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COMMUNICATIONS IN CONSTRUCTION
DESIGN

XIAOLING XIE

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

September 2002
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Abstract

Construction design has become an increasingly complex synthesis activity for which effective solutions depend upon co-operative participation by a number of people. Thus communication, including the integration of specialised knowledge and negotiation of differences between team members, is a vital process for collaborative design. A questionnaire survey was initially conducted to investigate communication issues and problems, which had been highlighted from a review of the literature, in current construction design. The results confirmed that communication among the different construction team members is often difficult although of paramount important to design outcomes. Based on these results, case studies have been carried out to gain further insights into communication issues and problems, and explore why and how they are caused. Through the application of multiple approaches, a model has been developed, which suggests strategies that may help participants communicate more effectively and ultimately improve the quality of construction design outcomes.
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Chapter One
Introduction

1.1 Background to Research

Construction design has become an increasing complex activity. There is a growing awareness of the need for better design management in the building industry (Baldwin et al., 1998). This is due in part to meeting the greater demands by clients in terms of technology, performance, economy, justification, and speed of design and construction. Often the processes of design and construction are conducted in parallel to fast-track the project (Austin et al., 1996). Fast-track construction has been described as the compression of project duration achieved by overlapping the design and construction of individual work packages (Newton, 1995). This increases the pressure put on designers to ensure that the contract documents are fully co-ordinated and issued on time. It is rare that a complete set of working drawings is made available before site work commences (Kwakye, 1991). The influence of fast track methods on design means that often the project cannot be designed in a logical order. Moreover, increasing dependence on sub-contractors increases the complex activities further, as noted by Baldwin et al (1998): more complex buildings have necessitated design input from an increasing range of specialist sub-contractors. Different forms of procurement have meant that the design work, and the deliverables of the design process, must be linked to the letting of the work packages to these sub-contractors.

The construction industry is well-known for its fragmentation. Each construction project involves several disciplines collaborating for a relatively short period in the development of the required facility (Wheeler, 1986; Popple and Towndrow, 1994). Design itself is an iterative interdependent process (i.e. in loops, not sequential). The ill-defined nature of design means that analyzing and understanding its problems is an important part of the design process. Moreover different interpretations or understanding of the problems and different design concepts from different disciplines are not easy to integrate to achieve a shared or commonly held understanding. These facts significantly affect the information gathering, sharing and finally solving for design problems (Cross and Cross, 1995).
These features, including the changing situation and characteristics of design processes and construction industry, make managing construction design processes a challenge: how can all the members involved in construction design be integrated and co-ordinated effectively?

In a typical building construction project, participants of the design team would include the architect, the structural engineers, the building service engineers, and the quantity surveyors. Although the client, main contractors, sub-contractors, materials suppliers, relevant authorities, and others are not internal members of the design team, their impact on the design is sometimes great, especial sub-contractors (specialists), and they undertake very important roles in the different phases of design and construction. Their roles fluctuate in importance and priority from one phase to another (Saad and Hancher, 1998). These members come usually from different disciplines and organisations, have different backgrounds, culture, experience and knowledge, and are located in different places. The increasing “globalisation” and complexity of construction implies that the project team may involve partners from widely distributed geographic areas, sometimes on different continents (Anumba and Evbumwan, 1999). These participants come to the design location with pre-existing patterns of work activities, specialized work languages, different expectations and perceptions of quality and success, and different organisational constraints and priorities (Sonnenwald, 1996). In performing the activities of design, the general trend is for these professionals/disciplines to work independently of one another, whilst making design decisions that inevitably affect each other (Evbuomwan and Anumba, 1998).

This poses difficulties for the management of construction design although effective management is crucial to the success of a project (Latham, 1994). Successful design performance of large multi-disciplinary projects requires enormous co-ordination to ensure that all cross discipline interactions are facilitated and all parties are constantly aware of the ever changing state of the project (Newton, 1995). Concurrent engineering involves the integration of all project team members, as well as all the stages in the
project life cycle, with a view to ensuring that all key life-cycle issues are addressed early in the design process (Anumba and Evbumwan, 1999). The greater the level of concurrency in a process, the greater is the level of co-ordination required (Anumba et al. 1997). The more the specialists (sub-contractors) are involved, the more collaboration is needed. The increasing range of specialist sub-contractors requires effective management of the interfaces between these organisations if the construction time schedules are not to be interrupted and the handover dates are not to be delayed (Potter, 1995). The more innovative, competitive and complicated the building design is and the more participants are involved, the more integrated collaboration is needed. Non-collaboration can lead to conflict and has a negative impact on the quality of the design process and design outcome (Sonnenwald, 1996), resulting in errors and inefficiency (Newton, 1995).

How can co-ordination in multi-team construction design be achieved? Sonnenwald (1996) suggests that communication is the vital process for collaboration during design. Communication systems are the central nervous systems which make it possible for hundreds of people to do dozens of tasks in an integrated and orderly manner, and to coordinate their efforts and skills towards a common goal (Guevara and Boyer, 1981). This is particularly true in the construction industry (Anumba and Evbumwan, 1999).

Hassan (1996), through interviewing designers, confirmed the importance of communication to the design process. Knoop et al (1996) presented results from an empirical study on the relation between the designer's performance and observed communication aspects. The results indicate that there is a significantly positive correlation between design performance and the amount and content of communication. Thomas et al (1998) analyzed the relationship between design success and communication from the data collected from 38 CII (Construction Industry Institute) organisations for 72 projects geographically dispersed in eight separate countries. The Correlation coefficient of these variables is 0.71, which clearly indicates the positive relationship between them. There are other studies and observations about the importance of communication to the design and construction processes, which are included in Appendix A.
1.2 Research Questions

Communication is an essential process for collaboration in construction design. However, although design team communication has been studied in traditional construction design, more effort is needed to understand the current communication issues and problems. Therefore, the aim of this research is to investigate how construction design can be improved through a comprehensive study of design communication issues and problems, and the development of an improved communications framework. The research questions of this study will seek to answer are:

- what are critical variables of effective communication in construction design?
- what are the communication issues and problems in current construction design?
- how do they occur?
- and why?

As communications are so important to design, these questions will hopefully provide the first step towards understanding the current issues and improving communications throughout the design process.

1.3 Objectives

The objectives required to meet the research questions are:

- to review the design process: design knowledge exploration- artefact context, design context, and technical and scientific knowledge;
- to review the theory of multidisciplinary teams;
- to review the theory of communication basic elements and models, communication processes;
- to review the communication processes in construction design.
- to investigate communication issues and problems in current construction design;
- to examine the issues and problems further and explore “how” and “why” they occur; and
- to construct a generalized communication model.

1.4 Work Undertaken

This research started with a literature review. The university library provided
preliminary texts about the subject area. Books and papers found in the library gave the historical context to current developments in this field and those related to it. Using this source, it was possible to understand the developments and important centers of research across the world. Searching of BIDS and online databases was undertaken to obtain recent papers. The British Library and other university libraries were also used.

The literature review covers several aspects that are related to this research, for example, design processes, multidisciplinary teams, communication theories, communications in construction design, and the research on communication effectiveness in the relevant areas. The review was employed to establish the research questions and the propositions of the present research.

In the process of developing a suitable data collection and analysis approach, a systems approach was employed, which helped to avoid the situation in which the collected data did not address the initial research questions (Simister, 1995). Research approaches have been classified in many different ways. One of the widely used and simple approaches is to distinguish among three strategies: (1) experiments that are undertaken to measure the effects of manipulating one variable on another variable; (2) surveys that involve a collection of information in a standardised form from respondents; and (3) case studies that allow an investigation to gain a holistic and meaningful characteristics of real-life-events by observation, interview, and documentary analysis (Robson, 1993).

Lee (1991) and Parthe (1993) argue that a single approach on its own may not provide an in-depth understanding of the issues in organisation. The application of multiple methods often proves to be more powerful than one single research method. In this research, multiple methods: questionnaire survey and case studies were applied to identifying the communication issues and their effects. The questionnaire survey was conducted to acquire more specific information about communication issues in current construction design and to identify the communication effectiveness variables and problems, which had been highlighted from the literature review. To explore these further, a multiple case study was used. The use of Case studies as a research strategy is well suited for the
research questions being addressed. A case study is best suited for answering "how" and "why" questions behind decisions (Yin, 1994). The questionnaire approach can only obtain a general behaviour of a phenomenon through statistical analysis and is insufficient to answer the above questions because the acquired information cannot be elicited in sufficient depth. Fig. 1.1 outlines the essential stages adopted in this research.
General review
Communication theories and concept
Communication processes in construction design

Research questions
What are the communication issues and problems in current construction design?
How do they occur and why?

Special review
The research on communication effectiveness in the relevant areas

Research propositions
The research questions will be investigated from three aspects:
Information flow; Communication variables; and Communication network

Case study approach
Select cases
Select the approaches of data collection
Case study protocol
Conduct 1 Case study
Write individual case study report
Draw cross-case examination
Develop a communication model
Write conclusion and further work

Questionnaire survey approach
Select the approaches of data analysis
Conduct the survey and analyze results
Conduct 2 Case study
Write individual case study report
Conduct 3 Case study
Write individual case study report

Fig. 1.1 Research layout
1.5 Main Findings and Contributions

The main findings and contributions of this study are summarised as follows.

To answer the questions proposed for this research, a questionnaire survey was initially conducted to investigate communication issues and problems, which were highlighted in the literature review, in current construction design. Through the analysis of the survey, a picture of communication in the current construction design emerges. It shows that effective communication in design plays a very important role in both design and construction processes. The procurement route significantly affects the communication process, especially for external communication. There are a number of common issues and problems in communication between those involved in the design process. These problems occur in the aspects of the communication variables and information flow, and appear frequently in both internal and external communication processes. These problems may seriously impact the construction design, and happen more often at certain stages of the design and construction processes, such as detail design and operations on site. IT has been extensively used in design communication and its usage continues to increase.

To gain further insights into these issues and problems, detailed case studies were proposed. Case studies were carried on three different projects characterised with different procurements, different subjects, different size, and at different stages. The results of the case studies demonstrate that communications during construction design are influenced by:

- procurement method;
- communication system;
- client;
- contractors and key subcontractors (specialists);
- resource;
- social collaboration;
- technical collaboration and
- key personnel
Based on the questionnaire survey and the case studies, a model of communications in construction design has been developed, as shown in Fig 9.2. This model consists of two parts. One concerns the variables of communications and monitoring tools. The other is about the communication strategies related to the influencing factors and at which stage the strategies are applicable. These strategies are:

- proper choice of procurement;
- well arranged programme;
- limited requirement changes;
- agreed communication procedures;
- common protocols for IT use;
- high quality brief;
- well trained and sufficient resource (personnel);
- early and adequate involvement of contractors and subcontractors;
- friendly environment;
- co-location design;
- regular face-to-face meetings; and
- key personnel stability and capability in communication.

The model has two functions. Firstly, the strategies accompanying operation conditions may be used as a guide for setting up project design in terms of team communication and as a practical way to positively influence the communication variables. Secondly, any problems present in the communication variables, which are found by the monitoring tools during the project operation, can lead to a review of the strategies and then solutions can be proposed to improve the communications.

Combining the variables and monitoring tools with the strategies may help participants communicate more effectively and ultimately improve the quality of construction design outcomes.
Chapter Two
Design communication

2.1 Design Process
In response to mature markets, increasing worldwide competition, fast technological development, and increasing liability regulation, many companies strive to economically create innovative systems or artefacts with high volume distribution. The creation of innovative artefacts often requires the exploration and integration of dynamic and diverse knowledge from multiple domains, disciplines and contexts among designers and specialists (Sonnenwald, 1996). Sonnenwald therefore suggests that the design process is a knowledge exploration process, which is divided into artefact context, design context, and technical scientific knowledge (see Fig. 2.1).

There are many models that describe design process, such as Luckman’s descriptive model (1984), French’s prescriptive model (1991), Pugh’s total design model (1990), and Sonnenwald’s knowledge exploration model (1996). Luckman’s descriptive model is one of many descriptive models. It depicts the processes of analysis, synthesis, and evaluation employed by the designer to develop a solution to a problem. French’s prescriptive model is based on four basic activities which are typical of a conventional engineering project: analysis, conceptual design, embodiment design, and detail design. The aim of the model is to encourage designers to follow the various stages of the design process and to work in a systematic manner. Pugh’s total design model is the most common model in design literature (Newton, 1995). Of course, no single model has been universally accepted as truly representative of the design process (Taylor, 1993). This is indicative of the complexities of the design process and the nature of the work being modelled (Newton, 1995). However each model focuses on certain aspects of the design process. For example, Sonnenwald’s model (1996) focuses on knowledge exploration in the design process. This is a good model for describing the need of communication in multi-team design processes.

In the design process with the use of knowledge exploration, the participants build on
their past experiences with artefact context, design context, or situations, and technical and scientific knowledge. They explore and integrate knowledge about the current (and evolving) artefact context, design context, and technical and scientific knowledge. The expected outcomes include the creation of an artefact to be useful in the future artefact context, perhaps the creation of new technical and scientific knowledge, and knowledge about the design process to be applied to a new design activity.

Exploration of the artefact context requires an understanding of how the artefact should support patterns of works, organization structure, social group and individual preferences (Rasmussen et al., 1994; Bucciarelli, 1988) as well as the artefact’s potential impact on the environment, culture, individual perceptions of reality, other artefacts, and systems (Krippendorf, 1989; Beer, 1974). Each artefact context can, of course, consist of multiple contexts. A challenge in design is how to explore and integrate knowledge about these contexts so that the artefact can support activities and values in each of these domains. If artefact contexts are not explored, design decisions may have a negative impact on users.

Furthermore, the design context must explore itself during the design process (Sonnenwald, 1996). Increasingly the design team includes participants from different disciplines, organisations and cultures because the creation of innovative artefacts require designers and specialists from a variety of disciplines and contexts not all of whom work in a single organisation, company or country. These participants come to the design process with pre-existing pattern of work activities, specialised work languages, and different expectations, perceptions of quality and success, and different organizational constraints and priorities. Design participants need to explore and integrate these differences. If the design context is not explored, the project team members may make design decisions that have a negative impact on other members’ work and on the artefact as a whole.

Similarly, exploration of technical and scientific knowledge may be required for a variety of reasons including finding solutions to design problems (Sonnenwald, 1996), data to support intuitive solutions, and methods to help interpret the artefact context. To create
innovative artefacts, the design participants must explore technical and scientific information from a variety of disciplines.

However, the exploration can be difficult for the design participants. Participants’ unique past experiences, specialised work language, and differences in work patterns, perceptions of quality and success, organizational priorities, and technical constraints may lead them to challenge or contest one another’s contribution. This phenomenon, characterised as ‘contested collaboration’, can lead to conflict, which has a negative effect on the quality of the design process and design outcomes.

![Diagram of knowledge exploration during the design process](Sonnewald, 1996)

Through studying the three explorations, Sonnenwald (1996) claims that communication is an important aspect in knowledge exploration and collaboration, which facilitates the sharing of meaning (Fig. 2.1).

Any construction design, especially building design, is essentially based upon the synthesis of ideas and restrictions provided by a series of contributors (Wallace, 1987).
This is a typical exploration process of the artefact context, design context, and technical and scientific knowledge.

2.2 Multidisciplinary Teams

The construction design team, such as a building design team, consists of a number of individuals, each of whom has his or her own specialisations (R.I.B.A., 1974). The design team therefore represents a range of disciplines, assembled together in order to produce a combination of expertise in relation to a complex problem. This situation represents a multidisciplinary team. The literature suggests that the entire group process is fundamentally different in multidisciplinary teams as compared to unidisciplinary ones (Wallace, 1987).

The main point is that the group process of multidisciplinary teams in relation to the interaction and compatibility of group and individual goals and value judgments, is fundamentally different from the corresponding process in unidisciplinary groups (Gelernter, 1970). In multidisciplinary teams, there is likely to be larger variations between individual goals and objectives, with consequent increased difficulties in establishing a team goal and reconciling the individual objectives with this overall group objective (Yoshda, 1980).

Yoshida (1980) suggested that this disparity of goals in a multidisciplinary team could lead to goal ambiguity. If a team goal has not been clearly defined at the outset, then the group process is forced to implant a team goal upon the individuals via a process of conflict and competition, since a range of individual goals are unlikely to be fully compatible with eventual perceived group goals, due to variations in individual value judgments (Shadish, 1981).

A second factor which affects multidisciplinary team interaction and participation in addition to goal ambiguity is that of role ambiguity, or team members not fully appreciating their role or position within the group. Wallace (1987) has suggested that the role ambiguity may lead to subsequent team apathy towards overall team goals,
suggesting that a lack of clearly defined member roles leads to a disruption of the testing and development stage of the group developmental process and particularly interfering with the establishment and implementation of a compatible group socio-emotional structure. Team apathy and group process interruption are clearly factors in the appearance of group conflict and group process realignment in the later stages, and therefore play an important part in the subsequent interaction and participation processes.

The third factor for consideration in relation to multidisciplinary teams as opposed to unidisciplinary teams is that of participation in relation to the solution formulation. Ysseldyke et al (1982) reported that multidisciplinary teams tend to consider a wider range of solution alternatives in attempting to arrive at an overall solution. They suggested that this wider ranging participation was caused by the combination of a greater and more varied range of experiences. This may seem clear, but it does have an implication in relation to role ambiguity. The results of Ysseldyke et al (1982) suggest that consideration of a wider range of variables may be related to goal and role ambiguity via the process of resultant conflict and competition.

The construction design team is characteristically of a highly multidisciplinary nature. This enhances the initial role and goal ambiguities which form initially within the group due to the lack of clear task-oriented alignment and the lack of an adequate socio-emotional preventative mechanism. These initial ambiguities are corrected as the socio-emotional and task-oriented definitions become more established. The correction procedure is only via a process of participants' interaction and communication (Wallace, 1987).

2.3 Communication Theory
As reviewed in Sections 2.1 and 2.2, the construction design process is a typical interaction process of multidisciplinary teams, and an exploration process of artefact contexts, design contexts, and technical and scientific knowledge. All of these suggest that the design process is dependent on the communication processes which take place within the design team over a period of time (Wallace, 1987; Sonnenwald, 1996).
understand the communication process during construction design, basic communication theories and their applications in construction design are reviewed in the following sections.

2.3.1 Communication definitions, function and importance

Communication has been defined in a number of ways. For example:

Communication is the transmission of information, ideas, attitudes, or emotion from one person or group to another (or others) primarily through symbols (Theodorson and Theodorson, 1969);

In the most general sense, we have communication wherever one system, a source, influences another, the destination, by manipulation of alternative symbols, which can be transmitted over the channel connecting them (Osgood et al., 1957);

Communication may be defined as the social interaction through messages (Gerbner, 1967);

Communication is the process of effecting an interchange of understanding between two or more people (Flippo and Munsinger, 1975); and

Communication may be defined as a dynamic transaction of simultaneously exchange verbal and non-verbal messages, resulting in shared meaning between two or more people (Staley, 1992).

Communication serves many functions in organisations. There are six functions that seem to dominate communication in the organisational context. The functions are inform, regulate, integrate manage, persuade, and socialise (Richmond and McCroskey, 1992).

Communication and co-ordination are called for to resolve any disagreements or conflicts that arise during the design (Peng, 1994).
Communication has significant importance in current construction design as evidenced by: Cocurrency in an integrated design and construction process requires greater discipline in the production, manipulation, storage, and communication of project information. Effective communication is vital for the success of concurrent engineering in construction (Anumba and Evbumwan, 1999).

Concurrent engineering practices are successful, only by eliminating unnecessary change and redesigns and by facilitating cross-functional teamwork based mutual communication supported with integrated product life cycle knowledge (Tomiyama, 1998).

2.3.2 Verbal and non-verbal messages
Verbal messages are represented in the spoken aspect of communication. Non-verbal messages however are transmitted from one person to another via facial expression, tone of voice, gestures, movements and touch.

2.3.3 Vertical and horizontal flows
Communication basically occurs in two planes—the vertical and the horizontal.

In the vertical plane, communication flows downwards from superiors to subordinates and vice versa in the upwards direction. Downward communication flows in an organisation are more frequent than upward flows as the superiors in an organisation are more likely to initiate communication. Downward flows tend to be more authoritative. Upward flows, when they do occur, tend to be more positive than negative in content (Rogers, 1975). “A superior tends to receive reports that tell him primarily what subordinates want him to hear” (Down, 1967). Upward flows are generally feedback on an operational performance.

Horizontal communication flows occur between peers in an organisation and are more frequent than vertical flows. One reason for this is that people are more prone to speak freely and openly to their equals than to their superiors (Downs, 1967). Horizontal flows
are more likely to be through informal channels and thus move more rapidly than vertical flows.

2.3.4 Communication process and elements
There are seven basic models used in communication research to describe the communication process (Windahl and McQuail, 1993), they are:

The Lasswell formula (Lasswell, 1948);

Shannon and Weaver's, Osgood and Schramm's, and Dance's models (Shannon, 1949; Schramm, 1954; Dance, 1967);

Gerbner's general model of communication (Gerbner, 1956);

Newcomb's ABX model, other 'balance' models and co-orientation (Newcomb, 1953);
Westley and MacLean's conceptual model for communication research (Westley and MacLean, 1957);

Maletzke's model of the mass communication process (Maletzke, 1963); and

Alternatives to transmission: ritual and attention models (Carely, 1975; McQuail, 1987).

These models describe the communication process from different perspectives, and have served different purposes, but the basic elements in the general terms are the same, which imply a sender, a channel, a message, a receiver, a relationship between sender and receiver, an effect, a context in which communication occurs and a range of things to which 'message' refers (Windahl and McQuail, 1993).

A model of the communication process developed by Schermerhorn et al. (1994) is depicted in Fig. 2.2. A discussion of the communication elements is follows.
The Sender (or source)

As the originator of communication, the sender knows best the intended idea and must encode the idea into the message to be sent (Thomas et al. 1998). The source could be individual or collection of individuals—one person, a group, and dyad (twosome), or an entire organisation (Richmond and McCroskey, 1992). For effective communication, first of all, the sender selects the message and the way of communication. The message must have the mutual meaning for two sides of communication. The method of communication used by sender must enable the receiver to receive the message.

The Receiver

The most important single element in the communication process is the receiver. (Rogers, 1977). The communication process is not completed until the message is understood by the receiver. How much the receiver knows about the topic is a key to his/her comprehension of the message.

For the sender and receiver, interpersonal communication skills and the relationship between them have a direct impact on the effect of communication. Language is often the most common barrier to effective communication. There is as much difference between the right words and the almost-right word as between lighting and lightning bug (Sigband and Bell, 1989). Poorly defined or poorly communicated ideas, sometimes stem from deficient language skills (Robar, 1998). In addition, the sender and receiver need to consider the backgrounds and experiences of each other... get to know one another's
attitudes and feelings (Richmond and McCroskey, 1992). If a good relationship and trust exist, the content is more freely communicated, and the recipient is more accurate in perceiving the sender's opinion.

**The Message**
A message is any verbal or non-verbal stimulus that elicits meaning in the receiver (Richmond and McCroskey, 1992).

**Channels**
In essence the communication channel is any medium which couples the source to the receiver (Wofford, *et al.* 1977). The channel can be formal or informal. They are complementary and substitutable in an organisation. Formal channels usually flow vertically and often tend to be directive (Sigband and Bell, 1989) and transmit messages explicitly recognized as official by the organisation. They are more likely to be in a written form (Rogers, 1976), for example, the schedules, memos, change orders, policies, etc. These channels also can be useful in keeping employee informed by transmitting newsletters and performance data (Thomas, *et al.*, 1998).

Informal channels of communication typically form a network or "grapevine" (Hunter, 1993). For the effect of these channels, different authors have different views. Some think that they are more effective, but others think that they are the least efficient, even though these channels carry many messages vital to project success (Wofford *et al.*, 1977; Sigband and Bell, 1989). They often contribute towards an organisation's effectiveness in reaching its goals (Roger, 1975).

In general, from interpersonal, interdepartment to interorganisational communication, the channel gradually changes from informal to formal.

**Media**
Media are the mechanisms by which the message can be transmitted. There are usually two media, one is hard and the other is soft. Thomas *et al.* (1998) gave the examples of
engineering, procurement, and construction project to explain hard and soft media. Hard media include contracts, procedure, plans, reports, policies, and regulations and soft media include team building sessions, disputes, and person-to-person exchanges. The hard media utilise the formal channels and the soft media usually take place in the informal communication channels.

**Barriers and Filters**

Barriers and filter are aspects of communication systems that limit information flow or "color" information as it is transmitted (Flippo and Munsinger, 1975). There are many factors that can become barriers and filters in the communication process of organizations. Apart from those mentioned above, organisational structure, size and location influence the flow of communications. The larger and more complicated the organization is, the more levels, barriers and filters the information needs to pass. Excessively long channels further inhibit communications flow (Thomas, *et al.* 1998).

**Feedback**

The receiver's response to a message provides feedback to the sender. It can be verbal or non-verbal but it is essential for the accurate completion of the communications process. Without feedback, the sender does not know if the message has been received and understood.

In reality, the communication process is complex, which is only introduced in general in this section. It is further addressed with consideration of the construction design process in the next section.

**2.4 Communication in Construction Design**

**2.4.1 Design team communication**

Any construction design is essentially based on the synthesis of ideas and constraints provided by a series of contributors. The participants of a design team in the construction industry usually consist of the architect, the structural engineer, the building service engineer, and the quantity surveyor. The client, main contractors, sub-contractors
(specialists), materials suppliers, relevant authorities and others also have an impact on the design, sometimes significant, especially sub-contractors (specialists), but their roles fluctuate in importance and priority from one phase to another (Saad and Hancher, 1998). As such the design team is multidisciplinary. An architect may be aware of the basic concepts of other’s design, but details input to the design evolution are provided by others. The process of conceptualization and transfer to the main design can only be achieved by communication. The various designers and specialists may develop their ideas independently to a certain extent, but ultimately these must be combined to produce a mutually acceptable design result (Wallace, 1987).

Derbyshire (1972) considered the building design process as being based upon the balancing of individual objectives or goals. Each member has a range of goals at the outset. These are input to the design at the appropriate stage in channels which indicate their importance to originator and possibly to the design itself. Derbyshire (1972) suggested that there are essentially two groups of objectives inherent in any building design process: firstly the design team itself has an overall goal, largely based upon meeting the requirements put forward by the client; secondly each individual member of the design team has individual goals which he seeks to impose or implement upon the design as it evolves. Individual objectives are put forward in channels at the appropriate time and are balanced by the process of the team’s interactive communication.

As the design process continues, the level of information available to the design team increases. Feedback is important to design team communications, related to the evolution of the overall design. The level of feedback and hence the likely effects upon objective balancing and subsequent communication patterns also vary as a function of the design stage (Wallace, 1987). Higgin and Jessop (1965) also noted this probability of objective or goal variation and observed the impact of the design stage upon it, in relation to the patterns of communication which are likely to be exhibited as a result. Their results suggest that the goal or objective variation disruption could be minimized by the introduction of a “sponsor” (an architect) at an early stage. This again highlights the importance of the communication system, in that if an architect is involved at an early
stage, he can influence the early objective formation of the client via the interactive communication system.

A second aspect of communication raised also by Higgin and Jessop (1965) is client requirement communication. The multidisciplinary nature of the design team means that the client is usually relatively non-specialised in terms of construction and design philosophy. This presents the obvious problem of a relatively "ignorant" and inexperienced individual attempting to communicate his requirement to a highly specialized and experienced design team. Higgin and Jessop (1965) suggested that the client typically forms an "idealized" objective judgment of the eventual building which is typically incorrectly communicated or channeled to the design team at the outset. This early lack of effective communication is a primary source of design team related conflict in the subsequent stages of design.

Conflict itself is another form of the design team communication which directly affects the evolution of the design. Higgin and Jessop (1965) noted that conflict typically increases towards the later stages of the design, and appears to be related to the degree of complexity and establishment of the design and the magnitude of subsequent feedback availability and appearance in communications. The appearance of conflict in communications does appear to be related to the design stage. It tends to occur as the communications changes from the strategical to the tactical. Using their own design plan of work terminology, they suggested that conflict typically increases in the later stages of the design, but could appear as early as the outline proposals and scheme design.

In most design teams, the cost information is largely provided by the quantity surveyor. This in turn suggests that the communication content of the quantity surveyor will become increasingly important in terms of overall design team communication towards the later stages of the design process (Derbyshire, 1972). Higgin and Jessop (1965) associated this with the change in design philosophy from strategical to tactical. They suggested that this increase in cost related communication, with the quantity surveyor as the primary originator, tends to increase the overall level of communication between the
architect and the quantity surveyor.

In line with Debyshire (1972), Mackinder and Marvin (1982) reported on the increasing level of feedback in design team communication towards the later stages of the design. They suggested that virtually all attempts at design rationalization follow the same basic process of "analysis-synthesis-evaluation" with a necessity for an increasingly communication-defined return loop in order to provide the feedback and backtracking with associated reanalysis of the design problem, which inevitably occurs when an initial design solution fails to work. They suggested that, because of the multidisciplinary nature of the building design team, the communication of each member becomes more and more channeled. It is necessary to rationalize one communication channel in relation to the design, but it becomes more and more difficult to rationalize them all coherently without modification of the individual elements using communication.

Mackinder (1980) reported that there are five communication factors related to aspects of the design: cost; aesthetics; durability and adequate performance; supply and availability; and replacement. Cost was reported to be the main factor for consideration in most cases, increasing in importance towards the later stages of the design process. Aesthetics was reported to be of particular value in isolating possible component solutions from a range of acceptable alternatives. The chosen component was then evaluated against other selection criteria, in order to see if it remained an acceptable choice. It was suggested that towards the later stages of the design, the architect increasingly considered the market availability and supply of elements of the design. The conflict within the design team leads to the disruption of these criteria in terms of individual objectives.

Derbyshire (1972) suggested that the client initially sought maintenance and durability characteristics with at least some aesthetic merit in the design, but cost reporting caused an objective reversal towards capital cost minimization. Architects tend to choose materials and forms of construction with aesthetics, maintenance and durability in mind. However, during the communication process, the client increasingly pressurizes the
architect to adopt cheaper solutions. This process is again characterized by the evolving level of design team conflict towards the later stages of the design.

The literature on design team communications suggests that the traditional building design process is a typical interaction process of multidisciplinary teams, and an exploration process of artefact contexts, design contexts, and technical and scientific knowledge. It is essentially a function of the communication processes (Wallace, 1987).

The design of modern buildings has become an increasing complex activity. The more complex building have necessitated input from an increasing range of specialist subcontractors (Baldwin et al., 1996). Fast-tracking, which is achieved by overlapping the design and construction phases, means that the contractor may be involved in very early stage-outline proposals (NEDC, 1990). The participants involved in the design come from widely distributed geographic areas, sometimes on different continents (Anumba and Evbumwan, 1999). In performing the activities of the design, the general trend is for these professionals/disciplines to be geographically dispersed, and their design decisions inevitably affect each other (Evbuomwan and Anumba, 1998). Design should require the exploration and integration of dynamic and diverse knowledge from multiple domains, disciplines and contexts among these participants. It needs the exploration of artefact context, design context and technical and scientific knowledge through communication (Sonnenwald, 1996). It needs to pass from goal ambiguity to role ambiguity via a process of communication. As such, an incredibly complex mass of communication are required in construction design (Hunter, 1993), as can be seen in the data flow models developed by Lewis (1992). If the communications are not effective, problems will inevitably arise, as described by Higgin and Jesson (1965), Hunter (1993) and Carter (1993).

2.4.2 The means of communication

Hunter (1993) reviewed the means of communication in the construction industry. She divided communication into traditional and electronic. Traditional communication is non-electronic transmission of verbal and non-verbal messages, the end product of the non-verbal communication is always recorded on paper via pen, typewriter or printer.
Electronic communication is a transmission of verbal and non-verbal messages from one electronic device to another in such a manner that the message remains and is heard, read or viewed in the electronic form.

Recently there has been considerable research and development in the application of computers and communication technologies for improving the communication between the various functional disciplines during the design and construction process.

Anumba and Evbuomwan (1999) proposed an integrated framework for concurrent life-cycle design and construction (CLDC). They suggested that within the framework, the integrated design and construction process was underpinned by a variety of design tools and techniques and by appropriate databases and knowledge bases. The framework is based on the need for effective communication of project information at all stages in a construction project's life cycle, which is recognised to be vital for virtual organisations (such as construction project teams) to achieve their goals (Rogers, 1995).

Bowles (1994), identified the primary objectives for information technology (IT) and communication to support concurrent engineering as follows:

- to reduce the effect of distance so that team members can interact as if co-located;
- to enable cost-effective, flexible applications to have a visual object representation;
- to manage the generation, storage, and distribution of data; and
- to facilitate the integration of applications so that the human-machine interface solves the business problem to provide smooth transfer between design, modelling, test, and production.

Mead (1999) observed the process of intranet-based construction projects to determine the effect on project communication effectiveness. The results indicate that when used properly, project specific intranet systems act as a key role in a project communication network. Intranets also have a positive effect on the timeliness and understanding of project information, and their use can improve the speed with which information is transferred between project players. On the negative side, intranet use seems to contribute
to the information overload of project participants.

In the design domain, an increasing number of technology developers are orienting their efforts towards supporting multidisciplinary groups. As reviewed by Perry and Sanderson (1998), groupware system designers are increasingly creating systems with a view supporting the work of design and engineering groups. Initial research efforts include experiments with the use of multi-media technologies to support groups of distributed designers. More recent research has widened the range of potential technologies, and the nature of the application areas such as: fashion design, architecture, and engineering. The growth of interest in 'Concurrent Engineering' as a research field proposes theoretical and prescriptive models for managing heterogeneous design groups, and researchers have made proposals on specifications and architectures for computer systems to support design using such systems. Such applications facilitating co-located or distributed design work include: shared screen (whiteboard), shared editor, designer's notepad, videoconference, intelligent agents for conflict detection, issue based information system (IBIS), work-flow management, people locators and awareness system, and virtual meeting room. These technologies have been developed and marketed as solutions to what are perceived to be problem areas for designers (Perry and Sanderson, 1998).

Computing and communication technologies, have played, and will continue to play, an important role in improving communication in building design and construction. Many technologies which Hunter (1993) reviewed and examined have the potential to be very useful in this industry. Perry and Sanderson (1998) suggested, however, that technological 'solutions' are unlikely to provide a simple remedy, which improves design efficiency. Many other variables also affect the effectiveness of communication.

2.5 Communication Effectiveness

Eyre and Med (1979) claimed that communication is, and always has been, an important feature of life. Never, however, has effective communication been more important than it is in the modern world. They argued that effective communication is essential and communication is not just the giving of information; it is the giving of understandable
information and receiving and understanding the message. The Emmerson Report (1962) highlighted the vital importance of effective communication of information amongst the various participants of a construction project. The present research is to investigate how to make the communication effectively in construction design, what are the variables that affect the effective communications? To fully understand these issues, the following part reviews previous studies addressing effective communication in construction projects or general design, and then synthesises the literature to develop the research questions of this study.

The construction industry has long recognized the need for an improvement in information exchange and communication. There is much research on the subjects of communication in general, but little on communication in the construction industry. In 1965, Higgins and Jessop produced an impressive report - "communication in the building industry", which stated among its conclusion that the main factor lying behind communications difficulties is the nature of the relationships between the communicators. Also, any attempt at improvement, however limited cannot hope to achieve any significant degree of success in the absence of much more information than is at present available, about just what job any communication is supposed to do. Their research into the communication process and problems in the building industry is a good start and provides a platform for further research. In recognition of the critical contribution of effective communication to success of an organisation, Guevara and Boyer (1981) investigated the causes of poor communication in nine unionized construction companies. The research highlighted four communication problems - distortion, gatekeeping, overload, and underload. The research identified that the problems were prevalent in the construction industry. They applied a technique, developed by Roberts and O'Reilly (1974), to evaluate and measure the effectiveness of construction communication. Multiple regression was employed to find out which communication variables were affecting the communication problems and to what extent. This was perhaps the first time, that a quantitative method has been used to measure construction communications. Later, others such as Knoop et al (1996) and Thomas et al. (1998), used a similar method to analyse relationships between design success and communication, and between the
designer’s performance and observed communication aspects. From the result of their quantitative analysis, it is clear that effective communications are essential to the successful completion of design and construction.

Carter (1993) investigated the communication problems identified by staff on an actual building site through structured interviews. The problems were divided into eight problem environments and classified within each problem environment into the following four categories:

- **Class A** - Problems associated with a computing or communication technology currently in use, or problems having the potential to be solved with such technologies.
- **Class B** - Problems arising from information transfer and traditional communications within the organization structure, typically those of omission, underload, overload and gatekeeping.
- **Class C** - Problems in relationships.
- **Class D** - Problems resulting from the organization structure, from management decisions, or those difficult to be classified into the above three categories.

His research in collecting the communication problems and the categories for communication issues in the building industry is commendable, although the generalization is questionable, as there is only one case.

Hunter (1993) furthered Higgin and Jessop’s (1965) research, using construction phase Data Flow Models to study the communication process in detail. This is a more complete investigation into the communication process in construction projects, through which several communication problems were discovered, examples of which are listed in Appendix B.

In addition to these studies about communication problems, other studies have also been carried out on the improvements in communication from other perspectives.

Sonnenwald _et al._ have studied communications within design domain since 1988. Their
research focuses mainly on information design. A descriptive model of design developed by them characterizes communication among the participants including the specialists and is very useful for general design studies. The model describes design phases, role themes, and intra and intergroup communication networks throughout the design process.


In the information exchange dimension of communication, some specific methods have been developed. These include IDEF0 based modeling of information flow, the design structure matrix analysis, ApePT and multi objective-multicriteria methods (Austin et al), and the design process model of detail building design. In addition, a design process model of concept building design has been developed by Pendlebury (1998). These techniques, methods and models aim to describe and facilitate information flow between the participants to enhance communication effectiveness.

Although these studies have highlighted the importance of effective communication for
project success, there has been little effort to reliably measure communication
effectiveness. An important step in improving team communications is the identification
and measurement of critical communication variables (Thomas et al, 1998). Studies by
the Construction Industry Institute (CII) research team in USA achieved this vital first
step by identifying such variables for team communication. Survey questionnaires were
developed for use on a large sample of CII projects providing essential data from which
the research team identified the variables contributing to effective communications.
These variables were categorized as accuracy, procedures, barriers, understanding,
timeliness and completeness. These variables were then used to develop an assessment
tool “Compass” for improving team communications. Through the use of the diagnostic
tool Compass, project communication effectiveness can be both measured and monitored,
and problem areas can be identified. This is critical in improving project team
communication (Thomas et al., 1998).

The development of Compass has received attention from other researchers and project
managers. Mead (1999) used Compass to analyze how project based intranets affect
project communication in three case studies. He noted that COMPASS has excellent
potential for assessing and identifying communication problems on the project, but the
program should be reevaluated and additional questions should be added that may help
identify specific communication barriers including information flow.

Another communication analysis method is social network analysis, which has been used
to analyse projects’ communication networks. The analysis focuses on the
communication patterns that develop between people and organisations. The goal of the
network analysis is to obtain high level descriptions of a social communication network
through an analysis of relational data. This form of research has developed rapidly over
the last twenty years, and is used widely in sociology and communication science
(Garton, 1997).

Several computer programs have been designed to analyse the structure of social
networks, including UCINET IV and Krackplot. UCINET IV provides organised
summaries and analyses of each individual in the network and a geometric description of
the strength of each linkage. In this way, communication positions, such as linker, liaison,
isoate, and star, can be identified from an analysis of the data.

Several researchers have described communication variables, information flow variables,
and IT, which affect communication effectiveness. A summary of their description
classification is shown in Table 2.1. A more detailed description can be seen in Appendix
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Table 2.1 Classification of variables affecting the communication effectiveness

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2.6 Summary
As reviewed, numerous studies have highlighted the importance of effective communications for project success and research has been carried to enhance the communication effectiveness in construction project or general design. The present research is aimed at investigating how construction design can be more efficient through a comprehensive study of the communication issues and problems. The previous research provides a platform for this study. In particular Guevara and Boyer's (1981) research on information flow from the organizational dimension, and CII's research on communication variables from a humanistic viewpoint, and social network research for communication analysis were taken into account in the present research. Owing to the fact that information technology (IT) plays an important role in the communication process of current construction design (Anumba and Evbuomwan, 1999; Anumba et al., 1997), IT was also regarded as an important factor in this research.

For clarity, the definitions for information flow variables, communication variables and social network analysis are supplied as follows.

For information flow (Hunter, 1993)

*Overload:* Overload is a situation in which the individual or system has more information than that can be utilized or processed, leading to breakdown i.e. there is no corresponding output of information from the receiver.

*Underload:* Underload is a situation in which an individual does not have sufficient information to make decisions.

*Distortion:* Distortion is the transformation of the meaning of a message by changing its content.

*Gatekeeping:* A gatekeeper is an individual so located as to control messages flowing through a communication channel.

For communication variables (Thomas et al., 1998)

*Accuracy:* The accuracy of information received.

*Procedures:* The existence, use, and effectiveness of formally defined procedures,
outlining scope, methods, communication strategy etc.

**Barriers:** The presence of barriers (interpersonal, accessibility, logistic, or others) interfering with communication between participants

**Understanding:** An understanding of information received or expected from other design participants.

**Timeliness:** The timeliness of information received including design and schedule changes.

**Completeness:** The amount of relevant information received.

For social network analysis

**Role:** The participant components of any communication network. The individuals can fulfill several different roles within a project network according to frequency of communication, such as an isolate and a star in communication network (Tichy and Fombrun, 1979).

**Centrality:** Centrality is a measure of the importance or prominence of an individual in a social network. This can obtained by analysing the strength of connections with other members of the communication network (Wasserman and Faust, 1994).

The specific research questions developed for this study are what the communication issues and problems are in current construction design and how they occur and why. In order to answer the research questions, a questionnaire survey was first conducted to investigate the issues and problems, highlighted from a literature review, in current construction design, such as information flow variables and communication variables. This was followed by three case studies to gain further insights to into these issues and problems.
Chapter Three
The Research Design

3.1 Research Design
In developing a suitable research methodology, the principle is that it must completely address the research question (Creswell, 1994). According to Yin (1994), proper research design may meet this objective. Research design is the logical sequence that connects the empirical data produced by research to the study's initial research questions and ultimately to its conclusions. One of the principal purposes of the design is to help avoid the situation in which the collected data do not address the initial research question (Simister, 1995). The research design should (Simister, 1995):

- make explicit questions the research should answer;
- provide research propositions about these questions;
- develop a data collection methodology; and
- discuss the data in relation to the initial research propositions.

This chapter is to address these issues in the research framework and the research methodology used during this study.

3.2 Research framework
The framework developed for this study was based on the Soft Systems Methodology (SSM). SSM is a strand of systems thinking developed by Peter Checkland in the 1970's from an action research programme. SSM emerged from the recognition of the lack of methodology to tackle unstructured problems, which are manifest in a feeling of unease but which cannot be explicitly stated without this appearing to oversimplify the situation (Checkland, 1981; Hong-Mihn, 2002).

As reviewed by Hong-Mihn (2002), SSM is defined as a clear process through which accommodation of conflicting viewpoints can be sought and as a process to tackle real world problems in all their richness. SSM allows formal expression of the problem,
which enables lessons to be learned and is a methodology examining problem situations to lead to decisions on action at the level of both “what” and “how”. SSM was used during the research process to define the “what” and “how” of this study.

The SSM method starts with the fact that at least one person regards a situation as problematic. There is a feeling that this situation should be managed in order to bring about improvement. The what and how of the improvement will all need attention, as will consideration of through whose eyes improvement is to be judged (Checkland, 1988).

For this research, the real-world problem situation considered was the poor performance in communications between construction team members in the UK. This leads to the question of what are the problems and issues in current construction design? The next question was then how the problems can be measured through relevant systems? And how do they occur? And why? Finally, the action to improve the situation can be summarised.

Following this logic, a research framework was developed, as shown in Figure 3.1. The framework shows the flow of ideas followed for this study. It can be seen that the research propositions are developed through research questions and a literature review of the relevant theories, concept and research on communication. In the research design, two research methods, questionnaire survey and case study, are chosen. A questionnaire survey was initially conducted to investigate communication issues and problems in current construction design. Based on the results of the survey, case studies were employed to explore communication issues and problems further so as to answer the research questions and understand how these issues and problems affect the communication effectiveness in construction design, how they are caused and why. For the case studies (also see 3.3.2 and Chapter Five), three cases were chosen, the case study protocol was designed, the methods of data collection and data analysis were selected, and a cross-case analysis was made. By a combination of the results of the case studies and the questionnaire, a communication model was developed.
General literature review
Communication theories and concept
........................
Communication processes in construction design

Research questions
What are the communication issues and problems in current construction design?
How do they occur and why?

Special review
The research on communication effectiveness in the relevant areas

Research propositions
The research questions are investigated from three aspects: Information flow; Communication variables; and Communication network

Research design
Research framework and methodology

Case study approach
Multiple case study: three cases are chosen in the study
Case study Protocol
Protocol to standardise case methods. Increase reliability
Data collection
Multiple sources of evidence are used: questionnaire, interview, observation and documentation
Data analysis
Pattern matching: COMPASS...
Explain-building: Content analysis...
Cross-case analysis
The replication logic is used in the three case studies

Questionnaire survey approach
Data collection
80 organisations are investigated
Data analysis
Analysis tool: Spss 8.0, Excel, and content analysis
Analyses results

Communication model

Fig. 3.1 Research framework

38
3.3 Research methodology

Robson (1993) suggested that research design in social sciences should typically consist of choosing one of three methodologies; a survey, experiment or case study. Through the literature review, Wallace (1987) concluded that there are four main methodological approaches to investigate team interaction: experimental direct observation and naturalistic direct observation; research interview; research questionnaire; and documentary evidence. The two classification are very similar, as a case study already includes direct observation, interview and documentary (Yin, 1994). For the present research, both questionnaire survey and case studies are chosen.

The use of experiments is rejected for use in this research. This is because experiments are usually undertaken to measure the effects of manipulating one variable on another variable and to find causal relationships between variables (Roson, 1993). For team communications, Wallace (1987) suggested that experiments involve the transfer of the group to a laboratory setting where the interaction can be monitored under stringently controlled conditions. It is rejected for use because of the following reasons:

- The procedure is expensive and impractical, because participants, who are involved in the design communication process, are in different organisations and usually not in the same place.
- Research reactance is necessarily high. An architect will behave differently in a sterilised laboratory where he or she is under intense scrutiny compared to the more “normal” behaviour exhibited in the known design team environment (Green and Taber, 1980).

3.3.1 Questionnaire Survey

A questionnaire survey can provide a common behaviour of phenomenon through statistical analysis, even if it may not effectively uncover the nature of the research. A picture of current status can be drawn from a questionnaire survey to confirm the findings from the literature review, either in terms of frequency or prevalence of particular attributes and variables, or the relationship between them (Oppenheim, 1992).
A questionnaire survey was chosen initially for this research so as to acquire more specific information about communication issues in current construction design and to examine the communication variables and problems that have been highlighted in Chapter Two.

3.3.1.1 Data Collection

A number of organisations involved in construction design were identified from New Civil Engineer (1999) and Consultants File (1998). In order to study communications in multi-team construction design, the survey targeted these organisations: main-contractors, sub-contractors, client's representative and design companies. 100 copies of the questionnaire survey were distributed in 48 organisations to staff who are frequently involved in internal or external communication in the design process. 50 responses were received. The questionnaire was established using the procedures recommended by Hoinville, et al (1977), Fowler (1993), and Prescott (1993). The considerations were the type of data collection instruments, the method of approach of respondents, the build-up of question sequences, and the order of questions (Oppenheim, 1992). These recommendations include:

- the questionnaire must be clear, unambiguous and easy to answer;
- the questionnaire should be attractively spaced and uncluttered;
- the questionnaire should use short sentences and be brief;
- the questionnaire should be written in simple language;
- the questions should be ranked in order of importance;
- biased terms should be avoided in order to get a real view from the respondents;
- the questionnaire must be designed to enable easy analysis; and
- the questionnaire should be self-explanatory.

The questionnaire survey was structured around a discussion of questions. The questionnaire was divided into two sections. Section A was designed to obtain general information about the respondents and their company and Section B to acquire more
specific information about communication issues in construction design, and to examine the communication effectiveness variables and problems that have been highlighted from the literature review.

The types of questions used in this survey were:

1. Open question (those for which enough space is provided for the respondents to write the replies); and

2. Closed questions (those for which a list of acceptable answers is provided to the respondents, normally by ticking one box or more). In some questions, a space was provided as an option for the respondents.

A copy of the questionnaire is given in Appendix C.

Before the questionnaire was sent out for the industry wide survey, it was carefully piloted, first with other academics in the department, and then with experts in different organisations. Their response, opinion, advice and comments about the questionnaire were taken into account and final design of the questionnaire was altered after consideration of the criticism of the earlier design.

3.3.1.2 Data Analysis

The results of questionnaire survey were analyzed using a combination of techniques based on the type of data. For quantitative data, patterns were sought from the responses using simple graphical techniques and frequency distributions. In the case of dichotomous variable, cross-tabulation or contingency tables were used. Computer assisted packages, for example, SPSS (Statistical Packages for Social Scientists) version 8.0 and Excel were used. SPSS was used for statistical analysis, such as frequency distribution and ranking. Excel was used to present the results of the analyses. Open-ended questions were analyzed using pattern-matching techniques, dependent on the volume and variety of responses.

The results and discussion of the questionnaire survey is presented in Chapter Four.
3.3.2 Case Study

From the questionnaire survey the communication effectiveness variables and problems that have been highlighted from the literature review, were investigated in current construction design. A picture of current status can be drawn from the questionnaire survey. In order to understand how these variables and problems affect the communication effectiveness in construction design, how they are caused and why, case studies are employed. The use of case studies as a research strategy is well suited for the research question being addressed. Case studies are best suited for answering 'how' and 'why' questions behind decisions (Yin, 1994). Case studies are often useful for providing an understanding of organization functioning, which are not well researched or documented and which would not yield meaningful results if investigated by means of a minimal contact strategy such as questionnaires (Bryman, 1989).

3.3.2.1 Case study approach

Yin (1994) and Bryman (1989) described several advantages for the case study approach. Case studies can aid understanding of complex social phenomena, and are useful for building theoretical and insights. As reviewed above, communication processes in construction design is very complex, involving many participants from different disciplines, organisations and cultures for a relatively short period to exchange a large volume of information. For these complex phenomena, only a case study methodology can act as the process of exploration, letting the researchers share their insights into the communication processes among these participants.

Case studies are also useful for studying phenomena that are experiencing rapid change (Mead, 1999). According to Yin (1994), case studies investigates contemporary phenomena within a real-life context. The construction industry has undergone a substantial change and construction design has become an increasing complex activity. Communications have also changed, especially in the application of the computing and information technology. A case study's flexibility allows issues to be explored as they develop in the data collection phase (Simister, 1995). Lincoln and Guba (1985) suggested
that this type of inquiry could allow the research findings to be intrinsically linked to the data. With the rapidly changing and dynamic nature of communication, case studies can give the researcher a flexible method of collecting and exploring the data (Mead, 1999).

Yin (1981) argues that case studies can be of three types: exploratory, descriptive or explanatory. The objective of explanatory case studies is to pose competing explanations for the same set of events and to indicate how such explanations may apply to other situations. Descriptive case studies aim to describe a certain phenomenon. The exploratory case studies set out to explore a certain phenomenon. What is important is the type of research question it answers, i.e. “what”, “who”, “where”, “how”, and “why”. The case studies utilised in this work can be defined as mainly exploratory as they aim at answering the question “how do the communication problems and issues in current construction design occur and why?”.

In case studies, communication auditing can also be applied. According to Booth (1988), communication auditing is defined as the process whereby the communications within an organisation are analysed by an internal or external consultant with a view to increasing organisation efficiency. He suggested that communication auditing could be carried out in the following way:

- Determine the amount of information underload or overload associated with the major topics, sources and channels of communication.
- Evaluate the quality of information communicated from and/ or to these sources.
- Assess the quality of communication relationships, specifically measuring the extent of interpersonal trust, supportiveness, sociability and overall job satisfaction.
- Identify the operational communications networks.
- Determine potential bottlenecks and gatekeepers of information.
- Describe individual, group and organisational patterns of actual communication behaviours related to sources, channels, topics, length and quality of interactions
- Provide general recommendations, derived from the audit.
3.3.2.2 The quality of case study research design

There are some concerns as to the quality of research design in case studies. Four tests have commonly been used to establish the quality of empirical social research, namely construct validity, internal validity, external validity, and reliability (Yin, 1994).

According to Kidder & Judd (1986), construct validity refers to the establishment of appropriate operational measures for the concepts being measured. Internal validity is enhanced where the observed and measured effect is due to identified causal relationship. External validity concerns the establishment of the domain to which a study’s findings can be generalised. Reliability demonstrates that the operations of a study, such as the data collection procedures, can be repeated with the same results.

Yin (1994) suggests the following methods for addressing these tests (Table 3.1)

<table>
<thead>
<tr>
<th>Tests</th>
<th>Case study tactic</th>
<th>Phase of research in which tactic occurs</th>
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<tr>
<td>Construct validity</td>
<td>- use multiple source of evidence</td>
<td>Data collection</td>
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<td>- establish chain of evidence</td>
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<td>- have key informants review draft case study report</td>
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<td>Internal validity</td>
<td>- do pattern-matching</td>
<td>Data analysis</td>
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<td>- do explanation-building</td>
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<td>- do time-series analysis</td>
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<tr>
<td>External validity</td>
<td>- use replication logic in multiple-case studies</td>
<td>Research design</td>
</tr>
<tr>
<td>Reliability</td>
<td>- use case study protocol</td>
<td>Data collection</td>
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<td></td>
<td>- develop case study data base</td>
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Table 3.1 Case Study Tactics for Four Design Tests

In order to enhance the quality, these tactics have been considered during the case study, as described in Chapter Five. As seen in Chapter Five, multiple sources of evidence are used in the data collection: questionnaire survey, interviews, direct observation and documentary evidence. This forms a research triangulation. With triangulation, the potential problems of construct validity can be found, as the multiple sources of evidence...
essentially provide multiple measures of the same phenomenon (Yin, 1994). To increase the reliability, firstly, the case study protocol is developed, which guides the research by providing the data collection procedures and instruments and general rules. Secondly a case study database is created. The data from the questionnaire survey are put in the computerised file, which is then analysed using the special tool, like COMPASS, UCINET IV and Krackplot. The data from interviews are recorded and transcribed as the evidence present in the case study report. In this research design, three cases have been chosen to meet the test of external validity. Bryman (1989) describes the advantages of multiple case studies as, enhancing the generalisation of the research and allowing special features of the cases to be identified through comparisons. According to Yin (1994), when two or more cases support the same theory, then replication may be claimed. Once such replication has been made, the results might be accepted for a much larger number of similar neighbourhoods. During data analysis of the communication variables and information flow variables in this research, two benchmarks, COMPASS and benchmarks for information flow variables (ITCHECK), have been used for the pattern-matching. One benchmark is developed from CII, and the other is developed from the survey of this research. Comparing the benchmark to the data collected from two surveys for each case, the communication issues and problems have been identified. Such pattern-matching, according to Yin (1994), can strengthen its internal validity in a case study. Due to time and resource limitations, it is difficult to carry out time series analysis in this research. However, two cross-section studies applied to each case could, to a certain extent, give credit to internal validity and make the results stand robustly. Moreover, there are some other tactics to enhance the quality of this research, described in Chapter Five.

3.3.2.3 Data Analysis

Yin (1989) suggests that case study research is often stymied by a lack of analytical rigor. Without a well designed analysis strategy, a researcher can often be overwhelmed by large quantities of data that are collected during the case study process. As such, it is important to choose a correct technique to analyze the data.

The techniques are highly dependent on the type of data obtained. For the quantitative
data, the following techniques will be used:

For general quantitative data:
- Frequency (software SPSS 8.0),
- Cross-tabulation (SPSS 8.0), and
- Qualitative content analysis

For qualitative data:
- Matrix techniques to represent masses of qualitative data by coding and quantifying (Simister, 1994),
- Charts of procurement structures,
- Charts of communications between team members,
- Cross sectional observation (Yin, 1994),
- Pattern-matching (COMPASS and information flow benchmark),
- Social network analysis (UCINET IV and Krackplot),
- Analyzing units (Yin, 1994), and
- Qualitative content analysis.

Chapter Five presents the case study methodology including the data collection and analysis in detail.

3.4 Summary
This chapter provides a description of the research design used for this study in two aspects: research framework and research methodology. The research framework has been presented, which is based on a SSM approach. The research methodology introduces the multiple methods proposed for this study: questionnaire survey and case studies. The data collection and analysis for the questionnaire survey has also been described. In addition, how to enhance the quality of case study research has been addressed, and data analysis for the case study has been outlined. Chapter Four and Chapter Five will show the two methods applied to this study in detail.
Chapter Four
Questionnaire survey

4.1 Introduction
This chapter reports a questionnaire survey conducted to ascertain the current status of communication issues in construction design. The survey is structured around a discussion questionnaire. The purpose of the questionnaires is to acquire specific information about communication issues in current construction design and to confirm the communication effectiveness variables and problems, highlighted from a literature review. The results of the questionnaire survey are used as the basis for case studies.

In Chapter Three, data collection and analysis have been described. This Chapter will present the results and discussion of the questionnaire survey.
4.2. Results and Discussion

Section A: General information

A1 What is the name of your firm/organisation?

The reason for this question was to establish the names of companies responding to the survey for any further contacts.

A.2 Which of the following describes your organisation most appropriately?

This is for identifying which type of organisation the respondents are from. The nature of their business might affect their responses.

The survey revealed that 48% of the organisations were from main contractors, 52% from design organisations as represented in Fig. A.2.

![Types of Organisation](image)

**Fig. A.2 Types of Organisation**

A.3 What is the turnover per annum of your organisation? (in £ millions)

The purpose of this question was to measure the size of the organisation by their annual turnover. This would help to determine the range of size of companies responding.

The companies were divided into three groups: small, medium and large. Companies with annual turnover up to £20 million were considered as small; Companies with annual turnover between 20 to 50 million were considered as medium and finally, companies with annual turnover more than £50 million were considered as large.
The survey results point out that the highest responses (68%) were received from large organizations and 18% from small organizations (Fig. A.3). The survey covered different sizes of the companies.

![Fig. A.3 Size of the organisation assessed by annual turnover](image)

**A.4(1) What is your position in your company?**

**A.4(2) What are your main duties and responsibilities?**

These questions were designed to elicit the information about the position, main duties and responsibilities of the respondents. The responses allowed the answer to tell if the questionnaire was sent to the appropriate person in the organisation.

The results show that most of the respondents are design managers, project managers, architects, quantity surveyors, principal engineers, and planners. They are regularly involved in internal and external communications during the construction design.

**A.5 In what kind of construction is your company generally involved?**

The question was design to find out the type of work undertaken by the companies responding.

The survey results show that 50% of the companies who responded undertake civil
and building works; whereas 30% of the respondents performed building works and 18% are involved in civil works, only 2% mentioned utility construction. These findings indicate that the highest responses were received from companies that engage in both civil and building works. These results are illustrated in Fig. A.5.

![Fig. A.5 Type of work undertaken by the responding companies](image)

**Fig. A.5 Type of work undertaken by the responding companies**

**A.6 Under which form of procurement do you usually take on/let work?**

This question was designed to identify the current procurement in use, the information from which will be used for further case studies.

The survey results indicate that the traditional and design and build are used more than others. 38% companies are adopting traditional, 36% design and build, 18% are using management contracting, and 8% are others. Therefore, the traditional, design and build, and management contracts are usually used in this sample of the current construction industry.

![Fig. A.6 Form of the procurement undertaken by the responding companies](image)

**Fig. A.6 Form of the procurement undertaken by the responding companies**
Section B: Design Communication Issues

B.1 From your experience, how important is effective communication during the design/construction process?

This question was designed to inquire the opinion of responses on the importance of the communication in construction design.

The survey results show that 88% of respondent tick critical and 12% tick very important (Fig. B.1), indicating that effective communication is critical for the construction design.

![Graph showing percentages of respondents considering the importance of communication on construction design](image)

*Fig. B.1 Percentages of respondents considering the importance of communication on construction design*

B.2 To what extent does the procurement route affect the communication process?

This question aimed to identify the influence of the procurement route on the communication process.

The survey results show that for internal communication, 52% respondents think that the influence is significant or very significant and 22% somewhat significant while 26% slightly or not significant. For external communication, most respondents (80%) think that the influence is highly significant or significant, and only 8% slightly or not significant as shown Fig. B2. It is obviously that the procurement route affects the communication process, especially external communication.
Fig. B.2 Influence of the procurement route on the communication (%)

B.3 (1) Do you/your company experienced communication problems related to Design during the design/construction process?
(2) How serious were the communication problems?
(3) At which level did these problems usually occur?
(4) At which stage of the design/construction process did most of these problems occur?

The questions were designed to identify the current issues related to communication problems in the design and construction process.

For question B3(1), as shown in Fig. B3(1), 24% respondents always experienced communication problems. 38% usually experienced these problems, 32% sometimes experienced these problems, and only 6% rarely experienced these problems.

Fig. B3(1) Frequency of communication problems experienced by respondents (%).
For Question B3(2), as shown in Fig. B3(2), 46% of the respondents believe that the problems are serious or very serious, 34% somewhat serious, and only about 20% less serious or not serious.

\[\begin{array}{c|c|c|c|c}
\text{Very serious} & \text{Serious} & \text{Somewhat serious} & \text{Not too serious} & \text{Not serious at all} \\
18 & 28 & 34 & 18 & 2
\end{array}\]

**Fig. B3(2) Effect of communication problems on construction design (%).**

For question B3(3), 12% of respondents place that the problems usually occur in internal communication and 38% in external communication, but many respondents (50%) place that the problems occur in both internal and external communication (Fig. B3(3)).

\[\begin{array}{c|c|c|c|c}
\text{Both int and ext} & \text{Ext communication} & \text{Int communication} & \text{Not too serious} & \text{Not serious at all} \\
50 & 38 & 12 & 18 & 2
\end{array}\]

**Fig. B3(3) The level at which the communication problems occur (%).**
For question B3(4), 27% of respondents point out that the problems usually occur in detail design stage, 17% in operations on site and completion stage, and 16% in scheme design stage. A graphical representation of the results is shown in Fig. B.3(4).

![Graph showing stages at which communication problems occur](image)

**Fig. B.3(4) The stages at which the communication problems occur (%).**

The survey results for question B.3 demonstrate that communication problems appear frequently in both internal and external communication in the design/construction process. These communication problems could seriously affect the construction design. The problems occur, more often in detail design, operations on site and completion, and scheme design phases.

**B.4 What are the important variables to a successful communication in construction design?**

This question is to ask respondents to rank the communication effectiveness variables, in terms of importance. The results demonstrate that, as described elsewhere (Thomas et al. 1998), the following variables are important to a successful communication in construction design. They are accuracy, completeness, timeliness, understanding, barriers, and procedures.
B.5 *How frequently do you receive inaccurate information related to design in the design/construction process?*

The survey results reveal that 56% respondents often experienced this problem, 24% sometimes, and 20% rarely or never.

![Bar chart showing the distribution of responses.]

**Fig. B.5 Respondents receiving inaccurate information (%).**

B.6 *How frequently do you receive late information related to design in the design/construction process?*

The survey results indicate that the majority of the respondents (64%) often experienced this problem, 26% sometimes and only 6% did not experience this problem, as shown in Fig.B.6.

![Bar chart showing the distribution of responses.]

**Fig. B.6 Respondents receiving late information (%).**
**B.7 How frequently do you receive incomplete information related to design in the design/construction process?**

The survey results reveal that 54% respondents often experienced this problem, and only 4% did not experience this problem, as shown in Fig. B.7.

![Fig. B.7 Respondents receiving incomplete information (%).](chart)

**B.8(1) Are there communication strategies in the projects where you are involved during the design / construction phase?**

(2) **Do you think whether it is necessary to have communication strategies in the design and construction?**

The survey results point out that 70% respondents have not adopted a formal strategy. 30% have adopted a communication strategy. Most of them think that it is necessary to set up a communication strategy in the design and construction.

**B.9(1) How well do you usually understand the information received from other people?**

(2) **How well do you usually understand the information required by other people?**

This question was designed to investigate the communication problem on understanding. In response to the question, the majority of respondents (74%) understand the information received very well or well. For understanding the information required, the majority of respondents (74%) also know it very well or well (Fig. B9). Therefore, there seems to be not apparent problems in understanding of information.
B.10 How easy do you think it is to communicate with staff internally and externally about design?

These questions were designed to investigate the problem on communication barriers. In response to the question, the majority of respondents (78%) communicate very easily, easily or somewhat easily with internal staff and only 22% not easy. However, 50% of them could not communicate easily with external staff. Therefore, there are no apparent problems in communication barriers with internal staff but there are with external staff.

Fig. B10. Communication barriers (%).
B.11 (1) How frequently do you/your company get more information than is needed?
(2) How frequently do you/your company get less information than is needed?

This question was designed to investigate the problem of information overload or underload. 40% respondents encounter information overload frequently or very frequently, and 42% sometimes. 48% respondents encounter information underload frequently or very frequently, and 44% sometimes (Fig. B11). This indicates that although there are some problems in information overload, information underload is more prevalent in construction design.

![Graph showing information overload and underload percentages](image)

**Fig. B11. The problems of information overload or underload (%)**

B.12 A gatekeeper is an individual so located as to control information flow through a communication channel. How important is this role?

How frequently do the problems in information management occur due to gatekeeping?

The survey results reveal that over half the respondents (52%) believe the role to be critical, 38% very important, and 6% important. This suggests that the problems with the information flow will appear if no one assumes the role of ‘gatekeeper’. 44% respondents believe that the problem in gatekeeping appears very frequently or frequently, 26% sometimes and 30% rarely or not at all, as shown in Fig.B.12.
Fig. B12. The problems due to gatekeeping (%).

**B.13. How frequently do you receive or send changed in meaning or lost in some contents during its dissemination?**

The survey results are shown in Fig. B13. Most of the respondents (94%) gave the answer "sometimes", "rarely" or "never" and only 6% gave the answer "always" or "usually", which indicate that distortion of information is not an apparent communication issue in these companies.

Fig. B13 The problems occurring due to information distortion (%).

**B.14 Do you think what are the reasons for the communication problems mentioned above?**

The survey results demonstrate that the main reasons for the communication problems in construction design are related to lack of co-ordination, conflicting information, poor communication skills, requirement changes, design changes, information
management, different disciplines, technical constraints, inter-personal relationship, information accessibility, etc.

The following questions (B.15(1)-(3)) were designed to find out the current status in applying IT on the construction industry. The analyses of the results are shown below.

**B.15(1) What kind of computing or communication technology (IT) does your company use?**

The results are shown in Fig. B15(1). All the respondents used E-mail, 90% CAD, 84% intranet, 80% document control system, 78% local and wide area networks, 74% cost management system, and 58% videoconference, but only a small number of them use CAE and others. This indicates that the companies investigated have used several forms of IT for their work.

![Fig. B.15(1) Percentages of responding companies using IT](image)

**Fig. B.15(1) Percentages of responding companies using IT**
B.15(2) How much of the design communication uses these technologies (as opposed to traditional one)?

In response to this question, most participants (85%) indicate that they or their companies have used IT over 40% for design communication (Fig. 15.2).

![Fig. 15(2) Percentages of using IT in design communication considered by respondents](image)

B. 15(3) How useful is IT for communications about the design during the construction/design process?

For this question, most answers are useful or very useful, and only a number of the respondents regard IT to be somewhat useful or not too beneficial (Fig. B15(3)).

![Fig.B.15(3) Assessment for the IT considered by respondents.](image)

As shown above, most respondents hold a positive attitude for using IT. Most companies have widely used IT to some degree. Quite a lot of design communication has been done using the IT.
4.3 Summary
This survey was conducted in the UK to investigate the communication issues and problems during construction design. Through this analysis, a picture of communication in the current construction design emerged. The findings may be summarised as follows.

- Effective communication plays a very important role in both design and construction processes. The communication process, especially external communication, is significantly affected by the procurement route. The forms of procurements usually used are traditional, design and build, and management contracting.
- Most respondents experienced communication problems, which appeared frequently in both internal and external communication processes. These problems can have a seriously impact on construction design, and occur more often in the phases of detail design, operations on site and completion, and scheme design.
- The six variables, accuracy, completeness, timeliness, understanding, barriers and procedures, are re-confirmed as contributing effective communications in construction design.
- Inaccurate information, late information, incomplete information and communication barriers with external members are prevalent in construction design. It appears that there are no particular problems in understanding.
- For information flow, except information distortion, there were problems in gatekeeping, information overload, and information underload although they happened to different extents.
- In general, the reasons for the communication problems in construction design are associated with a lack of co-ordination, information management and others.
- IT is extensively used in design communication, and its usage is increasing.

The survey demonstrates that there are a number of common issues and problems in communication between those involved in the design process, some of which remain unsolved. Of particular importance are how the procurement route affect the communication process and what are the causes for the communication problems. In addition, there is the difference of view between the survey respondents and previous studies (Sonnenwald, 1996; Thomas, et al, 1998; Knoop, et al, 1996) in understanding.
the information received or required. These require further exploration using case studies as introduced in the next chapter.
Chapter Five
Case Study Methodology

5.1 Introduction
The questionnaire survey (Chapter Four) has examined the communication issues and problems in current construction design. The survey provides a picture of the communication status, especially in three communication facets (aspects): communication variables, information flow, and IT. The survey demonstrates that there are a number of common issues and problems in communication between those involved in the design process, some of which remain unsolved. As described in chapter three, using the questionnaire survey solely is not suitable to answer the research questions, as the required information cannot be elicited in sufficient depth. Therefore case studies have been employed to explore these issues further. This chapter will present the methods applied to the case studies, which includes the data collection and analysis.

5.2 Choice of Cases
The case study approach to organisational research has varied in acceptance over many years. It is a very powerful research methodology (Simister, 1995). Some doubts and concerns have however been raised as to the generalisability of case study research findings. They have often been branded idiosyncratic as it did not seem to capture the scientific approach with its search for universal laws (Bryman, 1989). Yin (1979) and Mitchell (1983) argue that the aim of case studies is not to infer the findings from a sample to a population, but to engender patterns and linkages of theoretical importance. When two or more cases support the same theory, then replication may be claimed. The use of multiple cases is generally advantageous when compared with a single case study as the results are viewed as more robust (Yin, 1994). Although Bryman (1989) does not fully agree with Yin’s (1994) replication logic approach for the generalization of case study research, he still regards multiple case studies as enhancing the generalization of the research and allowing special features of the cases to be identified more readily through comparisons.
For this research, three cases were chosen. The criteria for the case choice are:

- the design of the construction project is significant and has some complexity;
- the project design is proceeding or just finished;
- it should include several phases of the project design, and reflect a variety of participants and procurement methods;
- apart from the traditional communications, the organisation should also use information technology as the means of communication; and
- the organizations involved in the design are willing to attend and release an amount of documented data.

According to the questionnaire survey (Chapter Four), three procurement methods, traditional, design and build, and management contracting, are mainly used in current construction industry. Consequently, three projects respectively containing these procurement methods have been chosen for case studies in the present research. The three projects mainly covered scheme design, detailed design, and operations on site and completion, which were identified from the questionnaire survey as having the greatest apparent problems in communication.

5.3 Data Collection

5.3.1 Observation period philosophy

Usually the design process takes place over a period of time. The observation and data collection duration is therefore of considerable importance (R.I.B.A, 1974). The methodology literature suggests that group interaction and communication process may be analyzed in two primary ways (Wallace, 1987);

Longitudinally

Observation of the process is from inception to completion on a continuous basis, thereby building up a complete and continuous picture (Derbyshire, 1972).

Cross sectionally
Observation of the process is at isolate moments at different stages, thereby building up a series of “windows” of the current characteristics at those points.

Clearly a longitudinal study provides a greater understanding of the communication issues than a cross sectional study. A longitudinal study, however, necessarily involves a considerable time commitment on the part of the researcher (Wallace, 1987), especially to observe the communication process across multiple design phases, so that the longitudinal study becomes unrealistic due to time and resource limitation. Owing to the fact that, as a PhD research project, the available time and the accessibility to the site are both limited, only cross sectional observation of the process was conducted in the present work.

5.3.2 The approaches of data collection

The case study is an area in which quantitative and qualitative approaches can be combined, which can help the researcher eliminate bias in data collection (Bryman, 1989; Mead, 1999). Creswell (1994) calls this multiple data collection approach “Research Triangulation”. The employment of triangulated studies have the two-fold effect of reducing the disadvantages of any single technique, while simultaneously gaining the advantages of each, or of the combination (Fellows and Lui, 1997). Multiple collection approach have been used in these case studies.

The main methods for data collection in the case studies are as follows:

**Questionnaire survey**

A questionnaire survey was employed in the case study to discover the communication issues and problems in the project. The survey included communication variables, information flow, and project communication network. Two questionnaire surveys have been conducted in each project at two different stages. Further exploration was conducted through interviews, observation, and document analysis on the basis of the questionnaire survey results.
Interview

Interviewing involves asking the subject questions. The type of question can vary to a considerable extent, together with the way in which it is presented, received and interpreted by the researcher. Interviews allows the participant freedom of expression, producing essential data (Simister, 1995).

For this research, two sets of interviews for each case have been used to explore further the communication issues and problems, which have been found out during the questionnaire survey. According to Fellows and Liu (1997), interviews are very powerful sources of data. Through them, the questions asked can aid exploration, discovery and confirmation.

Direct observation and Documentary evidence

Direct observation involves the researcher observing or recording the proceedings of people interacting in their natural environment (Nagao and Hinsz, 1980). It contains as little interpretation as possible and is as reliable as the observer can construct it (Fellows and Liu, 1997). It is this natural interaction environment that minimizes the problem of researcher reactance, which necessarily occurs in a fabricated or “artificial” laboratory experimental environment (Green and Taber, 1980).

Some of the techniques, which are widely used in communication auditing in the UK (Booth, 1988), belong to this approach: attending group discussions, communication diaries, and telephone call logging/monitoring. Moreover, the multi-team nature of the construction design relates well to an approach based on naturalistic direct observation in that the combination of a range of individual specialists is more validly analyzed from the viewpoint of non-reactive group observation than from that of a combined individual analysis (Wallace, 1987).

This approach has an established application to the research in design communication, such as Walz (1988), Olson et al (1992), Minneman (1991), Sonnenwald (1996), and Cross and Cross (1995). Some standardised and established observation, coding and
processing methodologies are available for this approach and have been appraised (Murray, 1954).

The use of document evidence is often an integral element in qualitative research. This approach can provide information on issues that cannot be readily addressed through other methods. They can check the validity of information deriving from other methods, they can fill any “gap” in data not readily discernible from other methods (Bryman, 1989). Sonnenwald (1996) used several documents to get the design situation history and information about events during the design process, technical and organisational tasks, characteristics of the organisational setting, interaction among participants and participants’ perspectives, and interpretations of these events, tasks, organisational culture and interaction. This information is very useful for research on design communication.

5.4 Unit Analysis
A case study has many potential units of analysis. The unit of analysis should be related to the way that the initial questions and propositions have been defined (Simister, 1995). According to McClintock et al (1979), the units of analysis are defined as individuals, groups or organisations, or they could be any activity, process, feature or dimension of organisation behavior. Yin (1994) argues that the units of analysis to be used during the research are one of the major problems in designing a case study.

Each case is a single construction project in this research. To find out what are the communication issues and problems in each project, three sets of units were employed. They are the communication variables, the information flow, and the project social network.

Communication variables
Communication effectiveness can be measured by analyzing communication variables that include accuracy, timeliness, completeness, understanding, barriers and procedures
during the design and construction process. These variables (units) were collected from each case and analyzed to assess the quality of communication for the project.

**Information flow**

Information flow can be measured by analyzing information flow variables that include distortion, gatekeeping, overload, underload during the design and construction process. These variables (units) were collected from each case and analyzed to show the performance of the information flow for the project.

**Social network**

Each project had its own communication network. This network includes participant roles and centrality. The analysis of the roles and centrality (units) were used to develop models that describe the network for each case in terms of the quantity of the communication.

**5.5 Linking the Data to the Research**

From the literature review and the questionnaire survey (Chapter Four) in current construction design, it has been found that communication variables, information flow variables, and patterns of the communication network affect the project communication effectiveness in terms of the quality and quantity of the communication during the design and construction process. Therefore, through analyzing and measuring these units, the communication issues and problems, which affected the communication effectiveness, were investigated for each project.

As shown in Fig. 5.1, these three sets of units provided a triangulated framework to answer the research questions. They provide an overlapping analysis of the communication issues and problems for each project. Once these units had been analysed, further research was conducted to obtain insights into the specific problems identified.
5.6 Data Measuring and Analysis

Yin (1989) stated that case study research was often stymied by a lack of analytical rigor. Without a well defined analysis strategy, a researcher can often be overwhelmed by large quantities of data that are collected during the case study. As such, it is important to choose a correct technique to analyze the data. For case study analysis one of the best analysis strategies is pattern matching, i.e. comparing an empirically based pattern with an existing one. In an explanatory study, pattern matching can be tied to the study’s unit’s of analysis to help support or refute the research (Yin, 1989). The previous sections have outlined three units of analysis: project communication variables, information flow, and social network, to measure communication effectiveness. This section summarises the data analysis, including a statistical survey of communication variables based on COMPASS developed by the Construction Industry Institute, a statistical survey of project information flow, and an analysis of the project social network.
5.6.1 Measuring and analysing communication effectiveness

The Construction Industry Institute (CII) in the USA identified six categories of communication as measures of the project communication effectiveness. The remit for the CII research team was to develop a tool for measuring communication effectiveness, which resulted in a questionnaire requiring participants to supply their perceptions of communication effectiveness. The study incorporated 72 projects as a sample to establish a direct link between communication effectiveness and project success. Statistical analysis of the data revealed the six critical communication effectiveness variables (accuracy, timeliness, procedures, understanding, barriers, and completeness). The variables were then used to develop an assessment tool “COMPASS” for measuring team communications. COMPASS can be used in IBM-compatible personal computers. Computer automation increases the tool’s usability by efficiently collecting and analyzing data and reporting the assessment results.

The COMPASS software itself analyses the responses to a series of questions in several ways. Firstly, pre-designed questions are ‘flagged’ as pertinent to specific critical communication variables. The responses to these questions are then scored and these scores are normalised to fit a 0 to 10 scale. The maximum and minimum values indicated the largest and smallest scores for the component questions respectively. These normalised scores are averaged across the complete sample under investigation. Each of these averaged scores is then weighted to reflect the relative importance of the communication variable. It is these normalised and weighted scores which are then used to compare against expected scores from the 72 CII projects that make up the original CII survey sample. Therefore the given CII average score within a communication variables category can be used as a simple benchmark figure for comparison. This evaluation feature enables users to monitor and compare their communication scores with the established benchmark. Very simply, a higher score in a category than the CII average indicates a better performance and a lower score than the CII figure indicates a poorer performance.
Although the communication variables were identified from USA projects, the projects were worldwide. The general questionnaire survey (Chapter Four) indicated that these variables are also critical in the UK construction industry. In addition, the research by Murray et al (2000) has used COMPASS for measuring the performance of communications for nine case studies in the UK. They found that the COMPASS questionnaire and its accompanying software were very useful in exploring the nature and quality of the communications within the project team. In this study, COMPASS was used to identify the performance of the communication in terms of the six variables.

5.6.2 Measuring and analyzing information flow

Guevara and Boyer (1981) investigated the causes of poor communication in nine unionised construction companies. Their research highlighted four communication problems – overload, underload, gatekeeping, and distortion. The research identified these as prevalent problems in the construction industry. They thought that these variables in information flow contributed considerably to effective communication in the construction industry. Mead (1999) also suggested that these variables should be included in the research into communication in the construction industry. As shown in the questionnaire survey (Chapter Four), except for distortion, the three other problems still exist in the construction industry. To measure communication effectiveness in information flow, it is necessary to create a benchmark for each information flow variable. This benchmark can then be compared with each individual project so as to evaluate its communication effectiveness in respect of information flow. From the data obtained in the questionnaire survey, a statistical analysis has been performed to provide an average mark for each of the variables (overload, underload, gatekeeping, and distortion).

The fifty responses from different design and construction companies were statistically analysed with the use of Excel and a mean score for each information flow variable (overload, underload, gatekeeping, or distortion) was acquired. In the analysis of the variables, the ‘very frequently’ is marked 4 points, ‘Frequently’ 3 points, ‘Sometimes’ 2 points, ‘Rarely’ 1 point, and ‘Not at all’ 0 point. Based on these definitions, the mean
scores for information overload, underload, gatekeeping, and distortion were obtained as 2.5, 2.7, 2.2, and 0.5, respectively. These mean scores were assumed to provide an indication of the current situation in construction design and were taken as the benchmarks in the subsequent case studies. According to Babbie (1990), an average has the advantages of reducing raw data to the most manageable form: a single number that can represent all the detailed data collected.

Once the benchmarks of the information flow were established, new data were collected from each case study for comparison. If the mean score of new data for a variable, e.g. information overload, was higher than the corresponding benchmark, there would be more problems than the industry average for this aspect; and if the mean score were lower than the corresponding benchmark, there would be fewer problems.

5.6.3 Measuring and analysing communication networks
To determine the quantity of the communication, and who is the “communication star”, who is the “isolator” in the project network social network analysis was undertaken.

Social network analysis focuses on the communication patterns that develop between participants and organisations. The use of social network has developed rapidly over the last twenty years, and is widely used in sociology and the communication sciences. A social communication network can provide high level descriptions through an analysis of relational data. These descriptions can be used to identify various kinds of patterns or to test hypotheses about those patterns in a set of relationships. These patterns are based upon the way that individuals or objects interrelate in a network (Rice and Richards, 1985). More specifically, whole network analysis is used to describe network relations, identify prominent patterns, trace information flow, and measure the strength of network ties in complex organizational networks (Garton, et al., 1997).

Several computer programs have been designed to analyze the structure of social networks, including UCINET IV and Krackplot. The programs are used to define clusters of nodes that have more contact with one another than with the nodes in other clusters.
(Farace & Mabee, 1980). These graph-theoretic programs separate data into a matrix, where the columns and rows identify the units of analysis. UNCINET IV provides organised summaries and analyses of each individual in the network and a geometric description of the strength of each linkage. In this way, communication roles and positions, such as linker, liaison, isolate, and star, can be identified from an analysis of the matrix data.

In UCINET IV, the centrality analysis can show the degree of communication centrality between members of the project team. During the network data collection phase, each participant was asked to complete a matrix. The columns and rows represented each of the respondents, and each relation is represented by one matrix. The strength of each relationship was quantified by assigning values to different variables. The matrix, as shown in Table 5.1, is an example showing how frequently each member of the project team communicates with other members of the team. In turn the data was input into the social network program (UCINET IV) to obtain the “centrality” of the project individuals. The centrality analysis shows where the frequent interaction is in the network. An actor with a large degree of centrality is in directly contact with or adjacent to many other actors in the network. This actor should be recognized by others as a major channel of relational information (Wasserman and Faust, 1994).

Table 5.1 Communication Frequency Matrix

<table>
<thead>
<tr>
<th>Communication Frequency</th>
<th>Arch</th>
<th>QS</th>
<th>Structure Engineer</th>
<th>Service Engineer</th>
<th>Client</th>
<th>Contractor</th>
<th>Sub Contractor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architect</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>QS</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Structure Engineer</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Service Engineer</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Client</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Contractor</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Sub-contractor</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Totals</td>
<td>21</td>
<td>13</td>
<td>18</td>
<td>15</td>
<td>12</td>
<td>18</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Note: The number indicates the frequency of communication. 5 means communicate several times a day, 4 once a day, 3 several times each week, 2 once a week, and 1 once two weeks.
Krackplot provides a visual representation of network actors by establishing coordinates through multidimensional scaling. Multidimensional scaling (MDS) is a very general data analysis technique that has been used widely in communications research (Wasserman & Fayst, 1994). With MDS, actors that communicate frequently to each other are closer together on the graph. Conversely, actors that communicate infrequently are separated by larger spaces. These visual representations help identify the structure of the network by showing the centrality of each participant and the strength of their communication with others. Sub-groups within the network can also be identified and tracked. Krackplot uses MDS routines to transform valued matrixes into useful graphic descriptions of a network known as a sociogram. Fig. 5.2 is an example of a krackplot graph that shows work interaction between members of an organization (Garton et al, 1997).

![Interaction Graph](image)

**Fig. 5.2 Interaction graph (Garton et al.).**

This sociogram provides the snapshots of organizational interaction structures which can indicate how static or dynamic these structures are over time (Garton et al, 1997). This
graphic model shows the roles of participants in the project, how closely they are linked to other participants, how they interact and communicate each other intensively and frequently. Through the constructed model, the researcher can identify linkages between participants and determine the strength of their relationship and understand who are in the centre of the project communication systems.

In the present study, UCINET IV and Krackplot have been used to analyse the social network and to highlight communication role, centrality and linkage for each case study.

5.6.4 Analysis of interview content
Based on the questionnaire, Compass analysis, and data matrix survey, the quality and quantity of communication and information flow at different stages for each project was examined. To further explore these communication issues, interviews were conducted with the members of each project, who were frequently involved in internal or external communication during the project process.

The interviews were tape recorded and later transcribed. The transcriptions were then analyzed by a technique called “content analysis”. In its simplest format content analysis is the extraction and categorisation of information from text (Simister, 1995). According to the review of Simister (1995), content analysis is concerned with extracting inferences from text, placing sections of text with similar meaning into discrete categories. The analysis of these categories will then give some indication concerning what inferences may be drawn from the text, i.e. what text means.

The data from the transcriptions were coded and placed into seven sub-categories with similar meaning. In order to make these more manageable the sub-categories were further rationalized looking for links so that they were grouped under headings that formed three core categories. These core categories and sub-categories are as listed below:

1. Project management
   - Procurement Method
   - Communication system
2. Project support environment

- Information
- Quality and quantity of resource (personnel)

3. Project co-ordination

- Social co-ordination
- Technical co-ordination
- Key personnel

5.7 Case study protocol

Yin (1994) suggests that a case study protocol is a major tactic for increasing the reliability of case study research and is intended to guide the investigator in carrying out the case study. According to Robson (1993), one of the problems with case study research is its inherent "looseness". One way to combat this looseness is to establish a protocol.

A protocol should provide an overview of the project, the definitive data collection procedures, and the instruments that will be used for data collection. It builds a framework for collecting and analyzing the data (Mead, 1999). A protocol developed for this research is outlined in the following steps.

Step One: Identifying suitable design project

The first step of the research process was identifying suitable projects that could be used for the development of individual case studies. Personal requests, and letters of inquiries were sent to project managers. The letter outlined the scope of the research and the data collection methods. The criteria for the case choice was as follows:

- the design of the construction project is significant and has some complexity;
- the project design is proceeding or just finished;
- it should include several phases of the project design, and reflect a variety of participants and procurement methods;
- apart from the traditional and electronic communications, the organisation should also use information technology as the means of communication; and
the organizations involved in the design are willing to participate and release an amount of documented data.

Step Two: Identifying the communication stars
Once a suitable project was chosen, the communication stars were identified. These personnel were involved in internal and external communications in the project. They mainly consist of lead consultants, client, contractor and principal subcontractors.

Step Three: First questionnaire survey
Copies of three questionnaires were sent to the communication stars. They were a communication pattern questionnaire (Appendix D), a COMPASS questionnaire and an information flow questionnaire (Appendix E). The COMPASS survey was about six communication variables including timeliness, accuracy, procedures, barriers, understanding, and completeness. The communication pattern survey used a matrix to ask who they communicated with and how often they communicated with. The information flow survey was concerning four information flow variables, underload, overload, gatekeeping, and distortion.

Step Four: Analysis of the collected data
The data collected from the COMPASS survey were analysed using the COMPASS communication assessment tool. The scores for the six variables (timeliness, accuracy, procedures, barriers, understanding, and completeness) were obtained from the communication variables' survey (Appendix E) for each project. The data collected from the information flow survey (Appendix E) were used to obtain the scores for the four variables (underload, overload, gatekeeping, and distortion) in each project. The data collected from the communication pattern survey (Appendix D) were input into a network analysis tool (UCINET IV) to determine the communication roles and centrality for each participant. Using a multi-dimensional scaling routine, these were developed into a graphical communication network for each project.

Step Five: First interview
Given the communication issues and problems found from the above surveys, most of the
communication stars were invited for an interview to discuss these issues and problems. Observation and document analysis were also used to aid the exploration. Through these, the communication processes were tracked: who talked to who, what kind of message was transmitted and through what channel. What kind of media, communication technologies, and tools were employed. The aim of these investigations was to find how the communication issues and problems occurred and why.

Step Six: Second survey
A few months later after completing the first survey (questionnaire, interview, etc.), the communication stars were asked to complete a second survey to see if the communication issues and problems changed at a different stage for each project. The method used in this survey was the same as that in the first survey (from steps three to five).

Step Seven: Comparison of the two surveys
The two surveys were undertaken at two different stages for each project, thereby building up different “windows” of the current characteristics of communications. Through comparison of the two surveys, a greater understanding of the communication issues and problems would be obtained.

Step Eight: Cross-case examination and conclusion
Finally, a cross-case examination was carried out. According to Yin (1994), each project consists of a whole study, in which convergent evidence is sought regarding the facts and conclusions for the case. Each case’s conclusions are then considered to be the information needing replication by other cases. When two or more cases support the same theory, then replication may be claimed. Analysing across cases enables conclusion to be drawn, which should indicate the extent of replication and why certain cases are predicted to have certain results, while other cases, if any, are predicted to have contrasting results. Based on the findings of the case studies, a communication model is developed.
Chapter Six
Case Study One: Basingstoke Shopping Centre

6.1. Project Description
The project is in a city centre and is in an area containing a mixture of residential, retail, business and office premises. The project comprises the design and construction of a new shopping centre, which will provide approximately 40,000 m² of new retail space and 8,600 m² of leisure space, including a foodcourt, restaurants and a multi-screen cinema. Associated works comprise drainage, incoming services, services diversions, service yards, external works and a bus station. The project also involves works to the existing shopping centre including alterations to enable linkages between new and existing centres. The estimated cost for the project was approximately £100 m. Preliminary design and scheduling started in 1994, and the detail design started in June 1999. All design work was completed on a "fast track" basis, where construction takes place in advance of the completed design documents. This project is due to be completed by October 2002.

One of objectives for this project was to create a 21st century landmark shopping centre, both imaginative and innovative, and adaptable for future requirements. In the view of the client, the most important objective is to complete the project and open for Christmas trading 2002. "That is busy time in a year. If we miss that, the next is Easter, but is not popular as Christmas. There is no point to open the new shopping centre in Jan and Feb, no one has any money left".

6.2 Project Contract Form
In July 1994 the Latham Report (Latham, 1994) challenged the construction industry to establish a more stable basis for cost reductions and to highlight the need for all construction parties to work more closely together as partners in order to be more effective. In response, Partnering has been suggested as a better procurement method for the construction industry. Partnering is a management approach used by two or more organisations to achieve specific business objectives by maximising the effectiveness of each participants' resources. The approach is based on mutual
objectives, an agreed method of problem resolution and an active search for continuous measurable improvement (Bennett and Jayes, 1995).

To avoid the adversarial relationships caused by competitive tendering and to harness the cost and time advantaged gained by close collaboration, the client chose a main contractor at a very early stage in the design process. Having a proven track record in successful partnering relationship in the previous project, the client and the main-contractor agreed to continue to develop partnering in the current project. Four sub-contractors joined the partnering agreement. The sub-contractors entered into a partnering agreement and a target cost plan was agreed against the sub-contractor's scope of works. In such cases gains and losses will be shared between the client, main contractor and the sub-contractor on an agreed individual basis.

From the beginning of the project, the client appointed the consultants from a select list to develop the design concept and detail design. The architects as design team leader are responsible for the overall administration of design process, especially to co-ordinate the structure engineers and service engineers to develop drawings and specifications for the project. The team was bound contractually to the client, but the partnering agreement also calls for them to work close to the contractor.

This project was constructed under a management contracting procurement method (Fig. 6.1). The main contractor was appointed initially as Construction Manager and become an integral member of the project team to provide pre-construction services. On this basis the main contractor was invited to attend design team meetings and to provide early planning and programming advice. It was agreed to procure the services of the main-contractor to join the design team and assist in the development of the design process, including procurement of sub-contractors. The procurement then proceeded on the basis of a two stage tender process leading to a Fixed Price Lump Sum. Like most of today's general contractors, the contractor used subcontractors to complete a large part of the work associated with the project. The main contractor has contractual links with the client, whilst each of the trade contractors is contractually linked to the main contractor.
6.3 Project Team

This is a large project involving a lot of participants and organisations. The Client is an international property investment, development and fund management group. They are active in Europe, North America, Australia, and Asia Pacific. Once this shopping centre is completed, the client will use it to attract other shopping centre projects in big cities. The main contractor is one of the largest commercial contractors in the UK. They have extensive experience in developing shopping centres and have worked with the client previously in many projects. M&E services is a key sub-contract in this project, with the specialist M&E contractor supplying special service design and installation for the shopping centre.

The client chose four consultant companies: architect, structural engineers, service engineers and QS. The architect's practice is small and this is their first large project, but they have a strong track record on architectural design and technical services, and have worked with the client previously on another shopping centre. The structural engineers are from a large company of structural, civil engineering. They have substantial experience of structural design and have worked on a number of large
projects including Heathrow Terminal Three. The service engineers are from one of the largest companies of service designers in UK. The QS firm is one of key members of this project. Like the architects, their company is relatively small, and this is their largest project.

The site is located in Basingstoke. The contractor's management team was resident on site when the detail design and construction was started, although their head office is over a hundred miles always. The M&E sub-contractor was also in the site. During the design stage, the consultants reminded at their own offices. Fig. 6.2 shows the widely dispersed geographical locations of the project team: The structural engineers and client are located in London over a hundred miles away from the site, and the QS and service engineers are located in various cities further away. The architects are located a few miles away from the site. During the construction period, some architects and engineers representatives were based on site.

![Fig. 6.2 Geographic location for main team members in case one](image-url)
6.4 Project Communication System

This is a relatively large project, and hence a lot of communications between team members are required: both formal and informal. Figs. 6.3 and 6.4 show the general structure of the communications between the different organisations at the initial design stage, and at the detail design stage and construction stage.

The widely dispersed geographical locations of the different organisations have prompted communications using a variety of mediums. The team members rely on the telephone very frequently to discuss the problems and the progress of the design. Fax has been used to show the small parts of the drawings which will be or is being discussed, or to confirm issues. Meetings are held regularly. Each organisation was connected to the internet via modem and standard phone line. E-mail was used to disseminate information relating to budget, meeting agendas, daily logs, and submittal logs. Additionally, a web site was used to post digital progress photos of the project. Computer Aided Design software was used in the design-oriented drawings of each design organisations including some sub-contractors. The CAD drawings circulate in the internal organisation through the intranet, and for the external organisation CD’s have been send by post. The client and main-contractor have got videoconferencing facilities in their head office, but they haven’t used these and do not intended to use this facility for this project as most members of the team haven’t had experience of this type of facility.

For internal communication, each organisation normally relies on face to face meetings.

On the contractor’s side of the process, a team from the main contractor manages the information including the coordination of subcontractors, and represents them in negotiatings with consultants. On the consultants’ side of the process, the architects act as administrators. All the information goes to them, and they issue the information to the other consultants. They represented the consultants and co-ordinate the design information including those sub-contractors with design responsibility. They then issue the information to the main-contractor.
Fig. 6.3 Communications in detail design stage (case one)
Fig. 6.4 Communications in detail design and construction stage (case one)
6.5 Presentation of Results

The case study for this project was undertaken from August 2000 to June 2001 during the detail design and construction. Multiple data collection approaches including interviews and questionnaire surveys were applied to the study, as described in the Case study protocol of Chapter Five. There were two rounds of interviews and questionnaire surveys. The people, who were asked attending the surveys, were frequently involved in the design and construction process from all the different organisations: client, owner, architects, structural engineers, service engineers, main-contractor and some sub-contractors. The survey participants are shown in Table 6.1.

6.5.1. Interviews

Two rounds of interview were held. The first was in August 2000 during the project detail design stage with some primary construction. The second was in June 2001 during the construction stage together with some detail design. Eight participants attended the first interview and eleven the second interview.

During the interviews with the project participants a number of communication issues were raised. Most of them noted that the communication structure is very open, and there are few barriers, but there are still many communication problems. The general consensus was that communication was not as good as it should have been. The problems between the different organisations are detailed as follows. Sources for the data quoted in this chapter are shown in Appendix F.

Between client and consultants

The leader architect complained of too many requirement changes from the client. These changes affected their ability to provide the quality of information in a timely manner [F-1] while the client was disappointed with the information provided by the consultants. He thought that the drawings did not work properly and had a lot of coordination problems in construction, which involved a lot of additional cost [F-2].

Between consultants

The lead QS felt that they suffered from inaccurate and incomplete information received. They did not get the whole picture to do the budget [F-3]. The architect got a lot of suffering because other disciplines overturned the original design [F-4].
<table>
<thead>
<tr>
<th>Organisations</th>
<th>Participants</th>
<th>Survey Attendance*</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Client</strong></td>
<td>Associate director (Client)</td>
<td>Interview1; Questionnaire1,2</td>
<td>Strategic project management</td>
</tr>
<tr>
<td></td>
<td>Project Manager</td>
<td>Questionnaire1,2; Interview2</td>
<td>Representing the client managing the project</td>
</tr>
<tr>
<td></td>
<td>Construction Manager</td>
<td>Questionnaire1,2</td>
<td>Monitoring the progress of the project</td>
</tr>
<tr>
<td><strong>Main Contractor</strong></td>
<td>Project Director</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Responsible for all aspects of the project</td>
</tr>
<tr>
<td></td>
<td>Information manager</td>
<td>Questionnaire1,2</td>
<td>Design team performance monitoring, construction information review</td>
</tr>
<tr>
<td></td>
<td>Design co-ordinator2</td>
<td>Questionnaire1,2; Interview2</td>
<td>Liasing with design team to obtain information, approvals and answers</td>
</tr>
<tr>
<td></td>
<td>Project manager</td>
<td>Questionnaire1,2</td>
<td>Managing the construction work</td>
</tr>
<tr>
<td></td>
<td>Design co-ordination</td>
<td>Questionnaire1</td>
<td>Applying the design information in procuring packages</td>
</tr>
<tr>
<td></td>
<td>Computer manager</td>
<td>Interview2</td>
<td>Maintaining the Computer system for the project</td>
</tr>
<tr>
<td></td>
<td>Information administrator</td>
<td>Interview2</td>
<td>Administering the information in, or distributing them to sub-contractors</td>
</tr>
<tr>
<td><strong>Architect</strong></td>
<td>Lead architect</td>
<td>Interview1; Questionnaire1</td>
<td>Responsible for all aspects of the design work</td>
</tr>
<tr>
<td></td>
<td>Architect1</td>
<td>Questionnaire1,2; Interview2</td>
<td>Architectural design; Representative of the architects on site</td>
</tr>
<tr>
<td></td>
<td>Architect2</td>
<td>Questionnaire1</td>
<td>Co-ordinating the overall architectural design</td>
</tr>
<tr>
<td></td>
<td>Architect3</td>
<td>Interview2; Questionnaire2</td>
<td>Representative of the architects on site</td>
</tr>
<tr>
<td></td>
<td>Design Co-ordinator</td>
<td>Questionnaire 2</td>
<td>Co-ordinating with external organisations</td>
</tr>
<tr>
<td><strong>Structure Engineer</strong></td>
<td>Lead Engineer</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Responsible for all aspects of the structural design</td>
</tr>
<tr>
<td></td>
<td>Structure Engineer1</td>
<td>Questionnaire1,2</td>
<td>Design and Co-ordination of structural work</td>
</tr>
<tr>
<td></td>
<td>Structure Engineer2</td>
<td>Questionnaire1,2</td>
<td>Co-ordinating with external organisations</td>
</tr>
<tr>
<td></td>
<td>Information manager</td>
<td>Interview2</td>
<td>Maintaining the Computer system in the organisation</td>
</tr>
<tr>
<td><strong>Service Engineer</strong></td>
<td>Service Engineer1</td>
<td>Interview1; Questionnaire1,2</td>
<td>Responsible for all aspects of the service design</td>
</tr>
<tr>
<td></td>
<td>Service Engineer2</td>
<td>Interview2;</td>
<td>Representative of the service engineers on site</td>
</tr>
<tr>
<td><strong>Quantity Survey</strong></td>
<td>Lead QS</td>
<td>Interview1; Questionnaire1,2</td>
<td>Budgeting and cost control for the project</td>
</tr>
<tr>
<td></td>
<td>QS1</td>
<td>Interview2; Questionnaire1,2</td>
<td>Cost planning, control, reporting and monitoring</td>
</tr>
<tr>
<td></td>
<td>QS2</td>
<td>Questionnaire1,2</td>
<td>Cost reporting and monitoring; Valuation of the works</td>
</tr>
<tr>
<td><strong>Steel Subcontractor</strong></td>
<td>Contract Manager</td>
<td>Interview1; Questionnaire1,2</td>
<td>Ensuring steelwork to comply with the requirements</td>
</tr>
<tr>
<td><strong>M&amp;E Subcontractor</strong></td>
<td>Operations Manager</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Managing the installation and manufacture of M&amp;E equipment</td>
</tr>
</tbody>
</table>

* Number 1 represent the first interview or questionnaire survey, 2 the second interview or questionnaire survey.
The structural engineer often received changed information, making the information issued to construction incorrect [F-5]. The service engineer was concerned that other disciplines ignored their requirements. They did not take into consideration their design. So they had to redesign to fit the structure [F-6].

**Between designers and main constructor or sub-contractors**

The contractor criticised the consultants that the design information was late and was often not of the quality and in sufficient detail to allow the contractor to be able to do their work [F-7]. The sub-contractors wasted a lot of time on the working drawings as the design information had been changed. Even more damage to the sub-contractors from the change was in the process of manufacture and installation [F-8]. The consultants complained of unclear requests from the contractors, which they did not know how to deal with [F-9].

**6.5.2 Questionnaire Survey**

The two questionnaire surveys were carried out during the case study. Twenty-one participants attended the first round questionnaire survey and nineteen the second questionnaire survey, which included the interviewees and others related to the project. The results of these surveys are presented under the three communication aspects: communication variables; information flow; and the Project Network.

**6.5.2.1 Communication variables**

The project communication scores provide an overall view at how the project is performing in terms of team communications on the communication variables: timeliness, accuracy, procedures, barriers, understanding, completeness.

As described in chapter five, using COMPASS, scores for each variable were developed for the project, and these scores were then compared with the benchmark scores that were developed from data collected on 72 CII projects. A low relative score indicates the presence of communication problems which may impact on project success. A summary of the scores developed can be seen in Table 6.2. Individual categories can be seen in Figs. 6.5 and 6.6. The comparison of the two rounds of results can be seen in Table 6.3.
Table 6.2. Total communication scores for case one

<table>
<thead>
<tr>
<th>Project</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>CII Project (Lowest Rated)</td>
<td>51</td>
</tr>
<tr>
<td>CII Project (Benchmark)</td>
<td>75</td>
</tr>
<tr>
<td>CII Project (Highest Rated)</td>
<td>87</td>
</tr>
<tr>
<td>Case One (First Survey)</td>
<td>63</td>
</tr>
<tr>
<td>Case One (Second Survey)</td>
<td>67</td>
</tr>
</tbody>
</table>

It can be seen that the total score was 63 in first round survey, which was lower than the total score of the CII benchmark (75). Except for the barriers, all of the communication variables received a lower score than the benchmark. The aspects of accuracy and completeness only received 3 compared with 5 in the benchmark. This indicated the presence of communication problems in these areas. In the second round survey, the Barriers were the same level. The situation of completeness and procedure were unchanged, the problems maintained the same score as in the first survey. There
was some improvement in the aspect of accuracy from 3 to 4, although the score was

![Communications Score - All Groups](image)

**Fig. 6.6 Communications score in the Second Survey for case one**

still lower than that of the benchmark. There was a big improvement in Timeliness, which reached the benchmark score of 9. The total score for the second round increased from 63 in the first survey to 67, but this figure is still below that of the CII benchmark.

**Table 6.3. Comparing the results of the two surveys in case one**

<table>
<thead>
<tr>
<th>Variables</th>
<th>CII Benchmark</th>
<th>First Survey</th>
<th>Second Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Procedures</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Barriers</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Understanding</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Timeliness</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Completeness</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
6.5.2.2 Information flow

The project scores for the information flow provide an overall view as to how the project is performing in terms of information flow between the team members in the aspects of overload, underload, gatekeeping and distortion (Guevara and Boyer, 1981).

As described in chapter five, using Excel, the scores for information flow in the above four aspects were developed for this project. These scores were then compared with the benchmark scores that were developed from the earlier questionnaire survey in current construction design.

![Graph showing information flow scores](image)

**Fig. 6.7 Information flow score for case one.**

The results of the comparing for the two round survey of the information flow can be seen in Fig. 6.7. A scale of 0 to 4 is used in this figure to represent the frequency of the problems. The larger the figure, the more frequently the problem occurs in that aspect.

The results of the first survey revealed that, except for distortion, the other three received higher score than the benchmark. The scores were 3.5 for Overload, 3.6 for underload, and 3.2 for gatekeeping. This indicates the presence of communication problems in those areas. In the second round survey, the scores for underload and
gatekeeping fell slightly to 3.2 and 2.6. Although there were some improvements in these areas, they were still higher than the benchmark. The score for overload increased to 3.7, which means that this problem is worse than the first survey. There seems to be little communication problems in distortion, the score is 0.3 and 0.4 for the two surveys, which is lower than the benchmark.

6.5.2.3 Project network analysis
Data from the communication patterns survey was gathered and then input into UCINET IV to develop statistical and graphical representations of the project communication network. This analysis consisted of two parts. One was an analysis of the centrality of each actor in the communication network. The results are presented in a graphical form produced by UCINET IV. The centrality is a measure of the importance or prominence of an actor in a social network as described in Chapter 3. The second was an analysis of the actors' linkages and their centrality within a project network. The result was presented in a graphical sociogram produced by UCINET IV in conjunction with a graphical generator called Krackplot.

Communication centrality
Figs. 6.8 and 6.9 show the centrality of the participants in the case study project network. The graphs show the positional strength of each participant by showing the "connectedness" of each person in the project communication network. Participants with a high degree of centrality typically take on a "Communicator star" role in a project network, while participants with a low degree typically assume an "isolate" role.

From Fig. 6.8, it can be seen that in the first survey the information manager, project manager and lead QS occupy the central role in the project communications. These people were well connected to the rest of the project team, and were instrumental in the distribution of information throughout the project network; whereas the lead architect and lead structure engineer have a lower score of centrality.

In the second survey, 4 month later, the picture has changed slightly which is shown in Fig. 6.9. The new design Co1 (Design Co-ordinator) now occupies a central role.
He is only lower than the project manager and has the second highest score of the centrality in the project communications.

**Fig. 6.8 Communication centrality in the first survey for case one**

**Fig. 6.9 Communication centrality in the second survey for case one**

**Network analysis**

A graphical representation of the communication positional role of each actor in the project organisation can be generated by exporting the MDS file, which produced by UCINET IV, to Krackplot. The graphics provide the descriptions of the positional role
of each participant in the project organisation as seen in Figs. 6.10 and 6.11. The two graphs show the geodesic distances between actors on the basis of frequency and intensity of interaction, where actors that are closer together on the graph represent closer communication links. In the graph, the lines represent the linkages between actors, and the length of the vector represents the connections between project participants.

![Communication network sociogram in the first survey for case one](image)

**Fig 6.10 Communication network sociogram in the first survey for case one**

It can be seen from Fig. 6.10 that in the first survey the Project manager, lead QS, information manager, and project manager were the central actors in the communication network, assuming a more important role as the project progressed. Note the positions of the lead architect and the lead structural engineer who were surprisingly not central during the design process.
Fig 6.11 Communication network sociogram in the second survey for case one

In the second round survey 4 month later, the pattern has changed as shown in Fig. 6.11. The design Co-ordinator was the central actor and also close to the design team members in the communication network. He co-ordinated with the design team and linked them to the construction team. Note the positions of design team who move further toward the centre, and the QS who has now moved away from the centre.

6.6. Discussion

6.6.1 Project management

6.6.1.1 Procurement

The project is both complicated and fast-track. The detailed design started in July 1999. At the same time, the contractor started working. The major detailed design should have been completed by Christmas 2000. One of the lead consultants complained [F-10] that they had not got enough time to develop the design and to co-
ordinate the information, before they issued the drawings to the contractor. So this inevitably caused problems. In common with other fast track projects, the project design suffered problems of inaccuracy and incompleteness because it was being resolved while the construction work was in progress. This is shown by the scores of accuracy and completeness in the two surveys (Figs. 6.5 and 6.6), which were much lower than the CII benchmarks. Most interviewees felt that the information they received was not complete and not of good quality.

What happened initially on the project was that the client could not make the decision about whether to go ahead or not. When they finally decided to go ahead, time was very short and the period of design was condensed to 15 months instead of 18 months. All of a sudden, the consultants had to do the design and pick up site issues at the same time. The consultants felt, and the contractor agreed, that it was too tight for the design team to prepare their design. Each discipline worked on the basis of information that was not developed to an appropriate level by others [F-11]. The detail design by the service engineers was based on the sketch design by the architects and structural engineers. So they had to make assumptions to get the work done. "How can people expect us to produce information of a high quality?" said the leader of the service engineers [F-12]. Most of interviewees argued that the client should commit to release the design team to produce the information early and allow for a longer design period. Since the design is an iterative interdependent process, it takes time to develop [F-13].

The major issue of management on this project is how to condense the period of design, how to overlap different phases and to what extent this could be achieved successfully were not addressed fully before the decisions were made. In many cases, construction processes started without the design on which they were based being developed to an adequate stage. Inevitably, late design changes took place. This happened for example in the design of the heating. The steelwork had been erected before three interdependent issues, the size and type of the heating equipment, the service area, and the beam size, were resolved. Accordingly, the steelwork was done improperly and had to be resized after these three issues were sorted out. "We have suffered a lot from this kind of thing", said one of the steel subcontractors [F-14].
There have been many requirement changes in this project, which suggests an inadequate brief and a loss of control by the management [F-15]. This had a very adverse affect on communications. The initial scheme was totally different from the final one, as the project grew. Since December 1999, there have been 481 requirement changes. Most of them had a significant impact on the design process. The whole floor and all the toilets at the centre have been changed. The Cinema has been changed and also the operator. The biggest changes occurred in the car parks and the park and ride system which was completely redesigned. More instructions to change the design were still being submitted although the design and some construction had been completed. The consultants said that these changes affected their ability to provide quality information in a timely manner, and when it passed a certain point, it was very difficult to cope with, especially for a fast track project, which is very sensitive to change.

6.6.1.2 Communication system

From the start the project has used electronic communications. The Intranet, local and wide area networks were used to enable drawings to be shared and edited between different participants. There are Document Control Systems and Cost Management Systems for the project management. People could log on information, such as letters, instruction and special drawings, into the electronic data management system. Everything was done electronically. Also the facilities of Videoconference were available at the client office and the head office of the main-contractor for discussing problems or aiding decision making at a very high level. Every one praised the electronic communication system "The computer is good for handing information, it is quick to change the information between different participants". This system had a positive impact on the timeliness score in the COMPASS analysis, especially when the participants were familiar with the system. It can be seen from the second survey that the score of timeliness is comparable to the benchmark (Fig. 6.6).

However the procedures for the exchange of information had not been defined clearly between interfacing parties. As a result, information underload frequently occurred, as shown in Fig. 6.7. Most interviewees felt that it was very difficult to complete their work with incomplete information. For example, the QS quite often received sketchy
information which was difficult to work with. There was more chance for misunderstanding and misinterpreting on the drawings [F-16]

In contrast to information underload, as shown in Fig. 6.7, information overload was prevalent in the different organisations, causing unnecessary stress and inefficiency. Everyone complained that they often received irrelevant information. The structural engineers received electrical diagrams. The service engineers received structural drawings [F-17], and the steel sub-contractor received all of the architect’s drawings. "These were a complete waste of our time" said the steel sub-contractor. In the sea of mail, useful information was ignored, which caused damages [F-18]. Worryingly, some wrong information went to the project members, which resulted in poor decisions being made [F-19]. Even worse was that some information the lead QS needed was never received.

The scores of procedures in the two round surveys for this project (Figs. 6.5 and 6.6), were lower than the CII benchmark, reflecting such a disorganized situation. One of the reasons for this was that information management was not set up at the start, according to the opinions of the interviewees. They suggested that the procedures should be defined accurately for providing information, and exchanging information between interface parties where they have experienced much confusion [F-20]. A lead consultant admitted, “We should make sure that communications are always undertaken in an efficient way between different organisations. We tried to organise this, but we failed to produce that level of knowledge on this job.”[F-21]

During the design and construction, there were two channels for information flow. The architects were responsible for managing and co-ordinating all the design information, whereas the main contractor was responsible for managing and distributing information to their subcontractors. The first survey indicated that these people were not good gatekeepers (Fig. 6.7). Many participants criticized the architect and the main contractor as they did not appoint suitable people to manage the information. For the architect, there was no senior staff involved. After the client pointed out this problem [F-22], the architects re-structured their team and introduced a design information co-ordinator. The recovery programme exercise also included an integrated design programme. The co-ordinator was a senior member of staff. He had
the authority to manage and coordinate the design information [F-23]. A similar situation occurred in the main contractor. After they realized that they had undervalued this function and should give it more attention [F-24], they appointed an engineer who has 25-years experience in the industry with main responsibility for information dissemination. Things changed after the organisations of architects and contractor brought those personnel in. “The quality of information is improved. Coordination is better, although there is still room for improvement. If they had been on the job a year before, it would have been beneficial.” said the interviewees [F-25]. “The Architect is now producing drawings that co-ordinate with our drawings, before they never did. Now there is a design programme with dates by which we can expect information from other disciplines” [F-26]. The result of the survey clearly indicates these changes. The gatekeepers in the second survey performed better than before, as did the overload, underload, and communication variables (Fig. 6.7, Table 6.2).

Like other fast track projects, this project overlapped the design and construction phases. The engineers thought it would be better if one party control the information flow between consultant team and construction team. A service engineer suggested that the client should learn from the design and build procurement to give this power to the contractor and make them become a lead player in information management. A structural engineer agreed with this. He has attended the design of terminal three at Heathrow airport, which was same procurement as this project. “The contractor set up a very clear programme for information flow and demonstrated very tight control over document exchange. It had a very positive impact on the project” [F-27].

It was the first time that the team members had used e-mail to circulate CAD drawings between various offices. Most of the designers used AutoCAD (version 14 or 20), whilst the structural engineers use micro station. From the beginning, each organisation used their own computer experts to make the system workable for them. The standards were complicated and not practical [F-28]. A lot of problems appeared in compatibility, format, layer setting, line type, plotter settings and so on. As a result, the participants could not use each other’s drawings. Therefore, a simple, friendly protocol and a set of exchange standards should have been set up at the outset. The protocol should have been observed and adjusted throughout the project.
6.6.2 Project support environment

6.6.2.1 Information

In this project, the procurement methods of management contracting and partnering were used to get the main-contractor involved at an early stage of the design. It was agreed that this positively influenced the design process, minimised mistakes, and produced an efficient and economic design by gaining specific construction knowledge from the contractor [F-29]. For example, the contractor helped the consultants to adjust the beams to make them cheaper and easier to build [F-30]. The client thought that the project gained a lot of benefit from the contractor’s early involvement [F-31].

However, in the view of the consultants, the involvement of the contractor was insufficient. The contractor was also not very enthusiastic [F-32]. The interaction between the consultants and contractor did not run smoothly. In many cases, the contractor did not take an active role in giving the consultants advice. Instead the contractor waited for information and then asked for changes [F-33]. The consultants were infuriated at this situation. One of the consultants commented "we should share our knowledge but this did not happen. Now we have the design. When we give it to the contractor on the site, they say 'you can do this better and you can do it in that way'. We should have known this before we designed it. If the communications had been better, we would have known this six months ago" [F-34].

There are 80 packages for this project. To help the design, the client and contractor agreed to get some of the principal subcontractors on board at an early stage such as M&E and the cladding subcontractor. The subcontractors helped the consultants in many ways [F-35]. But compared with other projects [F-36], the consultants thought if the client had paid the subcontractors to work simultaneously with the consultants, the information would have been more accurate [F-37]. Without the subcontractors involvement, the design by the consultants also produced difficulties for the subcontractors. The service subcontractor had to instigate a series of changes. They changed the installation size for the fans, which resulted in the redundancy of the structural drawings. This subcontractor also wanted to change the positions of certain holes, but it was too late, because the holes already existed. The M&E engineer stated that they could not keep the original design since it was completely impracticable. As
a result of unsatisfactory communication (Table 3), most of the interviewees, including the client and main contractor, realised the importance of the subcontractors' early involvement. This shows the benefit of bringing some specialists into the design team from the start, through paying for their consultancy or employing them as consultants rather than subcontractors [F-38].

6.6.2.2 The quantity and quality of the resources
The client criticized the performance of the consultants for the information they issued to the contractor "It was not of high quality. There were a lot of conflicts" [F-39]. And "the architects especially should be blamed, as they should make sure that all of the design worked" [F-40]. The consultants themselves also admitted that their design was not co-ordinated. The service engineer blamed the architect as they did not stick with the original layout [F-41]. He blamed the structural engineer that he did not consider their requirements, which caused a lot of redesigning. Whereas the structural engineer blamed the architects and service engineers that because they kept changing, they had to throw all the steel away [F-42].

The contractor complained that the design information always arrived 3, 4 or 5 weeks late and was often not what was required. The information had to go back to the design team before they could use it. It took a couple of weeks to get the feedback [F-43]. As indicated in the survey (Fig. 5), the information required at this stage was inaccurate and incomplete, and was not timely. Such low quality information brought a lot of trouble to the sub-contractors working with drawings, which were based on the original design of the consultants [F-44]. One of the biggest problems for the contractor and sub-contractor was that the things had been built or had been fabricated, but the consultants asked for changes. The contractor felt that the design by the consultants knocked their confidence. They could not pick up a drawing with confidence that it was right and could not go out and build it [F-45].

Most interviewees believed that one of the causes for these problems was inadequate resources: insufficient designers or designers with the wrong experience. The structural engineer thought that the architects did not put enough people on this project and stated that when they had 40 engineers, the architects should have had 60-70 staff and that never happened [F-46]. The QS and the contractor added that the
people who have not got the training played a part in the communication problems [F-47]. The lead architect admitted that it is currently very difficult to attract the right people with the necessary skills.

In the second survey, the communication scores in Accuracy and Timeliness increased (Fig. 6.6). The communication has been improved over the duration of the project with the designers working for more hours or extra people being brought in. Now there are around 80 people on site, 40 of whom are architects. The number of human resources is quite big for this size of project at this stage [F-48]. The introduction of a person responsible for information management also contributed to the improvement [F-49]. As shown in Fig. 6.9, the person occupied the central role and was well connected with others (Fig. 6.11).

As some of interviewees said, however, they had to have the right number at the right time and if more experienced designers were involved earlier during the information production, the performance would be better [F-50]. Especially, with regard to how architects and structural engineers arranged their resources at the earlier stage and what kind of experience they got at the early stage [F-51]. These were important because their work was a platform to the others. If this were not built well, it would cause a series of problems for the others.

The two round surveys (Figs. 6.5 and 6.6) showed that there were some problems in understanding and expectation from each other. The problems in information overload (Fig. 6.7) also reflected that each discipline had little knowledge about the others [F-52]. All of the project participants agreed that the professionals should have certain knowledge of others. It would make the interaction more effective if each discipline could be aware of others [F-53]. The QS gave an example of benefits obtained after employing a quality surveyor who had special knowledge of others [F-54].

In addition, through this project, the interviewees realised that the capability of the senior professional in the information management and coordination is very important and that the weakness in these aspects was one of the reasons which made this project unsatisfactory at the early stage [F-55]. Further discussion regarding these will be given in the key project personnel section.
6.6.3 Project Co-ordination

6.6.3.1 Social collaboration

Figs. 5 and 6 show that the barriers are the only variable having a similar score to the CII benchmark in the two surveys. This may be one of the strengths of the partnering procurement method used in this project. Although there appears to be some barriers in appreciation, common goals and interrelationships that affect communications, the partnering procurement route appears to minimise these barriers. This is because the processes of the design and management rely on the communication of information and partnering encourages people to work closely with each other. It also supports the communication from a social dimension (Bennett and Jayes, 1999). In many cases, the interviewees felt that the working environment was very good and friendly and the communication was easy and open. People helped each other and the problems had been resolved collaboratively rather than resorting to the contract or by preparing claims. The QS said that if on a traditional contract, the contractor would be building up the claim now and he would have a very good claim for the 12 weeks late information [F-56]. The contractor did not get as much input on the claim issues as they would normally have. Instead of arguments, they all tried to resolve the problems. For example, in the core changes in the car park they helped the consultants in a different way to avoid damages [F-57]. The contractor also mentioned how they sent their staff to give a hand to the client and how they spent three weeks working with the architect to find a way of making the stone bought by a subcontractor acceptable [F-58].

In the beginning, the client arranged a number of workshops for the team members, making them familiar with the partnering process. When the project started, however, the traditional procurement mentality still influenced these participants. Sometimes, the contractor tried to make excuses to avoid involving the design process and the architects still relied on their power to influence other disciplines and ignored others’ suggestions [F-59]. Obviously the participants have not completely got rid of the traditional concept and have not been used to the change of the procurement method. In some way, there were some disadvantages in the partnering method. The interviewees thought that this was too friendly, making the people lazy and less responsible. So some people were in favour of using D&B where there are pressure
and penalties, but most disagreed with that. The client said that it would not be comfortable to tell people if they caused the problem, there will be penalty and they will have to pay for it. That will worry them all the time about the penalty, damaging their imagination [F-60]. According to Bennett and Jayes (1999), if clear performance measures have been devised and the project progress has been monitored, then disadvantages mentioned can be reduced.

6.6.3.2 Technical collaboration

Most interviewees complained that the interface between designers or designers and sub-contractors was not clear, and the design for most sections of this project was not co-ordinated [F-61]. For instance, in the design of the headroom in the main mall the architect and structure engineer did not interact or communicate effectively. So eventually the headroom did not meet the client’s requirement. As a result, the beams for the mall, which had already been fabricated, had to be replaced with a resultant cost of £120,000. Because of the lack of communication, a lot of changes had been caused [F-62].

It is normal to encounter some design co-ordination problems in such a project. But many problems occurred. The client and the contractors have not usually met before. They tried to find an answer as to how these issues can be improved. Most of the interviewees believed that the design team should work in one place from the beginning. But some disagreed with that. “There is electronic communication available. We have e-mail, fax, telephone, and internet, the need to see face to face is not that important. They have their own web page, the participants can log in and see all the drawings.” said the client [F-63]. The QS, the lead engineers and the contractors argued that the co-location of design team members was a much better technical solution than the development of the so-called “virtual” team with its reliance on electronic communication channels but no informal contact [F-64]. The lead QS said, “our relationship with the contractor is stronger than it is with the other designers because we are in the same building. Sometimes, we assumed that everything could be done by fax or by e-mail, but they needed time to complete the process and this can be done better face to face” [F-65]. This view was supported by the project manager “In theory, with all the electronic communications, transfer of drawings and mails, you should not need it, but I am a believer that if you get people
together, the design will progress better. If people can nip up the stairs or down the corridor to have a chat with somebody then that would improve the communication. You would get a better feeling of the team and where they are going” [F-66]

The results, from the social network analysis of this project in the first survey during the project design (Figs. 6.8 and 6.10), also supported the view of the co-location. The lead QS and the members of the management occupied a central role in the communication network during the project design, while the lead architect and the lead structural and service engineers occupied a less important role than expected. In the second survey, the picture had changed as shown in Fig. 6.9. The new design co-ordinator from the architect side occupied a central role. He is only lower than the project manager and has the second highest degree of the centrality. Fig. 6.11 also shows the design co-ordinator is a central actor and close to the design team members in the communication network. There were some other changes: the design team moved further toward the centre, and the lead QS moved away from the centre. The two surveys indicate that working closely can increase the amount of the communication. In the first survey, the lead QS worked in the same place with other team members and had a high centrality. When he was away, the degree of centrality fell. From the beginning, the consultants worked separately in their own company so that they are not in the centre of the communications. Later on some consultants worked in the site office, they increased the frequency and intensity of interaction and communication with each other and with other members. The degree of centrality was therefore improved. The appointed design co-ordinator was responsible for coordinating design information and organising meetings to solve the design problems which arose in the construction. He worked in the site office 3-4 days a week and came any time if needed. He played an active role and communicated well with others.

The contractor thought that the face-to-face meetings were the best way to construct a shared understanding and answering questions rather than the electronic mail. He said that when you sent drawings electronically it was fairly quick but that relied on the other person looking at it and understanding it. Whereas if participants were sitting here face to face, it is easy to clear things up [F-67]. Having previous experience working in the same location, the structural and service engineers thought that the
face-to-face meeting was much better in terms of the developing of the design. "We discuss the drawings when we need to do so. The decisions were easier to make and supported by all team members. Late activities in the design process could be carried out without being hampered by different views from the team members on relevant design topics." [F-68].

From the beginning, the contractor recommended that the consultants should start in one office, he said "There is not a way it could happen properly unless they are all together in this short design period. But that was not done. You see, the cost on the human side of it was insurmountable and we are still paying the price for that now. A lot of arguments about the design appeared on site, which should have been sorted out when the design was conceived". Facing so many problems of design coordination, the client changed his mind. He thought that it may be worth paying the consultants to work together rather than work separately relying on other methods of communications [F-69].

6.6.3.3 Key project personnel
The study by Chapman (1999) showed that the Key project personnel, like the project manager, design manager and design discipline, play a very important role in the project co-ordination. In the early stage of this project, senior project personnel were not appointed to take this role for these interactions, co-ordinating activities across groups in both of the consultant team and construction team of this project. As discussed above, this was one of the reasons why communications were inadequate. There was some improvement when the senior project personnel were introduced in the organisations of the architects and main contractor. The participants realised the importance of co-ordination, especially information co-ordination through the improvement. The contractor felt that the information management was a key to working successfully. If it is not done properly, the whole process grinds to a halt. "It is time for a culture change. We should appreciate the job and give high value and credit to the information co-ordinator and controller" said the contractor [F-70]. The client is now considering the addition of a new criteria, the ability to manage information, when they appoint teams for the next project. The new assessment will include what is the strategy and structure of information management, how it is carried out and who is responsible for external co-ordination. "Before, when we
appointed the consultants, we assumed that if their design was good, they would have a good design management process. Now that is probably a wrong way to do it.” said the client [F-71]. In the past, with the consultants, deals were usually done at very high levels over lunch, rather than actually looking at the technical ability of the company to produce good quality information. Now the client is looking at how the company can perform in terms of information management, what skill level or resources it has got [F-72]. Facing the challenge, the leader of consultants and the contractor indicated that they will pay attention to the management and organise more training including IT knowledge and knowledge of other disciplines for senior personnel in order to improve the performance in fast track projects.

There have been considerable changes of key personnel in this project. The lead architect and structural engineers have both changed during the design period. This obviously affects the communications continuity during the development of the design, because it was not easy for new personnel to put the scheme together in the short time. One of the lead consultants complained, "when the design team went into the process it was agreed by the members, a replacement member came, who was starting with no knowledge at all. He inevitably wanted to change certain things. We were making decisions assuming a structure designed by the original designer, then basic assumptions were changed" [F-73]. This is obviously not good for trying to achieve the co-ordination necessary for timely information release.

The project management team also saw significant changes. From June 1999 to July 2000, those who are responsible for service engineering changed 4 times. Only one stayed with this project for six weeks. One engineer felt that it was very difficult to carry on his job under such circumstances. He said, "We discuss what we need and what we are doing, and then that person leaves. We get a new person, who doesn't know the situation, so we have to do it again. We can not then get the feedback until a few weeks later” [F-74].

It is apparent that the capability of key project personnel in information management and the stability of these personnel have a large impact on both the social and technical co-ordination of the network.
6.7 Summary

The main results of this case study can be summarised as follows:

Partnering can eliminate many communication barriers and had a positive impact on social collaboration in the design process. However, fast-track construction may have a negative impact on Accuracy and Completeness of the information, if the programme is not carefully considered and requirement changes are not controlled.

The use of project intranets can improve the speed of information flow. The system had a positive impact on the timeliness score, but it had a negative impact on Overload. Their usefulness and usage should increase, if the proper communication protocols have been set up at the outset.

Well defined procedures, such as outlining scope and communication strategy, may smooth the information flow in a timely and effective manner.

Senior staff as a gatekeeper and information manager can improve information co-ordination and enhance the quality of the information. One party controlling the information flow between the consultants and the contractor had a positive impact on the information exchange.

Insufficient or late involvement of the contractor and subcontractors had a negative impact on Accuracy of the communications, causing design changes.

Insufficient and inexperienced human resources had a negative impact on communications in terms of Accuracy, Timeless, Understanding and Overload.

Working in the same place can increase the degree of the interaction, communication and technical collaboration. It was easier to remove uncertainty and confusion between different participants in the early design stage. This had a positive impact on Timeliness, Understanding and Accuracy.

Changes in key project personnel had a negative impact on the continuity, Accuracy and Timeliness of communication.

The lack of capability in communication management had a negative impact on information flow and co-ordination in communication.


Chapter Seven
Case Study Two: Water Treatment Project

7.1 Project Description

Case study two is the design and construction of several water treatment plants. This project is being developed by a major water company in the UK, and consists of four small projects in different places. These will provide micro/ultra filtration membranes at the potable water sources in four existing sites to act as barriers against Cryptosporidium Oocysts. As a result of new regulations, the amount of these bacteria has been limited and it is required to monitor levels every day. The only way for water companies to avoid testing for Cryptosporidium Oocysts every day is to get rid of them by designing better water treatment systems. Ultra filtration membrane was selected for the four projects to filter out the bacteria from the water in the treatment systems.

In addition to the membrane for the four sites, the treatment system comprises the design and construction of the equipment for water balance, pre-filtration, chemical storage, neutralisation and recovery of chemical waste and disposal of wastewater. The estimated cost for the project in total was approximately £7.2 m. The project commenced in August 2000 and the required completion dates range from March 2002 to December 2002 for the different sites.

The major objective for this project was to complete the work on schedule, because the Drinking Water Inspect (DWI) set 1st March as the deadline for water companies to stop testing for Cryptosporidium Oocysts every day and to use permanent equipment to remove them. There are large penalties for those companies who fail to meet this requirement.

7.2 Project Contract Form

This project was constructed under a design-build agreement (Fig. 7.1). In this agreement, the client was seeking to utilise the contractor’s expertise in design to procure a more cost effective project designed and constructed in a short time-frame. In the pre contract phase, the client employed the consultants to produce a project
scope document together with detailed written performance specifications of the proposed water plant on their behalf. Based on this document, the client invited two contractors to tender. The contractors then had to interpret these requirements and present the client with proposals for meeting them. To help the contractors produce the primary design and pricing of these solutions, a membrane specialist was nominated by the client during the tender stage. The contractor was chosen according to the quality of the design and the price provided.

In the post contract phase, the contractor, who won the tender, has total contractual responsibility for the project and delegated design and construction responsibilities. They employed a specialist supplier to produce the membrane design and to install them, and employed professionals to do the civil design and construction. However most of the design and construction work was done by the contractor and their domestic sub-contractors. During this stage, the consultants provided the client’s quality assurance procedures and monitored the whole process.

![Diagram of Contractual Relationships for Case Two](image_url)

**Fig. 7.1 Contractual relationships for case two**
7.3 Project team

This project was conceived to meet the requirement proposed by DWI. The client is one of the major water companies in the UK. They are responsible for the water supply and wastewater treatment in large areas of the Midlands. From the beginning of the project, they appointed a consultancy company as technical representatives. This consultancy company has a regional reputation as consultants of water engineering and has worked for the client for many years. Both main contractors, who were invited to tender, are large commercial contractors in the design and construction of water engineering works in the UK, and both have worked with the client previously. The selected contractor is an international company.

A company based in Holland was selected to design, fabricate and install the equipment-membrane. This company is one of the leading companies in membrane filtration technology.

During the tender and design stages, the participants from the different organisations were located in various cities. There are considerable distances between these organisations, especially as the membrane specialist is based in another country. Fig. 7.2 shows the geographical locations of the project team. The contractor, who won the tender, with its design team is located on London. The client is located in the Midlands, and the consultants are located in Bristol. It takes about three hours driving to see each other. Another contractor, who lost the tender, is located in the north of England. It takes about three and half hours driving for them to see the client and about seven hours to see the consultants. The furthest team member is the membrane sub-contractor. Their design team is based in Holland, although they have a few representatives in the UK.

The sites are located at six different places. The design team members have visited these several times. However at the time of this research, the contractor has not yet entered the sites.

7.4 Project Communication System

Fig. 7.3 shows the general structure of the communications between the project team at the design and construction stages.
The team has mainly used traditional methods to communicate with each other. For the external communications, they relied on the telephone to discuss the problems and the progress of the design and construction. Fax has been used to show the small parts of the drawings which will be or are being discussed, or to confirm issues. Each organisation was connected to the internet via modem and standard phone line, and e-mail was used. For unsolved problems, meetings were arranged. The Dutch specialist travelled to the UK several times to see and talk to other parties for this project. Formal meetings have been held as required.

For the internal communications, each organisation normally relies on face to face meetings.

After the tender, the client decided to use computer technology to help to coordinate the project. They provided a web page that contained and updated the general information about the project to the participants. Using a password, the participants can access this page to post their files, and to navigate the updated information from other parties. Normally the page has been used to post the regulations, meeting minutes, daily reports concerning meeting times and clarification issues. They don't use the page for formal agreements and the exchange of CAD drawings, which are
Fig 7.3 Communications in Design and Construction
still circulated between participants by post, although sometimes e-mail is used to attach the drawings.

During the pre contract phase, no one was appointed as a gatekeeper for managing the information, although the lead consultant communicated with others on the client's behalf. During the post contract phase, information administration was handled by an information co-ordinator in the main contractor's organisation. He managed the paper work and distributed the information to internal or external designers and the sub-contractors. Also he and the project manager co-ordinated the information between each participant. At this stage, the lead consultant monitored the progress of the project on behalf of the client.

7.5 Presentation of results
The case study for this project was undertaken from January 2001 to June 2001 during primary design and the detail design stages. Similar to Case One, multiple data collection approaches including interviews and questionnaire surveys were used. There were two rounds of interviews and questionnaire surveys. The personnel, who were asked attending the surveys, were frequently involved in the design and construction process from different organisations: client, owner, architects, structural engineers, service engineers, two main-contractors and some sub-contractors. The personnel are shown in Table 7.1.

7.5.1 Interviews
Two rounds of interview were held. The first was in January 2001 in the pre contract phase. The second was in May 2001 in the post contract phase. Six personnel attended the first interviews and 8 the second interviews.

During the interviews, a number of communication issues were raised. The general consensus was that communication was not satisfactory in the pre contract phase, but it was quite satisfactory in the post contract phase.

In the pre contract phase, the two tendering contractors complained that the client did not give clear requirements, and much data provided in the scope document was inaccurate or changeable. The communication was not managed. On the one hand,
Table 7.1 Participants and their responsibilities for case two

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Participants</th>
<th>Survey attendance*</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Team Leader (Client1)</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Ensuring the project to be delivered in time and within cost</td>
</tr>
<tr>
<td></td>
<td>Senior Project manager (Client2)</td>
<td>Questionnaire1</td>
<td>Project strategic management</td>
</tr>
<tr>
<td></td>
<td>Project manager</td>
<td>Questionnaire1,2</td>
<td>Management of projects let to external consultants and contractors</td>
</tr>
<tr>
<td></td>
<td>Project engineer</td>
<td>Questionnaire1</td>
<td>Reviewing and commenting on the specific aspects of the design</td>
</tr>
<tr>
<td>Consultants</td>
<td>Project manager (Consultant1)</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Production of specification documentation; Tender administration and appraisal; Monitoring and Co-ordinating design</td>
</tr>
<tr>
<td></td>
<td>Leader engineer (Consultant2)</td>
<td>Interview1; Questionnaire1,2</td>
<td>Liaison with client and contractor</td>
</tr>
<tr>
<td></td>
<td>Engineer (Consultant3)</td>
<td>Questionnaire1</td>
<td>Production of specification documentation</td>
</tr>
<tr>
<td>Contractor A</td>
<td>Project manager (Contractor A1)</td>
<td>Interview1; Questionnaire1</td>
<td>Planning and control of inputs to bid process; Communicating with other organisations</td>
</tr>
<tr>
<td></td>
<td>Proposals Engineer (Contractor A2)</td>
<td>Questionnaire1</td>
<td>Technical and commercial preparation for tender</td>
</tr>
<tr>
<td></td>
<td>Senior estimator (Contractor A3)</td>
<td>Questionnaire1</td>
<td>Production of pricing for the civil works</td>
</tr>
<tr>
<td></td>
<td>Project manager (Contractor B1)</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Planning and control of inputs to bid process; Managing the interface with other organisations</td>
</tr>
<tr>
<td></td>
<td>Lead Engineer Contractor B2</td>
<td>Questionnaire1,2</td>
<td>Managing the indoor design and integrating the design with other organisations</td>
</tr>
<tr>
<td></td>
<td>Mechanical Engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Mechanical design; Appraisal of mechanical submissions from suppliers</td>
</tr>
<tr>
<td></td>
<td>Civil Engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Ensuring civil design sub contractors receive accurate design information and build within target cost</td>
</tr>
<tr>
<td></td>
<td>System Engineer</td>
<td>Interview2; Questionnaire2</td>
<td>System and process calculations; The design of P&amp;ID</td>
</tr>
<tr>
<td></td>
<td>ICA engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Detail design for control system and instrumentation</td>
</tr>
<tr>
<td></td>
<td>Electrical engineer</td>
<td>Questionnaire2</td>
<td>Electrical design</td>
</tr>
<tr>
<td>Contractor B</td>
<td>Project Manager (Spec_1)</td>
<td>Interview1; Questionnaire1,2</td>
<td>Responsible manager for the membrane of this project</td>
</tr>
<tr>
<td></td>
<td>Process Engineer (Spec_2)</td>
<td>Questionnaire1,2</td>
<td>Technical &amp; commercial offers to client, process design and operation philosophy</td>
</tr>
<tr>
<td>Membrane subcontractor</td>
<td>Managing director (Spec_3)</td>
<td>Interview2; Questionnaire2</td>
<td>Representative of the membrane company in UK</td>
</tr>
</tbody>
</table>

*Number 1 represents the first interview or questionnaire survey, 2 second interview or questionnaire survey
information was restricted and underloaded, and most of interviewees felt that it was
difficult to carry out their work with incomplete information. On the other hand
information overload also occurred, which meant the participants faced a sea of mail,
they could not find what the important issues were, and some information did not
reach those who needed it. The performance of communication in terms of quality and
quantity was quite low in this phase.

In the post contract phase, the contractor had total contractual responsibility for the
detail design and construction. The communication between the internal members in
the contractor's organisation ran smoothly. The communication between the
contractor and the civil subcontractor was also smooth. But quite a lot of
communication problems appeared between the contractor and the membrane
specialist. Both complained that the other side did not provide the information for
which they were responsible.

In common with other design and build contracts, the design benefited from input by
people with construction knowledge. Not many communication problems occurred in
the construction stage.

In Section 7.6, these communication issues will be discussed and the interview data is
analysed further.

7.5.2 Questionnaire survey
The two questionnaire surveys were held during the case study. As seen in Table 7.1,
fourteen participants completed in the first questionnaire survey and thirteen in the
second questionnaire survey. The results of these surveys are presented below
highlighting the three aspects: communication variables; information flow; and the
Project Network

7.5.2.1 Communication variables
The scores for the communication variables for this project were compiled using
COMPASS. A summary of the score can be seen in Table 7.2. Individual categories
can be seen in Figs. 7.4 and 7.5. The comparison of the two sets of results can be
seen in Table 7.3.
Table 7.2 Total communication scores for case two

<table>
<thead>
<tr>
<th>Project</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>CII Project (Lowest Rated)</td>
<td>51</td>
</tr>
<tr>
<td>CII Project (Benchmark)</td>
<td>75</td>
</tr>
<tr>
<td>CII Project (Highest Rated)</td>
<td>87</td>
</tr>
<tr>
<td>Case Two (First Survey)</td>
<td>60</td>
</tr>
<tr>
<td>Case Two (Second Survey)</td>
<td>66</td>
</tr>
</tbody>
</table>

Communications Score - All Groups

Fig. 7.4. Communications score in the first survey for case two.

It can be seen that the total score for this project is 60 for the first survey, whereas the benchmark score is 75. Each communication variable received a lower score than the benchmark, especially in the aspects of Accuracy, Completeness and Barriers, which only received 3, 3 and 7 comparing with 5, 5 and 9 in the benchmark. It indicated the presence of communication problems in these variables. In the second survey, Understanding and Procedure were unchanged, these problems maintained the same level as the first time. There were some improvements in the aspects of Accuracy, Completeness and Barriers from 3 and 7 to 4 and 8, although the scores were still
lower than the scores of the benchmark. There was a significant improvement in Timeliness, which reached the benchmark score of 9. The total score for the second survey increased from 60 in the first survey to 66, but this is still below the benchmark 75.

![Communications Score - All Groups](image)

**Fig. 7.5. Communications score in the second survey for case two.**

**Table 7.3. Comparing the results of the two surveys for case two**

<table>
<thead>
<tr>
<th>Variables</th>
<th>CII Benchmark</th>
<th>First Survey</th>
<th>Second Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Procedures</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Barriers</td>
<td>9</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Understanding</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Timeliness</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Completeness</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
7.5.2.2 Information flow

From the data collected during the survey, the scores for information flow were developed for the project, and these scores were then compared with the benchmark scores that were developed from the questionnaire survey in Chapter Five. A higher score indicates the presence of communication problems. The results of the two surveys can be seen in Fig. 7.6. On a scale of 0-4, the larger the figure, the more frequently the problem occurs in that aspect.

![Information flow score for case two.](image)

The results of the first survey revealed that the distortion scored 0.2, which was lower than that of the benchmark, and the gatekeeping was 2. However the overload, underload and gatekeeping received higher scores than that of the benchmark. They were 3, 3.2 and 2.5. These indicated that a few problems appeared in the distortion and more problems appeared in the information overload underload and gatekeeping. In the second round survey, the performances for Overload, Underload and gatekeeping improved. The scores changed to 2.4, 3 and 1.5, although the Underload was still higher than that of the benchmark. The distortion increased slightly to 0.3, but it is still lower than the benchmark.

7.5.2.3 Project network analysis

Data for this project from the communication patterns survey was gathered and then input into UCINET IV to develop statistical and graphical representations of the
project communication network. As described in Case One, this analysis consists of two parts. One is an analysis of the centrality of each actor in the communication network. Another is an analysis of the actors' linkages and their centrality within a project communication network.

![Fig. 7.7 Communication centrality in the first survey for case two](image1)

![Fig. 7.8 Communication Centrality in the second survey for case two](image2)

**Communication centrality**

The Figures below show the centrality of the participants in the project network of this case study. From Fig. 7.7, it can be seen that in the first round survey the lead consultants occupied the central role in the project communications. They were connected to the rest of the project team, and were instrumental in the distribution of
information throughout the project network: following them are the project manager from the main-contractor and personnel from the client organisations. As can be seen, one of the contractors had been involved in the project more than another contractor at that time. One of the lowest score of centrality is the membrane specialist.

In the second survey 5 months later, the pattern of communications has changed as shown in Fig. 7.8. The project manager in the main-contractor organisation occupied the central place and the score is very high. Following him are design engineers from the main-contractor organisation. The consultants and clients were changed to lower score, and the membrane specialists still had a very low score.

Communication Network
The Figures below provide the graphic descriptions' results from the Krackplot of this project, it shows the positional role of each participant in the communication network at the point in time of the two surveys.

From the Fig. 7.9, it can be seen that in the first survey the consultants were the central actors in the communication network, assuming a more important role as the project progressed. They were surround by other members from the client organisation and one of the main contractors. Note the position of the client who was very close to the central role. Note the position of another main-contractor who was self contained and far from central. Though the membrane specialist had been nominated at that time, they are still removed from the main communications.

In the second survey after 5 months, the pattern has changed which is shown in Fig. 7.10. The project manger from the main contractor organisation became the central actor who was surrounded by the engineers of his own company and the consultants on behalf of the client. However the position of the membrane specialists didn't change very much. They were still isolated from the rest of the team at this stage.
Fig. 7.9 Communication network sociogram in the first survey for case two

Fig. 7.10 Communication network sociogram in the second survey for case two
7.6 Discussion
Through the interview analysis, observation and documentation, the main issues which affect the communication process, have been identified. As in Case One, these are discussed under the headings of Project Management, Project Support Environment, and Project Co-ordination. Sources for the data quoted in this chapter are shown in Appendix G.

7.6.1 Project management

7.6.1.1 Procurement
This project was processed under a design-build agreement. In the pre-contract phase, the two contractors worked with the membrane specialists to produce the primary design to meet the project scope document proposed by the consultants on behalf of the client. There appeared to be many communication problems at this stage. The total score of the communication variables was only 60, which was much lower than the CII benchmark scores (75) (Table 7.2). The score for Barriers, was especially low, at 3 compared to 5 in the Benchmark (Fig. 7.4).

The communications occurred mainly between the two contractors and the membrane specialists during preparation of the tender file. The contractors worked with the membrane specialist to develop the design for the tender. The specialists were responsible for the design of the key high technology membrane equipment, while the contractors were responsible for the design of the water treatment plant including the equipment associated with the membrane. So their communications were a very critical factor for the successful design. However, the nature of the tender strongly discouraged the two contractors from communicating freely with the specialists because they were afraid that their ideas might leak to the other competitors, which could lead them to losing the tender. They would not allow more technical personnel to communicate with the specialists [G-1] and in most cases, the contractors only asked for information, but did not want to discuss fully with the specialists. The low score for Barriers reflected this worry. With such low interaction the specialists were left wondering if the contractors understood their expectations and would integrate their requirements in the design. From the survey, there was a problem in Understanding (Fig. 7.4). One contractor, however, thought that they could not do
anything to change the situation unless they were appointed a partner from the start. In that case, they would have had the confidence to communicate with the specialist and both of them could have made more effort to develop the design. For the client this might have been cheaper and quicker in the long run than the tendering process [G-2].

In the post contract phase, the winner of the contract (contractor 2) had total contractual responsibility for the detail design and construction. Communication improved and the total score of the communication variables increased to 66. Except for Understanding and Procedures, other scores were also improved (Fig. 7.5). This is because most of the members were in one organisation, making communication easy. However barriers to communication still existed between the contractor and the specialists. The specialists thought that the contractor did not regard them as an equal design partner but treated them with the conventional main contractor/sub contractor relationship. This made the specialists uncomfortable in talking to the contractor.

7.6.1.2 Communication system
In the pre-contract phase, there were no formal procedures defining the roles and responsibilities for the project. The exchange of information was not defined clearly between different organisations. Most of the participants thought that this was a small project and it was not necessary to establish formal procedures even if it was complicated. But in practice, without the procedures the information flow was not satisfactory, as shown in Fig. 7.6, with problems in the aspects of gatekeeping, information overload and information underload. During this stage, no one was formally appointed as responsible for co-ordinating information. The specialists just sent their information to everyone because they did not know who was the co-ordinator. The information flow was not controlled. The information was copied to everyone involved by e-mail. The client felt overwhelmed by a sea of mail and could not identify the important issues [G-3]. One contractor received two hundred drawings, taking five days to print out, but they did not need most of them. The specialists met the same problem as the contractor [G-4]. As well as information overload, information underload also occurred between the contractors and the specialists, and some communications failed to find their targets elsewhere. From this experience, the participants realised that there was a need for a procedure for
communication management. Such a procedure could bring about benefits according to previous projects which some interviewees had worked on [G-5].

In the post-contract phase, the communications between the internal members in the contractor organization (the winner of the tender) were informal. They worked in one place and could easily ask for information if needed. The project manager had a large involvement in the communication network. As seen in Fig. 7.8 and 7.10, he occupied the central place and the degree for Centrality was the highest. He talked to the members and organized meetings to sort out the problems immediately. He also worked with the information coordinator as gatekeepers controlling the information volume and flow direction between external and internal channels. Thus as shown in Fig. 7.6, there were few problems in information overload, gatekeeping and timeliness. But the communications between the contractor and the specialists were not satisfactory. The score for Procedure was the same as in the first survey, which was lower than that for the Benchmark. Although the contractor realised that there was a need for a procedure in the first survey [G-6], one was not implemented. Without a clear timetable for information exchange, it was difficult for the membrane specialists to meet the requirements of the contractor [G-7].

After the tender, the client created a web page. The participants could upload their documents on the website and therefore everyone could access up-to-date information from the others. Normally the information on the web page was regulations, meeting minutes, daily reports. It is good for the participants to know what was happening in the project without sending a lot of papers. The CAD drawings were mainly circulated within the contractor organisation. There were no apparent problems with the use of CAD drawings because the users had the same computer system, the same CAD versions, and a common protocol.

7.6.2 Project support environment

7.6.2.1 Information

During the tender stage, the two contractors prepared their design based on a scope document. This scope document was produced by the consultants, and much of the data in the document was provided by the client from the existing water plant. The tendering contractors complained that much fundamental data was inaccurate,
deficient and liable to change [G-8]. For example, the minimum abstraction was changed from 6 to 0 MLD and the average daily output from 6 to 17 MLD. There was no information about the water quality parameters, ground conditions and discharge consents. These problems were reflected in the first survey, showing much lower scores in accuracy and completeness than that of the benchmark (Fig. 7.4). According to the contractors, the inaccuracy and deficiency of these key parameters affected their design philosophy [G-9]. Any change of the parameters forced them to reselect and rearrange all the equipment for the water plant. Since the client had no previous experience about this kind of project [G-10], they did not know how badly affected the contractors would be by changes to key parameters [G-11] and hence did not make a great effort to investigate, test and confirm the parameters. Also, the client did not realize the importance of replying quickly to the contractor's queries, such as what process of water treatment they preferred or what were the criteria they would use to judge the price. The lower score of timeliness in the first survey (Fig. 7.4) reflected this problem, which made it difficult for the contractors to carry out their work [G-12].

7.6.2.2 The quantity and quality of the resources
The membrane is a new filtration technology for protection of the water supply against cryptosporidium. It is the key equipment in a water treatment plant. So in a large part, the success of this project was dependent on the process information that the membrane specialists provided and guaranteed in the final solution. This was why the client nominated the specialists from the start of the project in order to develop the design with the contractors. But the specialists did not assign resources specifically to the project. Apart from the commercial manager, no one was appointed to take responsibility for the technical issues because they were very under-resourced and understaffed [G-13]. One contractor complained that the specialists only supplied a general standardised quotation and it was difficult for them to find an engineer available to discuss more details for specific cases [G-14]. The other contractor agreed with this point saying angrily that he rang the specialists many times but no one answered the phone or rang him back. Even in the post contract phase, the specialists were still unable to produce any information after the contractor had been appointed for four weeks. According to the contractor they were entirely dependent on this information which was on the critical path for the program [G-15]. The low
involvement of communications for the specialists can be seen in the two surveys from Fig. 8 and 9. The specialists had a very low degree for centrality in the communication network with only 32 in the first survey and 18 in the second survey. They were “isolated” from the rest of the project team in terms of the project communications [Fig. 10 and Fig. 11]. The commercial manager from the specialists also admitted that they should have made more resources available as in other projects [G-16]. They should also develop design manuals, databases of key information and packaged information, which allow them to provide more readily standardised drawings, standardised information and technical response to the main contractor in a more timely fashion [G-17]. The inadequate resources and inability to supply information for the new project was one of the reasons why the performance of the communications was not satisfactory in terms of the Timeliness, Completeness, Underload and Understanding in the two surveys [G-18].

7.6.3 Project co-ordination
7.6.3.1 Social collaboration

Having a proven track record and a successful working relationship in previous projects, the client appointed the consultants as a partner for preparing the scope files and monitoring the design in the post contract phase. As a partner, the consultants took the initiative in this project. They were always available for answering questions raised by the tendering contractors [G-19] and as shown in Fig. 7.7, they had a very high degree of the communication centrality. They occupied the central role and were well connected with other members on the communication network (Fig. 7.9). The consultants maintained their enthusiasm for this role, even when the contractor was on board in the post contract phase. They pro-actively discussed with the contractor rather than waiting and answering questions reactively [G-20]. As illustrated in Figs. 9 and 1, the consultants had a relatively high degree of centrality, and communicated well with the contractor by their proximity on the sociogram.

The membrane specialists also worked as a partner in the project. Unlike the consultants, however, their involvement was very small (Figs. 7.7 and 7.9), even though they were nominated from the beginning. Besides their lack of resources, there was no incentive to produce the information since this was unpaid [G-21]. They felt that they were not treated as the consultants were in this respect [G-22].
indicates that the environment for honest and open communication was not built up. The partners were not open about the subject of the arrangement, which denied the important characteristic and essential principle of good partnering (John Bennett & Sarah, 1995). This might be one of the reasons why the specialists did not take an active role in the project as a partner.

Within the contractor's organization in the post-contract phase, the project manager took advantage of the team members working in the same place to organize some informal activities like every Friday lunch at a pub. Although they did not work together very long, only starting from the tender, the team members developed a good relationship and knew each other very well. This helped the free and open informal communications between them [G-23].

7.6.3.2 Technical collaboration
During the pre-contract phase, the financial constraints and the long distance between the membrane specialists and the contractors meant they were discouraged from meeting [G-24]. As shown in Fig. 3, the specialist was based in Holland and the contractors were in the UK. Their communications mainly relied on phone or e-mail, but this was not effective for them to discuss the technical issues regarding the design of water plants, especially the design including the membrane filter, which was developed using new technology [G-25]. In addition, the language difference brought about difficulties when they talked to each other by phone without the assistance of drawings [G-26]. Consequently, misunderstandings occurred as shown in Fig. 5. The contractors or specialists all agreed that they should see each other more frequently. The contractors thought that the specialists should come to England to go through the design [G-27]. However, the specialists thought that the contractors should come to Holland with their requirements and stay for a period of time. There was quite a lot that could be achieved in terms of visiting the specialist's facility and discussing with the engineer who was dedicated to the technology [G-28].

The face-to-face discussion was not enhanced even in the post-contract phase. The misunderstanding, as shown in Fig. 7.5, still existed between the specialists and the contractor. During this stage, the contractor did request more frequent meetings with the specialists. Especially in the interface of software control systems, the contractor
did want the specialists to come to work with their control engineers during the writing of the software because it required very closely co-ordinated work between them. But this did not happen. As a result, two control systems were designed and could not be matched well in many areas [G-29]. Apart from the membrane specialists, other designers were from the contractor and were located in one office. The team members could easily discuss changes or conflicts occurring. Team meetings were also held weekly, and at any other time as needed. They were interacting all the time, which brought a lot of benefit [G-30]. The result of the social network analysis reflected the sufficient communication between these members. They had a high degree of centrality: the project manager reached the highest score of 98, followed by other team members (Fig. 7.7); they occupied the central role and were well connected by their proximity on the project communication (Fig. 7.9). Such good communications gave the project immense support in technical collaboration. Few problems were found in the joint area between different disciplines.

In this project, the contractor was responsible for the M&E design, and a civil sub-contractor for the civil design. In order to co-ordinate their design with the civil design, the contractor appointed a civil engineer to the team. He was a liaison person working with other disciplines. He not only passed the information to the sub-contractor but also represented the civil side at the meetings or in the discussions. Through him, the communication bridge was well built between the two companies [G-31]. The design in the interface between M&E and civil was well coordinated.

Furthermore, because both companies had their own construction team, the design was considerably influenced by the staff for building practicality and was carried out easily in the construction stage.

7.6.3.3 Key project personnel
The lead consultants took on the role of interacting and coordinating activities with other organisations. They had the authority to manage the communications inside or to respond to external organisations. So for any information requested by others, they could arrange the necessary resources and instruct someone to produce the information by a particular time [G-32]. It was very important that in each company there was an appointed contact. However, in the specialist’s company there was no
specific person for the other companies to contact, and there was no one with sufficient seniority able to assign the necessary resources to ensure the work was carried out [G-33]. When the contractor requested information from, or gave instructions to, the specialists, believing that there was an authorized person who was able to act, it was not the case, which delayed the feedback [G-34].

In addition, there were changes in the personnel in the specialist’s organisation. The person who was involved in the pre-contract phase left the company. When the new project manager came he did not have knowledge of the history of the project [G-35]. On the chemicals, for example, he did not know what arrangements had been made, and how the decision had been taken. So he changed the design of the chemicals, which required larger premises [G-36]. It was very difficult to persuade him to return to what had previously been agreed. This made the contractor very frustrated because the changes meant the abortion of most of their design. All of the tank size and neutralisation chemical systems needed to be redesigned and rearranged to accommodate the changes in the insufficiently sized premises [G-37].

7.7 Summary
The main results of this case study can be summarised as follows:

The competitive tendering in the pre contract phase prevented the tendering contractors from opening their communication to other members, especially to the specialists. It had a negative impact on Barriers and Understanding. The communication improved in the post contract phase when the successful contractor came on board and had total control of the design and construction. However the conventional main contractor/subcontractor relationship discouraged an improvement in the Barriers and Understanding of communications.

The lack of a proper procedure in the early stages, which defined the roles, the responsibilities and the information exchanges in this complicated project, made the information flow uncontrolled between the different organisations. It had a negative effect on Gatekeeping, information overload and underload. It also had a negative effect on the information flow between the design participants from different organisations in the later stages. But it did not seem to affect the internal
communications, especially when the team members sat in one office and use the same computer system and CAD version. A good gatekeeper can control the volume and flow direction between external and internal communication, and had a positive impact on the scores of Overload and Timeliness.

It had a negative effect on the scores of Accuracy and Completeness if the client did not realise the importance of the key parameters and made a great effort to investigate, test and confirm them at the existing site. Also if the client was unaware of the importance of responding promptly to contractor queries the score for Timeliness was affected.

Inadequate resources and the inability to supply information can be one of the reasons which made communication fail in terms of Timeliness, Completeness, Underload and Understanding. It brought difficulties to other members who depended on effective communication and information exchanges in their work.

A partnership can encourage the partners to make a commitment to the project and to take an active role in the communication network. It can reduce the communication barriers. However, if the mutual objectives were not well established, the honest and open communication environment could fail and increased the communication barriers. Familiarity between the participants could be established through informal activities, which effectively helped their communication.

Working in the same place could increase the degree of interaction, communication, and technical collaboration. It was easier for the participants to remove uncertainty and confusion. This had a positive impact on Understanding. When team members worked in different places, the communications in the design process tended to be less effective, especially in the case of involving in new technology. It was more difficult for participants to understand without face-to-face talking aided by drawings.

Members in the design and construction teams working within one company provided more opportunities for communication with each other. So the design was favourably influenced by their construction knowledge and was put into practise more easily in
the construction stage. This had a positive impact on Accuracy and Timelines of communications.

Key project personnel in each organisation played an important role in the communication coordination activities. They had an effect on the speed of feedback to queries. Changes in the key personnel broke the dialogue between different organisations, causing a loss of knowledge of the historical development of the design leading to changes in the design. This had a negative impact on Timelines of communications.
Chapter Eight

Case Study Three: Leisure Centre Project

8.1 Project Description

Case study three is the design and construction of a leisure centre in the East Midlands. This project was being developed to offer a sensitive response to the local environment and, offer facilities in providing leisure services to encourage all its residents to participate in sports and recreational activities as a means of enhancing their health, fitness and quality life. The estimated cost for the project was approximately £8 million pounds, provided mostly by the Lottery Sports Fund.

The project has been designed based on an existing leisure centre, which was built in the 1970's. The facilities in the existing centre mainly consist of badminton court, sports hall, and outdoor swimming pool and learner pool dating back to 1920's. The new design is geared to supplement the existing accommodation, and is required to involve minimal disruption of the existing facilities. The additional facilities proposed include a 4 lane indoor swimming pool, learner pool, new car and bus parking and other supplement facilities to offer a building capable of intensive public use.

The project design consists of two phases: primary design and detail design. The primary design was prepared for the Lottery Sports Fund. The detail design started in April 2000 and was almost completed in March 2001. Construction was expected to be completed by December 2001.

There were two major objectives on this project. The first was to complete it within the budget, because this project was paid by the fixed Lottery Sports Fund. The second objective was to complete the project on schedule. The client wished to finish this project by December 2001, then they can have minimum for two months trading before 31th of March. The client can then claim back the VAT of the capital in that financial year from local authority.
8.2 Project Contract Form

The project was processed under a traditional lump sum contract agreement. Initially, the Client appointed a design team consisting of architect, structural engineer, service engineer and quantity surveyor for the design proposal. The architect was the design team leader who co-ordinated the design from the service engineers and structural engineers. The quantity surveyor provided cost advice and control. In the first stage, they prepared design proposals to support an application to the Lottery Sports Fund, in which the concept, contents and quality of the proposed facilities were defined. After the application was successful, the client executed a contract for the detail design and for production of the construction documents with these consultants. Once

![Fig. 8.1 Contractual relationships for case three](image)

the construction documents were completed, the client then executed a contract with the contractor to construct the facility. Before tender, a specialist for the filtration equipment of the swimming pool was nominated by the client. This specialist has a contractual relationship with main contractor. There is no direct contractual relationship between the contractor and the architect, but an informal relationship
exists because the architect acts as the owner’s agent during construction and administers the construction contract. These relationships are shown in Fig. 8.1.

8.3 Project Team

The project team is relatively small. The client is a local council. They were involved in the design and construction of another leisure centre, and have experience of leisure management. The design team comprises professionals: architects, structural engineers, service engineers and QS, who are from different local companies. Having worked on many projects in the local area, these consultants are familiar with each other and have a good relationship. The architects have experience in leisure centre design and have previous designed a similar leisure centre for this client. The filter sub-contractor is specialised in the design and manufacture of the facilities for the water treatment. The project contractor has an annual construction turnover of approximately £28 millions, and has worked with the consultants previously.

Fig. 8.2 Geographic location for main team members in case three
The site is located in East Midlands. Except for the filter sub-contractor, all of the main participants including the main subcontractors are located close to each other and close to the site. They are around about 50 miles away from the site, as shown in Fig. 8.2. The filter sub-contractor is based in Glasgow. Most participants are based in their own companies, and only the management team of the main contractor was located on site during the construction stage. When required, other team members also travelled the site.

8.4 Project Communication System

The general structure of communications between the project teams is shown in Fig. 8.3.

The team relied on the telephone to discuss problems and progress during the design and construction. Fax has been used to show the small parts of the drawings which will be or is being discussed, or to confirm issues. For more complex problems, formal meetings were held. Informal meetings were held when problems arose. Site meetings were held once a month for the consultants to resolve the issues which appeared in the construction process. CAD drawings were circulated between participants by post, although sometimes the consultants used e-mail with the drawings attached. Each organisation was connected to the internet via modem and standard phone line, but the site was not linked.

On the consultants' side of the process, the architects acted as administrators. All of the information went to them, they then issued the information to other consultants after classifying and approving it. Similarly they co-ordinated the information including those sub-contractors with design responsibility, then issued the information to the main-contractor. On the contractor's side of the process, information administration was handled by a single superintendent, who was located at the contractor's main office. He managed the paper work and distributed the information to the sub-contractors. A project manager on site managed and co-ordinated the work of subcontractors, and represented them in negotiations with the consultants.
Fig. 8.3 Communications in design and construction for case three.
8.5 Presentation of Results
The case study for this project was undertaken from January 2001 to June 2001 during the detail design and construction stages. Multiple data collection approaches including interviews and questionnaire surveys were used. There were two rounds of interviews and questionnaire surveys. The personnel, who were asked attending the surveys, are frequently involved in the design and construction process from each organisation: Client, owner, architects, Structure Engineer, service engineers, main-contractor and some sub-contractors, as shown in Table 8.1.

8.5.1 Interviews
Two rounds of interview were held. The first was in January 2001 during the detail design stage. The second was in June 2001 during the initial construction stage. Seven personnel attended the first interview and ten the second interview.

During the interviews, a number of communication issues were raised. The general consensus was that communication was quite good in the early design stage, but it had deteriorated in the early construction stage.

Initially, the communications were good between the client and the consultants. The client was able to specify, express and communicate their needs to the architects. The architects were able to explain the limitations imposed on the client's needs and the client was fully informed of all the possibilities of meeting their needs.

During the detail design stage, the consultants communicated with each other traditionally, but the communication was quite satisfactory. However, due to the shorter period of the design, problems appeared in the management of the communication, and the quality and quantity of the information. The engineers complained that some information they received were changeable, not detailed enough and inconsistent.

When the CAD drawings circulated within the team through e-mail, there were some problems in compatibility, format, line type, and plotter settings. It took a good deal
Table 8.1. Participants and their responsibilities for case three

<table>
<thead>
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<th>Participants</th>
<th>Survey attendance *</th>
<th>Responsibility</th>
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<td>Managing the contract and monitoring the progress of the project</td>
</tr>
<tr>
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<td>Interview1,2; Questionnaire1,2</td>
<td>The owner of the leisure centre</td>
</tr>
<tr>
<td>Architect</td>
<td>Architect1</td>
<td>Questionnaire1,2</td>
<td>Partner in change of the project</td>
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<tr>
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<td>Architect2</td>
<td>Interview1,2; Questionnaire1,2</td>
<td>Responsible for all aspects of the project</td>
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<td>Interview1,2; Questionnaire1,2</td>
<td>Project structure design</td>
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<td>Questionnaire1</td>
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<td>Interview1; Questionnaire1</td>
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</tr>
<tr>
<td>Filter subcontractor</td>
<td>Project engineer</td>
<td>Questionnaire1,2</td>
<td>Managing the design and installation of the filtration system</td>
</tr>
<tr>
<td>Cladding subcontractor</td>
<td>Cladding engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Managing the design and installation of the cladding</td>
</tr>
<tr>
<td>Steel subcontractor</td>
<td>Steel engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Managing the manufacture and installation of the steel work</td>
</tr>
<tr>
<td>Mechanical subcontractor</td>
<td>Project engineer</td>
<td>Questionnaire2</td>
<td>Managing the manufacture and installation of the M&amp;E equipment</td>
</tr>
<tr>
<td>Concrete subcontractor</td>
<td>Concrete engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Managing some concrete design and manufacture</td>
</tr>
<tr>
<td>Electrical Installation</td>
<td>Electrical engineer</td>
<td>Interview2; Questionnaire2</td>
<td>Supplying and installing electrical equipment</td>
</tr>
</tbody>
</table>

* Number 1 represent the first interview or questionnaire survey; 2 the second interview or questionnaire survey.
of time to tidy up the drawings received. The high accessibility of e-mail made caused information overload.

In common with other traditional contracts, this project suffered from communication problems in the early construction stage between the consultants and contractor. They argued on the details of the design information. They complained that the others did as little work as possible.

In Section 8.6, these communication issues are discussed and the interview data are further analysed.

8.5.2 Questionnaire survey
Two questionnaire surveys were undertaken during the case study. As can be seen in Table 8.1, 12 personnel completed the first questionnaire survey and 14 the second, which included the interviewees and others related to the project. The results of these surveys are presented below.

8.5.2.1 Communication variables
The scores of the communication variables for this project were developed using COMPASS. A summary of the score can be seen in Table 8.2. Individual categories can be seen in Figs. 8.4 and 8.5 and a comparison of the two sets of survey results can be seen in Table 8.3.

<table>
<thead>
<tr>
<th>Table 8.2. Total communication scores for case three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
</tr>
<tr>
<td>CII Project (Lowest Rated)</td>
</tr>
<tr>
<td>CII Project (Benchmark)</td>
</tr>
<tr>
<td>CII Project (Highest Rated)</td>
</tr>
<tr>
<td>Case Three (First Survey)</td>
</tr>
<tr>
<td>Case Three (Second Survey)</td>
</tr>
</tbody>
</table>

It can be seen from the figures and tables that the total score for this project is 70 for the first survey, which is very close to the benchmark scores (75). The performance of
Fig. 8.4 Communications score in the first survey for case three

Fig. 8.5 Communications score in the second survey for case three
Table 8.3 Comparing the results of the two surveys for case three

<table>
<thead>
<tr>
<th>Variables</th>
<th>CII Benchmark</th>
<th>First Survey</th>
<th>Second Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Procedures</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Barriers</td>
<td>9</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Understanding</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Timeliness</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Completeness</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

communications in the aspects of the Accuracy, Timeliness, Barriers and Completeness were the same scores as that of the benchmark. There are some problems in the aspects of Understanding and Procedures. Their scores were 8 and 7 compared with 9 and 8 in the benchmark. In the second survey, all of other variables received lower scores than the first survey except Understanding which held the same score as the first survey. The performance in terms of the project communication declined and the total score fell from 70 in the first survey to 67.

8.5.2.2 Information flow

As in case study one, from the data collected in the survey, scores for information flow were developed for the project. These scores were then compared with the benchmark scores that were developed from the questionnaire survey in Chapter Four. A higher score indicates the presence of communication problems in that aspect. The results for the two round survey of the information flow can be seen in Fig. 8.6. On a scale of 0-4 in this Fig, 0 represent never and 4 always. The larger the figure, the more frequently the problem occurred in that aspect.

The results of the first survey revealed that all aspects of the information flow received lower scores than the benchmarks. The scores were 0.2 for distortion, 1.5 for gatekeeping, 2.2 for Overload and 2.5 for Underload. These indicated that in this phase of the project, few problems were experienced in the flow of information between the different parties. In the second survey, the scores for all aspects of information flow increased. The scores increased to 0.3 for Distortion, 1.5 for
Gatekeeping. Whilst Overload and Underload were 2.7 and 3, higher than the benchmark figure. This indicates that the performances of the information flow in the four aspects deteriorated, and the problems in Overload and Underload occurred frequently.

Fig. 8.6 Information flow score for case three.

8.5.2.3 Project network analysis

Data for this project from the communication patterns survey was gathered and then input into UCINET IV to develop statistical and graphical representations of the project communication network. As described in Case One, this analysis consists of two parts. One was an analysis of the centrality of each actor in the communication network. Another was an analysis of the actors' linkages and their centrality within a project communication network.

Communication centrality

The Figures below show the centrality of the participants in this case study project network. From Fig. 8.7, it can be seen that in the first survey the Architects occupied the central role in the project communications. They were well connected to the rest of the project team, and were instrumental in the distribution of information throughout the project network; Following them are the main participants from other consultants' organisations: QS, structural engineers, and service engineers. The filter
specialist had been involved in some communications, and the lowest score of centrality is the main-contractor.

In the second survey, 4 month later, the pattern of communication has changed as shown in Fig. 8.8. The main-contractor occupies an important position. The contractors score is only lower than the architect, becoming the second highest score of the centrality in the project communications. The other consultants were also moderately involved, whereas the sub-contractors were involved to a relative low degree. The filter specialist especially received a very low score.

Fig. 8.7 Communication centrality in the first survey for case three

Fig. 8.8 Communication centrality in the second survey for case three
Communication network

The diagrams below (Figs. 8.9 and 8.10) provide a graphic description of the communication positional role of each participant at the time of the two surveys.
Fig. 8.9 Communication network sociogram in the first survey for case three

Fig. 8.10 Communication network sociogram in the second survey for case three
From Fig. 8.9, it can be seen that in the first survey the Architects were the central actors in the communication network, assuming the most important role as the design progressed. They are connected to other members of the design team. Note the position of the filter specialist who was isolated at this stage, although they had been nominated by the client.

In the second survey, 4 month later, the pattern has changed, which is shown in Fig. 8.10. The main contractor has become the central actor along with the architects and structural engineer. They are all well connected to the other sub-contractors. However the position of the filter specialist was still isolated at this stage.

8.6 Discussion
Through interview analysis, observation and documentation the main issues, which affect the communication process, have been identified. As in Case One, these are discussed under the headings of project management, project support environment, and project co-ordination. Sources for the data quoted in this chapter are shown in Appendix H.

8.6.1 Project management
8.6.1.1 Procurement
This project was carried out under a traditional lump sum contract agreement. The detail design was followed by the completed scheme design, which was examined by Sport England. The concept design was well developed. Therefore, in the detail design stage there were few major changes. The communication was quite satisfactory. The total score of the communication variables was 70, which was close to the CII benchmark score (75) (Table 8.2). The performance of communications in terms of Accuracy, Timeliness, and Barriers were also high, and had comparable scores to the benchmark (Fig. 8.4). However communication problems occurred during the construction stage. The total score of the communication variables fell to 67 and the scores for Barriers, Completeness and Understanding were low compared to the benchmark (Table 8.2 and Fig. 8.5).
During the construction stage, the contractor and the consultants took adversarial stances [H-1]. In common with other traditional contracts, the problems occurring between the contractor and the consultants were not resolved collaboratively but by resorting to the contract or by preparing claims. The contractor stated [H-2], that if the consultants did not provide them with the information by the day when it was requested, causing a delay, they would consider a claim. Everyone in this project tried to protect themselves. There was a fear that one’s openness in communication might be used against them [H-3]. Usually, the structural engineers avoided speaking to the subcontractors directly. This is because if they did so, there was a danger of taking responsibility for any problems caused by the subcontractors. Therefore, the structural engineers normally communicated with the subcontractors via the main contractor. This resulted in the exchange of information being convoluted and restricted.

The nature of the tender in the traditional contract prevented the contractor appointing specialists like the cladding and filter subcontractors at an early stage as this would cost the contractor more money [H-4]. This brought about difficulties for the consultants having insufficient information from these subcontractors to complete their design. As a result, they could not supply a complete picture of the design for the contractor [H-5], leading to a low score for Completeness.

In addition, the traditional procurement method, which separated the design and construction phases, did not provide the contractor with the opportunity to pass their construction knowledge to the consultants. The involvement of the contractor was very low. Their degree of the centrality was 17 in the communication network in the first survey (Fig. 8.9). Therefore, the consultants did not know the strengths and weaknesses of the contractor. They could not tailor their design for the contractor [H-6]. This inevitably caused misunderstanding about the information expected from each other, making the design unsatisfactory to the contractor. However, although the "voice" of the contractor increased in the second survey (Fig. 8.10), it was more likely that any significant change suggested by them would be turned down by the consultants because it was too late to act upon [H-7].

As is seen above, the low scores in Barriers, Completeness and Understanding stem mainly from the nature of traditional contract agreements. If the contract had been let
under a partnering agreement, the situation may have been improved. This is because in this case the contractor and subcontractors could be involved in the project at an early stage and all the participants can work in a more open and friendly environment [H-8].

8.6.1.2 Communication system
This is a relatively small project. Only few parties were involved in the pre-contract stage. They are familiar with each other and most of them have worked together before. Formal procedures for exchanging information were not established. However, the communications were satisfactory, as shown in Fig. 8.6, with few problems in the area of information flow. The leader of the design team, the architect, was a very good communicator [H-9] and achieved a high score of 1.5 as Information Gatekeeper. He controlled the information flowing through the communication channels in an effective way [H-10]. As shown in Figs. 8 and 9, the architect (Arch2) played a “star” role in the project network and his degree of the centrality was over 90%. During the design stage the architect with the design manager (Arch1) organized the meetings and coordinated all the professional teams to make the project move forward smoothly.

The time taken for the design of this project was shorter than previous projects undertaken by the consultants. The service engineers started their detail design at the same time as the architects without sufficient information from them. The structural engineers carried out their work in the same manner. This resulted in some imperfections in communication during the detail design, such as Completeness (Fig. 8.4). In this unusual situation, a structural engineer made a suggestion, which was agreed by a service engineer, that the architect should discuss with them a clear plan for information flow [H-11]. The lower score in Procedures (Fig. 8.4) also indicated the need for an improvement in the information management. The problems present in the joint areas could also have been avoided if they had been identified and defined clearly from the start. For example, it was not clear which discipline was responsible for the existing cables affecting the construction of the new building [H-12].

During construction, the contractor’s head office managed and distributed the construction information to their subcontractors. Many of the participants complained
about this process [H-13]. The scores in Overload, Underload and Timelines were therefore low in the second survey (Fig. 8.6). This was attributed mainly to the Gatekeeper (administrator), whose performance was not satisfactory (Fig. 8.6). Investigation showed that the contractor did not put the necessary resources into the information management and the administrators involved did not have engineering qualifications or proper training in IT. They did not classify nor prioritise the information. The distribution method of the information also caused delays in the delivery of the information (Timeliness). All the information first went through the head office and then it was passed to the site and subcontractors. The contractor did not install internet access on site, and they had no e-mail or plotting facilities there. Accordingly, information often did not reach the users in time [H-14].

The consultants and some specialists had used e-mail to circulate the CAD drawings. However there were problems in compatibility, format, line type, and plotter settings [H-15]. The engineers were dissatisfied with the electronic drawings received, which took a great deal of time to download and were often difficult to read directly. Moreover, a lot of irrelevant information was integrated in the CAD drawings. This had a negative effect on information overload [H-16]. This highlights the importance of careful planning before using e-mail for circulation of electronic drawings. The contents must be controlled, and a clear protocol and set of exchange standards should be set up and agreed well in advance.

8.6.2 Project support environment
8.6.2.1 Information
The client wished to finish the design in a short period. To speed up the design, they nominated the filter specialists at the early design stage. This was welcomed by the consultants. In this case, these specialists supplied the information on the water treatment system and the arrangement of the equipment to the consultants. This helped the consultants on the design of the layout, power and structure of the centre. However the specialists' input was limited since they did not start their detail design until the contractor gave them an official order and commitment to pay. Most of the information from the specialists was primary, not detailed [H-17]. The low score in Completeness (Fig. 8.4) indicated a problem in the first survey. At the design stage, the consultants did not know exactly how big the equipment was, and how it would be
supported. Issues such as how big the pipe was, and where it went were unresolved [H-18]. As a result, the consultants had to use an approximation in their design and leave a space to be completed at the construction stage [H-19]. This resulted in a lower score of Accuracy in the second survey.

In this project, the cladding specialists were appointed only after the construction stage started. Consequently in the design, the consultants could not take account of any cladding design requirements. So there were many things missing in the consultants' design. This missing information in turn brought about difficulties to the specialists. They could not put their design in as the steel work had already been designed and most of it had been fabricated [H-20]. As a results they claimed that they should have had initial involvement to make sure that the design was workable before the drawings went to fabrication.

The consultants were not very sure what the solution should be other than the specialists should be treated as members of the design team during the design stage. Nevertheless, both consultants and specialists realised that the client should have given a specific order to the specialists so as to produce a more complete design rather than just relying on incomplete information [H-21].

8.6.2.2 The quantity and quality of the resources
The consultants employed have a good reputation for their service, and have prior experience of designing leisure centres. These factors, together with others mentioned earlier, formed a good base for communication in the detail design. In general, communication was effective in the detail design stage.

However, there were still some problems concerning the exchange of information between the consultants. The engineers complained that the frequent changes in the architects' design meant their own design could not proceed efficiently [H-22]. The study indicated that these problems originated from the lack of management from the architects' organisation. The architects did not adjust their strategy of management to this new situation - the period of design was short and the consultants worked in parallel. They did not allocate more resources in order to produce design information of good quality and so reduce changes in the early stages. There was only one
architect actually involved in the detail design. It was very difficult for him to supply
the information without modifications within a short time. The changes, according to
the view of the engineers, could not be avoided when the design was developing.
Nevertheless, losing control of the changes had a big impact on the design of other
disciplines when working in parallel. [H-23]

It was found in the survey that the consultants did not use the computer effectively as
a design tool, but only as a drawing tool. Most of the consultants were not familiar
with specialist software to help their design. Consequently they were not able to
follow the design changes made by other disciplines quickly. For example, if the
service engineers could use the software to do the calculation in the service design
directly based on the electronic drawings from the architects, the changes from the
architects would not presented so many difficulties or delays [H-24].

The discussion above shows that the lack of resources represents a failure to control
design changes. Applying new technologies could reduce the undesirable effect of
these changes.

8.6.3 Project co-ordination
8.6.3.1 Social collaboration

Fig. 5 shows that the score for Barriers was comparable with the score equalling the
CII Benchmark in the first survey. One of the major reasons for this may be the good
relationship between the design team and the client, which was built up in previous
projects. They appeared to trust each other, and work together well. They respected
the advice from each other [H-25]. Open talk and friendly discussion usually solved
the conflicts between them [H-26]. As for the consultants themselves, they also tried
to help each other. The architects appreciated the help from the service engineers in
getting in touch with the filter specialist in their design of the layout [H-27]. When
problems occurred, the consultants compromised with each other and tried to find the
best way for all of them [H-28]. However, some improvements could still have been
made. For example, the structural engineers did not feel the other disciplines shared
their problems when they struggled with the paucity of information from the
specialists. They could have done better if other disciplines took an active role to
chase the information from the specialists for them [H-29].
In the second survey during the construction stage, the score for Barriers fell to 8 (Fig. 8.5). There appeared to be less collaboration and more conflict between the consultants and the contractor team. It was shown in the survey that the consultants and contractor frequently disagreed about the details of the design information [H-30]. They did not try to help each other solve the problems but resorted to contract documents to avoid involvement [H-31]. The way in which the contractor treated the subcontractors was not constructive, leading to a poor relationship. As mentioned in the procurement section, this resulted from the traditional contract arrangement.

The two surveys indicated that the contract forms and human issues, such as trust, respect and a good working relationships, have impacted on the scores for Barriers. A good relationship and mutual appreciation could increase the score, whilst a relationship, which was built up on the basis of the traditional contract, seems to have a negative effect on the score.

8.6.3.2 Technical collaboration

During the design stage, design meetings were held regularly. Through face to face meetings, conflicts between the consultants were easily resolved. When conflicts occurred, which involved two or more different parties, the meetings had a distinct advantage in arriving at a solution [H-32]. Because the consultants' companies are close to each other (Fig. 8.2), informal meetings were also able to be held. They met each other and discussed the design when the problems arose. This kind of communication had more advantages than telephone and fax. They appear to have gained much more from face to face meetings [H-33]. As a result, the design was well co-ordinated technically, which was confirmed at the later construction stage. Few problems were found in this joint areas. Less confusion emerged at the interface between the design team members.

According to the interviewees, however, the communication would have been more effective if the formal meetings had been better planned and organised. If more design meetings had been held at the early stages, conflicts, like the unmatched design between architects and structural engineers [H-34], could have been avoided. This is because the early-stage meetings could allow the participants to agree what was
expected from the beginning. This would draw people together on a regular basis when they tended to go in their own direction with their own ideas to develop their design independently, leading to conflicts [H-35]. Also, the early-stage meetings should be well planned, otherwise, some participants might sit there for hours to await the decisions relevant to them [H-36].

The filter specialists were based away from the consultants (Fig. 8.2). It was difficult for them to attend meetings. They came only once a month. Most of the communication between the consultants and the specialists was via telephone. So the communication was not sufficient and effective. The results of the social network analysis in the two surveys reflected this insufficient communication. The filter specialists obtained a very low degree of centrality in the communication network with only 20 in the first survey and 22 in the second survey (Figs. 8.7 and 8.8). In the specialist’s drawings, there were many conflicts with the consultants, indicating that there was a need for frequent meetings to co-ordinate their design. As a structural engineer commented, they really needed to discuss the topic with the team face to face rather than just pick up a phone to reach an agreement with one but not with the others [H-37].

Formal and informal meetings could sort out the conflicts easily and improve the quality of the communication. Well-arranged meetings at the early stage could have reduced the conflicts and made the design better co-ordinated.

8.6.3.3 Key project personnel

Since this project is relatively small and the work period was relatively short, there were not many changes of key personnel during the detail design. However, there were some changes of the key personnel in the feasibility design stage. One group of people worked on the project for a while and then left. Another group of people came and continued. This happened in both structural engineers and architects. According to a structural engineer, these changes in personnel were very disruptive and made the design break down into discrete packages [H-38].

8.7 Summary

The main results of this case study can be summarised as follows:
The traditional contract allowed the design to develop well, which had a positive impact on the communication variables at the design stage. However, it had a negative impact on Barriers, Completeness and Understanding of the communication in the construction phase.

The gatekeeper played a very important role in the management of the information flow. A good gatekeeper can maintain relevant information flow at appropriate time. It had a negative impact on Overload and Underload.

The procedures, such as the communication strategy, did not seem to affect the communication process. However it could be turned into a key factor when the design work was carried on in parallel, or the internet was used to circulate the CAD drawings.

The late involvement of specialists had a negative impact on the Completeness and Accuracy of communications.

Lack of resources invested by the consultants could be a factor in the failure to control the design changes and reduced the quality of the information. Applying new technologies could speed up the design and reduced the undesirable effect caused by the design changes.

Human issues, such as trust, respect, good working relationships and appreciation, could build a good environment for communications and had a positive impact on the score of Barriers.

Design meetings could increase the intensity and effectiveness of the interaction and helped resolve conflicts easily. It had a positive impact on Understanding of communications. Well-arranged meetings at the early stage could reduce the conflicts and made the design well co-ordinated.
9.1 Introduction

Three case studies have been conducted on different projects. They were characterized with different procurement routes, different subjects, different sizes, and different phases as shown in Table 9.1.

<table>
<thead>
<tr>
<th>Project type</th>
<th>Case One</th>
<th>Case Two</th>
<th>Case Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement</td>
<td>Management</td>
<td>Design and build</td>
<td>Traditional contract</td>
</tr>
<tr>
<td>Estimated cost</td>
<td>£100m</td>
<td>£7.2m</td>
<td>£8m</td>
</tr>
<tr>
<td>Complexity</td>
<td>Complicated</td>
<td>Moderate</td>
<td>Simple</td>
</tr>
<tr>
<td>Phase for research</td>
<td>Detail design phase</td>
<td>Pre-contract phase</td>
<td>Detail design phase</td>
</tr>
<tr>
<td></td>
<td>Construction phase</td>
<td>Post contract phase</td>
<td>Construction phase</td>
</tr>
</tbody>
</table>

Through the case study, the main factors, which influence the communication processes, have been identified for each case. In this chapter, these issues will be examined across the three cases simultaneously.

In the studies, the special features of each case were allowed to be identified more readily through comparisons, and the generalization of case study research for the three cases was made through a replication logic approach. Across the three cases, conclusions were drawn which revealed that there are certain factors in aspects of project management, project support environment, and project co-ordination, which can impact on the communication effectiveness between team members. Based on the findings of the three case studies, a model has been developed, which shows strategies that may help participants communicate more effectively and ultimately improve the quality of construction design outcomes.

9.2 Cross-Case Discussion

The three cases are discussed simultaneously under the headings of project management, project support environment, and project co-ordination as follows.

9.2.1 Project management
9.2.1.1 Procurement

Case one used a partnering method. Partnering can eliminate many communication barriers and had a positive effect on social collaboration in the design process. This is because the processes of design and management rely on the communication of information and partnering encourages people to work closely together. The working environment was friendly and the communication was easy and open. People helped each other. This project was both complicated and fast-track, which had a negative impact on the accuracy and completeness of the information and became worse when the client did not consider the design period carefully and lost control of the changes of requirement.

Case two was conducted under a design-build agreement. In the pre-contract phase, the competitive nature of the bidding process prevented the tendering contractors from opening their communication to other members, especially to the specialists. This is because each of the two tendering contractors was afraid that their ideas might leak to the other one, causing them to lose the project. Superficially, the client could obtain a cheap price, but the communication barriers would make the tendering contractors lose confidence to discuss the project frankly with the specialists appointed by the client. Therefore, they could not adequately understand the project and the tendering documents would not be of high quality. In the post contract phase, the winning contractor had total contractual responsibility for the design and construction. As a consequence, the communication was improved, especially in understanding for the design and construction. However barriers still existed between the contractor and the subcontractors or specialists. The contractor did not regard them as equal partners but treated them within the traditional main contractor/subcontractor relationship, making the subcontractors and specialists uncomfortable in talking to the contractor.

Case three was carried out under a traditional lump sum contract agreement. The sequential-nature of the traditional contract allowed the design to develop well as the design process did not overlap the construction stage. The performance of the communications was high in terms of Accuracy, Timeliness, and Barriers at the design stage. Nevertheless, many communication problems still occurred at the construction
stage. The problems between the contractor and the consultants were not solved collaboratively but by resorting to the contract or by preparing claims. Everyone tried to protect themselves as there was a fear that one's openness in communication might be used against them. This exerted a negative impact on the barriers and understanding of the communication in the construction phase. The traditional procurement method, which separated the design and construction phases, did not provide the contractor with the opportunity to pass their construction knowledge to the consultants so that the design by the consultants met some problems during construction.

Within the partnering method in case one, the communication was fully open and free and therefore eliminated the communication barriers. However, for the design-build and traditional methods, the communication was restricted due to commercial pressures.

9.2.1.2. Communication system

In case one, the procedures for the exchange of information were not defined clearly between interfacing parties, leading to information underload or overload. With information underload, it is very difficult for the participants to complete their work with incomplete information. Information overload causes unnecessary stress and inefficiency. In the first survey, the performance of the gatekeepers was poor, indicating that the information was not well managed and co-ordinated. In the second survey, their performance was considerably improved as some experienced senior members of staff were appointed as the information gatekeepers.

In case two, during the pre-contract phase, there were no formal procedures defining the roles and responsibilities for the project. Also, no one was formally appointed responsible for co-ordinating the information. Therefore, there were problems in information underload and information overload as in case one. At the post-contract stage, although there was no formal procedure for information exchange, the communication was satisfied because most of the team were in a single organisation (the contractor) and thus they could sit in one place to talk to each other. Moreover, the project manager was fully involved in the communication network. Accordingly, there were neither large problems
in the information flow, no problems in the communication variables within the contractor organisation. However, since there was no clear timetable for information exchange between the contractor and the specialists, the communication between them was not satisfactory.

Case three was a relatively small project, few parties were involved at the design stage. They were familiar with each other. Although the formal procedures for exchanging information were not set up, under the leadership of the architect the communication performance was generally satisfied. However, the completeness and procedures were still somewhat worse than the benchmark, when the design work was carried out in parallel. They could be improved if there was a formal plan for information management.

In all the three cases, computer technology (internet or intranet) was used to enhance the speed of information flow. The system had a positive impact on the timeliness. However, there were also some problems with the computer use. The easy access to the IT system could cause information overload. Furthermore, the computer system, CAD standards and versions were different for each individual discipline. This made collaborative working and information exchange more difficult than it should be. There should be a common protocol for CAD drawings and a set of exchange standards at the outset.

In all the three cases, there were no formal procedures such as a commonly agreed communication strategy. This had a small effect on the internal communication but had a large effect on the external communication. The appointment of a senior member of staff as a gatekeeper and information manager could improve information co-ordination and maintain relevant information flow at appropriate times. The usefulness and usage of IT should increase if proper communication protocols are set up at the outset.

9.2.2 Project support environment
9.2.2.1 Information
In case one, the main contractors and some principle subcontractors were involved at the early stage of design. This positively influenced the design process, minimised mistakes
and produced an efficient and economic design by gaining specific construction knowledge from the contractors. However the involvement of the contractor was insufficient and the involvement of the subcontractors was not early enough. The consultants did not obtain accurate information to develop their design, which caused many design changes.

In case two, the client could not feedback in time the queries from the contractors and many of the data that the client provided in the scope file from the existing site were inaccurate, incomplete and changeable. These affected the design badly.

In case three, the client made a clear brief and were able to specify, express and communicate their needs to the consultants. They also nominated the filter specialists at the early design stage to help the design work of consultants. However, the input of specialists was limited because they did not start their detail design until they obtained an official order. Accordingly, most of the information from the specialists was primary and inaccurate, adversely affecting the quality of the design by the consultants.

These three cases indicate that complete, accurate and timely information is very important for design development. If contractors and sub-contractors can pass their construction knowledge effectively to the design team at the optimum time, it will have a beneficial influence on the design process.

9.2.2.2 The quality and quantity of the resources

In case one, at the early stages the resources of consultants were insufficient and inexperienced. The design was not co-ordinated between the consultants. Later on, the communication was improved with the consultants working for additional hours or extra people being brought in. The communication scores in Accuracy and Timeliness increased. The introduction of a senior information manager also contributed to the improvement.

In case two, the membrane specialists, key personnel to the project design, did not assign
resources specifically to the project. They were very under-resourced. So the specialists only supplied the generally standardised information, making it difficult for the contractor to carry out the project design. Consequently the performance of the communications was not satisfied in terms of Timeliness, Completeness, Underload, and Understanding.

In case three, the consultants had a good reputation for their service, which formed a good base for communication in the detail design. In general, communications were effective. However, the resources were not well managed to meet the situation – the short period of design. This led to changes in design occurring and affected the quality of the communications. Using new technologies (special software for design) could have speeded up the design and reduced the undesirable effects caused by design changes.

The three cases show that the staffing of the design consultants, having both the right personnel and the right number at the right time, is very important in producing the quality information required. Inadequate resources and inability to supply information made the communications less efficient.

9.2.3 Project co-ordination
9.2.3.1. Social collaboration
In case one, partnering provided an open and friendly environment for the project implementation. It supported the communication from a social dimension. However, as the project continued, traditional attitudes still affected the participants to a certain extent, bringing about some problems and affecting the quality of the communication. Also, sometimes the participants were too friendly with each other, making them less formal and effective. This caused a problem of timely delivery of information. These disadvantages can be reduced, if clear performance measures are devised and the project progress is monitored (Bennett and Jays, 1999).

In case two, from the beginning, the client appointed the consultants and the membrane specialists as a working partner in order to carry out the project more efficiently. The
consultants worked very hard and they were always available for answering questions. However, the involvement of the membrane specialists was insufficient because they thought that the client did not treat them equally to the consultants. This demonstrates that the environment for honest and open communication was not built up between these partners. In the post-contract phase, the project manager in the contractor’s organisation organised some informal activities. Through these, the team members developed a good relationship, which helped free and open communications.

In case three, the client and the consultants or the consultants themselves had a very good relationship and they appeared to trust each other, leading to a satisfied score for Barriers. This had a positive impact on the design development. At the construction stage, the participants (consultants, contractor, and subcontractors) appeared to be less collaborative and more adversarial, leading to an undesirable barrier.

As shown above, human issues, such as good relationships and trust, can lower the barrier and build a good environment for communication. Partnership can encourage the partners to make a commitment to the project and to take an active role in the communication network so as to reduce the communication barriers. However, if the mutual objectives are not well established, honest and open (environment) communication may fail and increase the communication barriers. Moreover, if clear performance measures are not devised and the project progress is not monitored, problems will occur in the quality of the communication.

9.2.3.2. Technical collaboration
In case one, at the early stage, the interface between designers, or designers and subcontractors, was unclear, and the design for most sections was not coordinated. This situation was mainly attributed to the physical separation of the participants, which made them interact and communicate less effectively. Later on, some of the consultants worked at the same location. They increased the frequency and intensity of interaction and communication with each other about technical collaboration. Face-to-face meetings constructed a shared understanding rather than through the use of electronic mail or
phone calls. It was easy to remove uncertainty and confusion between different participants.

In case two, the long distance between the membrane specialists and the contractors prevented them from meeting frequently. Their communication relied mainly on telephone or e-mail. This was not effective for discussing technical issues. Also, the language difference between them brought about difficulties when they talked to each other by telephone. Accordingly, misunderstandings occurred. Their design could not be integrated in many areas. Apart from the membrane specialists and civil subcontractor, the designers were located in one office. They were interacting all the time, which gave the project immense support in technical collaboration. Although the civil subcontractor was separated from the contractor, the communication between them was effective because the contractor employed a civil engineer as a liaison person working in the company.

In case three, at the design stage, the main consultant companies were close to each other geographically. They could meet each other and discuss the design when the problems arose. As a result, the design was well co-ordinated technically. Nevertheless, the filter specialists were far away from the consultants. It was difficult for them to attend meetings to discuss the design face to face. So in the specialist's drawings, there were many conflicts with the detail produced by the consultants.

As all the three cases show, working in the same place can increase the degree of the interaction and communication. Frequent face-to-face discussions can remove uncertainty and confusion between different participants, increasing technical collaboration in the design.

9.2.3.3. Key personnel

In case one, there were considerable changes in key project personnel. This broke the dialogue between the participants and caused a loss of knowledge of the historical development of the project. This had a negative impact on Accuracy and Timeline of
communications. Furthermore, at the early stage, senior personnel for information management were not appointed to take a role for the interaction and co-ordination across the groups, making the information management less effective and reducing the quality of the communications. There were only improvements after the senior personnel were introduced to do this job.

In case two, the lead consultant took a major role for interacting and co-ordinating activities with other organisations. He had the authority to arrange necessary resources to produce the information by a particular time. However, in the membrane specialist's company there was not a specific person for other companies to contact. Therefore the company could not feedback in time the information required by other companies. Also, there were personnel changes in the specialist's organisation. This obviously affected the communication during the development of the design, causing many design changes.

In case three, the lead architect controlled the information flow through the communication channels in an effective way and had a good capability of co-ordinating the communication between different disciplines. This made a big contribution to the scores in communication variables and information flow. There were some changes in key personnel at the feasibility design stage. Although the changes were not a big issue for this short period project, they were detrimental and made the design break down into discrete packages.

In common for the three cases, key personnel for information management in each organisation play an important role in the communication co-ordination activities during the project development. Changes in key personnel break the dialogue between different organisations, causing a loss of knowledge of the historical development and leading to changes in the design.

Based on the above discussion, a comparison of the three cases is summarised in Table 9.2.
Table 9.2 Comparative matrix of factors influencing the communications

<table>
<thead>
<tr>
<th>No</th>
<th>Key Factors</th>
<th>Case One</th>
<th>Case Two</th>
<th>Case Three</th>
<th>Effect on Variables</th>
</tr>
</thead>
</table>
| 1  | Procurement | • The procurement builds a bridge of the communication between contractor and consultants.  
    • Fast track has a negative impact on Accuracy and Completeness of communications.  
    • The lack of capability in communication has a negative impact on Barriers and Understanding of communication at pre-contract stage. | • The procurement has a positive impact on communication management between design and construction phases at post-contract stage.  
    • The competitive tendering has a negative impact on Barriers and Understanding of the communication at pre-contract stage.  
    • The sequential-nature of the contract has a positive impact on Accuracy and Timeliness of the communication at design stage.  
    • Separating design and the construction process has a negative impact on the Understanding of the communication at construction stage. | | Barriers  
    Accuracy  
    Timeliness  
    Completeness  
    Understanding |
| 2  | Communication System | • No clearly defined communication procedures have a negative impact on information Underload, Overload and Gatekeeping.  
    • The use of IT has a positive impact on Timeliness, but it has a negative impact on Overlay. Proper common protocols are needed for multi-users. | • The formal communication procedures have a small impact on the internal communications but a big impact on external communications in terms of information Underload and Overload.  
    • Same as Case one (2). | • Not important as this is a small project; team members are familiar with each other; and lead consultants have strong capability in information management. But it becomes important issues when the design is working parallel or CAD is circulated through the internet. | Overload  
    Underload  
    Gatekeeping |
| 3  | Client | • Lack of knowledge about the periods of design required has a negative impact on Accuracy and Completeness of communications. | • Lack of knowledge about the key parameters for the design has a negative impact on Accuracy and Completeness of communications. | • A clear brief of the requirements for the design has a positive impact on Understanding of communications. | Accuracy  
    Completeness  
    Understanding |
| 4  | Contractor  
    key sub-contractor | • Insufficient or late involvement of contractor and subcontractors has a negative impact on Accuracy of communications, causing design changes.  
    • The lack of co-operation among design and construction team members has a negative effect on the quality of communication. | • Inadequate involvement of the specialist has a negative impact on the Completeness, Timeliness and Understanding of communications.  
    • Inadequate resources and the inability to supply subcontractors have a negative impact on the communications in terms of Timeliness, Completeness, Understanding and Overload. | • Inadequate involvement of the specialist has a negative impact on the Completeness and Accuracy of communications. | Accuracy  
    Timeliness  
    Completeness  
    Understanding |
| 5  | Resource (Designers) | • Insufficient and inexperienced resources have a negative impact on communications in terms of Accuracy, Timeliness, Understanding and Overload.  
    • The lack of appreciation between contractor and consultant discouraged the communication. | • Lack of resources and the inability to supply information have a negative impact on the communications in terms of Timeliness, Completeness, Understanding and Overload. | • Lack of management of resources has a negative impact on the quality of the communication.  
    • The capability of applying computer technologies could reduce the effect of information changes. | Overload  
    Accuracy  
    Underload  
    Timeliness  
    Completeness  
    Understanding |
| 6  | Social-collaboration | • Partnering method can minimize the communication barriers.  
    • The lack of appreciation between the consultants can reduce the quality of the communication. | • Partnership could increase the quality of the communication.  
    • Lack of appreciation between contractor and specialist discouraged the communications in terms of Barriers and Understanding.  
    • Informal activities could help increase the quantity of communications. | • Contractual relationship between consultants and contractor has a negative impact on Barriers of communications.  
    • A good working relationship and mutual appreciation have a positive impact on Barriers of communications. | Barriers  
    Understanding |
| 7  | Technical-collaboration | • Working in the same place can increase the quantity of the communication and easily remove uncertainty and confusion of design specially at an earlier stage. It has a positive impact on Timeliness and Accuracy of communications. | • Working separately decreases the quantity and effectiveness of communications. | • If the meetings can not be held regularly, Working separately decreases the quantity and effectiveness of communication. | Accuracy  
    Timeliness  
    Understanding |
| 8  | Key personnel (KP) | • The unstable KP has a negative impact on the continuity, Accuracy and Timeliness of communications.  
    • The lack of the capability in communication management has a negative impact on information flow and co-ordination in communications. | • The unstable KP causes the design changes and affects the quality of communication.  
    • Good capability in communication management has a positive impact on Timeliness of communications. | • The stability of KP is not a big issue for this small and short-period project, but it still affects design communication.  
    • Good capability in communication management has a positive impact on information flow and co-ordination in communication. | Overload  
    Accuracy  
    Timeliness  
    Underload  
    Gatekeeping |
9.3 Cross-Case Conclusion

Through the discussion and comparison of the three cases, the cross-case conclusion can be made as follows in the form of replication logic or special features (procurement) of each case.

1. Contracting management has a positive impact on the communication between contractor and consultants. However the procurement, which overlaps design and construction phases, has a negative impact on the Accuracy and Completeness of the information if the programme is not carefully considered and requirement changes are not controlled.

2. In design and build contracts the use of the competitive tending at the pre contract stage has a negative impact on the Barriers and Understanding of the communication. At the post contract stage the contractor can easily manage the information flow between design and construction, having a positive effect on the communication management.

3. The traditional contract allows the design to develop well, which has a positive impact on the design communications at the design stage. However, it has a negative impact on Barriers, Completeness and Understanding of the communications between consultants and contractor in the construction phase.

4. The absence of formal procedures such as the establishment of the communication strategies for a project has little impact on the internal communications but has a large impact on the external communications in terms of Underload, Overload, and Gatekeeping, especially when working concurrently.

5. The use of IT can improve the speed of information flow. The use of IT should increase with proper communication protocols and a set of exchange standards of CAD established at the outset.

6. If the client has no knowledge of design information, such as the key parameters or
the period required for design development, the quality of the design communication will be reduced. A clear brief has a positive impact on the Understanding of the communications.

7. Late or inadequate involvement of contractors or subcontractors (specialists) has a negative impact on the quality and quantity of the communications. This will have a beneficial influence on the design process if contractors and subcontractors (specialists) pass their construction knowledge effectively to the design team at the optimum time.

8. The capability of key personnel in communication management has an important effect on information flow and communication co-ordination. Changes in key personnel break the dialogue between different organisations, causing a loss of knowledge of the historical development leading to inevitable changes in the design.

9. Inadequate and inexperienced resources have a negative impact on communications. The staffing of the design consultants, having both the right personnel and the right number at the right time, is very important in producing the quality of information required for the rest of the team.

10. Co-location of the design team can enhance the degree of the interaction and communication. Frequent face-to-face discussions can remove uncertainty and confusion between different participants, leading to an increase in the technical collaboration in the design.

11. Partnering or creating good relationships, can build a good environment for communication and minimise many communication barriers. It has a positive impact on social collaboration in the design process. However, the traditional contract relationship or lack of appreciation between team members can increase communication barriers and misunderstanding.
In the first three points described above, the different procurements are examined, which allow special features of the procurement for each case to be identified more readily through comparisons. For the rest, the replication logic approach is applied for generalisation of the case study research, although there are some exceptions for certain points, such as points 4, 8, 10, and 11. It is seen that the partnering method used in case one may have a negative effect on the timeliness of communications, if clear performance measures are not devised and the project progress is not monitored. Case study two indicates that honest and open communication between partners may fail and reinstate communication barriers, if the mutual objectives are not well established. Although the communication strategy considerably affects external communication, as shown in point 4, it is not a big issue for case three. This is because the project is small; team members between different organisations are familiar with each other; and the lead consultants have a strong capability in information management. However it could become important even for a small project if the design team work in parallel or CAD drawings are circulated through the internet between different organisations. Case study one indicates that although the stability of key personnel is not a big issue for this small, simple and short-period project, it still affects the design communication and breaks the design into discrete packages. All the three cases show that working separately decreases the quantity and effectiveness of communication unless the meetings can be held frequently between the team members.

9.4 Model development
The analysis of the literature review and questionnaire survey has suggested the communication variables, the information flow variables and the variables from the social network analysis, which contribute to the effectiveness of communication in construction design. The problems, which occur in these areas, can be monitored with tools, such as COMPASS, IFCHECK, and UCINET. Analysis of the three case studies has suggested that there are certain factors (reasons), which could influence the variables. Communication strategies which affect these factors and hence have a positive impact on the variables and effectiveness of communication have also been proposed. The relationship between the variables, factors and strategies is shown in Fig.9.1.
Fig. 9.1 Relationship between variables, influencing factors and communication strategies

- Understanding
  - Barriers, Timeliness, Completeness, Accuracy

- Gatekeeping
  - Overload, Underload

- Communication system

- Client
  - Well arranged programme
  - Limited changes
  - High quality brief
  - Well trained and sufficient resource

- Resource

- Contractor
  - sub-contractor
  - Early and adequate involvement

- Social collaboration
  - Friendly environment

- Technical collaboration
  - Regular face to face meetings
  - Co-location design

- Key personnel
  - Stability, Capability

Key to Symbols
- Variables
- Influencing Factor
- Communication Strategy
<table>
<thead>
<tr>
<th>Tool</th>
<th>Variables for communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPASS</td>
<td>Communication Variables</td>
</tr>
<tr>
<td></td>
<td>Accuracy</td>
</tr>
<tr>
<td></td>
<td>Timeliness</td>
</tr>
<tr>
<td></td>
<td>Completeness</td>
</tr>
<tr>
<td></td>
<td>Understanding</td>
</tr>
<tr>
<td></td>
<td>Barriers</td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
</tr>
<tr>
<td>IF CHECK</td>
<td>Information Flow</td>
</tr>
<tr>
<td></td>
<td>Overload</td>
</tr>
<tr>
<td></td>
<td>Underload</td>
</tr>
<tr>
<td></td>
<td>Distortion</td>
</tr>
<tr>
<td></td>
<td>Gatekeeping</td>
</tr>
<tr>
<td>UCINET</td>
<td>Social Network</td>
</tr>
<tr>
<td></td>
<td>Role</td>
</tr>
<tr>
<td></td>
<td>Centrality</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication Strategies</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>EARLY DESIGN</td>
</tr>
<tr>
<td>Proper choice of procurement</td>
<td></td>
</tr>
<tr>
<td>Well arranged programme</td>
<td></td>
</tr>
<tr>
<td>Limited requirement changes</td>
<td></td>
</tr>
<tr>
<td>Agreed communication procedures</td>
<td></td>
</tr>
<tr>
<td>Common protocols for IT use</td>
<td></td>
</tr>
<tr>
<td>Project Supporting Environment</td>
<td>DURING DESIGN</td>
</tr>
<tr>
<td>High quality brief</td>
<td></td>
</tr>
<tr>
<td>Well trained and sufficient resource</td>
<td></td>
</tr>
<tr>
<td>Early and adequate involvement of contractors and subcontractors.</td>
<td></td>
</tr>
<tr>
<td>Project Co-ordination</td>
<td>DURING DESIGN</td>
</tr>
<tr>
<td>Friendly environment</td>
<td></td>
</tr>
<tr>
<td>Co-location design</td>
<td></td>
</tr>
<tr>
<td>Regular face to face meetings</td>
<td></td>
</tr>
<tr>
<td>Key personnel stability and capability</td>
<td></td>
</tr>
</tbody>
</table>

**Successful Project Design**

- Timeliness
- Good co-ordination
- Easy, economical construction

*Fig.9.2 Communication Model*
Based on these relationships, a model of communications in construction design, as shown in Fig. 9.2, has been developed. This model consists of two parts. One comprises the variables of communications and monitoring tools which have been described in detail in chapter five. The other contains the communication strategies and the stage at which the communication strategies are applicable.

As described in previous chapters, the communication variables and the information flow variables were identified by CII (1998) and Guerava and Boyer (1981) as the critical communication issues and problems contributing to effective communications. These communication issues and problems were then examined through a questionnaire survey in this research, and the results showed that these issues and problems were still prevalent in current construction design and could seriously affect design outcomes. Later, these variables combined with those from social network analysis were applied in the three case studies with the assistance of the monitoring tools: COMPASS, IFCHECK and UCINET. Through the use of the tools, the communication problems present in the three cases were measured, monitored and identified. As a result, in this model three types of variables were taken into account as the critical communication variables and assessed by their tools in the construction design process.

The communication strategies, as described are classified under the headings of project management, project support environment and technical co-ordination according to their functions. The strategies and the factors are discussed in detail in section 9.5.

The model has two functions: the strategies accompanying operation conditions may be used as a guide for setting up project design in terms of team communication and as a practical way to positively influence the variables of communication; and any problems present in the variables of communication, which are found by the monitoring tools during the project, can result in a review of the strategies and then resolutions can be proposed to improve the communications. Therefore combining these two parts may ultimately improve the quality of construction design outcomes and make the project design successful.
9.5 Influencing factors and communication strategies

In this section, the influencing factors and the communication strategies are discussed in detail under the heading of project management, project support environment and project co-ordination.

9.5.1 Project management

Procurement

Since the procurement has a profound effect on the communication patterns, Mead (1999) and Murray (2000) suggest that further research should be carried out to look at how the different procurement forms affect the communication process. In this research three different procurement methods at different stages were observed. They have a significant effect on the communication process. Some are positive, and some are negative. So the choice of procurement needs to include an assessment of its influence on team communications.

It can also be seen from the case studies that some shortcomings of communication caused by the procurement could be overcome through learning from others or other procurement situations. For example, traditional procurement (case three), which separates the design and construction, causing misunderstanding between team members, could be overcome if a person with construction knowledge is employed as facility manager at the design stage as in design and build procurement. This can offer support to the "traditional" consultants (Browan, 2001), so that the traditional contract can take design and build advantages. In case one, the contractor was appointed initially as a construction manager and became an integral member of the project team to provide pre-construction services in accordance with their pre-construction proposal document. However the contractor does not have sole responsibility for the integration of the project. According to Browan (2001), single point responsibility has a big advantage in information management as design and build procurement in the post contract phase. The engineers in case one agreed with this as referred to the benefits in a previous project from the contractor who controlled all processes in management contracting. For case two, whether to use the tending to choose contractor is questionable, especially when
there is another party (specialist) being involved. The case study indicated that the nature of the tender strongly discouraged the contractors from communicating freely with the specialists in the early stage, which caused a lot of misunderstanding in the later stage. Therefore the contractors thought that it might be better to a partner from the start. According to Brown (2001), Partnering encouraged by the Egan and Latham reports has provided significant incentive for design and build contractors to improve the design process.

**Programme arrangement and change management**

Mead (1999) suggested that typically, fast track projects suffer from accuracy and completeness problems because project design is being resolved while the construction work is in process. In common with other fast track projects, case one had such problems. This raises the questions of how to condense the period of design and how to overlap different phases. Design itself is an iterative interdependent process. The ill-defined nature of the design problems means that it takes time to achieve a shared or commonly held understanding from different disciplines (Cross and Cross, 1995). So the project manager or client needs to consider the design period and plan carefully. The crude compressing of programmes carries a strong risk of a project performance gap developing, with a high risk of overrun (Brown, 2001). There is one possibility to condense the design period, that is by working in the same place. This is because co-location of the team could increase the quantity of the communication, as shown in this research, and consequently remove uncertainty and confusion between different participants. As the project manager in case two said "without working together, we could not sort out the problems quickly and finish our design in time".

The control of the requirement changes is also a key factor affecting communications. Requirement changes are the primary cause of failure for the project (Brown, 2001). This is especially the case for fast track projects, which are very sensitive to changes. One change can have many knock-on effects. The lead architect in case one complained that the changes of the requirements affected their ability to provide quality information in a timely manner, and when it passed a certain point, it was very difficult to cope with this.
in a fast track project. So the limitation of requirement changes has a positive impact on
the quality of the communications.

**Communication procedures**

Many researchers mention the importance of communication management in design
(Newton, 1995). Many professional design organisations make substantially less profit
than they could, due largely to the ineffective planning and control of design work. Under
these circumstances, design work tends to lack direction and may result in decisions
being in a sub-optimal order, leading to expensive, unforeseen discoveries towards the
end of the design process (Whitney, 1990). Successful design performance of large
multi-disciplinary projects requires an enormous amount of co-ordination to ensure that
all cross discipline interactions are facilitated and all parties are constantly aware of the
every changing state of the project. An accurate and workable design plan is one advance
that would facilitate this (Nicholson, 1993).

The research by Serpell (1998) of construction improvement indicates that the lack of
planning is a major reason of the waste caused by increasing number of construction
companies. He suggests a methodology of improvement that should include building a
communicating plan to personnel. An important function of any information management
system is a filtering mechanism that can strip away extraneous data ensuring only the
information required by individuals is received (NEDC Report, 1990).

When interviewing the participants, most of them thought that an agreed communication
strategy was very important for effective communication. There were no formal
communication strategies in any of the three cases. As a consequence, problems of
information flow occurred between different organisations (external communications).
However, this had a small impact on the communications within the single organisation
(internal communication). It also had no significant impact on external communications if
team members were familiar with each other in small projects and lead consultants had
strong capability in information management as in case three.
Protocols for IT

Information technology plays a very important role in the communication process of multi-disciplinary design (Anumba and Evbuomwan, 1999). So the management of electronic communication, especially managing drawings within a CAD environment is absolutely essential to facilitate the communication from one discipline to another (Newton, 1995). Day and Faulkner (1988) suggest that the layering of drawings can aid selective information transfer. For example, if an architect layers floor layouts properly, only the basic floor details should be transferred to a structural engineer to calculate the floor loads, rather than superfluous information such as floor finishes, furniture layouts, which may exist on the complete layout drawings. On a larger information management scale attempts are being made to improve the co-ordination of information between different CAD systems (Bjork, 1989).

According to Brown (2001), there are no significant problems in using CAD formats for internal organisation for current design. However it is a challenge for the wider distribution of CAD drawings between different organisations. He suggests that effort and subsequent cost and time are required from all parties to ensure the success of such knowledge distribution. In this study there were few problems in case two, because the CAD drawings were circulated in their own organisation, whilst case one and case three appeared to have a lot of problems between different organisations in compatibility, format, layer setting, line type, plotter setting and so on. Although the protocols were set for case one, it was not used friendly and ultimately failed. "We should not only put in the effort to make common protocols, and but also observe and adjust them throughout the project" said the lead consultants. So proper common protocols have a positive impact on the exchange of CAD drawings between different organisations.

9.5.2 Supporting environment

Herbert (2001) identified that appropriate information and adequate resources are two key factors in the project support environment during the process of the project. This research looks at how they affect the communication process.
In the three case studies, the inappropriate information from outside design team was mainly caused by the client, contractors and sub-contractors.

**Client**

Somogyi's (1999) study noted that the low quality of information from the client was one of the three most common reasons for contract failures, and this happened mostly with unsophisticated client (Salisbury, 1998). This also has been confirmed in the present work. In case three, the client was able to specify and express their needs to the consultants, whilst the client in case two had no experience of the project, causing the problems in the quality of the information provided. According to Brown (2001), some of these problems could be overcome through the consultants' advice and the communication with the client, in sense of promoting genuine understanding of the implication. The project manager in case two and the lead consultant in case one agreed that it would be better in the earlier stage for the design process if they could let the client know what are key parameters for the design process. These parameters should be accurate, complete and unchangeable.

**Contractors and sub-contractors.**

The study of the three cases indicated that late or inadequate involvement of contractor or subcontractor (specialists) had a negative impact on the quality and quantity of the communication, causing significant problems of integration with consultant’s design. The involvement of the contractors was dependent on the procurements and the form of management, as discussed above. For all the three cases, the involvement of main subcontractors or specialists was earlier than usual. However, for case one the involvement of M&E subcontractor was not early enough. For case two and case three, the involvement of the specialists was insufficient, as they were not been paid for their services. As a result, the information supplied to the consultants was primary and questionable in terms of accuracy and completeness. Most interviewees argued that it would be much better for the design communications if some subcontractors or specialists were brought into the design team from the start and paid for their consultancy. The clients in all the cases also indicated that this was worth thinking about.
One of the lead consultants in case one had good experience in a previous project worked with an M&E subcontractor, who was appointed as designer member during the design stage. As seen in case two, in order to co-ordinate their design with the civil subcontractor, the contractor appointed a civil engineer to the team. This civil engineer was a liaison person working with other disciplines. He not only passed the information to the sub-contractor but also represented the civil side at the meetings or in the discussions. Through him, the communication bridge was built between the two companies. Hence the design in the interface between M&E and civil design was well coordinated.

The case studies demonstrate that the high quality of brief, and early and adequate involvement of contractors and subcontractors can support design communications with appropriate information.

**Resources**

Newton (1995) claimed that problems on the information provided are prevalent in all engineering domains. Poor information can lead to missing, incorrect or unclear documents, which will contain insufficient details and conflicting and uncoordinated information. These deficiencies contribute significantly to major problems associated with the construction industry: technical defects, quality of the finished work, variations and claims, and late completion and overspending on projects. Without sufficient and correct information, people cannot make a sensible decision. Nowadays, most construction projects overlap design and construction phases. This increases pressure on designers to ensure that the project design is fully coordinated, accurate and issued on time.

Poor quality information was provided by the consultants in all of the three case studies. One of the reasons, as discussed above, could be related to inadequate resources at the early stages. The resourcing at the early stages of a project was acknowledged to be critical in many studies and guides including the latest Egan report. The project managers in the three cases complained about the lack of consultants. However, according to
Brown (2001), lack of resources, although a real problem to those noting this issue, is in
the total project context, somewhat illusionary. Accepting a level standardization and
adopting a 'right first time' principle has the capacity to release later resources frequently
spent in reworking. Therefore, he suggests that the consultants may achieve longer term
efficiencies by considering in greater depth the basis upon which the initial design is
based. The amount of redesign or rebuild in the three cases also indicated a lack of
resources in the early stage, which resulted in poor communication and design changes.
"We should put more resources earlier rather than later to produce the quality
information. This might result in spending less resource and money for the whole
project" said the lead consultant in case one.

Apart from the quantity of the resources, this study shows that the quality of resource is
also very important for the communication process.

Higher productivity is positively correlated with well-educated and trained employees.
Successful and profitable firms implement education and training programmes at all
levels of the organizations (Gushgarl et al., 1997). But usually the traditional training is
not enough. As studied by Sonnenwald (1996), at present, most of the design is
completed by individuals or groups of individuals who have been trained in one
engineering discipline with limited experience or knowledge in other fields of
engineering. In Gameson's research (Barrett and Males, 1991), he notes that at a practice-
based level, language differs between various professionals with their educational
backgrounds. The potential for misunderstanding between the individuals is great. In this
case study, one of the factors responsible for information overload was the lack of
knowledge of other disciplines. People sent a lot of information to each other and most of
it was useless. Obviously information overload can be reduced if each discipline has
some knowledge of others. This kind of knowledge can also help different participants
communicate in terms of understanding. For instance, in case one, the QS can easily
communicate with M&E subcontractor, because they employed a quality surveyor with
similar knowledge.
The capability of using IT has become a very important communication skill for consultants. Lack of the communication skills is the most common barrier to effective communication (Thamhain, 1992). The classic paper trail of design development in terms of scribbled sketches and ideas may be acceptable for designers, but it is not so helpful to most clients. Appropriate models and virtual reality are easier for client to read (Brown, 2001). The client in case three said that if the architect could use 3D model to show the design, they could know more clearly about 'the products' provided and would not ask the architect to change the drawings later. Case three also showed that applying new technologies could speed up the design and reduce the undesirable effect caused by the design changes.

The study indicates that well trained and sufficient resource can enhance the quality of the communications and the speed of design. It can reduce design changes and prevent information overload.

9.5.3 Project co-ordination
Design is a process of knowledge exploration, which needs both social collaboration and technical collaboration. In this process, communication including integration of specialized knowledge and negotiation of differences between domain specialists, has emerged as a fundamental component of the design process (Sonnenwald, 1996).

Social-coordination
The social process of design interacts significantly with the technical process of design. It is clear that teamwork is a social process, and therefore social interaction, roles and relationship cannot be ignored in the analysis of design activity performed by team. Many aspects of team design activity can be influenced by social process factors like some human issues (Cross and Cross, 1995). These issues are particularly important, because many individuals have different cultural backgrounds and motivations, different expectations and perceptions of quality and success, and different organizational constraints and priorities (Sonnenwald, 1996). The research by Thamhain (1992)
indicates that the problems contributing to poor project performance have one thing in common: they all stem from humanistic issues.

The studies of the three cases in the present work showed that the human issues, which support design communications from social dimension, mostly arose from the relationship and appreciation. Sometimes they were influenced by the type of contracts, and sometimes they were influenced by the nature of personality or by the traditional culture in design organizations. The case study showed that the relationship and appreciation between team members could be improved through partnering method as in case one or informal activities like “Friday lunch” in case two. This improvement helped build a friendly environment, reducing the communication barriers and misunderstanding.

**Technical co-ordination**

Construction design has become an increasingly complex synthesis activity for which effective solutions depend upon co-operative participation by a number of people (Pietroforte, 1997). This has increasingly explored technical information from a variety of disciplines for designers. Thus communication has emerged as a necessary component of the design process (Sonnenwald, 1996).

In the three case studies, the relationship between distance and design communications has been explored using social network analysis. It shows that co-location of the design team (key specialists) can enhance the quantity of the communication. According to the empirical research by Willem (1996), when the amount of communication increases, the design performance, in quality, is better in the “vague” characteristics of the earlier design stage. The results in the present research also demonstrate that the quality of communications in terms of communication variables is improved by co-location working.

Co-location provides more opportunities for face-to-face talking, especially in an informal style. Because of design characteristics, drawings are clarified with requests for
clarification, such as meetings. These types of synchronous communication media are used for reducing information uncertainty and negotiating the intents of the above-mentioned documents (Pietroforte, 1997). Communication about ambiguous or ill-defined situations, e.g. those occurring during the design process, requires the use of rich and iterative media such as face-to-face talking (Daft and Lengel, 1986). According to Murray et al (2000), face-to-face discussions have one of the highest frequencies of interpersonal channels between two co-operating organisations in the period of uncertainty. His research supports the view that when organisational problems occur, people rely on informal channels (face to face) to obtain required information. Most interviewee agreed that working in the same place could remove uncertainty and resolve equivocality, thus increasing the degree of collaboration.

The case studies also indicated that co-location has big advantages for complicated and fast track projects like case one and case two, but it has no apparent advantages, in terms of cost, when the project is small like case three. In case three, the consultants are located closely and the meetings can be held easily like case three. As for a project involving members from abroad like case two or a big international project, it is required to balance the time and cost between working together in certain period and using videoconference for design communications. However, according to the view of most consultants in case one and case two, it is still necessary to hold certain meetings even if using videoconference. Because the behaviour is different between sitting together and seeing each other through videoconference, face-to-face contacts in the same place are more effective than those in videoconference.

Face to face talking, through co-location work or regular meetings, can enhance the quality of design communications and remove information uncertainty, thus increasing the degree of technical exploration and collaboration in complex synthesis design activity.
Key project personnel

Key project personnel, identified as the project manager, design manager, and design discipline leaders (Chapman, 1999), are regarded as the intergroup communication stars (Sonnenwald, 1996), and play a very important role in design co-ordination. They represent their group in these interactions, co-ordinating activities and strategies across groups in the design team. Discussion topics include results, failures, unexpected events and alternative plans. The impacts of changes in these communication stars on the design communications have been studied in this research. The results, which confirmed Chapman's research in 1999, show that changes in personnel break the dialogue between design participants, and cause a loss of knowledge of the historical development of the project. Project information is also so voluminous and complex that it cannot be passed in totality from one individual to another as in case one. Although it was not a big issue for small project like case two, it still affected design communications.

The case studies also show that the capability of key project personnel in information management has a significant impact on the design co-ordinations. This is particular important for big and complicated projects, especially for those whose information management is computerised. As described in case one, the project leader had experience and realised the importance of key project personnel in information management. The client is now considering the addition of a new criterion - the capability of key personnel in information management, when they set up a team for the next project. Facing the challenge, the leader of consultants and the contractor indicated that they would pay attention to the management and organise more training including IT knowledge and knowledge of other disciplines for senior personnel.

Therefore the stability of key personnel and the capability of key personnel in information management play an important role in communication coordination activities.
9.6 Summary

In this chapter, communication issues have been examined across the three cases simultaneously. The cross-case examination included the cross-case discussion and cross-case conclusion. Based on these, a communication model has been developed.

This model consists of two parts. Firstly the variables of communications and monitoring tools. Secondly the communication strategies and at which stage they are applicable. These strategies, which were developed from the case studies, have positive impacts on the communication variables, making communications between team members more effective. Combining these two parts may ultimately improve the quality of construction design outcomes and make the project design successful.

The two parts in the model have been discussed separately. The second part, in particular, is discussed in detail. The model has two functions: the strategies accompanying operation conditions may be used as a guide for setting up project design in terms of team communication and as a practical way to influence the variables of communication in positive side; and any problems present in the variables of communication, which are found by the monitoring tools during the project, can result in a review of the strategies and then resolutions can be proposed to improve the communications.
Chapter Ten
Conclusions and Future Work

10.1 Conclusions
Numerous studies have highlighted the importance of effective communications for design success (Thomas et al., 1998). The aim of this present research was to investigate how construction design can be made more effective through a comprehensive study of design communication issues and problems. Therefore the research questions for this study were proposed as follows:

- What are critical variables of effective communication in construction design?
- What are the communication issues and problems in current construction design?
- How do they occur?
- And why?

To answer these questions, a questionnaire survey was initially conducted to investigate communication issues and problems, which were highlighted in the literature review, in current construction design. A number of organizations involved in construction design were identified and questionnaires were distributed to personnel who are frequently involved in internal or external communications regarding the design process. The Statistical Package for Social Scientists (SPSS) version 8.0 was employed to analyse the data returned for statistical analysis, such as frequency distribution and ranking. Through this analysis, a picture of communication in the current construction design emerged. It shows that effective communication in design plays a very important role in both design and construction processes. The procurement route significantly affects the communication process, especially for external communication. There are a number of common issues and problems in communication between those involved in the design process. These problems occur in the aspects of the communication variables and information flow, and appear frequently in both internal and external communication processes. The problems may seriously impact the construction design, and happen more often at certain stages of the design and construction processes, such as detail design and
operations on site. IT has been extensively used in design communication and it is moving towards an increased usage.

To gain further insights into these issues and problems, detailed case studies were proposed. Case studies were carried on three different projects characterised with different procurements, different subjects, different size, and different stages. Two rounds of questionnaire surveys and interviews were held in each case. The quality and quantity of communications have been evaluated for each round survey of the three cases by using the analysis of content, communication variables (check tool-COMAPSS), information flow (check tool-ITCHECK), and social network (check tool-UCINET). The main factors, which could affect the communication process, have been identified for each case. Through the discussion and comparison of the three cases, the cross-case conclusion has been made for the communication influence factors in terms of replication logic or special features of each case. The conclusions indicate that communications during the construction design are influenced by

- procurement method;
- communication system;
- client;
- contractors and key subcontractors (specialists);
- resource;
- social collaboration;
- technical collaboration and
- key personnel

In relation to the influencing factors, the communication strategies have been proposed. These strategies, which were developed from the case studies, have positive impacts on the communication variables, making communications between team members more effective. The strategies are:

- proper choice of procurement;
- well arranged programme;
limited requirement changes;
agreed communication procedures;
common protocols for IT use;
high quality brief;
well trained and sufficient resource (personnel);
early and adequate involvement of contractors and subcontractors;
friendly environment;
co-location design;
regular face-to-face meetings; and
key personnel stability and capability in communication.

Based on the results from the case studies and the relationship between variables, influencing factors and communication strategies, a model of communications in construction design has been developed. The model consists of two parts (Fig. 9.2). One is about the variables of communications and check tools. The other is about the communication strategies and at which stage they are applicable.

The model has two functions: the strategies accompanying operation conditions may be used as a guide for setting up project design in terms of team communication and as a practical way to influence the variables of communication in positive side; and any problems present in the variables of communication, which are found (monitored) by the check tools during the project operation, can lead to a review of the strategies and then resolutions can be proposed to improve the communications.

Combining the variables and check tools with the strategies may help participants communicate more effectively and ultimately improve the quality of construction design outcomes, as shown in Fig. 9.2.

**10.2 Limitations**

As with all research, the findings have limitations. Three main limitations are evident, and give rise to scope for future research. The first limitation is the applicability of the
results to the construction design as a whole. Generalisability is a recognised limitation of the case study methodology, although it could be argued that through the replication of the model in the three cases and the two cross-sectional surveys the results could be applied industrially.

The second limitation is the range of the projects investigated. Although three different types of project were investigated, other types were not covered within the findings. These were insufficiently presented within the data to incorporate in any findings. Nevertheless their absence does not allow the conclusion and the communication model to be inclusive of all kinds of projects that could arise in the construction design.

The third limitation is from the study of communication itself. According to Hunter (1993), the study of communication is an inexhaustible one and the construction industry is so diversified and fragmented that a study of communications in design and construction always leaves unexamined areas or sections requiring further review. This research is based on an industry questionnaire and three different case studies. To draw a comprehensive picture on the communication issues, one needs to follow the projects through the whole process of each project for communication auditing (Derbyshire, 1972). Clearly, a longitudinal study would provide a greater understanding of the communication issues. A longitudinal study, however, necessarily involves a considerable time and access to key participants on the part of the researcher (Wallace, 1987). To observe the communication process across multiple design phases with a longitudinal study becomes difficult due to time limitation. Owing to the fact that as a PhD research project, the available time and the accessibility to the site are both limited, cross-sectional observation of the process in three cases was only conducted in this work. In addition, the participants involved and some documents are confined. Therefore, the picture acquired from this study may not be comprehensive and deep enough.

As for analysis tools, the Compass program developed by the CII has excellent potential for assessing and identifying communication problems on the project, but the program should be re-evaluated, particularly in regard to commercial building projects. Anomalies
that developed in the course of this research suggest that questions pertaining to the procedures and variables may not be a valid indicator of the project communication performance (Mead, 1999). The Social Network program is a valuable tool for analysing the project communication network. It may evaluate the quantity of communication on the basis of communication frequency matrix filled by the participants. However, this could lead to a discrepancy between the analysed result and the practice if the participants did not pay great attention to it.

10.3 Recommendations for future work

The following recommendations are made for future research:

- Carry out a longitdinal study on communication to build up a complete and continuous picture from inception to completion, and fully involved in several representative design and construction projects, in order to obtain more valuable and reliable information about communication in design and construction,
- Extend the research to include cases of other procurements and different stages, so that these may be verified and incorporated into the conclusion,
- Quantitative studies to underpin and generalise the research findings across a broad spectrum of construction design,
- Investigate the identified effects and model quantitatively to determine the relative strengths and extents of these factors,
- Evaluate how new technologies affect relationships, how attitudes may be changed and finally, the means of integrating new technologies into the construction design environment to such an extent that the interface is virtually seamless.
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Appendix A

The descriptions about the importance of communication for the design and construction processes
Communication is considered central to any relationship, and the establishment of effective communication protocols between collaborating parties is therefore essential (Anumba and Evbumwan, 1999).

The Emmerson Report (1962) highlighted the vital importance of effective communication of information amongst the various participants of a project.

Each discipline (designer) will have its own viewpoint on the most suitable solution for their requirement; co-ordination and communication is needed across the disciplines to reach a compromise suitable to all in such a situation (Newton, 1995).

Communication and co-ordination are called for to resolve any disagreements or conflicts that arise (during the design) (Peng, 1994).

Concurrent engineering practices are successful, only by eliminating unnecessary change and redesigns and by facilitating cross-functional teamwork based mutual communication supported with integrated product life cycle knowledge (Tomiyama, 1998).

Throughout a project, relevant information must be identified and disseminated among team members. Project performance can be enhance through the implementation of effective project communications and conversely, projects can fail if hindered by poor communication. Thus the project team communications is one of the major challenges to a project success. Numerous studies have highlighted the importance of effective communications for project success. (Thomas et al., 1998).

It is generally recognised that importance of information exchange between interdisciplinary design teams and among individual team members. The success of CE may largely depend on the effective communication of currently relevant engineering information. Communication play a major role in concurrent engineering environments (Knoop et al., 1996).
To take advantage of concurrent engineering, there is the need for effective communication” at all levels within the design and construction. (Anumba et al. 1997).

Team and communication skills are equally as important as their technical specialty skill, and the most important skill/trait needed to achieve high positions in construction organizations. The single most important factor that contributes to successful project management is communications (CII, 1986, 1987, 1992).

Through a survey to 500 engineering firms throughout the United States, Gushgari, et al (1997) found “communication is ranked as the most critical skill...attributable to long term profitability”.

The disparate technical and cultural aspirations of the design disciplines whose lack of a shared language prohibits their creative contribution without communication methods which unite them in shared objectives (Dowson, 1972 ).

The lack of communication of design intent and rationale which leads to unwarranted design changes, unnecessary liability claims, increase in the design time and cost, and inadequate pre- and post-design specifications. (Evbuomwan and Anumba, 1998).

Cocurrency in an integrated design and construction process requires greater discipline in the production, manipulation, storage, and communication of project information. Effective communication is vital for the success of concurrent engineering in construction (Anumba and Evbumwan, 1999).

The raw material of design is information. This information flow through all design activities and is the basis for decision-making. Effective communication (the conveying of information) is therefore critical to the work of a designer (Library Edition, 1997).
Appendix B

The classification of the descriptions about the communication
Higgins and Jessop, (1965) and Hunter(1993) in their research point out the problems associated with the design communication in building industry as follows.

1. There is not full understanding and agreement between them (Understanding).

2. The Architect fails to explain the limitations imposed on the client's needs, and the client is not fully informed of all the possibilities of meeting his needs (Understanding, Completeness, underload)

3. The architect-leading designer, fails to delegate duties to other members of the design team, leaving the burden of the design on himself and some aspects of building such as technology and costing which he might not be able to cope with alone. (Understanding, Procedures)

4. There is not always full understanding and agreement between the participants at feasibility stage. (Understanding, Accuracy, Completeness, Barriers)

5. There is the problem of a lack of continuous intercommunication between interdependent activities. (Timeliness, Underload)

6. It is suspected that an excessive amount of information communication occurs without following up with formal communication such as written documents to confirm the trivia that has passed between (Procedures)

7. A problem at scheme design related to the client is that of obtaining his approvals, because of inadequate communication and confirmation at the investigation and briefing phases. (Underload)

8. A communication problem which may arise at construction stage could be due to geographic location. It is not uncommon for the designers to be in a different country from the client. (IT)

9. Although there will always be representatives of the designers at site meetings some queries might arise regarding the design that will not be easily or accurately answered. (Accuracy, Completeness)
10. Cost control could also be a problem if the client has not adequately communicated his requirements on this matter. (Underload)

11. The means of ensuring design co-ordination is often not clear. If the intercommunication problems of the design team were analyzed in operational terms, more effective and rapid techniques could be devised for solved them. (procedure, IT )

Most companies recognise the importance of communication skills. they look for these skills in potential applicants and are likely to assess them when considering employees for salary increases or promotion. (Hamilton et al, 1997). (Accuracy, Barriers).

Communication skills are as important to the professional engineer as any of the technical and scientific skills more often associated with engineering undergraduate courses. They are also as vital to the engineer as to the business executive whose education and training places a much greater emphasis on those skill. (Hamilton et al, 1997). (Accuracy, Barriers).

The professional engineering designer must be able to understand the spoken and written word, quickly discern the message and formulate a response. He must be able to write quickly, accurately, grammatically and persuasively to a defined target audience and to speak coherently and with conviction to individuals or group audiences at all stages of the design activity. (Hamilton et al, 1997). (Understanding, Accuracy, Completeness).

Poor organizational structure results in inadequate representation of project stakeholders contributing to a lack of essential information. Too many layers of organization can be equally bad “... as the number of organisation filters increase with the levels of organisation” (Thomas, 1998). (Barriers)
The success of CE may largely depend on the effective communication of currently relevant engineering information, whereas data irrelevant at that point in time should be shielded (Knoop, et al, 1996). (Accuracy, Completeness).

Although CE is most urgent for the initial design phases, little is known about types and content of communicated information during these phases. (Knoop, et al, 1996). (Procedures).

Language is often the most common barrier to effective communication (Sigband and Bell, 1989) (Barriers).

The product performance during design, in terms of quality, is better when the (relevant) amount of communication increases (Knoop, et al, 1996). (Completeness).

Effective communication is essential and communication is not just giving of information; it is the giving of understandable information and receiving and understanding the message. (Erye and Med, 1979) (Understanding).

Communication effectiveness depends not only on the interchange between them participants, but more importantly, the understanding between them. (Thomas et al. 1998). (Understanding).

It is extremely important to determine which organizational characteristics affect communication problems (Guevara and Boyer, 1981). (Barriers).

Each manager or supervisor cannot perform his or her functions efficiently without accurate, timely and relevant information on which to base decision (Tenah, 1986). (Accuracy, completeness, timeliness)

In the Appropriate Project Characteristics Survey for design-build project procurement, which have done by Songer and Molenaar (1997), Two characteristics that have the highest impact on project success are well-defined scope and shared understanding of scope. (Procedures, Understanding).
Serpell and Alarcon (1998) applied the *Waste identification survey* tool to obtained results about causes of waste from the project waste surveys, the result indicate that three of the waste causes are correlated with information: Unclear information, Late information, information quality problems. In their *quality survey*, the Unknown work procedures is the second serious causes for quality problems. (Accuracy, Completeness, Timeliness, Barriers, Procedures).

In any design task, information relevant to the task has to be gathered from a variety of source (Cross and Cross, 1995). (Completeness).

Gathering and sharing of information that any design team would have to undertake (Cross and Cross, 1995). (Understanding).

The ill-defined nature of design problems means that analyzing and understanding the problem is an influential part of the design process. A team has to reach some shared or commonly held understanding of the problem. Again, in teamwork it will be necessary to communicate and share such concepts and ideas (Cross and Cross, 1995). (Understanding).

A significant aspects of teamwork would be the using and sharing of the available work-media (Cross and Cross, 1995).

A disadvantage of teamwork is likely to be that conflicts will arise between team members. Different interpretations or understandings of the problem may become evident; different design concepts may be favored by different members of the team (Cross and Cross, 1995). (Barriers).

Accelerating the whole construction process puts added pressure on designers to ensure contract documents are fully co-ordinated, accurate and issued on time... Many of design conflicts arise from poor co-ordination, not only within the design team but between design and construction. Poor co-ordination leads to omissions...The prompt arrival of vendor information and ensuring the scope of the project is accurately defined in the client's brief also becomes more significant as the
schedule is compressed... large numbers of designers per project, each with narrower specialties and responsibilities are now the norm on modern day design projects. These two effects have not been conducive to co-ordination and communication within the design team...A building are so interdependent that although a clearer understanding has evolved of the science of the these components, their combined design has become more complicated, Steward, (1981) confirms to this view by stating that technology that is now only advancing by the improved understanding...It is also essential that team members know how others use cross-information and how, and in what form, they require it to be structure. (Newton, 1995) (Accuracy, Barriers, Timeliness, Procedure, Understanding).

The availability, reliability and ease of assimilation of project information are known to be critical to the effective pricing, planning and execution of building design work (CPI, 1987) (Accuracy, Completeness, Timelines, IT).

Problems can be heightened if disciplines don’t have an understanding of the technology, terminology and philosophy of another disciplines work (Cooper & Jones 1993, Stockburger 1993) and is often impeded by architects and engineers jealously guarding their professional territory (Day & Faulkner 1988). (Barriers).

The design engineers spend between 20% and 30% of their time searching for and handing information, thus reducing the time available for actual ‘engineering’ or problem solving. (Noble, 1989). (Accuracy, Completeness).

Poor information management can lead to missing, incorrect or unclear document which will contain insufficient details and conflicting and unco-ordinated information. (Newton, 1995). (Procedures).

Full and free information for all members of the design team is an appealing idea (Tenah, 1984), but the proliferation in quantity of information and documentation in modern construction work makes this an impractical ideal (Bhandari, 1978). (Overload).

Too much information, known as information overload, have a detrimental effect on
design output, resulting in an increase in design error rate, inappropriate
generalizations and even the total avoidance of information. (Newton, 1995)
(Overload).

Computer Aided Draughting and Engineering (CAD and CAE) have the potential to
manage design information more efficiently (Wix, 1986) (IT).

Computer Supported Co-operated work software enables people to work remotely at
the same time on identical screen material using tools such as a share
whiteboard…multimedia meeting is virtually the ultimate in interactivity between all
the parties to the construction project. All participants in a complex distributed
construction project can communicate as effectively as if they were infect together in
one place in time (Hunter, 1993). (IT)

The Internet will be used to form virtual organisations where resources are levelled
through timely communication, and design and construction time scale will be
reduced through the collaborative sharing of project information (Mitchell, 1993) (IT,
Timeliness)

Information overload is large problem in the construction business. When the intranet
system is used improperly, the information overload appear. (Mead, 1999) (Overload,
IT).
Appendix C

Questionnaire survey on the communication processes in construction design
QUESTIONNAIRE SURVEY

Respondent’s Name: ____________________________

Date of Interview: ______________________________

QUESTIONNAIRE ON THE COMMUNICATION IN CONSTRUCTION DESIGN
SECTION- A  GENERAL INFORMATION

A.1 What is the name of your firm/organisation?

A.2 Which of the following describes your organisation most appropriately?

☐ Client/Owner
☐ Main-contractor
☐ Sub-contractor
☐ Design organisation

A.3 What is the turnover per annum of your organisation? (in £ millions)

<10 10-20 20-30 30-40 40-50 >50

A.4 (1) What is your position in your company?

A.4(2) What are your main duties and responsibilities?

A.5 In what kind of construction is your company generally involved?

☐ Building
☐ Civil Engineering
☐ Civil and building
☐ Other (please specify)
A.6 Under which form of procurement do you usually take on/let work? (please tick as Many as you appropriate)

- Traditional
- Design and Building
- Management contract
- Other (please specify)

SECTION-B DESIGN COMMUNICATION ISSUES

B.1 From your experience, how important is effective communication on design during the design/construction process?

- Critical
- Very important
- Important
- Fairly important
- Unimportant

B.2 To what extent does the procurement route affect the communication process?

<table>
<thead>
<tr>
<th>Internal Communication</th>
<th>External Communication</th>
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<tbody>
<tr>
<td>Highly significant</td>
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<tr>
<td>Significant</td>
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<tr>
<td>Somewhat significant</td>
<td>Somewhat significant</td>
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<tr>
<td>Not too significant</td>
<td>Not too significant</td>
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<tr>
<td>Not at all significant</td>
<td>Not at all significant</td>
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</tbody>
</table>

B.3 (1) Do you/your company experience communication problems related to design during the design/construction process?

- Always
- Usually
- Sometimes
- Rarely
- Never
(2) How serious are the problems?

- [ ] Very serious
- [ ] Serious
- [ ] Somewhat serious
- [ ] Not too serious
- [ ] Not at all serious

(3) At which level do these problems usually occur?

- [ ] Internal communication
- [ ] External communication
- [ ] Both of them

(4) At which stage of the design/construction process do most of these problems occur? (please tick as many as appropriate)

- [ ] Inception and Feasibility
- [ ] Outline Proposals
- [ ] Scheme Design
- [ ] Detail Design
- [ ] Production Information and Bills of Quantities
- [ ] Tender Action
- [ ] Project Planning
- [ ] Operations on Site and Completion

B.4 How important are the following variables to a successful communication in construction design (use 1 to 5; 5 represents the most important)?

a. Accuracy of information
b. Timeliness of information
c. Completeness of information
d. Understanding of information*  
  e. Barriers**
f. Procedures
g. Others (please specify)

*Understanding the information received or expected from other people.
**Aspects that interfere with communication, Such as interpersonal, accessibility, logistic, or others.**

B.5 How frequently do you receive inaccurate information related to design in the design/construction process?

- Always
- Usually
- Sometimes
- Rarely
- Never

B.6 How frequently do you receive late information related to design in the design/construction process?

- Always
- Usually
- Sometimes
- Rarely
- Never

B.7 How frequently do you receive incomplete information related to design in the design/construction process?

- Always
- Usually
- Sometimes
- Rarely
- Never

B.8 (1) Are there communication strategies in the projects where you are involved during the design and construction phase?

- Yes
- No

(2) Do you think whether it is necessary to have communication strategies in the design and construction?
B.9 (1) How well do you usually understand the information received from other people?
(2) How well do you usually understand the information required by other people?

<table>
<thead>
<tr>
<th>Information received</th>
<th>Information required</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Very well</td>
<td>□ Very well</td>
</tr>
<tr>
<td>□ Well</td>
<td>□ Well</td>
</tr>
<tr>
<td>□ Somewhat well</td>
<td>□ Somewhat well</td>
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<tr>
<td>□ Not too well</td>
<td>□ Not too well</td>
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<tr>
<td>□ Not at all</td>
<td>□ Not at all</td>
</tr>
</tbody>
</table>

B.10 How easy do you think it is to communicate with staff internally and externally about design?

<table>
<thead>
<tr>
<th>Internal Communication</th>
<th>External Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Very easy</td>
<td>□ Very easy</td>
</tr>
<tr>
<td>□ Easy</td>
<td>□ Easy</td>
</tr>
<tr>
<td>□ Somewhat easy</td>
<td>□ Somewhat easy</td>
</tr>
<tr>
<td>□ Not too easy</td>
<td>□ Not too easy</td>
</tr>
<tr>
<td>□ Not at all easy</td>
<td>□ Not at all easy</td>
</tr>
</tbody>
</table>

B.11 (1) How frequently do you/your company get more information than is needed?
(2) How frequently do you/your company get less information than is needed?

<table>
<thead>
<tr>
<th>Information overload</th>
<th>Information underload</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Very frequently</td>
<td>□ Very frequently</td>
</tr>
<tr>
<td>□ Frequently</td>
<td>□ Frequently</td>
</tr>
<tr>
<td>□ Sometimes</td>
<td>□ Sometimes</td>
</tr>
<tr>
<td>□ Rarely</td>
<td>□ Rarely</td>
</tr>
<tr>
<td>□ Not at all</td>
<td>□ Not at all</td>
</tr>
</tbody>
</table>

B.12 (1) A Gatekeeper is an individual so located as to control information flow
through a communication channel. How important is this role?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>□</td>
<td>Critical</td>
</tr>
<tr>
<td>□</td>
<td>Very important</td>
</tr>
<tr>
<td>□</td>
<td>Important</td>
</tr>
<tr>
<td>□</td>
<td>Fairly important</td>
</tr>
<tr>
<td>□</td>
<td>Unimportant</td>
</tr>
</tbody>
</table>

(2) How frequently do the problems in information management occur due to gatekeeping?

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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>□</td>
<td>Very frequently</td>
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<tr>
<td>□</td>
<td>Frequently</td>
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<tr>
<td>□</td>
<td>Sometimes</td>
</tr>
<tr>
<td>□</td>
<td>Rarely</td>
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<tr>
<td>□</td>
<td>Not at all</td>
</tr>
</tbody>
</table>

**B.13** How frequently do you/your company receive or send changed in meaning or lost in some contents during its dissemination?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>□</td>
<td>Always</td>
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<tr>
<td>□</td>
<td>Usually</td>
</tr>
<tr>
<td>□</td>
<td>Sometimes</td>
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<tr>
<td>□</td>
<td>Rarely</td>
</tr>
<tr>
<td>□</td>
<td>Never</td>
</tr>
</tbody>
</table>

**B.14** Do you think what are the reasons for the communication problems mentioned above?

**B.15 (1)** What kind of computing or communication technology (IT) does your
company use?

<table>
<thead>
<tr>
<th></th>
<th>Already Uses</th>
<th>Considers for future use</th>
<th>Does not consider using</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CAE</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>E-mail</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Videoconference</td>
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<tr>
<td>Intranet</td>
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<tr>
<td>Local and wide area networks</td>
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<tr>
<td>Document Control System</td>
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<tr>
<td>Cost Management System</td>
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<tr>
<td>Others (please, specify)</td>
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</tbody>
</table>

(2) How much of the design communication uses these technologies (as opposed to traditional one)

0-20%  20-40%  40-60%  60-80%  80-100%

(3) How useful is IT for communications about the design during the construction/design process?

- No at all benefit
- Not too benefit
- Somewhat useful
- Useful
- Very useful

B.19 Apart from the issues mentioned above, please write down any other communication issues or problems you usually meet during your work.

Thank you for completing the survey
Appendix D

Communication Patterns Survey
Please place a check mark in the appropriate box of the following sheets

<table>
<thead>
<tr>
<th>How often do you interact with this person on the design related activities?</th>
<th>Several Times Each Day</th>
<th>Daily</th>
<th>Several Times Each Week</th>
<th>Once a Week</th>
<th>Bi Weekly</th>
<th>Assessment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client (Grosvenor)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steve Brewer</td>
<td></td>
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<tr>
<td>Hunter Finlayson</td>
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<tr>
<td>Andrew Sharpe</td>
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<tr>
<td>Harry Algar</td>
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<tr>
<td>Main-Contractor (Laing)</td>
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<tr>
<td>Malcolm Nelson</td>
<td></td>
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<tr>
<td>Sean Cambridge</td>
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<tr>
<td>John Hornsby</td>
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<tr>
<td>Graham Wilcock</td>
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<td>Bill Mayhew</td>
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<tr>
<td>Architects (Lyons+Sloman+Hoare)</td>
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<tr>
<td>David Hicks</td>
<td></td>
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<tr>
<td>Alan Waring</td>
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<tr>
<td>Luke Rose</td>
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<td>John Wells</td>
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<td>Steve Hunt</td>
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<tr>
<td>Ed Ellert</td>
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<tr>
<td>Quantity Surveyor (BDB)</td>
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<tr>
<td>Ray Burch</td>
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<tr>
<td>Mike Fletcher</td>
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<td>James Piggin</td>
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<tr>
<td>Structural Engineer (WBP)</td>
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<tr>
<td>Cliff Turnbull</td>
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<tr>
<td>David Robison</td>
<td></td>
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<tr>
<td>Lee Leistone Jones</td>
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<tr>
<td>Gareth Davies</td>
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<table>
<thead>
<tr>
<th>Services Engineer (WSP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rob Gregory</td>
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<tr>
<td>David Kosterno</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Landscape Architects (HED)</th>
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</thead>
<tbody>
<tr>
<td>Ian Hodder</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub-contractor (Kvaerner)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D Lake</td>
</tr>
<tr>
<td>M Poole</td>
</tr>
<tr>
<td>M Dawes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub-contractor (Rowan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G Robinson</td>
</tr>
<tr>
<td>P Marshall</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic/Highways Consultant</th>
</tr>
</thead>
<tbody>
<tr>
<td>D Hodson</td>
</tr>
<tr>
<td>P Soper</td>
</tr>
</tbody>
</table>

* Give assessment of the quantity of the communication, for example, 0=Not enough communication, 1=Enough communication, 2=Too much communication.
Appendix E

Communication and Information Flow Variables Survey
Please answer the following questions concerning the communication issues on the design of this project in current stage. Remember that all responses will be kept in confidence.

1. What is your present position in your company and this project?

__________________________________________________________________________

2. What are your main duties and responsibilities?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

3. How often do you receive conflicting instructions from more than one person?

☐ Usually
☐ Sometimes
☐ Seldom
☐ Never
☐ Don't know

4. How often does poor communication or lack of coordination occur in your job?

☐ Frequently
☐ Sometimes
☐ Not too often
☐ Not at all
☐ Don't know

5. (1) Does this project have written procedures/practices for your work scope?

☐ Yes
☐ No
☐ Don't know

(2) How effective are these procedures?

☐ Very effective
☐ Somewhat effective
☐ Not too effective
☐ Not at all effective
☐ Don't know
(3) Is the procedures/practices being used?

☐ Always
☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don’t know

6. How often are you kept current with:

6.(1) Design Changes

☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don’t know

6.(2) Schedule Changes

☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don’t know

7. Do you feel you have adequate access to the people with the information necessary for you to perform your job?

☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don’t know

8. How well do you understand the information your supervisor (those above you) and other groups/other organisations on this project expect from you?

<table>
<thead>
<tr>
<th>Supervisor</th>
<th>Other groups/other organisations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very well</td>
<td>Very well</td>
</tr>
<tr>
<td>Somewhat well</td>
<td>Somewhat well</td>
</tr>
<tr>
<td>Not too well</td>
<td>Not too well</td>
</tr>
<tr>
<td>Not at all well</td>
<td>Not at all well</td>
</tr>
</tbody>
</table>
9. How often do you receive less information than you need (i.e., how often do you experience information underload)?

☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don't know

10. How often do you receive more information than you need (i.e., how often do you experience information overload)?

☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don't know

11. Do you receive necessary feedback on the information in time, which might affect your current work?

☐ Yes
☐ No

12. How often is the information you receive or send changed in meaning or lost in some contents during its dissemination?

☐ Usually
☐ Sometimes
☐ Rarely
☐ Never
☐ Don't know

13. A Gatekeeper is an individual so located as to control information flowing through a communication channel. How well the Gatekeepers act as this role in the current stage.

☐ Very well
☐ Well
☐ Somewhat well
☐ Not too well
☐ Not at all
Please answer the questions 14, 15 and 16 in the separate sheets provided

14. Comparing with other project, is the communication on the design of this project between the participants good or not good at the current stage?

15. Are there any problems associated with a computing or communications technology currently in use, or problems having the potential to be solved with such technologies.

16. Overall, how effective do you think communication is on this project in this stage?

☐ Very effective
☐ Somewhat effective
☐ Not too effective
☐ Not effective at all

Thank you for completing the survey
Appendix F

Data sources for chapter six
<table>
<thead>
<tr>
<th>No</th>
<th>Statement</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The initial scheme is totally different now, the whole thing grows and grows. Since December 1999, there have been 481 requirement changes, most of them have a very significant impact upon the design process... These changes affect our ability to provide the quality of information in a timely manner, and when it passes a certain point, it is very difficult to cope with.</td>
<td>Lead architect. First interview</td>
</tr>
<tr>
<td>2</td>
<td>Information as specific part of communication is poor. It is often late, and is not good quality. There are a lot of design changes... When we come to work out the actual construction details, the drawings don't quite work which has caused a lot of coordination problems. It involves a lot of additional cost, because of the delays.</td>
<td>Associate director from client. First interview</td>
</tr>
<tr>
<td>3</td>
<td>Inaccuracy or incomplete information affected us a lot. We tried to budget, we didn’t get all the picture. We tried to provide some information for the tenders, we didn’t have the complete information. As a result, the price risk was very high... In terms of the design information provided, I can’t figure out any one package, or one area that has been good.</td>
<td>Lead QS. First interview</td>
</tr>
<tr>
<td>4</td>
<td>We suffered a lot from other disciplines which overturned the original design, which was already agreed. This was not good for the co-ordination necessary for trying to achieve timely information release.</td>
<td>Architect1. Second interview</td>
</tr>
<tr>
<td>5</td>
<td>When we produced the construction information, we had a lot of information from the architect, and the mechanical/electrical engineer. What happened was that information used at that time, had changed. That made the incorrect information for construction, and the structural design had to be changed to accommodate it.</td>
<td>Lead structure engineer. First interview</td>
</tr>
<tr>
<td>6</td>
<td>The main problems are that we did our design on the structure drawings, which then changed. They didn’t take into consideration our design. They just ignored us, so we had to redesign to fit the structure.... Sometimes the architects don’t understand why we need certain space for the equipment and it is very difficult to change their minds.</td>
<td>Service engineer. First interview</td>
</tr>
<tr>
<td>7</td>
<td>Design information is late and is often not of the quality and in sufficient detail to allow the contractor to be able to do its work. The drawings arrived 3 or 4 weeks late. When the contractor opened the drawings, there was a lot missing. Then they had to go back to the design team to get answers... late delivery of steel frame information caused 5 weeks construction delay.</td>
<td>Project director from main contractor. First interview</td>
</tr>
<tr>
<td>8</td>
<td>Most of our working drawings in the core area, which were based on the original design of consultants, are wasted and need to be done again.... We should finish all cores in November. But we can’t start yet and some of them are delayed by 45 weeks. When the changes came, in many areas, we had to take out what had been fabricated, erected or even completed. It wastes a lot of work and money.</td>
<td>M&amp;E subcontractor. First interview</td>
</tr>
<tr>
<td>9</td>
<td>Sometimes the requests for detail information were not very clear, therefore it was difficult to give the answer</td>
<td>Steel subcontractor. First interview</td>
</tr>
<tr>
<td></td>
<td><strong>Procurement</strong></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>When the contractor was on board, they want the information immediately. But we haven’t started to design, we have not got enough time to develop them and to co-ordinate the information, before we issue them to the contractor, so it inevitably causes problems.</td>
<td>Lead architect. First interview</td>
</tr>
<tr>
<td>11</td>
<td>It was too tight for the design team to prepare their design. Each discipline worked on the basis of the information which has not been developed in the appropriate levels by others.</td>
<td>M&amp;E subcontractor. Second interview</td>
</tr>
<tr>
<td></td>
<td>The design went so fast that the co-ordination did not happen in the same sequence. What should have happened, was that the architect should have had a fair amount of layout drawings prepared before the engineer got hold of them. The architect should have worked with the engineer combining with service map to get a point before steel work was fabricated...... Obviously there was a lot of back and forth”</td>
<td>Project director from main contractor. First interview</td>
</tr>
<tr>
<td>Page</td>
<td>Text</td>
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<td>------</td>
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<tr>
<td>12</td>
<td>This short programme brought a lot of difficulties for the service engineers. They were asked to finish the detailed design ahead of the architects. Usually they follow the detailed design of the architect and structural engineer, their design is slightly behind the architect and structure engineer. M&amp;E engineer. First interview</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>For this project, the architects as well as structural engineers produced the sketch design instead of detail design, so we had to make the assumptions to get the design done. How can people expect us to produce the information in high quality? Service engineer. First interview</td>
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<tr>
<td></td>
<td>The clients should consider the design period and release the design teams earlier, so they could produce the information... the design is an iterative interdependent process, it takes time to develop. Architect, contractor, QS. Second interview</td>
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<tr>
<td></td>
<td>The whole design process isn’t a simple thing to work, we don’t just draw and stay still. We have to draw something to give the M&amp;E something to look through, then when they come back, we take it on board, then we change it, the engineers draw again, and it is a process, it is an evaluation. Service engineer. First interview</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>We have suffered a lot from this kind of thing...late introduction of podia 15 (heating equipment) on the roof.. results in changes of strong steel beams to support steel underneath...Late introduction of service voids through floors after steel selection, resulting in extra work on site.... Steel subcontractor. First interview</td>
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<tr>
<td></td>
<td>I don’t really think people worked the decision through properly. QS1. Second interview</td>
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<tr>
<td>15</td>
<td>The initial scheme is totally different from now, the whole thing grows and grows. Since December 1999, there have been 481 requirement changes. Most of them have significant impact upon the design process. This affects the effective communication massively. Leader architect. First interview</td>
<td></td>
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<tr>
<td></td>
<td>The whole floor and all toilets at the centre have been changed. The Cinema has been changed, and also did the operator. The biggest changes happened in the car parks and park and ride system which need completely redesigning. More instructions to change the design were still coming, although the design and some construction have been done. Architect2. First time questionnaire survey</td>
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<tr>
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<td>These changes affect our ability to provide the quality of information in a timely manner, and when it passes a certain point, it is very difficult to cope with. Architect3. First time questionnaire survey</td>
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<td></td>
<td>Communication system</td>
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<td>16</td>
<td>In the decoration of the building surface, there was just the line drawing on the screen. I thought it was cladding, but the architect thought it was a nice glass wall which would mean big cost differences.... There was more chance for misunderstanding and misinterpreting on the drawings. QS1. Second interview</td>
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<td></td>
<td>Across whole job, it is quite common to get incomplete information. We couldn’t cost the design correctly to get sub-contractor prices and to make sure those prices are in the budget. QS2. First time questionnaire survey</td>
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<tr>
<td>17</td>
<td>What I received was a structure engineer drawing of the column showing the carry the load on it. I don’t care about what kind of load that column can take, it is completely irrelevant to my job. That drawing goes to the bin. Service engineer1. First interview</td>
<td></td>
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<tr>
<td>18</td>
<td>This (information overload) made the useful information to be ignored. We sent the position of the ventilators to the structural engineer six months ago, they threw it in the bin without checking. They sent us the update information, we didn’t notice. Now the structure doesn’t fit on site for all of the ventilators. We paid the price. Service engineer1. First interview</td>
<td></td>
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<td></td>
<td>But some other drawings that come in would be relevant to me, but they sent me all this scrap. I miss some important things. Every thing he sent out, he sent to me. Some of these I don’t want, because they are useless to me, therefore the tendency is to miss the important things. Service engineer2. Second interview</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>The converting of main storage was an example. The client gave a sanction of the cost which was based on the canceled design. QS1. Second interview</td>
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<table>
<thead>
<tr>
<th>Page</th>
<th>The management information flow was a critical fact which determined whether the job was successful or not.</th>
<th>Lead structure engineer. First interview</th>
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<tr>
<td></td>
<td>The most critical factor in improving that situation is to define accurately for providing the information, exchanging the information between interface parties, especially in the joint area about which we had a lot of confusion at this time</td>
<td>Project director from main contractor. First interview</td>
</tr>
<tr>
<td>20</td>
<td>How can they define the information flow clearly in the interface, especially with the subcontractors. This was one of the reasons, I think, why the design failed in the grey area.</td>
<td>Design co-ordinator2 from main contractor. Second interview</td>
</tr>
<tr>
<td></td>
<td>All the problems were related to planning and managing the information process. The design was all about exchange of information.</td>
<td>Lead structure engineer. First interview</td>
</tr>
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<td></td>
<td>A clear strategy of information flow could be that at any point in time potential problems can be detected. The risks then could be identified, so that we could actually handle the risk.</td>
<td>Structure engineer. Second Questionnaire</td>
</tr>
<tr>
<td></td>
<td>The leaders of the project should set up a clear communication strategy and sort out all level of communications; who need the information, what details? when?</td>
<td>Architect2. First time questionnaire survey</td>
</tr>
<tr>
<td>21</td>
<td>We should make sure that communications are always undertaken in an efficient way in the different organisations. We try to organise this, but we fail to produce that level of knowledge on this job.</td>
<td>Lead architect. First interview</td>
</tr>
<tr>
<td>22</td>
<td>(The clients point this out) &quot;you got a guy missing in your team. This chap doesn’t exist – you haven’t got somebody high enough, pushing and doing the information management.”</td>
<td>Project manager from client. Second interview</td>
</tr>
<tr>
<td>23</td>
<td>Whereas what they tried to do before, was to get people down here in the organisation to do the chasing and people didn’t respect them. This was probably set up before that name was involved in the job</td>
<td>Project manager from client. Second interview</td>
</tr>
<tr>
<td>24</td>
<td>Most of our administrators have no building experience and proper training in IT. We undervalue this job, so when people are good at it, they want to go off and do something else. People tend to think it’s a low-grade job, there is not a lot of respect for the people who do it. We should give more credit for this job.</td>
<td>Project director from main contractor. Second interview</td>
</tr>
<tr>
<td>25</td>
<td>The quality of information is better. Coordination is better, although there is still room for improvement. If they had been on the job a year before, it would have been beneficial.</td>
<td>Client and main contractor</td>
</tr>
<tr>
<td>26</td>
<td>The architect is now producing drawings that co-ordinate with our drawings, before they never did. Now there is a design programme with dates by which we can expect information from them.</td>
<td>Structure and service engineers. Second interview</td>
</tr>
<tr>
<td>27</td>
<td>The contractor Xiao set up a very clear programme for the information flow and demonstrates very tight control over the document exchange. It was a very positive impact on the project.</td>
<td>Structure engineers. Second interview</td>
</tr>
<tr>
<td>28</td>
<td>This was a very comprehensive document. It was very good, but too complicated... We found the faults in it, but it is too far down the line to go back to change it all, we have to live with the problems.</td>
<td>Lead architect. First interview</td>
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**Information**

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<th>Consultants over the last few years have not generally got the detailed skill base. They are very good at doing nice pretty buildings and nice concepts but when it gets down to the nitty-gritty, the final detailing, there is not the big skill at the base. They are drawing the work, but they have never actually seen it being put together.</th>
<th>Project director from main contractor. Second interview</th>
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<td></td>
<td>The consultants were struggling with their problems about the expertise of the design. Certainly they couldn’t meet the dates by which the information should have been released wanted the information released by. They (the contractor) picked certain specialists up. They didn’t go down the normal contractual route of tendering and getting them on board.</td>
<td>Design co-ordinator2 from main contractor. Second interview</td>
</tr>
<tr>
<td>29</td>
<td>What they (the consultants) don’t realise is that the beam is 10 metres long and weighs 1.25 tonnes. It just pops on to the drawing.</td>
<td>Project manager from client. Second interview</td>
</tr>
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</table>

Design co-ordinator2 from main contractor. Second interview |
<p>| 30 | easy-done with it. What you have to do on site is to get that beam in place by hand, if you haven't got a crane there, it is horrendous. So we ask them to make a simple change or introduce another beam, retrospectively. It was much cheaper and easier to do so. | contractor. Second interview |
| 31 | If the contractor hadn't been involved in the project that early, we would be in a worse position than we are now. There were a lot of things that had to be resolved which the design team wouldn't have or couldn't have sorted out on their own. | Project manager from client. Second interview |
| 32 | The design was not our responsibility. We can't always tell the consultants: &quot;this is what we think, what we need.&quot; | Project director from main contractor. Second interview |
| 33 | The whole of that steel beam is erected and now we have got to go in and put in this little extra bit of steel. This is 20 metres up in the air. You can't get a crane to it, so that steel has got to be manhandled from ground level up 20 metres in the air, carted across the roof 40 metres and then put up and fixed by hand. Why do we need this steel, can't we just do it in brick and block work? | Design co-ordinator from main contractor. Second interview |
| 34 | After the design has been finished, the contractor still wants changes later to suit their way of the construction, like the change required in the service room. | Architect, structural and service engineers. Second interview |
| 35 | From my point of view, the contractor would be able to say that won't work on site, we have to change the detail, we have to refine it. The architect may know what it looks like, but he does not always know how to put it together to go to the boards. The contractor has a lot of good information there; he has to be able to help some of the programme, the project is not just his work. He has to try to programme the design as well; unfortunately all the design programme falls down, because all have to catch up, never actually catching up | QS1. Second interview |
| 36 | They (the contractor) should have done better. The reason the client appoints them so early, is for them to put in the design process, in order to make sure the design is correct before it is built. They have experienced people for the building, we are designers, we design on paper, not necessarily in fields, these people have fieldbility knowledge. They know how to build the things cheaper and better. So the contractor should interact there to tell us how to build it. We do the design, we give it to them, they can say 'well if you do it this way, it is better. It's easy on site, although it may not save money. So we will change some thing in the design to suit the construction. | Architect, structural and service engineers. Second interview |
| 37 | We should share our knowledge, but it doesn't happen as it should. Now we have the design, and when we give it to the contractor on the site, they say 'you can do this better, you can do it that way'. We should have known that, when we designed it. If communication was better, it would have happened six months ago&quot;. | Service engineer2; Second interview |
| 38 | Some subcontractors detailed a stone layout for the floor tiles. Some did a platinum which the architect choose. Some laid out all the stones, detailed all the thresholds and abutment details - done by them and then went to the architect for approval. This is a good practice. | Client and contractor; from the second interview |
| 39 | Consultants: &quot;It was a great help (from the subcontractor)....We did a lot less work, we did a very simple line, a very sketchy hand drawing with the minimum lines. We put less effort into it and have more time available at later stages. When the M&amp;E came on board, they put their buildability knowledge in. | Architect1, structure engineer1 and service2. First interview |
| 40 | If subcontractors were on board very early and they were paid a little money to do the design detail development, like VLY, it would be beneficial | Lead architect. First interview |
| 41 | If the client had paid the subcontractor to do the detail design at the same time as ours, we didn't necessarily produce the same level of information. We got more accurate information with which to develop our design. So the quality of information sent was much better | Architect1. Second interview |</p>
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<td>Not like this project, we just make a guess at some design, such as supporting the cladding, because we haven’t got the detailed technology about those materials. If we had known those sub-contractors in secondary steel design we could have made it more economic, so that the solutions we come up with, and can draw from the first time, would need no changes later</td>
<td>Architect2. Second interview</td>
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<td>38</td>
<td>It might be an idea to bring some specialists early and pay for their consultancy or employing them as consultants rather than subcontractors. We will be looking at this in the further</td>
<td>Project manager from client. Second interview</td>
</tr>
<tr>
<td>The quantity and quality of the resources</td>
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<tr>
<td>39</td>
<td>It was not good quality. There was a lot of conflict” between what he was receiving and what he thought he was going to get in the details of the drawing.</td>
<td>Project manager from client. Second interview</td>
</tr>
<tr>
<td>40</td>
<td>The architects especially should be blamed, because they were the design team leaders, their job was to make sure the design all worked.</td>
<td>Associate director from client. First interview</td>
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<tr>
<td>41</td>
<td>When they actually came to do the detailed design, they found that they couldn’t put the wall there because of a structural problem, they couldn’t do this with the ceiling because it was not good looking</td>
<td>Service engineer2. Second interview</td>
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<tr>
<td>42</td>
<td>Our information issued was valuable at that time. It was incorrect and needed to be changed later. For example, we put in the steel work according to the size given, but six month later, the service engineer came and said ‘sorry, those sizes were wrong...’ we have to throw all the steel away and put new ones in</td>
<td>Service engineer2. Second interview</td>
</tr>
<tr>
<td>43</td>
<td>Design information always arrives 3, 4 or 5 weeks late and is often not the one required. The information has to go back to the design team before they can use it. It takes a couple of weeks to get the feedback.</td>
<td>Design co-ordinator2 from main contractor. Second interview</td>
</tr>
<tr>
<td>44</td>
<td>You can imagine, how we suffered when the consultants changed their design around 150 holes we made in the working drawing were useless.</td>
<td>M&amp;E engineer. Second interview</td>
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<tr>
<td>45</td>
<td>We are not responsible for design on this job, but we feel we have to check everything. It knocks everybody’s confidence. They can’t pick up a drawing with confidence that it’s right and go out and build it. The first thing they do when they pick up a drawing is to think, ‘this is probably wrong, I will have to check this.’ We check the quality of their drawings then coordinate them. That leads to intense frustration.</td>
<td>Project director from main contractor. Second interview</td>
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<td>46</td>
<td>When we had 40 engineers, the architects should have had 60-70 architects and that never happened.</td>
<td>Structure engineer. Second interview</td>
</tr>
<tr>
<td>47</td>
<td>It was a resource issue coupled with others. It is numbers of people and their capabilities, and the quality</td>
<td>Lead QS. First interview</td>
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<tr>
<td>48</td>
<td>Some problems are because of the quality of training people as much as the experience of individuals. Shortages also played a part in communication problems – people don’t necessarily have the full knowledge of what they should be doing. Not just consultants, but contractors and subcontractors.</td>
<td>Project director from main contractor. Second interview</td>
</tr>
<tr>
<td>49</td>
<td>Now there are around 80 people on the site and about 40 architects who are a lot for this size of project at this stage.</td>
<td>Project manager from client. Second interview</td>
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<td>50</td>
<td>I’m sure some of it is due to this chap, although he has had the benefit of coming in at the latter part of the job when things are more defined, but still it has certainly improved the way they have organised themselves with that chap. They have produced quality information.</td>
<td>Project manager from client. Second interview</td>
</tr>
<tr>
<td>51</td>
<td>Consultants have to have the right number at the right time; and if more experienced designers were involved earlier during information production, the performance would be better</td>
<td>Client, QS and Contractor. First interview</td>
</tr>
<tr>
<td>52</td>
<td>We have learnt the lessons now, so next project we must look at how the architect and structural engineers arrange their resource at the earlier stage, and what kind of people and what kind of experience they have got.</td>
<td>Project manager from client. Second interview</td>
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<td>52</td>
<td>We don’t know what exactly other disciplines want, so if we don’t send them the information which causes the problems, that is our fault. So by just sending them, we are being safe.</td>
<td>Architect, structure, and service engineer. First interview</td>
</tr>
<tr>
<td>53</td>
<td>I had a year’s argument with the architect about how to put the cables in the control room. We need the floor voids for these cables, but the architect does not understand the complexity of the services, and ignored our requirement. He wanted to have a nice tall ceiling-nice big airy space, but we think this is a working environment. It would be much better to have a decent floor space and everything functional than to have a decorative ceiling. This is a big problem at the moment, which we have not yet resolved” said service engineer.</td>
<td>Service engineer1. First interview</td>
</tr>
<tr>
<td>54</td>
<td>One person is very familiar with acoustics. The rest of us find that it was difficult to understand everything he did. Another one has specialist knowledge of the service engineering. He knows how the consultants design and the sub-contractors work. He is slightly different from us, because he has got special training, so he works within and across organisations. I think it is useful that we have these kinds of links.</td>
<td>Service engineer1. First interview</td>
</tr>
<tr>
<td>55</td>
<td>We realised that the capability of the senior professional in information and coordination is very important through this project, and the weakness was one of reason which made this project fall down at the earlier stage.</td>
<td>Client and contractor. Second interview</td>
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**Social collaboration**

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<td>56</td>
<td>If on a traditional contract, the contractor would be building up the claim now, he would have a very good claim for the information 12 weeks later.</td>
<td>Lead QS. First interview</td>
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<tr>
<td>57</td>
<td>We were supporting the surfaces of walls. What we’ve done is to put in the steel supports from top to bottom and, to put the services on before they do the brickwork in order to save time. It is much quicker. If we weren’t in the partnering situation, we might just say ‘well when you finish the core we’ll start, this is not our problem’. You can see there is a different scenario.</td>
<td>M&amp;E engineer. First interview</td>
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<tr>
<td>58</td>
<td>If you had not been a partner, we would never have even suggested these. We would have written them a letter about these stones saying that they are not correct specifications, and we probably would have charged them for the resulting cost.</td>
<td>Project director from main Contractor. Second interview</td>
</tr>
<tr>
<td>59</td>
<td>As a professional, we need much more appreciation and sympathy for other engineering disciplines, and to accept each other’s faults. “you see the mistake, you scream at me. When you make the mistake, I will do a lot to you”</td>
<td>Structure engineer. Second interview</td>
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<td>60</td>
<td>It wouldn’t be comfortable to tell people if they cause the problem, it will be a penalty and they will have to pay for it. I don’t want them to worry all the time about these penalties, in my view that could damage their imagination.”</td>
<td>Project manager from client. Second interview</td>
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**Technical collaboration**

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<td>52</td>
<td>Design of the columns in the front of shop fronts. These columns have to be taken away, because it prevent the customers from seeing the goods.</td>
<td>Project director from main Contractor. Second interview</td>
</tr>
<tr>
<td>61</td>
<td>In the service area, around 150 holes have been found in the wrong place in the built steel and concrete structure. The holes through the structure were based on the original design, which indicated there were a lot of changes involved in the service design.</td>
<td>M&amp;E engineer. Second interview</td>
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<td>Firstly, we could be criticised for not liasoning with the architect to identify that requirement. The architect could be criticised for not making it explicit in his drawings which was a requirement. The architect could be criticised for not picking it up on our drawings once our drawings were issued and not identifying them as a problem until they were built on site.</td>
<td>Structure engineer. Second interview</td>
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<td>62</td>
<td>We should redo their working drawings, (it takes about a thousand pounds for each CAD drawing). Some need to put big deeper beams in, in order to let the pipes go through (it can make the beams expensive). Many new holes must be put in. According to the engineer, it can take probably 6-8 weeks before the new hole is done in the built structure.</td>
<td>M&amp;E engineer. Second interview</td>
</tr>
<tr>
<td>63</td>
<td>There is electronic communication available. We have e-mail, fax, telephone, and intranet, the need to see face to face is not that important. They have their own web page, the participants can log in and see all the drawings.</td>
<td>Associate director from client; First interview</td>
</tr>
<tr>
<td>64</td>
<td>The video-conference, phone, email or fax are just a compromise, they are formal, we have to have the reason to do that. If everyone is in the same place, I can make a cup of tea, someone in the tea room, “hi, how is your job going at the moment?” you find out some thing, you can understand the problems. It is easier to help each other to sort out them.</td>
<td>Lead QS. First interview</td>
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<td></td>
<td>We had this kind of experience with the cinema company. I think that working in the same place builds a strong and better team. It does distribute the information much better. May be it is more informal.</td>
<td>Structure engineer. Second interview</td>
</tr>
<tr>
<td>65</td>
<td>Our relationship with the contractor is stronger than it is with other designers because we are in the same building. Sometimes, we assume that everything can be done by fax or by e-mail, but we need time to complete the process and this can be done better face to face.*</td>
<td>Lead QS. First interview</td>
</tr>
<tr>
<td>66</td>
<td>In theory, with all the electronic communications, transfer of drawings and mails, you should not need it, but I am a believer that if you get people together, the design will progress better. If people can nip up the stairs or down the corridor to have a chat with somebody then that would improve the communication. You would get a better feeling of the team and where they are going.</td>
<td>Project manager from client. Second interview</td>
</tr>
<tr>
<td>67</td>
<td>When you sent drawings electronically it was fairly quick but it relied on the other person looking at it and understanding it. Whereas if participants were sitting here face to face, it is easy to clear the thing up.</td>
<td>Project director from main Contractor. Second interview</td>
</tr>
<tr>
<td>68</td>
<td>We discuss the drawings when there is a need. The decisions were easier to make and supported by all team members. Later activities in the design process could be carried out without being hampered by different views from the team members on relevant design topics.</td>
<td>Structure engineer. Second interview</td>
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<td>69</td>
<td>If you looked at it at day one, when you sat down and said ‘we’ll rent office space for 18 months for 120 people. We’ll have to put all the facilities in there. Then we’ll have to pay all these people because they are staying away from home. It will probably cost you umpteen thousand, a big commitment’. You would probably say, ‘I’m not doing it.’ This is in reality what happens. On the other side of the coin, you don’t know what it would cost you in poor information and poor communication and what benefit you might have got out of it… If you look at some multi-disciplinary practices, they are very successful in working together.</td>
<td>Project manager from client. Second interview</td>
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<td>Key project personnel</td>
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<td>70</td>
<td>It is time for the culture change. We should appreciate the job and give high value and credit for the information co-ordinator and controller.</td>
<td>Project director from main Contractor. Second interview</td>
</tr>
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<td>71</td>
<td>Before I appoint the consultants as to how good their design is, through experience of doing several projects, therefore we assumed that it will be through with a good design management process. Probably it is the wrong way to do it.</td>
<td>Associate director from client. First interview</td>
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<td>72</td>
<td>In the past with consultants, deals were done at very high levels over lunch, rather than actually looking at the technical ability of the company to produce good quality information. It was ‘the old boys network’, friendships, things like that that got people jobs. Now we are being a lot more critical and actually looking at how the company can perform in terms of information management, what skill level or resources its got, before we get a contract. Just because we have recent history experience doesn't mean that they will get another job.</td>
<td>Project manager from client. Second interview</td>
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<td>73</td>
<td>When the design team went into the process it was agreed by the members, a replacement member came, who was starting with no knowledge at all. He inevitably wanted to change certain things. We were making decisions assuming the structure was designed by</td>
<td>Lead Architect. First interview</td>
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<td>74</td>
<td>We discuss what we need and what we are doing, and then that person leaves. We get a new person, who doesn't know the situation, so we have to do it again. We then can not get the feedback until a few weeks later.</td>
<td>M&amp;E engineer. Second interview</td>
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Appendix G
Data sources for chapter seven
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<tr>
<th>No</th>
<th>Statement</th>
<th>Data Sources</th>
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<tr>
<td>1</td>
<td>It would more have been the confidence that team branch out and break down other barriers and overcome issues of information transfer, but both contractors were afraid that their ideas might leak to the others.</td>
<td>Project manager from Membrane subcontractor. First interview</td>
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<td>2</td>
<td>This potential is at present inhibited by adversarial attitude, which wastes the time of talented people in unproductive disputes. Partnering has emerged as a better way of working</td>
<td>Project manager from contractor B. First interview</td>
</tr>
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<td>3</td>
<td>We always received the document like that thick in which only a few pages we needed. We spent a lot of time to search what was the information we needed.</td>
<td>Client. First interview</td>
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<td>4</td>
<td>Very frequently we get design tenders with several hundred pages and only one or two pages of them is about the process design. There would be much better if we had set up the formal procedures.</td>
<td>Project manager from Membrane subcontractor. First interview</td>
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<td>5</td>
<td>It may have been useful if we could have developed some kind of charter or statement of approach. We should have discussed the program: who have got to give information by when, who is responsible for what, then we get everything agreed in the early on.</td>
<td>Project manager from Membrane subcontractor. Second interview</td>
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<td>6</td>
<td>I think that if we win this project We need communicate at regular bases. We need set up the formal procedures. They (the contractor) did not set any programs: what kind of information we need change, when? For the joint area, both of us need spend a lot of time to try to sort out the scope and responsibility.</td>
<td>Project manager from contractor B. First interview</td>
</tr>
<tr>
<td>7</td>
<td>I think that there were design changes during the project, which did affect the main contractors - changes to process flows, changes to process conditions and site specific issues (a). We have received the misleading information. Some of water quality data in the site are not correct.</td>
<td>Project Manager from Membrane subcontractor. First interview</td>
</tr>
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<td>8</td>
<td>The site (Chalford springs) of the plants 16 MLD flow downs to 13.8 MLD. That is a major change. ... Still the major issues, which are not resolved like the information of discharge to the rivers. These probably need resolving, because these affect the design Our correspondents with consultants within two months have 75 letters or e-mail to add the information. Some of them conflict... Some data suddenly tell us redundancy. We always receive the less information. We need a lot of information in the existing sites. They did not supply it for us. For example, we went to the meeting. We asked them to give us the information of ground conditions, where there is a very limited space to build new building. We didn't get any.</td>
<td>Project manager from contractor A. First interview</td>
</tr>
<tr>
<td>9</td>
<td>Some of the information change doesn't matter, but some is as important as how the plant is going to behave. The important design parameters need to be established very carefully, don't change them. The very critical one like this flow in Llandinam is a fundamental parameter. Changing it, even if a little, would change the design philosophy.</td>
<td>Project manager from contractor A. First interview</td>
</tr>
</tbody>
</table>
The quality of water we are going to treat is very important in the treatment process. The data we are given was misleading. In various tables the information is different. They should give very clear information. Project manage from contractor B. First interview

10 They were first time doing the complicated work (water treatment), (before just did pipe work). ClientI. Second interview

11 Next time I will ask them (client) to confirm the critical parameter. And when they do the draft information they should get another party what kind of information important to them should not change. We did a lot of extra work for it. Project manage from contractor B. First interview

12 The first thing is that the client need have good understanding what kind of project it is. They need know what type of treatment plant they want and what capacity. Project manager from contractor A. First interview

Feedback always is problem. Nobody wants give us feedback. It is very difficult to get that. When we went to the meetings, they can see our designs and in some cases, may be they didn't say “no, don’t do that, we prefer…”, they just let you said this what we think. Some of sights we need more feedback.

Project manager from contractor B. First interview

One of the things we asked is not clear from this document. How we are going to judge on the price? Are we looking for the lowest capital cost or the whole life cost.

Project manager from contractor A. First interview

The lack of definition is a big problem with this tender. You have two goal posts to shot between them. If the goal post keeps moving, I am not quite sure where I should move. When you do that, you have to rework thing and you have to make the assumption.

Project manager from contractor B. First interview

<table>
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<tr>
<th>Quality and quantity of resources</th>
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We were not able to assign resources specifically for the project and the knowledge of our resources are being utilised fully. Project Manager from Membrane subcontractor. First interview

13 The problem was that the specialists were very under resource, not enough people working… They have not got enough people to deal with this. Project manager from contractor B. First interview

14 They did not supplied sufficient information regarding this project and just supply a general standardised quotation… There is a problem with accessibility. It is not easy for us to contact the engineers to discuss more details for the individual case. Project manager from contractor A. First interview

15 We are entirely dependent on the information, which were on the critical path for the program. They have made us four weeks late. Project manager from contractor B. Second interview

16 That potentially raised some issues, which I think we could have managed better whether it is with additional resources as in other project… In this instance we did not assign that project team and won’t assign that project team for delivering the project and securing additional resources within the company structure such as drawing facilities, process support. Project Manager from Membrane subcontractor. First time interview

17 We are still developing procedures that best fit our particular situation. We need to reflect on in order to streamline the information transfer. That is something we are looking at in terms of developing design manuals, databases of key information, packaged information. That will allow us to provide more readily standardised drawings, standardised information, technical response to the main contractors in a more timely fashion Project Manager from Membrane subcontractor. First interview

18 Norit has delayed to give the information to us and the level of the information could not meet us… Project manager from contractor B. Second interview

For four weeks, they did not provide any information. How could we develop whole detail of the plant, which was related to the key equipment. Lead Engineer from contractor B. Second interview

Social collaboration

19 They (consultants) worked very well for the client. Project Manager from Membrane
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<th>Page</th>
<th>Text</th>
<th>Source</th>
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<tbody>
<tr>
<td>Previously we stood there reactively rather than productively, so we wait for the contractor to ask us the questions not ourselves involved. Now we are productive. The communication is much great and the discussion is on daily bases. We always phone them &quot;hello, what the thing going?&quot; if any thing happens, we can discuss that...</td>
<td>subcontractor. First interview</td>
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<td>They phoned us and discussed our planning of the design, and gave us the feedback to make us know whether this was a right approach. So the communication is far greater than before on the project of this type. Civil work, in the past, they just waited for us to provide the foundation design with calculation like that, drawings and calculation ... fully completed. They would say &quot;oh you missed this out, you made mistake here, and all that work would be aborted. Now they ask us about the way of the foundation design. So they could give us their opinion earlier rather than later.</td>
<td>Project manager from the consultant. Second interview</td>
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<td>The question is how to give somebody incentive to do the same thing. If ask you to jump to the window, you couldn't do it, do you. If give you a million pound to ask you to do that you might do it. That is incentive. What is the incentive to for the specialists to produce the information without pay?</td>
<td>Lead Engineer from contractor B. Second interview</td>
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<td>I would question whether that was because they had assigned the correct resources. That may well point in turn to the fact that they were operating on a reimbursable basis and already accepted quotation and were being reimbursed for their time. If that's the case then I think there is an opportunity for review by ultimately the client as to whether if they are going into true partnership basis</td>
<td>Project Manager from Membrane subcontractor. First interview</td>
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<td>We try to organize some informal activities like every Friday lunch at a pub. This developed a good relationship and knew each other very well. This helped free and open communications between the team members.</td>
<td>Project manager from contractor B. Second interview</td>
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<td>Technical collaboration</td>
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<td>It is very difficult for us during this period when no costs are being attributed to this process. We are not reimbursable at this stage. We presented the opportunities to the main contractor, none of which took it up, to visit Holland</td>
<td>Project Manager from Membrane subcontractor. First interview</td>
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<td>There are constraints on us in allowing first line engineers to travel and make expensive trips to Holland just like there are constraints on the specialists.</td>
<td>Project manager from contractor B. First interview</td>
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<td>We relied very heavily on electronic means of information transfer and telephone, which was not easy for the contractors to understand the philosophy of our new technology without face to face talking...... we were being asked the same question by the same company more than once on more than one occasion.</td>
<td>Project Manager from Membrane subcontractor. First interview</td>
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<td>We have to talk to the specialists by phone. It is more difficult. Because the engineers from Holland speak English that is not easy to understand..... There is some problem with technology words, because this is a new technology product. Holland English is very different from here. For example, we call pump, they call rotating machine. We call panel, they call electrical enclosure. This causes confusion when we phone each other.</td>
<td>Project manager from contractor A. First interview</td>
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<td>We try to get the Norit stay here for two or three days to go through the designs, but they are not available. They didn't have time to co-ordination. ... The detail information we couldn't sort out without the specialists. That was the problems. We need that information and equipment for our jobs for the projects.</td>
<td>Project manager from the consultant. Second interview.</td>
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<td>For contractors to send their teams to Holland for a period of time during the heart of this design phase. And there they would have access to the project team manager, mechanical engineer, draftsman. They would understand in detail the philosophy.</td>
<td>Project Manager from Membrane subcontractor. First interview</td>
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<td>In the interface of software control systems, the contractor did want the specialists to work in co-location with their respective control engineers during the software writing because it needs very close co-ordination work between them. But that did not happen</td>
<td>System engineer from contractor B. Second interview</td>
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<th>Page 30</th>
<th>The control system of the membrane has to be integrated into that of water plants. But we have the problems. The two control system could not link together in many areas. That is quite a key design if it is not treated with the seriousness like this it can fail the technology.</th>
<th>ICA from contractor B. Second interview</th>
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<td>Because we are all located close. We have weekly team meetings every week and it can be any time if needed. We are all located in the same place and can talk to each other. Our talk is not formal. Anybody who wants to discuss anything will come to my desk and start talking to me.</td>
<td>Lead engineer from contractor B. Second interview</td>
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<td>I can sit in area where I can overhear what three other people are doing. If Richard is on the telephone about a pump problem, I can hear what he is saying. And if he says something he’s not quite sure about something, I can say, “No, no, sorry Richard, we know that, it’s 2 metres.” People are interacting all the time.</td>
<td>Project manage from contractor B. Second interview</td>
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<td>In this particular project, it is very difficult because in the design stage it is not a linear process. It is an interactive process. It doesn’t mean that one finishes work and hands it to another. This is much more interactive where one person starts to work, and as soon as he starts to produce answers he communicates to this person who starts to work on those answers.</td>
<td>Mechanical Engineer from contractor B. Second interview</td>
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<td>Through a chatting, I knew the civil engineer thinking of a change of the drainage sump. So when I designed a level instrument for measuring the level of water in the drainage sump, I went to the civil engineer and said, “has this changed?” “Yes it has” “ok, I will design my PNID based on it”.</td>
<td>ICA engineer from contractor B. Second interview</td>
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<td>With informal talk, we pick up all the things and gaps in communication that occurs during the rest of the time. It doesn’t follow clear guidelines or procedures, but it depends on everybody contributing to that and sharing information with all their colleagues as soon as they can.</td>
<td>Lead engineer from contractor B. Second interview</td>
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<td>We talk to each other frequently. So the damages caused by the changes can be reduced. If person A has done his first bit of work and passes it on to person B, as soon as person A realises there may be a mistake in that or there may be a change, he tells person B immediately.</td>
<td>Electricity engineer from contractor B. Second interview</td>
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<td>It’s to make sure that we are working from common information. The fact that Mark Jones was today talking about the drainage sump having changed. I was saying, “Horace, do you know about that?” and Horace said, “Well, I’ve heard about it, but I haven’t seen the final things yet.” John was saying, “yes we have discussed it and we need to finalise it.” All I am doing is checking that people are talking to each other. I ask people to bring to that meeting any changes or issues that may be changed so that other people are aware of it. That is what our team meetings are for.</td>
<td>Project manager from contractor B. Second interview</td>
</tr>
<tr>
<td>Page 31</td>
<td>The interaction between Alpha (civil sub-contractor) and ourselves is very good. Civil engineer here - he is the liaison person, the interface, that is why the communication is so good. He doesn’t just pass the information. He also understands the information and discusses it with the Alpha. They are not in this office. So when decisions are made by mechanical engineers to change something, he acts as if he were employed by Alpha.</td>
<td>Project manager from contractor B. Second interview</td>
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<td>When we are making design changes here, it will have an affect on the civil construction. Alpha doesn’t have someone in this office. These decisions happen hourly. They change very quickly. We can’t be getting someone down from Alpha every day. So we employed a civil engineer. He is acting to make sure that the civil design team who are not here have a voice in our decision making process. It is working very well. It is his job to sort out any conflict.</td>
<td>System engineer from contractor B. Second interview</td>
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<td>If he thinks that the engineers here are doing something which will affect the civil works, he will discuss it with Alpha and make sure that they have their say, yes or no. He is here so that when there is a meeting, he can come and be the ears and voice of Alpha. That is very important because that is one of the big conflicts between mechanical and civil. That is why we have put him in that position so we have very good communication.</td>
<td>Lead engineer from contractor B. Second interview</td>
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He represents them at the meetings that we have in these decisions that we make. He represents the civil engineering aspects. If I say, “we want to do this to this pump, we will tell the civil people that they have to construct something different.” He will say, “No you won’t tell the civil people that because that is very difficult for us. Why can’t you do this instead?” and I say, “yeah, we can do that.” “well, that is much easier from a civil perspective.”

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<th>Key project personnel</th>
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Appendix H
Data sources for chapter eight
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<tr>
<th>No</th>
<th>Statement</th>
<th>Data Sources</th>
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<tbody>
<tr>
<td></td>
<td><strong>Procurement</strong></td>
<td><strong>Contractor Manager from the contractor. Second interview</strong></td>
</tr>
<tr>
<td>1</td>
<td>When we started on site, the basic design had been done, but not detail with most drawings. We knew exactly what they want to achieve, but the technical details which are needed to build it, were not there.</td>
<td><strong>Structural Engineer1 from the structure consultants company. Second interview</strong></td>
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<td>We couldn't issue the information in details sometimes, because for some elements our design was depended on a detailed fabrication and production drawing being produced by specialist...</td>
<td><strong>Service Engineer3 from the service consultants company. Second interview</strong></td>
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<td>The contractor tries to do as little as possible. They try to get the information as detailed as possible for the working drawings, which we were not supposed to do.</td>
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<td>If they (consultants) don't give us the information by the day we asked and cause a delay, we will think about making a claim.</td>
<td><strong>Contractor Manager from the contractor. Second interview</strong></td>
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<td></td>
<td>If they (contractor) really want some information related to that, I could introduce them. It was more positive to ask us than prepare claims.</td>
<td><strong>Architect2 from the architect consultants company. Second interview</strong></td>
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<td>3</td>
<td>We wouldn't want to speak to subcontractor directly. The danger is that if we speak to a subcontractor, even in the wrong tone of voice, the subcontractor says, 'I was instructed to do this by the consultants.'</td>
<td><strong>Structural Engineer1 from the structure consultants company. Second interview</strong></td>
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<td>4</td>
<td>They (the contractor) play off many potential subcontractors against each other and drive the price down until the last possible moment so as to acquire the best price.</td>
<td><strong>Service Engineer3 from the service consultants company. Second interview</strong></td>
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<td>5</td>
<td>How can I finish our design? We haven't got the details information from these specialists...</td>
<td><strong>Structural Engineer1 from the structure consultants company. Second interview</strong></td>
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<td>6</td>
<td>We could not talk to the contractor about different alternative arrangements - do you want the floor in concrete or timber, do you want the joists to span this way or that way. Different contractors have different views.</td>
<td><strong>Structural Engineer1 from the structure consultants company. Second interview</strong></td>
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<td>7</td>
<td>We wouldn't accepted the contractor's asking for the change of the method of the ground floor slab construction - cast in traditional checkerboard fashion which we assumed at the design stage. There isn't time for the main contractor to take our drawings on board and to start trying to suggest changes.</td>
<td><strong>Structural Engineer1 from the structure consultants company. Second interview</strong></td>
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<td>8</td>
<td>If they could appoint us right away, it would speed up... So in some ways it was a contractual problem which caused the communication problems.</td>
<td><strong>Project manager from the filter subcontractor. Second questionnaire survey</strong></td>
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<td>In a partnering arrangement, we would have been accepted on board earlier and have been invited to design team meetings, which would have helped.</td>
<td><strong>Cladding engineer from the cladding subcontractor. Second interview</strong></td>
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<td><strong>Communication system</strong></td>
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<td>9</td>
<td>He is a very good communicator. He was able to translate the design for us to understand it. While some professionals we met before said things which are quite technical, jargon. A lot of clients and operators don't understand.</td>
<td><strong>Client2 from the client organisation; First interview</strong></td>
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<td>10</td>
<td>He passed the clear and sufficient information to us, so we could make the sensible decisions.</td>
<td><strong>QS1 from the Quantity Survey company. First interview</strong></td>
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<td>11</td>
<td>He prevented an overload of information messages from outside by intentionally withholding information, which we did not need.</td>
<td><strong>Structural Engineer1 from the structure consultants company. First interview</strong></td>
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<td></td>
<td>In this special situation (short period of design), the architects should work out the timetable of the information flow, set the clear communication strategy and procedures.</td>
<td><strong>Service Engineer3 from the service consultants company. First interview</strong></td>
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<td>This job would have been done better, if the information flow had been more structured and planned more carefully.</td>
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<td>12</td>
<td>There were some existing cables. But no one tried to find out where exactly the cables were. When the contractor dug on the site, they found that they were not able to continue to work in this area because the cables were too close to the new foundation. If we had been informed that, the diversion of the cables could have been taken before construction, I am sure that some consultants were responsible for it.</td>
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<td>13</td>
<td>This job has a lot missing (mess). When we started working, the information and a set of drawings should be there.... Their management of the information is very poor. We couldn't get the update information. Sometimes we get the information, which wasn't related to us. They didn't take an active role to send information to the subcontractors and make sure that the subcontractors provide information for us.</td>
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<td>14</td>
<td>What was wrong? Why did the filter engineer still use the old version of our drawings? We had sent the new version to the contractor two months ago.</td>
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<td>15</td>
<td>The architects use the different system what we used. We use Autocad, but they use Archiecad. We always have the problem of compatibility. Their formats are not the same as ours. Whilst we are looking at the same drawing, the appearance is totally different and everything merges together. When we convert all layers to a different format, it lost something. Further than that with regard to line type, they all becomes far too thick or thin in print and it doesn't give the separation that the drawings are supposed to look like.</td>
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<td>16</td>
<td>They (sender) didn't sift through it. Sometimes the information was integrated with other items of information and we only wanted part of it. They don't break it down. The temptation of accessibility is to abuse the system, so people just copy to everybody and everybody disappears under a sea of email, most of which are not relevant. Email has become equivalent to mail shops and circulars. You get so much garbage, you can't see what the important issues are.</td>
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<td>17</td>
<td>When we started the detailed design, some of the information provided by the specialist was preliminary, not detailed. Quite often we asked very specific questions with regard to the details. Frequently the response didn't include what we want. There's a crucial bit of information missing so we couldn't complete the design as a whole.</td>
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<td>18</td>
<td>We didn't know particular items exactly what they were, and how they needed supporting, how big the pipes were, and where they went?</td>
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<td>19</td>
<td>We had to make a guess but it could be wrong... Obviously there are things that are going to require adjusting on site.</td>
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<td>20</td>
<td>When we came on board, there was a lot of missing in the original design and we couldn't input ours into it as the steel work had been designed and most of them had been fabricated. The client should have given a specific order to the specialists to produce a proper design rather than try to get the information from them for free.</td>
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<td>21</td>
<td>I am not too sure what the solution should be other than that the specialists should be treated as a member of the design team, but certainly we would get a benefit if the specialists had been involved at the design stage.</td>
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<thead>
<tr>
<th>Source</th>
<th>Interview Type</th>
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<tbody>
<tr>
<td>Client2</td>
<td>Second interview</td>
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<tr>
<td>Client1</td>
<td>Second interview</td>
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<tr>
<td>Cladding Engineer from the cladding subcontractor</td>
<td>Second interview</td>
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<tr>
<td>Filter Engineer from the filter subcontractor</td>
<td>Second interview</td>
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<tr>
<td>Structural Engineer1 from the structure consultants company</td>
<td>Second interview</td>
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<tr>
<td>Architect2 from the architect consultants company</td>
<td>Second interview</td>
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<tr>
<td>Service Engineer1 from the service consultants company</td>
<td>First interview</td>
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<tr>
<td>Structural Engineer2 from the structure consultants company</td>
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<tr>
<td>Service Engineer2 from the service consultants company</td>
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<td>Structural Engineer1 from the structure consultants company</td>
<td>Second interview</td>
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<td>Structural Engineer1 from the structure consultants company</td>
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<td>Structural Engineer1 from the structure consultants company</td>
<td>Second interview</td>
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<tr>
<td>Cladding Engineer from the cladding subcontractor</td>
<td>Second interview</td>
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<tr>
<td>Service Engineer3 from the service consultants company</td>
<td>Second interview</td>
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<tr>
<td>Architect2 from the architect consultants company</td>
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<th>Page</th>
<th>Text</th>
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<tbody>
<tr>
<td>22</td>
<td>If we were to do this again, we would definitely need to tell the client “last time we did a swimming pool, there was a major problem with the specialists, they didn’t present their information early enough. Can somebody do something about it this time”</td>
</tr>
<tr>
<td>23</td>
<td>We have got a current set of the drawings, but the others associated are no longer the current. We need the complete picture to be able to design the structure, frame, and things like that. We have got a discrepancy of the information…we don’t then get the continuity of work to go on and design.</td>
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<td>24</td>
<td>Service Engineer1 from the service consultants company. First interview</td>
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<td>24</td>
<td>Every time when something changes, it is an implication that all the other drawings and details might need changing. We never got the point where we could progress the design of the structure and frame…. It affected more than usual since the service work was carried out at the same time as architects.</td>
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<td>24</td>
<td>Structural Engineer1 from the structure consultants company. Second interview</td>
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<td>24</td>
<td>Based on the electronic drawings of architects, we could use the software to do the calculation directly in a very short time. In that case any changes of architect’s drawings would not bother us a lot</td>
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<tr>
<td>25</td>
<td>Social collaboration</td>
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<tr>
<td>25</td>
<td>The architects specialise in leisure centres. They have done an excellent job for us before. They are familiar with our procedure and the procedures of Sports England. They know what we need very well</td>
</tr>
<tr>
<td>26</td>
<td>The client have got very clear mind and know what they want… They have experience of leisure management and have given us good advice</td>
</tr>
<tr>
<td>26</td>
<td>We are open. We always have good solutions for the problems between us. …When we want some changes like the plant room, they would relook at it, and give us an option</td>
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<tr>
<td>27</td>
<td>Architect1 from the architect consultants company. First questionnaire survey</td>
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<tr>
<td>27</td>
<td>I appreciate the help from the service engineer of getting the information from the filter specialist. We had a lot of problems with another service engineer in a previous sport center project. They didn’t pass this information. That resulted in a lot of mess, we had to modify our design during the construction stage.</td>
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<tr>
<td>28</td>
<td>Client2 from the client organisation. First interview</td>
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<tr>
<td>28</td>
<td>Service Engineer1 from the service consultants company. First interview</td>
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<tr>
<td>28</td>
<td>We had conflict with the structural engineer of the place of the wall fans in a fitness room where the structural engineer put wind posts within the wall. We compromised rather than argued with each other. They spread the wind posts nearer to the window to provide a gap for the fans, we move the fans to the place supplied.</td>
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<tr>
<td>29</td>
<td>Architect1 from the architect consultants company. First questionnaire survey</td>
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<td>29</td>
<td>In most cases, I asked for the information from other consultants. They said they didn’t know and it was a matter of the sub-contractor… but so if you like, the service engineer didn’t wake up and say, 'I can help the structural engineer here by getting the information he needs to produce the bending schedule.' Instead they said, 'not our problem – go away'.</td>
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<tr>
<td>29</td>
<td>We feel it reflects badly on ourselves if there is a lot of structural work on-site that should really have been done in the fabrication shop, re-drilling and things like that. In most cases, it wouldn’t be our fault that it had been done because the information wasn’t available, but it still tends to come back towards us.</td>
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<tr>
<td>30</td>
<td>Structural Engineer1 from the structure consultants company. Second interview</td>
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<td>30</td>
<td>The consultants said that every thing the contractor needed was in the document, but the contractor said it was not. Their interpretation was different. …… both of them didn’t do a little further to sort it out</td>
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<tr>
<td>31</td>
<td>Client1 from the client organisation. Second interview</td>
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<td>31</td>
<td>The consultants did not really want to discuss things at a certain point because they didn’t want to get involved. They said ‘we haven’t this kind of responsibility according to the contract’.</td>
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<tr>
<td>31</td>
<td>Cladding engineer from the cladding subcontractor. Second interview</td>
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<td></td>
<td>Technical collaboration</td>
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<tr>
<td>32</td>
<td>When the conflict appeared in the position of the wall fans. Three of us: architect, structure engineer and me sat down together. Finally we found an alternative way which all of us could accept.</td>
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<td>33</td>
<td>This is a distinct advantage, You can easily walk to them and talk to them. You can obtain the immediate response. The meetings are easier to clear up the confusion area than phones and faxes.</td>
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<tr>
<td>34</td>
<td>In some areas, their design (architect and structure engineer) was separate, not married together. We don’t know whose drawings our design should be based on… Really we should work very closely at the beginning.</td>
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<tr>
<td>35</td>
<td>More meetings should have been held particularly at the early stage. So the people would know what was expected from beginning. … Particularly when people tend to each go off in their own direction with their own ideas and things develop independently. If you don’t draw those back together on a regular basis, you’ve got potential problems.</td>
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<td>36</td>
<td>In the early stage of design, the meetings were probably more concentrated on the client’s requirements rather than the issues that would have directly affected ourselves such as the structural and fundamental things... We probably sat there for hour waiting for the people to make decision about what colour the walls and carpets are</td>
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<tr>
<td>37</td>
<td>We really need discuss face to face and talk about it. So the topic is discussed in full. You pick up the phone to call individuals and you can get their agreement, but still need with the two others you’ve not yet phoned.</td>
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<td><strong>Key project personnel</strong></td>
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<tr>
<td>38</td>
<td>We had the odd changes here and also on the architect side. When a new person came, he had to pick up the project from the half way. It was more that everything has been broken down into discrete packages</td>
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