b>Team Leadership</b></p>	<p>Who should lead the team?</p>	<p>A designated project manager should lead the team</p>	<p>It is preferable to have a designated project manager to lead the team.</p>

**Table 7.20 (cont.): Development of Guidelines for the formation of CFPT from the Delphi studies**

Item No.	KEY ISSUE IN CFPT	MAIN ISSUE PRESENTED TO THE PANEILLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
5.	The necessary changes expected from current practice to support formation of CFPT	Important aspects that are expected to have high level of changes from the current practice resulted from the formation of CFPT	<p>High level of changes expected from the following aspects :</p> <ol style="list-style-type: none"> <li>Existing traditional procurement system</li> <li>Existing traditional work process</li> <li>Relationship between the various functional group in the project</li> <li>Roles of clients in the project leadership</li> <li>Initiative of the client in supporting the teamwork</li> <li>Team members should be co-located in the common office</li> <li>There should be a special criteria to select the team members</li> </ol>	<p>To realise the formation of the CFPT in construction the following changes expected from the current practice:</p> <ol style="list-style-type: none"> <li>Existing traditional procurement system</li> <li>Existing traditional work process</li> <li>Relationship between the various functional group in the project</li> <li>Roles of clients in the project leadership</li> <li>Initiative of the client in supporting the teamwork</li> <li>Team members should be co-located in the common office</li> <li>There should be a special criteria to select the team members</li> </ol>
6.	Team roles and authority in the design	<ol style="list-style-type: none"> <li>Should CFPT given the power to override individual functional group decision?</li> <li>Team accountability in the for project design with leading role taken by the designers</li> </ol>	<p>There is no consensus opinion of the panellist to support this</p> <p>The team should be given the accountability for project design with leading role taken by the designers</p>	<ul style="list-style-type: none"> <li>There should be a moderate approach in giving the team the power to overrule individual functional group decision.</li> <li>The team should be given the accountability for project design with leading role taken by the designers</li> </ul>

Table 7.20 (cont.): Development of Guidelines for the formation of CFPT from the Delphi studies

Item No.	KEY ISSUE IN CFPT	MAIN ISSUE PRESENTED TO THE PANELLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
	Team roles and authority in the design (cont.)	iii. Should team members given the authority and flexibility to contribute and review the design throughout the design development process. iv. Final adoption of the design for the project must be made upon the consensus decisions of team members. v. Final adoption of the design by the designers will take into account input from other team members but not necessarily require unanimous agreement decision of the team members. vi. Quantity Surveyor roles to support design process	Consensus opinion supporting the issue  There is no consensus opinion of the panellist to support this issue  Issue supported with consensus opinion of the panellists  Quantity surveyor must cost alternatives as design proceeds.	<ul style="list-style-type: none"> <li>• Team members given the authority and flexibility to contribute and review the design throughout the design development process.</li> <li>• Using consensus opinion as a criteria to adopt final design solution is inappropriate practice within current construction industry environment.</li> <li>• The designers (architects or engineers) should take leadership in design and make final design solution upon consideration of the requirements and inputs of other team members.</li> <li>• Quantity surveyor (estimators) have the role to support the design process by costing alternatives as design proceeds.</li> </ul>
7.	Requirement for co-location of team members	The need to accommodate a new physical working environment such as sharing common office	There is a need to provide team members with a new working environment such as co-location in a common office	<ul style="list-style-type: none"> <li>• Team members should be co-located in a common office.</li> </ul>

Table 7.20 (cont.): Development of Guidelines for the formation of CFPT from the Delphi studies

Item No.	KEY ISSUE IN CFPT	MAIN ISSUE PRESENTED TO THE PANELLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
8.	<p><b>Formation of the team at outset</b></p> <p><i>Requirement to support the formation of the team at outset</i></p>	<p>a. Requirement of change from current traditional procurement systems</p> <p>b. Requirement for education and training for project participants</p> <p>c. Clients willingness to pay for additional cost for the appointment of team members at outset</p> <p>d. Clients willingness to input additional resources to manage and co-ordinate the project team</p>	<p>Consensus opinion supporting the issue</p> <p>Consensus opinion supporting the issue</p> <p>Consensus opinion supporting the issue.</p> <p>No consensus opinion</p>	<p>To achieve the formation of CFPT from outset changes from the current practice are expected within the following aspects:</p> <p>a. There is a need to review the current procurement system.</p> <p>b. Training and education is an important instrument to support the team members participating in the team from outset</p> <p>c. Client must be willing to pay the initial additional cost for the appointment of team members at outset</p>
ii.	<p><b>Formation of the team at outset</b></p> <p><i>Mechanism to achieve the formation of the team at outset</i></p>	<p>The appropriate mechanism that may be used to achieve formation of the team at outset.</p>	<p>The appropriate mechanism that were considered highly important to achieve formation of the team from outset are:</p> <p>a. Initiative from client</p> <p>b. Initiative from parties approached by the clients</p>	<p>The important mechanisms to support the formation of the team at outset are through:</p> <p>a. The Initiative from client; and</p> <p>b. The Initiative from parties approached by the clients.</p>

**Table 7.20 (cont.): Development of Guidelines for the formation of CFPT from the Delphi studies**

Item No.	KEY ISSUE IN CFPT	MAIN ISSUE PRESENTED TO THE PANNELLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
9.	Organisational structure to support CFPT	The appropriate organisational structure to support CFPT within construction environment	No single type of framework (organisational structure) considered appropriate to support CFPT.	There should be flexibility in developing appropriate teamwork structure for the team to suit the actual need of construction project.
10.	Project information sharing <i>Important changes from the current practice</i>	The important changes needed to support information sharing among key members within collaborative working environment	The following changes are considered highly importance by the panellist: a. Changes in the industry culture b. Changes to the existing procurement systems c. Change in the attitude of project team members toward the use of IT tools d. Leadership in IT used for the project	1. The availability of key project information to the CFPT members is an important criterion working under collaborative (CE) environment. To achieve this objective require the changes within the following aspects: a. Changes in the industry culture b. Changes to the existing procurement systems c. Changes in the attitude of project team members toward the use of IT tools  2. There is a need for leadership in IT used for the project.

Table 7.20 (cont.) Development of Guidelines for the formation of CFPT from the Delphi studies

Item No.	KEY ISSUE IN CFPT	MAIN ISSUE PRESENTED TO THE PANNELLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
11.	<i>Project information requirements</i>	What are the appropriate project information requirement for CFPT ?	<p>The CFPT must be provided with the adequate information related to the:</p> <ul style="list-style-type: none"> <li>- the duties and responsibilities of other team members</li> <li>- the project priorities</li> <li>- the client's requirements</li> <li>- the end users' requirements</li> </ul>	<p>There must be openness toward sharing common project information within CFPT collaborative environment.</p> <p>Among the important project's information that need to be furnished to CFPT members are related to the:</p> <ol style="list-style-type: none"> <li>1. Project planning</li> <li>2. Project scheduling</li> <li>3. Basic design requirement</li> <li>4. Project cost</li> <li>5. The duties and responsibilities of other team members</li> <li>6. The project priorities</li> <li>7. The client's requirements</li> <li>8. The end users' requirements</li> </ol>
12.	<i>Appropriate tools to support CFPT communication</i>	What are the appropriate IT tools to support CFPT communication?	<p>The following IT tools were considered important by panellists to support CFPT communication:</p> <ul style="list-style-type: none"> <li>- Workgroup information systems</li> <li>- Shared project database</li> <li>- Electronic data and voice mail</li> </ul>	<p>The following IT tools are useful to support CFPT communication and information sharing:</p> <ol style="list-style-type: none"> <li>1. Workgroup information systems</li> <li>2. Shared project database</li> <li>3. Electronic data and voice mail</li> </ol>

Table 7.20 (cont.) Development of Guidelines for the formation of CFPT from the Delphi studies

Item No.	KEY ISSUE IN CFPT	MAIN SSSUE PRESENTED TO THE PANNELLISTS	FINDING FROM DELPHI STUDY	GUIDELINES FOR CFPT FORMATION BASED ON CE
13.	Roles of information manager	The need to allocate a member of a team for the role of information manager	Consensus agreement of the need to allocate a member of a team for the role of information manager.	There is a need for the CFPT to allocate a post of information manager.

5. Main structure  
 6. Service contractors  
 7. Carriers  
 8. Transport  
 9. Sub-structure  
 10. Suppliers

11. Client  
 12. Service contractors  
 13. End user (customer)  
 14. Suppliers  
 15. Carriers  
 16. Sub-structure

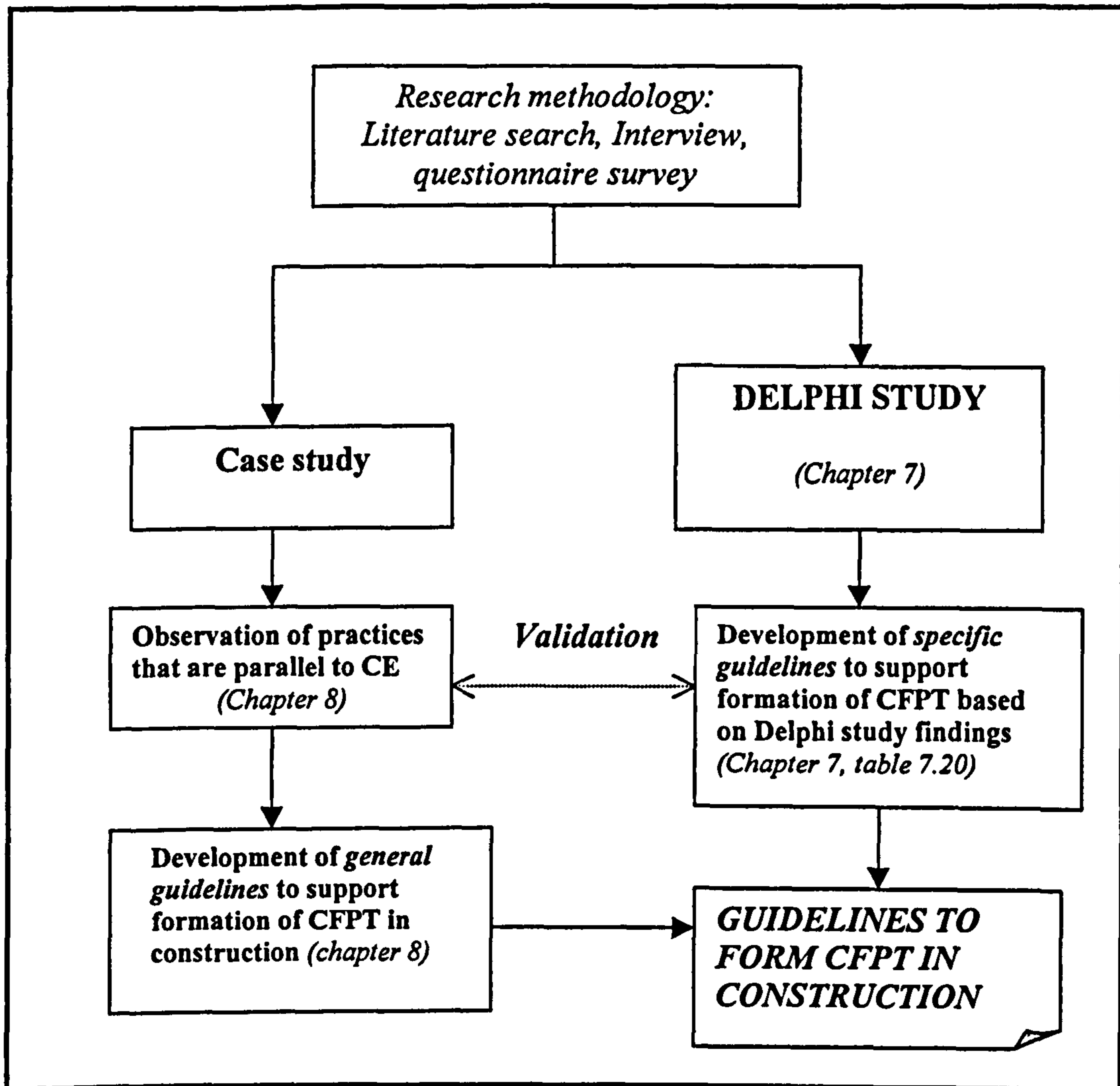
Notes:  
 Client consists of customers in the network who are used to the system to provide key information early in the day. Their information requirements are not recognized through a main structure. It is only through the inclusion of the main structure that the system can be designed.

Note: The information supplied here comes as a supplement to the data in Table 7.20

LIST OF PRIORITIES OF MEMBERS TO BE INCLUDED IN THE CFPT AT BRIEFING STAGE	LIST OF PRIORITIES OF MEMBERS TO BE INCLUDED IN THE CFPT AT LATER DESIGN STAGE (SKETCH DESIGN STAGE)
<ol style="list-style-type: none"> <li>1. Client</li> <li>2. End user (customer)</li> <li>3. Architect</li> <li>4. Engineers</li> <li>5. Main contractors</li> <li>6. Service contractors</li> <li>7. Surveyors</li> <li>8. Financiers</li> <li>9. Sub-contractors</li> <li>10. Suppliers</li> </ol>	<ol style="list-style-type: none"> <li>1. Architect</li> <li>2. Engineers</li> <li>3. Main contractors</li> <li>4. Sub-contractors</li> <li>5. Client</li> <li>6. Service contractors</li> <li>7. End user (customer)</li> <li>8. Suppliers *</li> <li>9. Surveyors</li> <li>10. Financiers</li> </ol> <p><b>Note:</b> Other sources of materials in the research indicate that it is important to include key suppliers early in the team. Therefore if their requirement is not represented through the main contractors, it is very important to include them in the team before sketch design stage commence.</p>

**\*Note: The information supplied here serve as a supplement to the item no. 1 in table 7.20**





**Figure 7.4** Approach in the development of "Guidelines to support the formation CFPT in construction"

## 7.8 Summary

The Delphi (inspired) study used in this research has the following features:

1. The use of thirteen construction industry experts as panellist
2. Two co-ordinators
3. Involved two rounds of voting
4. Involved two ways of communication: response and comments from panellist and feedback of the analysis of the vote.
5. Use 75 percent limit of score to determine the consensus level.

6. Use structured questionnaire survey as a instrument for panellist to response.
7. The two ways communication between panellist and co-ordinator was supported by the availability of other optional mean of contact for the panellist to clarify any issue throughout the process. The available means for the panellists were: face to face meeting, telephone; telefax; and e-mail.
8. Anonymity of the panellists were strictly maintained.

The overall study covers three major area related to the formation of CFPT to construction:

- Section A: The assessment to determine the team component and leadership
- Section B: The evaluation of the factors that support the formation of the team
- Section C: The evaluation of the information technology requirement to support the team

The major findings from the two round of Delphi (inspired) study are:

**Section A:**

1. The order of the priority of the major stakeholders to be included in the earlier stage of the design development phase of the project life cycle are:
  1. Client
  2. End user (Customer)
  3. Architects
  4. Engineers
  5. Main contractors
  6. Service contractors
  7. Surveyors
  8. Financiers
  9. Sub- contractors
  10. Suppliers

2. The order of the priority of the major stakeholders to be included in the later stage of the project design development (sketch design), if they are not included earlier are:
  1. Architects
  2. Engineers
  3. Main- contractors
  4. Sub- contractors
  5. Client
  6. Service Contractors
  7. End user(customer)
  8. Suppliers
  9. Surveyors
  10. Financiers
3. The panellist also determined the team should be flexible in term of the number of the representative from each functional group and the dynamic nature of the team in term of the number of membership throughout the project life.
4. A designated project manager considered the best party should lead CFPT.
5. Among the major contribution that the client can made to contribute to the team performance are by:
  - Being a team member at all time.
  - Involved in the decision making.
  - Ensure adequate preparation made at outset to facilitate other team member understanding of his requirements and constraints.
  - The client should exhibit good management practice in decision making, getting involved in the project, getting appropriate professional advice and be realistic with his requirements and goals.
  - The client must established good communication system.
6. The panellist suggest that the to overcome the lack of mutual trust culture in construction industry currently, among other are:

- We must aim for common goal in the project.
- Established long term relationship.
- Must take into consideration of the aspect related to human nature.
- Encourage the team members to get together in work and socialising.
- Avoid personal relationship of client with one particular party only.
- Clearly identify risk.
- Use partnering platform.
- Improve education and training on teamwork.
- Improve communication.
- Ensure fairness to all team members in all aspect
- Minimise competition.

### **Section B:**

1. The important factors that were being considered as highly need to be changed (improved) to support the CFPT implementation by the panellist are:
  - The existing traditional system
  - The existing traditional process
  - Roles of client in project leadership
  - The relationship between functional group
  - Client initiative to support teamwork
  - Adoption of special criteria to support teamwork
  - Collocation of team members in the common office

The less important factors are the used specific provision in the contract to support teamwork

2. The important requirement of the team determined from the analysis are:
  - The team must be given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members.
  - Team members must be given adequate authority and flexibility to contribute and to review the design throughout its development phase.

- The need for the project to accommodate a new physical working environment such as sharing common offices.
  - The need to change the attitudes toward sharing common project
  - The need for the quantity surveyor to cost alternatives as design proceeds.
  - The team need adequate information on:
    - i) project planning
    - ii) the end users' requirements
    - ii) project scheduling
    - iii) basic design requirements
    - iv) project cost
    - v) the duties and responsibilities of other team members
    - vi) the project priorities
    - vii) the client's requirements
    - viii) the end user's requirements
3. On the formation of the CFPT at outset the panellist strongly agree the following factors:
- That changes must take place within the traditional procurement system.
  - The need for education and training on collaborative teamwork for project participants.
  - The client must be willing to pay additional cost incurred for the appointment of the team from outset.
4. The following mechanism (strategies) were considered important by the panellist to support the formation of the CFPT from outset:
- Initiative from client
  - Initiative from the parties approach by client
5. There was no consensus opinion of the panellist on the appropriate organisational structure to support the CFPT.
6. The panellists considered the following major factors as the barriers to achieve the formation of CFPT from outset:
- Lack of understanding and confidence in the approach

- Lack of confidence in the certainty that the project will ahead
- Perceived problem such as:
  - additional cost incurred,
  - limitation of fund at early stage,
  - lack of common standard,
  - unwillingness to share project information
  - different level of team member training education
- Traditional 'adversarial relationship related issue
  - Lack of trust
  - Professional jealousy
  - Litigious nature of industry
  - Detach position of client and his reliance on professional team (designers)

### Section C:

1. High level of changes within the following factors expected to enable key information made available to team members are:
  - Change in industry culture
  - Change to the existing procurement system
  - Leadership in IT application
2. The IT tool that are considered important to support teamwork are:
  - Workgroup information system
  - Shared database
  - Electronic data and voice mail
3. There was a consensus agreement of the panellist that the a member of the team should be allocated the role of information manager to ensure effective project communication

The main contributions from the Delphi study to the research is it give a clear guideline of the important factors related to the objective of formation of CFPT based on CE principles within the existing construction industry environment.

**CHAPTER EIGHT**  
**DEVELOPMENT OF MATRIX MEASUREMENT GUIDELINE -**  
**TOWARD CONCURRENT ENGINEERING IN CONSTRUCTION**  
**(MMG-TCEiC) AND CASE STUDY**

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## **8.1 Introduction**

This chapter addresses the discussion on the development of the "Matrix Measurement Guideline - Toward Concurrent Engineering in Construction" (MMG-TCEiC) and the Case Study. MMG-TCEiC is a tool developed by this research to help the industry to map the process toward achieving a collaborative teamwork environment based on CE principles within construction project. It consists of a matrix of eight columns each with six levels of achievement. It was developed based on research findings on CE cross functional teamwork practices as well as collaborative working practices within construction industry environment.

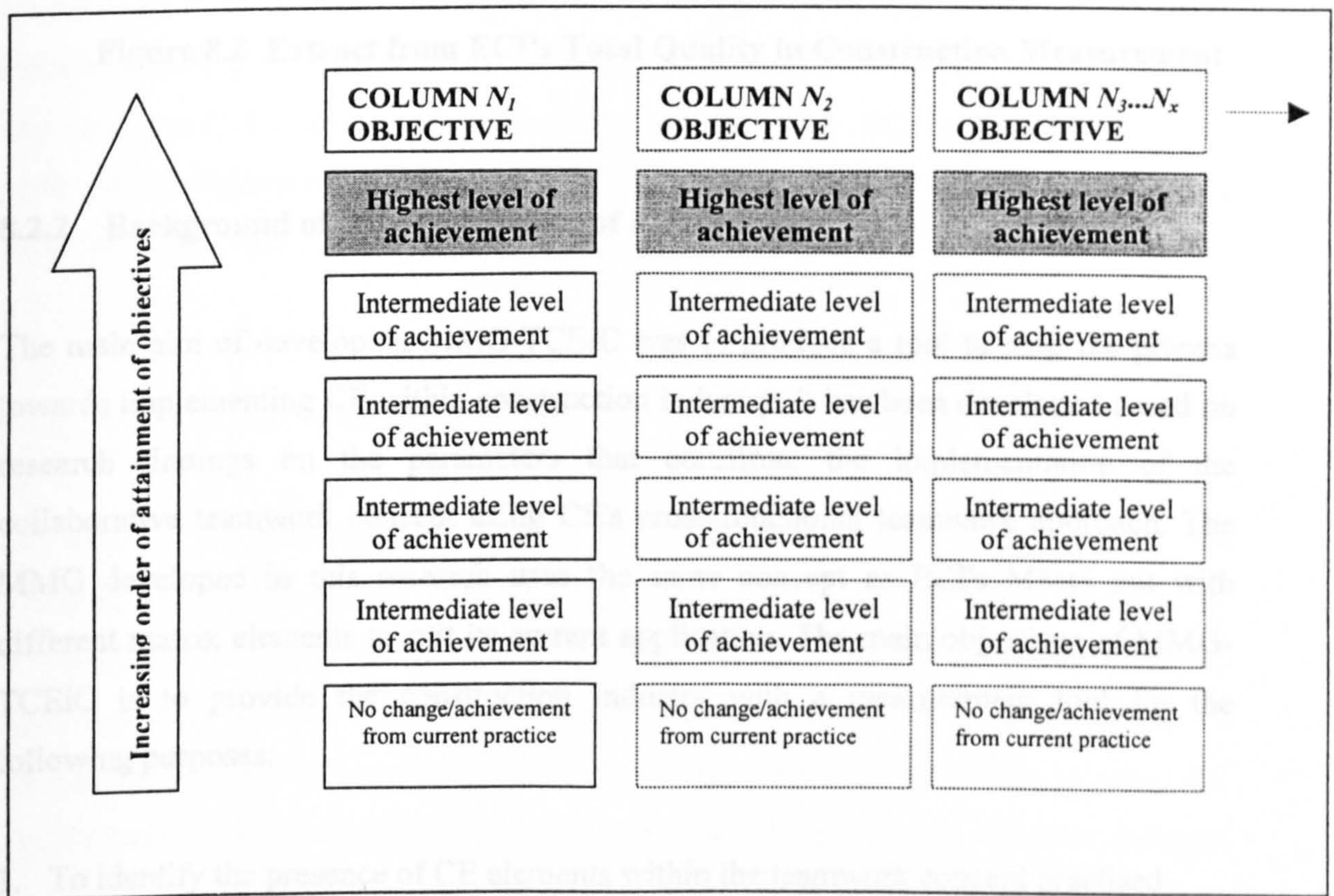
This chapter also addresses the findings from the case studies on four major construction projects. Various aspects related to the collaborative teamwork practices within the case studies were investigated. Case studies were used to demonstrate how the MMG-TCEiC might be applied. Apart from that, the findings from the case studies were used to validate the Guidelines for the Formation of the Cross Functional Project Team (CFPT) developed from Delphi study in chapter seven.

## **8.2 Background of Matrix Measurement Guideline (MMG) Development**

### **8.2.1 What is 'Matrix Measurement Guideline'?**

Matrix Measurement Guideline (MMG) is the term given by this research to generalise the original concept of using matrix table developed by European Construction Institute (ECI 1993). They used MMG concept to present the matrix for measurements of progress towards Total Quality in Construction. This concept was applied later by

Baldwin et al. (1997) when they developed the "Information Exchange Measurement Matrix for Construction Organisations". MMG is a tool designed to map the process of achieving a certain goal by satisfying the requirements of a set of objectives related to it. In principle MMG consists of the columns of the matrix, which represents the objectives that need to be achieved. Each column is divided into several levels of achievements in ascending order from the bottom to the top. This concept has been graphically shown in figure 8.1. Figure 8.2 shows the example of the partial MMG developed by ECI (1993).



**Figure 8.1 Basic concept of Matrix Measurement Guideline (MMG) structure**



	<b>COMMITMENT AND LEADERSHIP BY TOP MANAGEMENT</b>	<b>ORGANISED PROCESS AND STRUCTURE FOR TQM</b>	<b>SUPPLIERS RELATIONSHIPS (INTERNAL AND EXTERNAL)</b>	.....
<b><i>Level 5</i></b>	Fully committed and actively leading the process	Fully integrated with normal management systems	Active partnering taking place with joint improvement team-working	
<b><i>Level 4</i></b>	Committed with personal involvement	Fully defined, understood and implemented	Key staff involved in facilitating relationship	
<b><i>Level 3</i></b>	Nominates and support quality focus representatives at senior management level	Understood and partially implemented	Joint expectations reviewed and addressed	

**Figure 8.2 Extract from ECI's Total Quality in Construction Measurement**

### **8.2.2 Background of the development of MMG-TCEiC**

The main aim of developing MMG-TCEiC was to produce a tool to map the process towards implementing CE within construction industry. It has been developed based on research findings on the parameters that constitute the implementation of the collaborative teamwork concept using CE's cross-functional teamwork approach. The MMG developed in this research uses the same concept as ECI's MMG but with different matrix elements to suit its current application. The main objectives of MMG-TCEiC is to provide the construction industry with a measurement tool for the following purposes:

1. To identify the presence of CE elements within the teamwork concept practised within a construction project
2. To measure the limit of such practice within the eight major themes of the MMG-TCEiC against the desired practice in collaborative teamwork.
3. To determine the action necessary to improve the achievement within the future or current projects.

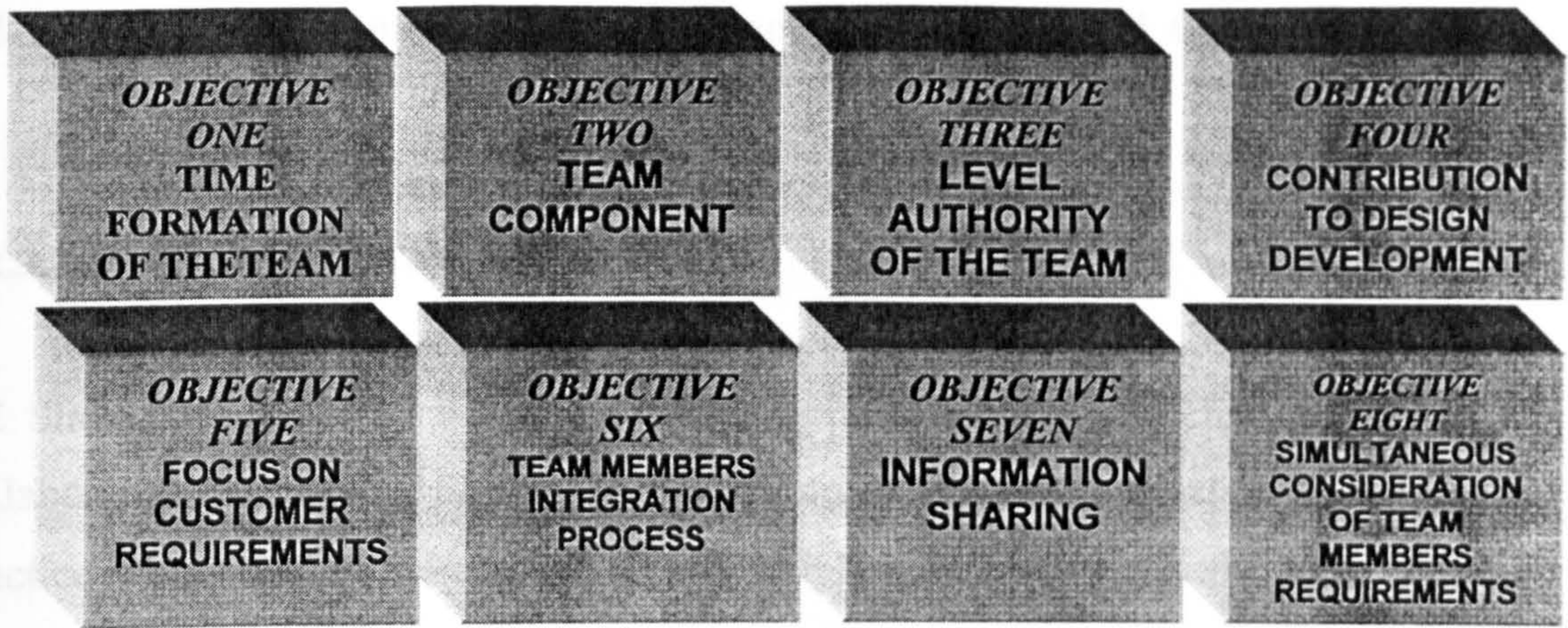
The evaluation is made by comparing the current practice of teamwork characteristics in the existing project against the normal features of cross functional team concept

based on CE principles. By measuring the limit of the practice of certain elements of CE within construction project, we are able to map their current position and devise our strategy for the next move in the route toward CE.

MMG is being devised by taking into consideration the need to customise its matrix with the actual practices of collaborative teamwork within construction industry. To achieve this objective the writer has tested MMG application against three major construction projects in the case studies. All these three case studies are known to have practised the concept of collaborative teamwork within their project. This is to ensure that the objectives made within MMG to implement CE are achievable within a construction environment. The organisations that participated in the case studies were identified through contact with senior industry representatives before each case study was conducted. In these earlier meetings, the relevant project that involved the participating organisations was identified and the existence of the collaborative working within them determined.

### **8.2.3 Basic structure of MMG-TCEiC**

The basis of the development MMG -TCEiC emanated from the aim to achieve the formation of cross-functional teamwork as a strategy to implement CE in construction. MMG-TCEiC has eight columns and six rows. The column objectives represent the eight important features of the cross functional team based on CE principle. These are the eight objectives that need to be achieved if any organisation wishes to adopt CE environment within their project. The theme for each of the column objective designed for MMG-TCEiC is shown in figure 8.3



**Figure 8.3 Eight objectives of MMG-TCEiC**

Each column is divided into six levels of rows. Each row describes the different level of characteristic relevant to the column attribute. Level one is the lowest level and has the description of the least relevant characteristic to CE cross-functional teamwork environment requirements. Level six describes the most desirable characteristic that fulfilled the column objective. The arrangement of columns is arbitrary. Each column should be evaluated independently. The three stages of CE practice are shown in table 8.1

**Table 8.1 Three stages of teamwork practice describe in MMG-TCEiC**

Level 6	<b>CE STAGE</b>
Level 5	
Level 4	<b>TRANSITION STAGE</b>
Level 3	
Level 2	<b>TRADITIONAL STAGE</b>
Level 1	

### **8.2.3.1 Description of three stages of achievement toward CE used in MMG-TCEiC**

#### **8.2.3.1.1 *CE Stage (Level 5 and 6)***

CE Stage consists of level 5 and 6 of the column matrix. The characteristic of the collaborative teamwork described in this region of the matrix meets with the desired practice within a CE environment. The description in level six is the more idealistic condition. However the achievement up to level five is adequate to fulfil the minimum CE requirements. These descriptions were developed from the findings from the literature review and interviews with CE practitioners.

#### **8.2.3.1.2 *Transition Stage Level 3 and 4***

The transformation stage represents the effort of improving the teamwork practice from traditional way toward more collaborative way. The practice is obviously different from what has been normally achieved in the traditional arrangement (described in the next section). The matrices describe in this stage indicate that there is a significant effort to create the collaborative teamwork environment in the project. This may be achieved through several approaches such as by using new (variation) procurement approach or partnering. However these practices still have many limitations compared to the CE approach of teamwork. Such practices cannot be recognised as CE even though their implementation results in better project performance and improvement compared with the traditional way.

Some of the limitations that may exist are:

- lack of participation of the key parties;
- lack of role in the design;
- does not fully formed during the design development time;
- lack of authority and flexibility;
- does not include customer/client representation in the team;

- the objective of the team formation lack of orientation toward design development;
- limitation still exist in the disseminating key project information; and
- simultaneous consideration of the team members requirement in the design is not the key objective in the team formation.

Those limitations may exist within a single column or several columns. They are evaluated independently, but are not mutually exclusive. For example if the formation of the team is not fully achieved within the design development stage, then it is impossible for the team to have adequate role in the design.

The descriptions developed in level 3 and 4 are also derived from the findings in the literature review, interviews and industry wide questionnaires survey.

#### **8.2.3.1.3 *Traditional Stage - Level 1 and 2***

The evaluations of the teamwork practices that fall under the 'Traditional Stage' indicate that the concept of collaborative teamwork has not been practised in the project. Any 'teamwork' achieved is done so in strictly defined functional division and rigid linear work process based on 'over the wall concept'. The matrices in the level 1 and 2 were developed from findings in the literature review, interviews and industry wide questionnaires survey.

#### **8.2.4 Detailed description of each of the column objectives**

The following sections will discuss the objective of each column matrix (C1 to C8). In figure 8.10 all these columns will be displayed in a single table.

### 8.2.4.1 Objective # 1 – Time of team formation

The main objective of this column is to evaluate the time frame within which the team is formed. The time factor is important to enable the team members to play their roles in the project as early as required and ensure that all their requirements can be simultaneously considered in the design development process. In a true CE environment the team is formed at the outset. Table 8.2 shows the matrix of Column Objective C1.

**Table 8.2 Matrix Column Objective C1 – Time of team formation**

<b>Level of attainment</b>	<b>MAIN THEME: Time of formation of the team (C1)</b>	<b>EVALUATION OF ACHIEVEMENT TOWARD CE IMPLEMENTATION</b>
<b>Level 6</b>	Team comprises of all key project members formed at outset of the project.	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	Formed in stages but all key members available before sketch/concept design phase commence.	
<b>Level 4</b>	Formed in stages but the inclusion of sub-contractors and key suppliers made after sketch/concept design.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but with some limitation by way of: 1. Using the traditional platform. 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	Form in stages but non-designers members include in final design stage only.	
<b>Level 2</b>	Form in stages but only includes key designer members during entire design phase.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	No formal collaborative team is formed.	

### 8.2.4.2 Column 2- Team component

The components of the team are crucial to determine the successful implementation of a CE environment. The team must have the right component of members to achieve the objectives of CE for simultaneous consideration of all parties' requirements and to enable all key members to contribute toward design development. Table 8.3 shows the matrix of Column Objective C2.

**Table 8.3 Matrix Column Objective C2 – Team component**

<b>Level of attainment</b>	<b>MAIN THEME: Team component (C2)</b>	<b>EVALUATION OF ACHIEVEMENT TOWARD CE IMPLEMENTATION</b>
<b>Level 6</b>	Consists of all key members including the clients, major sub-contractors and major suppliers.	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	Consists of all key members includes the clients, major sub-contractors and major suppliers. However major supplier representation in the team made through other party such as main contractor or specialist contractor.	
<b>Level 4</b>	Partnering team of designers and constructors based on mutual agreement or under D&B arrangement to work collaboratively but not including the client.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but with some limitation by way of: 1. Using the traditional platform. 2. Not all key members may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	Project management contractor's co-ordinated team consist of key members but confined to individual functional group.	
<b>Level 2</b>	Typical designers co-ordinated project team.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	No formal collaborative team being formed.	

### 8.2.4.3 Column 3 – Level of the authority of the team

Successful implementation of CE depends on the level of authority of the team. The team must be given adequate authority to make appropriate decision with regard to the design solution to enable it to fully functioning as desired under CE environment. Table 8.4 shows the matrix of Column Objective C3.

**Table 8.4 Matrix Column Objective C3 – Level of authority of the team**

<b>Level of attainment</b>	<b>MAIN THEME: Level of authority of the team (C3)</b>	<b>Evaluation of achievement toward CE Implementation</b>
<b>Level 6</b>	The team has adequate authority to make important project decisions including design.	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	The team has adequate authority to contribute and influence toward important project decisions (including design) but final decisions are made by clients.	
<b>Level 4</b>	Team members only given the authority to review final design and other project decisions.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but with some by way of: 1. Using the traditional platform; 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process
<b>Level 3</b>	Team members not given the opportunity to influence project design decision.	
<b>Level 2</b>	Team members do not involve in any other aspect except related to their functional role responsibilities only.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	No formal collaborative team formed.	



#### 8.2.4.4 Column 4 – Contribution to the design development

This column matrix describes the roles of the team members in the CE environment. The purpose of cross functionality component of the team is to enable simultaneous consideration of all project requirements in the design development process. All key team members are given the opportunity to contribute towards the design development process especially related to their own requirement. Table 8.5 shows the matrix of Column Objective C4.

**Table 8.5 Matrix Column Objective C4 – Contribution to the design development**

<b>Level of attainment</b>	<b>MAIN THEME: Contribution to the design development (C4)</b>	<b>Evaluation of achievement toward CE implementation</b>
<b>Level 6</b>	All team members involved in making contribution to formulate design solution from inception.	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	All team members involved in making contribution to formulate the design solution but in stages.	
<b>Level 4</b>	Not all members involved (esp. sub-contractors and major suppliers) in formulating final design solution.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but with some limitation by way of: 1. Using the traditional platform. 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	Team members only involved in reviewing the design solutions but not formulating them.	
<b>Level 2</b>	Each member reviews the design aspect related to each functional roles only.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	No contribution made at all unless the primary role as designers.	

### 8.2.4.5 Column 5 – Focus on client/customer requirements

One the main objective of CE implementation is to focus on the customer (client) requirement. This column describes the mechanism by which clients' requirements can be captured within CE environment. Table 8.6 shows the matrix of Column Objective C5.

**Table 8.6 Matrix Column Objective C5 – Focus on client/customer**

<b>Level of attainment</b>	<b>Focus on client/customer (C5)</b>	<b>Evaluation of achievement toward CE implementation</b>
<b>Level 6</b>	The client is a member of the team and participates from outset. All team members are able to address their need throughout project life cycle.	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	The client is a member of the team, which forms in stages before sketch design. Therefore not all members are able to address clients need from outset.	
<b>Level 4</b>	The client does not actively participate as a team member. Their requirements are addressed by the project manager and key designers, which represent the team.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but some limitation still exist by way of: 1. Using the traditional platform. 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	Clients needs are addressed by key designers in the design development stage. Other team members able to review their requirement in a later stage.	
<b>Level 2</b>	A collaborative team exists but client requirements are only addressed by key designers.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	Clients needs are only addressed by key designers. No collaborative team formed.	

### 8.2.4.6 Column 6 -Team member integration/organisation

This column describes how team members integrate in the project. Achieving this objective is critical to ensure team members are able to interact with each other in the most flexible manner and the removal of the ‘imaginary wall’ that impedes open project communication. Table 8.7 shows the matrix of Column Objective C6.

**Table 8.7 Matrix Column Objective C6 – Team members integration/organisation**

<b>Level of attainment</b>	<b>MAIN THEME: Team members integration/ organisation (C6)</b>	<b>Evaluation of achievement toward CE implementation</b>
<b>Level 6</b>	Team members integrate by removal of functional boundaries. May be physically collocated or virtually linked.	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	Team members integrate through their functional groups. May be physically collocated or virtually linked.	
<b>Level 4</b>	Team members integrate through their functional groups but not collocated or virtually link.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but with some limitation by way of: 1. Using the traditional platform 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	The team is organised with objectives to review each other requirements but with minimal influence to the project design.	
<b>Level 2</b>	The team is organised with the objectives to co-ordinate project task and information.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	No formal collaborative team formed.	

### 8.2.4.7 Column 7 – Information sharing

The ability for the team members to communicate effectively and share project information is crucial in a CE environment. Teams members must receive the project information related to each others' requirements to enable them to function effectively. A high level of transparency of project information is expected. The mechanism (tool) required to support team members' communication depends on the magnitude and complexity of the project. Table 8.8 shows the matrix of Column Objective C7.

**Table 8.8 Matrix Column Objective C7 – Information sharing**

<b>Level of attainment</b>	<b>MAIN THEME: Information Sharing  (C7)</b>	<b>Evaluation of achievement toward CE implementation</b>
<b>Level 6</b>	All pertinent project information including that related to design and planning available to all key team members and supported by through networking system	<b><u>CE STAGE</u></b>  The practice adequately supports CE environment.
<b>Level 5</b>	All pertinent project information including that related to design and planning available to all key team members even though not fully supported by networking system.	
<b>Level 4</b>	Information related to design and planning made available only to team members involved in the design. Other general project information available to the rest.	<b><u>TRANSITION STAGE</u></b>  Elements of collaborative teamwork exist but some limitation still exist by way of: 1. Using the traditional platform. 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	Information related to design and planning made available only to those involved in the design. Other general project information available to other key members.	
<b>Level 2</b>	High degree of information control applied in the project system. Team members only get information related to their functional roles only.	<b><u>TRADITIONAL STAGE</u></b>  A typical traditional practice based on rigid divisional of functional roles and using sequential work process.
<b>Level 1</b>	No formal collaborative team being formed. Exchange of information strictly regulated.	

**8.2.4.8 Column 8 - Support for simultaneous consideration of team members requirement**

The most important feature of CE is to enable the concurrent or simultaneous consideration of all project life cycle requirements in the design phase. In order to achieve this objective key project team members must be able to participate in the design process. Table 8.9 shows the matrix of Column Objective C8.

**Table 8.9 Matrix Column Objective C8 – Simultaneous consideration of requirement**

<b>Level of attainment</b>	<b>MAIN THEME: Simultaneous consideration of requirement  (C8)</b>	<b>Evaluation of achievement toward CE implementation</b>
<b>Level 6</b>	Simultaneous consideration of all key team members' requirements from outset.	<b><u>CE STAGE</u></b> The practice adequately supports CE environment.
<b>Level 5</b>	Consideration of key project members' requirements made in stages throughout the design development process.	
<b>Level 4</b>	Consideration of key team members' requirement made after design solution partially developed. A moderate tolerance of change allowed.	<b><u>TRANSITION STAGE</u></b> Elements of collaborative teamwork exist but some limitation still exist by way of: 1. Using the traditional platform. 2. Not every key member may benefit from such collaboration. 3. Collaboration of team do not aim toward making contribution to design development process.
<b>Level 3</b>	Simultaneous consideration of requirements can occur in D&B and partnering approach if directed for such objective. But will only involved the participating parties.	
<b>Level 2</b>	Consideration of requirements made after reaching design solution with minimal changes on design tolerated.	<b><u>TRADITIONAL STAGE</u></b> A typical traditional practice based on rigid divisional of functional roles and using sequential work process
<b>Level 1</b>	No simultaneous consideration of project members requirement under pure traditional over the wall approach.	

**Table 8.10**

**MATRIX MEASUREMENT GUIDELINE-TOWARD CONCURRENT ENGINEERING IN CONSTRUCTION (MMG- TCEiC) (COLUMN MATRIX C1 TO C4)**

	<b>Time of formation of the team (C1)</b>	<b>Team component (C2)</b>	<b>Level of authority of the team (C3)</b>	<b>Contribution to the design development (C4)</b>
<b>Level 6</b>	Team comprises of all key project members formed at outset of the project.	Consists of all key members: including the clients, major sub-contractors and major suppliers.	The team has adequate authority to make important project decisions including design.	All team members involved in making contribution to formulate design solution from inception.
<b>Level 5</b>	Formed in stages but all key members available before sketch/concept design phase commence	Consists of all key members includes the clients, major sub-contractors and major suppliers. However major supplier representation in the team made through other party such as main contractor or specialist contractor.	The team has adequate authority to contribute and influence toward important project decisions (including design) but final decisions are made by clients.	All team members involved in making contribution to formulate the design solution but in stages.
<b>Level 4</b>	Formed in stages but the inclusion of sub-contractors and key suppliers made after sketch/concept design.	Partnering team of designers and constructors based on mutual agreement or under D&B arrangement to work collaboratively but not including the client.	Team members only given the authority to review final design and other project decisions.	Not all members involved (esp. sub-contractors and major suppliers) in formulating final design solution.
<b>Level 3</b>	Form in stages but non-designers members include in final design stage only.	Project management contractor's co-ordinated team consist of key members but confined to individual functional group.	Team members not given the opportunity to influence project design decision.	Team members only involved in reviewing the design solutions but not formulating them.
<b>Level 2</b>	Form in stages but only includes key designer members during entire design phase.	Typical designers co-ordinated project team.	Team members do not involve in any other aspect except related to their functional role responsibilities only.	Each member reviews the design aspect related to each functional roles only.
<b>Level 1</b>	No formal collaborative team is formed.	No formal collaborative team being formed.	No formal collaborative team formed.	No contribution made at all unless the primary role as designers.

**Table 8.10 continues**

**MATRIX MEASUREMENT GUIDELINE-TOWARD CONCURRENT ENGINEERING IN CONSTRUCTION (MMG -TCEiC) (COLUMN MATRIX C1 TO C4)**

	<b>Focus on client/customer (C5)</b>	<b>Team members integration/organisation (C6)</b>	<b>Information Sharing (C7)</b>	<b>Simultaneous consideration of requirement (C8)</b>
<b>Level 6</b>	The client is a member of the team and participates from outset. All team members are able to address their need throughout project life cycle.	Team members integrate by removal of functional boundaries. May be physically collocated or virtually linked.	All pertinent project information including that related to design and planning available to all key team members and supported by through networking system.	Simultaneous consideration of all key team members' requirements from outset.
<b>Level 5</b>	The client is a member of the team, which forms in stages before design. Therefore not all members are able to address clients need from outset.	Team members integrate through their functional groups. May be physically collocated or virtually linked.	All pertinent project information including that related to design and planning available to all key team members even though not fully supported by networking system.	Consideration of key project members' requirements made in stages throughout the design development process.
<b>Level 4</b>	The client does not actively participate as a team member. Their requirements are addressed by the project manager and key designers, which represent the team.	Team members integrate through their functional groups but not co-located or virtually link.	Information related to design and planning made available only to team members involved in the design. Other general project information available to the rest.	Consideration of key team members requirement made after design solution partially developed. A moderate tolerance of change allowed.
<b>Level 3</b>	Clients needs are addressed by key designers in the design development stage. Other team members able to review their requirement in a later stage.	The team is organised with objectives to review each others requirements but with minimal influence to the project design.	Information related to design and planning made available only to those involved in the design. Other general project information available to other key members.	Simultaneous consideration of requirements can occur in D&B and partnering approach if directed for such objective. But will only involved the participating parties.
<b>Level 2</b>	A collaborative team exists but client requirements are only addressed by key designers.	The team is organised with the objectives to co-ordinate project task and information.	High degree of information control applied in the project system. Team members only get information related to their functional roles only.	Consideration of requirements made after reaching design solution with minimal changes on design tolerated.
<b>Level 1</b>	Clients needs are only addressed by key designers only. No collaborative team formed.	No formal collaborative team formed.	No formal collaborative team being formed. Exchange of information strictly regulated.	No simultaneous consideration of project members requirement under pure traditional over the approach.

### **8.3 The application of MMG-TCEiC**

The application of MMG-TCEiC involves the following steps:

1. Identification of the project
2. Identification of every elements relevant to the each of the eight objectives in the column matrix within the project
3. The actual practice within these elements is evaluated independently and their main features briefly but precisely described in words.
4. Each of these descriptions is individually compared to the standard MMG-TCEiC table (table 8.10) to their relevant theme and the level of their achievement is noted.
5. From the assessment made conclusion can be made whether the collaborative teamwork practices within the project that being studied is consistent with a CE environment or not. If a CE stage has not been fully achieved, the area that need more improvement can be easily identify and appropriate action can be devised to improve it. If the improvement is not possible with the current project, the assessment can provide a useful guideline for the future project that is intended to adopt CE practice.
6. The aim of the assessment is to provide a relative comparison to CE environment. Therefore quantification of the findings by using numerical value like percentage to express the degree of achievement toward CE is not used because of the difficulty to quantify the relative importance of each column matrix toward CE.



## **8.4 CASE STUDY ON COLLABORATIVE TEAMWORK IN CONSTRUCTION PROJECT**

### **8.4.1 Introduction**

The main aim of the case studies was to assess the practice of the collaborative teamwork within the construction project and its related issues. Four case studies were conducted with the project personnel representing the participating organisations. All the personnel interviewed had direct involvement as part of the management team of the collaborative teamwork. The case studies comprised the following types of construction projects:

1. Construction of major exhibition centre
2. Motorway construction
3. Commercial building construction
4. Warehouse rebuilding with new facilities project

The approach used for the case study was an in-depth interview technique focussed on the specific topic of how collaborative teamwork was being achieved/practised within the project. Three case study projects were still ongoing at that time and one had just been completed. The length of study from one case to another varied from one to two days. After an initial interview telephone, fax or email was used as necessary for further clarification of the issues discussed. In some cases, the writer was given the opportunity to visit and personally interviewed other team members within the collaborative teamwork within the project. In one case where the writer was given the opportunity to meet the key team members during the inception stage of the formation of the team. In all cases involved writers visit to the site except recently completed one. In all cases more than one person was involved in the study.

The interviews were supported by other documents or demonstration made by the interviewees to reinforce the verbal information given. Examples of such additional information provided include: demonstration of how the of GroupWare system being used to support collaborative teamwork within the project; sample of reports; work process chart showing how team members being incorporated early in the project; and

brochures. The typical open ended questionnaire used in the semi-structured interview were prepared in advance (appendix 3). However the sequence of the questions and the exact wording used was not necessarily maintained. The main issues covered in the case study were:

1. Background of the project.
2. Organisational structure of the collaborative team.
3. Teamwork characteristic with respect to the following parameters:
  - Time of team formation
  - Component of the team
  - Team authority
  - Team roles in the design development
4. Client /Customer involvement in the team.
5. Information sharing within the teamwork.
6. How team members requirements being encapsulated in the design process.

In every case study interview, careful assessment was made first to ensure the relevance of the question to the type of teamwork establishment that existed. A different approach in teamwork has been identified in the case study. Therefore a different approach in generating the information has been used for different project in the case study to allow the flexibility and the convenience of the respondents to express them in the manner that suit them best. The report on the case study presented here also aligned with the way the information was gathered. The writer argues that this approach is important to avoid any bias of the interviewees to respond to the standard format of question, which might not be relevant to them.

The review of the case studies results is presented in the following section. To ensure anonymity in these case studies, the case study will be identify as Case study A,B,C and D respectively.

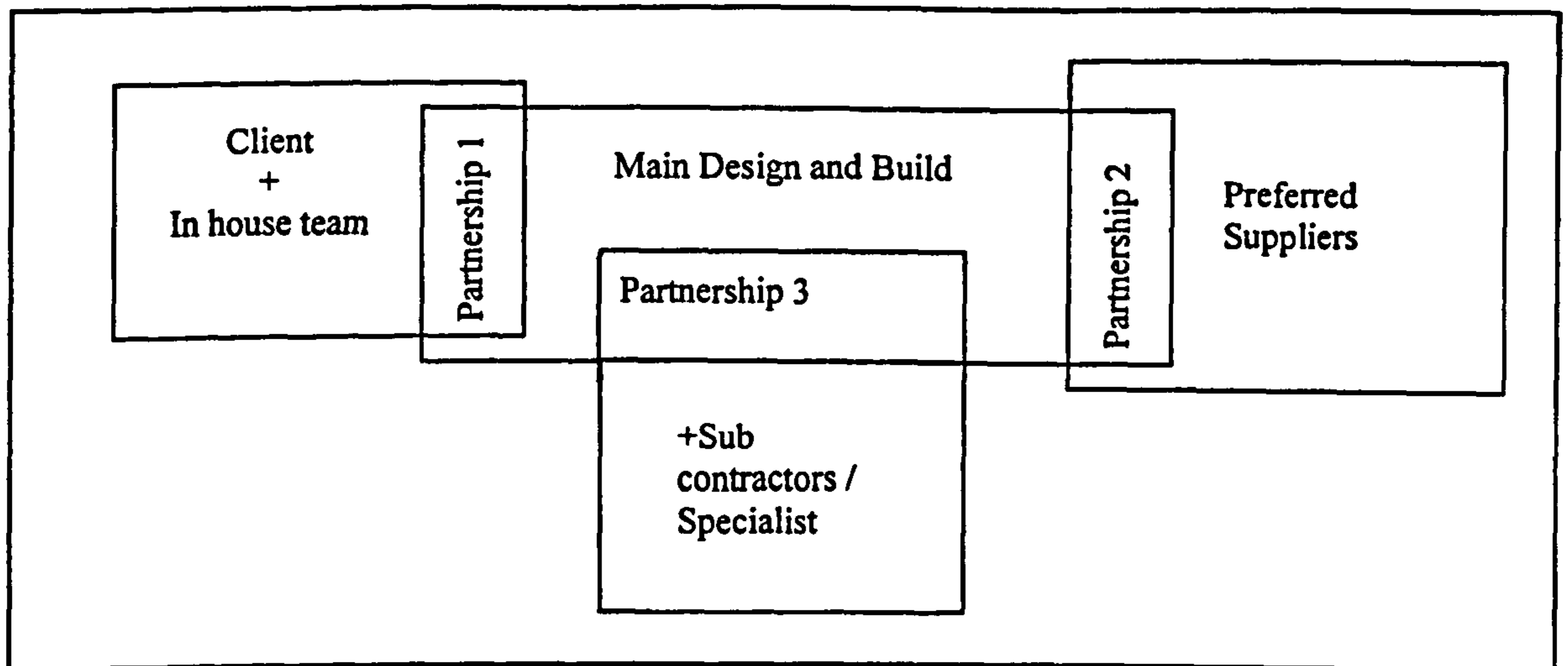
## **8.4.2 CASE STUDY A: Construction of Commercial Building**

### ***Project background***

The project consists of the development of the several commercial structures by a known developer in one of the UK's major city. This case study involved the evaluation of the collaborative teamwork concept that was being practised in the construction of one of those building in the development series. The building itself is a multi-storey business complex. The design and build contract with management has been used in the project together with a partnering approach to support the collaboration of the team members. The project is led by the client who is experienced in developing similar kind of project before.

### ***Collaborative teamwork structure for the project***

There were several layers of partnering arrangement involved in the project. The major partnering agreement existed between the developer (client) with the main contractors. Also included in this partnering team are other parties related to client's interest. The other level of partnership arrangement was established by the main D&B contractor with their sub-contractors and specialists. There was also a separate partnering arrangements and schemes between the main contractor and their preferred suppliers. Figure 8.4 shows how the different level of partnering scheme existed in the project.



**Figure 8.4 Overall teamwork relationship in the project**

The teamwork concept for the whole project was achieved around those partnering approaches. Within the contractor's team at site the collaborative teamwork concept was further enhanced by the use of the design and build procurement system to support the integration of the designers and builders functional group within the contractor's team.

The different levels of team that existed within the project are now described:

### ***Client's Team***

The client, who is also the developer, is an experienced organisation in commercial building development projects and had their own technical team either in house or through partnership with other organisations. The client's team consists of:

- In house quantity surveyors
- M&E Consultants
- Civil and building designers
- Concept architects

### ***Contractor's Team***

The main contractor, is a design and build contractor with their own organised team formed in a partnering relationship with sub-contractors/specialists contractors. On the secondary level of partnership the contractor also develop relationship with their preferred suppliers such as the steel frame suppliers.

### ***Design development process***

The client's in house designers prepared the initial conceptual design of the project. There was no involvement from other parties at this stage. Once design and build contract was awarded to the preferred partnering contractor (in this case the main D&B Contractor) the contractor developed the detail design based on the conceptual design provided to them. There was limited involvement of the preferred suppliers and other contractor's partnering members towards the development of the detail design. The client also had their in-house technical team to observe and approve the design process. Within the contractor's (design and build) team, there was cross-functional involvement between the design and construction team in the design development process.

### ***Level of authority of the team***

The use of the Design and Build approach for the project has enabled the contractor to build strong project teamwork around this single management concept. This is further enhanced by the partnering agreement with the sub-contractors/specialist contractors and the suppliers. A higher level of flexibility to address each others requirements has been achieved within contractor's team. However the separation of the client from other team members is evident. For other team members to address the client requirement require them to go through the designated channels. The main contractor takes the charge of representing 'their team members' requirements to the 'clients team'. Decisions made by the contractor are subject to the client's approval.

### ***Team member integration***

Team members were not co-located in the same office. Integration of designers and constructors was mainly achieved through single point management of design build contract. There were no special communication support systems designated for the project. Only principal partners, especially the designers, rely on the electronic medium to exchange design information.

### ***Concurrency in the project:***

#### ***Concurrency in considering team members requirement***

At the conceptual level there was lack of involvement of other team members except those in the client's team. The conceptual design was therefore developed without the consideration of the requirement of the members of the project team. However as the contractor developed the design further, the nature of the design build procurement allowed input from other parties within the contractor's team. However this contribution was constrained by the previously finalised conceptual design.

#### ***Concurrency in design and manufacturing***

Concurrency in design was achieved to some extent within the design build team. Sub-contractors and steel structure suppliers were able to perform their design and fabrication task simultaneously along with the main contractor within the collaborative partnering environment in the project. The same situation applied to the manufacturing (construction) task whereby there were no need to wait for the overall completion of the design before construction activity.

### 8.4.2.1 Application of MMG-TCEiC to Case Study A

The concepts of collaborative teamwork being practised in this project represent the typical teamwork approach in design and build system. The separation between the client's team and the contractor's team is evident. The collaborative environment in this project has been achieved through the partnering agreement (charter) implemented between the contracting parties. The dominant role of the client ensured their needs being addressed by the contractor.

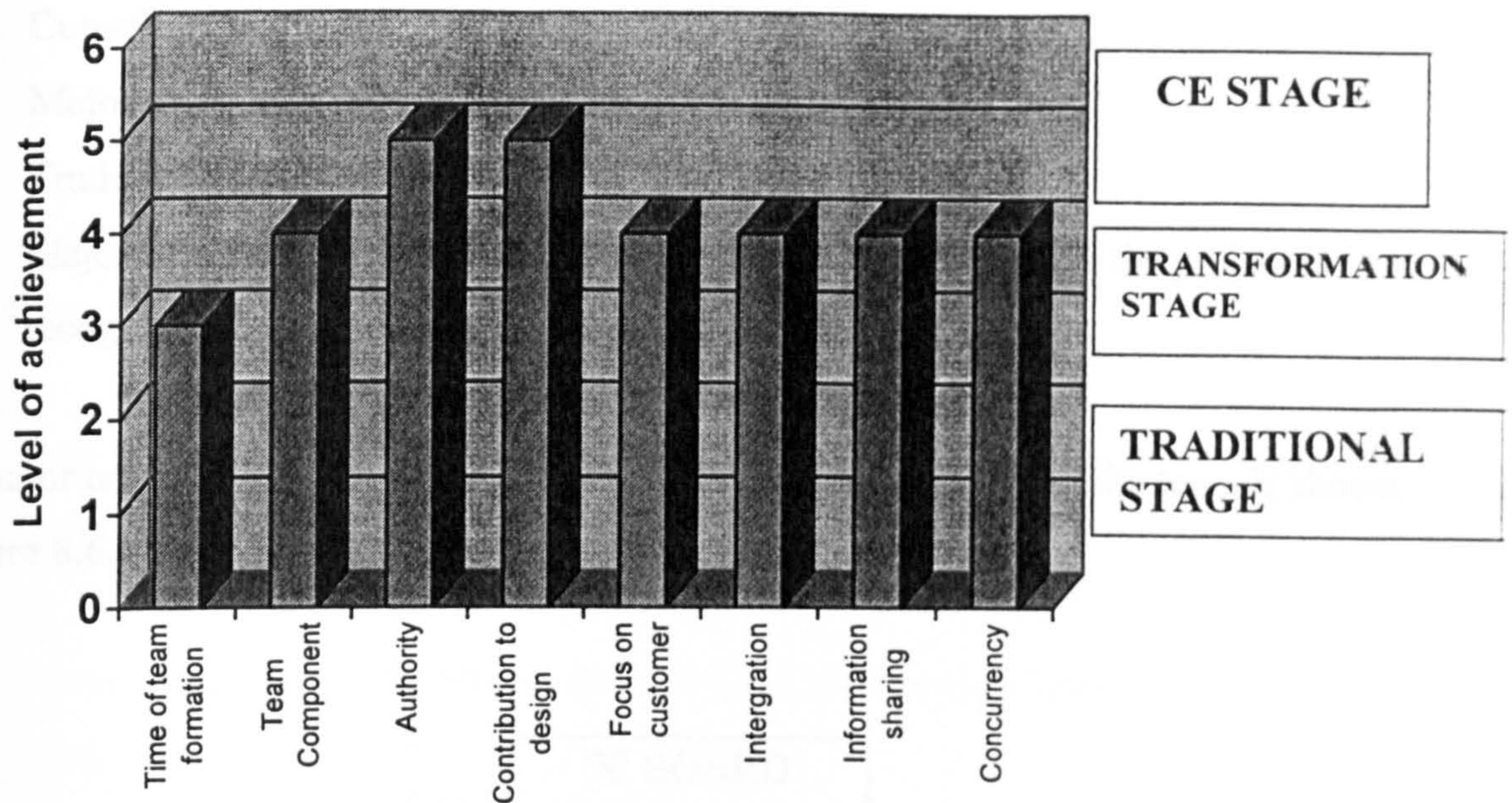
Mapping the achievement of the collaborative teamwork in this project using the MMG-TCEiC matrix table shows that the practice of collaborative teamwork in this project able to fit within the MMG-TCEiC matrices (table 8.11).

**Table 8.11 Mapping the process toward CE environment for Case Study A**

<b>CFT-CE ELEMENTS</b>		<b>Actual practice in the project</b>	<b>MMG-TCEiC Matrix</b>
<b>C1</b>	<b>Time of formation of the team</b>	Only key designers involved with client during briefing. Others involved in later stage with trade contractors and major suppliers involved before final stage of the design completed.	<b>Stage 2 – Level 3</b>
<b>C2</b>	<b>Team component</b>	Not every key project members involved in the team directly. Separate level of partnering arrangement exists. Client is not directly involved in the contractors team	<b>Stage 2 – Level 4</b>

<b>CFT-CE ELEMENTS</b>		<b>Actual practice in the project</b>	<b>MMG-TCEiC Matrix</b>
<b>C3</b>	<b>Level of authority of the team</b>	Major design decision made by design build contractor with client's consent.	<b>Stage 1 – Level 5</b>
<b>C4</b>	<b>Contribution to design development</b>	Design solution made in stages. Conceptual designs develop by client followed by detail design by D&B contractor. Input by other members in contractors partnering team members considered important.	<b>Stage 1 – Level 5</b>
<b>C5</b>	<b>Focus on client/customer</b>	Client lead the team. They determined that their requirement fully satisfied. Other members addressed clients need through main contractors. End user (customer) requirement addressed by client.	<b>Stage 2 – Level 4</b>
<b>C6</b>	<b>Team members integration/ Organisation</b>	Team members were not collocated neither rely on computer based communication system.	<b>Zone 2 – Level 4</b>
<b>C7</b>	<b>Information sharing</b>	Design information shared within key designers members only with limited involvement of the specialist and contractors and suppliers. Other information shared within partnering members.	<b>Zone 2 – Level 4</b>
<b>C8</b>	<b>Simultaneous consideration of requirement</b>	Achieved to some extent through D&B and partnering relationship.	<b>Zone 2- Level 4</b>





**Figure 8.5 Achievement of Case study A project toward CE environment**

### 8.4.3 CASE STUDY B : Construction of major exhibition centre

#### **Project background**

Case study B evaluated the collaborative teamwork concept implemented within the construction of the major exhibition centre project in UK. The project was still in the process of construction when the case studies being conducted. The client of the project is a public sector company. It is one of the major projects in UK construction industry, employing over two thousand workers during construction.

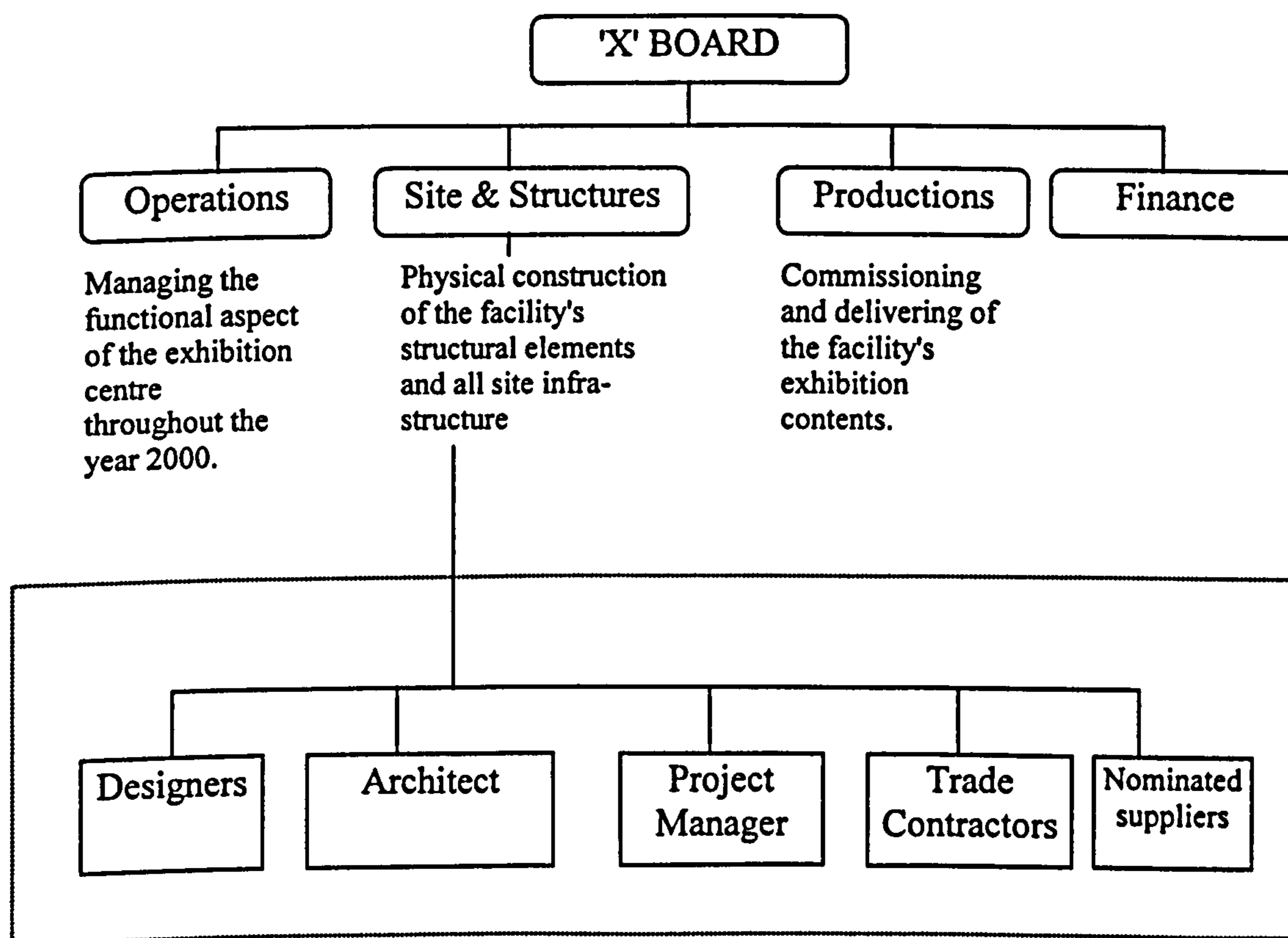
#### ***Project team members***

The key project team members consists of the:

- Construction manager (formed by the joint venture of two major construction companies).
- Architect

- Designers
- Consulting engineers
- Major sub-contractors
- Trade contractors
- Major suppliers for the specific item (suppliers involvement in the project is recognised through the trade contractors they belong).

The major organisation of the project team and the breakdown of the site team is shown in figure 8.6.



**Figure 8.6 Project organisation**

***Collaborative teamwork environment at site***

The collaborative teamwork approach in this project developed around the initiative of project management contractors who developed an integrated team by means of co-

location of team members in a common office. Communications were achieved by the used of a GroupWare system. The basic characteristic of the collaborative teamwork environment at site were based on the following fundamental approach:

1. The client involvement in the team was mainly recognised during the briefing process and approving the final output of the design.
2. The communication with the client could be easily established due to the small organisational structure of the client.
3. The team was given the flexibility, authority and independent to make their decision.
4. The team members shared common vision and objectives of the project. Even though each participant has separate contracts with the client, they had the same basic incentive as the contractor and the designer.
5. The team being collocated in the same building which employ the open plan office concept.
6. Team members were encouraged to talk with each other in their day to day operations rather than write. This 'talk' was then confirmed with a memo.

## Project development process and involvement of team members

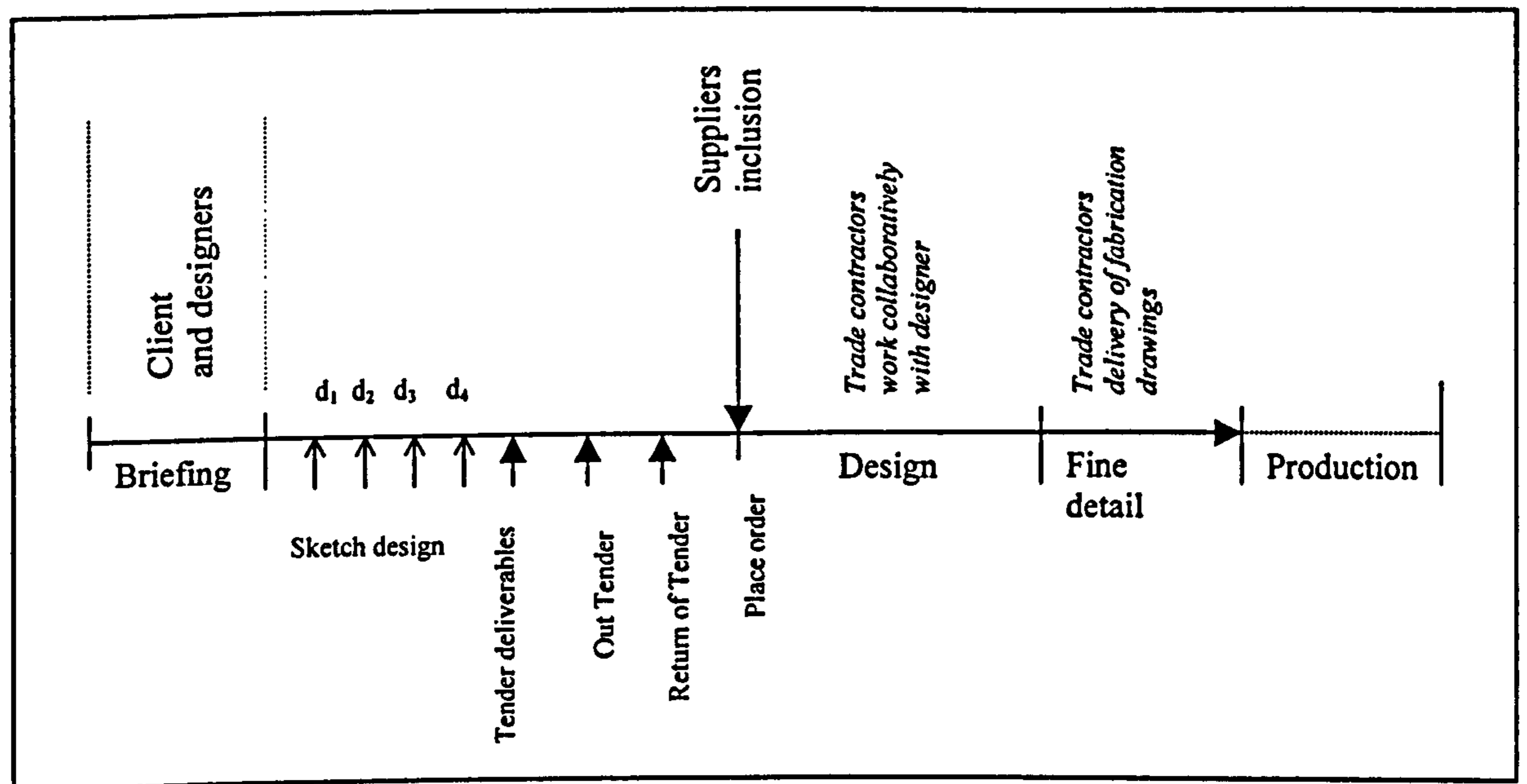


Figure 8.7 Linear work process for case study B project

The linear process of the project development is shown in figure 8.7. The briefing stage only involved the clients and the principle designers. The 'sketch design' process follows with several milestone (' $d_i$ ' dates) to enable the preliminary design to be tested to ensure that they will be able to meet the parameter of cost, time and quality. Important aspects that being checked through were: the cost check; their compliance with the brief; and to ascertain that the progress of the design will be able to meet the target dates for procurement. In the procurement process the project engaged the service of the trade contractors and orders were made to the suppliers. The design 'development phase' (as known in the project) is the final detail design phase, which incorporates the feedback from the trade contractors and the suppliers toward the constructability aspect of the design. The trade contractors were informed that they were expected to contribute toward the design development process. They also produced the fabrication drawing (shop drawing) prior to site production (construction).

### ***Design development of the project***

The task to deliver the project design lies within the responsibilities of the designers. On top of the designer is the client, who has the ultimate authority to approve or to veto any design decision. However prior to the final submission of the design for the client, the designers also incorporated the input from other team members especially with respect to area of constructability review and their compliance with brief, and adherence to the programme. The client's main contribution was realised during the briefing stage, and in approving the final output. Trade contractors are encouraged to contribute positively to secure the best possible product. If they found the any design development trend, which was likely to frustrate the programme, then they were motivated to propose the solution to such problem. Only a few specialist items were being procured directly, e.g. air handling units, transformers and chillers. Most of the suppliers were involved in the project team through the trade contractors they represented. Their contribution toward the design was also made via the trade contractors.

### ***Project communication***

The project are known to establish the advance networking system which capable to support any type of communication within electronic medium. There were WAN and LAN networking systems established for the project. Even though the main principles of the communication in the project were to encourage the individuals to communicate verbally with each other, but the main purpose of the networking system was to manage electronic information exchange. The networking system supports:

- electronic communication such as e-mail;
- the transaction of the electronic project model and drawing among the project team members (for example between the designer to the trade contractors);
- sharing of project general information; and
- sharing of basic office automation software (such as word processor and spreadsheet).

For the basic public (team) information, the network systems maintain a 'public folder' which contains many other 'soft folders' within its directory. These 'soft folders' keep the common information such as about the telephone directories, detail of client programme and detail of condition under contract at site.

All parties including the client, suppliers and the trade contractors had the opportunity to access to the network system. However the system also incorporates a security system to ensure that only the right information goes to the right parties. This is managed by classifying the information into three categories:

- Information that is made available to all parties and can be manipulated by them by virtue that all party has the ownership of such information.
- Information that is made available to all parties but not everybody has the ownership toward it and thus only the owner of such information can manipulate it.
- Restricted information only made available to certain parties.

Those categories of the information used on the project also reflect how the issue of transparency of project information was managed.

The interviewee also indicated that only a minimum level of effort was required to train the members to enable them to use the networking facilities. It was stated that, "when the people realised the benefit they could get from the IT, they will strive to adopt to it themselves, for example by learning it from the peer group."

#### **8.4.3.1 Application of MMG-TCEiC to Case Study B**

The following observations on collaborative teamwork environment were made this case study:

- The project team members have been co-located in the same building at site.

- High level of IT infrastructure has been established at site to support project communication.
- The design process incorporate the input from various project participants in the detail design stage.
- The briefing process only includes the key designers and the client.
- The inclusion of the trade contractors in the project is only made after the preliminary design stage.
- The trade contractors are made aware of the need to contribute toward the design development stage in procurement process.
- The collaborative teamwork environment strategically established at site is driven by a proper planing either physically such collocation of team member or philosophically such as talk not write.

In analysing the above observation, there is strong evidence to suggest that there is a high level of collaborative teamwork existing on this project. These findings were mapped using MMG-TCEiC to observe its achievement toward CE. The result is shown in table 8.12 and figure 8.8.

**Table 8.12 Mapping the process toward CE environment for Case Study B - Major Exhibition centre**

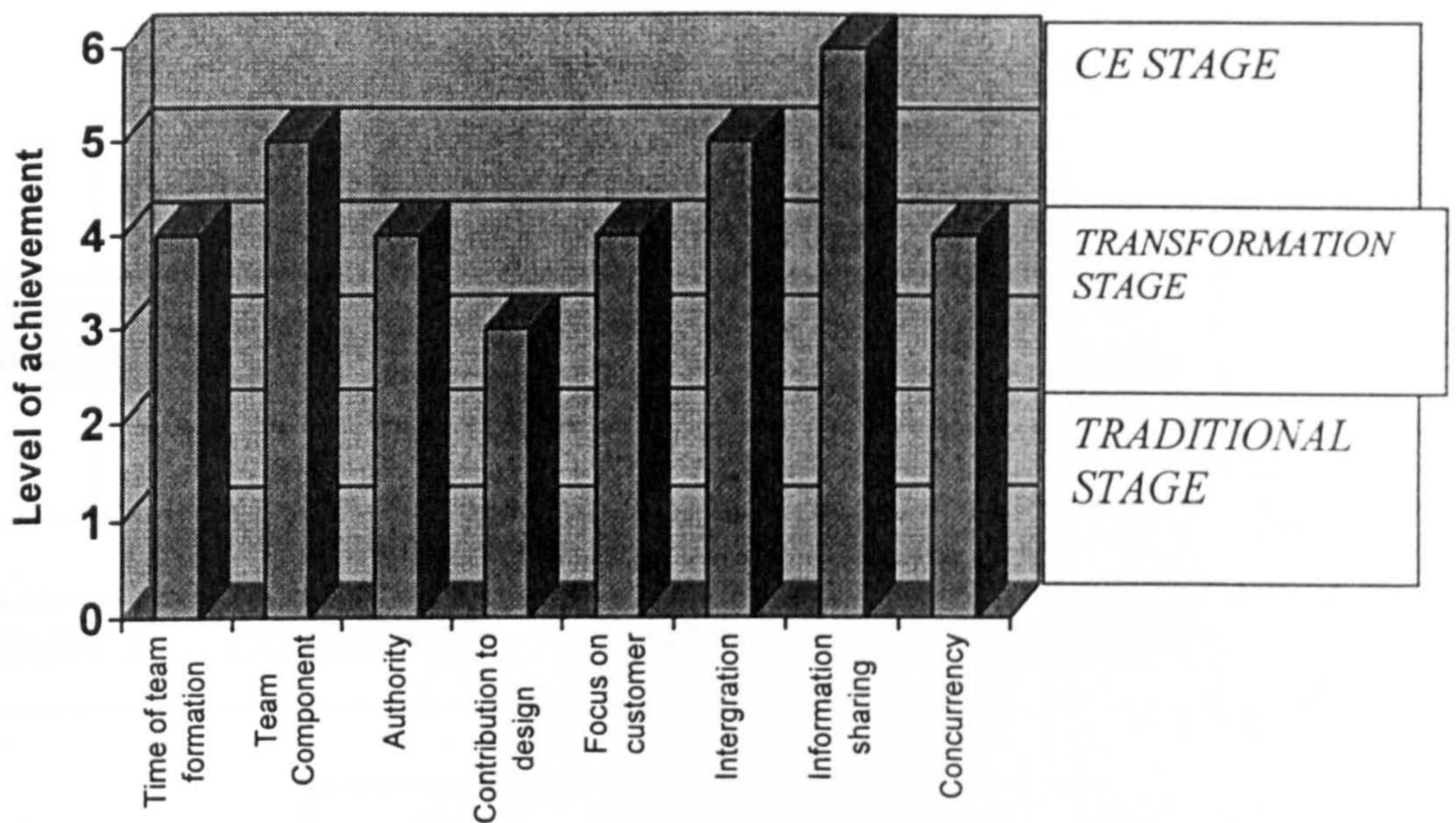
<b>CFT-CE ELEMENTS</b>		<b>Actual practice in the project</b>	<b>Evaluated CE Level</b>
<b>C1:</b>	<b>Time of formation of the team</b>	Only key designers involved with client during briefing. Others involved in later stage with trade contractors and major suppliers involved before final stage of the design completed.	<b>Stage 2 – level 4</b>
<b>C2:</b>	<b>Team component</b>	All key project members involved in the team but some of the major suppliers participate through their trade contractors	<b>Stage 1 – level 5</b>
<b>C3:</b>	<b>Level of authority of the team</b>	Major design decision made by the designer with client's consent. Other decision led by project manager also with client's consent.	<b>Stage 2 – level 4</b>
<b>C4:</b>	<b>Contribution to design development</b>	Only key designer involved in formulating design solutions while other members reviewing it in stages before final design decision made.	<b>Stage 2 – level 3</b>
<b>C5:</b>	<b>Focus on client/customer</b>	Customer need addressed by project manager and key designers rather than the team.	<b>Stage 2 - level 4</b>
<b>C6:</b>	<b>Team members integration/ Organisation</b>	Team being collocated. But organise through their functional group. The communication supported by the existence of WAN and LAN that support project communication.	<b>Stage 1 – level 5</b>
<b>C7:</b>	<b>Information sharing</b>	Project information made available to key team members supported by the used of GroupWare system with some control mechanism	<b>Stage 1 – Level 6</b>
<b>C8:</b>	<b>Concurrent task performance</b>	Achieved to some extent due to involvement of key members in reviewing the final design.	<b>Stage 2- Level 4</b>

*Partnering success of the project*

*The major team structure which is the main partnership for the project is as shown in*

*Figure 8.9*





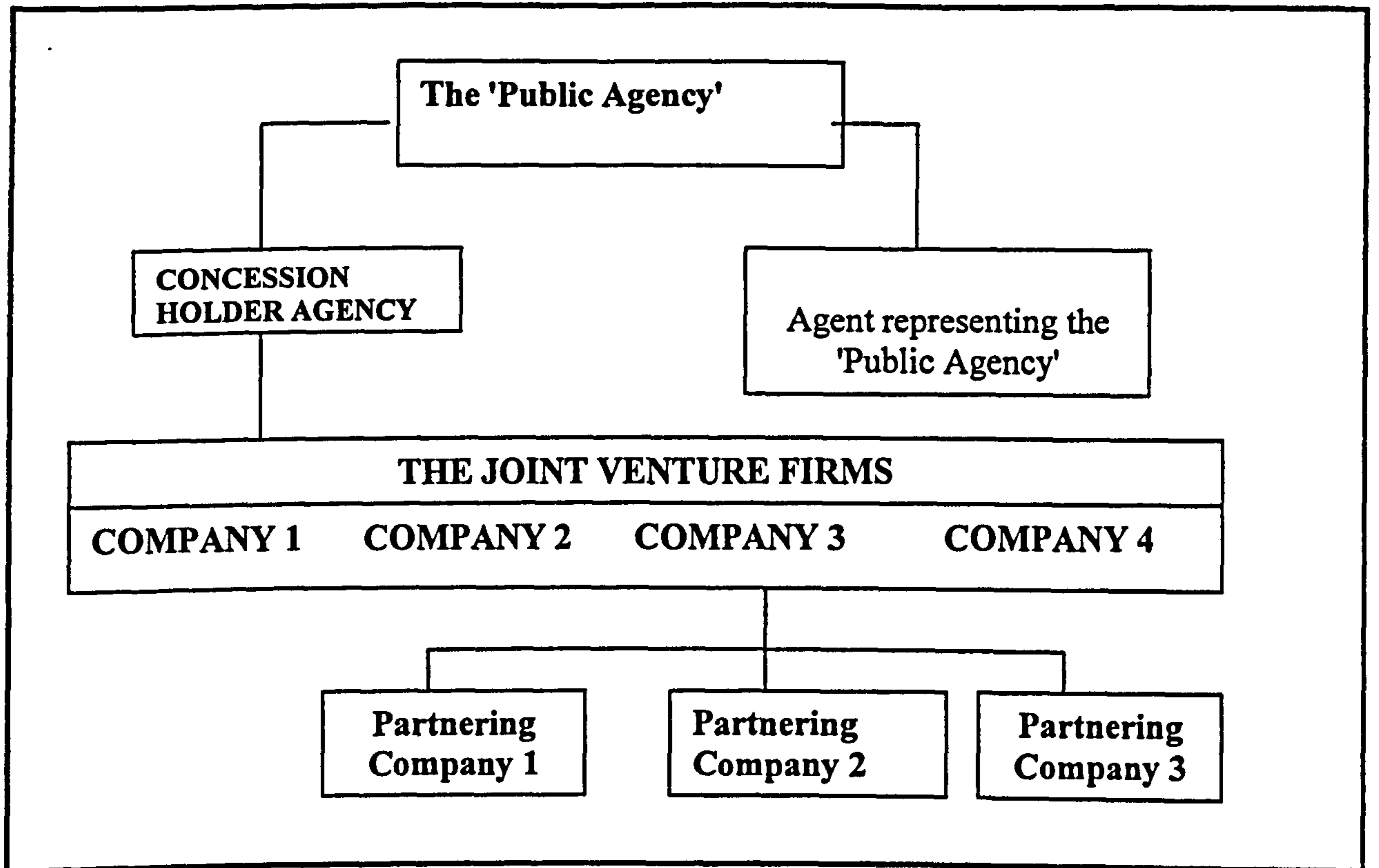
**Figure 8.8** Level of achievement in toward CE environment for case study B

#### **8.4.4 Case study C : Major Motorway extension and upgrading project**

Case study four involved the evaluation of the collaborative teamwork in a major motorway upgrading and extension project in Scotland. The project consists of the 36.5km new motorway construction and 101.3km operation and maintenance for 30 years. The award of the project based on the DBFO (design-build-finance-operate). Contract made by public agency to a concession holder consists of five major construction companies. The concession holder formed an agency and subsequently awarded the construction project to a joint venture company which comprised the four major construction firms. The completed project will cost £96 million for the new build and £14 million for the first five years for routine operations and maintenance contract.

##### ***Partnering concept of the project***

The major team structure which form the main partnership for the project is as shown in figure 8.9.



**Figure 8.9 Main Organisational structure of for case study C project**

***Collaborative teamwork concept achieved in the project***

The collaborative teamwork concept was achieved in this project through the partnership approach. The actual implementation at site was strongly influence by interest of the key partnering members as the concession holders for the project. The important feature of the collaborative teamwork in this project was the extensive use of the GroupWare system, the Lotus Notes to support project communication and information sharing. This will discussed in further section. Other important features of the collaborative teamwork are:

***Co-location***

Most of the team members are co-located at site. Those who are not at site are virtually connected through the projects own communications network infrastructure.

### ***Cross functionality of the team***

A true concept of cross functionality of team members within a single team has been practised within this project. Personnel from different organisations within the partnering team work together without being recognised from which organisation they belong. Personnel from different organisation have been put together into a common unit according to their functional role in the project.

### ***Work process***

The GroupWare system used has the ability to enhance the communications and to disseminate vital project information to all team members. Therefore, project information can be shared across the functional group in the project more efficiently. Basically, the project still follows the traditional path in which the designers will prepare the drawing and hand over to the constructor's team. However the use of the GroupWare systems minimised the 'imaginary wall' impact by enabling the design information to be distributed through the networking system. This provided the opportunity for the management and the construction team members as well as the client agent to suggest the required improvement or rectification for the design errors through the systems electronically as soon as it has been discovered. All the message or request has been transferred electronically alerting the designer's agent. Electronic communications between the designers' agents at site and with their head office has also been established.

### ***Information technology to support project communication***

The GroupWare system in this project used its own network infrastructure platform. The systems architecture was based on an Intranet of Local Area Network and remote users synchronised together through automated replication. At the time the study was conducted, the systems support 230 users with 12 remote users, span across 13 different sites covering all members of site operations from designers to sub-contractors. It operated 24 hours a day, all year round. Workflow was intrinsic in the systems development enabling data to be securely sent electronically from person to person,

with full audibility. Each main office had its own network (LAN) centred on a server connected through ISDN links to main server. The servers replicate each other at half hourly intervals to ensure each location has a full set of up-to date databases. During replication emails are also transferred between the servers and World Wide Web. Individual users access the system through the PC's on the LAN. The existence of individual PC's allows each user freedom to use their own software applications to support their own technical and administrative requirements in the usual way but they can still access to the server and LAN at any time they wish to transfer, share or back up files. Team members have their own control over the files and document they wish to share. There are some packages in the systems, which allow the users to access the information on a read-only basis such as AutoCAD Viewer and Technical Indexes.

The system use Windows NT and Windows 95 as operating system. Lotus Notes GroupWare software is being used to provide the platform for the workgroup computing environment and is the principal database system for data management. Lotus fax server is used to transmit and received facsimiles without the need to produce hardcopy unless necessary. The principles features used are shown in table 8.13.

**Table 8.13 Main features of the GroupWare system in case study C**

<p><b>Correspondence and communications</b></p> <ul style="list-style-type: none"> <li>▪ Email – Notes mail and internet mail</li> <li>▪ Correspondence – letters, phone note, memo, Minutes- automatically filed and numbered</li> <li>▪ Paperless faxing - Inbound and Outbound</li> <li>▪ Shared diary</li> </ul>	<p><b>Library and archive</b></p> <ul style="list-style-type: none"> <li>▪ Specification</li> <li>▪ Method of statement</li> <li>▪ Inspection sheets</li> <li>▪ Material testing</li> <li>▪ Temporary works</li> <li>▪ Weather information</li> <li>▪ Asset recording</li> </ul>
<p><b>Automated work-flow / Process</b></p> <ul style="list-style-type: none"> <li>▪ Approval to proceed process</li> <li>▪ Non conformances</li> <li>▪ Technical queries</li> <li>▪ Methods of statements</li> <li>▪ Quality procedures</li> <li>▪ Final negotiation</li> <li>▪ Works Orders</li> <li>▪ Technical queries</li> <li>▪ Document preparation, approval and distribution</li> </ul>	<p><b>Information sharing</b></p> <ul style="list-style-type: none"> <li>▪ Bulletin boards</li> <li>▪ Crime watch</li> <li>▪ Staff lists</li> </ul> <p><b>Other facilities:</b></p> <ul style="list-style-type: none"> <li>• Document control</li> <li>• Drawing control</li> <li>• Registration</li> <li>• Transmittal</li> <li>• Auditing facilities</li> </ul>

The main advantages observed in the implementation of GroupWare system in this project is the automated workflow system in processing the project information. The information or the request generated distributed to the target users very quickly. The systems database supports the retrieval and searching of the most up to date project information in "real time". This resulted in the improvement of work process time, increase efficiency and quality of information used in the project.

### ***Transparency issue of the information shared***

One of the major issues in the implementation of this type of 'open' information system is to regulate the right of the user to use and manipulate the available information. In this project, certain limitations were introduced as a control measure. First, each user is given the security code to enable them to access the system. This enabled them to access the system from any location provided they have the correct password. However not everybody accessible to the system can modify the database. There was some limitation imposed to users. "Non-partners" i.e. organisations that had not entered into the partnership agreement were not given the right to access to the system. However, they are provided with the printed copy of the relevant documentation as necessary.

#### **8.4.4.1 Application of MMG-TCEiC to Case Study C**

From the case study, two important issues were evident first, how the collaborative teamwork has been achieved in the project under the partnership environment and second how IT technology with specific reference to GroupWare system using Lotus Notes able to support the collaborative teamwork and change work process.

##### ***Collaborative teamwork:***

1. There is a uniqueness compared to other project in term of the partnership approach used in this project because:
  - a. The basis of the partnership approach based on DBFO project delivery system
  - b. The main partnering members are also the concession owner of the project
  - c. The partnership formed involved all key project members – Client (intermediate and ultimate), constructors, sub-contractors, and designers

Therefore, the all parties involved in the project have 'ownership' and interest in the project thus creates an ideal platform to achieve the collaborative environment to pursue mutual interest in the project.

2. The collocation of the team members under the same roof at site is seem to be the most critical factor that support the collaborative teamwork in the project.

3. The clients' representative was co-located at site full time.
4. The project has implemented to some extent the concept of cross-functional team by grouping together member from various organisation into a common team and collocated them in the same office.
5. What had been a setback in the observation with respect to the design development process is that there is lack of involvement from the construction 'functional' members in the earlier design development process. Much of the feedback are made after the design been completed. Much of the error and rework should be avoided if the contributions are made earlier as promoted in fundamental of CE principles.

*Use of IT to support collaborative teamwork*

6. Evidently, from the interviews, IT system using the Lotus Note s GroupWare has played the most vital role to support the collaborative teamwork in the project through enhance communication system and information exchange.
7. The GroupWare system used has create 'informalities' in communication which critical in collaborative teamwork environment.
8. The major advantage of using the Lotus Notes GroupWare system seems to be in supporting the work process- improving the quality of the information, huge saving in workflow process time and reduce the need for unnecessary hardcopy printing.

The above finding are mapped using MMG-TCEiC to determine the level of achievement toward CE environment. The results are shown in table 8.14 and figure 8.10

**Table 8.14 Mapping the process toward CE environment for Case Study C - Major Motorway extension and upgrading project**

<b>CFT-CE ELEMENTS</b>		<b>Actual practice in the project</b>	<b>Evaluated CE Level</b>
<b>C1:</b>	<b>Time of formation of the team</b>	Team members are form in stages. Not all key members involved in the design development from inception but involved in reviewing them	<b>Stage 2 - level 4</b>
<b>C2:</b>	<b>Team component</b>	All key project members involved in the team. Some suppliers may not be the partnering members.	<b>Stage 1 - Level 5</b>
<b>C3:</b>	<b>Level of authority of the team</b>	There is a separation between design and construction function. Construction team members only review the design. So did with other process.	<b>Stage 2 - Level 4</b>
<b>C4:</b>	<b>Contribution to design development</b>	Only key designer involved in formulating design solutions while other members reviewing it in stages before final design decision made.	<b>Stage 2 - Level 3</b>
<b>C5:</b>	<b>Focus on client/customer</b>	The client fully involved in the team through their agent at site. However their need are being addressed through the project manager.	<b>Stage 2 - Level 4</b>

*Table 8.14 continues on next page*



Table 8.14 continues.

CFT-CE ELEMENTS		Actual practice in the project	Evaluated CE Level
C6:	<b>Team members integration/ Organisation</b>	Team being collocated at site supported by GroupWare system to enhance from information exchange process	<b>Stage 1 – Level 6</b>
C7:	<b>Information sharing</b>	Project information made available to key team members supported by the used of GroupWare system with some control mechanism	<b>Stage 1 – Level 6</b>
C8:	<b>Simultaneous consideration of team members requirement</b>	Lack of simultaneous consideration of project downstream requirement. But team members still have the opportunity to review them and their requirement considered in later stage.	<b>Stage 2- Level 4</b>

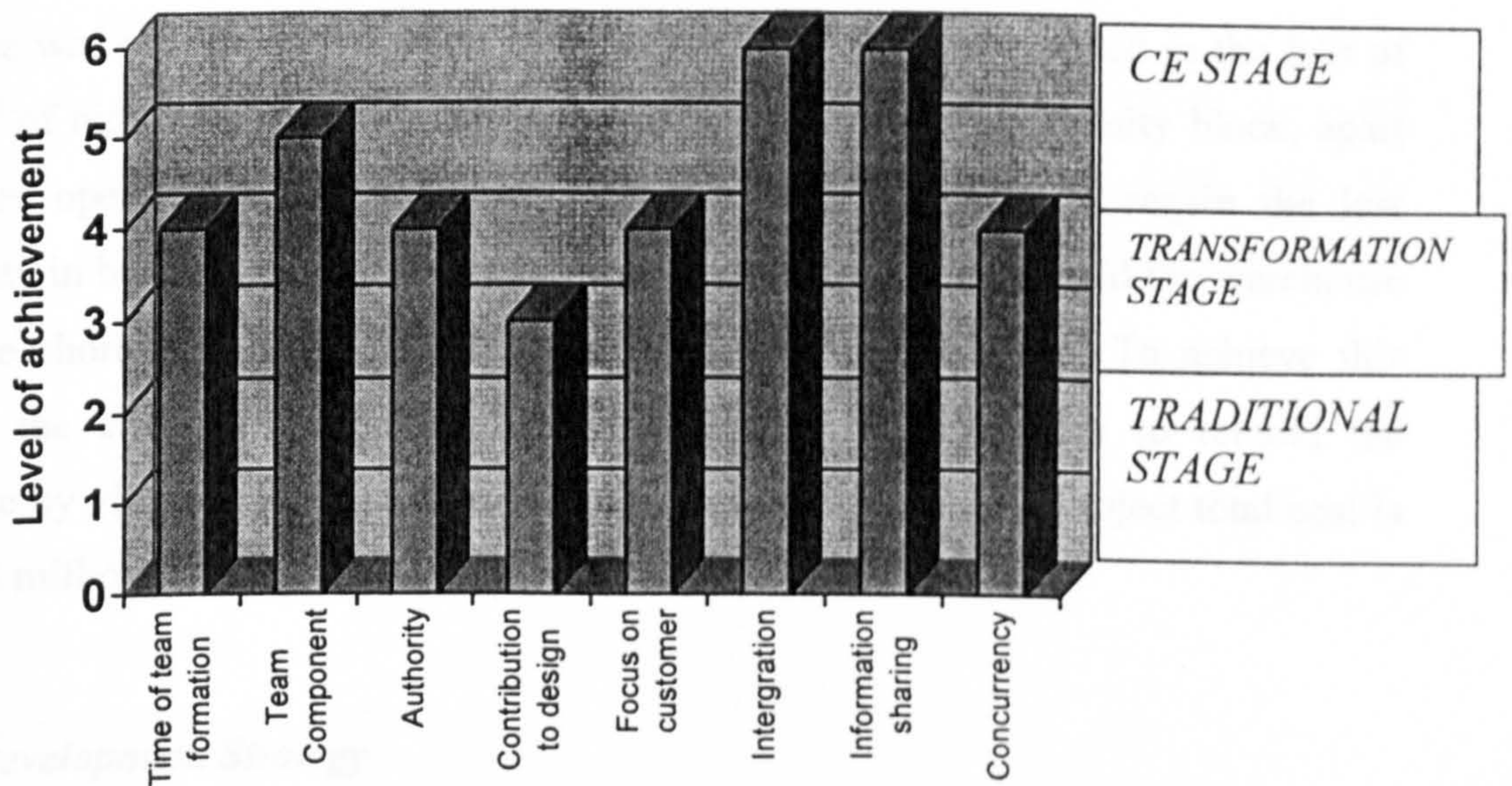


Figure 8.10 Mapping the process toward CE environment for case study C

#### **8.4.5 Case study D : Warehouse Rebuilding Project**

Case study C involved the evaluation of the collaborative teamwork implementation achieved in a major reconstruction work of warehouse with new additional facilities. Case study D was the only project that was completed during the interviews. Therefore, the writer has no opportunity to evaluate the implementation of the practices related to the collaborative teamwork at site as claimed. The writer does not regard the information from this project with the same merit with other case studies. The information provided was 'as claimed' by the interviewee. The finding from case studies is not being used to validate the Delphi findings and will not be mapped using MMG-TCEiC.

##### ***Project Background***

The project was necessitated by a fire which in the original warehouse in 1997. The warehouse was operationally critical to the client. The fire has resulted in the loss of 30,000m<sup>2</sup> of highly automated warehouse and 2,500m<sup>2</sup> of office-amenity block, apart from other operational upheavals and loss of stock. Therefore, to regain the lost opportunity in business, it was strategically critical for the client rebuild the warehouse within the shortest period to enable them continue their operation. To achieve this objective the client approached the main contractor to help them to rebuild the warehouse by virtue of their good relationship with the client. This project total cost is about £33 million.

##### ***Project Development Strategy***

In the brief client has required 15,000m<sup>2</sup> of warehousing by June 1998 and 30,000m<sup>2</sup> fully operational by September 1998. To meet this challenge the client and their 'partnering' contractor created a teamwork strategy for the project. Due to the nature of urgency of the project the team recognised that the traditional approach of work process was considered incapable delivering the project (re-construction of new warehouse and amenity building) within the available time. As an alternative, they engaged into a collaborative teamwork strategy to address the project requirement.

### ***Project Organisation***

The project was organised around the partnering concept with the client and the main contractor taking joint the leading roles. The team had two project managers, one from each of the client and main contractor organisations with discrete and common responsibilities. The common responsibilities were related to the commercial aspect. The team was led by the senior manager from the client organisation. In terms of the technical aspect, the project was broken down into smaller package known as clusters. Each cluster was lead by the designers. The examples of the clusters were (warehouse) envelope, alarm sprinkle systems, amenity block, etc.

### ***Collaborative teamwork environment***

The backbone of the teamwork organisation at site was based on the partnering strategy of the client, main contractors with other parties. The team jointly developed the project definition and the process of their partnership at the initial stage of their project. They later played the critical roles in leading other team members in collaborative teamwork environment. They argued that the teamwork approach used by them with the objectives to avoid 'traditional disharmony' arising out of 'changes and delays' could create:

- Ownership on the agreed rebuild solution
- Common goals
- No hidden agendas
- Risk recognition and avoidance

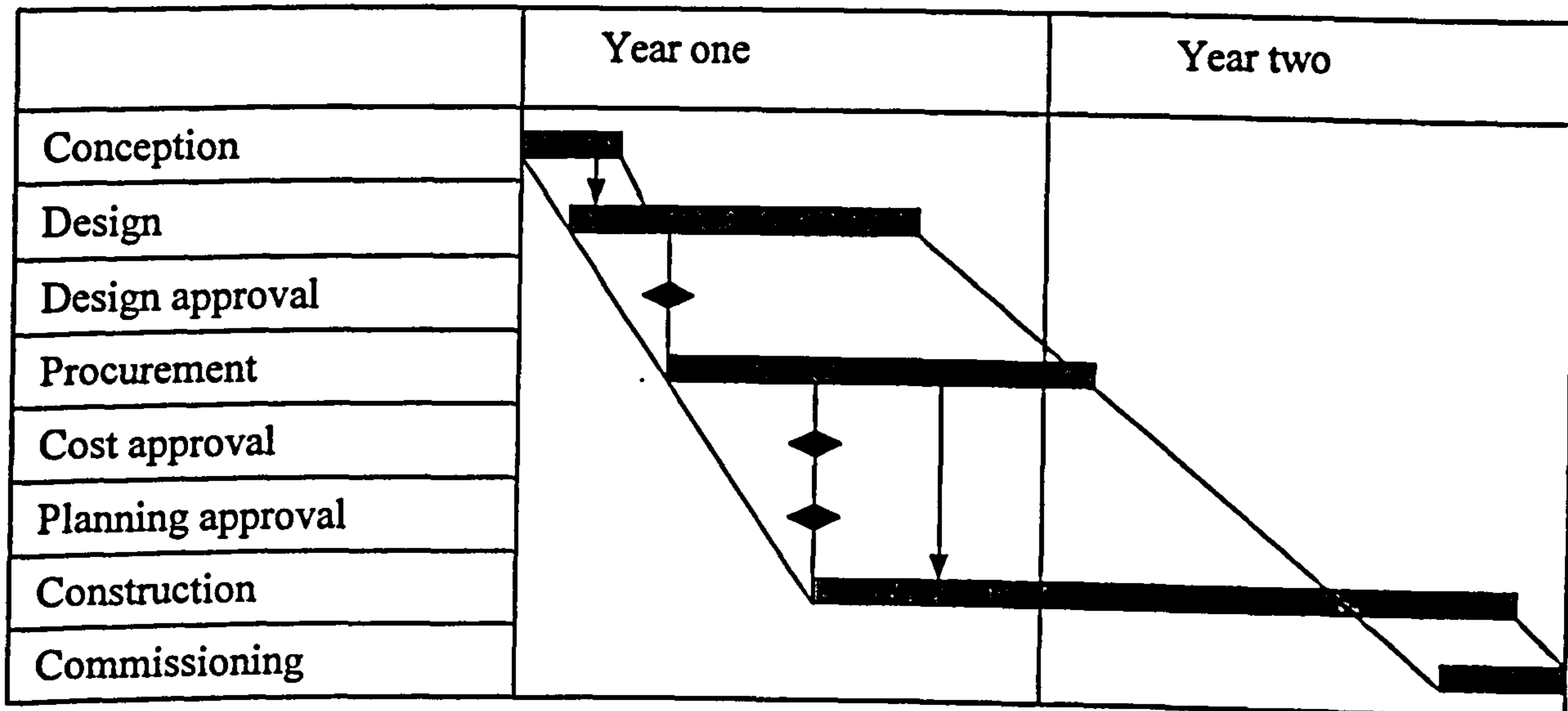
The team also had the following characteristic:

- Create a commercially stimulating environment
- Clear risk allocation
- Streamlined processes
- Inclusion of all
- Acknowledgement of differences

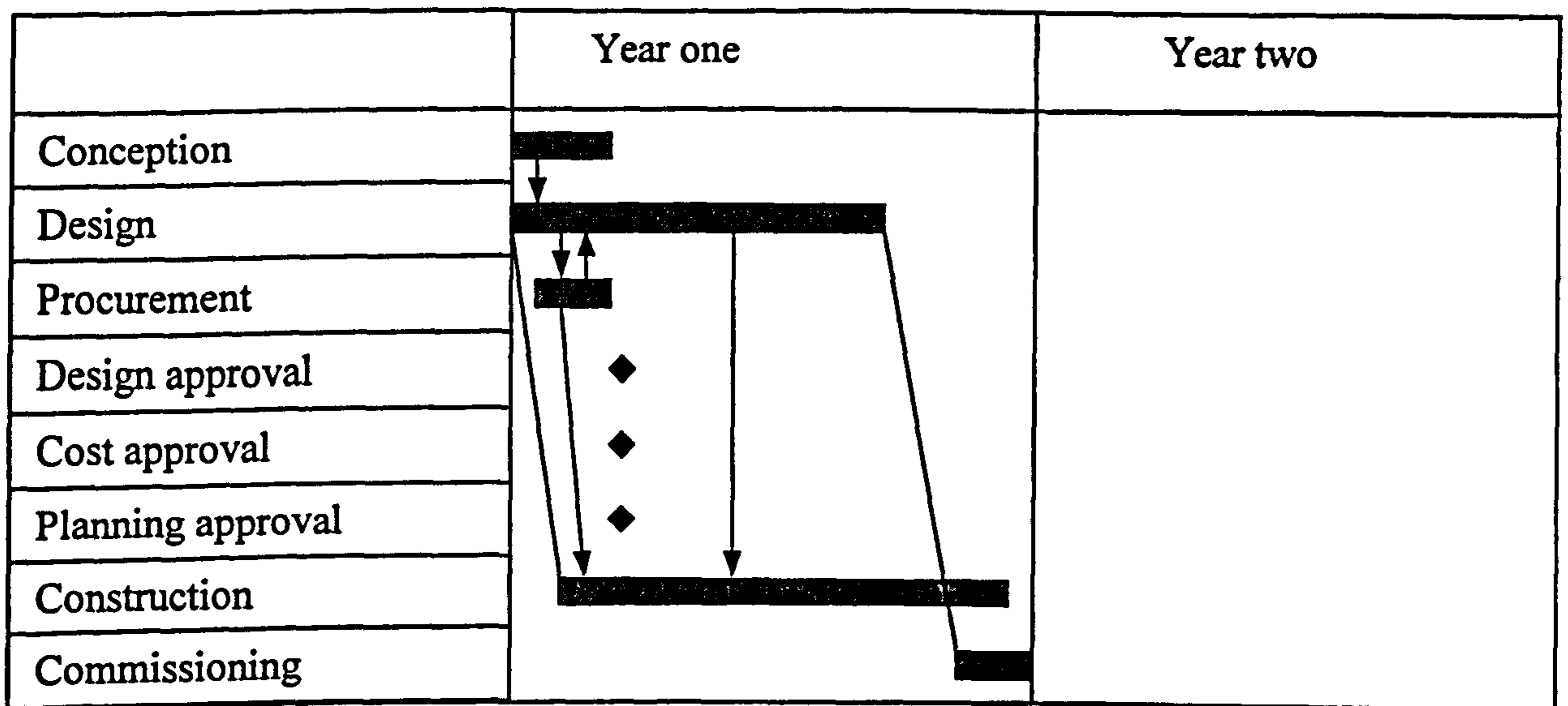
***Project development process***

The time constraint on this project demands a 'different' approach to the traditional process. The comparisons of the time saving benefit between the two approaches are shown in figure 8.11 and 8.12.

**Figure 8.11 Work programme using the traditional approach**



**Figure 8.12 Work programme using the 'alternative' approach**



The key features in this approach of 'compressed work programme' achieved by the ability to perform the design development task and the construction concurrently. This is contrary to the traditional approach as shown in figure 8.11. To achieve this objective, the clustering system had been adopted (as had been mentioned earlier). The involvement of the sub-contractors in the team was secured earlier in the project. However, they were involved in the briefing stage. Wherever appropriate, the sub-contractor was involved in the design process within their 'cluster'. However, one the major problems faced in getting the contractors (builders) contribution toward the design was the 'traditional way of work mentality'. They were reported as, *"hardly able to recognise the approach of requiring their contribution of ideas in the design process."* This has been quoted as one of the reasons why the team leader for the clusters were appointed from the designers.

For this project the New Engineering Contract reimbursable contract without liquidated damages was used. Incentives were given to the team members' achievement in time and cost. The aim was to share the cost and benefit by incentives and encouragement, not threaten and blame.

### ***IT to support teamwork***

The site maintains the system servers to support project design and communication. The IT systems used supported common access to a project 'library' where project information was made available to team members. The project library also included a 'memo board' to tell the team members what had been done and what more was needed.

### **8.5 Validation of Delphi finding with case studies**

In the chapter seven, from the analysis on the Delphi studies the research has developed series of guidelines toward achieving the formation of the CFPT within construction industry environment. The validation process of the 'guidelines' with the case studies has been accomplished in this research by observing for their relevancy in actual practice found. It must be clear that all the guidelines developed from the Delphi studies are considered consistent with CE principles. On the other hand not all practices within the collaborative teamwork environment in the case studies are consistent with CE as well. Therefore only those practices that were considered fulfilling the CE requirements are being observed for validation. The validation process is achieved by comparing the guidelines developed from Delphi studies to the actual practice in collaborative teamwork which are relevant to it. This validation process is presented in Table 8.15.

**Table 8.15 Validation of guidelines developed from Delphi study with case studies**

	<b>KEY ISSUE IN IMPLEMENTING COLLABORATIVE TEAMWORK ENVIRONMENT</b>	<b>PRACTICES FOUND FROM CASE STUDIES</b>	<b>RELEVANT ISSUE RAISED IN GUIDELINES DEVELOPED FROM DELPHI STUDIES</b>
1.	<b>Component of the team</b>	Team member comprises of all key project members	Cross functionality is the central issue in team members selection. The ranking represent multi-functionality component of stakeholders to be included in the team
2.	<b>Main strategy to achieve collaborative teamwork</b>	<ol style="list-style-type: none"> <li>1. Using Partnering and D&amp;B as the main platform</li> <li>2. Collocation of team members in common office</li> <li>3. Using GroupWare systems to support sharing of project information</li> </ol>	<ol style="list-style-type: none"> <li>1. Collocation of the team is important.</li> <li>2. Using appropriate IT tools such as GroupWare sharing common database to support teamwork.</li> </ol>
3.	<b>Team members participation in the design development process</b>	<ol style="list-style-type: none"> <li>1. The inclusion of all members made prior to the final design solution reached</li> <li>2. Members were given the opportunity to review their requirement and contribute to the design</li> </ol>	<i>Note: None of the practice in the case studies adequately satisfied CE requirements.</i>
4.	<b>Team members' accountability toward design</b>	The designers take the leadership role in the design while other team members making contribution	<ol style="list-style-type: none"> <li>1. Recommendation for the designer to maintain leadership in the design</li> <li>2. Team members must be given the opportunity to contribute to design and have their requirements incorporated.</li> </ol>
5.	<b>Project information sharing</b>	GroupWare systems has been used to support project communication and information sharing	<ol style="list-style-type: none"> <li>1. Using GroupWare, sharing of project information</li> <li>2. Using appropriate IT tools that support sharing common data base</li> </ol>
6.	<b>formation of the team from outset</b>	Team were formed in stages with inclusion of none designers members after the conceptual stage	Inclusion of the team members in stages (ranking of priorities of stakeholders)

	<b>KEY ISSUE IN IMPLEMENTING COLLABORATIVE TEAMWORK ENVIRONMENT</b>	<b>PRACTICES FOUND FROM CASE STUDIES</b>	<b>RELEVANT ISSUE RAISED IN GUIDELINES DEVELOPED FROM DELPHI STUDIES</b>
7.	<b>Type of IT used to support project communication</b>	<ol style="list-style-type: none"> <li>1. GroupWare systems using Lotus Notes and integrated with other software such as CAD</li> <li>2. Common IT facilities other than telephone and telefax: <ul style="list-style-type: none"> <li>• CAD system to support sharing of design information electronically</li> <li>• Common database for information sharing</li> <li>• Email systems to support project communication</li> </ul> </li> </ol>	The appropriate IT tool that can be useful to support collaborative teamwork is the GroupWare systems which support project database sharing and electronic data and voice exchange.
8.	<b>Clients' role in the project</b>	<ol style="list-style-type: none"> <li>1. Clients take leadership in initiating the formation of collaborative teamwork in the project</li> <li>2. Client participate in the team directly</li> </ol>	Client should take leadership to promote collaborative teamwork in construction.
9.	<b>Team members integration process</b>	<ol style="list-style-type: none"> <li>1. Team members was being co-located in a common office</li> <li>2. GroupWare systems was used to support team members integration process by enhancing the cross functional communication</li> </ol>	<ol style="list-style-type: none"> <li>1. Collocation in a common office an important changes required to suit collaborative working environment</li> <li>2. Using appropriate IT tools that can support sharing of common database.</li> </ol>
10.	<b>Simultaneous consideration of team members requirement</b>	The best practice within case study was team members were given the opportunity to contribute and getting their requirements considered after the concept design. This is not a very appropriate practice within CE environment.	<i>Note: None of the practice in the case studies adequately satisfied CE requirements for validation with findings from Delphi.</i>



	<b>KEY ISSUE IN IMPLEMENTING COLLABORATIVE TEAMWORK ENVIRONMENT</b>	<b>PRACTICES FOUND FROM CASE STUDIES</b>	<b>RELEVANT ISSUE RAISED IN GUIDELINES DEVELOPED FROM DELPHI STUDIES</b>
11.	<b>Team authority</b>	<ol style="list-style-type: none"> <li>1. The team was given the flexibility to make decision with the consent of the client other than design decision</li> <li>2. Designer take the lead in making design decision with client's consent.</li> </ol>	<ol style="list-style-type: none"> <li>1. The team must not be given the power to override an individual functional group's decision.</li> <li>2. The team must be given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members.</li> <li>3. Team members must be given adequate authority and flexibility to contribute and to review the design throughout its development phase.</li> <li>4. Final adoption of the design for the project cannot be made upon the consensus decisions of team members.</li> </ol>
12.	<b>Team leadership</b>	Team was lead by project manager	It is preferable to have a designated project manager to lead the team.

### 8.6 Additional guidelines for to support formation CFPT developed from case studies

Case studies provided an opportunity for the research to evaluate the Delphi findings with the practical implementation in collaborative teamwork. Most of the practices, which are parallel to CE within the case studies, were covered within the specific guidelines developed from the Delphi studies. However there are remaining issues which are considered important but, either not covered in Delphi guidelines or need to be reinstated parallel to the findings within the case studies as a general guidelines to support CFPT formation to achieve CE implementation in construction. Those issues

are presented below as general guidelines to support the formation of CFPT in construction:

- i. The inclusion of all key project members should be made before sketch design to ensure that all their requirements can be simultaneously considered in the design.
- ii. Key suppliers should be included in the team rather than being represented by other parties that directly employ them.
- iii. The team should be allowed to have greater flexibility to make important project decisions.
- iv. The clients or their representatives should be participate in the team as active members, so that their requirements can be addressed directly by team members.
- v. IT tools based on GroupWare system have not been widely used but can be useful to support team communication and integration.
- vi. The use of Design and Build and Partnering approach are considered as appropriate platform to support the realisation of CFPT formation within current construction industry environment.
- vii. The use of traditional procurement approach is inappropriate platform to support CFPT implementation.
- viii. In is customary within current practice that the designers should take the leadership in design development process and the final approval requires the client consent. This system should be maintained and incorporate within CFPT approach toward design.
- ix. The client has important roles toward promoting the formation of CFPT within construction project.

The overall guideline that includes the general guidelines and the specific guidelines to support formation of CFPT in construction is presented in appendix 11.

## **8.7 Summary**

This chapter has described the tool known as Matrix Measurement Guideline-Toward Concurrent Engineering in Construction (MMG-TCEiC). The aim of this tool is to help the industry to map the process toward achieving the practice of collaborative teamwork in a CE environment. MMG-TCEiC has eight columns with six levels of the attainment for each column. The levels of attainment are divided into three major stages: CE stage; intermediate stage; and traditional stage. The development of MMG-TCEiC is an important contribution of the research to the industry. It can be used to guide the project toward achieving CE environment.

The case studies conducted on four major construction projects, three of them have been tested on MMG-TCEiC. In the process, it was also being used to improve the matrix. In this process, the matrix table has been revised again for its final publication.

The findings from three case studies were also used to validate the 'Guideline for the formation of CFPT in Construction' which had been developed earlier using Delphi studies. There were many relevances found in the validation process.

The major findings from case studies in the collaborative teamwork practised within the four case studies are summarised here:

- 1. The use of partnering, D&B procurement has been the important strategy to achieve collaborative teamwork environment.**
- 2. The client has a leading role in achieving collaborative teamwork in construction.**
- 3. The co-location of team members is an important strategy to achieve collaborative teamwork environment.**
- 4. Single point of management systems like D&B are important approaches to support collaborative teamwork environment.**

5. The use of IT to support project communication system played a very important role to support teamwork

The analysis from the case studies also identified factors that are considered impede the achievement of collaborative teamwork as in CE environment. They were:

1. The use of traditional forms of contract impedes cross functional contribution and involvement toward design process.
2. The separation of client own team with contractors team from other 'independent' members in the project like trade contractors, suppliers impede the implementation of CE.
3. Lack of participation of all team members in the design development process is still common, even in the new forms of project procurement. This is undesirable when seeking as CE environment.
4. Too many levels of partnering impede the true integration of all team members.
5. Team members are normally given the opportunity to review design solution only when they are almost finalised. This is against the desired practice in CE environment.
6. Lack of participation of all team members from early stage of design development prevents their requirement to be simultaneously considered in the early stage of the design.

## CHAPTER NINE

### CONCLUSIONS AND RECOMMENDATIONS

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#### 9.1 Introduction

This chapter presents the main findings and conclusions of the research. These are followed by recommendations for further research.

The main aim of this research was to evaluate the potential of applying Concurrent Engineering (CE) philosophy to construction industry. CE is a production management philosophy that originated from the manufacturing industry. The research evaluated CE and found that it is a viable concept to be implemented in the construction industry, CE can be applied by the industry to achieve a collaborative teamwork environment and to change the traditional method of working. The research has developed the guidelines for the industry to implement CE by the formation of collaborative project teamwork. This collaborative teamwork is identified in this research as the Cross Functional Project Teamwork (CFPT). The research has developed a tool known as "Matrix Measurement Guideline - Toward Concurrent Engineering in Construction" (MMG-TCEiC) to complement the initiative and to guide the implementation of CE.

The research adopted the following methodologies to achieve the research aims and objectives: literature reviews; interviews with the respondents from construction and manufacturing industry; industry wide postal questionnaire survey; conducted two round of Delphi (inspired) studies with 13 construction industries experts; case studies conducted on four major construction projects. The writer also participated in several seminars to present the papers on the topics related to the research and discuss the issues with academic and industry representatives.

The main aim of the research was to propose the application of Concurrent Engineering (CE) philosophy to the construction industry by using collaborative teamwork approach. As a summary, the following objectives have been set forth within the scope of this research:

1. To investigate the practice of work process and teamworking within current construction projects
2. To identify the concepts and philosophy of CE.
3. To identify the methodology of CE implementation in other industries.
4. To identify the benefits and problems faced by organisations when implementing CE.
5. To assess the rationale and the potential benefits of implementing CE to construction.
6. To assess the presence in construction of elements that are parallel to CE and that are being practised within the current construction project and evaluate their level of achievement.
7. To establish the guidelines for the industry to form the Cross Functional Project Team (CFPT), i.e. the collaborative teamwork based on CE principles as an approach to achieve CE implementation in construction.
8. To develop a tool which can help the industry to map the process of the construction project towards achieving the CE environments.

## **9.2 General research conclusion**

The general conclusions derived from the research with respect to the assessment of the factors related to the collaborative teamwork environment in construction and the proposal for the adoption of the collaborative teamwork consistent with CE principles are as follows:

1. The main problems faced by construction industry, adversarial relationships and a high degree of fragmentation, result from the practice of the traditional work

processes. Therefore the solution to overcome this must be to address the key issue of improving the current traditional work processes which are based on the sequential process and fragmentation of project tasks.

2. From the literature search and questionnaire survey there was no evidence to support that CE has been fully implemented in construction as in other industry. What has been found is the practice of elements parallel to CE within partnering approach, fast track system and D&B procurement.
3. There is a strong desire for the industry to work in a collaborative way. This was evident from the research rankings and the trend within the industry to engage in partnering and D&B process.
4. CE is a viable concept to be adapted by construction industry because it has been proven successful in other industries by resolving the common type of problem that result from the practice of using traditional work processes.
5. The Delphi study in this research has developed guidelines on how to implement CE in construction. The findings from the Delphi study were supported by the case studies and the development of MMG-TCEiC. The case studies provided supporting evidence from the viewpoint of the practical approaches in realising some of the findings from the Delphi studies. The MMG-TCEiC, despite being a mapping tool, shows the gradual process to achieve CE environment. This is the preferred approach to the implementation of CE in construction organisations. This approach is consistent with the current practices within construction. By taking account of the findings from all methodologies of the research, it is concluded that to implement CE to construction requires:
  - i. A gradual transition to be made from the traditional practice of team working
  - ii. The use of Partnering approach, Design and Build procurement system and Project Management contract are the appropriate platform to realise CE implementation by incorporating the required improvement as guided by MMG-TCEiC and Delphi findings.

- iii. The clients being the 'ultimate' owner of the project should play significant roles to support CE implementation.
- iv. Co-location of team members in a common physical office has been determined in the research as effective solution to achieve teamwork integration.
- v. IT has been acknowledged to have significant roles to support teamwork communication, sharing project information and enhanced cross functionality process in the project.
- vi. The use of designated project manager that has adequate training of CE principles is a desirable approach to achieve CE implementation in construction.
- vii. The designer should maintain leadership in the design development process but with consideration of the input and requirements from other key members in the team.

### **9.3 Limitations of the research**

The findings of the research have the following limitations:

#### **9.3.1 Data collection**

The quantitative and qualitative data obtained from the research (other than that from the literature review) was mainly from the UK construction industry domain. The source of data used to get the responses for the consultants' group sample in the industry wide postal questionnaire survey was targeted within the consulting engineer's population. Therefore, there was limitation of the participation of the architectural consultants in the questionnaire survey.



### **9.3.2 Research findings**

The research findings developed from the industry wide postal questionnaire survey were limited by the available sample. Considering the limited number of responses, the findings cannot be generalised to represent the entire UK construction industry population. The Matrix Measurement Guideline-Toward CE in Construction (MMG-TCEiC) was developed and tested from only three case studies. Therefore, it has not been validated and tested within the industry in general.

### **9.4 Contribution**

The research has investigated factors related to the formation of the collaborative teamwork environment based upon a specific strategy, i.e. by using CE philosophy.

CE philosophy offers an alternative approach of how to deliver construction project with respect to the collaborative teamwork, work process and a focus towards the customer. These are undoubtedly the most important aspects of improvement that the industry is currently struggling to achieve. The main contribution made to construction industry throughout the research process are presented here:

#### *A. Evaluation of the achievement of collaborative teamwork in construction*

The findings toward the achievement of the collaborative teamwork in construction industry today are important because assumptions have been made about this aspect of CE but these have not been supported by appropriate research data. The practice of Partnering and D&B has been stated as examples of CE implementation in construction but no valid research data available. This research has investigated this issue and arrived at the conclusion that although Partnering approach and D&B exhibit practices of some elements parallel to CE this is inadequate to be justified as practising CE as the complete process found in other industries. This research has provided: qualitative and quantitative evidence of the current state of art of the limit of achievement in

collaborative teamwork within the current practice; and comparison of the profile of the involvement in and experience toward project exposure, authority, and communication of the contractors, sub-contractors and consultants as well as those using partnering approach in the construction project.

*B. The establishment of the ranking of factors that support and inhibit collaborative teamwork*

The rankings are an important contribution to the industry as they represented the desired priorities of that are needed to be addressed by the construction industry in the effort to promote the collaborative teamwork environment.

*C. The development of the guidelines to implement CE by using collaborative teamwork as the main strategy*

The research using the Delphi studies as the main methodology and supported by case studies has produced a guideline to support the formation of collaborative teamwork environment for construction project. These guidelines and their applications have been developed using CE principles to suit construction industry environment and current experience in teamwork.

*D. Development of Matrix Measurement Guideline*

The "Matrix Measurement Guideline - Toward CE in Construction " (MMG-TCEiC) is an important tool to enable the industry to map the process toward achieving the collaborative teamwork environment. MMG-TCEiC sets a benchmark towards collaborative teamwork and has three designated levels of achievement to enable the construction project to review their level of performance. It has eight columns objective and the evaluation of the achievement can be made independently. The ultimate aim of MMG-TCEiC is to enable the construction project to map their achievement toward CE environment for those who wish to implement CE. By using this tool, the limitation of

the current achievement can be identified and strategy can outline how to improve them.

## **9.5 Recommendation for future research**

The research had focussed on the fundamental aspect of implementing CE philosophy by the formation of the collaborative teamwork as the main strategy. CE is a relatively new management philosophy in construction and much work is needed to explore the issues relating to its implementation to construction. This is especially true from the organisational aspect. As a result from the current work undertaken it is recommended here that further research effort is undertaken in the following areas:

1. The implementation of CE philosophy requires some changes within the roles of the team members. Team members are expected to play more roles in making contribution toward design development process. This may raise some legal issues relating to the liability of the team members towards the design solution. Therefore further research is recommended to review this aspect.
2. The implementation of CE cannot be achieved on the traditional platform of procurement. Despite recommending D&B and Partnering as a suitable platform to initiate CE implementation in construction, it requires many amendments. Therefore it is recommended that a research effort to investigate the required changes require to be made to the existing D&B or Project Management procurement approach to suit their application as a platform to implement CE in construction.
3. This research has determined that the use of a designated project manager as an appropriate party to lead collaborative teamwork according to CE. Therefore further research recommended to investigate what are the required roles of PM to manage the construction projects that wish to implement CE.

4. The studies undertaken in this research have used samples from the contractors and consultants group of respondents. It is recommended that further research made to include the respondents from other key team members such as the key suppliers, clients, sub-contractors and specialist contractors to assess the requirement of their participation in the collaborative teamwork environment such as CE.
5. MMG-TCEiC has not been extensively validated industry wide. Further research is suggested to develop, validate and improve further MMG-TCEiC.
6. Evidence is provided of the application of IT to support collaborative teamwork in CE environment. However the level of IT tools needed varies from one project to another. A study needs to be undertaken to evaluate further IT requirements to support collaborative working in construction.

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## **APPENDIX 1**

**General guidelines for semi-structured interview :  
construction industry**

## **General guidelines for semi-structured interview with personnel representing construction organisation**

---

### ***Introduction***

1. Brief description of interviewer identity.
2. Brief description of the objective of the interview.
3. Declaration that all the information gathered solely used for research purposes only and that identity of the interviewee will remain unanimous.
4. Getting immediate feedback from interviewee how he/she prefers the interview process to take place.
5. Acquiring basic information about interviewee and his/her organisation background.

### ***Basic question to be asked***

1. What is your definition of the teamwork concept that is being practised within the construction industry today?
2. Can you briefly describe your personal experience in teamwork within your organisation?
3. What are the benefits of teamworking, and related problem to it within your organisation and within current construction industry scenario?
4. How project information being managed within teamwork?
5. What is the importance of IT in supporting teamwork?

### ***Ending interview***

Interviewer offers gratitude and appreciation for the co-operation of the interviewee.

## **APPENDIX 2**

### **General guidelines for semi-structured interview : manufacturing industry**

## **General guidelines for semi-structured interview with personnel representing manufacturing industry**

---

### ***Introduction***

1. Brief description of interviewer identity.
2. Brief description of the objective of the interview.
3. Declaration that all the information gathered solely used for research purposes and the identity of the interviewee will remain unanimous.
4. Getting immediate feedback from interviewee how he/she prefer the interview process to take place.
5. Acquiring basic information about interviewee and his/her organisation background.

### ***Basic question asked***

1. What is the motivation for the implementation of Concurrent Engineering philosophy to your organisation?
2. What is the general approach used to implement CE to your organisation?
3. Can you describe in detail the concept of Cross Functional Team that is being implemented within your organisation and other issue pertaining to it such as:
  - Leadership
  - Organisational structure
  - Identity
  - Roles
  - Participation in the design development process
  - Authority
4. Did the cross-functional team incorporate the participation of the suppliers?
5. What is the general issue raised from CE implementation within your organisation?
6. Please briefly describe a typical work process based on concurrent engineering concept for one of your organisation new product development?



7. How IT supports the implementation of Concurrent Engineering within your organisation?
8. What are the basic principles of CE philosophy as understood and practice by your organisation?
9. In your opinion, do you think CE is a suitable methodology to be applied to construction industry?

***Ending interview***

Interviewer offers gratitude and appreciation for the co-operation of the interviewee.

## **APPENDIX 3**

**General guidelines for the key issues to be discussed in the case study**

# **GENERAL GUIDELINES FOR THE KEY ISSUES TO BE DISCUSSED IN THE CASE STUDY**

---

## **1. Introduction**

- i. Brief identification of interviewer and background
- ii. Brief description of the research objectives
- iii. Agreement into the methodology of how to conduct the case study to suit the interviewee/s requirement and time requirement.

### *Main investigation:*

## **2. Project background**

- i. The purpose of the project
- ii. Project development background
- iii. Type of procurement use
- iv. Who are the key participants of the project
- v. Project organisational structure
- vi. Project design development process

## **3. Collaborative teamwork concept achieved in the project**

- i. Key features of the teamwork approach
- ii. Process of inclusion of team members
- iii. Leadership of the team
- iv. The role of client in the team
- v. Team authority
- vi. Team members roles in the design development process

#### **4. How teamwork integration being achieved?**

- i. Is the team co-located?
- ii. Any special procurement arrangement or approach such as partnering used?
- iii. How is the team being organised?

#### **5. Client, key suppliers and sub-contractors participation in the team**

- i. Is the client being a full time member of the team?
- ii. How did the team members address client's requirements?
- iii. Are key suppliers and sub-contractors part of team?
- iv. How were their requirements being considered in the design process?
- v. When did they participate in the team

#### **6. Project communication**

- i. How was communication within the team achieved?
- ii. To what extent is IT used to support team communication?
- iii. What are the basic IT facilities used to support teamwork communication?
- iv. What type of information is being shared within the project?

##### **6.1 The existence (application) of any specific IT tool used (such as GroupWare system) :**

- v. What are the basic features of such system?
- vi. What type of communication tools does it support?
- vii. Does it support the sharing of a common project database?
- viii. What type of information is available within the common project database?
- ix. Were all team members given access to all information within the database?
- x. What limitations were imposed within the project?

- xi. Were there any specific training and education programmes conducted to support team members and familiarise them with the new communication systems used?**

## **7. Ending Interview**

- i. Interviewer offers gratitude and thanks for the co-operation given.**
- ii. Request permission for further contact to clarify any further issues as necessary.**

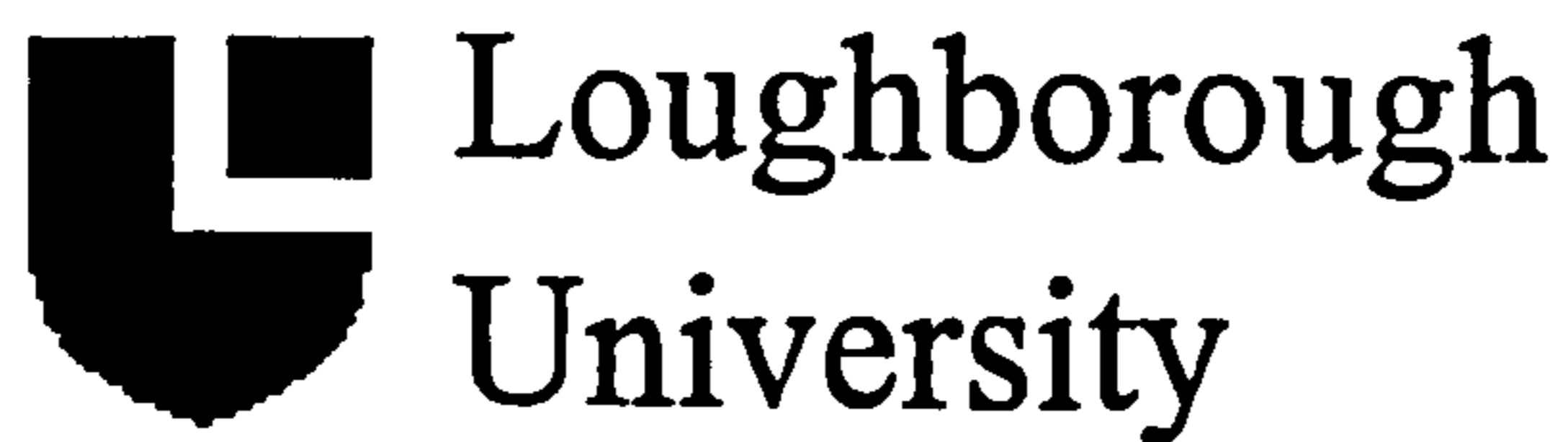
## **APPENDIX 4**

### **Sample of industry wide postal questionnaire**

**DEPARTMENT OF CIVIL AND BUILDING  
ENGINEERING**

**IMPROVING THE CONSTRUCTION PROCESS :  
THE TEAMWORK APPROACH**

**A QUESTIONNAIRE ON THE TEAMWORK ENVIRONMENT**



## **Introduction**

This questionnaire is part of the research work on the teamwork approach to improving the construction process which is currently being undertaken at the Department of Civil and Building Engineering, Loughborough University.

The use of teamwork is a very common approach for the execution of construction projects. However the nature of teamwork, its organisation, components and roles may vary depending on a number of factors. The aim of this questionnaire is to study the common features of the teamwork environments found in the UK construction industry, with special focus on its impact on the collaborative working environment and construction process.

The questionnaire is divided into two sections: Section A is dedicated to evaluating the general characteristics of the teamwork environment, based on personal project experience; Section B is to study on the general factors that support teamwork environment.

Please return the completed survey questionnaire using the self addressed enveloped enclosed to:

Department of Civil and Building Engineering  
Loughborough University  
Loughborough, Leicestershire  
LE11 3TU  
(Attn: Mr. Mohamad Ibrahim Mohamad)

Specific questions regarding the questionnaire should be addressed to Mr. Mohamad Ibrahim Mohamad at : 01509 263171 ext: 4133 or 01509 264994.

All responses will be treated in the strictest confidence.  
If you would like a copy of the survey results please attach your business card to the survey document.

Your assistance in completing the questionnaire is highly appreciated.



## GENERAL INFORMATION

**Company name :** \_\_\_\_\_(Optional)

**Company Address:** \_\_\_\_\_(Optional)

\_\_\_\_\_

**Type of organisation :**

Client / owner

Contractor

Consultant

Others, please specify

\_\_\_\_\_

**Respondent's name:** \_\_\_\_\_(Optional)

**Respondent's Position :** \_\_\_\_\_

**Contact telephone number :** \_\_\_\_\_(Optional)

**Number of years in construction industry experience :** \_\_\_\_\_

**SECTION A:**

The aim of this section is to evaluate the general teamwork environment that you have experienced within construction. *Please make your response based on a recently completed project in which you were involved.*

Q1. Please indicate the type of project and its total value by ticking (✓) the appropriate box,

Type of project:

Building	Civil Engineering	Construction	Offshore Engineering	Others
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Total value of the project

Less than £10 million	£10 - £20 million	£21 - £50 million	More than £50 million
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q2. Please indicate your organisation's function in this project,

Project management	<input type="checkbox"/>
Designers (Architect or Engineer)	<input type="checkbox"/>
Quantity Surveyors	<input type="checkbox"/>
Main Contractors	<input type="checkbox"/>
Sub-contractors	<input type="checkbox"/>
Main suppliers	<input type="checkbox"/>
Design build contractors	<input type="checkbox"/>
Others, please specify	<input type="checkbox"/>
.....	

Q3. Which type of contractual arrangement was used for the project:

Traditional contract	<input type="checkbox"/>
Design build contract	<input type="checkbox"/>
Management contract	<input type="checkbox"/>
Traditional method with partnering	<input type="checkbox"/>
Design build with partnering	<input type="checkbox"/>
If others, please specify	<input type="checkbox"/>
.....	

Q4. Please indicate by ticking (✓) in the appropriate box the degree to which your organisation was involved in contributing ideas to the other participant to perform the task at each stage of project life cycle indicated below:

Project Stage:	Degree of contributing			
	None	Minor	Some	Major
a. Briefing				
b. Project investigation				
c. Sketch design				
d. Design				
e. Preparation of working drawings				

Q5. How was the co-ordination of the work between the project participants achieved?

- a. Co-ordinated by the client
- b. Co-ordinated by the project manager
- c. Co-ordinated by the design consultant
- d. Co-ordinated through design-build team manager
- e. Others, please specify:

.....

**Q6.** The following statements cover various aspects relating to the project teams and their environment. (Project team is defined here as “ *individuals or groups from several organisations drawn temporarily together for the purpose of co-ordinating the project tasks.*”)

Please indicate the degree to which the following aspects were experienced by you on your last project.

	<b>Very Low</b>				<b>Very High</b>
<b>a.</b> Level of communication between functional groups.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>b.</b> Level of information sharing between functional groups.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>c.</b> Level of direct communication with the client.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>d.</b> Level of clear understanding of the overall projects goals.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>e.</b> Degree of flexibility in the project team (i.e. was your organisation allowed to express any ideas to improve aspects of the project design outside of your normal control)	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>f.</b> Degree of project authority given to your organisation to make vital decisions that affected other project’s tasks.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>g.</b> Level of understanding of other functional tasks in the project.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>h.</b> Level to which you were able to respond to problems outside your functional area.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>i.</b> The level of adversarial relationship that existed amongst the project team members.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>

## SECTION B

This section of the survey is designed to evaluate your opinion on the type of project environments that support and inhibit collaboration within teams.

Q1. How important are each of the following factors in promoting a collaborative team environment for construction?

Rating :      1 = unimportant (UI)      2 = fairly important (FI)  
                   3 = important (I)            4 = very important (VI)      5 = critical (C)

	UI	FI	I	VI	C
a. Availability of key information (design information, schedules, etc.) to all team members.	1	2	3	4	5
b. Ability of all team members to perform project tasks concurrently.	1	2	3	4	5
c. Addressing the client's requirements as a team.	1	2	3	4	5
d. Early consideration of construction and operational problems	1	2	3	4	5
e. The inclusion of team members from various functions within the project team.	1	2	3	4	5
f. Assigning adequate authority to key project participants to impact design decisions.	1	2	3	4	5
g. Improving existing procurement systems to support the formation of a united project team.	1	2	3	4	5
h. Initiative from the client.	1	2	3	4	5
i. Provision of information technology to minimise communication barriers.	1	2	3	4	5

**Q2. Please rate each of the following factors to show how important you believe they are as barriers to collaborative teamwork.**

**Rating :**      **1 = unimportant (UI)**      **2 = fairly important (FI)**  
                   **3 = important (I)**            **4 = very important (VI)**      **5 = critical (C)**

		<b>UI</b>	<b>FI</b>	<b>I</b>	<b>VI</b>	<b>C</b>
<b>a.</b>	<b>Diverse goals amongst project participants.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>b.</b>	<b>Existing traditional contract systems.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>c.</b>	<b>The temporary nature of the project.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>d.</b>	<b>Lack of knowledge of other functional areas.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>e.</b>	<b>Lack of mutual trust between project participants.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>f.</b>	<b>Lack of willingness to share project information.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>g.</b>	<b>Lack of a single management system to support interaction between team members.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>h.</b>	<b>Fear of a power struggle between different groups.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>i.</b>	<b>Lack of clear direction toward project goals.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>j.</b>	<b>Lack of the client support for the teamwork approach.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>k.</b>	<b>Difficulty in quantifying the benefits of working in close collaboration.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>l.</b>	<b>The traditional adversarial nature of construction.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>m.</b>	<b>Lack of commitment due to cost constraints.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>n.</b>	<b>The issue of who is going to lead the team.</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>

***Thank you for your assistance in completing the survey.***

## **APPENDIX 5**

### **Detail description of Delphi study objectives**

## **THE DETAIL OBJECTIVES OF DELPHI STUDY**

The main aim of the Delphi study conducted in this research was to get the consensus opinion of the industry experts toward the development of the guidelines to form the Cross Functional Project Teamwork (CFPT) as an approach to achieve CE implementation in construction industry.

The main objectives of the Delphi study were:

- I. To evaluate the basic component and characteristic of the CFPT
- II. To assess the supportive tool and mechanism to achieve the formation of CFPT;  
and
- III. To evaluate the implication of such formation of teamwork on the existing construction environment.

The detail description of objectives of the Delphi studies were:

1. To determine the composition of the team members which consist of those who can influence and contribute to project design.
2. To determine the number of team members.
3. To evaluate the teamwork leadership requirement.
4. To evaluate the consistency of the leadership throughout the project life cycle.
5. To evaluate evaluation of the role of client in supporting teamwork performance.
6. To asses the factor that can help the industry of the problem lack of mutual trust which inhibit the formation of teamwork.
7. To evaluate the level of changes expected on the current traditional work practice to achieve the formation of the collaborative teamwork based on CE principles in construction with respect to the following issue:
  - role of client on the project leadership
  - current procurement system
  - adoption of special criteria to select team members
  - collocation of team members into a common office



8. To evaluate the characteristic and the role of the collaborative teamwork within the following aspects:

- The team power to override an individual functional group's decision.
- Team accountability for project design
- authority and flexibility of the team to contribute and review the design
- Criteria for the adoption of the design for the project based upon the consensus decisions of team members.
- Type of information requirement for the team members within the collaborative team environment.
- The need for the project to accommodate a new physical working environment such as sharing common offices.
- To need to change the attitudes toward sharing common project information within collaborative working environment.
- The necessity for quantity surveyor (estimator) for the project to cost alternatives as design proceeds.

9. To evaluate the impact of formation of the team from outset as required in CE principle on the following aspect:

- Existing traditional procurement systems.
- The basic knowledge and ability of the project participants to work in such collaborative environment.
- Additional costs that will be incurred by clients due to the appointment of team members to the project earlier than normal under traditional contract systems.
- Additional efforts required by the clients to manage and co-ordinate the project team members working under such collaborative teamwork environment compared to those in the existing teamwork approach under the traditional contract system.
- Willingness of the client to pay additional costs for the appointment of all team members at the start of the project.
- The client input of the additional resources requirement to manage and co-ordinate the project teams.

10. To evaluate the strategy that can be used to achieve the formation of the team from outset such like:

- Initiative from clients
- Initiative from parties approached by the clients to develop the project
- Initiative from regulatory agencies
- Use of procurement system

11. To determine the form of frameworks within which the CFPT can work.

12. To identify the barriers to achieve the formation of the team at the outset of the project.

13. To evaluate the level of changes required within construction industry to adopt the extended use of information technology to enhance information within the following aspect:

- Project team composition.
- Cultural aspects
- Existing procurement systems
- The information technology commonly used on a construction project (telephone, fax, E-mail, etc.)
- The attitude of the project team towards the used of information technology tools.
- Leadership in IT use for the project (The management team for the project should lead the promotion of the use of information technology within the project)
- The way the project is managed must exhibit greater reliance on the use of IT.

14. To evaluate the appropriateness of the following IT tool to support collaborative working:

- Personal information systems (e.g. word processor, spreadsheet, databases, desktop publishing, presentation applications)
- Workgroup information systems (e.g. E-mail, video conferencing, workgroup decision support system, workgroup databases etc.)
- Enterprise information systems (e.g. EDI, interdepartmental management information system, inter enterprise systems integration)

15. To evaluate the importance of the increase use of the following IT tools to support collaborative teamwork:

- Shared project database
- Electronic meetings to minimise (not to replace) traditional face to face meetings.
- Electronic data and voice mail
- Electronic team scheduling
- Video conferencing
- Shared electronic project model

## **APPENDIX 6**

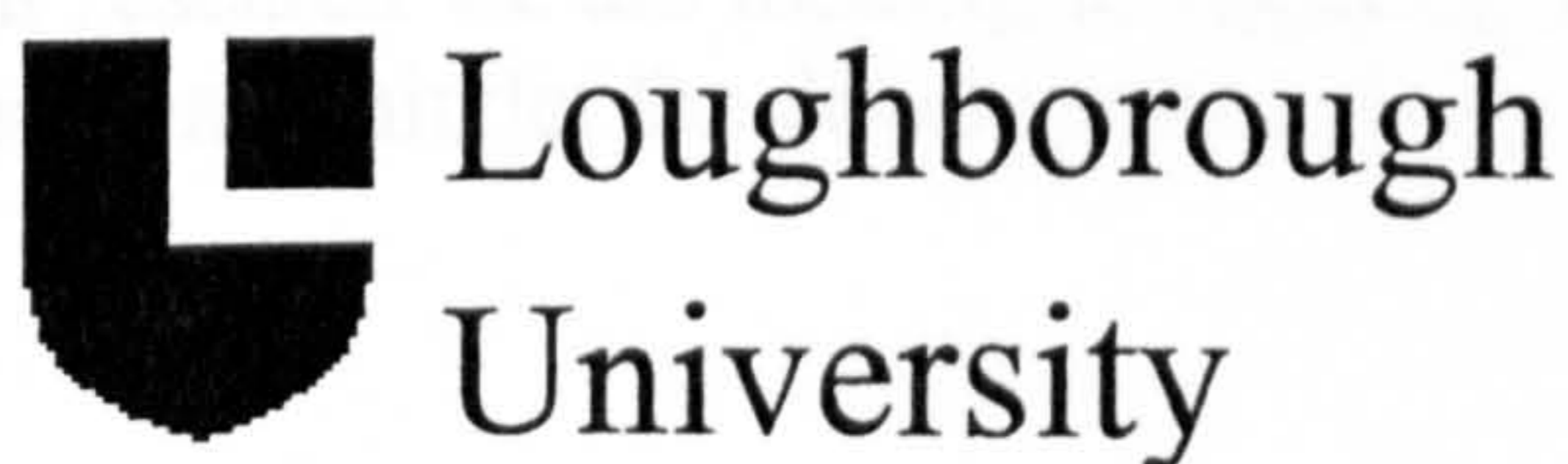
### **First Round Delphi (FRD) questionnaire**

# DEPARTMENT OF CIVIL AND BUILDING ENGINEERING

## A STUDY OF THE POTENTIAL OF CONCURRENT ENGINEERING IN CONSTRUCTION

### FIRST ROUND DELPHI QUESTIONNAIRE ON CROSS FUNCTIONAL PROJECT TEAM IN CONSTRUCTION

MAY 1998



## **A STUDY ON THE POTENTIAL OF CONCURRENT ENGINEERING IN CONSTRUCTION**

Concurrent Engineering is a management philosophy that originates from manufacturing. It has been defined as :

*" A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. The approach is intended to cause developers, from outset, to consider all elements of product life cycle from concept through disposal, including quality, cost, schedule and user requirements"*

The principles of Concurrent Engineering comprise:

- increased consideration of the manufacturing process in the product design
- the formation of a 'cross functional team' to accomplish the development process
- a focus on the customer during the development process
- the use of the 'lead time' as source of competitive advantage

of these principles it is the concept of the 'cross functional team' on which our research is centred.

In the construction industry we are familiar with the concept of teamwork. The major difference between the teamwork currently practised in construction compared to teamwork as required in Concurrent Engineering can be best understood by examining the basic characteristics of the cross functional team (CFT) approach. In the CFT approach:

- formation of the CFT is made from the inception of the project
- CFT supports the removal of the boundaries between the functional groups
- the main objective of the CFT is to enable the members to contribute during the design stage
- CFT team members may comprise of a wide range of members including the client and the supplier
- CFT members are normally given adequate authority to make important design decisions
- the CFT supports process change, a more flexible concurrent (overlapping) development of project tasks.

Within our research we are looking to focus on these aspects and determine the factors that will help, and hinder the development of cross functional teams.

## **BACKGROUND OF THE SURVEY WORK AND THE DELPHI TECHNIQUE**

We are undertaking a survey of industry and academic experts to establish a consensus view of the factors relating to cross functional teams. This survey will be conducted by using a technique known as The Delphi Technique. The Delphi Technique is a set of procedures for eliciting and refining the opinions of a group, usually a panel of experts. The essence of the technique comprises a series of questionnaires sent to a pre-selected groups of experts. These questionnaires are designed to elicit and develop individual responses to the problems posed and to enable the experts to refine their views as the group's work progresses in accordance with the assigned tasks. The main objective of technique is to explore ideas and agree suitable information for decision making.

Prior to this Delphi survey, we have conducted an industry wide mail questionnaire survey to develop a better understanding on the factors relating to existing teamwork within the industry and to form a general agreement on the factors that inhibit and support teamwork. The initial survey was conducted in December 1997 with 160 questionnaires send to contractors and consultants within UK construction industry. This Delphi questionnaire has been developed based on the findings from that 'exploratory' survey with the aim to form a consensus opinion on the factors relating to the implementation of a 'cross functional project team' approach within the construction industry.

In accordance to the Delphi procedure, we plan to conduct the survey in two or three rounds. This questionnaire represents the first round of Delphi. Once we have received all the responses from the panel of experts, we will analyse and summarise the outcomes and will present them to the panellists along with the second Delphi questionnaire which will be developed from the findings of the first round. The aim of the second round survey is to give the panellists the opportunity to review their opinions in respect of all the experts' responses. If necessary the process will continue for the third and final round.

### **CONFIDENTIALITY**

We will maintain strictest confidentiality with respect to all the information provided by the panellists. The results of the survey analysis will be presented in a general form and the individual identity of the panellists will be treated as confidential throughout the process.

## **WHAT WE NEED YOU TO DO**

In this Delphi questionnaire you are requested to:

1. **REVIEW** all issues in this questionnaire and indicate your choice (vote) for each question accordingly. Most questions require you to rate or select your choice from the available options. A few questions require brief written answer.
2. **MAKE COMMENTS** on any issue or question as you wish. Feel free to suggest clarifications, argue in favour of or against issues, ask questions. (Please use separate sheet of paper to write them but do not forget to include the reference for the section, and question number).
3. **RETURN** your completed questionnaire with any other additional sheets you wish to include by using the return enveloped provided by ..... 1998 to:

Department of Civil Engineering  
Loughborough University,  
Loughborough, Leicestershire  
LE11 3TU  
(Att: Mr.Mohamad Ibrahim Mohamad)

Specific queries regarding the Delphi questionnaire should be addressed to :  
Mr. Mohamad Ibrahim at : 01509- 264994 (E-mail: M.Mohamad-  
Ibrahim@Lboro.ac.uk)

or

Dr. A.N.Baldwin at : 01509 - 222605 (E-mail : A.N.Baldwin@Lboro.ac.uk).

Your assistance as a panellist in this Delphi questionnaire is highly appreciated.



## GENERAL INFORMATION OF THE PANELIST

*(Note: The information in this section will be remain confidential and required for the purpose of facilitating the management of the Delphi process only)*

**Your name :** \_\_\_\_\_

**Your position:** \_\_\_\_\_

**Your contact address:** \_\_\_\_\_  
\_\_\_\_\_

**Contact telephone number :** \_\_\_\_\_

**E-mail :** \_\_\_\_\_

**Number of years construction industry experience :** \_\_\_\_\_

**SECTION A**

The aim of this section is to determine the composition of the cross functional project team, its characteristics and leadership.

*"Collaborative teamworking based upon concurrent engineering principles requires all parties in the project to work in a unified project team. (This team is commonly known as 'cross functional team'.)"*

Q1. The following is a list of the important stakeholders in the construction project. Please rate the importance of :

- i. their ability to influence project design (*Influence*)
- ii. their contribution to the design of the project (*Contribution*)

(Where the rating is on the scale from 1 to 5 indicating the increasing level importance in ascending order; 1 indicates the least important and 5 as the most important.)

a.	client	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
b.	architects	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
c.	engineers	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
d.	surveyors	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
e.	end user (customers)	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
f.	main contractors	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
g.	sub - contractors	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
h.	suppliers	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
i.	service contractors	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
j.	financiers	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
k.	others (please specify and rate their importance)												
•	.....	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
•	.....	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5
•	.....	<i>Influence</i>	1	2	3	4	5	<i>Contribution</i>	1	2	3	4	5

**Q2.** What is the maximum number of the persons that should be available to represent each functional group within a cross functional team to ensure that it efficiently represents the interests of all parties involved.

*(Please tick to vote your choice in the appropriate box)*

- i. strictly one representative for each functional group
- ii. depends on the role of the group, some may have more than one representative.
- iii. more than one representative for each group but of equal numbers
- iv. others, please specify
- .....

**Q3.** In your opinion, for the maximum efficiency of the cross functional project team, should the number of the team members:

*(Please tick to vote your choice in the appropriate box)*

- i. remain the same throughout the project life cycle
- ii. change in number depending on the project phase
- iii. others, please specify
- .....

**Q4.** Who do you consider the most appropriate party to lead the team?

*(Please tick to vote your choice in the appropriate box)*

- i. clients or their representatives
- ii. a designated project manager
- iii. designers
- iv. engineers
- v. others, please specify:
- .....

**Q5. Should the leadership of the team vary at different stages of the project life cycle?**

*(Please tick to vote your choice in the appropriate box)*

i. Yes, it should

ii. No, it should remain the same

iii. Others, please specify

.....

**Q6. How best can client contribute to team performance?**

*(Please write your opinion below and continue in other sheet if necessary)*

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

**Q7. Our survey shows that lack of mutual trust is considered as a major inhibitor to collaborative teamwork. In your opinion, how can construction industry overcome this barrier?**

*(Please write your opinion below and continue in other sheet if necessary)*

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

**SECTION B**

This section aims to evaluate the factors that support the formation of a cross functional project team and its roles.

*"Experience from other industries has found that, in a teamwork environment based on concurrent engineering principles, team members will usually be given adequate authority and flexibility to contribute and influence the project design especially in the area of requirements for manufacturing (construction) and operation. The team is normally formed at the outset stage of the project."*

**Q1.** If we are to achieve a similar teamwork concept in construction with adequate authority and flexibility, what level of changes do you expected to take place? Score these changes on a scale of 0 to 4 where rating indicating level of changes are:

**0 = no change    1 = low    2 = moderate    3 = high    4 = very high**

Changes within the:

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| a. existing 'traditional' procurement system.   | 0 | 1 | 2 | 3 | 4 |
| b. existing 'traditional' work process.   | 0 | 1 | 2 | 3 | 4 |
| c. relationship between the various functional groups in the project.                               | 0 | 1 | 2 | 3 | 4 |
| d. role of the client in project leadership   | 0 | 1 | 2 | 3 | 4 |
| e. initiative of the client in supporting the teamwork.   | 0 | 1 | 2 | 3 | 4 |
| f. allowance for special provision in the contract to support teamwork approach as mentioned above. | 0 | 1 | 2 | 3 | 4 |
| g. adoption of specific criteria to select team members.  | 0 | 1 | 2 | 3 | 4 |
| h. others, please specify and rate them:  |   |   |   |   |   |
| • .....   | 0 | 1 | 2 | 3 | 4 |
| • .....   | 0 | 1 | 2 | 3 | 4 |
| • .....   | 0 | 1 | 2 | 3 | 4 |

Q2. If teamwork concept similar to other industries is to be developed for construction projects, how important are each of the following issues. Please rate the importance of these issues on a scale of 1 to 5.

**(Where the rating indicates the increasing level importance in ascending order; 1 indicates the least important and 5 as the most important.)**

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| a. The team is given the power to override an individual functional group's decision.   | 1 | 2 | 3 | 4 | 5 |
| b. The team is given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members. | 1 | 2 | 3 | 4 | 5 |
| c. Team members must be given adequate authority and flexibility to contribute and to review the design throughout its development phase.                     | 1 | 2 | 3 | 4 | 5 |
| d. Final adoption of the design for the project must be made upon the consensus decisions of team members.  | 1 | 2 | 3 | 4 | 5 |
| e. All team members must be given adequate project information with respect to:   |   |   |   |   |   |
| i) project planning   | 1 | 2 | 3 | 4 | 5 |
| ii) project scheduling  | 1 | 2 | 3 | 4 | 5 |
| iii) basic design requirements  | 1 | 2 | 3 | 4 | 5 |
| iv) project cost  | 1 | 2 | 3 | 4 | 5 |
| v) Others, please specify and rate your level of agreement:   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |

**Q3.** Another important aspect of the concept of collaborative teamwork based on concurrent engineering principles is that the formation of the team is made at the outset of the project.

Such practice is not normal within construction. If the construction industry wants to achieve a teamwork concept that is initiated at such early stage of the project what level of change is necessary within each of the followings? Please rate the changes on a score of 0 to 4 where:

**0 = no change    1 = low    2 = moderate    3 = high    4 = very high**

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| a. existing traditional procurement systems.  | 0 | 1 | 2 | 3 | 4 |
| b. the basic knowledge and ability of the project participants to work in such collaborative environment.   | 0 | 1 | 2 | 3 | 4 |
| c. additional costs that will be incurred by clients due to the appointment of team members to the project earlier than normal under traditional contract systems.  | 0 | 1 | 2 | 3 | 4 |
| d. additional efforts required by the clients to manage and co-ordinate the project team members working under such collaborative teamwork environment compared to those in the existing teamwork approach under the traditional contract system. | 0 | 1 | 2 | 3 | 4 |
| e. others, please specify and rate them:  |   |   |   |   |   |
| • .....   | 0 | 1 | 2 | 3 | 4 |
| .....   |   |   |   |   |   |
| • .....   | 0 | 1 | 2 | 3 | 4 |
| .....   |   |   |   |   |   |
| • .....   | 0 | 1 | 2 | 3 | 4 |
| .....   |   |   |   |   |   |

**Q4.** The following are the mechanisms that may be used to achieve the formation of the team at the outset stage of the project. Please rate the level of their importance on a scale of 1 to 5.

(Where the rating is on the scale from 1 to 5 indicating the increasing level importance in ascending order; 1 indicate the least important and 5 as the most important.)

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| a. initiative from clients  | 1 | 2 | 3 | 4 | 5 |
| b. initiative from parties approached by the clients to develop the project | 1 | 2 | 3 | 4 | 5 |
| c. initiative from regulatory agencies                                      | 1 | 2 | 3 | 4 | 5 |
| d. use of procurement system  | 1 | 2 | 3 | 4 | 5 |
| e. others, please specify and rate them:                                    |   |   |   |   |   |
| • .....   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |

**Q5.** In concurrent engineering there are variety of forms of frameworks within which the cross functional team can work. Which is the most appropriate of these within a construction industry environment?

*Tick your vote in the appropriate box*

- |  |                          |
|--|--------------------------|
| a. Matrix form of organisation.  | <input type="checkbox"/> |
| b. A core 'cross functional project team' surrounding by smaller functional teams.   | <input type="checkbox"/> |
| c. 'Virtual organisation' form of 'cross functional project team' in which co-ordination and communication rely on information technology. | <input type="checkbox"/> |
| d. No specific form can be defined because it depends on the individual project's requirement as in other industries.                      | <input type="checkbox"/> |
| e. Others, please specify:   | <input type="checkbox"/> |
| .....  |                          |



Q6. What are the barriers to achieve the formation of the team at the outset of the project?

*(Please write your opinion below and continue in other sheet if necessary)*

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....

**SECTION C**

*"For the collaborative working, key information needs to be made available to all team members."*

The aim of this section is to evaluate the information systems required to support communication for the 'cross functional project team'.

Q1. In order to achieve the above objective in UK construction industry, what is the level of change that you consider needs to take place with regard to the following.  
 Rate the level of change on a scale of 0 to 4 where rating indicating level of changes are:

**0 = none    1 = low    2 = moderate    3 = high    4 = very high**

a. project team composition.	0	1	2	3	4
b. cultural aspects.	0	1	2	3	4
c. existing procurement systems	0	1	2	3	4
d. the information technology commonly used on a construction project (telephone, fax, E-mail, etc.)	0	1	2	3	4
e. criteria for selection of project team members	0	1	2	3	4
f. others, please specify and rate them:	0	1	2	3	4
• .....	0	1	2	3	4
• .....	0	1	2	3	4
• .....					

Q2. Some experts consider that information technology (IT) is important to minimise communication barriers on construction projects.

In your opinion, what level of importance should be given to the following information technologies to facilitate collaborative working in construction. Please rate the importance on a scale of 1 to 5.

(Where the rating is on the scale from 1 to 5 indicating the increasing level importance in ascending order; 1 indicate the least important and 5 as the most important.)

- |   |   |   |   |   |   |
|---|---|---|---|---|---|
| a. Personal information systems (e.g. word processor, spreadsheet, databases, desktop publishing, presentation applications)        | 1 | 2 | 3 | 4 | 5 |
| b. Workgroup information systems (e.g. E-mail, video conferencing, workgroup decision support system, workgroup databases etc.)     | 1 | 2 | 3 | 4 | 5 |
| c. Enterprise information systems (e.g. EDI, interdepartmental management information system, inter enterprise systems integration) | 1 | 2 | 3 | 4 | 5 |
| d. Others, please specify and rate them:  |   |   |   |   |   |
| • .....   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |
| • .....   | 1 | 2 | 3 | 4 | 5 |

Q3. Communication in collaborative working requires an information manager for the project. Do you agree that a member of the team must be allocated this role?

(Please tick your vote in the appropriate box)

- |                   |                          |
|-------------------|--------------------------|
| Strongly agree    | <input type="checkbox"/> |
| Agree             | <input type="checkbox"/> |
| Neutral           | <input type="checkbox"/> |
| Disagree          | <input type="checkbox"/> |
| Strongly disagree | <input type="checkbox"/> |

**Thank you for your participation.**


## **APPENDIX 7**

### **Second Round Delphi (SRD) questionnaire**

# DEPARTMENT OF CIVIL AND BUILDING ENGINEERING

## A STUDY OF THE POTENTIAL OF CONCURRENT ENGINEERING IN CONSTRUCTION

**SECOND ROUND DELPHI QUESTIONNAIRE  
ON CROSS FUNCTIONAL PROJECT TEAM IN CONSTRUCTION  
SEPTEMBER 1998  
(version 1.1)**

 **Loughborough  
University**

## **A STUDY ON THE POTENTIAL OF CONCURRENT ENGINEERING IN CONSTRUCTION**

Concurrent Engineering is a management philosophy that originates from manufacturing. It has been defined as :

*" A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. The approach is intended to cause developers, from outset, to consider all elements of product life cycle from concept through disposal, including quality, cost, schedule and user requirements"*

The principles of Concurrent Engineering comprise:

- increased consideration of the manufacturing process in the product design
- the formation of a 'cross functional team' to accomplish the development process
- a focus on the customer during the development process
- the use of the 'lead time' as source of competitive advantage

of these principles it is the concept of the 'cross functional team' on which our research is centred.

In the construction industry we are familiar with the concept of teamwork. The major difference between the teamwork currently practised in construction compared to teamwork as required in Concurrent Engineering can be best understood by examining the basic characteristics of the cross functional team (CFT) approach. In the CFT approach:

- formation of the CFT is made from the inception of the project
- CFT supports the removal of the boundaries between the functional groups
- the main objective of the CFT is to enable the members to contribute during the design stage
- CFT team members may comprise of a wide range of members including the client and the supplier
- CFT members are normally given adequate authority to make important design decisions
- the CFT supports process change, a more flexible concurrent (overlapping) development of project tasks.

Even though some elements of CE had been practice in construction today, but CE is a different philosophy compared to the existing practice like in partnering or design build approach. In CE, teamwork is not initiated from the need for mutual business partnership but rather derived from the need to improve the work process by considering all the downstream requirement in the design phase to minimise error and rework, improve the quality of the end product, increase concurrency of work and reduce project time.

Within our research we are looking to focus on these aspects and determine the factors that will help, and hinder the development of cross functional teams.

## **BACKGROUND OF THE SURVEY WORK AND THE DELPHI TECHNIQUE**

We are undertaking a survey of industry and academic experts to establish a consensus view of the factors relating to cross functional teams. This survey will be conducted by using a technique known as The Delphi Technique. The Delphi Technique is a set of procedures for eliciting and refining the opinions of a group, usually a panel of experts. The essence of the technique comprises a series of questionnaires sent to a pre-selected groups of experts. These questionnaires are designed to elicit and develop individual responses to the problems posed and to enable the experts to refine their views as the group's work progresses in accordance with the assigned tasks. The main objective of technique is to explore ideas and agree suitable information for decision making.

Prior to this Delphi survey, we have conducted an industry wide mail questionnaire survey to develop a better understanding on the factors relating to existing teamwork within the industry and to form a general agreement on the factors that inhibit and support teamwork. The initial survey was conducted in December 1997 with 160 questionnaires sent to contractors and consultants within UK construction industry. This Delphi questionnaire has been developed based on the findings from that 'exploratory' survey with the aim to form a consensus opinion on the factors relating to the implementation of a 'cross functional project team' approach within the construction industry.

In accordance to the Delphi procedure, we plan to conduct the survey in two or three rounds. This questionnaire represents the first round of Delphi. Once we have received all the responses from the panel of experts, we will analyse and summarise the outcomes and will present them to the panellists along with the second Delphi questionnaire which will be developed from the findings of the first round. The aim of the second round survey is to give the panellists the opportunity to review their opinions in respect of all the experts' responses. If necessary the process will continue for the third and final round.

### **CONFIDENTIALITY**

We will maintain strictest confidentiality with respect to all the information provided by the panellists. The results of the survey analysis will be presented in a general form and the individual identity of the panellists will be treated as confidential throughout the process.

## **THE SECOND ROUND DELPHI QUESTIONNAIRE**

The Second Round Delphi (SRD) survey is the continuation of the previous First Round Delphi (FRD) questionnaire survey. The development of the SRD is based on the responses and feedback that we received from the panellists from the FRD. The FRD has been a successful round with the encouraging participation of the thirteen panellists, i.e. 100% rate of response.

In this SRD we have:

- i. Taken out all the questions that have achieved the desired consensus level of agreement in the FRD. (We set the minimum level of 75% of the responses as the consensus level)
- ii. Giving the option to the panellists to reconsider their FRD vote on each of the questions (issues) that have not reach the consensus level.
- iii. Made further clarifications on the questions in the SRD wherever necessary.
- iv. Added new questions based on the feedback by the panellists.

### **WHAT WE NEED YOU TO DO:**

In this SRD questionnaire you are requested to:

1. **REVIEW** all issues in this questionnaire and indicate your choice (vote) for each question accordingly. You have the option to reconsider your previous vote if you wish, for the questions that did not reach the consensus level of agreement in the FRD. However, please vote for the new included item. Most questions require you to rate or select your choice from the available options in a similar manner as the FRD.
2. **MAKE COMMENTS** on any issue or question as you wish. Feel free to suggest clarifications, argue in favour of or against issues, ask questions. (Please use separate sheet of paper to write them but do not forget to include the reference for the section, and question number).
3. **RETURN** your completed questionnaire with any other additional sheets you wish to include by using the return enveloped provided by ..... 1998 to:

Department of Civil Engineering  
Loughborough University,  
Loughborough, Leicestershire  
LE11 3TU  
(Att: Mr.Mohamad Ibrahim Mohamad)



Specific queries regarding the Delphi questionnaire should be addressed to :  
Mr. Mohamad Ibrahim at : 01509- 264994 (E-mail: M.Mohamad-  
Ibrahim@Lboro.ac.uk)

or

Dr. A.N.Baldwin at : 01509 - 222605 (E-mail : A.N.Baldwin@Lboro.ac.uk).

Your assistance as a panellist in this Delphi questionnaire is highly appreciated.

**SECTION A**

**Q1.** In the First Round Delphi (FRD), panellists have rated the level of importance for each of the major stakeholders of the construction project based on their 'Influence' and 'Contribution' to the design of the project within the cross functional team.

In analysing the responses, we have computed the relative index (R.I.) factor for each stakeholder and ranked them in accordance to their score. The higher the score (i.e. the R.I factor) the greater the importance of the stakeholder presence in the cross functional team with respect to their ability to influence or to contribute to design of the project.

For further clarification from the FRD please read the following statements :

- i. The term *influence* reflects the ability of the stakeholder to use their power to sway or direct decisions within the design. This role is critically important during the inception and the conceptual stage of the project design.
- ii. The term *contribute* refers to the ability of the stakeholder to supply ideas and review the design during the design development stage to ensure that it will consider all the 'downstream' problems in the construction and operation.
- iii. The term *Engineer* represents all the parties that are involved project design development and project supervision and includes Civil and Structural Engineers, Mechanical and Electrical Engineers and similar professionals.

Please review the rankings shown on the next page, if you wish to suggest new rankings, please indicate these by stating your new ranking beside the existing one.

**RANKING OF THE STAKEHOLDERS IN THEIR ABILITY TO INFLUENCE PROJECT DESIGN:**

STAKEHOLDER	RANKING BASED ON COMPUTATION FROM FIRST ROUND DELPHI RESPONSES	YOUR NEW RANKING (Optional)
clients	1*	
end user (customer)	1*	
architects	3	
engineers	4	
main contractors	5	
service contractors	6	
surveyors	7	
financiers	8	
sub-contractors	9	
suppliers	10	

\* indicate same R.I. factor.

Your comment :

**RANKING OF THE STAKEHOLDERS IN THEIR ABILITY TO CONTRIBUTE TO PROJECT DESIGN:**

STAKEHOLDER	RANKING BASED ON COMPUTATION FROM FIRST ROUND DELPHI RESPONSES	YOUR NEW RANKING (Optional)
architects	1	
engineers	2	
main contractors	3	
sub-contractors	4	
clients	5	
service contractors	6	
end user (customer)	7	
suppliers	8	
surveyors	9	
financiers	10	

Your comment:

- Q4** From the First Round Delphi survey, there was no unanimity in the responses to the question of the appropriate party to lead the team. We have added additional wording to clarify each choice. Please review the statements. Please confirm your original vote or reconsider your choice by ticking in the appropriate box.

<b>Q.</b>	<b><i>Who do you consider the most appropriate party to lead the team?</i></b>	<b>FRD votes</b>	<b>Your FRD vote</b>	<b>Your Second Round Delphi vote.</b>
<b>i.</b>	Clients or their representative (Representative refers to the party appointed by the client other than the designers (architects or engineers)).	15.4%		
<b>ii.</b>	A designated project manager (refers to a professional project manager with adequate skill and capability to manage the project.	61.5%	✓	
<b>iii.</b>	Designers (refers to consultant group either architects or engineers)	0%		
<b>iv.</b>	Engineers (item deleted and included in the (iii.) option.	0%		Not required
<b>v.</b>	Others)	23.1%		

- Q5.** There was no unanimity in the responses to the question "Should the leadership of the team vary at different stages of the project life cycle".

As a further clarification, this question is related to influence of the different stages of the project phase toward the leadership requirement. This question has been extended as follows:

*Should the leadership of the team vary at different stages of the project life cycles to meet the different requirements of each stage of the cycle.*

Please confirm your original vote or reconsider your vote by ticking in the appropriate box.

<b>Q.</b>	<b><i>Should the leadership of the team vary at different stages of the project life cycle?</i></b>	<b>% of FRD votes</b>	<b>Your FRD vote</b>	<b>Your Second Round Delphi vote.</b>
<b>i.</b>	Yes, it should.	30.8%		
<b>ii.</b>	No, it should remain the same	61.5%	✓	
<b>iii.</b>	Others	7.7%		

**SECTION B**

Experience from other industries has established that, in a teamwork environment based on concurrent engineering principles:

- A team is normally formed at the outset of the project
- Team members are given opportunity to influence and contribute to the project design
- Full consideration is given to manufacturing (construction) and operational issues.

If a similar teamwork concept in construction is to be achieved there will have to be changes in the existing traditional practices such as in the procurement system and the traditional work practice.

Q1. In the FRD you were requested to predict the level change expected for each of the given issues. On some of these issues consensus was reached. Please review your FRD vote and either confirm it or revise it by circling the appropriate number. One additional issue has been added. Please vote on this question.

The scale for the level of changes are:

0 = no change    1 = low    2 = moderate    3 = high    4 = very high

Q.	<i>If we were to achieve a similar teamwork concept in construction with adequate authority and flexibility, what level of Changes do you expect to take place? Changes within:</i>	FRD votes analysis		Your FRD vote	Your Second Round Delphi vote
		<3	≥3		
d.	The role of the client in project leadership (Project leadership as defined here is the general role of leadership to support teamwork rather than a specific technical and project management role that may be taken up by other professional such as project manager).	38.5%	61.5%	②	0 1 2 3 4
f.	Allowance for special provision in the contract to support teamwork approach as mentioned above (i.e. use the procurement system to support the formation of the teamwork by clearly stipulating the requirement in the contract)	50%	50%	③	0 1 2 3 4
g.	Adoption of specific criteria to select team members.	41.7%	58.3%	②	0 1 2 3 4
h.	New issue added: (Please vote): Collocation of project team members into a common office.				0 1 2 3 4

- Q2. In the FRD, panellists were requested to evaluate statements related to teamwork. The following statements are those where a consensus was not reached. Additional statements based on the panellists suggestion has also been included.

Please review your FRD vote and either confirm it or revise it by circling the appropriate number from 1 to 5 on the scale. (Circle 5 if you strongly agree and 1 if you disagree.)

Q.	<i>If a teamwork concept similar to other industries is to be developed for construction projects:</i>	FRD votes analysis		Your FRD vote	Your Second Round Delphi vote.
		≤3	>3		
a.	The team must be given the power to override an individual functional group's decision.	50%	50%	③	1 2 3 4 5
b.	The team must be given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members.	46.2%	53.8%	③	1 2 3 4 5
d.	Final adoption of the design for the project must be made upon the consensus decisions of team members. (Please read question "f." carefully to avoid conflicting response).	63.6%	36.4%	③	1 2 3 4 5
Please vote for the following new items that have been added:					
e.	The team must be provided with the adequate information relating to:				
v.	the duties and responsibilities of other team members	1	2	3	4 5
vi.	the project priorities	1	2	3	4 5
vii.	the client's requirements	1	2	3	4 5
viii.	the end users' requirements	1	2	3	4 5
f.	Final adoption of the design by the designers will take into account input from other team members but not necessarily require unanimous agreement decision of the team members.	1	2	3	4 5
g.	The need for the project to accommodate a new physical working environment such as sharing common offices.	1	2	3	4 5

## Q2. (Continues....)

h.	Attitudes toward sharing common project information must be change from the current attitude when working in the traditional project environment.	1 2 3 4 5
i.	The quantity surveyor (estimator) for the project must cost alternatives as design proceeds.	1 2 3 4 5

- Q3. An important aspect of collaborative teamwork based on concurrent engineering principles is that the formation of the team is made at the outset of the project. Such practice is uncommon in construction. The experts from other industries consider that, if construction wishes to achieve a similar teamwork concept, changes must be made within the existing traditional practice.

No consensus was reached in the following issues are the in the First Round Delphi. Please reconsider your first round vote and either confirm it or revised it by indicating how strongly you agree with each of the statements below. (If you strongly agree circle 5. If you disagree circle 1)

Q.	Please indicate how strongly you agree with each of the statements below.	FRD votes analysis		Your FRD vote	Your Second Round Delphi vote
		Score $\leq 3$	Score $>3$		
c.	The client must be willing to pay additional costs for the appointment of all team members at the start of the project.	38.5%	61.5%	③	1 2 3 4 5
d.	The client will be required to input additional resources to manage and co-ordinate the project teams.	53.8%	46.2%	③	1 2 3 4 5

- Q4. This question seeks the agreement of the panellists on how the formation of the team may be achieved at the outset stage of the project. Please review your vote and also vote for the new item included in this question as suggested.

The rating scale is from 1 to 5 where 1 indicate your disagreement and 5 if you strongly agree.

Q.	<i>Different mechanisms may be used to achieve the formation of the team. Please rate the level of importance of the use of</i>	FRD votes analysis		Your FRD vote	Your Second Round Delphi vote
		Score $\leq 3$	Score $> 3$		
d.	Procurement system	50%	50%	⑤	1 2 3 4 5
e.	(New item added): initiative from industry groups	1 2 3 4 5			

- Q5. This question seeks to determine the most appropriate form of framework within with the cross functional project team can work within construction industry. The analysis of the panellists responses did not indicate a consensus opinion. Please review your vote and tick in the appropriate box.

Q.	<i>Which is the most appropriate of these (framework within with cross functional team may work) within a construction industry environment?</i>	% of vote in FRD	Your vote in FRD	Your Second Round Delphi vote.
a.	Matrix form of organisation	9.1%		
b.	A core 'cross functional project team' surrounding by smaller functional teams.	45.5%		
c.	'Virtual organisation' form of 'cross functional project team' in which co-ordination and communication rely on information technology.	27.3%	✓	
d.	No specific form can be defined because it depends on the individual project's requirement as in other industries.	18.2%		
e.	Others	0%		



## SECTION C

This section is designed to evaluate the information systems requirements for cross functional project teams.

For the collaborative working, important information needs to be made available to all team members. Experience from other industries indicates that information technology plays an important role in supporting collaboration between project team members.

Q1. The following statements are general issues related to the changes required within the construction industry to adopt the extended use of information technology to enhance information sharing. Please review your vote and add a vote for the additional question added at the suggestion of several panellists.

Please rate the level of changes required on scale 0 to 4 where rating indicating level of changes are:

0 = none      1 = low      2 = moderate      3 = high      4 = very high

Q.	<i>How important are the changes listed below in order to achieve the above objective?</i>	% of vote in FRD		Your vote in FRD	Your Second Round Delphi vote
		Score < 3	Score ≥ 3		
c.	Changes to the existing procurement systems (i.e. by using the procurement system as one of the strategy to enforce the usage of appropriate information technology tools to enhance project communication)	38.5%	61.5%	④	0 1 2 3 4
d.	Changes in the information technology commonly used on a construction project (telephone, fax, E-mail, etc.)	38.5%	61.5%	④	0 1 2 3 4
	Please vote for the following new items added:				
f.	The attitude of the project team (Team members are expected to be more open in their attitude towards the used of information technology tools.	0 1 2 3 4			
g.	Leadership in IT use for the project. (The management team for the project should lead the promotion of the use of information technology within the project)	0 1 2 3 4			
h.	The way the project is managed must exhibit greater reliance on the use of IT.	0 1 2 3 4			

Q2. This question evaluates the level of importance of information technology to facilitate collaborative working in construction. Please review your rate for the questions listed and place your Second Round Delphi vote.

Please add your vote for each of the new questions added at the suggestion of the panellists.

Please indicate the importance on a scale of 1 to 5 where 1 indicates unimportant and 5 indicate highly important.

Q.	What level of importance should be given to the following to facilitate collaborative working.	% of vote in FRD		Your vote in FRD	Your Second Round Delphi vote.
		Score $\leq 3$	Score $> 3$		
a.	Personal information systems (e.g. word processor, spreadsheet, databases, desktop publishing, presentation applications)	61.5%	38.5%	③	1 2 3 4 5
c.	Enterprise information systems (e.g. EDI, interdepartmental management information system, inter enterprise systems integration)	41.7%	58.3%	④	1 2 3 4 5
d.	New items: (Please vote for all these items.) The increase of the following IT tools to support collaborative teamwork:				
i.	Shared project database	1 2 3 4 5			
ii.	Electronic meetings to <u>minimise</u> (not to replace) traditional face to face meetings.	1 2 3 4 5			
iii.	Electronic data and voice mail	1 2 3 4 5			
iv.	Electronic team scheduling	1 2 3 4 5			
v.	Video conferencing	1 2 3 4 5			
vi.	Shared electronic project model	1 2 3 4 5			

*Thank you for your participation.*

## **APPENDIX 8**

**Feedback to Delphi study panellist:  
Results of First Round Delphi study analysis**

FIRST ROUND DELPHI (FRD) SURVEY  
RESULT ANALYSIS

**THE ABILITY OF THE MAJOR STAKEHOLDERS  
TO CONTRIBUTE TO THE 'DESIGN' OF THE PROJECT**

SECTION A QUESTION 1		RATING					NO. OF RESPONSES
		1	2	3	4	5	
	<b>CONTRIBUTE</b>						
a.	client	0 0.0%	3 23.1%	7 53.8%	0 0.0%	3 23.1%	13
b.	architects	0 0.0%	1 7.7%	1 7.7%	2 15.4%	9 69.2%	13
c.	engineers	0 0.0%	1 8.3%	2 16.7%	3 25.0%	6 50.0%	12 no vote - 1
d.	surveyors	1 7.7%	6 46.2%	4 30.8%	2 15.4%	0 0.0%	13
e.	end user (customers)	0 0.0%	8 61.5%	0 0.0%	3 23.1%	2 15.4%	13
f.	main contractors	0 0.0%	1 7.7%	6 46.2%	2 15.4%	4 30.8%	13
g.	sub - contractors	0 0.0%	4 30.8%	3 23.1%	4 30.8%	2 15.4%	13
h.	suppliers	2 15.4%	5 38.5%	3 23.1%	2 15.4%	1 7.7%	13
i.	service contractors	2 16.7%	2 16.7%	3 25.0%	4 33.3%	1 8.3%	12 no vote - 1
j.	financiers	7 53.8%	3 23.1%	2 15.4%	0 0.0%	1 7.7%	13

**THE RANKING OF THE MAJOR STAKEHOLDERS' INFLUENCE / CONTRIBUTION  
TO THE DESIGN OF THE PROJECT.**

<b>RANKING (INFLUENCE)</b>		
<b>No.</b>	<b>R.I.</b>	<b>STAKEHOLDER</b>
1	0.86	CLIENT
1	0.86	END USER (CUSTOMER)
3	0.85	ARCHITECTS
4	0.75	ENGINEERS
5	0.66	MAIN CONTRACTORS
6	0.60	SERVICE CONTRACTORS
7	0.58	SURVEYORS
8	0.57	FINANCIERS
9	0.54	SUB- CONTRACTORS
10	0.49	SUPPLIERS

<b>RANKING (CONTRIBUTE)</b>		
<b>No.</b>	<b>R.I.</b>	<b>STAKEHOLDER</b>
1	0.89	ARCHITECTS
2	0.83	ENGINEERS
3	0.74	MAIN CONTRACTORS
4	0.66	SUB- CONTRACTORS
5	0.65	CLIENT
6	0.60	SERVICE CONTRACTORS
7	0.58	END USER (CUSTOMER)
8	0.52	SUPPLIERS
9	0.51	SURVEYORS
10	0.37	FINANCIERS

\*R.I. - Relative Index

**MAXIMUM NUMBER OF REPRESENTATIVES FOR EACH FUNCTIONAL GROUP IN THE TEAM**

<b>SECTION A Q2</b>			<b>REMARK</b>
<i>What is the maximum number of the persons that should be available to represent each functional group within a cross functional team to ensure that it efficiently represents the interest of all parties involved?</i>			
	<b>No. of responses</b>	<b>Percent (%)</b>	
i. Strictly one representative for each functional group.	2	15.4%	<i>Consensus</i>
ii. Depends on the role of the group, some may have more than one representative.	11	84.6%	
iii. More than one representative for each group but of equal numbers	0	0%	
iv. Others	0	0%	
<b>TOTAL</b>	<b>13</b>	<b>100%</b>	

**CONSISTENCY OF THE NUMBER OF TEAM MEMBERS THROUGHOUT THE PROJECT LIFE CYCLE**

<b>SECTION A Q3</b>			<b>REMARK</b>
<i>In your opinion, for the maximum efficiency of the cross functional project team, should the number of the team members,</i>			
	<b>No. of responses</b>	<b>Percent (%)</b>	
i. remain the same throughout the project life cycle	0	0%	<i>Consensus</i>
ii. change in number depending on the project phase	13	100%	
iii. others. please specify	0	0%	
<b>TOTAL</b>	<b>13</b>	<b>100%</b>	

**LEADERSHIP OF THE CROSS FUNCTIONAL TEAM**

<b>SECTION A Q4</b>			<b>REMARK</b>
	<i>Who do you consider the most appropriate party to lead the team?</i>	<b>No. of responses</b>	<b>Percent (%)</b>
i.	clients or their representatives	2	15.4%
ii.	a designated project manager	8	61.5%
iii.	designers	0	0%
iv.	engineers	0	0%
v.	others, please specify: Person with adequate skill and capability	2	15.4%
	Design builders?	1	7.7%
	<b>TOTAL</b>	<b>13</b>	<b>100%</b>

**CONSISTENCY OF LEADERSHIP OF THE CROSS FUNCTIONAL TEAM**

<b>SECTION A Q5</b>			<b>REMARK</b>
	<i>Should the leadership of the team vary at different stages of the project life cycle?</i>	<b>No. of responses</b>	<b>Percent (%)</b>
i.	Yes, it should	4	30.8%
ii.	No, it should remain the same	8	61.5%
iii.	Others, please specify <i>Depend on the skill base of the manager</i>	1	7.7%
	<b>TOTAL</b>	<b>13</b>	<b>100%</b>



**LEVEL OF CHANGES EXPECTED FROM THE FORMATION OF THE CROSS  
FUNCTIONAL PROJECT TEAM IN CONSTRUCTION INDUSTRY**

<b>SECTION B Q1</b>											
<i>If we are to achieve a similar teamwork concept in construction with adequate authority and flexibility, what level of changes do you expect to take place? Indicate the level of change on scale of 0 to 4 where 0 = no change and 4 = very high.</i>											
	RATING					OTHERS	NO. OF RESPONSES	TOTAL SCORE		REMARK	
	0	1	2	3	4			<3	>=3		
a.	0.0%	7.7%	15.4%	15.4%	53.8%	3 to 4=1 7.7%	13 100%	23.1%	76.9%	Consensus	
b.	0.0%	7.7%	15.4%	53.8%	23.1%		13 100%	23.1%	76.9%	Consensus	
c.	0.0%	0.0%	23.1%	38.5%	38.5%		13 100%	23.1%	76.9%	Consensus	
d.	0.0%	0.0%	30.8%	46.2%	15.4%	2 to 3=1 7.7%	13 100%	38.5%	61.5%		
e.	0.0%	0.0%	23.1%	38.5%	30.8%	3 to 4=1 7.7%	13 100%	23.1%	76.9%	Consensus	
f.	0.0%	25.0%	25.0%	33.3%	16.7%	n=1	12 100%	50.0%	50.0%		
g.	0.0%	0.0%	41.7%	41.7%	16.7%	n=1	12 100%	41.7%	58.3%		
h.											

Note: nr - no response

**ISSUES RELATED TO THE FORMATION OF THE CROSS FUNCTIONAL PROJECT TEAM IN THE  
CONSTRUCTION INDUSTRY**

<b>SECTION B Q2</b>											
		RATING					OTHERS	NO. OF RESPONSE	TOTAL SCORE		REMARK
		1	2	3	4	5			<=3	>3	
<i>If a teamwork concept similar to other industries is to be develop for construction project : ( 1=disagree 5 = strongly agree)</i>											
a.	The team is given the power to override an individual functional group's decision.	8.3%	16.7%	25.0%	33.3%	16.7%	nr=1	12 100%	50.0%	50.0%	
b.	The team is given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members.	0.0%	23.1%	23.1%	30.8%	23.1%		13 100%	46.2%	53.8%	
c.	Team members must be given adequate authority and flexibility to contribute and review the design throughout its development phase.	0.0%	0.0%	8.0%	54.0%	38.0%		13 100%	7.7%	92.3%	Consensus
d.	Final adoption upon the consensus decisions of team members.	9.1%	18.2%	36.4%	0.0%	36.4%	nr=2	11 100%	63.6%	36.4%	
e.	All team members must be given adequate project information with respect to:										
	i) project planning	0.0%	0.0%	7.7%	30.8%	53.8%		13 100%	7.7%	92.3%	Consensus
	ii) project scheduling	0.0%	0.0%	15.4%	15.4%	61.5%		13 100%	23.1%	76.9%	Consensus
	iii) basic design requirements	0.0%	0.0%	7.7%	23.1%	69.2%		13 100%	7.7%	92.3%	Consensus
	iv) project cost	0.0%	7.7%	7.7%	30.8%	46.2%		13 100%	23.1%	76.9%	Consensus
	v) Others										
	Duties and responsibilities of other team members				1						
	Project priorities										
	Understanding clients prime requirement										
	Client vision										
	Information requirement for each team										
	Team processes										
	Programme				1						

Note: nr - No Response

**LEVEL OF AGREEMENT ON THE ISSUES RELATED FROM THE FORMATION OF THE  
CROSS FUNCTIONAL PROJECT TEAM AT THE OUTSET OF THE PROJECT**

<b>SECTION B QUESTION NO. 3</b>														
<i>Changes in the existing practice due to the formation of the team at the outset of the project. (1= disagree, 5= strongly agree).</i>														
	<b>RATING</b>										<b>NO. OF RESPONSES</b>	<b>TOTAL SCORE</b>		<b>REMARK</b>
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>&lt;=3</b>	<b>&gt;3</b>							
<b>a.</b>	Changes must be made to the 'traditional' procurement system.										13	15.4%	84.6%	Consensus
<b>b.</b>	The participants to a project will need educating and training in collaborative working.										13	15.4%	84.6%	Consensus
<b>c.</b>	The client must be willing to pay additional costs for the appointment of all team members at the start of the project.										13	38.5%	61.5%	
<b>d.</b>	The client will be required to input additional resources to manage and co-ordinate the project teams.										13	53.8%	46.2%	
<b>e.</b>	Others, please specify and rate them: Physical working environment Share common office Share common CAD Risk must be clearly defined including ownership QS must cost alternative as design proceeds Much clearer definition of roles and responsibilities													

**MECHANISM TO ACHIEVE THE FORMATION OF THE CROSS FUNCTIONAL PROJECT TEAM AT THE OUTSET OF THE PROJECT**

<b>SECTION B QUESTION NO.4</b>											
<i>The following are the mechanisms that may be used to achieve the formation of the team at the outset stage of the project. (1 = little importance, 5= great importance)</i>											
	<b>RATING</b>							<b>NO. OF RESPONSES</b>	<b>TOTAL SCORE</b>		<b>REMARK</b>
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>&lt;=3</b>	<b>&gt;3</b>				
<b>a</b>	Initiative from clients.										
	0	0	2	5	6		13				
	0.0%	0.0%	15.4%	38.5%	46.2%			15.4%	84.6%		Consensus
<b>b</b>	Initiative from parties approached by the clients to develop the project.										
	1	0	1	6	5		13				
	7.7%	0.0%	7.7%	46.2%	38.5%			15.4%	84.6%		Consensus
<b>c</b>	Initiative from regulatory agencies.										
	2	6	3	0	1		12				
	16.7%	50.0%	25.0%	0.0%	8.3%		*n=1	91.7%	8.3%		Consensus
<b>d</b>	Use of procurement system.										
	1	2	2	4	3		12				
	8.3%	16.7%	16.7%	33.3%	25.0%		*n=1	41.7%	58.3%		
<b>e</b>	Others, please specify and rate them Commitment of client to use team member throughout the project initiative from industry group										
					1						
					1						

Note: nr = No response

**SUITABLE FRAMEWORK IN WHICH A CROSS FUNCTIONAL  
PROJECT TEAM CAN OPERATE**

<b>SECTION B QUESTION NO. 5</b>				
<i>In concurrent engineering there are variety of forms of frameworks within which the cross functional team can work. Which is the most appropriate of these within a construction industry environment?</i>				
		<b>NO. OF RESPONSES</b>	<b>PERCENTAGE (%)</b>	<b>REMARK</b>
<b>a</b>	Matrix form of organisation.	1	9.1%	
<b>b</b>	A core 'cross functional project team' surrounding by smaller functional teams.	5	45.5%	
<b>c</b>	'Virtual organisation' form of 'cross functional project team' in which co-ordination and communication rely on information technology.	3	27.3%	
<b>d</b>	No specific form can be defined because it depends on the individual project's requirement as in other industries.	2	18.2%	
<b>e</b>	Others, please specify.	0	0.0%	
	<b>TOTAL</b>	<b>11</b>	*	2 panellists undecided.

**THE LEVEL OF CHANGES EXPECTED TO SUPPORT DISSEMINATION KEY  
INFORMATION FOR THE TEAM**

<b>SECTION C Q1</b>												
<i>For the collaborative working, key information needs to be made available to all team members."</i>												
<i>How important are the changes listed below in order to achieve the above objective?</i>												
<i>(Level of change: 0 = no change, 4 very high)</i>												
	0	1	2	3	4	NO. OF RESPONSE		TOTAL		REMARK		
						0, 1 & 2	3 & 4					
a.	1 7.7%	3 23.1%	2 15.4%	4 30.8%	3 23.1%	13	46.2%	53.8%				
b.	0 0.0%	0 0.0%	1 7.7%	3 23.1%	9 69.2%	13	7.7%	92.3%	Consensus			
c.	0 0.0%	1 7.7%	4 30.8%	2 15.4%	6 46.2%	13	38.5%	61.5%				
d.	0 0.0%	1 7.7%	4 30.8%	1 7.7%	7 53.8%	13	38.5%	61.5%				
e.	1 7.7%	0 0.0%	5 38.5%	3 23.1%	4 30.8%	13	46.2%	53.8%				
f.					1 1 1							

**THE IMPORTANCE OF INFORMATION TECHNOLOGY  
TO SUPPORT TEAMWORK**

<b>SECTION C Q2</b>										<b>REMARK</b>
<i>The importance of the following IT to facilitate collaborative working in construction.</i>										
<i>(1=unimportant, 5 = highly important)</i>										
		<b>RATING</b>					<b>NO. OF RESPONSES</b>			
		1	2	3	4	5			<=3	>3
<b>a.</b>	Personal information systems (e.g. word processor, spreadsheet, databases, desktop publishing, presentation applications)	0 0.0%	1 7.7%	7 53.8%	1 7.7%	3 23.1%	13 3 to 4=1 7.7%	61.5%	38.5%	
<b>b.</b>	Workgroup information systems (e.g. E-mail, video conferencing, workgroup decision support system, workgroup databases etc.)	0 0.0%	1 7.7%	2 15.4%	4 30.8%	6 46.2%	13 100%	23.1%	76.9%	<i>Consensus</i>
<b>c.</b>	Enterprise information systems (e.g. EDI, interdepartmental management information system, inter enterprise systems integration)	1 8.3%	0 0.0%	4 33.3%	3 25.0%	4 33.3%	12 nr=1	41.7%	58.3%	
<b>d.</b>	Others, please specify and rate them: Meeting and talking Verbal CAD common database Prog. and scheduling system Construction and reporting system Electronic project file Electronic project model Shared electronic data									

*Note: nr= No response*

## AGREEMENT ON THE APPOINTMENT OF THE INFORMATION MANAGER

<b>SECTION C Q3</b>				<b>REMARK</b>
<i>Do you agree that a member of the team should be allocated the role of information manager for a project to ensure effective communication?</i>				
	<b>NO. OF RESPONSES</b>	<b>PERCENTAGE (%)</b>	<b>Total</b>	
Strongly agree	5	38.5%	(Agree + Strongly agree). 76.9%	Consensus
Agree	5	38.5%		
Neutral	2	15.3%		
Disagree	1	7.7%	Disagree + Strongly disagree 7.7%	
Strongly disagree	0	0.0%		
<b>TOTAL</b>	<b>13</b>			



## **APPENDIX 9**

**Feedback to Delphi study panellists:  
Results of second and final round Delphi study analysis**

SECOND AND FINAL ROUND DELPHI SURVEY  
RESULT ANALYSIS

**THE RANKING OF THE MAJOR STAKEHOLDERS' INFLUENCE / CONTRIBUTION TO THE DESIGN OF THE PROJECT.**

<b>RANKING (INFLUENCE)</b>			
<b>STAKEHOLDER</b>	<b>NO. OF RESPONSE</b>	<b>MEAN RANKING</b>	<b>FINAL RANKING</b>
CLIENT	11	1.00	1
END USER (CUSTOMER)	11	1.27	2
ARCHITECTS	11	3.09	3
ENGINEERS	11	4.00	4
MAIN CONTRACTORS	11	5.09	5
SERVICE CONTRACTORS	11	6.18	6
SURVEYORS	11	7.18	7
FINANCIERS	11	7.45	8
SUB-CONTRACTORS	11	8.73	9
SUPPLIERS	11	10.00	10

<b>RANKING (CONTRIBUTION)</b>			
<b>STAKEHOLDER</b>	<b>NO. OF RESPONSE</b>	<b>MEAN RANKING</b>	<b>FINAL RANKING</b>
ARCHITECTS	11	1.09	1
ENGINEERS	11	2.00	2
MAIN CONTRACTORS	11	3.45	3
SUB-CONTRACTORS	11	4.27	4
CLIENT	11	5.55	5
SERVICE CONTRACTORS	11	5.82	6
END USER (CUSTOMER)	11	6.55	7
SUPPLIERS	11	6.82	8
SURVEYORS	11	8.00	9
FINANCIERS	11	9.82	10

**MAXIMUM NUMBER OF REPRESENTATIVES FOR EACH FUNCTIONAL GROUP IN THE TEAM**

<b>SECTION A Q2</b>		<b>REMARK</b>	
<i>What is the maximum number of the persons that should be available to represent each functional group within a cross functional team to ensure that it efficiently represents the interest of all parties involved?</i>			
		<b>No. of responses</b>	<b>Percent. (%)</b>
i.	Strictly one representative for each functional group.	2	15.4%
ii.	Depends on the role of the group, some may have more than one representative.	11	84.6%
iii.	More than one representative for each group but of equal numbers	0	0.0%
iv.	Others	0	0.0%
	<b>TOTAL</b>	<b>13</b>	<b>100.0%</b>
			<i>Consensus</i>

**CONSISTENCY OF THE NUMBER OF TEAM MEMBERS THROUGHOUT  
THE PROJECT LIFE CYCLE**

<b>SECTION A Q3</b>		<b>REMARK</b>	
<i>In your opinion, for the maximum efficiency of the cross functional project team, should the number of the team members,</i>			
		<b>No. of responses</b>	<b>Percent. (%)</b>
i.	remain the same throughout the project life cycle	0	0%
ii.	change in number depending on the project phase	13	100%
iii.	others, please specify	0	0%
	<b>TOTAL</b>	<b>13</b>	<b>100%</b>
		<i>Consensus</i>	

### LEADERSHIP OF THE CROSS FUNCTIONAL TEAM

SECTION A Q4		FIRST ROUND		SECOND ROUND		REMARK
		No. of responses	Percent. (%)	No. of responses	Percent. (%)	
Who do you consider the most appropriate party to lead the team?						
i.	clients or their representatives	2	15.4%	1	7.7%	Consensus
ii.	a designated project manager	8	61.5%	11	84.6%	
iii.	designers	0	0.0%	0	0.0%	
iv.	engineers	0	0.0%	0	0.0%	
v.	others, please specify:			1	7.7%	
Person with adequate skill and capability		2	15.4%			
Design builders?		1	7.7%			
TOTAL		13	100.0%		100.0%	

### CONSISTENCY OF LEADERSHIP OF THE CROSS FUNCTIONAL TEAM

SECTION A Q5		FIRST ROUND		SECOND ROUND		REMARK
		No. of responses	Percent. (%)	No. of responses	Percent. (%)	
Q5. Should the leadership of the team vary at different stages of the project life cycle?						
i.	Yes, it should	4	30.8%	3	23.1%	No consensus
ii.	No, it should remain the same	8	61.5%	9	69.2%	
iii.	Others, please specify	1	7.7%	1	7.7%	
TOTAL		13	100.0%	13	100%	

**LEVEL OF CHANGES EXPECTED FROM THE FORMATION OF THE CROSS  
FUNCTIONAL PROJECT TEAM IN CONSTRUCTION INDUSTRY**

<b>SECTION B Q1</b>											
<i>If we are to achieve a similar teamwork concept in construction with adequate authority and flexibility, what level of changes do you expected to take place? Indicate the level of change on scale of 0 to 4 where 0 = no change and 4 = very high.</i>											
	RATING				OTHERS	NO. OF RESPONSES	TOTAL SCORE		REMARK		
	0	1	2	3			4	<3		>=3	
a.	0	0	0	0	0	13	23.1%	76.9%	Consensus		
	0.0%	7.7%	15.4%	15.4%	53.8%	100%	23.1%	76.9%	Consensus		
b.	0	0	0	0	0	13	23.1%	76.9%	Consensus		
	0.0%	7.7%	15.4%	53.8%	23.1%	100%	23.1%	76.9%	Consensus		
c.	0	0	0	0	0	13	23.1%	76.9%	Consensus		
	0.0%	0.0%	23.1%	38.5%	38.5%	100%	23.1%	76.9%	Consensus		
d.	0	0	0	0	0	13	38.5%	61.5%	FRD No consensus		
	0.0%	0.0%	30.8%	46.2%	15.4%	100%	38.5%	61.5%	FRD No consensus		
<b>SECOND ROUND DELPHI VOTE</b>											
e.	0	0	0	0	0	13	15.4%	84.6%	SRD Result: Consensus		
	0.0%	0.0%	7.7%	69.2%	15.4%	100%	15.4%	84.6%	SRD Result: Consensus		
f.	0	0	0	0	0	12	50.0%	50.0%	FRD No consensus		
	0.0%	25.0%	25.0%	33.3%	16.7%	100%	50.0%	50.0%	FRD No consensus		
<b>SECOND ROUND DELPHI VOTE</b>											
g.	0	0	0	0	0	12	33.3%	66.7%	SRD Result: NO consensus		
	0.0%	25.0%	8.3%	50.0%	16.7%	100%	33.3%	66.7%	SRD Result: NO consensus		
	0	0	0	0	0	12	41.7%	58.3%	FRD No consensus		
	0.0%	0.0%	41.7%	41.7%	16.7%	100%	41.7%	58.3%	FRD No consensus		
	0	0	0	0	0	12	16.7%	83.3%	SRD Result: Consensus		
	0.0%	0.0%	16.7%	58.3%	25.0%	100%	16.7%	83.3%	SRD Result: Consensus		
<b>NEW ISSUE ADDED</b>											
h.	1	0	0	0	0	10	10.0%	90.0%	SRD Result: Consensus		
	10.0%	0.0%	0.0%	50.0%	40.0%	100%	10.0%	90.0%	SRD Result: Consensus		

ISSUE RELATED TO THE FORMATION OF CROSS FUNCTIONAL TEAM IN CONSTRUCTION

SECTION B Q2	REMARK	TOTAL SCORE		NO. OF RESPONSE	OTHERS	RATING					
		<=3	>3			1	2	3	4	5	
if a teamwork concept similar to other industries is to be developed for construction project. (1=disagree 5=strongly agree)											
a.	The team is given the power to override an individual functional group's decision. SECOND ROUND DELPHI VOTE	50.0%	50.0%	12	n=1	8.3%	16.7%	25.0%	33.3%	16.7%	
b.	The team is given the accountability for project design with the leading role taken by the designers and the supporting roles taken by other team members. SECOND ROUND DELPHI VOTE	50.0%	50.0%	12	n=1	16.7%	8.3%	25.0%	33.3%	16.7%	
c.	Team members must be given adequate authority and flexibility to contribute and to review the design throughout its development phase.	46.2%	53.8%	13		7.7%	0.0%	7.7%	63.8%	30.8%	
d.	Final adoption of the design for the project must be made upon the consensus decisions of team members. SECOND ROUND DELPHI VOTE	7.7%	92.3%	13		0.0%	0.0%	0.0%	54%	36%	
e.	All team members must be given adequate project information with respect to: project planning	63.6%	36.4%	11	n=2	8.1%	18.2%	36.4%	0.0%	36.4%	
i.	project scheduling	46.2%	53.8%	13		2	3	1	4	3	
ii.	basic design requirements	23.1%	76.9%	100%		15.4%	23.1%	7.7%	30.8%	23.1%	
iii.	project cost	7.7%	92.3%	13	3 to 4=1	0	0	1	4	7	
iv.	NEW ISSUE ADDED The duties and responsibilities of other team members	7.7%	92.3%	100%	8	0	0	0	7.7%	89.2%	
v.	The project priorities	23.1%	76.9%	100%	8	0	0	0	23.1%	69.2%	
vi.	The client's requirements	7.7%	92.3%	13	4 to 5=1	0	1	1	4	6	
vii.	the end user's requirement	0.0%	100.0%	10		0	0	0	3	7	
viii.	account input from other team members but not necessarily require unanimous agreement decision of the team members.	0.0%	100.0%	10		0	0	0	30.0%	70.0%	
ix.	The need for the project to accommodate a new physical working environment such as sharing common offices.	0.0%	100.0%	10		0	0	0	2	8	
x.	Attitudes toward sharing common project information must be changed from the current attitude when working in the traditional project environment.	0.0%	100.0%	10		0	0	0	20.0%	80.0%	
xi.	The Quantity Surveyor (estimator) for the project must cost alternatives as design proceeds.	0.0%	100.0%	10		0	0	0	20.0%	80.0%	
xii.		30.0%	70.0%	10		0	3	0	2	5	
xiii.		10.0%	90.0%	10		0	0	1	4	5	
xiv.		0.0%	100.0%	9	n=1	0	0	0	5	4	
xv.		0.0%	100.0%	9		0	0	0	5	4	



**LEVEL OF AGREEMENT ON THE ISSUES RELATED FROM THE FORMATION OF THE CROSS  
FUNCTIONAL PROJECT TEAM AT THE OUTSET OF THE PROJECT**

<b>SECTION B QUESTION NO. 3</b>		<b>RATING</b>										<b>TOTAL SCORE</b>		<b>REMARK</b>	
		<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>NO. OF RESPONSES</b>								
<i>Changes in the existing practice due to the formation of the team at the outset of the project. (1= disagree, 5= strongly agree).</i>															
<b>a.</b>	Changes must be made to the 'traditional' procurement system.	0 0.0%	0 0.0%	2 15.4%	2 15.4%	9 69.2%	13		15.4%	84.6%			>3	Consensus	
<b>b.</b>	The participants to a project will need educating and training in collaborative working.	0 0.0%	1 7.7%	1 7.7%	5 38.5%	6 46.2%	13		15.4%	84.6%				Consensus	
<b>c.</b>	<b>The client must be willing to pay additional costs for the appointment of all team members at the start of the project.</b>	2 15.4%	0 0.0%	3 23.1%	3 23.1%	5 38.5%	13		38.5%	61.5%					
<b>SECOND ROUND DELPHI VOTE</b>															
<b>d.</b>	The client will be required to input additional resources to manage and co-ordinate the project teams.	1 7.7%	1 7.7%	1 7.7%	3 23.1%	7 53.8%	13		23.1%	76.9%				SRD Result Consensus	
	<b>SECOND ROUND DELPHI VOTE</b>														
		2 15.4%	5 38.5%	2 15.4%	2 15.4%	2 15.4%	13		69.2%	30.8%				SRD Result NO Consensus	

**MECHANISM TO ACHIEVE THE FORMATION OF THE CROSS FUNCTIONAL PROJECT TEAM AT THE OUTSET OF THE PROJECT**

		RATING										NO. OF RESPONSES	TOTAL SCORE		REMARK	
		1	2	3	4	5	1	2	3	4	5		<=3	>3		
<b>SECTION B QUESTION NO.4</b>																
The following are the mechanisms that may be used to achieve the formation of the team at the outset stage of the project. (1 = little importance, 5= great importance)																
a	Initiative from clients.	0	0	2	5	6	13	0.0%	0.0%	15.4%	38.5%	46.2%	15.4%	84.6%	Consensus	
b	Initiative from parties approached by the clients to develop the project.	1	0	1	6	5	13	7.7%	0.0%	7.7%	46.2%	38.5%	15.4%	84.6%	Consensus	
c	Initiative from regulatory agencies.	2	6	3	0	1	12	16.7%	50.0%	25.0%	0.0%	8.3%	91.7%	8.3%	Consensus	
d	Use of procurement system.	1	2	2	4	3	12	8.3%	16.7%	16.7%	33.3%	25.0%	41.7%	58.3%		
<b>SECOND ROUND DELPHI VOTE</b>		0	3	2	5	3	13	0.0%	23.1%	15.4%	38.5%	23.1%	38.5%	61.5%	SRD Result NO Consensus	
e.	initiative from industry group	0	2	2	5	1	10	0.0%	20.0%	20.0%	50.0%	10.0%	40.0%	60.0%	SRD Result NO Consensus	

Note: nr = No response

**ORGANISATIONAL STRUCTURE TO SUPPORT CROSS FUNCTIONAL  
PROJECT TEAM IN CONSTRUCTION**

<b>SECTION B QUESTION NO. 5</b>			
<i>In concurrent engineering there are variety of forms of frameworks within which the cross functional team can work. Which is the most appropriate of these within a construction industry environment?</i>			
	<b>NO. OF RESPONSES</b>	<b>PERCENTAGE (%)</b>	<b>REMARK</b>
<b>a</b>	1	9.1%	
	Matrix form of organisation.		
<b>b</b>	5	45.5%	
	A core 'cross functional project team' surrounding by smaller functional teams.		
<b>c</b>	3	27.3%	
	Virtual organisation' form of 'cross functional project team' in which co-ordination and communication rely on information technology.		
<b>d</b>	2	18.2%	
	No specific form can be defined because it depends on the individual project's requirement as in other industries.		
<b>e</b>	0	0.0%	
	Others, please specify:		
	<b>TOTAL</b>	*	2 panellists undecided.
	<b>11</b>		

**THE LEVEL OF CHANGES EXPECTED TO SUPPORT DISSEMINATION KEY  
INFORMATION FOR THE TEAM**

		SECTION C Q1										REMARK		
		For the collaborative working, key information needs to be made available to all team members."												
		How important are the changes listed below in order to achieve the above objective? (Level of change: 0 = no change, 4 very high)										TOTAL		
		0	1	2	3	4	1	2	3	4	RESPONSE	0, 1 & 2	3 & 4	
a.	Changes in the composition of the project team.	0 7.7%	3 23.1%	2 15.4%	4 30.8%	3 23.1%	1 7.7%	2 15.4%	3 23.1%	4 30.8%	13	46.2%	53.8%	Question being drop.
b.	Changes in the industry culture.	0 0.0%	0 0.0%	1 7.7%	3 23.1%	9 69.2%	13	7.7%	92.3%	Consensus				
c.	Changes to the existing procurement systems.	0 0.0%	1 7.7%	4 30.8%	2 15.4%	6 46.2%	13	38.5%	61.5%					
<b>SECOND ROUND DELPHI VOTE</b>		0 0.0%	1 7.7%	2 15.4%	3 23.1%	7 53.8%	13	23.1%	76.9%	SRD result Consensus				
d.	Changes in the information technology commonly used on a construction project (telephone, fax, E-mail, etc.).	0 0.0%	1 7.7%	4 30.8%	1 7.7%	7 53.8%	13	38.5%	61.5%					
<b>SECOND ROUND DELPHI VOTE</b>		0 0.0%	2 15.4%	2 15.4%	2 15.4%	7 53.8%	13	30.8%	69.2%	No consensus				
e.	New criteria for selection of project team members.	1 7.7%	0 0.0%	5 38.5%	3 23.1%	4 30.8%	13	46.2%	53.8%					
<b>NEW ISSUES ADDED IN SRD</b>		0 0.0%	0 0.0%	1 7.7%	2 15.4%	7 53.8%	10	7.7%	69.2%	SRD result Consensus				
f.	The attitude of the project team (Team members are expected to be more open in their attitude towards the use of information technology tools.)	0 0.0%	0 0.0%	1 10.0%	2 20.0%	6 60.0%	10	10.0%	90.0%	SRD result Consensus				
g.	Leadership in IT use for the project. (The management team for the project should lead the promotion of the use of information technology within the project)	0 0.0%	0 0.0%	1 10.0%	3 30.0%	6 60.0%	10	10.0%	90.0%	SRD result Consensus				
h.	The way the project is managed must exhibit greater reliance on the use of IT.	1 11.1%	1 11.1%	3 33.3%	3 33.3%	1 11.1%	9	55.6%	44.4%	SRD result NO Consensus				

**THE IMPORTANT TYPE OF INFORMATION TECHNOLOGY  
TO SUPPORT TEAMWORK**

SECTION C Q2		The importance of the following IT to facilitate collaborative working in construction. (1=unimportant, 5 = highly important)	RATING										REMARK
			NO. OF RESPONSES										
			1	2	3	4	5	<=3	>3				
a.	Personal information systems (e.g. word processor, spreadsheet, databases, desktop publishing, presentation applications)	0 0.0%	1 7.7%	7 53.8%	1 7.7%	3 23.1%	13 3 to 4=1 7.7%	61.5%	38.5%				
	<b>SECOND ROUND DELPHI VOTE</b>	0 0.0%	2 15.4%	6 46.2%	4 30.8%	1 7.7%	13 100.0%	61.5%	38.5%	SRD result NO consensus			
b.	Workgroup information systems (e.g. E-mail, video conferencing, workgroup decision support system, workgroup databases etc.)	0 0.0%	1 7.7%	2 15.4%	4 30.8%	6 46.2%	13 100%	23.1%	76.9%	Consensus			
c.	Enterprise information systems (e.g. EDI, interdepartmental management information system, inter enterprise systems integration)	1 8.3%	0 0.0%	4 33.3%	3 25.0%	4 33.3%	12 nr=1	41.7%	58.3%				
	<b>SECOND ROUND DELPHI VOTE</b>	1 7.7%	0 0.0%	6 46.2%	2 15.4%	4 30.8%	13	53.8%	46.2%	SRD result NO consensus			
d. (i)	Shared project database	0 0.0%	0 0.0%	0 0.0%	3 30.0%	7 70.0%	10	0.0%	100.0%	SRD result CONSENSUS			
ii.	Electronics meeting (not to replace) traditional face to face meeting	2 20.0%	1 10.0%	3 30.0%	4 40.0%	0 0.0%	10	60.0%	40.0%	SRD result NO consensus			
iii.	Electronic data and voice mail	0 0.0%	1 10.0%	1 10.0%	5 50.0%	3 30.0%	10	20.0%	80.0%	SRD result CONSENSUS			
iv.	Electronic team scheduling	0 0.0%	1 11.1%	2 22.2%	4 44.4%	2 22.2%	9 1Panel. NV	33.3%	66.7%	SRD result NO consensus			
v.	Video conferencing	0 0.0%	2 20.0%	3 30.0%	4 40.0%	1 10.0%	10	50.0%	50.0%	SRD result NO consensus			
vi.	Shared electronic project model	0 0.0%	2 20.0%	3 30.0%	2 20.0%	3 30.0%	10	50.0%	50.0%	SRD result NO consensus			

Note: nr= No response

**AGREEMENT ON THE APPOINTMENT OF THE INFORMATION MANAGER**

<b>SECTION C Q3</b>			
<i>Do you agree that a member of the team should be allocated the role of information manager for a project to ensure effective communication?</i>			
	<b>NO. OF RESPONSES</b>	<b>PERCENTAGE (%)</b>	<b>REMARK</b>
Strongly agree	5	38.5%	(Agree + Strongly agree). 76.9%
Agree	5	38.5%	
Neutral	2	15.3%	Consensus
Disagree	1	7.7%	Disagree + Strongly disagree 7.7%
Strongly disagree	0	0.0%	
<b>TOTAL</b>	<b>13</b>		

## **APPENDIX 10**

**Feedback to Delphi study panellists:  
Executive summary of Delphi Study**

## Executive Summary of Delphi Study on Cross Functional Project Team in Construction

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- The concept of cross functional project team (CFPT) based on concurrent engineering philosophy is new in construction. It is a different concept from the traditional teamwork approach as normally practised. This Delphi study help to generate the consensus view from the panellists of how it can be implemented in construction (Introduction).
- The formation of the CFPT for construction project should be a gradual process depending on the project development phase. CFPT is expected to be flexible but a dynamic team. This features are reflected by the gradual inclusion of the stakeholders into the team and the variation of the number of member that represent each functional group in the team (section A, question 1 to 3).
- A designated project manager is being considered as the appropriate party to lead the CFPT (section A, question 4).
- The clients have important roles to support the CFPT. They can do so by: practising a good decision making system; have adequate preparation at outset; and getting involved in the project team (section A, question 6).
- To overcome the barrier of lack of mutual trust in construction there is a serious need for the industry to work in a collaborative teamwork environment. It is also important for the industry to address the issues related to the human factor, industry cultural issue and lack of fairness in the existing systems (section A, question 7).
- To achieve the CFPT in construction changes have to be made to the: existing traditional procurement systems; traditional work process; and the existing nature of relationship between the various functional groups in the project. The clients must play important roles in project leadership and take appropriate initiative to support CFPT. Specific criteria must be adopted to select team members and collocation of the members in a common office is an important strategy to be considered (section B, question 1).
- The CFPT must be given with the adequate authority and flexibility to allow them to participate and contribute in the design development process to ensure that all the downstream requirement will be considered. However a 'soft' approach strategy is more desirable in giving the authority to the CFPT when it come to the need to make the ultimate design decision as not to upset the existing practice and other jurisdictional issues (section B, question 2a to 2d).
- All CFPT members must be given adequate project information with respect to the planning, cost, design, clients and end users requirements. There is a need for industry to change the attitude toward sharing the project information (section B, question 2a to 2i).



- The formation of CFPT must be made at outset of the project. To achieve this it is recommended that changes have to be made to the traditional procurement system. It is also important to have development and training programme to adapt to collaborative working environment. The client must be willing to invest the initial additional cost due to formation of the team at outset to reap a greater benefit from it for the project later (section B, question 3).
- The formation of the CFPT at outset can be achieved through the initiatives by the clients or the party approached by them (section B, question 4).
- There is no specific organisational structure determined for CFPT to operate. This is consistent with the practise in other industry (section B, question 5).
- The factors that seem to be the inhibitors toward formation of CFPT at outset are related to the: lack of understanding and confidence in the approach; perceived problem that may be resulted from its implementation; and the traditional adversarial relationship nature of the industry (section B, question 6).
- Sharing key project information is critical to support the CFPT environment. To achieve this objective, it is suggested that changes need to be made on: the industry culture; existing procurement systems; and on the attitude of the project team members. It is also important to have the leadership to support the IT used in the project (section C, question 1 and 3).
- The use of IT to support the project should be flexible enough depending on the actual project requirement. The emphasis to develop the workgroup information system to support the basic communication need of the team is important. However, there is no critical requirement to focus on the need to have the advance IT tools such as video conferencing, electronic meeting and shared electronic devices to support the CFPT environment (section C, question 2).

## **APPENDIX 11**

### **Guidelines for the Formation of the Cross Functional Project Team (CFPT) in Construction**

# **GUIDELINES FOR THE FORMATION OF THE CROSS FUNCTIONAL PROJECT TEAM (CFPT) IN CONSTRUCTION INDUSTRY**

## **1.0 GENERAL GUIDELINES**

- 1. The client has important roles toward promoting the formation of CFPT within construction project.**
- 2. The use of traditional procurement approach is inappropriate platform to support CFPT implementation.**
- 3. The use of Design and Build and Partnering approach are considered as appropriate platform to support the initiation of CFPT formation within current construction industry environment.**
- 4. The inclusion of all key project members should be made before sketch design to ensure that all their requirements can be simultaneously considered in the design.**
- 5. Key suppliers should be included in the team rather than being represented by other parties that directly employ them.**
- 6. The team should be allowed to have greater flexibility to make important project decisions.**
- 7. The clients or their representatives should be participate in the team as active members, so that their requirements can be addressed directly by team members.**
- 8. IT tools based on GroupWare system have not been widely used but can be useful to support team communication and integration.**
- 9. In is customary within current practice that the designers should take the leadership in design development process and the final approval requires the client consent.**

This system should be maintained and incorporate within CFPT approach toward design.

## **2.0 SPECIFIC GUIDELINES DEVELOPED FROM DELPHI STUDY**

### **2.1 Team Component**

#### **2.1.1 Inclusion of members into the CFPT during briefing stage**

The priority of the members to be included in the briefing process can be based on the rankings of the stakeholders that can influence the design:

1. Client
2. End user (customer)
3. Architect
4. Engineers
5. Main contractors
6. Service contractors
7. Surveyors
8. Financiers
9. Sub-contractors
10. Suppliers

#### **2.1.2 Inclusion of the members at later stage of the design development phase**

The list of the priorities of the members to be included in the later stage of the design (before the commencement of the sketch design phase) if their inclusion in the team have not been considered earlier, can be based on the following ranking of members "that have the ability to contribute to the design":

1. Architect
2. Engineers
3. Main contractors
4. Sub-contractors

5. Client
6. Service contractors
7. End user (customer)
8. Suppliers \*
9. Surveyors
10. Financiers

**Note:**

The findings from the research indicated that it is important to include key suppliers early in the team. Despite their eighth position in the ranking determined by the Delphi study, it is strongly recommended that their inclusion into the team should be made before sketch design stage commence.

### **2.1.3 Number of representation from each functional group in the CFPT**

There should be flexibility in term of the number of each functional group representation in CFPT depending on their roles. It should depend on the actual requirement of the project. However as a matter of general guideline the overall size of the team should not be too big to ensure its effectiveness.

### **2.1.4 Consistency of the number of the team members throughout the project**

There number of the team members should not be fixed. It should be varied from one stage to another throughout the project life-cycle.

### **2.1.5 Team Leadership**

It is preferable to have a designated project manager to lead the team.

## **3.0 Essential changes that should take place to realise CFPT formation**

To realise the formation of the CFPT in construction the following changes expected from the current practice:

1. Existing traditional procurement system
2. Existing traditional work process

3. Relationship between the various functional group in the project
4. Roles of clients in the project leadership
5. Initiative of the client in supporting the teamwork
6. Team members should be co-located in the common office
7. There should be a special criteria to select the team members

#### **4.0 Team authority**

##### **4.1 General**

There should be a moderate approach in giving the team the power to overrule individual functional group decision.

##### **4.2 Roles in the design development process**

1. The team should be given the accountability for project design with leading role taken by the designers
2. Team members should be given the authority and flexibility to contribute and review the design throughout the design development process.
3. Using consensus opinion as a criterion to adopt final design solution is inappropriate practice within current construction industry environment.
4. The designers (architects or engineers) should take leadership in design and make final design solution upon consideration of the requirements and inputs of other team members.
5. Quantity surveyor (estimator) has the role to support the design process by costing alternatives as design proceeds.

#### **5.0 Physical requirements for team**

It is highly recommended that the CFPT members to be collocated in a common office.

## **6.0 Formation of team at outset**

### **6.1 Expected changes from current practice**

To achieve the formation of CFPT from outset changes from the current practice are expected within the following aspects:

1. There is a need to review the current procurement system.
2. Training and education is an important instrument to support the team members participating in the team from outset
3. Client must be willing to pay the initial additional cost for the appointment of team members at outset

### **6.2 Mechanism to achieve formation of the team from outset**

The important mechanisms to support the formation of the team at out are through:

1. The Initiative from client; and
2. The Initiative from parties approached by the clients.

## **7.0 Structure to support team**

There should be flexibility in developing appropriate teamwork structure for the team to suit the actual need of construction project.

## **8.0 Project information requirement**

### **8.1 General**

There must be openness toward sharing common project information within CFPT collaborative environment.

## **8.2 Expected changes in industry**

The availability of key project information to the CFPT members is an important criteria working under collaborative (CE) environment. To achieve this objective require the changes within the following aspects:

1. Changes in the industry culture
2. Changes to the existing procurement systems
3. Changes in the attitude of project team members toward the use of IT tools

## **8.3 Important information for the team**

Among the important project's information that need to be furnished to CFPT members are related to the:

1. Project planning
2. Project scheduling
3. Basic design requirement
4. Project cost
5. The duties and responsibilities of other team members
6. The project priorities
7. The client's requirements
8. The end users' requirements

## **8.4 Supporting IT tools**

The following IT tools are useful to support CFPT communication and information sharing:

1. Workgroup information systems
2. Shared project database
3. Electronic data and voice mail



## **8.5 IT leadership in the team**

There is a need for leadership in IT used for the project. It is also recommended for the appointment of the post of information manager in the CFPT.