A Mapping Approach to Investigating Information and Communication Technology (ICT) Implementation during the Building Design Process

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

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31st March 2006
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<td>Two dimensional</td>
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<tr>
<td>ABC</td>
<td>Activity based costing</td>
</tr>
<tr>
<td>ADePT</td>
<td>Analytical Design Planning Technique</td>
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<tr>
<td>AI</td>
<td>Artificial intelligence</td>
</tr>
<tr>
<td>AIQS</td>
<td>Australian Institute of Quantity Surveyors</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organization</td>
</tr>
<tr>
<td>CWIC</td>
<td>Collaborative Working in Construction</td>
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<tr>
<td>EDI</td>
<td>Electronic data interchange</td>
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<tr>
<td>GDCPP</td>
<td>Generic Design and Construction Process Protocol</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HTML</td>
<td>Hypertext Markup Language</td>
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<td>ICT</td>
<td>Information Communication Technologies</td>
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<tr>
<td>IDEF0</td>
<td>(Integration DEFinition language 0)</td>
</tr>
<tr>
<td>IGES</td>
<td>Initial Graphic Exchange Specification</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
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<tr>
<td>MDP</td>
<td>Mapping the Design Process</td>
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<tr>
<td>PAN</td>
<td>Personal Area Network</td>
</tr>
<tr>
<td>PDAs</td>
<td>Personal Digital Assistants</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>OD</td>
<td>Operating Systems</td>
</tr>
<tr>
<td>RAIA</td>
<td>Royal Australian Institute of Architects</td>
</tr>
<tr>
<td>RIBA</td>
<td>Royal Institute of British Architect</td>
</tr>
<tr>
<td>SMTP</td>
<td>Simple Mail Transfer Protocol</td>
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<tr>
<td>STEP</td>
<td>STandard for the Exchange of Product-model data</td>
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<tr>
<td>VANs</td>
<td>Value Added Networks</td>
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<td>VRML</td>
<td>Virtual Reality Modelling Language</td>
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ABSTRACT

Building design is a complex process that involves multi-disciplinary professionals working together throughout the multi-processes of a project. The success of this process is highly dependent on effective communication and adequate information flow; any incorrect or inadequate information flow will result in a failure in project management.

Information and communication technologies (ICT) have been implemented and integrated into many of the individual processes of building design, but little is known of the extent and intensity of ICT implementation. Not is there any clear indication about where future development might occur.

The purpose of this study is to develop and validate an ICT implementation map, focusing on the usage level, the impact, barriers and other issues of ICT implementation during the building design process for current practice, and to predict future trends over the following five years (2005 to 2009).

Five “strands” for the research were identified and discussed: the existing information management and communication during the building design process; to what extent design professionals adopt ICT in their daily routine; the impact of technology; the barriers to the implementation of technology; existing communication problems faced by design team member during the building design process; and the techniques and tools used during the building design process.

IDEFO process mapping software was used to map the building design process for traditional contract procurement projects (design-bid-construct). The process map was further tested by four rounds of Delphi survey. Data collected from the four rounds of Delphi survey were adapted in proposing an “ICT Implementation Map during the Building Design Process” (for current usage and in five years time). The proposed ICT Implementation Map was tested and further improved through interviews with three experts.

The findings of the research support its aim and objectives and demonstrate that advances in technology have increased the efficiency and effectiveness of building design process management. Moreover, the proposed maps provide a baseline for design professionals or decision makers when asked to adopt new technologies to facilitate the design process.
1 INTRODUCTION

1.1 INTRODUCTION

Design is a process of human interaction and consequently the outcomes contain the interpretations, perceptions and prejudices of the people involved (Gray and Hughes., 2001). The building design process involves multi-disciplinary professionals working together throughout the multi-processes of a project. Enormous amounts of data are generated during the different stages of the design process, presented in drawings, specifications, bills of quantities, and other construction documents. This information is transferred between different project participants throughout the design and construction processes, thus effective means of communication and information management are the keys to facilitating the success of these processes and to eliminate some of the factors which can lead to project disputes.

While the quality of design has been shown to impact on all subsequent stages of a project’s life cycle (Zaneldin, 2000), effective communication and adequate information flow are critical to the success of a construction project; any incorrect or inadequate information flow will result in a failure in project management (Munns and Bjeirmi, 1996).

The up-take rate of Information and Communication Technology (ICT) in Australia has been among the best in the OECD according to Bennett et al. (2003). By adopting advanced information and communication technology to facilitate the building design process, most problems currently found in the process may be eliminated.

The purpose of this study is to develop and validate an ICT implementation map focusing on the usage level, the impact, barriers and other issues of ICT implementation during the building design process for current practice, and to predict future trends over the following five years (2005 - 2009). Given the rate of technology change for ICT over the past four decades, the period of prediction is a deliberately safe, conservative choice.

1.2 RESEARCH AIM AND OBJECTIVES

The aim of this research is to better understand how Information and Communication Technology (ICT) is implemented during the building design process. The study involves three objectives:
To examine the manner in which ICT is used by the building design professions during the building design process, with a focus on large-scale office/commercial projects in Australia.

To investigate and map existing design processes using the IDEF0 (Integrated DEFinition) functional modelling technique.

To propose a best practice model for ICT implementation during the building design process that improves information exchange and levels of communication between participants.

1.3 RESEARCH QUESTION

While focused on the building design process occurring on large-scale office/commercial building projects in Australia, this research is largely generic and will attempt to answer the following questions (refer to Figure 1-1):

- **Research Question One** - How can process mapping be used to describe and document the building design process?
- **Research Question Two** – What aspects of work done by design professionals are influenced by ICT?
- **Research Question Three** – How much do building design professionals use ICT tools?
- **Research Question Four** - What are the impacts of ICT implementation by building design professionals during the design process?
- **Research Question Five** - Can a best practice model be mapped for ICT use during the design process?
- **Research Question Six** - What is the future trend (over five years) of ICT implementation during the building design process?
1.4 MOTIVATION FOR THE RESEARCH

The building design process for most large scale projects is highly fragmented, involving many players from different professional disciplines who are brought together at different stages throughout the procurement life cycle of unique projects. These professionals, due to their different views of the building, describe it in different levels of detail. As a result, the creation and use of information within the design become less homogenous and more fragmented. Moreover, much of the wasted time and cost encountered in construction projects can be traced back to poor information and communication – insufficient, inaccurate, inconsistent, and late or combinations of all of these (Zaneldin, 2000). This research focuses on the potential of developing a best practice ICT model for improving building design management. Several aspects of the building design process have motivated the research, including the need to reduce fragmentation; the logic of the project life cycle; the inefficiencies of information management; and development in ICT.

1.4.1 The need to reduce the level of building design process fragmentation

Designing is a process of human interaction and consequently the outcomes contain the interpretations, perceptions and prejudices of the people involved (Gray and Hughes, 2001). Each designer will have different ideals and perceptions on his or her design, and acceptability of the outcomes is based on the willingness of each individual to accept modifications to those ideals and perceptions.
“The separation of design and construction processes, including the late involvement of specialists and poor communication between design and construction teams, was all identified as leading to inappropriate design solutions. Designers were criticised for having a ‘solo mentality’, a discomfort in reaching definitions, and for deliberately mystifying the design process.”

(Macmillan, 2000)

The traditional system of building procurement pursued the goal of differentiation and specialization within the construction industry as a means to promote technological innovation. A system was divided into subsystems, within which were people who were experts in their fields. Specialization allowed greater flexibility and increased productivity. However, as the degree of specialization increased, the problems associated with fragmentation, like breakdowns in the communication infrastructure, began to negate the benefits of specialization. Problems arose based on issues such as the growth of adversarial cultures, the use of different design tools and the production of design documents that were not properly coordinated with other disciplines and were not consistent with any standard format. These issues can lead to design interference, inconsistencies, discrepancies, omissions and errors (Zaneldin, 2000).

The increased complexity of construction projects can involve project team members from different geographical areas needing to work together for a relatively short period on the design and construction of a project; face to face meetings may be difficult in terms of transportation cost, time and personal inconvenience (Anumba et al., 1997a).

Furthermore, the parties involved in a building project may adopt a sequential approach to the design of the project such that downstream participants have little or no influence at the earlier design stages (Anumba and Newnham, 2000). For example, the architect may be responsible for generating the initial design concept, which is then passed onto the various engineering professionals for detailed technical implementation. This ‘over the wall’ approach to project development has resulted in numerous problems such as:

- “Inadequate capture, analysis and prioritisation of client requirements,”
- The fragmentation of design and construction information with data generated at one stage not automatically available for reuse ‘downstream’,
The lack of communication of design intent and rationale,
Unwarranted design changes, disputes and liability claims,
Increase in design cost and time.”

(Anumba and Evbuomwan, 1997)

1.4.2 The Life Cycle Costing Logic

The quality of design has an extensive impact on all subsequent stages of a project’s life cycle. Producing a quality design is highly dependent upon effective design management among the diverse disciplines involved in the process. At each stage of the design process, different designers get together periodically and set the design criteria and constraints, which must be met before proceeding to the next level of detail. In the early stages of the life cycle of a project (refer Figure 1-2), there is greater potential for project cost reduction and lower costs to implement such changes. When major document revisions are required, their costs tend to negate the cost reduction potential (Kirk and Dell’Isola, 1995). It is, therefore, a worthwhile investment to spend effort in generating high quality design (representing a low percentage of total project life-cycle cost) that does not create problems at later stages where cost reductions are very hard to achieve and redesign is extremely expensive.

Figure 1-2 Life Cycle Costing (Kirk and Dellisola, 1995)
1.4.3 Inefficiencies of Information Management

According to den Otter and Prins (2002), when considering information there are six connected terms often entangled with each other: data, information, communication, knowledge, knowledge base and documents. This research focuses mainly on the communication aspect.

Communication is further defined as “a process of exchanging information between sender and receiver to equalize the information on both sides. Within the exchange the following constituent steps can be distinguished: information gathering and transmission (the sender’s activity); information receiving and interpreting (the receiver’s activity); information storage and retrieval as well as information publication (activities done by sender and receiver). The proposed generated meaning can be distorted or partly lost during all these steps.”

(den Otter and Prins., 2002)

Traditionally, design communication relies primarily on manual methods of crosschecking and frequent exchange of drawings and documents. The results of inadequacies in this process are often delays, interference and rework, which will lead to cost overruns and client dissatisfaction.

1.4.4 Developments in Information and Communication Technology

Computers are used to solve some of the independent problems faced by individual participants in the design process. For example, there are computer-aided design (CAD) systems, management information systems (MIS), and database systems (DBS).

Communication technologies, such as electronic mail and electronic file transfers, which allow the electronic exchange of information, have rapidly become accepted and used in the construction industry. They enable improved communication and information management between design team members, compared with traditional paper based methods. These technologies can help to overcome geographical location and time zone differences between team members.
Other IT communication tools such as Internet-based telephony, videoconferencing, file sharing, Internet chatting, white-board discussion and document-transfer may be used, individually or together to facilitate communication between the design team members for a building project.

Issues of the affordability and the productivity of information and communication technologies (ICT) have gradually begun to diminish. ICT power is rapidly increasing and ICT devices are becoming miniaturised. Massive data storage capacities are being developed and huge volumes of information can now be prepared for distribution. Extensive networks, such as the Internet are able to connect and communicate people and bodies of knowledge across the world in a fraction of second. Within these platforms, the development of intranet and extranet systems permits the dedicated use of secure project information sharing facilities, unconstrained by geographical location or temporal differences, that can make a major contribution to the management of specific projects and which can provide clients and managers alike with a continuously transparent window on their projects.

As a result, new work practices are being constantly devised. These changes have been occurring so rapidly that many governments, corporations, and companies are only now beginning to realise the implications that they will bring to both industry and society.

1.5 OUTLINE METHODOLOGY

A six stage approach is proposed for conducting this research.

Stage 1: Literature Review

A comprehensive review of the relevant literature will be carried out in order to develop an understanding of previous work in the field of ICT implementation during building design processes. This review will explore the design process of building projects and identify problems and potential improvements. It will survey recent advances in ICT tools as well as the impact of IT factors on the construction industry.

The literature review will assist in understanding what is known and what is not known about the research questions. It will be possible to refine the questions and propose a technique to
collect the required primary information. This will then inform the structure of a data collection instrument to focus on large-scale office/commercial building projects with contract sum above Aus$100million. This size and scope of project is deliberately chosen to provide the best type and intensity of primary data with an acceptable level of typicality.

**Stage 2: IDEF0 Model Development**

Understanding from the literature review will assist in developing a draft ICT implementation model using IDEF0 process mapping language. The draft model will be tested using a Delphi survey approach.

**Stage 3: Delphi Survey**

The Delphi survey method will be adapted for data collection and to test the IDEF0 process model. Delphi survey techniques have been widely used to predict future trends of technology use. The draft design process model will be tested among pre-selected experts from the building design professions.

Pilot testing will be used to validate the survey questions and to identify possible ambiguities in wording of Delphi questions and instructions.

The Delphi process involves an iterative use of a questionnaire instrument by means of “rounds”. Questionnaires are sent to the Delphi panellists for their consideration; they are then returned to the researcher for summarization of group response data and resent to panellists for reconsideration and further review until no further differences in the summarization can be detected. The Delphi process thus continues until it reaches an acceptable form of consensus between participants.

**Stage 4: Proposed ICT Implementation Map**

The information derived from the relevant literature and the data collected from the Delphi survey are used to develop an implementation framework for ICT implementation during the building design process.
Stage 5: Testing the ICT Implementation Map

The ICT Implementation Map will be in the form of a best practice model which can be tested through interviews with experts. Feedback from the interview will be used to fine-tune the model.

Stage 6: Writing up

The whole of the research is written up in thesis form, with the following structure:

Chapter One introduces the context of the study, the research aims and objectives, the research questions, the motivation for the research and an outline of the research methodology.

Chapter Two presents a literature review of the state-of-the-art situation of ICT in the process of building design – which covers three stages (RAIA, 1993): schematic design stage, design development stage and documentation stage. Five strands are identified here: design communication; design information management, ICT; the impact of technology; and the challenges. Brief information on IDEF0 process mapping methodology is discussed here.

Chapter Three presents the model development process using IDEF0 process modelling language. The model development process involves four phases: data gathering phase; process map structuring phase; map documentation phase; and feedback interaction phase. The top level IDEF0 map is presented and the research variables are defined.

Chapter Four justifies and describes the research methodology, focusing on data analysis procedures. Literature review on the topic of Delphi approach is conducted and presented in this section.

Chapter Five comprises the Delphi instrument administration process and analysis. The results of a four round interaction Delphi survey, conducted among preselected experts from the industry, are presented and analysed in this section.
Chapter Six focuses on the development of the proposed ‘ICT implementation maps’. The data collected from the four rounds of Delphi survey are mapped onto the proposed ‘ICT implementation map’ during building design process for current usage and to forecast future trends (over 5 years). In addition to indicating the ICT usage level for each of the building design processes (identified through the Delphi survey), the ICT implementation map also incorporates the issues such as: design communication; design information management; ICT; impact of ICT and challenges which had been discussed as part of the Delphi survey.

Chapter Seven summarises the findings from the interviews with experts. The purpose of this stage is to test the proposed ICT implementation maps for ‘current’ and ‘future’ usage developed in the earlier stage. Six questions were prepared to focus on the development of the maps and these are discussed during interviews with three experts. The interviews revealed that the initial maps were too complicated and time consuming to understand and read. Modified maps were prepared based on respondent’s comments.

Chapter Eight concludes the study of the implementation of information communication technologies (ICT) during the building design process for ‘current’ and to forecast ‘future’ trend in five years time. This chapter summarises the main findings of the previous chapters, and draws a conclusion as to whether the research aim and objectives have been meet. Further research topics in this field are identified and recommendations are made for the practice of building design.

1.6 Limitation

The following limitations apply in this research study:

- The study is limited to large scale office/commercial projects, where large-scale is defined as projects with contract sum equivalent to or greater than Aus$100million. While such projects demonstrate much of the complexities inherent in building design, they are also consistent in terms of the range of professional disciplines involved in the design process and the nature of the problems and challenges encountered.
- The study is limited to the perceptions of the pre-selected building design professionals involved during the building design process. A study covering the complete range of design activity by every possible participant in the process would be impracticable. The research therefore focuses on the main protagonists.
The study is limited by the potential bias of respondents due to their profession and position in an organization. A benefit of the Delphi technique is that it allows such biases to be exposed.

For the purpose of this study, ICT is defined and shall include but is not limited to the tools listed in Section 2.3.3 of the thesis.

Generalizations for the ICT implementation map from this study are limited to the conclusions/decisions derived from the data collection period (spring 2004 to spring 2005).

Delphi method is a very challenging research technique and the implementation is greatly dependent on the researcher’s capabilities throughout the interaction.

ICT is moving at a rapid rate, and as a result, there are limitations upon the period for which many of the specific technologies mentioned and used in today’s world can be considered up-to-date for tomorrow’s world.

Finally, this research approaches the problems and barriers from a design management point of view and does not deal in depth with of ICT implementation in terms of technical and economic aspects.

Despite these limitations, the research does present an extensive investigation of the building design process and the role and implications of the ICT associated with this process. The research methodology has facilitated a “rich” picture to be drawn of the process and the related ICT issues.
2 LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, a review of the extant literature on information and communication technology (ICT), and its application in the building design professions of the construction industry, is presented. First, the building design process is reviewed, using the three main stages of design process identified in the RAIA Guide Note (RAIA, 2000) and RIBA Plan of Work (1999) as a topic structure. Secondly, ICT application in the building design process in terms of information management as well as communication is reviewed. Thirdly, literature regarding the impact and challenge of ICT developments to the building design process is presented. The final section of the chapter deals with a process-mapping technique and its use for building design management.

2.2 THE PROCESS OF BUILDING DESIGN

The building design process is a multi-disciplinary process, performed in a series of iterative steps, to conceive, describe and justify increasingly detailed solutions and costing to meet the needs of the building client (Hassan, 1996). It is appropriate here to follow the life cycle of a typical building design process in order to analyse and to explore the means of improving the management of the process.

The building design process is an iterative, multidisciplinary and multistage process (Zaneldin, 2000). Traditionally, architects are considered to be the first party involved in the design process as they are responsible for generating the initial design concept, which is then passed onto engineering and other design professionals for the detailed design work to be carried out (Anumba, et al., 2002). Each designer will have different ideas and perceptions about his or her design responsibility and activity, and the acceptability of the final outcome is based on the willingness of these individuals to accept their role. Conflicts can arise during the iterative steps of the overall design process and will lead to further fragmentation of the process itself (Zaneldin, 2000).

The fragmented nature of the building design process has always brought communication problems between design team members (Zaneldin, 2000; Faniran, et al. 2001; Anumba, et al.)
Data generated during the design process are substantial in nature and difficult to manage, this can pave the way for claims and contractual disputes if information is lost or is inappropriate or is wrongly interpreted. Design documentation for a building project contains a large amount of data presented in a variety of formats and media, including drawings, specifications, bills of quantities, and other construction documents. As various information is transferred between different project participants throughout the building design process, an effective information management system and means of communication are keys to successful outcomes.

Meland (2000) defines building design management as “a managerial function of the design and product development process in construction projects. The main task is co-coordinating the work of different contributors in the design process: architect, different engineering consultants, governing bodies and the project owner”. The issue of how ICT can help and to improve this process is the focus of the current research.

The building design process encompasses pre-construction activities relating to consideration of the planning, design, construction, operation and maintenance of a building, and even for its subsequent de-construction or disposal. The RAIA Guide Note (RAIA, 2000) and RIBA Plan of Work (1999) provide a basis for identifying the essential design steps through which construction projects must pass. These guides are not intended to be specific to any kind of project, neither are they intended to be immutable. They assume that the building design process is based upon a traditional and separated procurement approach (design – bid – construct) where design is carried out independently of construction. While other procurement systems are acknowledged, this approach will be adopted for the purposes of the research.

The Architect Agreement [Long Form], Scope of Services, RAIA Guide Note (RAIA, 2000) identifies three main stages of the design process and refers to:

- Schematic Design (A1)
- Design Development (A2)
- Documentation (A3)
Other terminologies for the above stages are as follow:

<table>
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<tbody>
<tr>
<td>Schematic Design</td>
<td>Outline proposals</td>
<td></td>
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<tr>
<td>Design Development</td>
<td>Detail proposals</td>
<td>Sketch design</td>
</tr>
<tr>
<td>Documentation</td>
<td>Final proposals</td>
<td>Working drawings</td>
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Given the RAIA Guide Note (RAIA, 2000) and RIBA plan of work (RIBA, 1999), the ‘pre-tender’ stages (after briefing and before tendering stage) of the building design process were selected for the purpose of the research. The following section covers three design stages: a brief description adopted from the ‘Architect’s Job Book’ (RIBA, 1995), on definition, purpose, task to be done and people directly involved in each design stage; and an extract from ‘Building Design Management’ (Gray and Hughes, 2001), identifying the relationships of designers with other parties.

2.2.1 Schematic Design Stage

The design brief obtained from the feasibility stage must be turned into a detailed evaluation of the specific functional needs of all of the users of the proposed building. The initial (design) brief must be developed. The purpose of this stage is to determine a general approach to layout, design and construction in order to obtain authoritative approval of the client for the outline proposals and their accompanying report (RIBA, 1995).

The designer has to develop the brief further. This will entail studies of user requirements, technical problems, planning, design and costs, as necessary to reach decisions. The building’s appearance, layout, choice of technological systems, and materials have to be finalized at this stage. The design team may also have to negotiate with the requisite planning authority to achieve detailed planning approval for the building on the chosen site (RIBA, 1995).

Parties involved in this stage are mainly the designer, project manager and client. Designers will lead this stage in conjunction with the project manager who provides process management and also production method evaluation. The client is closely involved in decision-making and must be kept informed (Gray and Hughes, 2001).
2.2.2 Design Development Stage

At the Design Development stage, the design proposal approved by the client at the Schematic design stage must be worked up into a more detailed level. The purpose of this stage is to complete the brief and decide upon particular proposals, including planning, arrangement, appearance, constructional method, and outline specification. The designers must make sure that all the major systems relating to the building are specified and integrated into the final project scheme (RIBA, 1995).

The design team has to finalize the final development of the brief, commence the full design of the project by the architect, proceed with preliminary engineering designs, continue with the cost planning process and prepare any explanatory reports. The team also needs to submit proposals to comply with any regulatory approval procedures (RIBA, 1995).

Parties involved in this stage are: client (and/or client representatives), architects, engineers, quantity surveyors and other design specialists, as well as all statutory and other approving authorities. Designers will lead this stage in conjunction with managers who provide process management and also production method evaluation. The client is closely involved in decision-making and kept informed (Gray and Hughes, 2001).

2.2.3 Documentation Stage

Once the outcomes of the earlier stages have been approved, detail design of the systems in the building can proceed. At this stage, all parties must be fully coordinated in order to obtain final decisions on every matter related to design, specification, construction and cost. Any co-ordination failure during this stage may lead to conflict and extra cost, and will inevitably delay the completion of the design stage of the project.

At this stage of the building design process, almost all parties are involved. The management processes become dominant. Specialist trade contractors are involved with designers in providing advice and knowledge of their systems. The client is involved at key decision points.
2.3 IDENTIFYING STRANDS

This section will review the literature directly relevant to ICT and its implications during the building design process. The findings will be presented as a series of issues referred to as “strands”. These include:

- Design communication
- Design information management
- Information and Communication Technologies (ICT)
- The impact of technology
- The challenges

2.3.1 Design Communication

Communication is the process by which information is exchanged between two entities and in most cases this will involve two identifiable individuals, but it also includes information exchange between individuals and organizations or between two organizations (Rezgui, et.al. 2001).

According to den Otter and Prins (2002), human communication can be distinguished in three aspects:

- “Face to face/meetings and distance communication: containing both verbal and non-verbal communication. Verbal communication refers to information transferred through short verbal message; whereas non-verbal communication uses documents or other media.

- Formal and informal communication: communication organized in a structured way is formal communication. On the other hand, informal communication refers to information exchange in ways where formal rules and hierarchies are eliminated.

- Types of information exchange: information exchange can be presented in different formats. For example, verbal and non-verbal; graphical and non-graphical; digital and non-digital, etc.”

(den Otter and Prins, 2002)

No matter how the communication between each party is conducted and in whatever format the information is presented, all information affecting the building design should be gathered
and made available to all the parties concerned in the early design stages. Important information will include client’s expectation, constraints to be met, etc. Other means of communication should also be maintained throughout the design process to facilitate effective co-ordination between the design team members.

According to Anumba et al. (1997a) the following considerations need to be taken into account in terms of the desired communication infrastructure for the design team members.

- “Concurrency in an integrated design and construction process requires greater discipline in the production, storage and communication of design information.
- Design information necessarily consists of both graphical and non-graphical information, which must be communicated between members of the project team.
- The greater the level of concurrency in a process, the greater the level of co-ordination required - this entails an increased level of communication between the various stages and activities in the process, as well as between the project team members.
- Paper-based communication of design information is now inadequate to cope with the high level of functionality (in terms of speed, accuracy, usability, ease of modification, enhanced visualization, improved co-ordination, etc) required in a collaborative design environment.
- The increasing ‘globalisation’ and complexity of construction projects means that project teams often involve partners from widely distributed geographical areas, sometimes in different continents. As face-to-face meetings in such circumstances are expensive in terms of time, money and personal inconvenience, effective communications protocols able to collapse time and distance constrains are therefore necessary.
- The fast pace of technological development, particularly in computing and telecommunications, dictates that, for the construction industry to remain competitive, it must take advantage of new and emerging technologies such as multimedia, virtual reality and broadband communications networks.”

(Anumba et al., 1997a)

The development and implementation of ICT tools and techniques to address these issues will be considered later in this review.
2.3.2 Design Information Management

As noted, the communication process is concerned with the exchange of information. This information must be captured and represented in order for it to be analysed and processed for the benefit of an organization or a project (Rezgui, et. al., 2001).

The building design process is information intensive. It requires the interactive involvement of many professionally-trained personnel from multi-disciplinary backgrounds working together to generate a product that meets a client’s needs on time and within budget. These professionals, with their different backgrounds and experience will have different mental perspectives of the building and its requirements, and will tend to describe it in different technical terms and on different levels of detail. As a result, the creation and usage of information within the design process tends to become heterogeneous and fragmented. Moreover, most wasted time and cost in construction project can be traced back to poor co-ordination caused by inadequate information - insufficient, inappropriate, inaccurate, inconsistent, late, or combinations of any of these (Tam, 1999). Efforts have been made by each professional discipline to develop computer software application tools to support their individual roles; however, incompatible systems used by individual professional have produced “Islands of Automation in Construction” (Hannus, 1995). For example: the design team may use computer aided design software to produce drawings, while the cost consultants may require these drawings to produce their cost plans. If the CAD program cannot exchange data with the estimating program, much exchange of information on paper will result, even when the work was initially produced on a computer.

Design information contains data presented in more than one format such as: sketches, schemes, visual images and symbols, audio transactions, drawings, words, etc. Effective management of this information is essential to ensure project success.

Traditionally, the dissemination of design information is through drawings and text documents. Computer usage in the design process has merely changed the paper-generation process. Drafting boards, lead pencils and ink pens have been replaced by powerful computers armed with computer-aided design (CAD) software and electronic plotters. Computers have altered the paper producing process.
Producing a CAD-based drawing takes a fraction of the time required to produce it on a drafting board. The end result is that computers have actually afforded the efficient production of more paper-based communications. While this may seem like a step in the right direction, it is actually a step backward because the power of CAD tools is being constrained by the communication delivery means, i.e., paper. It is common to find CAD-based paper-printed drawings produced by collapsing an unreasonable number of CAD layers in a single sheet. Each CAD layer represents some aspect or system of the proposed building, e.g., floor layout, ceiling layout, structural grid, hydraulic reticulation and electrical power distribution. This practice renders the paper-printed drawings almost unreadable, which in turn leads to misinterpretation, higher uncertainty, omissions, rework, conflict between operatives and poor quality. This practice certainly constitutes a misuse of the technology, yet it is brought about by the desire to include excessive information in a drawing (and the false assumption that condensing information in this way leads to greater efficiency) and by the need to deliver it via paper (Peri, 2003).

However, according to De Lapp et al. (2004), utilizing CAD can improve design accuracy and lower project costs when compared with hand-prepared drawings. They note that:

“Using CAD can reduce costs if used to transfer design information developed by one discipline (e.g., column locations by architects) for use as backgrounds by other disciplines in developing drawings (e.g., HVAC duct locations by mechanical designers).”

(De Lapp et al. 2004)

Technology has thus improved the traditional process to a certain level. However, there is a need for better ways of exchanging project information to achieve effective and efficient building design processes.

### 2.3.3 Information and Communication Technologies (ICT)

Information and Communication Technologies (ICT) can be further classified into three categories: ICT infrastructure – covers all hardware and software; ICT for communication – to achieve mutual understanding between parties; and ICT for information management – to organize massive quantities of data.
2.3.3.1 ICT Infrastructure

“ICTs may be defined as the new breed of information technologies generated by the progressive merger between telecommunications and computing. Examples of ICTs are the Internet, VoIP, e-applications such as telemedicine, e-business, e-learning and e-governance.”

(ITU, 2003)

ICTs may include many types of technologies, for the purpose of this research the focus on ICTs includes: computer workstations and display facilities; software; specialist hardware; technology-based recording and processing systems for sound, still and moving images; graphic calculators; and a wide range of associated communications facilities.

As noted earlier, the building design process is fragmented and there is a need to adopt new tools to facilitate the co-ordination and communication between multi-disciplinary design team members during the building design process. Various Information Technology tools such as CAD, Internet, hardware and software, can help to achieve this.

In practice, each discipline uses its own specific tools, which may require different software environments especially when each discipline resides in a different organisation. Efficient information exchange between different application tools is difficult. In practice, information, both in text and drawings still has to be transferred in hard copy between disciplines in many instances. Thus, there is a need to put together all the information into an integrated environment in order to reap the potential benefits of effective ICT implementation.

The infrastructure of the information society consists of both a technology base and human resources (Bergmann, et.al., 2002). Technological factors such as telecommunication networks and services, information exchange standards as well as some security issues are briefly described below.
**Internet**

How many different ways do we use the Internet? We use it as a backbone to send and receive emails. People ‘surf the net’ for information and many people use it in their work environment to conduct research. Now it has been introduced to the building industry for use as a communication and information management tool.

Among the recent computer advances that can have major impact on the design process is the Internet. The Internet is the most well known, the largest, the most recent, and the most rapidly developing implementation of information infrastructure, linking hundreds of thousands of individual networks all over the world (Laudon and Laudon, 2002).

In the 30 years since the desktop computer was introduced in the 1970s, ICT has changed so dramatically that it has overwhelmed even the most sophisticated user. One universally-held view, however, is that the Internet is a vast resource of information.

The Internet has emerged as a revolutionary low-cost computerised tool for worldwide communication and sharing of information. It is particularly useful to support information-dependent processes, such as a multi-disciplinary design, that require close co-operation among a group of diverse and possibly remote experts. The Internet can provide unsurpassed benefits to the design process. With their powerful ability of being easily programmable, internet-based systems are perceived to provide custom solutions for design co-ordination and communication as well.

The most important Internet services for business include e-mail, Usenet newsgroups, LISTSERVs, chatting, Telnet, FTP, gophers, and the World Wide Web (Laudon and Laudon, 2002). The capability and the function of these services is described in Table 2-1.
Table 2-1 Major Internet Services (Source: Laudon and Laudon, 2002)

<table>
<thead>
<tr>
<th>Facility</th>
<th>Functions Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-mail</td>
<td>Person-to-person messaging; document sharing</td>
</tr>
<tr>
<td>Usenet newsgroups</td>
<td>Discussion groups on electronic bulletin boards</td>
</tr>
<tr>
<td>LISTSERVs</td>
<td>Discussion groups and messaging using e-mail mailing list servers</td>
</tr>
<tr>
<td>Chatting</td>
<td>Interactive (real time) conversations</td>
</tr>
<tr>
<td>Telnet</td>
<td>Log on to one computer and do work on another</td>
</tr>
<tr>
<td>FTP</td>
<td>Transfer files from computer to computer</td>
</tr>
<tr>
<td>Gophers</td>
<td>Locate information using a hierarchy of menus</td>
</tr>
<tr>
<td>World Wide Web</td>
<td>Retrieve, format, and display information (including text, audio graphics, and video) using hypertext links</td>
</tr>
</tbody>
</table>

The construction industry has been slow to adapt new technologies, but the Internet is by far the fastest growing computer technology the construction industry must catch up with. The best-known form is the World Wide Web (WWW also known as ‘the Web’), which is certainly the fastest growing repository of information available (Anumba et al., 1997b).

The construction industry is discovering the benefits of the World Wide Web. Many individuals and organisations in the construction industry have found a home on the World Wide Web by having their own Website as well as being listed in many directory sites containing information they want to publish to the public. Design professionals can use the advantages of the Internet for communication. For example during the course of a project, they might use a project-specific Website to communicate about the critical design changes that inevitably occur during the design process; as well as information tools, using hypertext links to embed design information within the site or to other related sites based on 2D environments created using Hypertext Markup Language (HTML) or new 3D environments based on the use of Virtual Reality Modelling Language (VRML).
Although connections to the Internet are widely available, most companies have avoided using them at remote locations and offices because of security concerns. The Internet is a highway that carries considerable personal and organizational information and data, much of which is sensitive or proprietary. Design information might be exposed to theft or sabotage. Internet hackers have found ways to penetrate ICT security systems. With the unauthorised access, the culprits can gain entry into computer systems at sites all over the world. However, with the introduction of new solutions to security and confidentiality issues, such as firewalls and secure encryption technologies, the Internet technology can be considered as a low-cost tool for effective communication among remote experts.

**Intranet**

Design professionals are required to share design information with each other during the design process for a building project. For instance, an architect will need to pass the outline design to the structural engineer for further design on the structural aspects while the mechanical and electrical engineer will also need to design the M&E services for the same layout. Each designer needs to have access to the same design information as well as communicate within the same (or similar) group of people. This may be achieved through the use of an Intranet provider.

Intranet refers to an internal network based on Internet and World Wide Web technology and standard; it is private and is protected from public access through firewall (a software device) protection (Laudon and Laudon, 2002). An intranet will act as a means to link the group members together during the specific project period and permit members of the group to access and transmit (“upload” and “download”) information, as well as keeping out unwanted and unauthorised visitors.

**Extranet**

The term “extranet” comes from “extended intranet”. It is defined as “...a secured network that connects several Intranets via the Internet, which form a larger virtual network that allows remote users to securely connect over the Internet to the enterprise’s main intranet. It allows two or more enterprises to communicate and collaborate in a controlled fashion” (Turban *et al.*, 2005). In other words, an extranet can be viewed as part of an enterprise
intranet with restricted access (password-protected), which gives additional access to the authorised users outside the enterprise. Security and privacy are serious concerns so extranets are generally secured behind a firewall, which allows only authorized users access to the enterprise’s information (McLeod and Schell, 2004).

The use of extranets is becoming a very popular means for project members to access and exchange information. It may be seen as a good solution for online collaboration and document sharing among project team members. It enables documents to be shared with people in multiple locations with additional control over who sees what, and when they see it. This relatively inexpensive use of ICT has been piloted successfully on several construction sites which have demonstrated savings in time for the contractors and design team consultants, helping both to avoid delays and to assist with the smooth flow of work on site (Emmitt and Gorse, 2003).

However, not all project participants have made the move to adopt extranets as their communication framework and this may due to some drawbacks of their use. Some of these disadvantages include issues such as: costs; security; web server facilities and their development; legacy systems integration; ongoing support and maintenance. Extranets require a large amount of information system (IS) group time and energy, much more than it takes to get an intranet or web site set up and running (Wailgum, 1998).

**Windows Operating Systems**

Gorman and Stubbs (2004) define operating systems (OS) as “... a collection of system programs that allow the user to run program software and to manage hardware” It is the program that, after being initially loaded into a computer by a boot program, manages all the other programs in the computer.

Microsoft Windows, one of the most commonly used operating platforms, was first announced in November 1983, as an extension of the then predominant MS-DOS operating system that would provide a graphical operating environment for PC (personal computer) users (www.microsoft.com). It was a not-very-good graphical user interface (GUI) balanced precariously on top of DOS: slow and having a very flat look (Holcombe and Holcombe,
However, the GUI gradually improved with each subsequent version Microsoft has produced. It should be borne in mind, however, that such improvements have only been achieved by the ever-increasing speed, power and capacity of PC hardware systems. Today, Microsoft Windows is the most widely used OS for PC users and has been adopted as their standard desktop operating systems by many users.

**Personal Area Network (PAN)**

The term Personal Area Network (PAN) was first introduced by Zimmerman (1996) at IBM’s Almaden Research Centre (San Jose, CA). The concept of PAN is presented to demonstrate how electronic devices on and near the human body can exchange digital information by capacitively coupling Pico amp currents through the body (Zimmerman, 1996). PAN enables transfer of information via microprocessors that are placed in PAN transmitters and receivers. It will cover the personal space surrounding the person within the distance that can be covered by voice and has a capacity in the range of 10bps to 10 Mbps.

PAN is seen as a new member of the telecommunication family in the construction industry. It is a network solution that enhances our personal environment, either work or private, by networking a variety of personal and wearable devices (such as: PDAs, Weboards organizer, hand computers, cameras and head mounted displays) that surround a person within the distance that may be covered by the voice, and providing communication capabilities within that personal space and with the outside world (Prasad and Ruggieri, 2003). PANs enable better communication and information exchanges between team members in a more efficient way. For example, PAN gives a project designer the ability to wirelessly synchronize with a desktop device to access email or the Internet on site.

**Bluetooth**

“L.M.Ericsson of Sweden invented Bluetooth in 1994. The Bluetooth Special Interest Group (SIG) was founded by Ericsson, IBM, Intel, Nokia and Toshiba in February 1998, to develop an open specification for short-range wireless communications. The group now consists of over 1900 companies.”

*(LXE Inc, 2003)*
“Bluetooth” is another type of wireless communication technology that is built around the notion of PAN. The technology allows users to make effortless, instantaneous connections between wide ranges of communication devices. It allows mobile (cellular) telephones, computers and PDAs to interconnect with each other, or with office or home telephones.

The purpose of Bluetooth is to avoid the problems that come with both infrared and cable synchronizing (Shaw, 2003). This technology has eliminated the inconvenient cable arrangements that otherwise has to take place between devices. Such cables create clutter and limit device placement. The wide range of Bluetooth-enable devices in the market allows collaborative work between project team members. Besides, the multi-point capabilities of Bluetooth communication allow one interface to support communications with multiple devices such as printers, scanners, PDAs, and other PCs, etc (LXE Inc, 2003).

**Information Exchange Standard**

One of the most common types of information that design professionals exchange is referred to as “CAD” (Computer Aided Design) documents. As a result, there has been a considerable amount of attention given to the problems associated with this activity.

One of the biggest problems associated with CAD document exchange relates to the way that documents are structured internally. Despite the fact that CAD systems have been around since the 1960s, there is still a reasonable amount of conjecture about the way a CAD document should be organised. Drawings from two different CAD systems may provide identical output on paper, but the organisational structure of the CAD documents may be entirely different. This can cause many problems when these documents are exchanged.

A number of key organisational methods are used in CAD system. Each of these methods is usually implemented inconsistently between different systems (ACADS, 1993). Some of the system features and their associated problems include:

- **“Layers”: A drawings can be organised by placing drawn entities into common associated groupings such as walls, doors, and floor. These layers can use a variety of naming or numbering conventions. These conventions are rarely well documented or universally accepted.**


- **Text/Fonts:** Text can be defined using many different fonts. These fonts are not always available on each system that a drawing is transferred to.

- **Symbols:** A library of pre-drawn objects can be used as part of a CAD system. The naming convention of these symbols and their organisational structure can vary considerably between systems.

- **Line types:** A variety of standard and customised line types can be used by some CAD systems. There are no universal standards for the way these line types are defined or translated.

- **Plotting:** Drawings can be organised in different ways to provide the scales and layout necessary to produce hardcopy output.

- **Colours:** On some CAD systems colour is used to indicate line widths, and on others is used only for organisational and identity purposes. The range of colours used, and the line widths they represent usually vary from system to system.”

  *(ACADS, 1993)*

In the development of CAD interchange methods, standards have come to represent varying levels of sophistication. These standards are DXF, DWG, IGES, STEP, etc. They range from the lowest level of sophistication: the DXF interchange standard used by AutoCAD, to the complex: International STandard for the Exchange of Product-model data (STEP) standard.

DXF is an ASCII based standard, which defines the database of entities found in an AutoCAD drawing file. One of the limitations of this standard is that there are specific versions of DXF for each version of AutoCAD (McCarthy, 1990). The standard only describes entity types which are native to the AutoCAD package. This can cause considerable problems for other CAD packages when a DXF file is imported. Recently, the native AutoCAD DWG format has been used increasingly instead of DXF; it is a binary format similar to DXF, and much quicker (Anumba *et al.*, 2000).

The Initial Graphic Exchange Specification (IGES) was developed in 1980 by Boeing Aircraft, General Electric and the US National Bureau of Standards, to provide a neutral data format for the digital exchange of information amongst CAD systems (Lide, 2001). The specification itself is quite complex. As a result of its complexity, its poor implementation,
and the popularity of AutoCAD and other PC based CAD systems, IGES has not been widely adopted (Douglas, 1992).

The standard for exchange of product data (STEP) is a further development of the IGES standard, which uses an alternative approach to CAD data exchange. The approach STEP takes is to involve the complete description of product model data, as opposed to the entity-based approach used by standards like DXF.

STEP is more complex than any of the previous standards used, because it is designed to be more than one type of document. STEP is a set of resources, data exchange methodologies, interfacing methodologies and conformance testing procedures. These approaches are combined to prepare a set of application protocols (Aps) on which whole industries can base their particular exchange requirements (Mitchell, 1995). It is intended as an international standard that covers all applications and has been adopted by the International Standards Organization (ISO). In STEP, the ISO 10303 Part 225 standard (www.iso.org) deals with “Building Elements Using Explicit Shape Representation”. STEP uses the standardised computer language, EXPRESS, to describe the data structures in the application (Anumba et al., 2000).

An important effect of STEP is that it will enable a wide variety of industries to use concurrent engineering methods to improve the quality and speed at which products can be developed and facilitate the seamless interchange of information between design team members using heterogeneous CAD systems.

Authentication

As on-line Internet business transactions continue to grow, from email communication to banking transactions, Internet security becomes more of an issue. Being able to verify who you say you are is important to the seller and vice versa, to the customer. You may not want to give your credit card detail to the on-line retail site with the risk that they may use your credit card for other fraudulent transactions. The best and most common way to provide this sort of protection verification is via the concept of authentication.
A definition of authentication refers to “the process of identifying an individual, usually based on a username and password. In security systems, authentication is distinct from authorization, which is the process of giving individuals access to system objects based on their identity. Authentication merely ensures that the individual is who he or she claims to be, but says nothing about the access rights of the individual” (Wi-FiPlanet.com).

The most common form of authentication is user name and password, although this also provides the lowest level of security. The weakness of the conventional user name and password system is that passwords can be stolen, accidentally revealed or forgotten. For this reason, many Internet transactions require a more stringent authentication process such as: digital certificates and digital signatures to more accurately identify the user.

**Digital Signature**

A handwritten signature marks a document with a person’s unique identifier indicating that person’s approval of the document’s contents. There are electronic, bit-map versions of handwritten signatures that can be printed on paper. This is referred to as a digital signature (GSI, 1999).

A digital signature is designed as “an electronic signature that can be used to authenticate the identity of the sender of a message or the signer of a document, and possibly to ensure that the original content of the message or document that has been sent is unchanged” (http://www.SearchSecurity.com ). The main uses of a digital signature are for authentication and verification (Roorda, 1999).

A digital signature acts as a real signature and provides the same level of verification in the digital world as it does in the real world. It associates a digital code with a set of electronic data, where the code is generated using a private key that uniquely identifies the person that is approving the contents of the data set (GSI, 1999). A digital signature mitigates the risk of faulty transactions and provides security for e-transaction users.

The American Bar Association’s Section of Science and Technology Information Security Committee has pointed out that a signature is not part of the substance of a transaction, but
rather of its representation or form (ABA, 1996). They further note the purposes that signing writings serve:

- **Evidence:** A signature authenticates writing by identifying the signer with the signed document. When the signer makes a mark in a distinctive manner, the writing becomes attributable to the signer.

- **Ceremony:** The act of signing a document calls to the signer’s attention the legal significance of the signer’s act, and thereby helps prevent “inconsiderate engagements”.

- **Approval:** In certain contexts defined by law or custom, a signature expresses the signer’s approval or authorization of the writing, or the signer’s intention that it has legal effect.

- **Efficiency and logistics:** A signature on a written document often imparts a sense of clarity and finality to the transaction and may lessen the subsequent need to inquire beyond the face of a document. Negotiable instruments, for example, rely upon formal requirements, including a signature, for their ability to change hands with ease, rapidity, and minimal interruption.”

  (ABA, 1996)

Digital signatures are created and verified by cryptography, the branch of applied mathematics that concerns itself with deliberately transforming messages into seemingly unintelligible forms and back again (ABA, 1996). In other words, cryptography refers to a process associated with scrambling (re-ordering) plaintext into cipher text (encryption), then back again (decryption), as shown in Figure 2-1.

![Figure 2-1 the encryption/decryption process](image)

(ABA, 1996)
Cryptography

Encryption is the means of dealing with security by temporarily giving information meaningless characteristics by virtue of an algorithm (NM, 1998). It is the conversion of data into a form called cipher text that can only be understood by authorised people. It gives protection to the sender from any unlawful third party interceptor. However, for any meaning, or common understanding, to be achieved between the intended parties to such communication, a re-conversion process is necessary. Decryption is the process of converting encrypted data back into its original form, so it can be understood (http://www.whatis.com).

According to ABA (1996), “Digital signatures use what is known as public key cryptography, which employs an algorithm using two different but mathematically related ‘keys’, one for creating a digital signature or transforming data into a seemingly unintelligible form (private key), and another key for verifying a digital signature or returning the message to its original form”.

A private key is defined as “the secret key in a public key cryptography system, used to decrypt incoming messages and sign outgoing ones; while a public key refers to the publicly available key in a public key cryptography system, used to encrypt messages bound for its owner and to decrypt signatures made by its owner” (http://www.modssl.org).

2.3.3.2 ICT for Communication

ICT provides real time communication tools to facilitate the building design process. This section will cover some of the commonly used technologies and tools.

Electronic Mail

Electronic mail, or e-mail, is used for the computer-to-computer exchange of messages and is an important tool for communication and collaborative work (Laudon and Laudon, 2002). It can be used to send messages over varying distances. At a simple level, email can be used in a local office environment using LAN (Local Area Network). At the most powerful level, messages can be sent to users anywhere in the world using the Internet platform. Depending on the load on the network, e-mail can usually be delivered with minutes of it being sent (Goldstein and Heard, 1990).
One of the greatest benefits of e-mail, is that allows users to exchange information in any asynchronous manner (Mitchell, 1995). When e-mail is sent, it does not require the intended recipient to be at the other end waiting to receive the document. Instead, email is stored in an electronic mailbox of an e-mail sub-system (a software application). This enables design team members to be separated by considerable differences in time and location yet still communicate effectively. With the use of mobile (wireless) computers, it is also enables communication to be conducted from practically any location in the world (Mitchell, 1995).

E-mail is rapidly establishing itself as a universal communication tool for workers in collaborative environments. In fact, studies have shown that recipients are much more likely to reply an e-mail message than a written request, primarily because of the ease by which a response can be formulated (Pike, 1995). The time taken to respond to design queries is reduced and thus helps to eliminate design discrepancies and facilitates design co-ordination as well as communication.

Attachments with mail messages can be sent across the Internet providing that the message is converted to Simple Mail Transfer Protocol (SMTP) when it goes through an Internet communication gateway. Due to the nature of the information being transferred during design process, one of the issues to be considered is the size of the attached files. Although there is no theoretical limit to the size of an e-mail message that can be sent, there are practical considerations that should be made. If an e-mail message has a large file attached to it, it can sometime take a considerable amount of time to pass through gateways on a network. If very large files are encountered, these can sometimes crash the gateways or the system. As a result, gateways are configured to incorporate file buffers which limit the size of such files. Files that are too big are rejected and the message is simply returned to the sender. A practical limit for most e-mail messages is 1MB or less. Larger files should be transferred using other network protocols, or compressed to fit file size buffers.

**Videoconferencing**

Videoconferencing is one form of electronic conferencing, which is growing in popularity among many firms for its suitability to facilitate real time meetings and exchange of information, thus reducing travel time and cost. It helps design teams by promoting remote collaboration from different locations or filling in personnel expertise gaps.
“The videoconferencing unit permitted face-to-face discussions, but more importantly provided a means of showing video material to the design team. The site staff filmed an area where a design problem had arisen, or where the design team required up-to-date information and this could be relayed within the hour.”

(Thorpe et. al., 1995).

According to Laudon and Laudon (2002), desktop videoconferencing systems (sometimes referred to as video telephony) typically provide a local window, in which we can see ourselves, and a remote window to display the individual with whom we are communicating. They also provide facilities for ‘whiteboard sharing’, allowing design members to transfer, co-view, discuss and co-edit data files containing textual and/or graphical information (Anumba et al., 1997b). Software products such as Microsoft NetMeeting, Gallant InterVision Pro, and Netscape Communicator’s Conference are examples of commercially available videoconferencing tools for desktop videoconferencing over the Internet.

**Groupware Solution**

“Groupware” refers to hardware and software technology used to facilitate communication between dispersed groups of people or individuals and enable interaction between them. It is a general term used to classify software products that enable better coordination and collaboration between groups of people, the information systems and their business processes (BT, 1995).

Laudon and Laudon (2002) point out that groupware is built around three key principles: communication, collaboration, and coordination. It allows groups to work together on documents, schedule meeting, route electronic forms, access shared folders, participate in electronic discussions, develop shared databases, and send e-mail.

An example adopted from Ellis and Wainer (1999, P.425-426) gives a better picture of how groupware works.
“Almost everyone is familiar with electronic mail, and understands that this is a technology used at different times, and different places by its participants. The sender does not expect an immediate reply from the receiver. This can be contrasted with face-to-face electronic meeting room technology, sometimes called group decision support systems (GDSS – the research area that studies the use of computing and communication technologies to support group activities). These systems typically consist of the following networked technology in a single room:

- Presenting technology (large screen projector, or electronic whiteboard);
- Computation technology (a workstation or portable PC for each participant);
- Group process technology (voting tools, brainstorming tools, etc.);

Notice that in contrast to electronic mail, a GDSS is designed to support real-time face-to-face interaction among people, so it is called ‘same time, same place’ technology”.

(Ellis and Wainer 1999, P.425-426)

Commercial groupware products such as: Lotus Notes (http://www.lotus.com), Open Test’s Livelink (http://www.opentext.com), Groove (http://www.groove.net), and IM Conferencing (http://www.imconferencing.com/), enable people to work directly with other people over the response time for processing transactions.

**Workflow Solution**

Workflow is one of the sub-categories from groupware solutions (BT, 1995). It is defined as “… a unit of work generating products or services which are related to, or result in, customer satisfaction. Every workflow has a main customer, who is served by a supplier, or a cooperative network as being a chain of customers and suppliers, working towards the satisfaction of the main customer” (Schal, 1996). Workflow management on the other hand refers to “… the process of streamlining business procedures so that documents can be moved easily and efficiently” (Laudon and Laudon, 2002).

As discussed earlier, the building design process frequently involves multidisciplinary professionals working in geographic dispersed locations; with the associated risks of miscommunication, errors and delay. Workflow management software automates processes such as routing documents to different locations, securing approvals, scheduling, and
generating reports (Laudon and Laudon, 2002). In this case, each professional team member may be able to work on the same document at the same time, thus allowing quicker completion time and eliminating unnecessary errors and conflicts.

Workflow management software systems all serve the same purpose: to define, manage, and execute workflow processes through the implementation of software, running on one or more workflow engines, which is able to interpret the process definition and interact with workflow participants and applications (WMC, 1999). Examples of such systems include:

- **Action Workflow** ([http://www.actiontech.com/](http://www.actiontech.com/)): a system that provides a workflow model and architecture based upon the philosophical notions of Heidegger, and the linguistic speech act theory (Lafon, 1999).
- **Staffware** ([http://www.staffware.com/](http://www.staffware.com/)): a system that has the ability to manage long running, people intensive processes and short lived, sub-second, system-to-system process and the various points between those two extremes.

**Visualisation**

Visualization is defined by the Oxford English Dictionary as “... a form of a mental vision, image, or picture of (something not visible or present to sight, or of an abstraction); to make visible to the mind or imagination” (OED, 1989). In an article written by McCormick et al. (cited by Domik, 2000) visualization has been defined as “... a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. In many fields it is already revolutionizing the way scientists do science”.

According to Domik (2000), computer generated data visualizations appeared in the late 1940’s when tables become much too large for a human to comprehend and manage. These visualizations, then called plots, were followed by the growth of computer graphics and systems that permitted the rapid, often interactive, generation of scientific data sets. However, in today’s society with the expansion of the Internet- and web-based technologies, visualization has become a means for communication.
Three broad classes of visualization systems have been pointed out by John (1997) where some rely on textual languages; others rely on a visual (usually graph-based) language; others use a spreadsheet-like (tabular) metaphor. Different language types are adopted to represent different information types to provide better visualization as well as understanding.

**Personal Digital Assistant (PDA)**

PDAs (Personal Digital Assistants) are defined as “… small, pen-based, handheld computers capable of entirely digital communications transmission, with built-in wireless telecommunications capabilities as well as work organization software” (Laudon and Laudon, 1998). A PDA can deliver many or all of the following functions: cellular phone, fax device, web browser, personal organizer, address book, scheduling calendars, MP3 music player and digital camera, in addition to truncated versions of most standard popular computer application software. PDAs are also called: pocket PCs, handheld organizers, palm pilots or personal information managers (PIMs).

PDAs can be viewed as a scaled down versions of personal or laptop computers. PDAs contain essentially anything one might need from a computer when on the move; however they are not intended to be completely self-contained but are designed to synchronize with a desktop PC and keep information up to date on both sides (Tull, 2002).

As the physical features of PDAs are uniformly small size, lightweight, and easy to carry in the hand, they are widely used by design professionals to keep track of to-do lists, schedule important appointments; store and access names, addresses and phone numbers; send email; and as a digital camera.

**2.3.3.3 ICT for Information Management**

ICT has provided industries with great advantages in terms of speed of operation, consistency of data generation, accessibility and exchange of information (Stewart and Mohamed, 2003). This section describes some of the tools used by design professional to facilitate design information management.
Office Automation System

An office automation system includes the following:

Word processor

Word processor refers to computer software applications that are used to create and print documents. The Computer Jargon Directory (http://www.yulia.com/) defines word processor as “a software application for preparing largely text-based documents, from basic letters to company newsletters and reports.” Most word processors incorporate small versions of other program/application types e.g. that enable us to create drawings, make simple tables and edit figures. Some permit links to other documents/files, or check grammar or spelling automatically. The most common word processor programs available are: Microsoft Word (www.microsoft.com) and Lotus WordPro (www.lotus.com). Others are Sun StarOffice (www.sun.com/staroffice), OpenOffice (www.openoffice.org) and WordPerfect (www.wordperfect.com).

To perform word processing, a computer is required with a word processor program installed, together with a link to a printer if hard-copies of output are required. A word processor enables the creation of a document which can be displayed on screen; stored as a file (on hard drive, server, disk or other storage medium; printed as hard-copy; inserted into another document as a link; transmitted to someone else; or uploaded to a web-site.

The great advantage of word processing over conventional manual writing or using a typewriter is flexibility in writing and editing. Text can be corrected at the point of error, deleted, or cut/copied and pasted elsewhere in that or another document. Drawings or graphics from other (compatible) software programmes can be inserted. Also, document files can be labelled and saved as different versions of the same document.

Other advantages of using a word processor are:

- Time saving - corrections to word processed documents can be made more quickly compared to manual hand writing or by using a typewriter.
- Better appearance – documents look more polished and professional, without any trace of errors.
- Sharing of documents – documents may be re-used for other purposes with minor modification to the existing document.
Spreadsheet

Spreadsheets have always been used for accounting purposes and the recording of everyday transactions. An electronic version of a spreadsheet system, called ‘VisiCalc’, was invented in 1978, by a Harvard Business School student, Daniel Bricklin and his co-creator or co-inventor Bob Frankston (Power, 2003). Different people define spreadsheets differently, but there are two terms that are common in any definition: column and row. Broadly, a spreadsheet is defined as: a two dimensional matrix medium that displays accounting or other data in the cells created by the intersections of multiple rows and columns. It is also a computer application program that simulates a physical spreadsheet by capturing, displaying, and manipulating data (text, numeric or formulae) arranged in rows and columns (whatis.com).

Modern spreadsheet applications permit relatively sophisticated statistical and other manipulations of data, and provide the facility to display results in a wide variety of graphic chart formats.

Database

The building design process is extremely decentralized as each project involves multi-disciplinarian professionals working together but in different location. It is not an industry practice to keep project teams together from project to project due to the multiple locations of project sites, and the fragmented separation of projects, clients and professionals. Thus, the data management process for construction tends to be more complicated compared to other industries.

A database is defined as “... a collection of data organized to serve different purposes (or different users) efficiently by centralizing the data and minimizing redundant data. Rather than storing data in separate files for each application, data are stored physically to appear to users as being stored in only one location” (Laudon and Laudon, 1998, pp271). Thus, historical data can be stored in a company database to prevent loss of data and to provide reference material to team members.

Database applications can be an integral part of a CAD system in some instances to support the efficient and economic running of an individual project by a design firm (Cornick, 1996). These ‘relational’ databases can provide passive technical data on building for design
guidance or be used as a guide to quality, environmental and health /safety procedures. Some have a more active role, for example when a CAD application also has the capability of measuring and pricing the building work represented by the graphic output for the building design

**Sketches / Hardcopy Data**

Digital versions of information storage and transfer are widely used today, but the construction industry still places heavy reliance on paper-based records such as hand-written notes and reports, word processed documents, CAD drawings, spreadsheet data report, survey data, photographs and sometimes videotape. All of these may be used and exchanged among project team members. These data are often bulky and difficult to handle. Substantial physical storage facilities are required to keep them.

**Computer Aided Design (CAD)**

The development of CAD computer-based systems for architecture, engineering and construction has essentially been driven by the need to represent and display a whole or part of a building form and material in either a 2D or 3D mode (Cornick, 1996)

Two dimensional (2D) CAD drawings have been and continue to be used as an aid for the more efficient production of working drawings, making repetitive tasks easier, quicker and less tedious (Emmitt and Gorse, 2003). Building designers use these high powered computing and advanced graphics applications and their associated workstations for everyday tasks to ease the design process. Some of the benefits of 2D CAD as highlighted by Sun and Howard (2004, pp 60) are as follow:

- “2D CAD tools increase productivity, especially at the information production stage. This benefit is more evident when design changes become necessary. Instead of re-producing all the drawings, CAD allows designers to make changes to the existing ones.
- 2D CAD tools help to improve the quality of design information. Using traditional paper drawings, keeping data accurate and consistent is a big challenge. In CAD drawings, all measurements are precise.
• 2D CAD tools help to increase the speed of information exchange between project team members. Previously, it would take several days to send drawings through the post. Now CAD drawing files can be attached to e-mails or sent via the Internet instantly.

• 2D CAD tools allow designers to reuse previous drawings or part of the drawings.

• 2D CAD tools make the drawing storage and archiving task easier. Paper drawings present storage problems as they deteriorate, are usually very large and cause documentation problems. A CAD file stored in a structured directory on a PC (plus appropriate back-up storage) prevents these problems from occurring which will also ease quality assurance issues.”

(Sun and Howard, 2004, pp 60)

3D Modelling

One of the limitations of 2D drawings is that they try to represent a three-dimensional building on a two dimensional plan where some of the information cannot be represented explicitly (Sun and Howard, 2004). Thus there is a need for 3D modelling, a three-dimensional geometry modelling method. By adopting a 3D modelling technique as their presentation tools, design professionals are able to demonstrate to their clients their capability to create appropriate and interesting spatial experiences in a more understandable way. Note that in CAD applications, 3D modelling is not truly three-dimensional, it simply represents the three dimensional planes of building design (length, width/breadth and depth/height) in a two-dimensional format.

Multimedia

“Multimedia technologies facilitate the integration of two or more types of media, such as text, graphics, sound, voice, full-motion video, still video, or animation, into a computer-based application” (Laudon and Laudon, 2002). The aim is to broaden the communications bandwidth between the end-user and the system, thereby enhancing the quality of the user interface (Anumba et al., 1997b).

Multimedia has been adopted in the building design process to facilitate the communication and presentation of the design ideas and concepts. As computers are more extensively used in the design process, it has been argued that design documents will eventually begin to integrate
information from CAD, text, video, animation, and database sources (Bouchlaghem, et.al., 2004; Su, and Chan, 2003). The interactive nature of multimedia makes it highly suited to making comprehensive design concept presentations for designers, clients and other interested parties. As people always say, “a picture is worth a thousand words”, the richness of the data being presented and the dynamic alternate paths that can be taken in the exploration of the design thus achieve improved results (Shen et al., 2001).

Moreover, a research case study revealed that: “… relaying of video to design teams over a multimedia link could reduce the need for design engineers to visit a site, and fulfil the requirements for improved knowledge of progress and site condition, without additional travel costs and time delays.”(Thorpe et al., 1995)

The most difficult element to incorporate into multimedia information systems has been full-motion video, because so much data must be brought under the digital control of the computer (Laudon and Laudon, 2002). Due to the massive amounts of data in each video image, and the difficulties this creates for real-time display, the usual delivery method for most multimedia is CD-ROM. Even when complex compression techniques are used, it is difficult to compress graphic, video, and audio data without compromising their quality, thus the need for high capacity storage media.

**Artificial Intelligence**

Artificial intelligence (AI) refers to the development of computer-based systems that can behave intellectually like humans, with the ability to learn languages, accomplish physical tasks, use a perceptual apparatus, and emulate human expertise and decision making (Laudon and Laudon, 2002). It is expected that such techniques will play an increasingly significant role in the development of software applications for the construction industry (Alshawii and Underwood, 1999).

Adopting AI techniques into the building design process will facilitate collaborative working between design team members. AI directly addresses the integration of multi-disciplinary perspectives and provides a framework for resolving design conflicts between members. Further benefits have been addressed (Anumba et al., 2002) and these are as follows:
“Having agents communicate with each other across the Internet brings great increases in speed of convergence to a satisfactory design, compared with the traditional inter-disciplinary interaction;

- Decentralization of traditional and inadequate project command and control structures;
- Effective decomposition of large-scale problems;
- Improved collaborative and concurrent engineering;
- Easier and cheaper access to (routine) specialist information (especially as agent-based systems are made available on the World Wide Web).”

(Anumba et al., 2002)

**Electronic Data Interchange (EDI)**

Electronic data interchange (EDI) is a form of electronic communication that allows businesses to exchange transaction data and documents in structured formats that can be processed by computer applications software and without human intervention (Copeland and Hwang, 1997). EDI transactions can include the exchange of quotations, purchase orders, invoices, and any other type of business data that is included on any type of business form. The major goal of EDI is to replace paper documents with their electronic counterparts, thus reducing the time spent on printing, mailing and re-entering information (Hasselbring and Weigand, 2001).

One of the key features of EDI is that it can use special networks and clearing houses to transmit messages. In addition to being able to directly communicate with other companies using the public telephone network, special third party organizations known as value added networks (VANs), can also be used. These network providers are responsible for administering and providing a secure infrastructure to transmit sensitive commercial information, and for providing a secure electronic mailbox facility (Wayner, 1994).

According to Wayner (1994), “the central mailbox, or clearinghouse, is able to perform functions such as transaction of data from different formats, and standard e-mail. The clearinghouse also offers the ability to process messages in batches rather than individually. This allows a subscriber to the service to access his/her mailbox at varying frequencies, depending on the volume and urgency of the messages being received”.

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**Digital Pen**

Professionals describe ‘digital pen’ as “a battery-operated writing instrument that looks like a regular ball-point pen but which allows the user to digitally capture a handwritten note or drawing” (http://MobileComputing.com). The pen includes a tiny camera, in-built memory and a Universal Serial Bus (USB) cradle or Bluetooth interface to let the user upload the data record of the handwritten notes to a personal computer. A digital pen writes on a special digital paper coated with millions of tiny dots, thus making it possible to identify the exact location of the pen at every key stroke.

The information stored in the pen memory can be easily transferred to personal computers or other IT devices such as mobile phones, PDAs via a Bluetooth or USB interface.

Digital Pen enhances communication among project professionals. Data captured on site can be transmitted to other IT devices, saved and stored, and accessed by other team members anytime and anywhere.

All the technologies described in this section are commercially available and are affordable to most design firms. The utilisation of these technologies can enhance the co-ordination between design team members and provide them with a collaborative environment that will help them to participate in the design process in a more effective and efficient way.

### 2.3.4 The Impact of Technology

When looking at the positive impacts ICT brings, most of the common perceptions relate to time and cost saving, improved communication, better information management, better decision making and client satisfaction (Moreau and Back, 2000; Huijbregts, 2002; Stewart and Mohamed, 2003; Rezgui et al., 2001; Duyshart et al., 2003). The positive impacts of ICT can be categorized into tangible (or hard) factors such as: cost saving, time saving, staff reduction and operational efficiencies. Less tangible (or soft) factors include: accuracy, quality, convenience, variety, timeliness, flexibility, functionality, reliability, useability, user satisfaction, utilisation, relevance, and security (Duyshart et al., 2003).
There are also negative impacts on ICT implementation. This section covers both the positive and negative impacts.

One of the most important impacts of ICT is cost. Duyshart et al. (2003) point to seven major areas of cost that could be directly affected through the use of information technology initiatives. These cost areas are:

- **“Plan printing** – reduced numbers of prints through centralized management and user demand printing.
- **Paper supplies** – reduction of overall paper consumption.
- **Photocopier/fax hire** – reduction of hire charges based on reduced number of copies.
- **Postage/Couriers/Taxis** – reduction in the number of physically exchanged documents.
- **Photography** – elimination of traditional chemical based processing with use of a digital camera.
- **Interstate travel** – reduction of travel requirements due to improved communication and access to information.
- **Telephone/mobile** – reduction of the number of calls due to improved communication.”

(Duyshart et al., 2003)

Time and speed have also been viewed as important factors associated with ICT. Activity time is associated with the total elapsed time from the point when an activity starts to the time it is fully completed. It therefore includes work time as well as time spent waiting or idle (Moreau and Back, 2000).

Based on ethnographic interviews conducted in a study that attempted to explore the relationship between information and communication technology (ICT) and team working, Egbu et al. (2001), conjectured that: “ICT is vital to project participants in speeding up their work. ICT enables faster and usually more efficient outputs to be generated, and greatly aids their working processes”. Belmiro et al. (2000) state that a number of benefits arise in terms of time saving: faster the activity times, speeding up of communication flows; quicker
decision making; eliminating travel time; sharing data bases (global environment); and eliminating intermediates from the communication process.

ICT applications have made a wide range of information and research sources available in a digital format for easy access. Research in the real estate industry shows that the quality of information exchange and communication has improved through the adoption of technology (Huijbregts, 2002). ICT use increases cooperation and enhances collaborative working because it reduces task uncertainty between professionals through the effects on information exchange intensity and channel formalization. As Stern and Kaufman argued (cited in Nakayama, 1999): “... the greater the amount of information exchange, the greater the possibility for mutual understanding of each other’s goals, which can lead to increase cooperation.”

For recording and reporting functions, the quality of information exchanged has improved due to the decrease in data duplication and the time expended in re-entering received data. The result is more up-to-date information that is often directly linked into decision-making as well as reporting.

Whilst ICT certainly appears to have cost and time benefits, there is a downside. ICT implementation can increase a firm’s or professional susceptibility if it shares sensitive operational information with other parties. This has brought into play risk and security issues for electronic data exchange between parties.

Egbru et al. (2001) found that many ICT users believe that ‘too much’ computer-mediated communication can lead to feelings of alienation and frustration. The use of e-mail is frequently cited as being both indispensable and troublesome. Although it speeds up communication and reduces much of the need for paper, it can cause ‘interactional difficulties’. This finding is supported by Rozell and Gardner (2000). It has been suggested that e-mail and other computer mediated systems, such as video/tele-conferencing, can make people lazy and less likely to partake in face-to-face communication.
2.3.5 The Challenges

There can be significant implementation barriers associated with ICT implementation. Various authors (Peansupap and Walker, 2005; Whyte et al., 2002; Hannus et al., 2003; Kalian et al., 2001; Egbu et al., 2001; Anumba et al., 2002) have suggested that the barriers to ICT implementation in the workplace may fall into four main categories: cultural, technical, management and organisational issues.

Cultural Barriers

Cultural barriers to ICT implementation include:

- **Threat of IT**: In-experienced users may feel threatened by IT. Appropriate training is important for users, especially for any who are lagging in education (Love et al., 2001, cited in Peansupap and Walker, 2005).
- **The project-based nature of construction**: projects are discontinuous and temporary endeavours and there are often poor linkages between project and business processes, which create problems for rapid assimilation of new ideas within construction firms (Gann and Salter, 2000 cited in Whyte et al., 2002; Hannus et al., 2003).
- **The adversarial attitudes and fragmentation**: of the different participants in most construction projects under traditional building procurement systems (Egan, 1998 and Barlow and Lowenberg, 1999, cited in Whyte et al., 2002).
- **The ‘engineer’s paradigm’**: an emphasis on the short-term aspects of project management rather than wider issues of business management, resulting from the fact that management techniques usually originate from practice (Pries and Janszen, 1995 cited in Whyte et al., 2002).

Technical Barriers

Technical barriers to ICT implementation include:

- **Improper Implementation Approach**: An all-at -once changeover can cause minimum disruption but is risky; parallel systems are safer, but expensive and slow; a gradual transition is appropriate so as to avoid these issues (Kalian et al., 2001).
\begin{itemize}
\item \textit{Lack of adequate training and education}: Lack of skills and know-how about IT may result in poor performance by end users thus underachieving the primary objectives of ICT introduction into the organisation (Kalian \textit{et al.}, 2001).
\end{itemize}

\textit{Managerial Barriers}

Managerial barriers to ICT implementation include:

\begin{itemize}
\item \textit{Not Identifying ICT Opportunities}: Not analysing the potential value chain and failure to apply ICT to information-intensive activities and linkages; and lack of adaptability by end users and clients (Peansupap and Walker, 2005).
\item \textit{Lack of Resources Commitment}: ICT being treated as an expenditure and not an investment; not being viewed for the long-term, i.e. benefits do not come immediately but gradually; and not including adequate resources (Peansupap and Walker, 2005).
\item \textit{Low level of perceived benefits from ICT investments}: the construction industry is conservative to adopt new technology unless it is convinced about the contribution of the technology (Li and Wang, 2003).
\end{itemize}

\textit{Organization Barriers}

Organisational barriers to ICT implementation include:

\begin{itemize}
\item \textit{Different perspective on ICT}: Unable to continuously consolidate the integration process of ICT to the rest of the business; not teaming up users and ICT specialists to further develop the system and its applications; and not teaming managers of independent systems (Egbru \textit{et al.}, 2001).
\item \textit{Lack of Top Management Support}: “Organisational structures which foster protective functional managers and which do not support integration, reward systems which are based on individual goals and lack of client and supplier involvement” (Parsael and Sullivan, 1992; cited in Anumba \textit{et al.}, 2002).
\end{itemize}
2.4 PROCESS MAPPING

A process map is useful in building design as it can be used to capture the required information for executing the design process properly. It is an important tool for design professionals as it helps them to construct, test and analyse, as well as to manipulate the design concept before building the real product. It is also sometimes used for training and for managing change.

The following section includes brief discussion on the definition of process and some common process mapping methods. It concludes with the IDEF0 mapping methodology as the focus of this research.

2.4.1 Definition of Process

The Longman dictionary defines process as “a set of actions or changes that develop or happen naturally; or a continued set of actions performed in order to make or do something”.

In the context of workflow management, process is seen as “… the representation of a business process in a form that supports automated manipulation, such as modelling, or enactment by a workflow management system. The process definition consists of a network of activities and their relationships, criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated IT applications and data.”

(WfMC, 1996)

2.4.2 Process Mapping Methodology

Process mapping is the representation (graphically or in text) of the related activities identified in a business process. The nature of the activities is indicated, and quantitative aspects may be included.

Published references to process mapping include:
“Process mapping is a management tool initially developed and implemented by General Electric as part of their integrated ‘workout’, ‘best practices’, and ‘process mapping’ strategy to improve significantly their bottom-line business performance. The process mapping concept is used to describe, in workflow diagrams and supporting text, every vital step in your business process.”

(Hunt, 1996, P.1)

“Process mapping, sometimes referred to as process modelling or process protocol, has long been a tool used to assess manufacturing processes. Process mapping helps the company and employees identify value adding activities, bottlenecks, and waste. The graphical presentation of the process map is especially helpful in visualizing and quantifying the amount of time spent on each activity during the entire process.”

(Process Mapping Homepage, 1999)

Process mapping tools have proved to be an excellent means for accomplishing the entire requirements for process documentation. It is an important way to capture the required information for executing a process properly. Hunt (1996) points out that process mapping is a proven analytical and communication tool intended to help in improving existing processes or to implement a new process-driven structure in order to re-engineer business processes. Process mapping is a process management tool that can be used to better understand the current process and to eliminate or simplify those aspects requiring change (Hunt, 1996). According to Hunt (1996), the leading process mapping tools are divided into five categories: (1) Simple Flow-Chart Graphic Tools, (2) Process Mapping Products, (3) IDEF Process Mapping Products, (4) Process Simulation Products, and (5) Process-Mapping Related ABC Products. The following section covers a brief description for each of the five process mapping tools based on Hunt (1996).

**Simple Flow-Chart Graphic Tools**

The simplest process mapping tool is pencil and paper. In many cases, particularly when trying to begin a process mapping effort, it is possible to start with pencil sketches that describe the key boxes or elements of the processes. This can be expanded by writing process block-diagram information on small stick-on notes and pasting them onto oversize sheets of
paper, or they can be applied to a whiteboard or wall surface. This enables the magnitude of the process mapping effort to be visualised. The use of this simple approach is often sufficient to begin process improvement; it is quickly possible to communicate to the process mapping team the priority areas of interest and potential improvement.

**Process Mapping Software Products**

Process mapping software products are emerging that are specifically created to focus on the needs of re-engineering process improvement users. BPWin is a good example of an integrated software approach that provides process mapping and simulation, and also provides an easy link to other software products (Hunt, 1996).

**IDEF Process Mapping Software Products**

The fundamental concepts of IDEF (Integrated computer-aided DEFINition) process mapping are based on the ideas of structured analysis that have produced significant payoffs in diverse business applications (Hunt, 1996).

The following shows several types of IDEF software and their application in different fields (Mayer *et al.*, 1992):

- **IDEF0** – functional or activity modelling
- **IDEF1** – information modelling
- **IDEF1x** – data modelling
- **IDEF2** – system dynamics modelling
- **IDEF3** – process description capture
- **IDEF4** – Object oriented design
- **IDEF5** – concept/ontology capture
- **IDEF6** – information system (IS) design capture
- **IDEF8** – user interface modelling
- **IDEF9** – scenario-driven IS design
- **IDEF10** – implementation architecture modelling
- **IDEF11** – information artefacts modelling
- **IDEF12** – organization modelling
Benefits include reductions in development costs, fewer system integration failures, and uniformly better communication (Hunt, 1996). An IDEF software-created process map consists of diagrams, text, and glossary that are cross-referenced to each other. Either paper or computer graphic process map diagrams are the major output of the IDEF process mapping software products.

**Process Simulation Software Products**
Generally, process simulation software tools are used to address the dynamic properties such as “what-if” and “to-be” process mapping analysis steps that often provide the greatest benefit to process improvement initiatives. Process mapping simulation software tools provide an effective means to examine potential process improvements before substantial funds are invested in a new product or process improvement effort; they also provide an early warning if disconnects or implementation conflicts can be identified without actually making the planned change in the process (Hunt, 1996).

**Activity-Based-Costing (ABC) Software Products**
Activity based costing (ABC) segregates and manages product and process costs differently to the traditional cost accounting approach. ABC is a methodology that measures the cost and performance of activities, resources, and cost objects. Resources are assigned to activities; then activities are assigned to cost objects based on their use. ABC recognizes the casual relationship of cost drivers to process activities (Hunt, 1996).

### 2.4.3 The IDEF0 Approach
IDEF0 process mapping approach was selected for the purpose of this study. This section discusses the basic elements of the IDEF0 modelling technique, identifies the basic components of syntax (graphical component) and semantics (meaning), specifies the rules that govern the use of the IDEF0 technique, and describes the types of diagrams used. The information provided in this section is based on portions of the Integration Definition for
IDEF0 (Integration DEFinition language 0) is designed to model the decisions, actions, and activities of an organization or system (Mayer et.al., 1992). It is based on SADT (Structured Analysis and Design Technique), developed by Douglas T. Ross and SofTech, Inc. In its original form, IDEF0 includes both a definition of a graphical modelling language (syntax and semantics) and a description of a comprehensive methodology for developing models (FIPS 183, 1993).

“IDEF0 is a modelling technique based on combined graphics and text that are presented in an organized and systematic way to gain understanding, support analysis, provide logic for potential changes, specify requirements, or support systems level design and integration activities. An IDEF0 model is composed of a hierarchical series of diagrams that gradually display increasing levels of detail describing functions and their interfaces within the context of a system. There are three types of diagrams: graphic, text, and glossary. The graphic diagrams define functions and functional relationships via box and arrow syntax and semantics. The text and glossary diagrams provide additional information in support of graphic diagrams.”

(FIPS 183, 1993)

Figure 2-2 shows the arrow position and roles for a box diagram. Arrows connected to the bottom side of the box represent mechanisms. Upward pointing arrows identify some of the means that support the execution of the function. Other means may be inherited from the parent box. Mechanism arrows that point downward are call arrows that enable the sharing of detail between models (linking them together) or between portions of the same model (FIPS 183, 1993).
Function boxes are linked together to map the process. Some boxes are complex enough that the task within the box can have its own “child” process map diagram. These “parent” and “child” diagrams are linked together in a “context diagram” (Figure 2-3), which can be represented as a tree diagram (Grout, 1998).

One feature of IDEF0 is that it progressively gets into greater and greater levels of detail through decomposition. As shown in Figure 2-4, an IDEF0 functional model starts with the representation of the whole system as a single unit – a box with arrow interfaces to functions outside the system. “Since the single box represents the system as a whole, the descriptive name given in the box is general. As a function is decomposed into its sub-functions, the interfaces between the sub-functions are shown as arrows. The name of each sub-function box plus its labelled interfaces defines a bounded context for that sub-function. Overall, these parent and child diagrams compose the whole system function model” (FIPS 183, 1993).
According to the specification (FIPS 183, 1993), IDEF-0 maps should only contain 4-6 process boxes per map. Additional detail will force the mapping to continue on another map at a lower level in the hierarchy. The map numbering convention that provides the hierarchical links between maps will not provide unique numbering schemes for more than 9 boxes per map. This limit to the number of boxes per map does not impede the documentation and presentation of detailed process information. To the contrary, using multiple levels of hierarchy provides the capability to specify at whatever detail is needed. Moreover, those needing less detail are not forced to absorb all the details. IDEF-0 is at once easy to read and extremely detailed.
IDEF0 may be used to model a wide variety of automated and non-automated systems. For new systems, IDEF0 may be used first to define the requirements and specify the functions, and then to design an implementation that meets the requirements and performs the functions. For existing systems, IDEF0 can be used to analyse the functions the system performs and to record the mechanisms (means) by which these are done (FIPS 183, 1993).

The result of applying IDEF0 to a system is a model that consists of a hierarchical series of diagrams, text, and glossary cross-referenced to each other. The two primary modelling components are functions (represented on a diagram by boxes) and the data and objects that inter-relate those functions (represented by arrows) (FIPS 183, 1993).

As a function modelling language, IDEF0 has the following characteristics (FIPS 183, 1993):

- “It is comprehensive and expressive, capable of graphically representing a wide variety of business, manufacturing and other types of enterprise operations to any level of detail.
- It is a coherent and simple language, providing for rigorous and precise expression, and promoting consistency of usage and interpretation.
- It enhances communication between systems analysts, developers and users through ease of learning and its emphasis on hierarchical exposition of detail.
- It is well tested and proven, through many years of use in Air Force and other government development projects, and by private industry.
- It can be generated by a variety of computer graphics tools; numerous commercial products specifically support development and analysis of IDEF0 diagrams and models.”

(FIPS 183, 1993)

IDEF0 is a diagramming technique that shows component parts, inter-relationships between them, and shows how they fit into a hierarchical structure (AIT, 1995). The top-down feature of the IDEF0 model starts by representing the whole building design process as a simple unit in a single box. Further decomposition of the boxes into sub-activities will provide more detailed information for each sub-activity thus giving a clear idea on how each building design activity works.
The IDEF0 process modelling technique was selected for the representation of the building design process in this research as IDEF0 provides a good representative understanding of the “current” situation of the building design process. The model provides a means for communication and presentation of results for the DELPHI survey data collection process, where all the panel experts were looking at the same model with the same definitions.

The proposed building design process model, using IDEF0 process modelling technique, will be discussed in Chapter 4.

2.4.4 Models Review

The following is a review of four design process models. The information gleaned from the review of these process models will form the basis for the development of the research design process model.

The four models are:

- Generic Design and Construction Process Protocol (GDCPP);
- RIBA Plan of Work;
- Analytical Design Planning Technique (ADePT);
- Conceptual Design Framework Model.

1. **Generic Design and Construction Process Protocol (GDCPP)**

“The Process Protocol (GDCPP) was funded by the EPSRC under the Innovative Manufacturing Initiative (IMI) and undertaken by the University of Salford with seven industrial partners during 1995-98. Using manufacturing principles as a reference point, a framework of common definitions, documents and procedures were developed to help construction project participants work together seamlessly.”

([www.processprotocol.com](www.processprotocol.com))
According to figure 2-5, the design and construction process protocol was mapped into:

Eight sub-processes (Activity Zones-the Y-axis):

- Development Management;
- Project Management;
- Resource Management;
- Design Management;
- Production Management;
- Facilities Management;
- Health & Safety, Statutory and Legal Management;
- Process Management;

Four broad stages (X-axis):

- Pre-Project;
- Pre-Construction;
- Construction;
- Post-Construction

Ten phases:

- Demonstrating the Need;
- Conception of Need;
- Outline Feasibility;
- Substantive Feasibility Study & Outline Financial Authority;
- Outline Conceptual Design;
- Full Conceptual Design;
- Coordinated Design, Procurement & Full Financial Authority;
- Production Information;
- Construction;
- Operation and Maintenance.

Aouad et al. (1998a) point out that the process protocol has highlighted the need for greater ‘front end’ activity in the process and this map puts the argument that the emphasis on feasibility and design is of crucial importance - a ‘new way of working’. The current research focuses on the pre-construction stage for building design process, thus the process protocol provides a good guide while developing the proposed research model.
Figure 2-5 Generic Design and Construction Process Protocol (www.processprotocol.com)
2. **RIBA Plan of Work for Design Team Operation**

The Royal Institute of British Architect Plan of Work for Design Team Operation was originally published in the first edition Handbook of Architect’s Job Book in 1964 and had been updated throughout the years. Its intention was to provide a model procedure for methodical working of the design team, and also to serve as a framework for other sections of the Handbook (RIBA, 1980).

This model is chosen for review due to the levels of detail it contains, and its familiarity to building design professionals. The simplest levels of this model have four phases: Briefing; Sketch Plans; Working Drawings; and Site Operation. These phases sub-divide into 12 stages. These stages were updated in 1999 (RIBA, 1999)

Brief descriptions for each stage are as follows:

“A: (Inception) Appraisal Identification of Client’s requirements and possible constraints on development. Preparation of studies to enable the Client to decide whether to proceed and to select probable procurement method.

B: (Feasibility) Strategic Briefing Preparation of Strategic Brief by, or on behalf of, the client confirming key requirements and constraints. Identification of procedures, organizational structure and range of consultants and others to be engaged for the project. [Identifies the strategic brief (as CIB Guide) which becomes the clear responsibility of the client]


D: (Scheme Design) Detailed proposals. Complete development of the project brief. Preparation of detailed proposals. Application for full development control approval.

E: (Detail Design) Final proposals. Preparation of final proposals for the Project sufficient for co-ordination of all components and elements of the Project.
F: (Production information) F1: Preparation of production information in sufficient detail to enable a tender or tenders to be obtained. Application for statutory approvals. F2: Preparation of further production information required under the building contract. [Now in two parts, F1 - the production information sufficient to obtain tenders and F2 - the balance required under the building contract to complete the information for construction]

G: (Bill of Quantities) Tender documentation. Preparation and collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the construction of the Project. [Solely concerned with the documentation required for tenders. Particularly useful with D+B or management contracts]

H: (Tender action). Identification and evaluation of potential contractors and/or specialists for the construction of the project. Obtaining and appraising tenders and submission of recommendations to the client.

J: (Project Planning) Mobilization. Letting the building contract, appointing the contractor. Issuing of production information to the contractor. Arranging site handover to the contractor.

K: (Operation on Site) Construction to Practical Completion. Administration of the building contract up to and including practical completion. Provision to the contractor of further information as and when reasonably required.

L: (Completion) After Practical completion. Administration of the building contract after practical completion. Making final inspections and settling the final account. [Clearly separated from the construction phase]”

(RIBA, 1999)

This model clearly set out the details of the work to be carried out and identifies the role and responsibilities of major parties in the building team within the project life cycle for the procurement of a fully designed building project, which is the focus type of procurement for this research. However, this research will focus on the early stage of the construction cycle, i.e. from outline proposal to detail design stage of the process as equivalent to schematic design, design development and documentation stages as in RAIA advisory note (RAIA, 2000).
According to the research undertaken by CONBPS, perceptions of the role of the architect differ (Poon et al., 2000). The architect is no longer the leader of the construction team and the design manager responsible for coordinating the whole design task. Roles of other participants should be added, such as consultant engineer, project manager and other specialists. Poon et al., (2000) further point out that: “the construction process is not sequential, as time is the most important element in the modern world; this is in conflict to the RIBA plan of work”. Thus, the current research has adopted the RIBA plan of work as a brief guide in conjunction with the RAIA advisory note and then further explores the building design process in detail using the IDEF0 process modelling technique.

3. Analytical Design Planning Technique (ADePT)

The ADePT planning methodology provides a powerful, yet simple means of understanding the interdependencies between tasks in the design process (Austin et al., 2002). These authors further point out that it challenges the way the product is viewed at a general level, placing greater emphasis on understanding and analysing the process of design. The ADePT methodology (see Figure 2-6) and associated computer tool, PlanWeaver, have been developed to facilitate improved planning and management of design (Austin et al., 1999a).
This methodology consists of three stages.

- “The first stage of the methodology is a model of the building design process, representing design activities and their information requirements;
- The data in this model are linked via a dependency table to a dependency structure matrix (DSM) analysis tool which is used in the second stage to identify iteration within the design process and schedule the activities with the objective of optimizing the task order; and
- The third stage of the methodology produces design programs based on the optimized process sequence.”

(Austin et al., 1999b, pp.279-280)

This model is chosen for review due to its similarities with the technique adopted. The ADePT methodology adopted IDEF0 to produce a model of building design in the first stage which is also the focus of this research. The building design process model (DPM) covers a wide range of building systems, which means that the design activities and information dependencies in a complex building design process can be represented and the ADePT planning methodology can be used to programme and manage the design phase of such projects (Austin et al., 1999)

Some of the benefits of ADePT include: improved understanding of the optimal design program; integration with the overall project program (especially the construction stage); assessment of the effects of decisions on cost, risk and design flexibility; and reduction in abortive work through the timely understanding and approval of inter-related loops of design (Austin et al., 2002).

4. **Conceptual design framework model (MDP).**

The “Mapping the Design Process (MDP) during the conceptual stage of building project” research project, conducted at the Martin Centre at Cambridge University, aimed to generate a flexible and adaptable design framework, the application of which would serve to improve the effectiveness of interdisciplinary interaction and collaborative design activity during the conceptual phase of building project (Austin et al., 2002).
As shown in Figure 2-7, the model comprises four levels of definition: the very top level is undertaking conceptual design; with the second containing two stages: develop business need into design strategy, and develop design strategy into concept proposal; the third level contains five phases - interpret, develop, diverge, transform, and coverage; and the fourth and final level contains twelve generic activities including: specify the business need, assess functional requirements, identify essential problems, develop functional requirements, set key requirements, determine project characteristics, search for solution principles, transform and combine solution principles, select suitable combinations, firm up into concept variants, evaluation and choice of alternatives, and improve details and cost options.

“The approach was intended to be flexible and adoptable, to accommodate different types of project, client, and design environment, while still offering a structure to which project specific, sub-model can be connected” (Steele et al., 2000). This graphical method has well illustrated design iteration in a way which is intuitively understood by design team members and helps them to reflect on their own design process.

However, this framework focuses on the conceptual design process and thus provides insufficient scope for this research.
Figure 2-7 Revised Version of the Preliminary Conceptual Design Framework Model

(Source: Macmillan, et.al, 2002)
2.5 SUMMARY

The early sections of this chapter identified the three phases of the building design process, adopted from the RAIA Advisory Notes (RAIA, 2000) and RIBA Plan of Work (1999), as the main focus for this research. These phases are: ‘schematic design stage’, ‘design development stage’ and ‘documentation stage’. Additionally, for each design stage, a definition, purpose, task to be done and people involved, as well as the relationships of designer with other parties, were presented.

The second section reviewed the literature directly relevant to ICT and its implications during the building design process. The findings were presented as a series of issues or “strands”, which covered design communication, design information management, ICT, and the impact and challenge of ICT developments for the building design process.

The process mapping methodology was explained and described, beginning with a brief definition of process and process mapping, and concluding with the IDEF0 mapping methodology as the focus of this research. Four process models of building design were reviewed. These were: Generic Design and Construction Process Protocol (GDCPP), RIBA Plan of Work, Analytical Design Planning Technique (ADePT), and Conceptual Design Framework Model.

The next chapter will focus on the presentation of a model of the design process using IDEF0 functional modelling technique, and definitions of the research variables.
3 IDEF0 MODEL DEVELOPMENT

3.1 INTRODUCTION

“Processes are about changes of state. A process model is thus a description of a development or a course of events. The process model contains the verbs that we think are characteristic of the process. But giving verbs visual representations is not as easy and intuitively achieved as is the case for nouns...The modelling method is, in many cases, a filter between what is desired to express and what is possible to express.”

(Linde, 2001)

This chapter will discuss the different types of model, the development of the building design process model, how the process can be mapped, and how the IDEF0 process mapping software is adapted. The model presented in this chapter is an improvement and expansion of a high level GDCPP Process Protocol Map developed by the University of Salford in conjunction with the industrial partners to the GDCPP and Process Protocol Level II Project (GDCPP, 1996). The original model was designed to support and encourage integration and proper co-ordination between the various participants or stakeholders of a construction project (Aouad et al., 1998b).

The Advisory notes published by The Royal Australia Institute of Architects (RAIA), ‘AN10.01.100-Guide Note’ (RAIA, 2000) and ‘AN10.01.101-Practice note’ (RAIA, 1993) as well as The RIBA Outline Plan of Work (1998) were also adopted as a guide for developing the lower level activities during the building design process.

3.2 MODEL CLASSIFICATION

According to NAAIDT (1995), “... a model is a representation of reality constructed to explore particular aspects or properties. It is usually a simplification of reality but in the case of a full-size prototype, even though virtually all aspects are modelled they can still only represent reality since the object did not exist before this stage! It is also likely that a second version of any of these first prototypes would be modified as a result of the evaluation, or field testing, or the model and any production version would probably use alternative materials and processes.”
Models can be classified into many categories based on different schemes. Hazelrigg (1996) pointed out that there are predictive models and descriptive models. A predictive model is a model that predicts or forecasts a future trend of a system or behaviour. SearchCRM.com (http://searchcrm.techtarget.com) defines predictive modelling as “… a process used in predictive analytics to create a statistical model or future behaviour… it is made up of a number of predictors, variable factors that are likely to influence future behaviours or results”. On the other hand, a descriptive model describes a process and how it will behave (Rangel, 1999). One fundamental difference that must be understood between predictive models and descriptive models is that “… descriptive models can be and often are precisely correct; predictive models are rarely precisely correct” (Hazilrigg, 1996).

A second scheme of categorizing models is supported by Rangel (1999), NAAIDT (1995), and Raftery (1998). They consider that there are three types of model: iconic, analogue and symbolic. Raftery (1998) brought out a further type, the conceptual model. They are described as follows:

- **Iconic models** – are scaled transformations of the actual physical system. A good example is a scaled architectural model of a building where only the identical shape, colour and layout are presented in the model. This may be used principally to communicate design ideas between designers, engineers and to clients. For example, sketches, 3D prototypes, MS paint, animation, photograph may be used to represent reality.

- **Analogue models** – “... explore particular features of an idea by stripping away detail and focusing, via a suitable analogous representation, on just a few key elements” (NAAIDT, 1995). An example of an analogue model in building economics is the cash flow curve where the project elapsed time is represented by a distance along a horizontal line, and the cumulative expenditure of the project is represented by a distance along a vertical line (Raftery, 1998).

- **Symbolic models** – “... are mathematical representations of the phenomenon under scrutiny” (Raftery, 1998). Symbolic models are an abstraction of reality that is very useful at analysing performance and predicting events. Common examples include mathematical models to represents: population growth and heat flow.

- **Conceptual models** – Raftery (1998) described these as “… conceptual models
represent our conception of which variables are relevant and how they are related. They often take the form of flow charts, or what are sometimes referred to unkindly as swirling arrow grams”.

The main objective of this study is to investigate and to map existing design processes and to propose a best practice model for ICT implementation during the building design process. The last model type is certainly best suitable for the purpose of the study. The proposed process model will generally require decomposition in levels of details showing the interrelationships between all variables. The process models are presented in the form of flow charting using IDEF0 modelling language, and are thus conceptual process models.

3.3 MODEL DEVELOPMENT PROCESS

According to Hunt (1996, pp.175 – 177), the model development process involves several phased activities including: data gathering phase; process map structuring phase; map documentation phase; and feedback interaction phase.

3.3.1 Data Gathering Phase

Activities required in the data gathering phase include:

Read Background Information – to become familiar with information about the subject area by collecting and reading source information prior to interacting with the Delphi experts. Most of the source information for this research comes from literature review on the subject area inside and outside the construction industry.

Parallel Interviews – interviews should be held with “process experts” who are familiar with the process mapping tools adopted. An interview with a process mapping expert who is familiar with IDEF0 modelling language was held before any mapping activities started. This is to ensure understanding of the tools selected to ease the model development progress.

Outside-the-Box Thinking – sufficient analysis time was given to mind mapping and to see the big picture of the building design process to be mapped.

Prior Setting – In this stage, the need for the preparation of a key process map to be created is examined, and priorities and procedures for the Delphi data
collection process are established.

3.3.2 Process Map Structuring Phase

The development of the process map structuring phase requires:

**Drawing Up a Draft Map** – begins with drawing up a draft process map based on information obtained from the literature review. The preliminary map for the building design process commences by sketching out the activities boxes and arrows and includes the identification and listing of random data elements. This preliminary map is first created using a sketch-type paper and pencil approach and is then transferred to computer generated process flow diagrams using Meta Software’s Design /IDEF0 Functional Modelling Language.

**Redraw** – “… redraw includes the analysis and re-examination stage of process mapping, corresponding to editing and rework of the verbal text. The mapping activity here is concerned not with creating but with graphical editing, clarifying, simplifying, and rearranging the process map information gathered during the data gathering process” (Hunt, 1996). The draft process map for this research was developed after discussion with experts. Advice collected during the discussions was adopted to improve understanding of the draft map.

3.3.3 Map Documentation Phase

Requirements for developing the process mapping model in the map documentation phase include:

**Write Text** – the draft model developed from the previous stage is modified and further improved at this stage. Properly structured text will be provided, based on the preliminary data gathering research. Descriptions for each variable (refer to figure 3-1), must be given in the final report. The variables shown in the process model are:

- Feasibility studies – produced from the previous stage (input- as *Label 1*)
- The building design process (the function- as *Label 2*)
- The design process success, to improve communication and information flow (output- as *Label 3*)
- The procedures/ guidelines and the requirement for the process (control- as *Label 4*)
○ The ICT tools used and people involved in the process (mechanism-as 

*Label 5*)

**Edit** – "...similarly, the editing of proper structured process map text. It corresponds to 'Redraw' of the graphic notation." (Hunt, 1996). The model proposed at this stage, after writing text for each variable, may need additional editing work following further discussion with experts.

**Proofing** – the proposed process map will require proofreading and correction to ensure it is completed before sending out as part of the Delphi survey.

3.3.4 Feedback Interaction Phase

The final stages for the mapping development process in the feedback interaction phase include:

![Figure 3-1 Top Level Diagram for Building Design Management Process (A-0 diagram)<!--Figure 3-1 Top Level Diagram for Building Design Management Process (A-0 diagram)-->
Read It – the draft preliminary process map will be sent out for review and comment among the Delphi experts.

Reaction – this refers to the researcher’s reaction to the experts’ comments returned during the Delphi rounds. Changes and modifications to the preliminary process map may be required.

Group Meetings – “… this is all the time spent in group meetings reviewing progress or brainstorming the next steps in developing the process map.” (Hunt, 1996). After each round of the Delphi process, feedback from Delphi experts will be analysed to plan the further development of the process map. This process is repeated until a consensus is achieved in Delphi rounds.

3.4 THE PROPOSED MODEL

The top level diagram of the proposed model is presented in Figure 3-1. As mentioned earlier, IDEF0 modelling language, a process modelling technique based on a well established Structured Analysis and Design Technique (SADT) is adopted.

3.4.1 Assumptions to the model

In developing the model, certain assumptions are made:

- The activity schedule based on a ‘fully designed commercial building project’ also refers to the traditional ‘design-bid-construct project’ approach to building procurement, and may vary for alternative procurement methods.
- Advisory notes published by The Royal Australia Institute of Architects (RAIA), ‘AN10.01.100-Guide Note’ (RAIA, 2000) and ‘AN10.01.101-Practice note’ (RAIA, 1993) were adopted as the guide for developing the lower level activities during the building design process.
- The RIBA Outline Plan of Work (1998) was adopted as a reference for developing the lower level activities during the building design process.
- ‘ICT tools’ and ‘people’ which act as mechanisms are not mapped in this process model.

Figure 3-1 describes the interrelationship between variables represented using IDEF0 modelling language. The next section describes each of the research variables in a more
detailed way.

3.4.2 Model Interpretation

The detailed process model for the building design process is presented in Appendix-A. The following describes the interpretation of the process model:

- The process model is presented in hierarchical (top down) format;
- The model should be read from left to right;
- Interpretation of the model should normally go from ‘output’ from one activity to ‘input’ of another activity, however, the ‘output’ of one activity can sometimes act as ‘control’ to another activity in the process map.
- Figure 2-3 represents the context diagram of the process map. The activities numbers represent each unique building design activity and should be interpreted as: A0 as the top level, A4 as the second level, A45 as the third level, and A452 as the lower level in the process map (see chapter 2.4.3).

3.5 Definition of Research Variables

Figure 3-1 presents the top level context diagram which sets the model scope and boundary for the research. This section defines the model’s variables and their relationship to each other. While the process map will be mapped using IDEF0 language, each activity is assigned an identification code (e.g. A1, A11, and A111…), as it gets into greater and greater levels of detail through decomposition.

3.5.1 Feasibility Studies Stage (as Input)

At the Feasibilities Studies Stage, a study of user requirements, site conditions, planning, design, and cost parameters is carried out to provide the client with an appraisal and recommendation in order that the client may determine the form in which the project is to proceed, ensuring that it is feasible, functionally, technically and financially (RIBA, 1980).

The feasibility study stage (for a commercial investment project) also explores the financial feasibility (financial performance) of the project, on a return-to-investment basis for the client over the investment period, using projections of the estimated rental incomes and operating
costs. This financial modelling process informs the subsequent design process.

The following design information and decisions are obtained at the end of this stage and are used as an input for the next stage which is the Outline Design Stage.

- “Additional information on the client’s requirements to that provided at the inception stage (stage before feasibility);
- Detailed information on the site;
- Information from third parties who may be involved with the proposed building;
- Predictive information on costs”

(Thompson, 1999)

3.5.2 Building Design Process (as Function)

The model focuses on the pre-tender stages of the building design process. In the Architect Agreement [Long Form], Scope of Services, RAIA Advisory Note (AN10.01.100) (RAIA, 2000) the three main stages of the design process refer to:

- Schematic Design
- Design Development
- Documentation

Each of these design stages is broken down into different sub-stages with a series of activities for each sub-stage. Accomplishment of these activities may require the involvement of more than one member of the design team and sometimes produces more than one product. As a result, various tools are introduced as aids to help team members perform their roles in each activity. Figure 3-2 shows the three main design stages that are the focus of this research.
3.5.2.1 Complete Schematic Design Stage (A1)

The schematic design stage follows the pre-design and site analysis stage (RAIA, 1993). At this stage the architect, with help from other members of the design team, carefully analyses the client’s requirements, takes into account the constraints disclosed earlier, collects together all the relevant information, considers the various alternatives, decides in outline the best design solution and prepares the outline scheme drawings (Thompson, 1999).

Participants in this process are: client/client’s representative; architect; engineers (civil, structural, mechanical, electrical); quantity surveyor (cost consultant); project manager; and other specialist consultants. The sub-stage breakdown from the outline design stage includes the following 25 lower level activities:
A11 – Develop and Define Design Requirements

This stage involves the following activities:

- **Liaise with Authorities (A111)** – This activity involves consultation with relevant local, regional, state and federal authorities to confirm all planning regulations. These include: car parking requirements; height restrictions, density requirements, and zoning requirements.

- **Site Analysis (A112)** – site context analysis involves the preparation of a master plan for overall development and phasing to show its best utilisation.

- **Conduct Outline Feasibility Design (A113)** – this stage requires the involvement of various members of the design team:
  - Architect design services consist of preparing conceptual site and building plans; preliminary sections and elevations; development of approximate dimensions, areas and volumes.
  - Initial involvement of various engineers for their professional recommendations including, earthworks design, structural design, mechanical design, hydraulic service design, electrical design, civil design, and landscape design.

- **Assessment of Consultants’ recommendations (A114)** – to gather, analyse and assess the recommendations from consultants.

- **Conduct environmental analysis (A115)** – to consider the environmental strengths and weaknesses of the proposed development, and scan the environment for opportunities on the selected site;

- **Seek client’s initial feedback (A116)** – presentation to the Client to review recommendations from previous stages for feedback.

A12- Estimate Resale Value

This stage is only applicable to private commercial projects and involves the following activities:

- **Identify potential resale target/buyer (A121)** – to identify potential buyers and to find out the target group;

- **Assessment of resale value (A122)** – to assess the resale value of the building (final product), and may involve market analysis;
**A13- Conduct Value Management Process**

"Value management has been defined as a proactive, creative, problem solving service that involves the use of a structured, facilitated, multi-disciplinary team approach to make explicit the client’s value system using function analysis to expose the relationship between time, cost and quality” (Kelly et al., 2004, pp. 77). According to Kelly et al. (2004), conducting a value management workshop during outline design stage involves the following activities:

- **Review concept brief (A131)** – to review concept brief obtained from previous stages and to confirm the client’s objectives for the project. This review may cover: the initial plans, elevations, sections, specification and cost plan of the proposed facility. It is important to fully understand the concept brief, particularly the functional space requirements and adjacency prior to the allocation of costs for each element of the project.

- **Allocate costs (A132)** – this stage involves the allocation of costs from the cost plan to functions and spaces.

- **Highlight mismatches and risks (A133)** – to identify and to highlight any mismatches between cost allocation to functions and spaces. To run risk assessment for each design option.

- **Evaluation and development of alternative solutions (A134)** – evaluation of design alternative and brainstorming for better solutions.

- **Presentations (A135)** – presentations of preferred solution to the client or client’s representative.

**A14- Preparation of Outline Proposal**

Prepare Outline proposal stage involves the following activities:

- **Ensure outline plan fulfils project brief (A141)** – to ensure that the outline design drawings encompass the requirements of the client brief.

- **Prepare design proposal (A142)** – produce sketch drawings based on the information obtained from various stakeholders including engineers, cost consultant, authorities and other consultants.

- **Review authorities’ requirements (A143)** – to review authorities’ requirements to ensure that the outline schematic design meets all regulatory requirements.
- **Liaise with cost planning consultant (A144)** – liaise with cost planning consultant to prepare preliminary costing for the project, for comparison with target budgets.
- **Assess client’s initial feedback (A145)** – Assess client’s initial feedback from stage A116.
- **Initial Planning Permit Application Preparation (A146)** – prepare initial scheme design drawings, based on authorities’ comments, consultants’ recommendations and client’s feedback.

**A15- Prepare Preliminary Estimate**

The following activities are involved:

- **Development of Probable Cost and Program (OPC) (A151)** – liaison with cost consultant to develop: probable construction cost range for the project.
- **Engineering cost studies/ liaise with engineers (A152)** – undertake cost studies to determine appropriate engineering solutions.
- **Search for principal solutions (A153)** – assess and decide upon appropriate design/cost solutions for the principal elements of the project.
- **Select suitable design/cost solution combination (A154)** – assemble and choose the most appropriate combinations of design/cost solutions.
- **Evaluation of alternatives (A155)** – prepare costings to an appropriate level of detail, and compare with budget targets.
- **Improve details and cost options (A156)** – improve the details and cost options within the alternative design solutions considered; update costing and budget comparisons; report to client for decision-making.

**3.5.2.2 Complete Design Development Stage (A2)**

At this stage the design team should have a clear idea of the brief from the previous stage in order to prepare a sufficiently detailed scheme design to show the spatial arrangement of the various parts of the proposed building, as well as its appearance and an indication of the materials to be used (Thompson, 1999). Team members have to work together and coordinate their design outcomes.
Gray and Hughes (2001) emphasise that the completion of the design development process is a crucial client decision point in a project as well as a key point in the management of the process. They further point out that the client and the designer must agree on the complete scope of the work.

More participants are involved in this stage of the design process. In addition to the design team constituted for the earlier stages, statutory and other authorities will be involved, together with other specialists such as landscape architects, interior designers, acoustic, illumination, communication and security consultants. The sub-stage breakdown of the Design Development Stage includes the following 15 lower level activities.

**A21- Prepare Sketch Design Documentation**

This stage involves the following activities:

- **Develop expansion of architecture design drawings (A211)** – the development and expansion of architectural schematic design documents, revised in accordance with client’s instructions and as necessitated by any revision to cost estimates, including: plans at each level, elevations, sections and other details or schedules sufficient to fully explain the design (RAIA, 1993).

- **Prepare preliminary engineering design (A212)** – consists of the continued development of the various engineering designs as done in the outline feasibility design stage A113.

- **Coordinate/liaise with all consultants (A213)** – coordinate and integrate the design work with all consultants.

- **Make required design changes (A214)** – make required changes based on consultants’ recommendations.

- **Presentation of the schematic design (A215)** – presentation of the schematic design to all relevant stakeholders, such as: client, building owner, staff committee, user groups, boards of directors, financiers, and owner’s consultants for comment (RAIA, 1993).

- **Design Visualisation – Model Construction (A216)** – model construction (if necessary); physical and/or virtual models of the proposed building, showing the interrelationship of the spatial layouts, in 2D and 3D formats, are very useful for many clients; they are also an effective way of depicting constructional methods.
A22- Run Design Evaluation Session

This stage involves the following activities:

- **Integrate preliminary consultants’ advice in design (A221)** – all design team members work together to make final decisions regarding design aspects, materials, finishes, services, and various other matters.

- **Review authorities/council requirements (A222)** – review all relevant planning and authorities’ requirements eg. area calculations and car parking (RAIA, 2000).

- **Gather feedback from all authorities and consultants (A223)** – feedback from all authorities and consultant is consolidated into necessary design change proposals.

- **Finalised design documents (A224)** – finalise and make required design changes based on authorities’/consultants’ feedback.

- **Apply for planning permit (A225)** – lodgement of documents by the architect on behalf of the client to the relevant authorities for planning approval (RAIA, 1993).

A23- Prepare Sketch Design Cost Plan

Prepare Sketch Design Cost Plan Stage involves the following activities:

- **Estimating building cost (A231)** – cost consultant prepares more detailed cost plan for the project, based upon development of outline design, for comparison with target cost budgets.

- **Prepare alternative estimates (A232)** – for different construction methods, materials, engineering systems to ensure that best design solutions are obtained within the established budget.

- **Prepare program budget (A233)** – show how the total cost is allocated among the various parts of the project.

- **Prepare time schedule & organization plan (A234)** – prepare outline time schedule and organization plan to give the client an indication as to when building work will commence on site and how long it will take to complete, together with a hierarchical diagram of stakeholders based upon contractual/ communication/ authority structures.
3.5.2.3 Complete Documentation Stage (A3)

The complete documentation stage for the proposed building will commence upon confirmation of approval of the planning permit. The design brief should not be modified after this point in the design process as any changes may require reapplication of the planning permit and result in inevitable delay in the commencement of building work on site. The main objectives of this stage are: to obtain the necessary building permit; to obtain rationalization and integration of sub-systems; to consider Occupational Health and Safety requirements for the design (RAIA, 2005); and to provide scoping information to appoint specialist trade contractors (Gray and Hughes, 2001).

“The National Occupational Health and Safety Commission (NOHSC), in association with state bodies and other relevant stakeholders, has developed a draft national framework for OHS improvement, including the concept of ‘safe design’, which encourages the adoption of systematic approaches by government and industry” (RAIA, 2005). Again, as stated in the “Occupational Health and Safety: safe design guide” (RAIA, 2005), “… safe design encompasses all aspects of building design to ensure that a building can be safety built, used, maintained, and demolished by those who construct and use it.”

During this stage, the building design is developed in a more finished form, including more detailed drawings and specifications and incorporating the specialist contributions of the various consultants (Thompson, 1999). Full design of every part of the building must be produced at the end of this stage.

Depending upon the procurement system used for the project, the building contractor may become part of the design team at this point. The sub-stage breakdown for the Detail Design Stage includes the following 14 lower level activities.

**A31- Conduct Detail Design Management**

The Conduct Detail Design Management stage involves the following activities:

- *Prepare detailed architectural drawings (A311)* – develop the scheme design drawings in a more finished form, including more detailed drawings and specifications
and incorporating the specialist contributions of the various consultants. The documents include:

- Working drawings for tendering and construction.
- Specifications comprising detailed written descriptions of the project materials and workmanship standards required.

- **Develop detail engineering design (A312)** – develop engineering documentation, setting forth in detail the various engineering construction requirements of the project for tendering and construction purposes, consisting of the preparation of final engineering calculations; drawings; specifications and schedules.

- **Coordinate/liaise with all consultants (A313)** – coordinate and integrate sub-consultant design with the architectural drawings and specifications (RAIA, 2000).

- **Presentation to authority/council (A314)** – final presentation to local authority/council before lodgement to ensure design complies with all building regulations.

- **Preparations of documents for building permit application (A315)** – prepare documentation including dimensioned plans, sections and elevations to adequately describe the design for the purpose of obtaining approval to construct (RAIA, 2000).

**A32- Conduct Cost Checking**

This stage involves the following activities:

- **Analysis & evaluate design alternatives (A321)** – interaction between all project professionals and facility manager (if appointed) to ensure that the building provides its users with basic elements that maintain the necessary comfort which allows them to carry out their jobs.

- **Investigate design cost efficiency (A322)** – ensure cost efficiency of the proposed building design, consider and identify which elements of the building require the least maintenance, and incur the fewest breakdowns and repairs and also those with the most maintenance and repair requirements.

- **Identify and analyse life cycle cost (A323)** – assess the life cycle cost of the building (short-term; medium-term; and long-term).

- **Review optimization of energy performance (A324)** – review energy performance for the proposed design, to consider which elements within the building are the most energy inefficient.
- **Conduct design cost check (A325)** – cost consultant to review the cost plan after all stages and to carry out cost studies and cost checks as the design reaches finalisation.

### A33- Audit Completion of Detail Plan

Audit Completion of Detail Plan involves the following activities:

- **Lodgement for building permit (A331)** – submit application to the relevant authority for building permit approval.
- **Rationalise & integrate sub-systems designs (A332)** – rationalize and integrate all design sub-systems to make sure there are no conflicts.
- **Consider Occupational Health and Safety- Safe Design (A333)** – ensure that the proposed design can be safely built, used, maintained, and demolished by those who construct and use it (RAIA, 2005).
- **Conduct risk management (A334)** – assess and balance the contingencies of risk with their specific contractual, financial, operational and organizational requirements by transferring through the combination of insurance, risk financing, and contract indemnification provisions.

### 3.5.3 Design process success (as Output)

Design process success is achieved when all requirements specified are met - time and within budget - with no remaining conflicts between project team members; and client’s satisfaction is achieved.

### 3.5.4 Improve communication (as Output)

One of the main benefits proposed for ICT tools in the building design process is that they enable more natural forms of communication through ICT application (BT, 1995). For example, videoconferencing can replace a face to face meeting, where it can take place at any time with less effort. In this research study, communication is said to be improved when the any of following are achieved:

- Time required to respond to queries is reduced;
- Cost savings can be achieved on travelling, overheads, communication;
- Decision making can be done faster;
Communication quality is improved.

3.5.5 Improve quality of Information Flow (as Output)

A key to successful sharing of industry information is the ability to structure and arrange information so that it can be accessed easily (BT, 1995, pp.22). The quality of information flow among project participants is determined from the following:

- "Improve documentation quality;
- Decrease design errors and requests for information;
- Save time and save cost;
- Reduce response time to answer queries"

(Weippert et al., 2003)

3.5.6 Types of Procedures and Guidelines (as Control)

The procedures and guidelines to be taken into account during the building design process are:

- **Cost and time guide** – usually set by the client at the very beginning of the inception or feasibility stage and used as a guideline for later decision making.

- **Legal & statutory procedures** – according to RIBA (1980, pp.407-408), as soon as possible after being commissioned for a project, the designer should confirm with his/her client and the client’s legal adviser a range of matters which may affect development of the project; to find out which authorities are concerned with which functions, the nature and form of applications which are required, and to whom they should be addressed.

- **Value management checklists** – produced during the value engineering process and used for exploration of alternative solutions.

- **Building cost guide** – published and updated frequently; used during the design process as a guideline for estimating the cost of each component.

- **Cost planning** – prepared by appointed consultant. As the cost of any project is significant, particularly to the client, cost estimation and cost planning are expected at frequent and regular stages of the design process.

- **Cost allocation guide** – similar to the cost guide, this may be prepared by the cost consultant to show the approximate cost allocation to each element or component.
- **Design specification** – produced by each designer stating the detail of the design to simplify the cost estimating process; it may also be used as a guideline by the cost consultant while preparing tender bills of quantities.

- **Engineering design guide** – engineering design begins towards the end of the outline design process. Used by specialist engineers as a reference while preparing engineering drawings.

- **Summary report** – a summary report is produced after the detail scheme design stage and used as a guideline in later stages of the design process as it provides detailed design information on what has been achieved at the earlier stage.

- **Occupational Health & Safety – Safe Design Guide (RAIA, 2005)** – to be used as a guideline/procedure while preparing design to ensure safe design of “workplaces”.

### 3.5.7 Types of Requirements (as Control)

During the building design process, many requirements have to be considered. The types of requirement that are included in the research model are categorized as: client’s requirements; business requirements; market requirements, user requirements; site requirements; statutory requirements and authority and planning requirements. All project team members (including designer, specialist contractor, project manager, etc.) must ensure that the final product meets all these requirements.

### 3.5.8 ICT Tools (as Mechanism)

Various ICT tools are used by project team members during the building design process to provide a more effective and efficient output. In this study, ICT tools are categorised into: ICT infrastructure; ICT for information management; and ICT for communication. Details for each of these categories were explained in Chapter 2.

### 3.5.9 People (as Mechanism)

As mentioned in Chapter 2, the building design process involves multi-disciplinary professionals working together to achieve a common purpose. The individual people will not be mapped in the IDEF0 building design process mapping model, but they will be briefly discussed here due to their interrelationship with each other and their particular needs for ICT
tools. According to the RAIA Advisory Note (RAIA, 1994) and RIBA hand book (1980, pp 54-67), the allied professionals involved during the building design process and their functions comprise:

- **The architect** – based on his/her level of training and according to qualification and experience, may carry out:
  - land and building site survey;
  - technical studies in feasibility;
  - preparation design drawings and illustrations;
  - model making of simple kind;
  - production drawings, specification and schedules;
  - special technical investigations;
  - liaison with specialists and consultants’ staff;
  - programmed checking of resources, costs, information;
  - administrative support, e.g. statutory controls, contract administration, specialist quotations; and
  - assist site inspection.

- **The quantity surveyor/cost consultant** – is trained and qualified to advise designers on matters relating to cost and contracts in building, civil engineering, and mechanical and electrical engineering projects. The normal service of a cost consultant includes:
  - provision of cost advice;
  - cost checking of the detail design and production drawings against the agreed cost plan; and
  - provision on advice on tendering procedures and contractual arrangements.
  - preparation of tender bills of quantities where required.

- **The structural engineer** – advises on:
  - soil and climatic conditions, wind loads and temperature limits;
  - natural drainage and traffic considerations;
  - the stability of the building at as low a cost as possible;
  - the form of structure which will fulfil the many functions required (including the ground loads and stresses which will result from the design); and
  - expansion and contraction treatment for the structure.

- **The services engineer** – is concerned with:
  - the provisions for control of the internal environment by means of heating, ventilating, air-conditioning and lighting installations, and;
- the provision of utilities, such as electrical supplies, lifts, compressed air;
- the inclusion of hydraulic services and drainage.

- The landscape architect – is concerned with:
  - the open space around the building;

- **The local authorities/council/ building surveyor** – represents local authorities as an officer of central or local government or the building survey (note: this function has been privatised under many jurisdictions. Private building surveyors certify the compliance of the project with planning law and building regulations) may be concerned with providing information on:
  - transport and communications, retailing, employment, economic growth or decline, social and demographic facilities, resource management, pollution, ecology or recreation and leisure;
  - control over land use, preservation orders for trees and buildings, advertisements, overhead lines and underground pipes, natural resources and land compensation.

- **The acoustic consultant** – these services are concerned with:
  - precise acoustical measurement of all environmental noise leading to initial acoustical technical schemes and feasibility studies;
  - predicting acceptability levels resulting from environmental noise-climate measurements for determination of acoustic design parameters in structures, architectural, building acoustics and engineering acoustics.

- **Other designers** who may be involved during the building design process include:
  - interior designer;
  - illumination specialists;
  - security specialist;
  - property agencies;
  - financial specialists.

### 3.6 SUMMARY

In this chapter, a model of the building design process was developed for a large commercial building project. Conceptual models were considered as the most suitable type of model for the research.
The model development process is described. This involves several phased activities including: data gathering phase; process map structuring phase; map documentation phase; and feedback interaction phase.

The final section of this chapter focused on the proposed IDEF0 model for the building design process. Research variables were defined and assumptions were made to the model. A total of 54 activities were derived from the three main design stages: schematic design stage; design development stage; and documentation stage. Other research variables identified include: feasibility studies stage (as input); building design process (as function); design process success (as output); improve communication (as output); improve quality of information flow (as output); types of procedure and guideline (as control); types of requirements (as control); ICT tools (as mechanism); and people (as mechanism).

The next chapter focuses on the research methodology and design, looking at the design and administration of the DELPHI survey and data analysis procedures.
4 RESEARCH METHODOLOGY & DESIGN

4.1 INTRODUCTION

A staged approach has been adopted for the purpose of this research. Stage one was the literature review. Related literature was reviewed so as to give deep knowledge on the research topic. The literature was sourced mainly from conference and journal papers, books, academic theses and dissertations and Internet resources.

Understanding derived from the literature review assisted in clarifying relevant issues and in model development. Delphi technique was adopted to test and verify the proposed model.

Five “strands” for the research were identified and discussed in the literature review (Chapter 2). The issues mainly focus on: the existing information management and communication during the building design process; to what extent design professionals adopt ICT in their daily routine; the impact of technology; the barriers to the implementation of technology; existing communication problems faced by design team member during the building design process; and the techniques and tools used during the building design process.

Process model development comprised the second step for the research process. IDEF0 process mapping was chosen to map the building design process for traditional contract procurement project (design-bid-construct) for a large scale commercial investment building project. For this research, the building design process is confined to the pre-construction stages as stated in Architect Agreement [Long Form], Scope of Services, RAIA Advisory Note (RAIA, 2000) as: schematic design stage, design development stage and the documentation stage. People are not mapped into the conceptual IDEF0 process map, however, they are mapped in the ‘ICT implementation maps’ at a later stage of the research. In stage three of the research, the process model is validated and tested by experts through Delphi survey.

Four rounds of Delphi surveys were conducted between November 2004 and April 2005. The data collected from all Delphi rounds are presented and analysed in Chapter 5.
Data collected from four rounds Delphi survey were adapted in proposing an “ICT Implementation Map during the Building Design Process” (current and in five years time) in stage five of the study (presented in Chapter 6). The proposed ICT Implementation Map was be tested and further improved through interviews with three experts during November 2005. The modified copies of ‘ICT implementation maps’ and the analysis of result from interview are presented in the discussion in Chapter 7.

Conclusions and recommendation for future research are presented in the final chapter (Chapter 8) of this thesis.

This chapter justifies the research methodology selected, and describes the technique used to gather the primary data necessary for the development of the ‘ICT implementation maps for the building design processes’.

4.2 Research Design Justification

Choosing an appropriate research approach is essential to research success. Selection of an appropriate research approach may be based on the natural perspective of the research and the research questions to be answered. One of the main components of this study is the development and testing of ICT implementation maps for the building design process, where participants are encouraged to offer comment on all the issues under review and to propose new ideas. Interaction between the participants and the researcher may be necessary during the data collection process. As a result of the expense and time commitments necessary to bring together all participants to explore these issues and the fact that exploration of these issues do not lend themselves to the use of statistical, analytical techniques, Cabaniss (2001) suggests that the Delphi method is the most appropriate means of collecting data for this type of research.

Kennedy (2002, pp.112) argues that: “... one of the key advantages of Delphi methodology lies in its use of qualitative technique to draw on collective expert judgement in a format that allows for a subsequent quantitative analysis of these data... the methodology is systematic and uniform and can be used to collect data from individuals who are widely separated geographically.” While one of the key issues for this study aims to explore the usage level of
ICT during building design process, some quantitative data are expected. This further enhances the decision to adopt Delphi technique for data collection as best suiting the purpose of this study.

4.3 **Design and Administration of the Delphi Survey**

“Delphi may be characterised as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.”

(Linstone and Turoff, 1975)

“Delphi is an attempt to elicit expert opinion in a systematic manner for useful results. It usually involves iterative questionnaires administered to individual experts in a manner protecting the anonymity of their responses. Feedback of the results accompanies each iteration of the questionnaire, which continues until convergence of opinion, or a point of diminishing returns is reached. The end product is the consensus of experts, including their commentary, on each of the questionnaire items, usually organised as a written report by the Delphi investigator.”

(Sackman, 1975)

Wedley (1980) points out that the RAND Corporation formulated the Delphi process in the early 1950’s to enable geographically dispersed warfare experts to predict changes in military technology. He further notes that their new concept was classified and kept a military secret until the 1950’s.

‘Delphi’ was named after the site of the Greek oracle “where necromancers foretold the future using hallucinogenic vapours and animal entrails” (Linstone and Turoff, 1975). They state that the early uses of modern Delphi techniques were to carry out studies for the U.S. Air Force to examine the potential effectiveness of automatic attack. The study involved a series of questionnaires with controlled feedback to determine the opinion of a group of experts about the U.S. industrial systems most likely to be offensively targeted by Soviet strategic planers. At that time, the alternative would have been an extensive and costly data-collection process, including programming and executing computer models that could not be handled by available computers (Linstone and Turoff, 1975).
In 1975, two important books on the Delphi-method were published, one by Delbecq, Van de Ven and Gustafson and the other by Lindstone and Turoff (cited by Costa, 2000). These books primarily addressed theoretical and methodological issues regarding the technique. At the same time, Sackman (1975) published a book called “Delphi Critique” to highlight some of the negative aspects of the method.

Over the past 50 years a variety of Delphi techniques has been developed. In addition to consensus building, Delphi techniques were developed for such uses as decision making, needs assessment, identifying objectives, future forecasting and policy making (Ferris, 1998). Today, the Delphi technique is widely used by corporations, universities, government agencies, and non-profit organizations for planning, technical and strategic evaluations as well as forecasting in many areas (Ziglio, 1996).

The characteristics of Delphi compiled by Sackman (1975) are as follows:

- “The format is typically, but not always, a paper and pencil questionnaire; it may be administered by mail, in a personal interview, or at an interactive, online computer console. The basic data-presentation and data-collection technique is the structured, formal questionnaire in each case.
- The questionnaire consists of a series of items using similar or different scales, quantitative or qualitative, concerned with study objectives.
- The director, participants, or both may generate the questionnaire items.
- The questionnaire is accompanied by some set of instructions, guidelines, and ground rules.
- The questionnaire is administered to the participants for two or more rounds; participants respond to scaled objective items; they may or may not respond to open-ended verbal requests.
- Each iteration is accompanied by some form of statistical feedback, which usually involves a measure of central tendency, some measure of dispersion, or perhaps the entire frequency distribution of responses for each item.
- Each iteration may or may not be accompanied by selected verbal feedback determined by the director.
- Individual responses to items are kept anonymous for all iterations. However, the director may list participants by name and affiliation as part of the study.
Outliers (upper and lower quartile responses) may be asked by the director to provide written justification for their responses.

Iteration with the above types of feedback is continued until convergence of opinion, or ‘consensus’, reaches some point of diminishing returns, as determined by the director.

Participants do not meet or discuss issues face to face, and they may be geographically remote from one another."

The following sections provide a brief discussion on the Delphi process and the reasons behind the adoption of Delphi technique.

### 4.3.1 The Delphi Process

Delphi is a systematic polling of opinions of a panel of experts knowledgeable on a given topic through iterative administration of questionnaires - referred to as ‘rounds’ (Dalkey et al., 1972). The experts are selected based on the areas of expertise required. They are presumably people who have clear, systematised ideas about their special area of knowledge, and who can reply in consistent and organised fashion. The experts are asked a series of questions about the likelihood of certain events occurring. In most cases, the first questionnaire poses the problem in broad terms and invites answers and comments. Responses to the first questionnaire are then summarized and used to construct the second questionnaire, which presents the results of the first and gives participants an opportunity to refine their responses, clarify issues, identify areas of agreement or disagreement, and develop priorities.

Hostrop describes how Helmer, one of the developers of Delphi, envisioned the method (cited by Costa, 2000, p.53-54):

- “Participants (who usually remain anonymous) are asked to state their opinion on a specific topic in the form of brief written responses to prepared questionnaires, such as recommended activities or predictions for the future.
- Participants are then asked to evaluate their responses against some criterion, such as importance, and chance of success.
- Next the statements made by the participants are received by the investigator.
Each participant then receives the refined list and a summary of responses to the items and, if in the minority, is asked to revise his (or her) opinion or to indicate reason(s) for remaining in the minority.

The statements made by the participants are again received by the investigator who further clarifies, refines, and summarizes to the responses.

Each participant then receives the further refined topical list, which includes both an updated summary of responses and a summary of minority opinions. Each participant is also given a final chance to revise his (her) opinions.

Finally, this investigator receives the last round of questionnaires, which he (she) then summarizes in a final report. The successive, individual and independent process of re-questioning each of the experts, via the investigator, is designed to eliminate misinterpretation of the question and the feedback, and to bring to light knowledge available to one or a few members of the group, but not all of them.”

Figure 4-1 presents a schematic illustration of the Delphi process.
Figure 4-1 Flowchart for the Delphi Process (Source: Joppe, 2001)
4.3.2 Evaluation of Delphi

As with all other research methods, the Delphi approach attracts support and criticism. One of the major benefits of Delphi is the anonymity of participants. Hess and King (2002) state that anonymity is often adopted to promote frank discussion, improve group response, and reduce inhibitions among panellists. Some of the advantages (Williamson, 2002) are as follows:

- “Delphi elicits responses from experts who bring knowledge, authority and insight to the issues involved.
- The systematic bringing together of expert views in several rounds to reach consensus provides a stronger basis for decision than do individual judgments.
- Experts can be gathered from all over the world and are not limited to a geographic region.
- The process also provides a cooperative learning exercise for the experts involved.
- It allows respondents to modify their answers without the pressure of face-to-face interaction. Thus the effect of strong personalities and people of higher status is avoided.
- It allows for the exploration and review of the assumptions, information or opinions leading to different assessments.
- Controlled feedback and anonymity help panellists to revise their views without publicly admitting that they have done so. They are thus encouraged to take up a more personal viewpoint rather than a cautious institutional position.
- By giving respondents the chance to consider the answer and reasons of other respondents and to modify their own answers, a consensus of opinion may emerge. The degree of divergence of opinion, if any, and the reasons for it, can be gauged.
- Experience has shown that in Delphi applications there is an increasing convergence in the opinions of respondents from iteration to iteration. Where accuracy of response can be checked, it seems to increase with iteration.
- The process is relatively inexpensive to organize and administer.”

(Williamson, 2002)

Other advantages are such as:

- “It is one of the few forecasting methods that have a fair to good prediction accuracy over different time horizons – short-term, medium, and long range”

(Costa, 2000).
“Embraces the philosophy that the whole is greater than the sum of its part, which will promote teamwork and group decision-making” (Costa, 2000).

“Motivates independent thought and gradual formation of group decision, which is appropriate for open-ended problems” (Costa, 2000).

“Ability to explore, coolly and objectively, issues that required judgment” (Gordon, 1994).

“The technique eliminates open discussions and committee activity and thus reduces the influence of psychological factors such as specious persuasion, unwillingness to abandon publicly expressed opinions and the bandwagon effect of majority opinion” (Sharma et al., 2003)

Among the disadvantages of Delphi method, the large amount of time required to conduct several rounds for data collection is one of the issues that concerns researchers most. The most extensive critique on Delphi approach is made by Sackman (1975) who criticizes the method as being unscientific. His complaints against the Delphi method are in terms of the concept of ‘expert’ as follows:

- “The concept of expert is virtually meaningless in experiments dealing with complex social phenomena.
- Sole or primary reliance on expert opinion in the social sciences has long been discredited and now has no serious advocates.
- Anonymous panels chosen in unspecified ways increase the likelihood of contaminated, elitist “expert” samples.
- There exists an uncontrolled and unknown expert halo effect in Delphi contributing to expert oversell.
- Collective expert opinion directly reinforces unaccountability for Delphi results for all concerned: the director, panellists, and users.
- Experts and non-experts consistently give indistinguishable responses in forecasting or evaluating social phenomena impacting on common values and attitudes.
- There is no explicit matching of skills required by Delphi questions against objectively measurable skills of the panellists.”

(Sackman, 1975)
To deal with the criticisms on ‘experts’, the selection criteria for the panel experts were set after discussion with the research supervisors and building professionals to ensure that well experienced and qualified panel experts were recruited. However, as Philips (1990) (cited by Kennedy, 2002, pp.111) comments: “… what is crucial to the objective of any inquiry – whether is quantitative or qualitative – is the critical spirit in which it has been carried out”.

4.3.3 Objective of Delphi for this study

The primary objective of this Delphi study is to test and verify a proposed building design process mapping model using IDEF0 functional modelling language. The proposed model is intended to map all activities involved during the building design process, taking into account the requirements, procedures and guidelines that affect the process as well as the outcomes of the process, together with the aid of ICT tools.

The model is based on the preconstruction stages of the building design process set out in the RAIA Advisory Notes (AN10.01.100) and RIBA Plan of Work (1998). It provides a clear picture of how one activity is related to another during the building design process.

The second purpose of the Delphi study is to identify and rank-order the desirable ICT tools used for building design management, and to explore the positive impacts and barriers of ICT implementation for the building design process.

In terms of technology forecasting, Levary and Han (1995) state that the objective of the Delphi method is to combine expert opinions concerning the expected development time into a single position. According to Linstone and Turoff (1975, p.4) the following are situations where the Delphi technique is best applied:

- “The problem does not lend itself to precise analytical methods, but benefits can be derived from subjective judgments on a collective basis.
- The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise.
- More individuals are needed than can effectively interact in a face-to-face exchange.
- Time and cost make frequent group meetings infeasible.
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be referred and/or anonymity assured.
- The heterogeneity of the participants must be preserved to assure validity of the results, i.e., avoidance of domination by quantity or by strength of personality (bandwagon effect).”

Ziglio (1996) points out that Delphi technique allows a group of geographically dispersed experts to approach a problem or issue in a systematic fashion. This has advantages over traditional face-to-face discussion while many problems can arise when group members meet face to face. Experts’ opinions will often be affected by factors such as dominant personality, the tendency to want group approval, specious persuasion, unwillingness to abandon publicly expressed opinions and the bandwagon effect of majority opinion (Sharma et al., 2003).

Moreover, the creation of the proposed model is a dynamic process which usually requires the participation of more than one person. Throughout the research process, the initial diagrams/models are required to be distributed to Delphi experts for review and comment. The diagrams/models will change to reflect correction and comments from the experts throughout the process. More detail is also expected to be added to the model.

### 4.3.4 Internet-based DELPHI Survey

A modification of the classic Delphi survey was adopted in this research as the survey questionnaires were initially administered through the worldwide web. Adapting the web-based survey instrument for the Delphi survey allows participants from separated geographical area to undertake the survey at any convenient time. The online feedback features incorporated in this web-based methodology can be used to illustrate complex data in spreadsheet format for easy analysis.
Data collection as well as data analysis for the web-based Round 1 Delphi survey was difficult, and proved too cumbersome and complicated for the Round 2 survey. One of the major weaknesses of the web-based survey was that it limited the format of the questionnaire presented. Also, the web-based survey had to be completed in one sitting. Since the following rounds of the survey required a different format, difficult to present in web-based format, a fresh approach to online data collection was needed. Thus, the remaining rounds of Delphi data collection were changed from Web-based to Internet-based format, and questionnaires were designed using a spreadsheet and sent via e-mail attachments.

### 4.3.5 Delphi Panel Selection Criteria

The selection of the expert panel is a crucial stage of Delphi study. There are no fixed rules to define the precise number of experts required for a Delphi panel, or to set the criteria for the knowledge or experience required from them. The selection process itself is not specified, and thus all these issues will be heavily influenced by the nature and scope of the study.

Dictionary.COM ([www.dictionary.com](http://www.dictionary.com)) defines an expert as: “*a person with a high degree of skill in or knowledge of a certain subject*”. This general definition of expert is used while selecting Delphi panels for this research. The “subject” referred to here is the building design process. Experts in this process were identified in a number of ways: through literature searches for people who have published work on the topic; through professional associations such as the Royal Australian Institute of Architects (RAIA) and the Australian Institute of Quantity Surveyors (AIQS); through referrals made by supervisors; through other institutions and universities; and via Internet search. Each person selected for the Delphi panel was required to meet the following criteria:

- They are involved in the pre-construction stage of building design for a project.
- They have work experience in the construction industry for large scale office/commercial building projects.
- They have educational qualifications at the minimum of bachelor degree level from a recognized university/institution; or
- If they do not fully meet the above mentioned criteria, they must be well-known international/national researchers who have some extensive involvement in the research topic.
4.3.6 Recruitment Procedure

Once a list of potential panellists had been formulated, each of them was first contacted via email during August, 2004. Invitation letters were sent to them with a request for their participation in the study. The invitation letter (refer to Appendix-B) covered the following information.

- Brief introduction of the researcher
- Purpose of the inquiry
- Aim and objectives of this study
- The planned round and expected time to complete each round question
- Assurance of anonymity
- Researcher and supervisor contact details
- Consent form to sign and return stating that they are willing to participate. (This is a research ethics requirement of RMIT University).

Ten suitable individuals eventually agreed to participate. On 6th October 2004, an email notice to begin Round 1 of the Delphi survey was sent to participants thanking them for their willingness to participate and their contribution to the research. A planned schedule for all four survey rounds was attached for their reference.

4.3.7 Description of the Delphi panel

The ten Delphi panel members were each assigned a code from D01 to D10. These codes are mainly used for analysis purposes. Brief background information for each of the participants is as follows:

*D01* is a research scientist for Commonwealth Scientific and Industrial Research Organization (CSIRO) in the Division of Manufacturing and Infrastructure Technology. Some of his publications on the related research topics include: ‘collaborative framework for building design’; ‘supporting collaborative building design: a multi-agent approach’; computer modelling of building for compliance checking’; and ‘knowledge-based communication process in building design’.
D02 also works for the CSIRO Division of Manufacturing and Infrastructure Technology. He is a leading participant in the International Alliance for Interoperability (IAI-AC) and a member of the road mapping management team for Collaborative Working in Construction (CWIC). Topics of two of his publications include: ‘the role of software in harmonizing building standards’; and ‘supporting collaborative building design: a multi-agent approach’.

D03 has 25 years in the construction industrial dealing with medium to large scale projects. He is currently working as a project manager for a Consulting Engineering firm. His work involves providing a full range of engineering design and project management services, across all sectors - office, retail, industrial and residential development.

D04 is a civil and structural engineer and project manager working for a Consulting Engineering firm. His work involves providing total structural engineering design services and project management for commercial and retail developments such as shopping centres, community facilities, office and industrial developments and urban infrastructure. He is also involved in the CWIC Road mapping management team.

D05 has been a practicing architect for 23 years and has experience on a wide range of projects for private, commercial and government clients in Australia and the United Kingdom. His project involvement has included the preparation of project briefs, feasibility studies, master planning, design, documentation and contract administration. He has a significant role in practice development and administration and is currently a director of a large architectural consultancy.

D06 is Professor of Urban Studies and Public Policy, Director of the Australian Housing and Urban Research Institute Research Centre, and Senior Research Associate at lab.3000, RMIT University, Melbourne. He was Foundation Executive Director of the Australian Housing and Urban Research Institute from 1993 to 1998. He has served on a number of Federal and State Government advisory organizations, including the National Advisory Committee on Housing and Urban Development. His current research project seeks to ‘map’ the emerging intersections of the design and information technology sectors – to identify and better understand the forces driving the innovation and growth of ‘digital design’ clusters in the regional economy.
**D07** is a recognised trainer for delivering training on concept modelling and simulations, Workflow Analyser toolset and IDEF (integrated definition for processes) methodology. Working as a product manager for a software applications company, she is recognised as a specialist on Business Process Re-engineering and regularly invited as a keynote speaker for industry leading seminar organisations. She has experience with a multi disciplinary consulting engineering organisation as business manager for 7 years. With professional membership of the Australian Institute of Management and Australian Institute of Project Management, she is currently working as a senior project manager for ASIC Project Office (APO).

**D08** is currently working for a large retail organisation as National Store Development Specialty Planner. He graduated with a double degree in Bachelor of Architecture and Bachelor of Property and Construction from the University of Melbourne. He is a qualified architect with more than six years experience.

**D09** is an associate of a company that provides a full range of professional consulting quantity surveying services. He holds a Bachelor of Applied Science in Construction Management degree from RMIT University, and is an associate member of the Australian Institute of Quantity Surveys (AIQS). His involvement in the pre-construction stage of building projects includes the provision of professional services for: preliminary estimates; feasibility studies; cost planning reports; assessing cost and value management/ value engineering.

**D10** is currently a director for a major Australian quantity surveying and property consultancy. Some of the services he provides during the pre-construction stage of building design include: preparation of preliminary elemental estimates based on preliminary design; preparation of detail estimates and cost planning advice; estimating of building services; participation and leadership in the value management process; comparative cost studies and advice on cost effective design solutions; advice on materials selection and general buildability advice.
4.3.8 The Delphi Rounds

Round 1
It was planned to survey participants four times, using a modified Internet-based Delphi technique at Round 1. All of the research questions are to be answered throughout the rounds. The Round 1 questionnaire (see appendix C) mainly focuses on the extent of ICT use during the pre-construction stages of building design process. Section A of the survey questionnaire was designed to collect demographic information from participants. In section B, five-point Likert-like scale questions were used to determine the extent of current and predicted future use of ICT tools used in performing the lower level activities during the building design process. The five-point rating scale was calibrated as follows:

- **(5) Essential** – you believe these tools are necessary to allow project participants to perform work that was not possible before; and they will continue to be necessary in the future.
- **(4) Helpful** – you believe these tools significantly decrease effort and make the design process more efficient and of better quality; and that they will continue to do so in the future.
- **(3) Fairly useful** – you believe these tools are useful in performing jobs; and will continue to assist in the future.
- **(2) Not used** – you are not currently using these tools, and you have no intention of using them in the future;
- **(1) Un-necessary** – you have no interest in these tools and they will not be needed in the future.

Section C gave participants the opportunity to include any additional activities in the list of lower level building design process activities during the building design process for large scale commercial investment building projects.

Round 2
Delphi Round 2 (see appendix D) began with a summary of the results of the additional lower activities suggested in Round 1 Section C. All of these activities were categorised and participants were asked to rate them using the same procedure and scales used for Round 1 Section B. For Round 2, in Section B an attempt was made to find out what kinds of ICT tools
building professional actually use in performing each of those activities. There are three ICT categories: ICT Infrastructure; ICT for Communication; and ICT for Information Management. Participants were asked to rate how frequently each tool was used for each building design activity using the following Likert scale:

- 4 = Daily
- 3 = Weekly
- 2 = Occasionally
- 1 = Never
- 0 = Not applicable

They were asked to first assess the current use, then the predicted future use for each tool, and to add further ICT tools to the list provided. This concluded the Delphi Round 2 survey.

**Round 3**

Delphi Round 3 (see appendix E) aimed to answer the following questions:

- What are the current barriers to the implementation of ICT tools?
- What are the impacts of ICT implementation by building design professional during design process?
- What value is added by the use of ICT tools for building design Management?

Round 3 began with asking Delphi experts to reconsider their rating of the original 40 building design process activities of Round 1 plus the 14 activities added in Round 2. The experts were given the descriptive statistics ratings from the previous rounds. In addition, they were asked to select as many as apply from the following set of alternatives relating to the value added by using ICT tools in building design activities:

- **C = Cost efficiency** = able to produce more with lower cost.
- **T = Time efficiency** = able to produce more in shorter time period.
- **Q = Quality** = able to perform the task in better quality than it previously was and with less effort.
- **O = Opportunity** = able to perform task that may not have been previously done.
The Delphi experts were then asked to identify and rate “barriers” for ICT implementation based on the following scales:

- **T** = lack of **training** for soft/hardware implementation
- **C** = Cultural barriers such as: threat of ICT; project based nature of construction project; adversarial culture between project professionals, etc.
- **A** = lack of **availability** of some soft/hardware
- **L** = Legal issues such as: security
- **S** = lack of top management **support**
- **I** = lack of **investment** in soft/hardware

The Round 3 Delphi experts were invited to make additional comments.

**Round 4**

Round 4 (see appendix F) was the final round of Delphi survey for this research. In this round, the researcher was seeking to gain consensus on the need for ICT use during all of the design stages. The Round 4 questionnaires were called back once after receiving comment from Delphi panel members who experienced difficulty answering some of the questions. Revised questionnaires were sent out two weeks later.

The revised Round 4 (see appendix G) survey questionnaire comprised three sections: A, B and C. In Sections A & B, some design activities were highlighted in GREEN colour in various design stages. These activates were highlighted because experts’ responses to these activities from the Round 3 Survey varied from the “Common View” of the majority of the collected data.

Panellists were asked to re-consider carefully their previous responses on these highlighted activities and to choose either: - ‘Agree with the Mode’ or ‘Disagree with the Mode’ and provide reasons in the “Your Comment” column.

Section C of Round four again sought additional comments to the research. Five questions were posted for collection of comments, derived from comments received through the earlier Delphi rounds. The five questions were:
The design and evaluation activities are highly dependent on staff expertise and experience of individual practices. Whilst ICT has proved beneficial for communication and information management, it will not replace the expertise and experience of a design team. Do you agree with the above statements?

The variety and type of ICT infrastructure available on the marketplace is not a major concern to the industry, because the construction industry is capable of adjusting its operation processes to suit the available ICT in the marketplace. The major concern for the industry is whether or not quality improvement could be achieved by adopting new ICT software. Do you agree with the above statements?

Other ICT tools that should be included are: Visualisation tools (4D CAD, VR, GIS); Management tools (document management, construction planning, cost planning, digital photography); and Communication tools (Voice over IP, mobile communications such as XDAII). Would you agree or disagree that your office’s productivity can be further enhanced if (any or all of) the above mentioned ICT tools are used in your current practice?

As the evolution of ICT is so rapid, upgrading your existing software also involves a major hardware improvement. Do you agree with the above statement?

Do you agree or disagree that the quality and productivity of the building design process could be further enhanced in the future if an integrated communication model could be formulated and efficiently implemented among the relevant project stakeholders?

Completion of the four rounds of Delphi survey provided sufficient data to prepare an ICT Implementation Map. Development of the proposed ICT map is discussed in Chapter Five.

4.4 DATA ANALYSIS PROCEDURES

The primary data analysis is presented in Chapter 5. “Descriptive statistics” are used as the basic analytical approach. These provide a simple quantitative method of analysis, produce a general overview of the results and give an idea of what is happening (Naoum, 1998). Note that the response data is not sufficiently adequate (in quantity) to support the use of inferential statistics. For the most part, the results are presented in tabulation format, bar chats, histograms, or pie charts.
Responses to questions designed in Likert scale format are analysed by calculating the mean of the results and their central tendency. The mean is calculated by summing the scores from each individual response and dividing the result by the number of respondents (Ahmad, 2000) as follows:

\[
\text{Mean} = \frac{\sum_{i=1}^{5} A_i X_i}{\sum_{i=1}^{5} X_i}
\]

for five interval Likert scale.

Where \( A_i \) = constant expressing the weight given to \( i \), \( X_i \) variables expressing the frequency of the response for \( i \):

\( i = 1,2,3,4,5 \)

\( X_1 \) = the frequency for responses labelled “essential”
\( X_2 \) = the frequency for responses labelled “helpful”
\( X_3 \) = the frequency for responses labelled “fairly useful”
\( X_4 \) = the frequency for responses labelled “not used”
\( X_5 \) = the frequency for responses labelled “unnecessary”

Where:

\( A_1 = 5 \)
\( A_2 = 4 \)
\( A_3 = 3 \)
\( A_4 = 2 \)
\( A_5 = 1 \)

The mean values are further split into discrete categories as follows:

- Essential: mean score >4.5 ≤ 5.0
- Helpful: mean score >3.5 ≤ 4.5
- Fairly useful: mean score >2.5 ≤ 3.5
- Not used: mean score >2.5 ≤ 1.5
- Unnecessary: mean score <1.5
Where calculating the ‘usage level’ of ICT tools for the building design process, the mean values will be grouped into the following categories.

- **Daily** mean score >3.5 \(\leq\) 4.0
- **Weekly** mean score >2.5 \(\leq\) 3.5
- **Occasionally** mean score >1.5 \(\leq\) 2.5
- **Never** mean score >0.5 \(\leq\) 1.5
- **Not applicable** mean score <0.5

The **standard deviation** is a statistic that describes how tightly the data are clustered around the mean. When the data are tightly bunched together and the bell-shaped frequency distribution curve is leptokurtic, the standard deviation is small. When the data are spread apart and the frequency distribution curve is mesokurtic, the standard deviation is quite large (RobertNiles.com).

\[
\text{Standard deviation} = \sqrt{\frac{n \sum x^2 - (\sum x)^2}{n^2}}
\]

Where,
- \(X\) = one value in the set of data;
- \(n\) = the number of values in the data
4.5 SUMMARY

This chapter has described the selection and justification of Delphi survey as the primary data collection methodology for the purpose of this study. Topics reviewed include: the Delphi process; evaluation of Delphi; objective of Delphi for this study; Internet based Delphi survey; Delphi panel selection criteria; recruitment procedure; description of the Delphi panel; and the Delphi rounds.

The proposed data analysis procedures are described. “Descriptive statistics” were used as the basic analytical approach. Responses to questions designed in Likert scale format were analysed by calculating the mean of the results and their central tendency.

The next chapter will focus on the analysis of results collected from the four rounds of Delphi survey.
5 DELPHI SURVEY: ANALYSIS AND RESULTS

5.1 INTRODUCTION

This study aims to better understand how Information and Communication Technology (ICT) is being implemented during the building design process and its future usage in five years time. A Delphi panel of 10 experts chosen from the building industry was invited to assist in answering the following research questions:

- How do design professionals perform their work with the assistance of ICT?
- To what extent do building design professionals use ICT?
- What are the current barriers to the implementation of ICT tools?
- What are the impacts of ICT implementation by building design professionals during design process?
- What value is added by the use of ICT tools for building design management?
- How can process mapping be used to describe and document the ICT implementation methodology during the building design process?
- Can a best practice model be mapped for ICT use during the design process?
- What are the future trends of ICT implementation during building design process?

The data from the four rounds of Delphi survey are presented and analysed on a round by round basis in this chapter.

5.2 DELPHI ROUND 1

Following on the scrutiny and advice of staff from the School of Property, Construction and Project Management, RMIT University, the Round 1 questionnaire (refer to Appendix-C) was modified and distributed to the Delphi panel.

The Delphi Round 1 questionnaire survey began in the second week of October 2004, (11th October, 2004 – 17th October, 2004). Participants were given one week to complete the web-based questionnaire. A covering ‘Instruction Letter’ was first sent out via email to provide participants with information on:
- A brief introduction on the IDEF0 modelling language;
- Instructions for answering the web-based questionnaire;
- An assigned personal code for each participant;
- The web-link to the Round 1 questionnaire;
- A reminder about the submission date for Round 1 questionnaire.

Follow up phone calls were made to ensure all participants had received the email message and that they were aware of the submission date for the Round 1 survey. Further follow up telephone calls were made to panel members who had not responded by the due date. Round 1 of the Delphi survey took two weeks to complete. Response data were entered into spreadsheet format for descriptive analysis.

The Delphi round 1 survey comprised three sections which sought both quantitative and qualitative data. Section A collects demographic information. Section B looks at the extent of ICT tools used during the building design process; while section C allows participants to add in any activities which they believe have been omitted in section B. The results for all three sections of Round 1 are presented below.

**Response: Round 1 Section A**

This section collected demographics information about the participants. The collected data is presented in Table 5-1.

A wide variation existed in participants’ experience in the construction industry including: architect, engineer, quantity surveyor, academic, researcher, client’s representative and IDEF0 expert, ranging from 5 to 34 years, with 1 expert having 5 years of experience, 2 having between 6 and 10 years of experience, 4 experts having more than 20 years of experience, and 3 having more than 30 years of experience in the construction industry. Six of the ten Delphi panel members had participated in research, published, or led workshops related to their fields of practice. On the basis of the data, none of the panel members could be disqualified through lack of experience.
When asked how much of their work required ICT tools, one expert selected the lowest range of 10-19%; one selected the range of 20-29%; one selected the range between 30-39%; one selected the range between 50-59%; one selected the range between 70-79%; while 2 experts selected the range between 80-89% and the remaining 3 experts selected the range between 90-100%. A mean of 67% was calculated for this variable, to represent the average usage of ICT tools required in performing activities during building design process. The modal value was “90 – 100%”.

Table 5-1 Demographics of Delphi survey panel of experts

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expert Profession</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>architect</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>engineer</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>quantity surveyor</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>academic</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>researchers</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>Client's representative</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>IDE70 expert</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>Male</td>
<td>9</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Age range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20+</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>40+</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>50+</td>
<td>6</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Year of experience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10yrs</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>&gt;10yrs</td>
<td>8</td>
<td>80%</td>
</tr>
<tr>
<td><strong>Research participation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>6</td>
<td>60%</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
<td>40%</td>
</tr>
<tr>
<td><strong>ICT Usage (MEAN)</strong></td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>(Portention of experts' work requiring ICT tools)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Believe ICT tools improve work capabilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>10</td>
<td>100%</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

The final question asked if the panel members believed that ICT tools can improve work capabilities. All of them agreed.
Response: Round 1 Section B

Section B of the Round 1 Delphi survey looked at the level of ICT currently used during the building design process, and sought participants’ forecasts for ICT use five years ahead. This provided baseline references from which to measure shifts in the responses for subsequent rounds. Analysis of results for this section is presented together with the responses received in the final Delphi round (see Table 5-10 and Table 5-12).

Section B contained forty Likert-scale questions. Delphi panel members were asked to select a five-point Likert-scale interval to represent their opinion of the extent of usage (current and future) of ICT tools for performing each of the 40 lower level activities listed for the building design process. The five intervals for the Likert scale were:

- **(5) Essential** – you believe this tool allows project participants to perform work that was not possible before;
- **(4) Helpful** – you believe this tool significantly decreases effort and makes things much more efficient and of better quality;
- **(3) Fairly useful** – you believe this tool is useful in performing the job;
- **(2) Not used** – you are not currently using this tool, but it could be used and you have interest on using it in future;
- **(1) Un-necessary** – you have no interest in this tool and it is not needed to be used in the future.

Response: Round 1 Section C

The Delphi panel participants were asked to suggest additional activities which should be included in the building design process map. The responses were summarised, assigned activity codes, and are shown in Table 5-2.
Table 5-2 Summary Result for Round 1 Section C: additional process activities suggested by panellists

<table>
<thead>
<tr>
<th>Activity No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A112</td>
<td>Site analysis</td>
</tr>
<tr>
<td>A116</td>
<td>Seek client’s initial feedback</td>
</tr>
<tr>
<td>A121</td>
<td>Identify potential resale target/buyer</td>
</tr>
<tr>
<td>A131</td>
<td>Review concept brief</td>
</tr>
<tr>
<td>A133</td>
<td>Highlight mismatches and risks</td>
</tr>
<tr>
<td>A141</td>
<td>Ensure outline plan fulfils project brief</td>
</tr>
<tr>
<td>A143</td>
<td>Review authorities’ requirements</td>
</tr>
<tr>
<td>A145</td>
<td>Assess client’s initial feedback</td>
</tr>
<tr>
<td>A151</td>
<td>Development of Opinion of Probable Cost and Program (OPC)</td>
</tr>
<tr>
<td>A152</td>
<td>Engineering cost studies/ liaise with engineers</td>
</tr>
<tr>
<td>A213</td>
<td>Coordinate/liaise with all consultants</td>
</tr>
<tr>
<td>A223</td>
<td>Gather feedback from all authorities and consultants</td>
</tr>
<tr>
<td>A311</td>
<td>Prepare detailed architectural drawings</td>
</tr>
<tr>
<td>A323</td>
<td>Identify and analyse life cycle cost</td>
</tr>
</tbody>
</table>

Fourteen additional activities were suggested by the Delphi experts during the first round survey. These activities were incorporated into the Round 2 questionnaire survey.

Comment was received from panel member D05, who stated:

“Generally speaking, most design and evaluation activities are reliant on expertise and experience. Whilst gathering of reference material and communication can occur using IT systems and can be very useful, however, they will not replace the design team’s ability and knowledge.”

Although ICT tools are widely used during the building design process, and many professionals rely on these tools when dealing with everyday tasks, decision making is still based on individual team members’ professional knowledge, experience and expertise. ICT tools are used to inform and confirm or reject professional judgement.
5.3 Delphi Round 2

As noted earlier, administration of the web-based Round 1 survey was found to be too complicated. The major weaknesses of the web-based survey are that it limits the format of questionnaire presented, and that it has to be completed in one sitting. Since the following rounds of survey required a different format, a fresh approach to data collection was adopted. The Delphi Round 2 questionnaire was designed using Microsoft Excel spreadsheet format and administered via an attachment to email messages to panel members.

The email announcement of the beginning of the Round 2 survey included the following attachments (refer to Appendix-D):

- Instruction to begin Round 2 Delphi Survey, and
- Round 2 questionnaires in Microsoft Excel format.

The Delphi Round 2 survey took two weeks to complete. Email questionnaires were sent out on the 3rd November 2004 and finalized on the 14th November 2004. However, after follow up phone calls and emails trying to capture missing responses for Round 2 survey, one panel member dropped off at this point due to personal reasons. Only 9 of the 10 experts who participated in Round 1 completed the Round 2 questionnaires, giving a 90% response rate.

In Section A of the second round of the Delphi survey, the experts were asked to rate (in terms of current and future usage) the new activities added subsequent to Round 1. Analysis of result for section A is undertaken in conjunction with other rounds and presented later in this chapter (see Table 5-10 and Table 5-12).

When part A was completed, the Delphi experts were instructed to proceed to Round 2, Section B.

Section B of the survey aimed to explore how ICT tools are used in building design activities. There are three ICT categories: ICT Infrastructure; ICT for Communication; and ICT for Information Management. A brief description for each of the tools listed below was made available in the questionnaire for better understanding. The 29 ICT tools in the three categories to be rated were:
**ICT Infrastructure**

- Internet;
- Intranet;
- Extranet;
- Window;
- Personal Area Network (PAN);
- Bluetooth;
- Information Exchange Standard (IES);
- Authentication;
- Digital Signature;
- Cryptography;

**ICT for Communication**

- Email;
- Chat;
- Videoconferencing;
- Groupware Solution;
- Workflow Solution;
- Personal Digital Assistant (PDA);
- Personal Area Environment (PDE);
- Visualization;
- Virtual Reality (VR);

**ICT for Information Management**

- Word processor;
- Spreadsheet;
- Database;
- Computer Aided Design (CAD);
- 3D Modelling;
- Hardcopy data;
- Multimedia;
- Artificial Intelligence (AI);
- Electronic Data Interchange (EDI); and
- Digital Pen.
Each of these tools was to be rated once for each building design activity using the following scale:

- 4 = Daily
- 3 = Weekly
- 2 = Occasionally
- 1 = Never
- 0 = Not Applicable

All experts were asked to first give their ‘overall rating’ (level of usage of each tool to the building design activities) for each of these tools for the activities listed. Then, they were asked to rate the individual tools to each activity accordingly.

Finally in Round 2, Section C of the questionnaire allowed Delphi experts to add in ICT tools not already covered in the list. Comments were also invited.

**Response: Round 2 Section B**

The response ratings for the twenty nine ICT tools and building design activities are summarized and presented in Table 5-3 and Table 5-4. The mean rating response value for each of these tools is first calculated. Then the ICT tools that the Delphi experts rated as being used during building design process were rank-ordered according to the mean rating values, in descending order from 4.00 to 0.78. This process was repeated for the experts’ opinion about future use of the ICT tools.

The highest current usage level of ICT tools was found to be ‘email’ under the “ICT for Communication” category. The mean rating value for ‘email’ was 4.00; followed by word processor and spreadsheet, indicating almost daily use of these tools for all Delphi experts during the building design process. Of the total 29 tools used, 10 were rated 2.5 or higher, indicating frequent use (at least once every few days). Twelve tools scored mean value ratings below 1.5, indicating that the Delphi experts have never or only occasionally used those tools during the building design process.
<table>
<thead>
<tr>
<th>rank-order of Mean of experts’ ratings</th>
<th>rank-order of Mean of experts’ rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean values for current use rating</td>
<td>Mean values for future use rating</td>
</tr>
</tbody>
</table>

| 5-3 Current Use |  | 5-4 Future Use |  |  |
|---|---|---|---|
| C¹ | Mean - C³ | ICT Tools | ICT Tools | Mean -F⁴ | F² |
| 1 | 4.00 | Email | Email | 4.00 | 1 |
| 2 | 3.89 | Word processor | Word processor | 3.89 | 2 |
| 3 | 3.56 | Spreadsheet | Spreadsheet | 3.56 | 3 |
| 4 | 3.44 | Hardcopy data | Internet | 3.56 | 3 |
| 5 | 3.22 | Window | Intranet | 3.33 | 5 |
| 6 | 3.11 | Internet | Window | 3.33 | 5 |
| 7 | 2.89 | Database | Database | 3.22 | 7 |
| 8 | 2.67 | CAD | Hardcopy data | 3.22 | 7 |
| 8 | 2.67 | Intranet | PDA | 3.11 | 9 |
| 10 | 2.56 | PDA | IES | 3.11 | 9 |
| 11 | 2.44 | IES | CAD | 2.89 | 11 |
| 12 | 1.89 | Extranet | Bluetooth | 2.67 | 12 |
| 12 | 2.22 | Authentication | Authentication | 2.56 | 13 |
| 14 | 1.78 | Multimedia | Videoconferencing | 2.56 | 13 |
| 15 | 1.67 | Videoconferencing | PDE | 2.56 | 13 |
| 16 | 1.56 | 3D modelling | 3D modelling | 2.56 | 13 |
| 16 | 1.56 | EDI | Multimedia | 2.56 | 13 |
| 18 | 1.44 | Bluetooth | Extranet | 2.44 | 18 |
| 18 | 1.44 | Groupware solution. | EDI | 2.44 | 18 |
| 20 | 1.33 | PAN | Digital Signature | 2.33 | 20 |
| 20 | 1.33 | Digital Signature | Chat | 2.33 | 20 |
| 22 | 1.22 | Workflow solution. | PAN | 2.22 | 22 |
| 22 | 1.22 | PDE | Groupware solution. | 2.22 | 22 |
| 22 | 1.22 | Visualisation | Cryptography | 2.11 | 24 |
| 25 | 1.11 | Chat | Visualisation | 2.11 | 24 |
| 25 | 1.11 | VR | VR | 2.00 | 26 |
| 27 | 1.00 | Cryptography | Workflow solution. | 1.89 | 27 |
| 27 | 1.00 | Digital Pen | Digital Pen | 1.78 | 28 |
| 29 | 0.78 | AI | AI | 1.67 | 29 |
According to Table 5-4, email, word processor and spreadsheet were still ranked highest when panel experts were asked to predict future usage of ICT tools (for the next five years). On the other hand, their predictions for the use of the Internet increased from a mean value of 3.11 (current) to 3.56 (future), signifying future almost daily use of such tools. All of the 29 tools were predicted to be adopted to accomplish building design activities in the future.

Noticeable changes in the mean values of ratings from current to future usage occurred for the following tools (refer to Figure 5-1):

- **PAN** – mean value increased from 1.33 to 2.22, indicating occasional or even weekly use of the tool in the future, compared to current occasional use / never used.
- **Bluetooth** – mean value increased from 1.44 to 2.67, indicating occasional to weekly usage of the tool in the future compared to current occasional use / never used.
- **Digital Signature** – mean value increased from 1.33 to 2.33, indicating an occasional or even weekly use of the tool from current occasional use / never used.
- **Cryptography** – mean value increased from 1.0 to 2.11, indicating occasional use of the tool in the future, compared to current never used.
- **Chat** - mean value increased from 1.11 to 2.33, indicating occasional or even weekly use of the tool in the future, compared to current occasional use / never used.
- **Videoconferencing** - mean value increased from 1.67 to 2.56, indicating occasional
to weekly use of the tool in the future, compared to current occasional use / never used.

- **PDE** - mean value increase from 1.22 to 2.56, indicating occasional to weekly use of the tool use in the future, compared to current occasional use / never used.

**Response: Round 2 Section C**

In Section C of the Round 2 questionnaire, specific examples were sought from the Delphi experts on the three categories of ICT (current and future use) to accomplish each of the activities during the building design process.

The examples provided by the Delphi experts were primarily concerned with the use of ICT tools for communication and information management. Mobile communication tools such as the new generation cellular telephony, e.g., “… experts are now using XDA II by O2 which allows digital photos to be taken on site, and facilitate assessment and valuations for progress claims, insurance replacement valuation, tax and depreciation schedules, etc.” Other examples of the use of new generation telephony include communication by cellular telephone via Bluetooth technology for sending emails and browsing information on line. Visualization tools that enhance communication with clients were also mentioned, and included tools such as 4D CAD and Geographical Information Systems: “… these tools have been used to present concept design idea to clients beyond those in CAD documentation and emails.”

Examples of Information Management tools included: document management systems, construction planning or management tools (MS Project, etc.), 4D CAD applications, and cost planning tools: “… use of technology allows better information management during the building design process, real time information retrieval, and better budgeting.”

Another ICT tool suggested by the Delphi expert included Voice over Internet Protocol (VoIP): “VoIP which will probably be applicable to infrastructure and communication, being the convergence of data and voice on local networks.”

This concluded the second Delphi round.
5.4 DELPHI ROUND 3

The email notice announcing the beginning of Delphi Round 3 was sent out on the 22nd November 2004. The message included “Instructions for Round 3” in Word document format and the “Round 3 Survey Questions” in Excel format. Copies can be found in Appendix-E.

The Delphi experts were recommended to print out the instructions for easy reference while making their responses to the Round 3. Section A of the Round 3 survey questionnaire was designed in three blocks, looking at ‘current’ issues for ICT application during the building design process. Block 1 of Section A covered 54 activities during the building design process (made up from the original 40 activities of Round 1 plus the 14 activities added by the Delphi experts). The Round 2 ICT tool rating score values were provided for each activity and the Delphi panel members were asked to review and reconsider their original ratings for current and future usage. Again, results for this section are analysed with the final responses in Round 4 and presented in section 5.5 (Experts’ perception of ICT implementation during the Building Design Process, see Table 5-10 and Table 5-12).

Block 2 of Section A looked at the experts’ perceptions about how ICT tools could help them accomplish each activity during the building design process (current and future). Value added issues were indicated to allow the experts to choose from the following scale intervals.

- **C** = Cost efficiency (able to produce more with lower cost).
- **T** = Time efficiency (able to produce more in shorter time period).
- **Q** = Quality (able to perform the task in better quality than it previously was and with less effort).
- **O** = Opportunity (able to perform task that may not have been previously done).

Block 3 of Section A aimed to explore the barriers for ICT implementation during building design activities (currently and five years hence). The Delphi experts were required to indicate from the following scale:

- **T** = Lack of **Training** for soft/hardware implementation.
- **C** = Cultural barriers such as: threat of ICT; project based nature of construction project; and adversarial culture between project professionals.
- **A** = Lack of **Availability** of some soft/hardware.
- L = Legal issues such as security.
- S = Lack of top management Support.
- I = Lack of Investment in soft/hardware.

Comments and suggestions from Delphi experts were invited in the final section of the questionnaire. An extension of time was given to allow the panel experts another week to cope with their tight schedules. Of the nine experts who responded to the Delphi Round 2, all completed the Round 3 questionnaire.

**Response: Round 3 – Value Added nature of ICT Implementation**

The most frequently selected value added issues for current use of ICT tools by the majority of experts were time and quality, followed by cost and opportunity (refer to Tables 5-5 and 5-6). The highest percentage was 78% for all of those issues listed (activities highlighted in “yellow”). ‘Cost efficiency’ was popular with panel members for activity A141-Ensure outline plan fulfils project brief, while ‘time efficiency’ was selected by 78% of the experts for activity A135-Presentations. ‘Quality’ was highly cited by panel members for five activities: A131-Review concept brief; A132–Allocate costs; A212-Prepare preliminary engineering design; A311-Prepare detailed architectural drawings; and A312-Develop detail engineering design. Finally, the highest chosen rate for ‘opportunity’ was found for activities A115-Conduct environmental analysis and A324-Review optimization of energy performance.
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Cost</th>
<th>Time</th>
<th>Quality</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A111</td>
<td>Lease with Authorities</td>
<td>22%</td>
<td>67%</td>
<td>67%</td>
<td>33%</td>
</tr>
<tr>
<td>A112</td>
<td>Site Analysis</td>
<td>44%</td>
<td>44%</td>
<td>33%</td>
<td>22%</td>
</tr>
<tr>
<td>A113</td>
<td>Conduct Outline Feasibility Design</td>
<td>33%</td>
<td>56%</td>
<td>44%</td>
<td>33%</td>
</tr>
<tr>
<td>A114</td>
<td>Assessment of Consultant’s recommendations</td>
<td>33%</td>
<td>56%</td>
<td>44%</td>
<td>33%</td>
</tr>
<tr>
<td>A115</td>
<td>Conduct environmental analysis</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
<tr>
<td>A116</td>
<td>Seek client's initial feedback</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
<tr>
<td>A121</td>
<td>Identify potential resale target/buyer</td>
<td>33%</td>
<td>56%</td>
<td>44%</td>
<td>33%</td>
</tr>
<tr>
<td>A122</td>
<td>Assessment resale value</td>
<td>67%</td>
<td>56%</td>
<td>56%</td>
<td>67%</td>
</tr>
<tr>
<td>A131</td>
<td>Review concept brief</td>
<td>67%</td>
<td>44%</td>
<td>56%</td>
<td>67%</td>
</tr>
<tr>
<td>A132</td>
<td>Allocate costs</td>
<td>22%</td>
<td>11%</td>
<td>56%</td>
<td>44%</td>
</tr>
<tr>
<td>A133</td>
<td>Highlight mismatched and risks</td>
<td>33%</td>
<td>33%</td>
<td>22%</td>
<td>22%</td>
</tr>
<tr>
<td>A134</td>
<td>Evaluation and development of alternative solutions</td>
<td>44%</td>
<td>44%</td>
<td>78%</td>
<td>78%</td>
</tr>
<tr>
<td>A135</td>
<td>Presentations</td>
<td>44%</td>
<td>44%</td>
<td>33%</td>
<td>56%</td>
</tr>
<tr>
<td>A141</td>
<td>Ensure outline plan fulfills project brief</td>
<td>44%</td>
<td>33%</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>A142</td>
<td>Prepare design proposal</td>
<td>68%</td>
<td>67%</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>A143</td>
<td>Review authorized requirements</td>
<td>44%</td>
<td>33%</td>
<td>56%</td>
<td>56%</td>
</tr>
<tr>
<td>A144</td>
<td>Leans with cost planning consultant</td>
<td>44%</td>
<td>44%</td>
<td>67%</td>
<td>33%</td>
</tr>
<tr>
<td>A145</td>
<td>Assess client's initial feedback</td>
<td>55%</td>
<td>56%</td>
<td>55%</td>
<td>44%</td>
</tr>
<tr>
<td>A146</td>
<td>Initial Planning Permit Application Preparation</td>
<td>44%</td>
<td>78%</td>
<td>44%</td>
<td>22%</td>
</tr>
<tr>
<td>A151</td>
<td>Development of Opinion of Probable Cost and Program (OPC)</td>
<td>67%</td>
<td>78%</td>
<td>78%</td>
<td>56%</td>
</tr>
<tr>
<td>A152</td>
<td>Engineering cost study/lease with engineers</td>
<td>33%</td>
<td>56%</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>A153</td>
<td>Search for principal solutions</td>
<td>44%</td>
<td>44%</td>
<td>67%</td>
<td>78%</td>
</tr>
<tr>
<td>A154</td>
<td>Select suitable design/cost combination</td>
<td>44%</td>
<td>44%</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>A155</td>
<td>Evaluations of choices of alternatives</td>
<td>44%</td>
<td>56%</td>
<td>67%</td>
<td>56%</td>
</tr>
<tr>
<td>A156</td>
<td>Improve details and cost options</td>
<td>78%</td>
<td>78%</td>
<td>78%</td>
<td>44%</td>
</tr>
<tr>
<td>A211</td>
<td>Develop expansion of architecture design drawings</td>
<td>67%</td>
<td>56%</td>
<td>78%</td>
<td>22%</td>
</tr>
<tr>
<td>A212</td>
<td>Prepare preliminary engineering design</td>
<td>56%</td>
<td>44%</td>
<td>78%</td>
<td>78%</td>
</tr>
<tr>
<td>A213</td>
<td>Coordinate liaison with all consultants</td>
<td>55%</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
</tbody>
</table>

Table 5-5 Value Added Issues on ICT Application during Building Design Process -1/2
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Cost</th>
<th>Time</th>
<th>Quality</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A214</td>
<td>Make required design changes</td>
<td>44%</td>
<td>56%</td>
<td>56%</td>
<td>44%</td>
</tr>
<tr>
<td>A215</td>
<td>Presentations of the schematic design</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A216</td>
<td>Design Visualisation – Model Construction</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A221</td>
<td>Integrate preliminary consultant's advice in design</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A222</td>
<td>Review authorities/council requirements</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A223</td>
<td>Gather feedback from all authorities and consultants</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A224</td>
<td>Finalised design documents</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A225</td>
<td>Apply for planning permit</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A231</td>
<td>Estimating building cost</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A232</td>
<td>Prepare alternative estimates</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A233</td>
<td>Prepare budget program</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A234</td>
<td>Prepare time schedule &amp; organization plan</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A311</td>
<td>Prepare detailed architectural drawings</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A312</td>
<td>Develop detail engineering design</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A313</td>
<td>Coordinate/align with all consultants</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A314</td>
<td>Presentation to authority/council</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A315</td>
<td>Preparations of documents for building permit application</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A321</td>
<td>Analysis &amp; evaluate design alternatives</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A322</td>
<td>Investigate design cost efficiency</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A323</td>
<td>Identify and analyse life cycle cost</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A324</td>
<td>Review optimization of energy performance</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A325</td>
<td>Conduct design cost check</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A331</td>
<td>Legislation for building permit</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A332</td>
<td>Rationalise &amp; integrate sub-systems designs</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A333</td>
<td>To consider Occupational Health and Safety - Safe Design</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
<tr>
<td>A334</td>
<td>Conduct risk management</td>
<td>65%</td>
<td>67%</td>
<td>65%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Table 5-6 Value Added Issues on ICT Application during Building Design Process -2/2
Figure 5-2 indicates a substantial increase in rating score values over all four issues for implementing ICT tools to accomplish more building design activities over the ensuing five years. Value added issues scored by the Delphi panellists for future use of ICT tools for overall building design process included Time (57%), Quality (56%), Opportunity (49%), and Cost (48%). The highest score ratings (activities highlighted in “pink”) for each value added issue to individual activity were: 89% of panel members selected ‘improve quality’ for A216—Design Visualisation–Model Construction; ‘time efficiency’ for A223-Gather feedback from all authorities and consultants. Similarly, ‘opportunity’ was rated 89% for activity A324-Review optimization of energy performance. High (78%) scores for ‘cost efficiency’ and ‘improve quality’ were found for the following activities (activities highlighted in “yellow”):

- A111 – Liaise with Authorities
- A115 – Conduct environmental analysis
- A134 – Evaluation and development of alternative solutions
- A146 – Initial Planning Permit Application Preparation
- A151 – Development of Opinion of Probable Cost and Program (OPC)
- A156 – Improve details and cost options
- A211 – Develop expansion of architecture design drawings
- A212 – Prepare preliminary engineering design
- A233 – Prepare budget program
- A311 – Prepare detailed architectural drawings
- A312 – Develop detail engineering design
- A323 – Identify and analyse life cycle cost
- A325 – Conduct design cost check
- A331 – Lodgement for building permit
Response: Round 3 – Barriers for ICT Implementation

One further issue was explored in the Delphi Round 3 survey. This related to barriers to ICT implementation during the building design process. Analyses of results are shown in Table 5-7 and Table 5-8.

The two highest scoring current barriers for ICT Implementation were: ‘lack of availability of some soft/hardware’ (33% of the Delphi experts) followed by ‘lack of training for soft/hardware implementation’ (30%). ‘Cultural barriers’ such as: threat of ICT, project based nature of construction project, adversarial culture between project professionals and ‘lack of investment in soft/hardware’ attracted lower scores (21%). Fewer than 10% of the participating experts believed that ‘legal’ and ‘support’ issues acted as barriers for ICT implementation.
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Table 5-7 Barriers for ICT Implementation during Building Design Process

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Table 5-8 Barriers for ICT Implementation during Building Design Process 2/2
In their forecasts for the next five years, the Delphi experts believed that the main barriers for ICT implementation might refer to ‘training’ and 41% of the experts voted ‘lack of training for soft/hardware implementation as the main barrier for future ICT implementation. Following this were: ‘cultural issues’ (38%); and ‘lack of availability’ (27%); ‘lack of investment’ (25%). Minor increases showed in the voting for ‘legal issue’ (from 3% to 8%) and ‘lack of top management support’ (from 8% to 15%).

Comparison between the current and future panel opinion ratings for barriers to ICT implementation revealed the results shown in Figure 5-3. Increases were found for all issues except ‘lack of availability’. The Delphi experts believe that the availability of soft/hardware will increase dramatically over the next five years. Importantly however, the Delphi experts consider that barriers such as lack of training, cultural and legal factors, management support and investment constraints will continue to impact the adoption of ICT tools in the foreseeable future. These are issues which the construction industry, including the professions associated with it, need to address as a matter of urgency if the benefits of ICT implementation are to be fully realised.

![Figure 5-3 Comparison of rating on current barriers for ICT implementation and in year 2009.](image-url)
5.5 Delphi Round 4

The email notice to begin Round Four was first sent out on the 18th March 2005. Complaints were received from respondents regarding their difficulties in understanding and completing the Round 4 Section A and Section B questions. The Round Four surveys were then recalled for review and improved to ensure easier comprehension and answering.

The main problem with the first Round 4 survey was due to the shading of the tabled summary of Round 3 responses in Section A and Section B (refer to Appendix-F). The Delphi experts found that the time required in understanding the shading and making decisions was excessive.

The revised Round 4 survey was pilot tested with staff in the School of Property, Construction and Project Management at RMIT University before re-distribution. Modifications were made to Sections A and B, where activities which varied from the common view (mode) were highlighted in GREEN colour and flagged with a request for reconsideration. Either “Agree with the Mode” or “Disagree with the Mode” options were given to respondents. Comments were invited when respondents disagreed with the modal view. Minor changes were also made to the “Comment made in 3 Rounds by experts” section, and all five questions were rephrased for better understanding.

The revised Round Four Delphi surveys were sent out on the 8th April 2005 and requested responses by 17th April 2005. The message included a “Comment made in 3 Rounds by experts” file in word document format and the “Revised Round 4 Survey Questions” in Excel format. Copies are located in Appendix-G.

The Round 4 survey begins with comment on five statements summarised from panel members in the previous Delphi rounds. Every attempt was made to preserve the original wording used by the respondents, without sacrificing clarity or brevity. The five statements made by panel members were:
• The design and evaluation activities are highly dependent on staff expertise and experience of individual practices. Whilst ICT has proved beneficial for communication and information management, it will not replace the expertise and experience of a design team. Do you agree with the above statements?

• The variety and type of ICT infrastructure available in the marketplace is not a major concern to the industry, because the construction industry is capable of adjusting its operational processes to suit the available ICT in the marketplace. The major concern for the industry is whether or not quality improvement could be achieved by adopting new ICT software. Do you agree with the above statements?

• Other ICT tools that should be included are: Visualisation tools (4D CAD, VR, GIS); Management tools (document management, construction planning, cost planning, digital photography); and Communication tools (Voice over IP, mobile communications such as XDAII). Would you agree or disagree that your office’s productivity can be further enhanced if (any or all of) the above mentioned ICT tools are used in your current practice?

• As the evolution of ICT is so rapid, upgrading your existing software also involves a major hardware improvement. Do you agree with the above statement?

• Do you agree or disagree that the quality and productivity of the building design process could be further enhanced in the future if an integrated communication model could be formulated and efficiently implemented among the relevant project stakeholders?

The Round 4 survey questionnaires aimed to finalise the experts’ ratings on the current usage level and usage level in year 2009 of ICT tools for the fifty four building design activities identified and confirmed in the previous rounds. To minimise and to avoid bias of experts’ decision, summaries of panellists’ ratings were presented together with modal values for each activity. Panel members were invited to compare their own ratings with these statistics (for both current and future usage).
Response: Round 4 – Responses to Five Comments from Delphi Experts

Statement 1- “The design and evaluation activities are highly dependent on staff expertise and experience of individual practices. Whilst ICT has proved beneficial for communication and information management, it will not replace the expertise and experience of a design team. Do you agree with the above statements?”

All Delphi panel members agreed with this statement, and believe that ICT tools facilitate design practice. Each ICT tool is an increasingly basic and necessary tool for developing design information, exchange, and testing new concepts. It is also useful for prototyping and scenario construction and interrogation. However, the extent to which any of these tools can benefit an organization is highly dependent on the operators’ expertise.

One panellist stated: “Many [ICT] tools have been invented in offices, or by spending enormous financial resources to secure the best possible intelligence in the market. While architecture or building design is an intellectually intensive industry, best design can only be produced by the individual staff member’s past project experience and his/her design talent. ICT is only a tool that assists our office to improve productivity in general. It can never replace the importance of each individual designer.”

However, another panellist comments: “… given that all factors are equal, this statement can be true … When you have two teams with same design/evaluation skills, one using traditional design tools, and one using interoperable software that supports quick, automatic/semi-automatic communications between disciplines, the superiority of the latter is self-explanatory.”

Statement 2: “The variety and type of ICT infrastructure available on the marketplace is not a major concern to the industry, because the construction industry is capable of adjusting its operational processes to suit the available ICT in the marketplace. The major concern for the industry is whether or not quality improvement could be achieved by adopting new ICT software. Do you agree with the above statements?”
An issue brought out by a panel member was ‘cost’ of implementation, “… availability is dependent on cost. There are many systems available for consideration, but costs restrict their use, hence, evolving and adapting to what is available is the norm.” Another panellist voiced the same concern where cost is the main concern of his company in adapting new systems and new infrastructure. Costs involved are all types from the capital investment cost to maintenance costs and training costs.

It was suggested that: “... there is a useful interface role for advanced business service organizations advising industry as to the appropriate ICT tools to use and training employees in their application.” By adopting this approach, industry may be keener to adopt changes and this may also reduce company investment cost.

‘Force’ was another issue pointed out by Delphi members, where they do not believe that the construction industry is aware of the benefits of ICT and will only use ICT when forced to in order to stay competitive in the industry. A panellist wrote: “We always need to be aware of what is available in relation to our clients, consultants and our competitors. We need to remain up to date and carefully evaluate the introduction of new or updated programs and hardware. You do not always go with the first thing available.”

Indeed, one panel member brought out an example of the current practice in his organization. He acknowledged: “...from our past experience of using ICT infrastructure, some of the functions provided in the ICT application are not useful for our profession. In most cases, we only utilize approximately 60% to 70% of the available function. Hence in our daily operation, we have to adjust our working process to suit the ICT in our office. The incentive for our office to decide whether to adopt a new ICT tool is its ability to improve our internal productivity.”

Quality improvement could be achieved by adopting new ICT software to some extent, new organization of people as well as productivity using innovative ICT software could add benefit to the quality of work. Conversely, knowing about the restrictions and the difficulty of accessing this development could be helpful.
Statement 3- ‘Other ICT tools that should be included are: Visualisation tools (4D CAD, VR, GIS); Management tools (document management, construction planning, cost planning, digital photography); and Communication tools (Voice over IP, mobile communications such as XDAII). Would you agree or disagree that your office’s productivity can be further enhanced if (any or all of) the above mentioned ICT tools are used in your current practice?’

Again, ‘cost’ and ‘time’ were the two main issues in adopting these tools. First of all, software/hardware acquisition and training can be costly in the short term. The experts said, “The extra time, human resource and staff training facilities required to use the new tools can be costly. In the early stage, the productivity would decrease because the staff is not familiar with the new tool. It generally takes our office several months to familiarize with a new ICT tool. But it has been proved to be beneficial for the office productivity in the long-term.”

Legal issues constituted another concern to a panel member. Hard copy data were produced and kept in record as a back up for those soft data made during the project progress. A panel expert commented: “Legally speaking, hard copies of all recorded conversations are required, so there is still an element of double handling with verbal ICT tools.” He further suggested a mix of those available systems is required to improve productivity. For example, “cost planning software, CAD, and automated CAD measuring software are sold separately; a successful combined solution is yet to be marketed.”

One of the Delphi expert believed that: “the use of advanced ICT tools must be a coordinated effort that is based on workflow and standards that are commonly agreed upon with the project. If not the case, getting ICT tools with no consideration of others may be an expensive but not practicable option.”

Statement 4- “As the evolution of ICT is so rapid, upgrading your existing software also involves a major hardware improvement. Do you agree with the above statement?”

There were opposing views on this statement. Some of the experts believe that better software usually calls for increased hardware demands. Experts see the major cost factor and barrier is training staff to adopt the upgraded software. Upgrading existing software also involves a major hardware improvement. Hardware here involves not only ICT but also people. This has
prevented the take up of appropriate software. “They all cost money and people need to be trained. The usefulness of all these add-ons depends very much on the people using them and their own design skills. You must never lose sight of the project objectives and too often time is lost on peripheral activities that do not necessarily help the outcome” (Comment from one expert).

In contrast, another expert pointed out that, “Technology change comes secondary to the organizational and process changes”. An example was given based on current practices in his organization “… we only utilize 60 to 70% of the available function provided in the ICT software. New functions provide in the upgrade version may not be relevant for our business.” He further stated that “… upgrading of software always accompanies the need to upgrade our existing hardware. This further increases our operating cost. However, with all the extra expense, our productivity has not been upgraded because we do not use much of the new function in the ICT tool.”

‘Compatibility’ is the major issue to force an upgrading in software and thus hardware. An expert panel member pointed out that one of the main reasons to incur major upgrading was to ensure compatible communication with others. “Upgrading existing software and hardware does not enhance our productivity; however we have to do so to stay compatible with our stakeholder. For example, if our consultants are all using AutoCAD 2006, we are forced to upgrade our system to the same level; otherwise we would not be able to read the drawings they produced.”

Statement 5- “Do you agree or disagree that the quality and productivity of the building design process could be further enhanced in the future if an integrated communication model could be formulated and efficiently implemented among the relevant project stakeholders?”

The experts questioned what ‘an integrated communication model’ would mean. Their feedback was ‘yes’ if the model means systems allowing employees at different points in the organization to work collaboratively on various aspects of a construction project. However, if a poorly designed integrated model was adopted, it would result in double or even triple handling of tasks due to the increased errors and inconsistencies.
Some comments seem to disagree with the statement. One panel member stated that: “… project communication is low at all times and it used to be a lot better. Programs for projects were generally longer and we had more time to communicate and coordinate... Nothing beats meeting with the project team on a regular basis and speaking to one another. Too much time is spent at computer screens sending emails to the person sitting next to you. It takes a disciplined project leader to make a good project. ICT infrastructure can help but other things need to be in place first.”

Others suggested that if more user friendly and easily-familiarized integrated communication tools could be generated, it would definitely help to improve efficiency and to cut down staff training cost and time.

**Response: Round 4 – Experts’ perceptions of ICT implementation during the Building Design Process**

The four rounds of Delphi survey provided useful information about panel members’ decision making processes in general as well as information about individual practices. Results from each of the rounds provided baseline references for the research and produced shifts in respondents’ opinions after feedback from each round was given. However, the primary focus of this research is based on the final responses from Round 4.

In Round 4, Delphi panel members were asked to give their final ratings for the 54 building design process activities, in terms of current and future usage levels of ICT tools.

After follow-up encouragement, eight completed responses were received. One respondent dropped out at this stage due to a tight schedule of work. The quantitative response data from the Round 4 questionnaire is shown in Table 5-9 for current ICT tool usage and in Table 5-11 for future usage. The mean, mode and standard deviation statistics were calculated for each process activity. Comparisons of changes in the statistics between Rounds 3 and 4 are presented in Table 5-10 and for Rounds 1 – 4 in Table 5-12.
**Response ratings for current ICT usage**

Table 5-9 shows the expert panellists’ ratings of the usage level of ICT for the 54 building design activities. These ratings were based on 5 point Likert-scales where:

- 5 = Essential,
- 4 = Helpful,
- 3 = fairly useful,
- 2 = Not used, and
- 1 = Un-necessary.

The last row in Table 5-9 indicates the Average MEAN rating value for the level of CURRENT use of ICT during building design process.

Seventeen activities exhibit mean ratings of > 3.5 (see Table 5-9, activities highlighted in “yellow”), indicating that these ICT tools have decreased effort and made things much more efficient and of better quality. Ten activities display mean ratings of ≤2.5 (see Table 5-9, activities highlighted in “grey”), indicating that these ICT tools are not currently used by panel members, although they could be used and the experts have interest on using them in future.

During Round 4 of the Delphi survey, some panel members changed their ratings for some of the activities (Table 5-10). The highest changes were the 29% increase in rating recorded for activities: **A233-Prepared budget program** and **A314-Presentation to authority/council**. This is followed by a 25% increase for activities: **A113-Conduct Outline Feasibility Design** and **A145-Assess client’s initial feedback**. In contrast, a decrease of more than -10% in the experts’ rating occurred in the following activities: -20% decrease for **A121-Identify potential resale target/buyer**; -16% decrease for **A141-Ensure outline plan fulfils project brief**; -15% decrease for **A334-Assess foreseeable risk**; -13% decrease for **A143-Review authorities’ requirements**; and -11% decrease for **A151-evelopment of Opinion of Probable Cost and Program (OPC)** and **A213-Coordinate/liaise with all consultants**. A 7% increase in overall MEAN rating occurred through the increase from 2.97 mean value in Round 3 to the 3.19 mean rating in the final round.
<table>
<thead>
<tr>
<th>CODE</th>
<th>ACTIVITIES</th>
<th>Previous Rating from all Other Participants</th>
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<td>A1</td>
<td>Complete Outline Design Stage</td>
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<td>Prepare Functional Brief</td>
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<td>Identify Functional Requirements</td>
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<td>Identify &amp; solve essential problem</td>
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<td>Run environment analysis</td>
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<td>Prepare Initial Possibility</td>
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<td>Ensure outline plan fulfills project brief</td>
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<td>Prepare design proposal</td>
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<td>Communicate design ideas with authorities</td>
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<td>Engineering feasibility studies/feasibility with engineer</td>
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<td>Compare detailed and cost options</td>
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<td>Design Preliminary Design</td>
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<td>Develop model</td>
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<td>Pre-negotiation with authorities/council</td>
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<td>Solicit feedbacks from all authorities and various consultant</td>
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<td>A224</td>
<td>Make required changes</td>
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<td>Apply for preliminary planning permit</td>
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<td>Prepare Design Plan</td>
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<td>Prepare contract design</td>
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<td>Design contract design</td>
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<td>Complete Detailed Design Stage</td>
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<td>Conduct Detail Design/Development</td>
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<td>Evaluate design drawings</td>
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<td>Execute detail engineering design</td>
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<td>Negotiation with authority for building permit</td>
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<td>Identify and analyze lifecycle costs</td>
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<td>Review: optimization of energy performance</td>
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<td>Audit Completion of Design Plan</td>
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<td>Obtain building permit</td>
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<td>Conduct acceptance &amp; integration of sub-systems</td>
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<td>Overall MEAN</td>
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Table 5-9 CURRENT Rating for ICT use during Building Design Process (Delphi Round 4)
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<th>ACTIVITIES</th>
<th>MEAN CURRENT</th>
<th>%</th>
<th>Change</th>
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<td>A11</td>
<td>Develop and Define Design Requirements</td>
<td>Round 1</td>
<td>Round 2</td>
<td>Round 3</td>
</tr>
<tr>
<td>A111</td>
<td>Locate with Authorities</td>
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Overall MEAN: 2.97, 3.19, 7% |

Table 5-10 Comparison of Result for CURRENT ICT usage ratings for Rounds 1 - 4

140
Response ratings for future ICT usage

The mean rating for future usage (five years to 2009) of ICT tools for the building design process increased to 4.03 in Round 4. Six activities displayed mean ratings ≥4.5, indicating that the experts believe these tools allow project participants to perform work that was not possible before (see Table 5-11, activities items highlighted in yellow). Of the 54 building design process activities listed, 49 scored ≥3.5 (including 6 activities of mean ratings ≥4.5); signifying the experts’ belief that ICT tools are useful in performing the job. The remaining five activities were rated >1.5 but ≤2.5 and included: A121-Identify potential resale target/buyer; A315-Preparations of documents for building permit application; A331-Lodgement for building permit; A332-Rationalise & integrate sub-systems designs; and A334-Conduct risk management (refer to items shown in Table 5-11 with grey mean rating). The experts’ believed that these activities did not incorporate the use of ICT, but ICT could be used and the experts were interested on using it in future.

Most of the Delphi panel members changed their personal rating scores for future ICT usage towards the MODE when responding to the final Delphi round (Table 5-12). As a result, the Round 4 changes to the MEAN rating values for most of the activities showed a favourable increase of 38% for activity A122-Assessment resale value; followed by 36% for activity A325-Conduct design cost check; and 29% for A232-Prepare alternative estimates; A324-Review optimisation of energy performance; A333-To consider Occupational Health and Safety-Safe Design (highlighted in yellow as shown in Table 5.12).

An activity which brought significant negative changes in the Round 4 MEAN rating values for future ICT usage refers to 29% for A121-Identify potential resale target/buyer (highlighted in grey as shown in Table 5-12). It indicates a change in MEAN rating categories from current mean rating of 3.33, fairly useful (expert’s believe this tool is useful in performing the job) to future mean rating of 2.38 (experts are not currently using this tool, but it could be used and you have interest on using it in future). This may due to the reason where potential buyer in the near future may not change and effort done now may be used as a reference in future. Negative changes in MEAN value for other activities do not show a shift in categories.

Overall a 12% increase in MEAN rating value was recorded, representing the increase from 3.61 mean values in Round 3 to 4.03 mean rating values in Round 4 of the Delphi survey.
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<td>0.92</td>
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</tr>
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<td></td>
<td>A231 Estimating building cost</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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</tr>
<tr>
<td></td>
<td>A232 Prepare alternative activities</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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<td></td>
<td>A233 Prepare budget program</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A234 Prepare time schedule &amp; organization plan</td>
<td>5</td>
<td>4.50</td>
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<tr>
<td>A3</td>
<td>Complete Documentation Stage</td>
<td></td>
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<tr>
<td></td>
<td><strong>A31</strong> Conduct Detailed Design Management</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>A311 Prepare detailed architectural drawings</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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<td>A312 Develop detail engineering design</td>
<td>5</td>
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<td>0.92</td>
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<td>A313 Coordinate/relationship with all consultants</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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<td>A314 Presentation to authority/council</td>
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<td>4.50</td>
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<td>A315 Preparations of documents for building permit application</td>
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<td>A4</td>
<td>Conduct Cost Checks</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>A41 Analyse &amp; evaluate design alternatives</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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</tr>
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<td></td>
<td>A42 Investigate design cost efficiency</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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</tr>
<tr>
<td></td>
<td>A43 Identify and analyse life cycle cost</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
<td></td>
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<tr>
<td></td>
<td>A44 Review optimization of energy performance</td>
<td>5</td>
<td>4.50</td>
<td>0.92</td>
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<tr>
<td></td>
<td>A45 Conduct design check</td>
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<td>A5</td>
<td>Audit Completion of Detail Plan</td>
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<td>A51 Lodge claim for building permit</td>
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<td>A52 Rationalise &amp; integrate sub-systems designs</td>
<td>4</td>
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<td>A53 To consider Occupational Health &amp; Safety Design</td>
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<td>A54 Conduct risk management</td>
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**Table 5-11 FUTURE Rating for ICT use during Building Design Process**

142
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<tr>
<th>CODE</th>
<th>ACTIVITIES</th>
<th>Notes</th>
<th>MEAN</th>
<th>Changes</th>
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<td>A1</td>
<td>Complete Schematic Design Stage</td>
<td>FUTURE</td>
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<tr>
<td>A11</td>
<td>Develop and Define Design Requirements</td>
<td>Round 1</td>
<td>Round 2</td>
<td>Round 3</td>
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<td>Liaise with Authorities</td>
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<td>Site Analysis</td>
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<td>3.79</td>
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<td>Conduct Outline Feasibility Design</td>
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<td>A114</td>
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<td>3.90</td>
<td>4.00</td>
</tr>
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<td>Conduct environmental analysis</td>
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<td>3.90</td>
<td>4.63</td>
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<td>Seek client’s initial feedback</td>
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<tr>
<td>A12</td>
<td>Identify final potential tenure/buyer</td>
<td>2.90</td>
<td>3.33</td>
<td>2.39</td>
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<td>Assessment resale value</td>
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<tr>
<td>A13</td>
<td>Conduct Value Management Process</td>
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<td>Review concept brief</td>
<td>2.70</td>
<td>3.44</td>
<td>3.58</td>
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<tr>
<td>A132</td>
<td>Allocate costs</td>
<td>3.70</td>
<td>3.90</td>
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<td>Highlight mismatch and risks</td>
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<td>4.00</td>
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<tr>
<td>A134</td>
<td>Evaluation and development of alternative solutions</td>
<td>4.10</td>
<td>3.90</td>
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<td>A135</td>
<td>Presentations</td>
<td>3.70</td>
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<td>4.90</td>
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<td>A14</td>
<td>Preparation of Outline Proposal</td>
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<td>A141</td>
<td>Ensure outline plan fulfills project brief</td>
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<td>Access client’s initial feedbacks</td>
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<td>4.44</td>
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<td>A146</td>
<td>Initial Planning Permit Application Preparation</td>
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<tr>
<td>A15</td>
<td>Prepare Preliminary Estimate</td>
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<tr>
<td>A151</td>
<td>Development of Option of Probable Cost and Program (OPP)</td>
<td>2.90</td>
<td>4.44</td>
<td>4.75</td>
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<tr>
<td>A152</td>
<td>Engineering cost survey/ basis with engineers</td>
<td>3.20</td>
<td>4.33</td>
<td>4.75</td>
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<td>A153</td>
<td>Search for principal sources</td>
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<td>3.60</td>
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<tr>
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<td>Select suitable design/ent solution combination</td>
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<td>3.60</td>
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<td>Evaluations of choices of alternatives</td>
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<td>Improve details and cost options</td>
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<td>B1</td>
<td>Complete Design Development</td>
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<tr>
<td>B11</td>
<td>Prepare Sketch Design Documentation</td>
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<tr>
<td>B121</td>
<td>Develop expansion of architecture design drawings</td>
<td>4.30</td>
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<td>4.90</td>
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<td>B122</td>
<td>Prepare preliminary engineering design</td>
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<td>3.83</td>
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<td>Coordinating with all consultants</td>
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<td>3.67</td>
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<tr>
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<td>Make required design changes</td>
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<td>3.50</td>
<td>4.25</td>
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<td>Design Visualization – Model Construction</td>
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<td>3.00</td>
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<tr>
<td>B12</td>
<td>Run Design Evaluation Session</td>
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<tr>
<td>B121</td>
<td>Integrate preliminary consultant’s advice in design</td>
<td>4.10</td>
<td>3.50</td>
<td>3.63</td>
</tr>
<tr>
<td>B122</td>
<td>Review authorities’ requirements</td>
<td>3.90</td>
<td>3.40</td>
<td>4.25</td>
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<tr>
<td>B123</td>
<td>Gather feedback from all authorities and consultants</td>
<td>2.40</td>
<td>3.70</td>
<td>4.25</td>
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<td>B124</td>
<td>Finalised design documents</td>
<td>4.00</td>
<td>3.90</td>
<td>4.13</td>
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<tr>
<td>B125</td>
<td>Apply for planning permit</td>
<td>3.60</td>
<td>3.40</td>
<td>4.25</td>
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<tr>
<td>B3</td>
<td>Prepare Schematic Design Cost Plan</td>
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<tr>
<td>B231</td>
<td>Estimating building cost</td>
<td>4.10</td>
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<td>4.63</td>
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<tr>
<td>B232</td>
<td>Prepare alternative estimates</td>
<td>3.70</td>
<td>3.30</td>
<td>4.25</td>
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<td>B233</td>
<td>Prepare budget program</td>
<td>4.00</td>
<td>3.70</td>
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<tr>
<td>B234</td>
<td>Prepare time schedule &amp; organization plan</td>
<td>3.90</td>
<td>3.40</td>
<td>4.13</td>
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<tr>
<td>B1</td>
<td>Complete Documentation Stage</td>
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<td>B111</td>
<td>Complete detail design management</td>
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<tr>
<td>B1111</td>
<td>Prepare detailed architectural drawings</td>
<td>3.40</td>
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<td>B112</td>
<td>Develop detail engineering design</td>
<td>4.30</td>
<td>3.80</td>
<td>4.25</td>
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<tr>
<td>B113</td>
<td>Coordinating with all consultants</td>
<td>4.10</td>
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<td>B114</td>
<td>Present to authorities/ council</td>
<td>4.10</td>
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<tr>
<td>B115</td>
<td>Preparations of documents for building permit application</td>
<td>3.30</td>
<td>2.80</td>
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<tr>
<td>B11</td>
<td>Complete Cost Checking</td>
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<tr>
<td>B111</td>
<td>Analyse &amp; evaluate design alternatives</td>
<td>3.30</td>
<td>3.10</td>
<td>3.88</td>
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<tr>
<td>B112</td>
<td>Investigate design cost efficiency</td>
<td>3.70</td>
<td>3.30</td>
<td>4.13</td>
</tr>
<tr>
<td>B113</td>
<td>Identify and analyse life cycle cost</td>
<td>3.20</td>
<td>4.11</td>
<td>4.38</td>
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<tr>
<td>B114</td>
<td>Review optimization of energy performance</td>
<td>4.00</td>
<td>3.50</td>
<td>4.00</td>
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<tr>
<td>B115</td>
<td>Conduct design cost check</td>
<td>3.90</td>
<td>3.30</td>
<td>4.00</td>
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<td>B12</td>
<td>Final Completion of Design Plan</td>
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</tr>
<tr>
<td>B121</td>
<td>Lodgement for building permit</td>
<td>3.10</td>
<td>2.70</td>
<td>2.63</td>
</tr>
<tr>
<td>B122</td>
<td>Rationalize &amp; integrate sub-systems design</td>
<td>3.30</td>
<td>2.80</td>
<td>3.35</td>
</tr>
<tr>
<td>B123</td>
<td>To consider Occupational Health and Safety / Life Design</td>
<td>3.30</td>
<td>2.90</td>
<td>3.75</td>
</tr>
<tr>
<td>B124</td>
<td>Conduct risk management</td>
<td>3.40</td>
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<td>2.63</td>
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<td></td>
<td>Overall MEAN</td>
<td>3.61</td>
<td>4.63</td>
<td>12%</td>
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Table 5-12 Comparison of Result for FUTURE ICT usage ratings for Rounds 1 - 4

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5.6 SUMMARY

The data from the four rounds of Delphi survey have been presented and analysed on a round by round basis in this chapter.

The analysed data will be mapped onto the proposed ‘ICT implementation maps’ of the building design process and presented in Chapter 6.
6 DEVELOPMENT OF THE PROPOSED ICT IMPLEMENTATION MAP

6.1 INTRODUCTION

This chapter describes the development of the ‘ICT implementation map’ and the related issues.

The data collected from the four rounds of Delphi survey were mapped onto the proposed ‘ICT implementation map’ of the building design process, to represent the Delphi panel members’ views about current and future trends (in 5 years) of ICT usage. In addition to indicating the ICT usage level for each of the building design processes (confirmed through the Delphi survey), the ICT implementation map also focuses on the issues discussed as part of the Delphi survey. These issues are:

- Design communication
- Design information management
- Information and communication technologies
- Impact of ICT
- Challenges

6.2 EXTRACTING BUILDING DESIGN ACTIVITIES & THEIR RELATIONSHIPS FROM IDEF0 MAP

The ‘ICT implementation map’ incorporates the 54 building design activities as discussed in section 3.5.2. These activities confirmed through the Delphi survey, are extracted from the IDEF0 map (section 3.4 and 3.5) developed earlier. The building design process activities include:

- A111 – Liaise with Authorities
- A112 – Site Analysis
- A113 – Conduct Outline Feasibility Design
- A114 – Assessment of Consultant’ recommendations
- A115 – Conduct environmental analysis
- A116 – Seek client’s initial feedback
- A121 – Identify potential resale target/buyer
- A122 – Assessment of resale value
- A131 – Review concept brief
- A132 – Allocate costs
- A133 – Highlight mismatched and risks
- A134 – Evaluation and development of alternative solutions
- A135 – Presentations
- A141 – Ensure outline plan fulfils project brief
- A142 – Prepare design proposal
- A143 – Review authorities’ requirements
- A144 – Liaise with cost planning consultant
- A145 – Assess client’s initial feedbacks
- A146 – Initial Planning Permit Application Preparation
- A151 – Development of Opinion of Probable Cost and Program (OPC)
- A152 – Engineering cost studies/ liaise with engineers
- A153 – Search for principal solutions
- A154 – Select suitable design/cost solution combination
- A155 – Evaluations of choices of alternatives
- A156 – Improve details and cost options
- A211 – Develop expansion of architecture design drawings
- A212 – Prepare preliminary engineering design
- A213 – Coordinate/liaise with all consultants
- A214 – Make required design changes
- A215 – Presentations of the schematic design
- A216 – Design Visualisation – Model Construction
- A221 – Integrate preliminary consultant’s advise in design
- A222 – Review authorities/council requirements
- A223 – Gather feedback from all authorities and consultants
- A224 – Finalised design documents
- A225 – Apply for planning permit
- A231 – Estimating building cost
- A232 – Prepare alternative estimates
- A233 – Prepare budget program
- **A234** – Prepare time schedule & organization plan
- **A311** – Prepare detailed architectural drawings
- **A312** – Develop detail engineering design
- **A313** – Coordinate/liaise with all consultants
- **A314** – Presentation to authority/council
- **A315** – Preparations of documents for building permit application
- **A321** – Analysis & evaluate design alternatives
- **A322** – Investigate design cost efficiency
- **A323** – Identify and analyse life cycle cost
- **A324** – Review optimization of energy performance
- **A325** – Conduct design cost check
- **A331** – Lodgement for building permit
- **A332** – Rationalise & integrate sub-systems designs
- **A333** – To consider Occupational Health and Safety - Safe Design
- **A334** – Conduct risk management

The relationship between activities was mapped using arrows, modified from the concept of IDEF0 arrow positions and roles as shown in Figure 6-1, where:

- **Arrow in (Black)** – represents input/output
- **Arrow in (Red)** – represents control (act as procedure and guideline or requirement to the activity)

![Figure 6-1](image-url)  
*Figure 6-1  Abstracting relationships between activities from IDEF0 arrow positions*
Referring to Figure 6-1, the ‘function name’ which was originally presented in box format was converted to circle format with activities coded in each circle. The circle format facilitates easier composition of the map. An arrow in black, connecting activity numbers A111 and A112 means that A111 acts as an input to A112 (and vice-versa). However, the arrow in red connecting activities A112 and A113 means that the output from A112 acts as a control to A113.

The next step involved producing a draft map showing the relationship between each activity. Figure 6-2 represents the first draft map showing the activity relationships extracted from the original IDEF0 map. The ovals surrounding the circled activities represent MEAN usage rating values (inner oval: Essential = mean >4.5 ≤ 5.0; next oval: Helpful = mean >3.5 ≤ 4.5; outer oval: Fairly useful = mean >2.5 ≤ 3.5). The activity circle shading colours represent the three different stages of the building process:

- Schematic design stage (represented by activities in ‘green’)
- Design development stage (represented by activities in ‘blue’)
- Documentation stage (represented by activities in ‘pink’)

![Figure 6-2 Draft map showing relationships between design activities](image-url)
6.3 Identify Rating for each Activity

The rating for each activity refers to the current usage level of ICT tools during building design process and the usage level forecast for the future in 5 years time (as perceived by the Delphi survey participants). The statistics were developed after four rounds of Delphi survey and calculated as mean values. The mean values were then assigned into discrete categories as follows:

- **Essential** mean score >4.5
- **Helpful** mean score >3.5 ≤ 4.5
- **Fairly useful** mean score >2.5 ≤ 3.5
- **Not used** mean score >2.5 ≤ 1.5
- **Unnecessary** mean score <1.5

Analyses for ‘current’ usage level of ICT tools, from four rounds of Delphi survey shows that:

- No activity was rated under the ICT tool usage category ‘essential’;
- 33% of the activities were rated under the ICT tool usage category ‘helpful’ including:
  - A111 – Liaise with Authorities
  - A113 – Conduct Outline Feasibility Design
  - A115 – Conduct environmental analysis
  - A116 – Seek client’s initial feedback
  - A131 – Review concept brief
  - A133 – Highlight mismatched and risks
  - A145 – Assess client’s initial feedbacks
  - A146 – Initial Planning Permit Application Preparation
  - A152 – Engineering cost studies/ liaise with engineers
  - A156 – Improve details and cost options
  - A211 – Develop expansion of architecture design drawings
  - A214 – Make required design changes
  - A215 – Presentations of the schematic design
  - A233 – Prepare budget program
  - A311 – Prepare detailed architectural drawings
A312 – Develop detail engineering design
A314 – Presentation to authority/council
A323 – Identify and analyse life cycle cost

- 48% of the activities were rated under the ICT tool usage category ‘fairly useful’
  including:
  
  A112 – Site Analysis
  A114 – Assessment of Consultant’ recommendations
  A134 – Evaluation and development of alternative solutions
  A135 – Presentations
  A141 – Ensure outline plan fulfils project brief
  A142 – Prepare design proposal
  A144 – Liaise with cost planning consultant
  A151 – Development of Opinion of Probable Cost and Program (OPC)
  A153 – Search for principal solutions
  A154 – Select suitable design/cost solution combination
  A155 – Evaluations of choices of alternatives
  A212 – Prepare preliminary engineering design
  A216 – Design Visualisation – Model Construction
  A221 – Integrate preliminary consultant’s advise in design
  A222 – Review authorities/council requirements
  A224 – Finalised design documents
  A225 – Apply for planning permit
  A231 – Estimating building cost
  A232 – Prepare alternative estimates
  A234 – Prepare time schedule & organization plan
  A313 – Coordinate/liaise with all consultants
  A321 – Analysis & evaluate design alternatives
  A322 – Investigate design cost efficiency
  A324 – Review optimization of energy performance
  A325 – Conduct design cost check
  A332 – Rationalise & integrate sub-systems designs

- 19% of the activities were rated under the ICT tool usage category ‘not used’
  including:
  
  A121 – Identify potential resale target/buyer
\textit{A122} – Assessment of resale value  
\textit{A132} – Allocate costs  
\textit{A143} – Review authorities’ requirements  
\textit{A213} – Coordinate/liaise with all consultants  
\textit{A223} – Gather feedback from all authorities and consultants  
\textit{A315} – Preparations of documents for building permit application  
\textit{A321} – Analysis & evaluate design alternatives  
\textit{A333} – To consider Occupational Health and Safety- Safe Design  
\textit{A334} – Conduct risk management

- None of the activities was rated under the ICT tool usage category ‘unnecessary’;

The overall result of the survey indicates that ICT tool usage in the great majority of building design process activities is currently perceived as being ‘helpful’ or ‘fairly useful’ (33 + 48 = 81%).

However, analysis of the survey data for perceived ‘future’ usage level after four rounds of Delphi survey provides the following summary as represented in Figure 6-3. ICT tool usage for several design activities moved into the “essential” (Rating 5 in figure) category (11% compared to 0% for current usage rating, and the scoring for the ‘helpful’ (Rating 4 in figure) category improved sharply to 78%.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure6-3.png}
\caption{Future ICT tool implementation for activities during the Building Design Process}
\end{figure}
11% of the activities were rated under the ICT tool usage category ‘essential’ including:

- **A115** – Conduct environmental analysis
- **A145** – Assess client’s initial feedbacks
- **A151** – Development of Opinion of Probable Cost and Program (OPC)
- **A152** – Engineering cost studies/ liaise with engineers
- **A215** – Presentations of the schematic design
- **A231** – Estimating building cost

33.33% of the activities were rated under the ICT tool usage category ‘helpful’ including:

- **A111** – Liaise with Authorities
- **A112** – Site Analysis
- **A113** – Conduct Outline Feasibility Design
- **A114** – Assessment of Consultant’s recommendations
- **A116** – Seek client’s initial feedback
- **A122** – Assessment of resale value
- **A132** – Allocate costs
- **A133** – Highlight mismatched and risks
- **A134** – Evaluation and development of alternative solutions
- **A135** – Presentations
- **A141** – Ensure outline plan fulfils project brief
- **A142** – Prepare design proposal
- **A143** – **Review** authorities’ requirements
- **A144** – Liaise with cost planning consultant
- **A146** – Initial Planning Permit Application Preparation
- **A153** – Search for principal solutions
- **A154** – Select suitable design/cost solution combination
- **A155** – Evaluations of choices of alternatives
- **A156** – Improve details and cost options
- **A211** – Develop expansion of architecture design drawings
- **A212** – Prepare preliminary engineering design
- **A213** – Coordinate/liaise with all consultants
- **A214** – Make required design changes
A216 – Design Visualisation – Model Construction
A221 – Integrate preliminary consultant’s advise in design
A222 – Review authorities/council requirements
A223 – Gather feedback from all authorities and consultants
A224 – Finalised design documents
A225 – Apply for planning permit
A232 – Prepare alternative estimates
A233 – Prepare budget program
A234 – Prepare time schedule & organization plan
A311 – Prepare detailed architectural drawings
A312 – Develop detail engineering design
A313 – Coordinate/liaise with all consultants
A314 – Presentation to authority/council
A321 – Analysis & evaluate design alternatives
A322 – Investigate design cost efficiency
A323 – Identify and analyse life cycle cost
A324 – Review optimization of energy performance
A325 – Conduct design cost check
A333 – To consider Occupational Health and Safety- Safe Design

- 9% of the activities were rated under the ICT tool usage category ‘fairly useful’ including:
  A131 – Review concept brief
  A315 – Preparations of documents for building permit application
  A331 – Lodge for building permit
  A332 – Rationalise & integrate sub-systems designs
  A334 – Conduct risk management

- 2% of the activities were rated under the ICT tool usage category ‘not used’ including:
  A121 – Identify potential resale target/buyer

- None of the activities was rated under the ICT tool usage category ‘unnecessary’.
Figure 6-4 Current vs. Future rating on ICT implementation during building design process
According to Figure 6-4, the experts’ perceptions of future ICT usage in five years time have increased for all building design activities. This reflects the experts’ belief that ICT tools will be used more intensively to complete all building tasks in the future, and this may due to some of the issues discuss below

### 6.4 IDENTIFY ISSUES FOR IMPLEMENTATION

Issues for implementation were discussed earlier in Chapter 2 section 2.3. Five strands were first identified from literature review and presented as a series of issues and were further tested with the panel experts during the Delphi rounds. These issues include:

- **Design communication** – can be distinguished in to three aspects as pointed out by den Otter and Prins (2002):
  - “Face to face/meetings and on distance communication: containing both verbal and non-verbal communication. Verbal communication refers to information transferred through short verbal message; whereas non-verbal communication uses documents or other media.
  - Formal and informal communication: communication organized in a structured way is formal communication. On the other hand, informal communication refers to information exchange in ways where formal rules and hierarchies are eliminated.
  - Types of information exchange: information exchange can be presented in different formats. For example, verbal and non-verbal; graphical and non-graphical; digital and non-digital, etc.”

    *(den Otter and Prins, 2002)*

- **Design information management** – where data can be presented in more than one format such as:
  - Sketches
  - Schemes
  - Image (visual images and symbols)
  - Voice (audio transaction )
  - Drawings
  - Words
- **Information Communication Technologies (ICT)** – classified into three categories:
  - ICT infrastructure – covers all hardware and software;
  - ICT for communication – to achieve mutual understanding between parties;
  - ICT for information management – to organize massive quantity of data.

- **The impact of technology** – both tangible and intangible factors, including:
  - Cost efficiency - Duyshart *et al.* (2003) point to seven major areas of cost that could be directly affected through the use of information technology initiatives. These include cost reduction in: plan printing; paper supplies; photocopier/fax hire; postage/couriers/taxis; photography; interstate travel; and telephone/mobile.
  - Time efficiency – Belmiro *et al.* (2000) state that a number of benefits arise in terms of time saving: faster activity times, speeding up of communication flows; quicker decision making; eliminating travel time; sharing data bases (global environment); and eliminating intermediates from the communication process.
  - Quality – refers to the ability to perform the task to a higher standard than it previously was and with less effort. The quality of information exchanged has improved due to the decrease in data duplication and the time expended in re-entering received data. The result is more up-to-date information that is often directly linked into decision-making as well as reporting.
  - Opportunity – refers to the ability to perform tasks that may not have been previously done (or were not capable of being done under existing data environments). For example: ICT use increases cooperation and enhances collaborative working because it reduces task uncertainty between two professionals through the effects on information exchange intensity and channel formalization. As Stern and Kaufman (cited in, Nakayama, 1999) argue, “the greater the amount of information exchange, the greater the possibility for mutual understanding of each other’s goals, which can lead to increase cooperation.”

- **The challenges** – literature findings (Peansupap and Walker, 2005; Whyte *et al.*, 2002; Hannus *et al.*, 2003; Kalian *et al.*, 2001; Egbu *et al.*, 2001; Anumba *et al.*, 2002) suggested that, the barriers to ICT implementation in the workplace fall into four main
categories (refer to Chapter 2.3.5). These are:

- Cultural barriers
- Technical barriers
- Management barriers
- Organisational barriers

All the issues discussed above will be mapped in the proposed ICT implementation map together with 54 building design activities and their rating for current use and future trends in five years time. The next section focuses on the mapping development process for the ‘current’ and ‘future’ maps.

6.5 DEVELOPING THE ICT IMPLEMENTATION MAP

This section describes the steps required in developing the proposed ICT implementation map. All the issues discussed earlier in this chapter are brought together in the proposed ICT implementation map. The steps carried out include:

- Activities were grouped according to their mean survey ratings.
- Relationships between activities were drawn out using arrow formats (representing in black for ‘input/out’ and in red for ‘control’).
- Issues affecting the level of implementation were identified and mapped.

These processes were first done for the proposed ‘current’ ICT tool implementation map and then repeated for the ‘future’ ICT tool implementation map.

Figures 6-5 and 6-6 represent the summary findings from the four rounds of Delphi survey. The 54 activities during building design process are grouped into three stages as:

- Schematic design stage (represented by activities in ‘green’)
- Design development stage (represented by activities in ‘yellow’)
- Documentation stage (represented by activities in ‘pink’)

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Figure 6-5 Map of Current ICT Implementation during the Building Design Process

Legend

- Schematic Design Activities (total: 25 activities)
- Design Development Activities (total: 15 activities)
- Documentation Activities (total: 14 activities)
- Overall Rating 5 (Essential) (percentage: 0%)
- Overall Rating 4 (Helpful) (percentage: 33.33%)
- Overall Rating 3 (Fairly useful) (percentage: 48.18%)
- Overall Rating 2 (Not Used) (percentage: 18.52%)
-  Input/Output
- Control
Figure 6-6 Map of Future ICT Implementation during the Building Design Process
All 54 activities were then grouped according to their mean survey ratings where the highest ratings are grouped in the inner circle and the lowest ratings in the outer circle. The relationship between activities was linked by arrows in ‘grey’ (represented input/output) or in ‘red’ (representing control).

The five main issues identified were also mapped out in the ICT implementation map referring to:

- Design communication
- Design information management
- Information communication technologies (ICT)
- The impact of technology
- The challenges

6.6 SUMMARY

This chapter has presented the development process for the ICT implementation maps. These maps represent the findings from the four rounds of Delphi surveys. A total of 54 building design activities were mapped out according to the experts’ perception of the usage level of ICT tools for each activity for current and future usage over the next 5 years. The ICT implementation maps will be fine-turned through interviews with experts.

The following chapter presents the main findings from the interviews and shows how the maps are modified. The implementation of the modified maps will also be discussed.
7 VALIDATION OF THE BUILDING DESIGN PROCESS MAPS

7.1 INTRODUCTION

The ICT implementation maps (for current ICT usage in the building design process and predicting future usage over the next 5 years) represent data collected from the Delphi surveys. This chapter reports the outcomes from a focus group established to test the robustness of the IDEF0 maps and their underlying concepts.

Interviews were conduct during November 2005. The focus group comprised three experts selected on the basis of their background and experience. Two experts were selected from the Delphi panel to participate in the interviews: (1) IDEF0 expert ‘D07’ (2) building designer ‘D08’. A development manager (‘D11’) was new to the research and selected based on his experience and current involvement in the construction industry.

D11 is currently working as a development manager for a medium-large property development organization. He graduated with a double degree in Bachelor of Architecture and Bachelor of Property and Construction from the University of Melbourne, and has more than 5 years experience in design, planning and project delivery of residential and commercial projects.

7.2 THE INTERVIEWS

This section covers: how interviews were arranged, where interviews were conducted, how the interviews were conducted, and the analysis process.

7.2.1 Interview Format

A series of semi-formal interviews was conducted with the three experts. The principle reason for conducting these interviews was to test and to improve the proposed ICT implementation maps. Participants were contacted by email stating the purpose of the interviews.
The interview questions were formatted on a semi-structured basis. The questionnaires contained six open-ended questions, and took thirty to forty-five minutes for each participant to complete.

The face-to-face conversation interviews all occurred in each participant’s place of business. The interview processes were digitally recorded and the data collected were later transcribed verbatim for analysis. The quantitative data from transcripts were then analysed for similarity of phrases item by item and are presented in the next section.

7.2.2 Interview Responses

The interview questions and responses are as follows:

1. Do you think the proposed “ICT Implementation Map” is self-explanatory? If not, how could it be improved?

‘Complicated’ is one of the most important issues raised by the interviewees. They found that too much information is provided on the maps and may lead to misinterpretation. The IDEF0 expert (D07) responded to this question in depth as she has experience dealing with models and mapping:

“The map is too complicated for readers as too much information is provided; you need an explanation for each activities box.
Using hatching to differentiate the ratings seems difficult to read and I recommend shaded colour instead.
The relationships between activities represented by the arrows are too complicated and the reader can hardly follow them. I suggest taking out a level of detail as the relationships are already shown in the IDEF0 map.
I suggest the ‘polyline’ used to group design activities should be shown in one single solid colour (eg. grey/black), as it will stand out and be clear to the reader.
The formatting of the five issues on the maps does not properly represent them. Some modification is needed to make them relate to all activities.”

Other comments also related to the complexity of the maps, suggesting where a level of detail should be omitted from the map for better understanding.
2. In your opinion, what are the strengths and weaknesses of using the proposed map as a guide to implement new ICT tools to a project?

One of the strengths is that a model can be so powerful in sending message to reader. IDEF0 expert (D07) stated that: “A diagram can be powerful in tracking a journey as it shows what has been done and what has changed in just one view”.

Information presented and mapped out in the model represented information collected from the four round Delphi survey. Readers can easily and quickly recapitulate the outcomes of the survey research by looking at the two maps.

Building designer (D08) noted that the ‘current’ and ‘future’ maps provide a comparison base for present status and future trends for ICT implementation. Comparing the ‘current’ and ‘future’ maps shows a substantial potential increase in the usage level of ICT tools in the future, with a hint of heavy dependency on technology for conducting future building design work.

On the other hand, development manager (D11) suggested that: “The proposed maps were complete in showing how ICT is being used during the building design process, and the issues indicated will definitely help the decision making processes involved when adopting new technology”.

The weakness of the models is primarily due to their complexity. Too much information is compressed into the two maps, resulting in complication and increasing the potential for misinterpretation. Modifications to the formatting of the maps were necessary.

3. How do you think the proposed “ICT Implementation Map” could help design professionals in decision making for adopting new ICT tools in the building design process?

Relating the ICT implementation maps to decision making process brought out several positive responses. These are summarised as follows:

- Focusing on the ‘future’ map, it was clearly shown that there is a need to adopt new technologies, based on research with different people.
The maps show what people want, as a manager or decision maker, it is important to provide people with the tools, techniques and encouragement, making them more time rich and efficient.

The proposed maps may act as strong guideline for decision making process. It can be used as a tool to assess the financial requirement for adopting new ICT tools (e.g. training cost), potential benefits, possible obstacles, resources required, when considering adopting a new ICT tool into a practice.

The proposed map shows where ICT resources are currently concentrated, where they might be needed in 5 years, and what issues will be encountered in aiming towards those targets. These maps act like triggers to strategic thinking about ICT implementation for building design professionals.

4. In the Delphi survey, some activities were rated 5, (essential use of ICT tools); meaning that experts believe that “ICT tools are necessary to allow project participants to perform work that was not possible before; and these tools will continue to be necessary in the future”. How do you think ICT tools could be used, or used more intensively, in these activities?

A115 – Conduct environmental analysis. This activity involves work done to consider the environmental strengths and weaknesses of the proposed development, and scan the environment for opportunities on the selected site. This was clearly a design activity area where the implementation of ICT tools has not yet been fully thought through.

Interviewees believe that this activity has a big influence on risk management where ICT will help to make environmental or site analyses more accurate, with less time and effort. This should help to reduce the probability of occurrence of the risk of design failure. ICT tools also provide a more effective communication medium for various stakeholders.

A145 – Assess client’s initial feedback. This activity involves work done to assess client’s initial feedback from stage A116.

The IDEF0 expert (D07) gave an example for this activity: “Technology helps an organization to stay competitive. Most design professionals are time poor. The help of technologies enables them to work more efficiently and effectively, therefore maintaining competitiveness.”
The other interviewees pointed out that they do not use much technology in this activity as their professional experience helps most in assessing the client’s initial feedback.

**A151 – Development of Opinion of Probable Cost and Program (OPC).** This activity involves work done to liaise with the cost consultant to develop opinion regarding a probable construction cost range for the project.

Estimating software performs well in this activity. It helps cost professionals to work more effectively, especially dealing with re-work or re-calculation for design changes. Building designer (D08) stated that: “We implement computerised calculating methods together with AutoCAD drawings to develop an OPC in the initial design stage. These ICT tools not only provide a rapid OPC report but also give us less trouble when modifying the OPC as the design changes in later stages.”

**A152 – Engineering cost studies/ liaise with engineers.** This activity involves work done to undertake cost studies to determine appropriate engineering solutions.

Everything dealing with cost could involve the use of estimating software to reduce time and increase efficiency. Building designer (D08) drew attention to this: “We heavily rely on ICT tools when liaising with our engineers. Especially in the area of assessing the feasibility of an engineering proposal. We have used AutoCAD drawings and MS Project when determining the engineering cost and future time programme.”

**A215 – Presentations of the schematic design.** This activity involves presentation of the schematic design to all relevant stakeholders, such as: client, building owner, staff committee, user groups, board of directors, financier, and owner’s consultants, for comment.

Interviewees suggested that ICT tools can increase efficiency, reduce time, especially in costing designs. They can also create illustrations to reflect client expectations. The use of applications such as 3D graphical modelling can enhance the presentation of the schematic design proposal to facilitate client understanding of the design concept.

**A231 – Estimating building cost.** This activity requires the involvement of the cost consultant in preparing more detailed cost plans for the project, based upon development of outline design, for comparison with target cost budgets.
Interviewees suggested that activities related to cost estimating involve many estimating software applications. Integrating the CAD drawings produced by architects and engineers to estimating software, in order to calculate the building cost, will improve efficiency and accuracy.

5. Six out of fifty four activities (11%) from the Delphi survey were rated 3 or lower (representing a forecast of ‘fairly useful’ or ‘not used’ for ICT tools over the next five years). How do you think the use of ICT tools could be improved over this period for these activities?

A131 – Review concept brief. This activity involves work done to review the concept brief derived from previous stages and to confirm the client’s objectives for the project. These include outcomes such as: the initial plans, elevations, sections, specification and cost plans of the proposed facility. It is important to fully understand the concept brief, particularly the functional space requirements.

Interviewees thought that, since the project had not progressed far at this stage, there was little rationale for increased ICT usage. However, design risk should reduce with the help of technology. For example, a more accurate calculation can be provided with technology, to avoid errors at later stages.

A315 – Preparation of documents for building permit application. This activity involves preparation of documentation including dimensioned plans, sections and elevations to adequately describe the design for the purpose of obtaining approval to construct.

Interviewees believe that ICT tools can certainly improve the time required for preparing the documentation required for permit applications. These tools include 3D CAD drawing, colour scheme sketch and digitalised shadow diagram program applications, all of which would all improve the productivity in this stage.

A331 – Lodgement for building permit. This activity refers to the application submitted to the relevant authority for building approval.
Interviewees noted that authorities such as local councils were heavily paper based, and most application need to be done in paper hard copy. This can be improved by promoting ‘online application’, where drawings and application form are submitted electronically. This will not only simplify the process but will avoid or reduce the cost for paper archival storage in the long term if all documents were stored electronically.

**A332 – Rationalise & integrate sub-systems designs.** This activity involves work done to rationalize and integrate all design sub-systems to make sure there are no conflicts.

Interviewees agree that the adoption of ICT tools to this activity will definitely improve efficiency and reduce the risk of design co-ordination errors. Building designer (D08) commented: “*An integrated computerised graphical programme that allows the architect and client to efficiently visualise the proposed sub-systems could certainly be beneficial in this stage.*”

**A334 – Conduct risk management.** This activity involves work done to assess and balance the contingencies of risk with their specific contractual, financial, operational and organizational requirements by transferring through the combination of insurance, risk financing, and contract indemnification provisions.

Technology can certainly help risk management to be done more accurately, with less time and effort. For example, the use of computerised planning and scheduling applications such as MS Project can help in managing the risk of project time over-run.

**A121 – Identify potential resale target/buyer.** This activity involves work done to identify potential buyers and to find out the target group. This activity was rated 2 in the Delphi survey data analysis, which means that ICT tools are not being used here. Respondents believe that the lower rating may be due to ‘past experience’. However, analysis of design elements can have huge impact on re-sale values. For example, ICT tools can help in calculating long-term benefits. Also, a computerised database of historical resale values could assist identifying potential resale targets.

6. **Please speculate on any other ICT developments, which might occur over the next 5 years, that you think could affect the building design process.**
Taking into account the trends of increasing “computer literacy”, increasing backgrounds of higher education in the population, and increasing interest in the use of ICT in the construction industry, respondents believe that the building design process will become increasingly computerised in the future. ICT is getting cheaper and more popular, and building professionals are becoming more adept with it and dependent on it to handle everyday tasks. They will have to adopt and adapt these technologies to stay competitive, and to save time and money in the long term.

The use of 3G mobile devices will expand in the future to cater for everyday tasks, to provide better communication between various stakeholders, and to improve productivity.

7.3 THE MODIFIED MAPS

Figure 7-1 represents the modified map for current ICT implementation during building design process. Figure 7-2 represents the modified map for future ICT implementation over the next five years.

Changes made to the original maps were as follows:

- Clustering of activities has been transformed to grey polyline, with activities grouped in single free-form clusters of related activities (For example: activities A111, A112, A113, A114, A115 staying in a cluster represented the children activities of parent activity A11).
- Arrow representations of ‘Input/output’ and ‘control’ are removed.
- Levels of ICT usage are represented by colour shading, where the darker shade in the inner circle represents the highest rating (5) and shading for decreasing usage becoming progressively lighter towards the outer circles.
- The issues of ICT implementation are re-drawn as an enveloping set of constraints surrounding the whole building design process.
Figure 7-1  Map of 'Current' ICT Implementation during the Building Design Process (54 Building Activities extracting from IDEF0 map)
Figure 7-2 Map of ‘Future’ ICT Implementation during the Building Design Process (54 Building Activities extracting from IDEF0 map)
7.4 Summary

This chapter summarises the findings from interviews with three experts. The purpose was to test the robustness of the proposed ICT implementation maps. Six questions were posed to focus on the development of the maps. The interview responses showed that the initial maps were too complicated and time consuming to understand. These responses guided a series of formatting modifications to the maps.

The following chapter reviews the main findings of the research into ICT and the building design process, and presents these as a series of conclusions and recommendations.
8 CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This chapter concludes the study of the implementation of information and communication technologies (ICT) during the building design process. The main findings of the research are presented, and recommendations are made in terms of changes to current practice and directions for research. The extent, to which the aims and objectives have been achieved, is examined.

8.2 SUMMARY OF MAIN FINDINGS

The building design process is a complex process. It requires multi-disciplinary professionals working together throughout the multi-processes of a building project.

This dissertation has presented the development and validation of ICT implementation maps focusing on the usage level, the impacts, barriers and other issues of ICT implementation during the building design process for current practice, and to predict future trends over the following five year (year 2005 - 2009). The building design process has been mapped out using IDEF0 process modelling language. This process model was validated and tested by experts through Delphi survey. Delphi methodology was used in order to move the panel of experts independently toward acceptable consensus on the issues of implementation. The fifty-four building design activities were developed from three main stages of the building design process (Schematic Design; Design Development; and Documentation) to the following eleven sub-stages:

Complete Schematic Design Stage (A1)
- A11 – Develop and Define Design Requirements
- A12 - Estimate Resale Value
- A13 - Conduct Value Management Process
- A14 - Preparation of Outline Proposal
- A15 - Prepare Preliminary Estimate

Complete Design Development Stage (A2)
- A21 - Prepare Sketch Design Documentation
- A22 - Run Design Evaluation Session
• A23 - Prepare Sketch Design Cost Plan

**Complete Documentation Stage (A3)**

• A31 - Conduct Detail Design Management
• A32 - Conduct Cost Checking
• A33 - Audit Completion of Detail Plan

A contribution of this study is the development of the ICT implementation maps from current and future perspectives. The findings of the Delphi experts in four rounds of survey have been used as input for the development of the ICT implementation maps.

The ICT implementation maps not only provide evidence of the likelihood of increasing use of ICT tools over the next five years, but also provide a baseline for design professionals or decision makers in considering the adoption of new technologies to facilitate the process. The maps show what design professionals believe they will want, and may be used as a tool to assess the associated issues such as the financial impacts of adopting new ICT tools (e.g. training costs), potential benefits, possible obstacles to implementation, and resources required, when considering adopting new ICT tools for design practice.

The outcome from the Delphi survey provided additional evidence that the main barrier to ICT implementation is ‘cost’. Experts pointed out that: “*Availability is dependant on cost. There are many systems available for consideration, but costs restrict their use, hence, evolving and adapting to what is available is the norm.*” The costs involved include the capital investment plus the costs of financing, maintenance and training. On the other hand, an opportunity cost reduction might occur through the promotion of ‘online’ application processes for planning and building permits from local authorities.

Another finding of this study is related to ‘legal issues’. Hard copy data are produced and kept as a back up records for the soft data generated by ICT during the project progress. A panel expert commented: “*Legally speaking, hard copies of all recorded conversations are required, so there is still an element of double handling with verbal ICT tools.*” Legal and cultural change may be required for the industry to move from this reliance on hardcopy records, and stay competitive in the long term, as discussed in next section.
A particular issue emerged during the four round Delphi survey. When asked to comment if ICT implementation could improve quality and productivity in the building design process, one expert believed that: “… nothing beats meeting with the project team on a regular basis and speaking to one another. Too much time is spent at computer screens sending emails to the person sitting next to you.” This appears to be consistent with Egbu et al. (2001) who found that many ICT users believe that ‘too much’ computer-mediated communication can lead to feelings of alienation and frustration. The use of e-mail is frequently cited as being both indispensable and troublesome. Although it speeds up communication and reduces much of the need for paper, it can cause ‘interactional difficulties’. This finding is supported by Rozell and Gardner (2000). It has been suggested that e-mail and other computer mediated systems, such as video/tele-conferencing, can make people lazy and less likely to partake in face-to-face communication.

Finally, it is important to note that the proposed “ICT implementation maps” encompass and represent outcomes from data generated during this research. However, such maps need to be routinely and systematically updated to ensure that state-of-the-art information is captured and provided to the construction industry.

**8.3 RECOMMENDATIONS FOR PRACTICE**

The advocacy of ICT as a means to improve the building design process is accepted by most of the Delphi survey panel of experts. However, in many respects, the use of technology and the many developments it can bring are still looked upon with fear and trepidation. People instinctively resist changes that will have a marked effect on their daily lives. Ways of enhancing a better understanding of technology and reducing misconceptions are needed to educate building design professionals to the way that the technology can be adopted. A number of individual recommendations for the construction industry can be identified from this research:

- **Education of building design professionals.** Building design professionals need to be made aware of the wider context of Information and Communication Technology (ICT) in addition to the traditional applications. An understanding of the broader context of technology used in the industry will help to facilitate the process.
- **Education of the construction industry.** In general, there is a need to increase awareness of how ICT can be used to assist a better communication path between team
members during the building design process.

- **Demonstration of IT systems.** One of the best ways to convince people of the way that new technologies can be used is to demonstrate their use. The professional institutions, suppliers, government, and universities need to establish seminars and workshops, to demonstrate the appropriate uses of ICT systems.

- **Promoting continuous improvement.** Continuous improvement involves all building design participants. To facilitate continuous improvement, project stakeholders need to attain, maintain, monitor and exchange information about the performance of all participants from the architect to manager as well as site workers in each project, to learn from experience and to ensure that outcomes meet project requirements.

- **Recommendation of appropriate technologies.** Ongoing independent reviews of ICT tools implementation during the building design process should be on the agenda of many professional institutes. Findings from these reviews need to be passed on to the members of the institutes and to the construction industry in general, to assist in the selection of appropriate technologies. Communication media such as journals, video-recordings, and interactive software can be used.

### 8.4 Recommendations for Future Research

Throughout this thesis, a number of areas were identified for further research. The following list summarises possible areas for further research.

- An in-depth study on security issues in the use of ICT tools for information transfer and storage during the building design process.
- Further study on the problems and barriers of ICT implementation during building design process focusing on the issues other than management, such as technical issues and financial issues.
- A study of the changes to and development of ICT to help practitioners in different ways.
- Develop process maps, using IDEF0 language, for the building design process for other procurement method such as design and build.
- This research has focused focus on the pre-construction stages of the building design process. Other stages such as construction stages and post-construction stages should be taken into consideration. It is recommended to develop process maps, using IDEF0 language, for phases other than pre-construction stage.
8.5 Achievement of Research Objectives

The aim of this research was to better understand how Information and Communication Technology (ICT) is implemented during the building design process. To meet this aim, the following research objectives were formulated. Six research questions were developed to address the objectives.

**Objective 1** – to examine the manner in which ICT is used by the building design professions during the building design process (with a focus on large-scale office/commercial projects in Australia). Research questions two, three and four were developed to accomplish objective 1. (Research question one was attempted in objective 2)

**Research Question Two** – What aspects of the work done by design professionals are influenced by ICT?

Fifty four building design activities were mapped, using IDEF0 process maps. Analysis of Delphi survey responses for current ICT usage ratings showed that seventeen activities exhibit mean ratings of > 3.5 indicating that these ICT tools decrease effort and increase efficiency and output quality. Ten activities display mean ratings of ≤2.5, indicating that ICT tools are not currently used in undertaking them, although they could be used and experts have an interest in using them in future.

The Delphi survey responses for ‘future rating’ (five years to 2009) of ICT tools usage for the building design process showed that six activities displayed mean ratings ≥4.5, indicating that the experts believe in the capacity of these tools to allow project participants to perform work that was not possible before. Of the 54 building design process activities listed, 49 scored ≥3.5 (including 6 activities of mean ratings ≥4.5 and the remaining 5 activities achieved rating <3.5); signifying the experts’ belief that ICT tools are (or could be) useful in performing the job.

Comparison between the overall mean survey response data values for ‘current’ and ‘future’ ICT usage shows that the mean rating for ‘future usage’ (five years to 2009) of ICT tools for the building design process was 4.03, compared to 3.19 for ‘current usage’. This indicates evidence of substantial confidence of the experts in the increasing use of ICT across a range of building design process activities in the future. This has implications for technology
development; technology investment decisions; technology maintenance and uprating; staffing; and staff education, training and re-training. These issues were brought out by the Delphi experts during the Round 4 survey and presented in section 5.5.

**Research Question Three** – How much do building design professionals use ICT tools?

This question was addressed during Round 2 of the Delphi survey. Findings from the survey found that the highest current usage level of ICT tools was for email under the ICT for Communication category. The mean rating value for email was 4.00; followed by word processing and spreadsheet applications, indicating almost daily use of these tools for all Delphi experts during the building design process. Of the total 29 tools used, 10 were rated 2.5 or higher, indicating frequent use (at least once every few days). Twelve tools scored mean value ratings below 1.5, indicating that the Delphi experts had never used those tools during the building design process. These were:

- Bluetooth
- Groupware solution
- PAN (Personal Area Network)
- Digital Signature
- Workflow solution
- PDE (Personal Digital Environment)
- Visualisation
- Chat
- VR (Virtual Reality)
- Cryptography
- Digital pen
- AI (Artificial Intelligence)

Email, word processing and spreadsheets were still ranked highest when the Delphi survey panel experts were asked to predict future usage levels for the ICT tools (for the next five years). However, their predictions for the use of the Internet increased from a mean value of 3.11 (current) to 3.56 (future), signifying future daily use of the Internet. All of the 29 tools were predicted to be adopted or adapted to accomplish building design activities in the future.
Research Question Four - What are the impacts of ICT implementation by building design professionals during the design process?

The literature review showed that positive (“value adding”) impacts of ICT implementation by building design professionals during the design process relate to:

- Cost efficiency (able to produce more with lower cost).
- Time efficiency (able to produce more in shorter time period).
- Quality (able to perform the task to higher standard and with less effort).
- Opportunity (able to perform tasks that may not have been previously done).

The most frequently selected value added benefits for ‘current’ usage of ICT tools, according to the majority of experts in the Delphi survey were time and quality, followed by cost and opportunity.

Analysis of the ‘future usage’ Delphi survey ratings indicates a substantial increase in rating score values over all four issues.

Negative impacts of ICT implementation could be viewed as ‘barriers to implementation’. The literature shows that these are:

- Lack of training for soft/hardware implementation.
- Cultural barriers such as: threat of ICT; project based nature of construction project; and adversarial culture between project professionals.
- Lack of availability of some soft/hardware.
- Legal issues such as security.
- Lack of top management support.
- Lack of investment in soft/hardware.

The Delphi survey experts believed that ‘lack of availability of some soft/hardware’ and ‘lack of training for soft/hardware implementation’ are the two main current barriers to ICT usage in the building design process. However, ‘training’ is forecast to be the main barrier for future ICT usage and ‘lack of training for soft/hardware implementation’ as the main barrier for ICT implementation in the future. The Delphi experts believe that the availability of soft/hardware will increase dramatically over the next five years.
Objective 2 – to investigate and map existing design processes using the IDEF0 (Integrated DEFinition) functional modelling technique. Objective 2 of this study was met by answering the following question.

Research Question One - How can process mapping being used to describe and document the building design process?

The main objective of this study is to investigate and to map existing design process and to propose a model for ICT implementation during the building design process. The conceptual model type is best suited for this purpose as it represents the variables that are relevant and shows how they are related. The proposed process model will generally require decomposition in levels of detail, showing the interrelationship between all variables. IDEF0 modelling language, a process modelling technique based on a well established Structured Analysis and Design Technique (SADT) was adopted to map the building design process in this study. The process map was developed to investigate the interrelationships among the following:

- Feasibility studies – produced from the previous stage (as input)
- The building design process (as function)
- The design process success, to improve communication and information flow (as output)
- The procedures/ guidelines and the requirement to the process (as control)
- The ICT tools used and people involved in the process (as mechanism)

Fifty four activities were decomposed from three pre-construction stages stated in Architect Agreement [Long Form], Scope of Services, RAIA Advisory Note (RAIA, 2000) which referred to: schematic design stage, design development stage as well as the documentation stage. These activities were mapped in four levels of an IDEF0 process model for building design process (refer to Appendix-A).

Objective 3 - to propose a best practice model for ICT implementation during the building design process that improves information exchange and levels of communication between participants. The following questions address the above objective.
Research Question Five - Can a best practice model be mapped for ICT use during the design process?

Best practice models for ‘ICT implementation during building design processes (for current usage and representing forecast future usage trends in five years time) were developed as the end result of this study (refer to figure 7-1 and 7-2). The maps were derived from the data collected from the four rounds of Delphi survey. ICT usage levels for each of the building design processes (identified through the Delphi survey) were shown in these maps. These maps also depicted the issues discussed as part of the Delphi survey. These issues are:

- Design communication
- Design information management
- Information and communication technologies
- Impact of ICT
- Challenges

These maps were modified and improved through focus interviews with three building design experts. Interviewees confirmed that the proposed maps were complete in showing how ICT is being used during the building design process, and that the issues indicated would help the strategic decision making process for professional designers when adopting new technology.

Research Question Six - What is the future trend (over five years) of ICT implementation during the building design process?

The future trend (over five years) of ICT implementation during the building design process again was shown in the ‘future’ map (Figure 7-2). Respondents believe that the usage of ICT tools will increase dramatically for most of the building design activities over the next 5 years. Some of the reasons driving this predicted increase in usage level of ICT include: the increasing cheapness of these technologies; the increased availability of technologies; the greater capacity of new technologies; the need to integrate and co-ordinate activities with fellow designers on a project team; and the need to maintain commercial competitiveness.

The aims and objectives of the research are considered to have been achieved.
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Purpose:
To map pre-construction stages of building design process for 'design-bid-construct project'.

Viewpoint:
Building design professional overview of the building design process.
C1 Types of Procedures & Guidelines

Feasibility Outputs
I1 Liaise with authorities
I3 Re-address func brief

I2 Client's and End user interviews

C2 Types of Requirements

Planning approval guideline

Authorities' requirements specified

Site analysis

Site master plan completed

Outline design sketch completed

Completed list of recommendations

Assessment of consultant recommendations

Completed Environment analysis

Seek client's initial feedback

Feedback-to proceed

Negative feedback

A1

A11

A111

A112

A113

A114

A115

A116

O1

P.4
identify potential resale target/buyer

Feedback-to proceed

market analysis

list of potential buyer

Assessment of resale value

Resale value obtained
Positive feedback to proceed

Review concept brief

Allocate costs

Cost allocation completed

Mismatch & risk to project was highlighted

Evaluation & development of alternative solutions

Client's requirements

Client agree to proceed

Re-address func brief

Completed revision of concept brief

I1

Review concept brief

A132

Allocate costs

A131

Highlight mismatch & risks

A133

Evaluation & development of alternative solutions

A134

Presentation

A135

C1 Types of Requirements

I2

Consultant's advice

I1

Positive feedback to proceed

Client's requirements

Client agree to proceed
Development of OPC

Eng. feasibility studies/ liaise with engineers

Search solution for principles

Select suitable design/cost solution combination

Evaluate choice of alternatives

Cost guide

Types of Procedures & Guidelines

Outline plan completed

probable cost range for project obtained

preliminary eng. design

best solution found

best combination achieved

Cost guide

improve details & cost options

Concept Approved

Concept declined

Choose best solution

Concept declined

Types of Procedures & Guidelines

Probable cost range obtained

Eng. feasibility studies/ liaise with engineers
Meta Software

DATE: 3/12/2005

NOTE: 1 2 3 4 5 6 7 8 9 10

COMPLETE DESIGN DEVELOPMENT

I1 Concept Approved

C1 Types of Requirements

C2 Types of Procedures & Guidelines

Prepare Sketch Design Documentation

Completed sketch plan

Run Design Evaluation Session

Detail Scheme dwgs completed

Prepare Sketch Design Cost Plan

Client commitment to proceed

NODE: A2
title: Complete Design Development

number: P.9
Completed sketch plan

Integrate preliminary consultant's advice in design

Consensus achieved

Review authority/council requirements

Completed revision

Gather feedbacks from all authority and consultants

Sumarised feedbacks

 Changes complete

Finalised design documentation

Completed finalisation

Apply for planning permit

Detail Scheme dwgs completed

Types of Procedures & Guidelines

Design guideline

Legal and Statutory statutory procedure

Completed revision

Sumarised feedbacks

Finalised design documentation

Completed finalisation

Apply for planning permit

Detail Scheme dwgs completed

Types of Procedures & Guidelines

Design guideline

Legal and Statutory statutory procedure

Completed revision

Sumarised feedbacks

Finalised design documentation

Completed finalisation

Apply for planning permit

Detail Scheme dwgs completed

Types of Procedures & Guidelines

Design guideline

Legal and Statutory statutory procedure

Completed revision

Sumarised feedbacks

Finalised design documentation

Completed finalisation

Apply for planning permit

Detail Scheme dwgs completed
Prepare Sketch Design Cost Plan

A23

C1 Types of Procedures & Guidelines

I1 Detail Scheme dwgs completed

Estimate building cost

Prepare alternative estimates

Prepare budget programme

Prepare time schedule & org. plan

Client commitment to proceed

bldg. cost estimation completed

building cost guide

Alternative estimation completed

cost allocation guide

budget programme completed

Meta Software

3/12/2005

DATE: 3/12/2005

AUTHOR: Meta Software

PROJECT:

REV: 3/12/2005

NOTES: 1 2 3 4 5 6 7 8 9 10

CONTEXT:

WORKING

READER

DATE

PUBLICATION

A2
Client commitment to proceed

Conduct detail design management

Documentation for lodgement completed

Completed cost checking

Conduct cost checking

Design process success

Improve Communication

Improve Info. Flow
Client commitment to proceed

Prepare detail architectural drawings
A311

Develop detail eng. design
A312

detail eng. design completed

C1 Types of Requirements

Client req.

C2 Types of Procedures & Guidelines

Coordinate/ liaise with all consultants
A313

Integration of sub-systems design obtained

Presentation to authority/ council
A314

Finalised authorities' comments before lodgement

Preparations of documents for building permit application
A315

Documentation for lodgement completed
O1

design guidelines

local legislation

Client req.

completed arch. dwgs.
I1: Documentation for lodgement completed

C1: Types of Requirements
- Analyse & evaluate design alternatives
  A321
- Investigate design cost efficiency
  A322
- Identify and analyse life cycle cost
  A323

C2: Types of Procedures & Guidelines
- Conduct design cost checking
  A325
- Review optimisation of energy performance
  A324
- Energy consideration finalised
- Building cost guide
- Completed cost checking
  O1

Types of Requirements:
- Client's & user's req.
- Design evaluation completed
- Cost investigation completed
Completed cost checking
I2
I1
Documentation for lodgement completed

Lodgement for building permit
A331

building permit approved

Rationalisation & integration of sub-system design
A332

sub-system integration completed

To consider Occupational health & safety - Safe design
A333

Safe design obtained

Advisory Note (AN13.01.103)

Types of Procedures & Guidelines
C1

To conduct risk management
A334

Design process success
O1
Improve Communication
O2
Improve Info. Flow
O3
Assumptions to the model

- The activity scheduled based on ‘fully designed commercial building project’ also refer to ‘design-bid-construction project’ and may be varies from other procurement methods.
- Advisory note published by The Royal Australia Institute of Architects (RAIA), ‘AN10.01.100-Guide Note’ and ‘AN10.01.101-Practice note’ were adopted as the guide for developing the lower level activities during building design process.
- RIBA Outline Plan of Work 1998 was also adopted as a reference for developing the lower level activities during building design process.
- ICT tools’ and ‘people’ which act as mechanism were not being mapped in this process model.

Model Interpretation

- The process model was presented in hierarchical (top down) format;
- The model should be read from left to right;
- Interpretation of the model should normally go from ‘output’ to ‘input’ of another activities, however, the ‘output’ of one activity can sometime act as ‘control’ to another activity in our process map.
- The activities number represented each unique building design activity and should be interpreted as:
  (A0 as the top level, A1, A2, A3 as the second level, A11, A12, A13... as the third level, and A111, A112, A113...as the lower level in our process map).

Definition of Building Design Process

- Liaise with Authorities (A111) - This activity involves consultation with relevant local, regional, state and federal authorities to confirm all planning regulation. These are such as: car park requirements; height restriction, density requirement, and zoning requirements.
- Site Analysis (A112) - site context analysis involves the preparation of a master plan for overall development and phasing to show its best utilisation.
- Conduct Outline Feasibility Design (A113) - this stage requires the involvement of various design team, such as:
  - Architect design services consist of preparing: conceptual site and building plans; preliminary sections and elevations; development of approximate dimensions, areas and volumes;
  - Initial involvement of various engineers for theirs professional recommendations includes, when applicable: structural design, mechanical design, hydraulic design, electrical design, civil design, and landscape design.
Definition to Building Design Process (continue)

- **Assessment of Consultant’s recommendations (A114)** - to gather, analyse and run assessment of recommendations from all trade consultants.

- **Conduct environmental analysis (A115)** - to consider the environmental strengths and weaknesses of the proposed development, and scan the environment for opportunities on the selected site;

- **Seek client’s initial feedback (A116)** - presentation of the Clients to review recommendations from previous stages for feedback.

- **Identify potential resale target/buyer (A121)** - to identify potential buyer and to find out the target group;

- **Assessment of resale value (A122)** - to assess resale value of the building (final product), may involve market analysis;

- **Review concept brief (A131)** - to review concept brief obtained from previous stages and to confirm client’s objectives for the project. These are such as: the initial plans, elevations, sections, specification and cost plan of the proposed facility. It is important to fully understand the concept brief, particularly the functional space requirements and adjacency prior to the allocation of cost for each trade.

- **Allocate costs (A132)** - this stage involves the allocation of costs from the cost plan to functions and spaces.

- **Highlight mismatched and risks (A133)** - to identify and to highlight any mismatched between cost allocation to functions and spaces. To run risk assessment for each design option.

- **Evaluation and development of alternative solutions (A134)** - evaluation of design alternative and brainstorming for better solutions.

- **Presentations (A135)** - presentations of preferred solution to clients or client’s representative.

- **Ensure outline plan fulfils project brief (A141)** - to ensure that the outline design drawings encompass the requirements of the brief prepared earlier.

- **Prepare design proposal (A142)** - producing a sketch drawings based on the information obtained from various stakeholders includes engineers, cost consultant, authorities and consultants.

- **Review authorities’ requirements (A143)** - to review authorities’ requirement to ensure that the outline schematic design meets all regulatory’ requirements.

- **Liaise with cost planning consultant (A144)** - liaise with cost planning consultant to prepare preliminary costing for the project, for comparison with target budgets.

- **Assess client’s initial feedbacks (A145)** - Assess client’s initial feedbacks from stage A116.

- **Initial Planning Permit Application Preparation (A146)** - prepare initial scheme design drawings, based on authorities’ comments, consultants’ recommendations and client’s feedback.
Definition of Building Design Process (continue)

- **Development of Opinion of Probable Cost and Program (OPC) (A151)** - liaison with cost consultant to develop opinion regarding probable construction cost range for the project.
- **Engineering cost studies/liaise with engineers (A152)** - undertake cost studies to determine appropriate engineering solutions.
- **Search for principal solutions (A153)** - Assess and decide upon appropriate design/cost solutions to principal elements of the project.
- **Select suitable design/cost solution combination (A154)** - Assemble and choose the most appropriate combinations of design/cost solutions.
- **Evaluations of choices of alternatives (A155)** - prepare costing to appropriate level of detail, and compare with budget targets.
- **Improve details and cost options (A156)** - to improve the details and cost options within the alternative design solutions considered; update costing and budget comparisons; report to client for decision-making.
- **Develop expansion of architecture design drawings (A211)** - the development and expansion of architectural schematic design documents, revised in accordance with client’s instructions and as necessitated by any revision to estimate cost, including plans at each level, elevations, sections and other details or schedules sufficient to fully explain the design (AN10.01.101.4.02).
- **Prepare preliminary engineering design (A212)** - it consist of the continued development of the various engineering design as done in outline feasibility design stage A113.
- **Coordinate/liaise with all consultants (A213)** - coordinate and integrate the design work with all consultants.
- **Make required design changes (A214)** - make required changes based on consultants’ recommendations.
- **Presentations of the schematic design (A215)** - presentation of the schematic design to all relevant stakeholders, such as: client, building owner, staff committee, user groups, boards of directors, financier, owner’s consultants for comment (A10.01.101.4.11)
- **Design Visualisation - Model Construction (A216)** - model construction (if necessary): physical and/or virtual models of the proposed building, showing the interrelationship of the spatial layouts, in 2D and 3D formats, are very useful for many clients; they are also an effective way of depicting constructional methods;
- **Integrate preliminary consultant’s advise in design (A221)** - all design team members have to work together to make final decisions regarding design aspects, materials, finishes, services, and various other matters.
- **Review authorities/council requirements (A222)** - review all relevant planning and authorities’ requirements, are calculations and car parking (A10.01.100-clauseB8).
- **Gather feedback from all authorities and consultants (A223)** - feedback from all authorities and consultant is consolidated into necessary design change proposals.
- **Finalised design documents (A224)** - to finalised and make required design changes base on authority’s/consultants’ feedback.
Definition of Building Design Process (continue)

- **Apply for planning permit (A225)** - lodgement of documents by the architect on behalf of the client to the relevant authorities for planning approval (AN10.01.101.4.12).
- **Estimating building cost (A231)** - cost consultant prepares more detailed cost plan for the project, based upon development of outline design, for comparison with target cost budgets.
- **Prepare alternative estimates (A232)** - for difference construction methods, materials, engineering systems to ensure that best design solutions are obtained within the established budget.
- **Prepare budget program (A233)** - show how the total cost is allocated among the various part of the project.
- **Prepare time schedule & organization plan (A234)** - prepare outline time schedule and organization plan to give the client an indication as to when building work will commence on site and how long it will take to complete.
- **Prepare detailed architectural drawings (A311)** - to precede on the basis of the scheme design drawings and to develop in a more finished form, including more detailed drawings and specifications and incorporating the specialist contributions of the various consultants. The documents include as stated in AN10.01.101.5.02 are:
  - Working drawings for tendering and construction
  - Specification comprising detailed written descriptions of the content of the project materials and workmanship.
- **Develop detail engineering design (A312)** - develop engineering documentation, setting forth in detail the various engineering construction requirements of the project for tendering and construction purposes, consisting of the preparation of: final engineering calculations; drawings; specifications and schedules.
- **Coordinate/liaise with all consultants (A313)** - coordinate and integrate sub consultant design with the architectural drawings and specifications (A10.01.100).
- **Presentation to authority/council (A314)** - final presentation to local authority/council before lodgement to ensure all design complies with building regulations.
- **Preparations of documents for building permit application (A315)** - prepare documentation including dimensioned plans, sections and elevations to adequately describe the design for the purpose of obtaining approval to construct (A10.01.100).
- **Analysis & evaluate design alternatives (A321)** - interaction between all project professionals and facility manager (if appointed) to ensure that the building provides its users with basic elements that maintain the necessary comfort which allows them to carry out their jobs;
- **Investigate design cost efficiency (A322)** - to ensure cost efficiency of the proposed building design, to consider and identify which elements of the building require the least maintenance, and incur the fewest breakdowns and repairs. Also, those with the most maintenance and repair requirements.
Definition of Building Design Process (continue)

- **Identify and analyse life cycle cost (A323)** - assess the life cycle cost of the building; in short-term; medium-term; and long-term.

- **Review optimization of energy performance (A324)** - review energy performance for proposed design, to consider which elements within the building are the most energy inefficient;

- **Conduct design cost check (A325)** - cost consultant to review the cost plan after all stages and to carry out cost studies and cost checks as the design team finally shape their details.

- **Lodgement for building permit (A331)** - submit application to the relevant authority for building approval

- **Rationalise & integrate sub-systems designs (A332)** - rationalize and integrate all design sub-systems to make sure they have no conflicts.

- **To consider Occupational Health and Safety- Safe Design (A333)** - to ensure that the proposed design can be safely built, used, maintained, and demolished by those who construct and use it (AN13.01.103).

- **Conduct risk management (A334)** - to assess and balance the contingencies of risk with their specific contractual, financial, operational and organizational requirements by transferring through the combination of insurance, risk financing, and contract indemnification provisions.
Invitation Letter

School of Property, Construction and Project Management

12th Oct, 2004

Casta YL Choong,
RMIT University,
GPO Box 2476V
Melbourne VIC 3001
Australia

Dear Sir/ Madam,

Re: Development of a best practice model for the building design process on large-scale commercial projects: A Delphi Study.

My name is Casta YL Choong. I am undertaking a PhD research programme with School of Property, Construction and Project Management at RMIT University. The title of my research is “A best practice model for the building design process on large-scale commercial project – a Delphi survey”. I am writing to invite your participation in a Delphi study on the issue of Information and Communication technology (ICT) during the building design process. This study will form the basis of my PhD research supervised by Associate Professor Peter Stewart and Mr. Geoff Outhred from School of Property, Construction and Project Management at RMIT University.

The aim and objectives of this study are:-

- To better understand how Information and Communication Technology (ICT) is currently being implemented during building design process on large scale office building projects.
To investigate and to propose a best practice model for ICT use during the building design process using IDEF0 modelling language.

To test and improve the best practice model using a Delphi panel.

To revise the best practice model based on the likely developments in ICT over 5 years. This revised model will also be tested using a Delphi panel.

The best practice models developed as part of this research will enable organisations to adapt their current approach towards a best practice model and then to plan improvements to account for ICT innovations in the coming 5 years.

A panel of 9 experts will be surveyed using Delphi approach. You have been selected and invited to participate in this study based on your understanding of the research area. Your experiences, insights, and opinions concerning the issues being explored will provide a valuable contribution to the best practice model being developed as part of this research. The data collected as part of the Delphi process will seek to identify areas of consensus and disagreement among the panellists and this will help refine the best practice model.

In this first stage we expect there to be five survey rounds. The study is scheduled to be completed in two to three months time. The amount of time necessary for completion of each round will vary with each panellist, but should range from approximately half to one hour for each round. The summary result of each stage will be analysed and made available to you for your reconsideration in the next stage. A final report will be presented to you at the conclusion of this research.

All participants will retain anonymity, as the Delphi rounds will be conducted by mail and each participant will be assigned a unique code which will only be known by the researcher and supervisor. Participation in this research is voluntary and anyone may refuse to answer any question at any time during the research and any unprocessed data may also be withdrawn.

We hope you are willing to participate in this research study and your acceptance will be confirmed once you complete the enclosed ‘Consent Form’. The completed consent form should be mailed/fax to me at the address supplied below.

Thank you for your consideration and please do not hesitate to contact me or my supervisor.
on (Tel: 613-9925 3453 or email: peter.stewart@rmit.edu.au) should you required further information.

Regards,

Casta YL Choong,
PhD Candidate,
School of Property, Construction and Project Management,
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RMIT University
Swanston Street
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Mobile: 0413 091 122
CONSENT FORM

RMIT HUMAN RESEARCH ETHICS COMMITTEE

Prescribed Consent Form for Persons Participating In Research Projects Involving Interviews, Questionnaires, Focus Groups or Disclosure of Personal Information

PORTFOLIO OF Design and Social Context

SCHOOL/CENTRE OF Property, Construction and Project Management

Name of participant:

Project Title: A Best Practice Model for Building Design Process on large-scale Commercial Projects – A Delphi Study

Name(s) of investigators: (1) CASTA YILI CHOONG (2)

Phone: 0413 091 122

1. I have received a statement explaining the interview/questionnaire involved in this project.

2. I consent to participate in the above project, the particulars of which - including details of the interviews or questionnaires - have been explained to me.

3. I authorise the investigator or his or her assistant to interview me or administer a questionnaire.

4. I give my permission to be audio taped □ Yes □ No

5. I give my permission for my name or identity to be used □ Yes □ No

6. I acknowledge that:
   (a) Having read the Plain Language Statement, I agree to the general purpose, methods and demands of the study.
   (b) I have been informed that I am free to withdraw from the project at any time and to withdraw any unprocessed data previously supplied.
   (c) The project is for the purpose of research and/or teaching. It may not be of direct benefit to me.
   (d) The privacy of the information I provide will be safeguarded. However should information of a private nature need to be disclosed for moral, clinical or legal reasons, I will be given an opportunity to negotiate the terms of this disclosure.
   (e) The security of the research data is assured during and after completion of the study. The data collected during the study may be published, and a report of the project outcomes will be provided to_____________(researcher to specify). Any information which may be used to identify me will not be used unless I have given my permission (see point 5).

Participant’s Consent

Name: ___________________________ Date: ___________________________

(Participant)

Name: ___________________________ Date: ___________________________

(Witness to signature)

Where participant is under 18 years of age:

I consent to the participation of ___________________________ in the above project.

Signature: (1) ___________________________ (2) ___________________________ Date: ___________________________

(Signatures of parents or guardians)
Participants should be given a photocopy of this consent form after it has been signed.

Any complaints about your participation in this project may be directed to the Secretary, RMIT Human Research Ethics Committee, University Secretariat, RMIT, GPO Box 2476V, Melbourne, 3001. The telephone number is (03) 9925 1745.

Details of the complaints procedure are available from: www.rmit.edu.au/council/hrec
APPENDIX-C

DELPHI ROUND ONE SURVEY PACK

Email Notice to begin Round One

Dear [Participant],

Thank you for agreeing to participate and share your knowledge, expertise with us in the Delphi study to develop a best practice model for the building design process on large-scale commercial project. Since contacting everyone, it has become obvious that there are a number of issues to be included, and it is possible that the number of rounds may increase as a consequence. I hope this will not cause you any difficulty, and I still plan to complete all rounds well before Christmas. I have planned for a maximum of 5 rounds and there are scheduled as follows:

October 12 – 17: First round response to questionnaires
October 26 – 31: Second round response to questionnaires
November 9 – 14: Third round response to questionnaires
November 23 – 28: Forth round response to questionnaires
December 7 – 12: Final round response to questionnaires

I have to admit that the schedule is compressed but we are hoping it will reduce the time you have to commit to the Delphi rounds. A notice to begin Round 1 survey will be sending out soon comprises instruction to answer Round 1 questions, a web link for the online questionnaire, and an assign code for each of you. Once again thank you for your participation.

Regards,
Casta
Instruction to Begin Delphi Study Round 1
(October 12 – 17, 2004)

Dear [Participant],

Thank you for agreeing to participate and share your knowledge, expertise with us in the Delphi study to develop a best practice model for the building design process on large-scale commercial project. Since contacting everyone, it has become obvious that there are a number of issues to be included, and it is possible that the number of rounds may increase as a consequence. I hope this will not cause you any difficulty, and I still plan to complete all rounds well before Christmas. I have planned for a maximum of 5 rounds and there are scheduled as follows:

October 12 – 17: First round response to questionnaires
October 18 – 25: I will review and analyse the responses

October 26 – 31: Second round response to questionnaires
November 1 – 8: I will review and analyse the responses

November 9 – 14: Third round response to questionnaires
November 15 – 22: I will review and analyse the responses

November 23 – 28: Forth round response to questionnaires
November 29 – December 6: I will review and analyse the responses

December 7 – 12: Final round response to questionnaires
December 13 – 19: I will review and analyse the responses

I have to admit that the schedule is compressed but we are hoping it will reduce the time you have to commit to the Delphi rounds. The following section will provide a brief description on how to interpret the research model.

Please Note: I should make you aware of the research topic, to enable you to answer question more comprehensively. I have therefore described below the IDEF0 model. This is for your interest and information only, and you do not need to be fully aware of this research technique in order to answer the questions. So please do not be daunted by the research system.
How to interpret the research model (which use the IDEF0 modelling language)

The graphical language of IDEF0 contains two basic constructs: boxes representing activities and arrow segments representing ICOM entities (see figure 1). ICOMs refer to: Inputs (information or physical things), Control (rules or policies that guide how the activities are performed), Output (information or physical things), and Mechanisms (resources used to perform the activities).

Figure 1 Arrow positions and roles

IDEF0 models are developed through a process of top down structured decomposition. The fundamental building block of an IDEF0 model is the activity, which may be decomposed into subactivities, sub-subactivities, and so on. Activities are decomposed into subactivities (children), which in turn, are decomposed into sub-subactivities (grandchildren), and so on. Activity numbers show the decomposition. Activity A12 is the child of activity A1. Activity A452 is a child of A45 and so on. A list of activities and children is called an “activity tree” (see figure 2).

Figure 2 IDEF0 Parent to Child diagram Numbering (Activity tree)
For the purpose of this research project we will be focusing on the pre-construction stage of building design process which encompasses the ‘outline design’ through to ‘detail design’ stage.

*Figure 3* shows the top-level IDEF0 context diagram developed to represent the scope of this process. You will find a bracket on the ‘people’ arrow which represents no further decomposition for this entity. In this study, the context diagram was decomposed into three main sub-functions, namely: ‘complete outline design’; ‘complete scheme design’; and ‘complete detail design’. *Figure 4* is an IDEF0 diagram which encodes the ‘building design process’. *Figure 5* shows a further level of decomposition at the level of the ‘complete outline design’ sub-function. In total, four levels of functional decomposition were prepared for this study for your review and comment. The model will be modified based on the comments from yourself and the other Delphi panel members.

![Figure 3 Top Level Diagram for Building Design Management Process (A-0 diagram)](image)
Figure 4 IDEF0 A0 Diagram for Building Design management Process

Figure 5 IDEF0 A1 Diagram for Complete Outline Design
ROUND 1 of the Delphi questionnaires has three sections:

(Note: Please print out this section and read in conjunction with the Internet Survey)

Section A:
We will begin by collecting some demographic information from you and the other participants.

Section B:
This section will ask you to assess the extent to which you believe ICT tools are being used during each of the lower level activities. You will be asked to rate the current usage of these ICT tools and then the usage level you forecast in 5 years time.

We are not expecting you to be an expert user of each of these tools, as we are just seeking your expert opinion on how these tools have and will be adopted by the building design industry for the specific activities listed.

A five-point Likert-like rating scale will be used to determine the extent of use for each tool to each activity. The categories are:

- (5) Essential – if you believe these tools allow project participants to perform their work they can never done before;
- (4) Helpful – if you believe these tools have significantly decrease effort and make things much more efficient and better quality;
- (3) Fairly useful – if you believe these tools are useful in performing job;
- (2) Not used – if you are not currently using these tools and interesting on using it in future;
- (1) Un-necessary – if you have no interest in these tools and not desire to use it in the future.

Section C:
In section C, each panellist is given an opportunity to include any lower level activities as well as the list of lowest level activities during building design process that you feel we have left out. For example, if you believe we have left out a lowest activities in lower-activity “A14 – Prepare Cost Planning” please add in with a code as” A145 – activity name (if the lowest level activities happen after A144). Or if the activities happen earlier straight after activities code A141, please put your suggested activity code as: A142 and we will move the original
activity to later stage with new code.

We would also like you to add in any sub-activity that you believe we have missed out in the space provide towards the end of Section C.

The web questionnaire is now available for Round 1 and your response is requested by **October 17, 2004.** You may access the Round 1 questionnaires at:

http://survey.tce.rmit.edu.au

We have assigned you a user ID for this study and it is: __________
Please register yourself with your email address and chosen password before proceed to the Delphi survey Round 1 survey.

Please do not hesitate to contact the researcher at s3061458@student.rmit.edu.au or mobile: 0413091122, should you require further information. Once again, thank you for your time and your contribution to this research.

Regards,
Casta YL Choong
PhD Candidate,
School of Property, Construction and Project Management,
**Building 8, Level 8, Room 74** (8.8.74)
RMIT University
Swanston Street
Melbourne
# ROUND 1. PART A  DEMOGRAPHICS

## A1 Personal Information

<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<table>
<thead>
<tr>
<th>Phone</th>
<th>Email</th>
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<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

## A2 Personal Experience

<table>
<thead>
<tr>
<th>How long have you been working in the field of building design?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Have you participated in research, published, workshop related in your fields?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Approximately how much of your work required ICT tools?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Do you believe ICT tools have improved your work capabilities?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>A1</td>
</tr>
<tr>
<td>----</td>
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<tr>
<td>A11</td>
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<td>A111</td>
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<td>A112</td>
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<td>A113</td>
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<td>A114</td>
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<td>A141</td>
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<td>A142</td>
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<td>A33</td>
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<tr>
<td>A331</td>
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<tr>
<td>A332</td>
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<tr>
<td>A333</td>
</tr>
<tr>
<td>A34</td>
</tr>
</tbody>
</table>

5 = Essential  
3 = Fairly useful  
1 = unnecessary  
4 = Helpful  
2 = Not used
### ROUND 1 - PART C

If you believe there are activities that we have omitted, please add in the following space.

<table>
<thead>
<tr>
<th>A1</th>
<th>Complete Outline Design Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1.1</td>
<td>Prepare Functional Brief</td>
</tr>
<tr>
<td>A1.2</td>
<td>Conduct Value Management</td>
</tr>
<tr>
<td>A1.3</td>
<td>Prepare Concept Design</td>
</tr>
<tr>
<td>A1.4</td>
<td>Prepare Cost Planning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A2</th>
<th>Complete Scheme Design Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2.1</td>
<td>Prepare Detail Scheme Design</td>
</tr>
<tr>
<td>A2.2</td>
<td>Run Design Evaluation Session</td>
</tr>
<tr>
<td>A2.3</td>
<td>Prepare Budget Plan</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A3</th>
<th>Complete Detail Design Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3.1</td>
<td>Conduct Detail Design Management</td>
</tr>
<tr>
<td>A3.2</td>
<td>Conduct Facilities Assessment</td>
</tr>
<tr>
<td>A3.3</td>
<td>Audit Completion of Detail Plan</td>
</tr>
</tbody>
</table>

**Others**

<table>
<thead>
<tr>
<th>Please specify:</th>
</tr>
</thead>
</table>
Dear Delphi panel member,

Please confirm receipt of this message.

Thank you very much for your responses to round 1 survey. After many days of reviewing your feedback and refining the questions for Round 2, we are now ready to commence the next round.

You will find two documents attached to this email, firstly the “Instructions for Round 2” in word document format and the “Round 2 Survey Questions” in Excel format. Comments and suggestions from the first round survey have encouraged me to changes the Round 2 questionnaire from web-based to Excel format.

Brief descriptions of all activities and all ICT tools have been included with the Round 2 Questions to ensure you understand the context for each question.

Obviously the Round 2 survey is later than originally scheduled and so we hope that you will be able to respond to this round fairly quickly so that we can still finish by Christmas.

We hope you can submit responses via email attachment for Round 2 survey by 7th November 2004 (Sun), but if that is not possible could you email or call me to let me know the date you expect to return the survey.

Once again, thank you for your contribution to the research. I would like to say that your knowledge and patience has greatly helped the progress of this research.

Regards,
Casta
Instruction to begin Round 2 Delphi Survey
(Note: Please print out this section and read in conjunction with the attached survey question in excel format)

Dear Delphi Panel members,

Once again we would like to remind all participants that we are not expecting you to be an expert user of each of these tools, we are just seeking your expert opinion on how these tools have and will be adopted by the building industry. The following section provides a brief description of the Round 2 questionnaire.

Section A
This section is a summary of those additional lower level activities that you have suggested in Round 1 Section 3. All of these activities have been categorised and you are required to rate them using the same procedure and scale used for Round 1. The five point Likert-like rating scale used in the last Round was as follows:-

- (5) Essential – if you believe these tools allow project participants to perform work that was not possible before;
- (4) Helpful – if you believe these tools have significantly decrease effort and made things much more efficient and of better quality;
- (3) Fairly useful – if you believe these tools are useful in performing job;
- (2) Not used – if you are not currently using these tools, they could be used and you have interest on using it in future;
- (1) Un-necessary – if you have no interest in these tools and they are not needed to be used in the future.

Section B
In section B, we would like to know what kinds of ICT tools you are using and the level of usage for each of those activities. There are three ICT categories: ICT Infrastructure; ICT for Communication; and ICT for Information Management.

We would like you to first give an overall rating (level of usage of each tool to the building design process) for each of these tools to those activities listed. Then, you are asked to rate the individual tools to each activities accordingly.
You may leave the boxes blank if you believe they have the same rating to the “overall rating” you have rated earlier, or if you believe they have differ rating, please rate accordingly.

**Section C**
In Section C, you are welcome to add in tools that you believe we have left out in the section. Please fill in the activities number which you believe the tools are applied to.

Finally, we would appreciate some comments on how we could improve the process for the next Round.

Please submit responses for Round 2 survey by 7th November 2004 (Sunday) via email attachment, and please do not hesitate to contact me at s3061458@student.rmit.edu.au or on my mobile: 0413091122, should you require further information. Once again, thank you for your time and your contribution to this research.

Regards,
Casta YL Choong
PhD Candidate,
School of Property, Construction and Project Management,
Building 8, Level 8, Room 74 (8.8.74)
RMIT University
Swanston Street
Melbourne
## R2-SECTION A: SURVEY ON THE LEVEL OF ICT TOOLS USED DURING BUILDING DESIGN PROCESS

Please give each activity below (as suggested in Round 1 survey) a separate rating according to the following values: 5= Essential; 4= Helpful; 3= Fairly useful; 2= Not useful; 1= Unnecessary.

The first rating is for CURRENT use of ICT by professionals to perform these activities. Second rating is for FUTURE (in 5 years) where professionals will use ICT while conducting each of these activities.

**Please note: a brief description for each activities will display when you move your mouse to the red corner right top.

<table>
<thead>
<tr>
<th>A1</th>
<th>Current ICT used</th>
<th>Future ICT used</th>
</tr>
</thead>
<tbody>
<tr>
<td>A11 Develop and Define Design Requirements</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A12 Site Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A16 Seek client's initial feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A17 Estimate results</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A18 Identify potential results, target users</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A19 Integrate Value Management Process</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A20 Review concept brief</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A21 Highlight mismatches and risks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A22 Prepare Outline Proposal</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A23 Ensure outline plan fulfills project brief</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A24 Review authorities' requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A25 Assess client's initial feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A26 Prepare Preliminary Estimate</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A27 Development of Opinion of Probable Cost and Program (OPC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A28 Engineering cost estimates/ issues with engineers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A29 Complete Design Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A30 Prepare Sketch Design Documentation</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A31 Coordinate all consultants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A32 Run Design Evaluation Session</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A33 Gather feedback from all authorities and consultants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A34 Complete Documentation Stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A35 Conduct Detail Design Management</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A36 Prepare detailed architectural drawings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A37 Conduct Cost Checking</td>
<td>5 4 3 2 1</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>A38 Identify and analyze life cycle cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Again, to give you a refresh, ICT tools for this study are categorised into 3 categories and refer to:

**ICT Infrastructure**: Internet, Internet; Internet; Windows Operating System; Personal Area Network (PAN); Bluetooth, Information Exchange Standard, Authentication, Digital Signatures, and Cryptography Technology, etc.

**ICT for Communication**: Email, Videoconferencing, Chatroom Solution, Workflow Solution, Teleconferencing, Personal Digital Assistant (PDA), etc.

**ICT for Information Management**: Office Automation System, Database, Sketches / Hardcopy Data, CAD, 3D Modelling, Multimedia, Artificial Intelligence (AI), Electronic Data Interchange (EDI), Digital Fax, etc.

Five-point Likert-like rating scale:
(a) Essential – if you believe these tools allow project participants to perform work that was not possible before.
(b) Helpful – if you believe these tools have significantly decreased effort and made things much more efficient and of better quality.
(c) Fairly useful – if you believe these tools are useful in performing work.
(d) Not used – if you are not currently using these tools, they could be used and you have interest in using these tools in future.
(e) Unnecessary – if you have no interest in these tools and they are not needed to be used in the future.

YOU HAVE COMPLETED R2-SECTION A

Please proceed to R2-Section B (Current) Questions
## ROUND 2: SECTION B: SURVEY ON USAGE LEVEL OF ICT TOOLS (FUTURE)

### Future ICT Application Used

Please rate how you anticipate the usage level of the following ICT tools for each activity. Choose a rating from 1 to 5, where 1 = Daily, 5 = Occasionally, and 0 = Not applicable. You have had one year of "Usage Rating". Rate each tool for each activity based on the frequency of use. Then, add up the total score for each activity to get the overall "Usage Rating".

*Note: You may choose a tool for each activity. You may also use the same tool for the same activity multiple times.*

### Design Activities for Outline design stage

<table>
<thead>
<tr>
<th>Activity No.</th>
<th>ICT Tools</th>
<th>ICT for Infrastructure</th>
<th>ICT for Communication</th>
<th>ICT for Information Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Create Schematic Design Stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A11</td>
<td>Develop and Outline Design Requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A12</td>
<td>Line with Architect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A13</td>
<td>Site Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A14</td>
<td>Conduct Preliminary Feasibility Design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A15</td>
<td>Assessment of Consultant recommendations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A16</td>
<td>Conduct environmental analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A17</td>
<td>Stakeholder initial feedback</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A18</td>
<td>Estimate Scope of Work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A19</td>
<td>Identify potential rate per unit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A20</td>
<td>Prepare design proposals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A21</td>
<td>Review contractors' proposals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A22</td>
<td>Line with consultant contract</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A23</td>
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<td>Search for principal subcontracts</td>
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<td>Obtain data for actual subcontracts</td>
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<td>Prepare plans for actual subcontracts</td>
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<td>Obtain details and cost estimates</td>
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<td>Complete Design Development</td>
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<td>Provide updated subcontracts</td>
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<td>Obtain feedback from all architects and consultants</td>
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<td>Apply for planning permit</td>
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<td>Prepare Detailed Design Cost Plan</td>
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<td>Establishing bidding cost</td>
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<td>Prepare alternative estimates</td>
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<td>Prepare budget program</td>
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<td>Prepare for change &amp; organization plan</td>
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<td>Controls Final Design Management</td>
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<td>Develop final engineering design</td>
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<td>Submit for final design</td>
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<td>Conduct Cost Checking</td>
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<td>F2</td>
<td>Analyze &amp; evaluate design alternatives</td>
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<td>F3</td>
<td>Investigate design cost effectiveness</td>
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<td>F4</td>
<td>Identify and analyze at-risk cost</td>
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<td>F5</td>
<td>Review, create &amp; evaluate design</td>
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<td>Conduct design cost check</td>
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<td>G1</td>
<td>Audit Completion of Final Plan</td>
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<td>G2</td>
<td>Conduct final audit</td>
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<td>G3</td>
<td>Payment &amp; separate subcontracts</td>
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<td>To consider Occupational Health &amp; Safety Design</td>
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<td>G5</td>
<td>Conduct site management</td>
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</table>

**Overall "Usage Rating"**

You have completed Section B. Please proceed to Section C Questions.

### Please proceed to Section C Questions
ROUND 2 SECTION C

If there are any ICT tools which you think we have omitted in the previous Part B, please add in the following space provided.

<table>
<thead>
<tr>
<th>ICT Categories</th>
<th>ICT Tools</th>
</tr>
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<tbody>
<tr>
<td>ICT Infrastructure</td>
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</tr>
<tr>
<td>ICT for Communication</td>
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<tr>
<td>ICT for Information Management</td>
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<tr>
<td>Others</td>
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</tbody>
</table>

COMMENT FOR ROUND 2 SURVEY

THANK YOU FOR COMPLETING ROUND 2 SURVEY!!

Please save this copy and send it back to me via email attachment

HAVE A NICE DAY...
Email Notice to begin Round Three

Dear Delphi panel member,

Thank you very much for your responses to round 2 survey. This is the third round. Once again, we have spent days reviewing your feedback and comments before refining the round three survey.

We have found the results from round 1 and round 2 interesting and so we will probably need to spend some time in analysis after this round. We will email you the preliminary outcomes after the analysis is completed.

You will find two documents attached to this email, firstly the “Instructions for Round 3” in word document format and the “Round 3 Survey Questions” in Excel format. Please read all directions carefully before answering the questions. We suggest that you print out the “Instructions” for ease of reference throughout this round of questions.

Each of your responses to the survey is significant to this research and we hope you can submit responses via email attachment for Round 3 survey by 28th November 2004 (Sun), but if that is not possible could you email or call me to let me know the date you expect to return the survey.

Once again, thank you for your contribution to the research. I would like to say that your knowledge and patience has greatly helped the progress of this research.

Regards,

Casta
Instruction to begin Round 3 Delphi Survey
(Note: Please print out this section and read in conjunction with the attached survey question in excel format)

Dear Delphi Panel members,

Thank you for your responses to Round 2. Here we commence the third round of this survey. Round 3 will be used to provide you with an opportunity to reconsider your rating for “current” and “future” use of ICT tools for the full range of activities in building design process. If there are any activities which you have omitted during the previous stage, could you please rate them accordingly.

R3-Section A (Current) and B (Future)

Following each activities code and description will be your previous rating for each activity (refer column C). Please review your original rating and leave it blank if you do not need to change this, enter a new rating if your need to change it.

The five point Likert-like rating scale used in the pass rounds was as follows:-

- (5) Essential – if you believe these tools allow project participants to perform work that was not possible before;
- (4) Helpful – if you believe these tools have significantly decrease effort and made things much more efficient and of better quality;
- (3) Fairly useful – if you believe these tools are useful in performing job;
- (2) Not used – if you are not currently using these tools, they could be used and you have interest on using it in future;
- (1) Un-necessary – if you have no interest in these tools and they are not needed to be used in the future.

In BLOCK 2, we are seeking your view on the value added by using of ICT tools in each activity. Choose as many as you wish based on the following scale:

C = Cost efficiency means able to produce more with lower cost

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T = **Time efficiency** means able to produce more in shorter time period
Q = **Quality** means able to perform the task in better quality than it previously was and with less effort
O = **Opportunity** means able to perform task that may not have been previously done

Finally, we ask you to identify “barriers” for ICT implementation. Choose as many as you wish with the following scale:

- **T** = lack of training for soft/ hardware implementation
- **C** = Culture barriers such as: threat of ICT; project based nature of construction project; adversarial culture between project professionals, etc.
- **A** = lack of availability of some soft/ hardware
- **L** = Legal issues such as: security
- **S** = lack of top management support
- **I** = lack of investment in soft/hardware

**R3 – Section C**

Please feel free to comment or suggest any other “value added” issues or “barriers” that you believe we have left out in the previous section.

Please submit responses for Round 3 survey by 28th November 2004 (Sunday) via email attachment, and please do not hesitate to contact me at s3061458@student.rmit.edu.au or on my mobile: 0413091122, should you require further information. Once again, thank you for your time and your contribution to this research.

Regards,
CASTA
<table>
<thead>
<tr>
<th>CODE</th>
<th>ACTIVITIES</th>
<th>Your</th>
<th>Current ICT used</th>
<th>Value added</th>
<th>Barriers</th>
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<td>Facilitate</td>
<td>Time</td>
<td>Cost</td>
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<td>Site Analysis</td>
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<td>Constitute Outline Flexibility Design</td>
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<td>A15</td>
<td>Conduct environmental analysis</td>
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<td>A16</td>
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<td>A18</td>
<td>Identify alternative designs</td>
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<td>Conduct Value Management Process</td>
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<td>Evaluation and development of alternative designs</td>
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<td>Presentations</td>
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<td>Prepare Preliminary Estimate</td>
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<td>Development of Opinion of Probable Cost and Program (OPC)</td>
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<td>Engineering cost studies with engineers</td>
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<td>Search for principal solutions</td>
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<td>Select suitable design / cost solution combination</td>
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<td>Evaluations of choices of alternatives</td>
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<td>Improvement of design and cost options</td>
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<td>Complete Design Development</td>
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<td>Coordinate with all consultants</td>
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<td>Make required design changes</td>
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<td>Rent Design Evaluation Session</td>
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<td>Integrate preliminary consultant's advice in design</td>
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<td>Review authoritization requirements</td>
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<td>Gather feedback from all authorities and consultants</td>
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<td>Finalized design documents</td>
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<td>Allow for planning permit</td>
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<td>Prepare Schematic Design Cost Plan</td>
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<td>Prepare budget program</td>
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<td>Prepare time schedule &amp; organization plan</td>
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<td>Analyze &amp; evaluate design alternatives</td>
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<td>Investigate design cost efficiency</td>
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<td>Identify and analysis life cycle cost</td>
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<td>Review optimization of energy performance</td>
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<td>Conduct design cost check</td>
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<td>Audit Completion of Detail Plan</td>
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<td>Lodgement for building permit</td>
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<td>Rationlize &amp; integrate subsystems designs</td>
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<td>To consider Occupational Health and Safety Design</td>
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<td>A65</td>
<td>Conduct risk management</td>
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YOU HAVE COMPLETED R3-SECTION A FOR CURRENT

Please proceed to R3-Section B (Future Questions)
### R2 - Section B: Survey on the Level of "Future" ICT Tools Used during Building Design Process

Please rate according to the following scales:

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<tr>
<th>Code</th>
<th>Activities</th>
<th>Your Rate</th>
<th>Current ICT Used</th>
<th>Value Added</th>
<th>Barriers</th>
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<td>A1</td>
<td>Complete Schematic Design Stage</td>
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<td>A11</td>
<td>Define scope and phasing</td>
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<tr>
<td>A12</td>
<td>Engage manufacturers and consultants</td>
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<td>Select consultants</td>
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<td>Develop tender packages</td>
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<td>A15</td>
<td>Conduct environmental analysis</td>
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<td>Seek client's initial feedback</td>
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<td>Assessment of value</td>
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<td>A13</td>
<td>Conduct Value Management Process</td>
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<td>A131</td>
<td>Review conceptual briefs</td>
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<td>Allocate costs</td>
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<td>Highlight mismatched risks</td>
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<td>Evaluate and develop of alternative solutions</td>
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<td>Prepare design proposal</td>
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<td>A143</td>
<td>Review authorities' requirements</td>
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<td>Collect design costs</td>
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<td>A145</td>
<td>Access client's initial feedback</td>
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<td>A146</td>
<td>Prepare Design Intent Application Preparation</td>
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<td>Preparing Preliminary Estimate</td>
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<td>Development of Opinion of Probable Cost and Program (OPC)</td>
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<td>Engineering cost studies/ analysis with engineers</td>
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<td>Develop schematic design drawings</td>
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<td>Review authorisations/ requirements</td>
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<td>Gather feedback from all authorities and consultants</td>
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<td>Develop cost plan</td>
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<td>Complete Design Management</td>
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<td>A331</td>
<td>Prepare details of architectural drawings</td>
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<td>Develop detail engineering design</td>
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<td>Conduct cost checking</td>
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<td>A232</td>
<td>Investigate design cost efficiency</td>
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<td>A233</td>
<td>Identify and analysis lifecycle cost</td>
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<td>A234</td>
<td>Optimize strategies</td>
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<td>Conduct cost analysis</td>
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<td>Audit Completion of Design Plan</td>
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**You have completed R3 Section B for (Future)**

Please proceed to R3 Section C (Comment)
### Round 3 Section C

#### COMMENT FOR ROUND 3 SURVEY

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THANK YOU FOR COMPLETING ROUND 3 SURVEY!!

Please save this copy and send it back to me via email attachment.

HAVE A NICE DAY...
APPENDIX-F

DELPHI ROUND FOUR SURVEY PACK

Email Notice to begin Round Four

Thank you for all of the time and effort you have already invested in this research, and I am pleased to say that this should be the final round. This is also the most important round as we are now seeking to gain consensus on the need for ICT during all of the design stages. We have modified Round 4 survey based on some of the experts’ comment to ensure a better understanding on this survey. You will find on the attached summaries all of your answers against those of the other experts.

You will find two attachments in this email:-

Attachment 1: Comment made in Round 3 by the Experts

- In this section, kindly please express your comments for the five statement made by panel members in the previous rounds.

Attachment 2: Round 4 Questionnaire

- Round 4 Questionnaire comprise three sections: Section A, B & C
- You should only answer and focus on those highlighted activities in Green for Section A & B
- Rating in ‘green’ refers to MODE (also known as common view); while your rating will highlighted in ‘orange’. You can either agree or disagree with the MODE.
- You are required to comment on why you cannot agree with the common response.
- Section C required your comment for this round survey.

I would appreciate you completing this round by 17th April, and if you need any further assistance then please contact me by email at s3061458@student.rmit.edu.au / casta1122@yahoo.com. Once I have analysed all of the responses, I will send you a copy of the process map which highlights the activities where ICT will assist the design stages of construction projects, as well as a summary of the findings.

Thank you again for all of your assistance on this research project, it would not have been possible without your help.

Regards,
Casta
Comments made in Round 3 by the Experts

1. *The design and evaluation activities rely on having staff with expertise and experience. Whilst ICT has proven beneficial for communication and information management, it will not replace the expertise and experience of a design team.*

What is your comment?

2. *There is no need to be concerned about ICT infrastructure, as the construction industry will use whatever is available in the marketplace.*

What is your comment?

3. *Other ICT tools that should be included are: Visualisation tools (4D CAD, VR, GIS); Management tools (document management, construction planning, cost planning, digital photography); Communication tools (Voice over IP, mobile communications such as XDAII), etc.*

What is your comment?
4. *There is a need for improved hardware (graphic cards, monitors) for display of 3D and 4D CAD drawings.*

What is your comment?

5. *The current levels of interaction between design team members at each of the design stages are lower than they will be in the future. When an integrated model is used then all members of the design team will interact more actively. This should then improve the productivity and quality of the design work being undertaken by the design team.*

What is your comment?
<table>
<thead>
<tr>
<th>A1. <strong>Complete Schematic Design Stage:</strong></th>
<th>Function Rating from All Other Participants</th>
<th>Current ICT use</th>
<th>CURRENT</th>
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<tr>
<td>A11. Learn with Auditory</td>
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<td>ACTIVITIES</td>
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<td>Revised Rating</td>
<td>Reuse ICT Capabilities</td>
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<td>A1 Review Upcoming Construction Project Strategies</td>
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<td>A2 Revise and Update Design Strategies</td>
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<td>A3 Update with Authorities</td>
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<td>A4 Itemize Project Budgets</td>
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<td>A5 Reroute Design Changes</td>
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<td>A6 Review Consultant’s Recommendations</td>
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<td>A7 Conduct Environmental Analysis</td>
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<td>A8 Update and Implement Feedback</td>
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<td>A9 Identify Potential Site Opportunities</td>
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<td>A10 Assessment Results</td>
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<td>A11 Conduct Value Management Process</td>
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<td>A13 Finalize Project Plan</td>
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<td>A14 Prepare design proposal</td>
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<td>A15 Review and edit contract requirements</td>
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<td>A16 Ensure that project plan is complete</td>
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<td>A17 Finalize design document</td>
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<td>A20 Conduct Design Development</td>
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<td>A23 Coordinate with project manager</td>
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<td>A24 Ensure that project plan is complete</td>
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<td>A25 Conduct Design Development</td>
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<td>A26 Prepare design document</td>
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<td>A27 Coordinate with project manager</td>
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<td>A28 Ensure that project plan is complete</td>
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**YOU HAVE COMPLETED R3 SECTION D FOR FUTURE**
Please leave us as much comment as possible on your rating:

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<th>COMMENT</th>
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THANK YOU FOR COMPLETING 'ROUND 4' SURVEY!!

Please save this copy and send it back to me via email attachment.

HAVE A NICE DAY...
APPENDIX-G

REVISED ROUND FOUR SURVEY PACK

NOTICE TO CALL BACK DELPHI ROUND FOUR SURVEY

Dear Delphi Panellist,

Further to the Round 4 Delphi Survey that has been sent out on 18/03/05, few participants have commented to me that they have some difficulties understanding the questionnaire. Particularly on the SECTION A & B.

Hence I have decided to recall Round 4 Delphi survey. You are kindly requested to ignore the survey that has already sent out to you. Meanwhile please note that an amended Round 4 Survey will be prepared and forwarded to you shortly.

Please accept my sincere apology for any inconveniences.

You valuable feedback is critical for this research, and you participation is highly appreciated.

Regards,

casta
Email Notice to begin REVISED Round Four

Dear Delphi Experts,

Thank you for all of the time and effort you have already invested in this research, and I am pleased to say that this should be the final round. This is also the most important round as we are now seeking to gain consensus on the need for ICT during all of the design stages.

You will find on the attached summaries all of your answers against those of the other experts.

Please note that this is the amended Round 4 Delphi Survey which would supersede the previous survey sent to you dated 18th March 2005.

You will find two attachments in this email:-

Attachment 1: Comment made in Round 3 by the Experts
- In this section, we need your comments for the five statement made by panel members in the previous rounds.

Attachment 2: Round 4 Questionnaire
- Round 4 Questionnaire comprise three sections: Section A, B & C
  - In Section A & B, you would find that there are activities that have been highlighted in GREEN colour in various design stages. These activates are highlighted because your response to these activities from Round 3 Survey is varied to the "Common View" of the majority of the collected data. In other words, your comments on these activities are different to most of the other surveyors from our finding.
  - In Section A & B, we need your attention and response ONLY on these highlighted activities.
  - You would note that in the highlighted activities, the common views from other surveyors are marked in GREEN. Your response from Round 3 survey is marked in ORANGE which is different to the Common View.
  - You are kindly requested to re-consider carefully your previous responses on these highlighted activities. If you believe the Common View does represent your opinion then please tick the column "Agree with the Mode". However, if you still believe that your previous response reflects the true situation of your practice then please select "Disagree with the Mode" and provide your reason in "Your Comment" column.
  - In Section C, we need your general comments regarding to Round 4 Survey. If there is anything you...
believe that would be beneficial for this research please specify in this section.

I would appreciate you completing this round by 17th April, and if you need any further assistance then please contact me by email at casta1122@yahoo.com (preferably) / s3061458@student.rmit.edu.au. Once I have analysed all of the responses, I will send you a copy of the process map which highlights the activities where ICT will assist the design stages of construction projects, as well as a summary of the findings.

Thank you again for all of your assistance on this research project, it would not have been possible without your help.

Regards,

Casta
Comments made in Round 3 by the Experts-REVISED

1. The design and evaluation activities are highly depend on the staff’s expertise and experience of individual practice. Whilst ICT has proven beneficial for communication and information management, it will not replace the expertise and experience of a design team. Do you agree with the above statements?

What is your comment?

2. The variety and type of ICT infrastructure available on the marketplace is not a major concern to the industry. Because the construction industry is capable to adjust its operation process to suit the available ICT in the marketplace. The major concern for the industry is whether quality improvement could be achieved by adopting new ICT software.

What is your comment?

3. ‘Other ICT tools that should be included are: Visualisation tools (4D CAD, VR, GIS); Management tools (document management, construction planning, cost planning, digital photography); Communication tools (Voice over IP, mobile communications such as XDAII), etc.’

Would you agree or disagree that your office’s productivity can be further enhanced if the above mention ICT tools are used in your current practice.

What is your comment?
4. *As the evolution of existing softwares is so quickly, often upgrade your existing software also involves a major hardware improvement. Do you think it is necessary?*

What is your comment?

5. *Do you agree or disagree that the quality and productivity of various design process could be further enhanced in the future if an’ integrated communication model’ can be formed and efficiently implemented among various stakeholders.***

What is your comment?

THANK YOU FOR YOUR COMMENTS ON THE ABOVE STATEMENTS, KINDLY PLEASE PROCEED TO ROUND-4 QUESTIONNAIRE!!!
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<th>Your Actions Code for OOG</th>
<th>Your Comments if you disagree with Model</th>
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### A1: Complete Schematic Design Stage

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<td>Concept Outline and extent of Design</td>
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### A2: Design and Define Design Requirements

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<td>Engineering Cost Estimation</td>
<td>Review and Validation of Design</td>
<td>Selection and Development of Alternatives</td>
<td>Preparation</td>
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### A3: Conduct Final Measurement Process

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<td>Cost Estimation</td>
<td>Review and Validation of Design</td>
<td>Selection and Development of Alternatives</td>
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### A4: Complete Design Development

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### A5: Site Design and Design Development

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### A6: Conduct Final Evaluation

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<td>Selection and Development of Alternatives</td>
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### A7: Prepare Sketch Design Cost Plan

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### A8: Complete Documentation Updates

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### A9: Conduct Cost Checking

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### A10: Audit Completion of Design

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**YOU HAVE COMPLETED** 8/4 - SECTION A FOR (CURRENT)**

Please proceed to fill Section B (Future) Questions
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<th>Progress Rating From All Users Participant(s)</th>
<th>Your Response For this Review</th>
<th>Your COMMENT if you disagree with Model</th>
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YOU HAVE COMPLETED R4 SECTION B FOR (FUTURE)

(please proceed to R4 Section C for comments)
Please leave us as much comment as possible on your rating:

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THANK YOU FOR COMPLETING 'ROUND 4' SURVEY!!

Please save this copy and send it back to me via email attachment.

HAVE A NICE DAY...