Using Information and Communication Technology to Facilitate Supply Chain Management in the New Zealand Construction Industry

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ABSTRACT

The New Zealand construction supply chain today is inefficient. From a literature review it is found that non value adding activities including waste of time and materials are caused by islands of information with ineffective communication between supply chain participants. This represents an opportunity for Information and Communication Technology (ICT) to provide a strategic supply chain management model for the industry enabling interaction and shared information between all parties. To evaluate the performance of ICTs in the New Zealand construction supply chain, this thesis uses as a case study newly launched software---BlueSky. BlueSky was developed by the Building Integration Software Company located in AUT Technical Park. BlueSky was designed to integrate the fragments of the current information flow of the chain from architect through to the end property owner. Supporting Data was gathered by distributing a structured questionnaire designed to find the opportunities and inhibitors for utilizing ICTs to facilitate the synthesis of the chain. 200 responses were received. The study was funded by a TEC grant. The BlueSky case study is based on two pilot sites; one is an architectural design company and the other is a master contractor company in Auckland. The case study also evaluated the potential problems which may bring risks to supply chain members and provide possible recommendations for future research. The study found from the results of the questionnaire that a significant shift in the mindset of participants of the supply chain will be necessary in terms of collaboration and team work if mutual benefits are to be achieved. It is found that in the two pilot sites BlueSky did make a significant difference in terms of reduced cost, accuracy of information, improved documentation management, and overall increased speed and clarity of information. In the wider community of the industry as a whole considerable education is needed to break down mistrust between members. In general each member appears to be determined to secure the best result as individuals rather than considering the overall outcome for the whole chain. This reluctance to co-operate is coupled with a reluctance to utilize ICTs. Recommendations are made to overcome this mindset.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Research Context

A supply chain can be viewed as a complex web of information systems, operational activities and management techniques that exist amongst entities that maintain relationships of varying strengths with one another (Bjork, 2002).

It is generally accepted in the literature that efficient Supply Chain Management (SCM) is an effective way to reduce cost. This can be achieved through building long term relationships with customers and suppliers to achieve benefits for each component of the supply chain (Chopra, 2002). An individual component (enterprise) needs to ensure information flow in the entire supply chain to achieve these benefits (Goldstein & Zack, 1989). However, in the construction industry, the information flow from building component manufactures, suppliers, designers and architectures to the builders, land developers, quantity estimators, building trades and building owners is complex and often chaotic.

Research Question

The research question of this thesis is "How can Information and Communication Technology (ICT) facilitate the synthesis of supply chain management in the New Zealand construction industry".

The thesis was based on New Zealand construction industry where the student is an employee of Building Integration Software Company (BISCO). This study considered how the development of new information technology can be employed in the construction industry to integrate information flow and material flow through the entire supply chain and what kind of effects it will bring into construction supply chain management based on a case study of two pilot sites, an architectual design company and a master contractor company in Auckland using “BlueSky”, a construction supply chain management software currently developed by BISCO. This study seeked to clarify and summarize the current business process for the supply chain in the New Zealand construction industry using BlueSky pilot sites as an example. Opportunities and risks arising from utilizing BluSky were considered. The outcomes of using BlueSky were examined carefully from both positive and negative sides. The study also identifyied a growing need for future research in collaboration of ICTs and construction supply chain management.

The objectives of the thesis are to:

1. Identify problems inherent in supply chain management and partnering in the New Zealand construction industry.
2. Identify how ICT might be used within the supply chain to facilitate benefits for the construction industry.
3. To propose a supply chain model using ICTs for use in the New Zealand construction industry.

This thesis is produced in partial fulfillment of Master of Business Degree. The thesis is a research based thesis by way of case study, with a focus on an amalgamated business management strategy, encompassing supply chain integration and ICTs within the construction industry.

The status of New Zealand construction supply chains does not seem to have changed much in the last decades. Peansupap and Walker (2006) observed that any lack of cohesion and co-ordination is less the result of ill-will or malignancy on the part of any groups or individuals, but more the result of forces beyond the control of any individual or group and which are affecting all.

From previous researches, three main conclusions can be drawn according to the current status of construction supply chains (Vrijhoef & Koskela 2000). First , the construction supply chain has a great deal of waste and problems. Secondly, most of waste and problems have a negative flow effect on other stages of the construction supply chain than where it is recognized. Thirdly, waste and problems are because of the antiquated and short sighted control of the construction supply chain and also the independent control of each stage of the chain.

1. Waste and problems in construction supply chains: Sobotka (2000) found in his study on construction material flows that delivering the physical flow of material between elements of the supply chain only from 0.3% to 0.6% of the total time is value being added. Only for the interface between the main contractor and the supplier has an average cost reduction potential of 10% (of material costs) through improved logistical procedures been shown (Sobotka, 2000). The waste can be even higher when taking the whole supply chain into consideration.

2. Root causes of waste and problems in former stages of the construction supply chain: Sobotka(2000) found that incomplete planning and information on the amount of necessary material are characteristic for materials purchasing in construction component manufacturing, Vrijhoef and Koskela (2000) found that the construction component orders are generally made according to the incomplete and wrong design data. In another study on the supply of concrete façade component, Roy and Gaze (2003) found that several of the problems in the factory were caused by external chain partners. The design documents are often insufficient and most of the issues are not described in detailed. Changes are caused by unavailable, late, wrong and incomplete information and are often not well communicated. On the other hand, the factory may bring problems for other chain partners as well. When trying to improve its activities it supplied elements in a different order. The factory needed to have all drawings at the same time because of its own inadequate scheduling of its information needs.

3. Myopic control of the construction supply chain: It was shown that the purchasing price is the primary criterion for supplier selection (DTI Internet, 2006). O' Brien (2000) found that subcontractors are nearly always selected according to price. Roy and Gaze (2003) found that decision making on the improvement of supply chain is often limited by those solutions one has experience of. It is customary to use material inventories as buffers against disruption. Similarly, Marsh and Finch (1998) found that nearly all supply chain partners add a time buffer to their schedule to allow for lack of co-operation and an inefficient flow of information. Adding a buffer increases the time cost.

According to these previous researches, it can be seen that waste and problems in construction supply chains are extensively present and persistent. As a result of interdependency, the occurrence of waste and problems are interrelated with causes in other stages of the supply chain (Ward, 2005). What is more, myopic control of the construction supply chain enlarges waste and problems and makes things even worse. It is obvious that forces are not controlled and their organizational after effects hindered the development of construction supply chain. A part of the new model, such as open building system, sequential procedure, the new construction mode, design/build and partnering, have directly attacked this lack of cohesion and co-ordination (Stevens, 1989). There are several other examples: generic initiatives, like re-engineering, time compression, quality and information technology. These have been recently implemented in construction (Peansupap & Walker, 2006). However, only few of them succeed.

What may be the reason for the failures? One possibility is pointed by Peansupap and Walker (2006) who compared a time compression program in construction with a corresponding program in manufacturing. They conclude that for builders with their project culture it is easier to implant renewal efforts (Peansupap & Walker, 2006). However, at the same time this means that a fundamental mental change was hardly needed in implementing the construction time compression program, and thus its cultural and mental influence was limited.

In another research, Dainty et al.,(2001) it is shown that communication perspective provide a useful conceptual basis for analyzing construction supply chains. In this study, the author showed primary evidence for the relevance of communication and the construction supply chain waste and problems.

The one way construction supply chain can be understood as a network of commitments, which are emerged from continuous conversations for action just like other kinds of business (Dainty et al., 2001). These conversations and commitments are regularly carried out in the critical phases of a construction supply chain: design, materials procurement and logistics and site coordination.

In another thorough study on design management (Vrijhoef & Koskela, 2000), the central problems found were defined as follows:' the involved persons perceive uncertainty on what has to be done, who has to do it and when it has to be ready. The actors in the design project organization have no common and clear understanding on what should be designed'. This pointed out that conversations for action were either ineffective or missing in the coordination of design.

Vrijhoef and Koskela (2000) found different supply chain management problems in different stages of the construction supply chain. Many of the problems are caused directly and indirectly by insufficient coordination, communication, and these commitments lead to wrong inform about schedule changes, late confirmation of deliveries, and lack of feedback procedures.

From site coordination point of view, Dainty (2001) found that the specialists [contractors] are just thrown together and told to sort things out between themselves. These kinds of phenomena in the supply chain are the causes of misunderstanding. It shows a complete lack of coordination and structure in the communication and collaboration on site.

The study of Naim and James (2001) about quality defect costs summarizes the situation in construction: "they claim that the majority of causes for defects are related to various forms of ambiguity, such as ambiguity about clients wishes (e.g. concerns, interests and requests), ambiguity about organizational structure and responsibilities (e.g. actors/ performers, agreements and promises), and ambiguity in drawings (e.g. descriptors of conditions and client specifications)."

It is not surprising for communications via ICT to be regarded as the most important opportunity for the future construction supply chain management. There have been many attempts to capture the essence of construction information using various components of Information Technology. For example, web-based or mobile based supply chain management system could provide Just-In-Time communications between architects and builders: when the architects update the house plan, the information will be sent immediately to a mobile device through which the builders can get information on-site (Peansupap & Walker, 2006). This will reduce the time cost and increase the accuracy of the information significantly. Moreover, new ICTs such as Radio Frequency Identification (RFID) could also be used in material flow management to locate and track raw material on a real-time basis (Marsh & Finch, 1998). The ultimate goal of ICT as it related to construction supply chain management is to collect, access, analyze the supply chain partners' requirements and enhance the performance of SCM in construction industry.

1.2 Methodology

A case study incorporating action research was selected as the main research methodology.

In deciding which research strategy and methods were most appropriate Yin (2003) suggested that three conditions need to be considered.

1. The type of research question.
2. The extent of control the researcher has over actual behavioral events.
3. The degree of focus on contemporary as opposed to historical events.

Yin claimed that generally case studies were the preferred strategy when 'how' or 'why' questions were being considered, when the researcher had little control over events, and when the focus was on contemporary phenomenon within some real life context.

Validity of Case Study As A Research Strategy

Yin formulated a set of methodological principles for case studies that were consistent with the conventions of positivism. Earlier, Lee (1989) had also made a good "case" for case studies to be accepted as vechicles for research. Klein and Myers (1999) cite Yin and state that for academic research, 'case study research is now accepted as a valid research strategy', p.68.

The case study was based on the Building Integration Software Company Ltd (BISCO), a start up company located in AUT Technical Park. BISCO is currently developing a construction supply chain management software. The first version has just been released to its two pilot site, an architectural design company and a master constractor company in Auckland. The student was involved in the process of the business process review, software implemetation, benefits analysis and risk management.

Structured questionnaire also played an important role in this research. Survey and questionnaire are normally used as one of the primary research strategies employed by behavioral and social scientists to identify the human behaviors and beliefs. In this research, a structured medium length, multi-part questionnaire was used to determine the current New Zealand construction industry supply chain management situation and ICT adoption rate and trend. It contained both open-ended and close-ended questions.

Data collection

Stake (1994) and Yin (2003) advise that case study research allows researchers to understand the nature and complexity of processes by using multiple sources of data. Yin identified primary sources of data as being documentation, archival records, interviews, direct observation and participation. According to Stake the importance of multiple sources of data to enable triangulation was well established. For this research the researcher used each of the primary sources identified above, plus the researcher kept a diary of events.

Data analysis

The unit of analysis was the project for the two pilot sites using BlueSky software. This was a single case study which enabled a holistic study of systems and processes, management intervention, and outcomes.

CHAPTER 2: RESEARCH METHODOLOGY AND DESIGN

2.1 Introduction

This chapter outlines the research paradigm, methodology and design used in the collection of data for this study. The aim of this study is to examine managerial and economic aspects of the introduction of information technology into construction supply chain management, its recent rapid growth, and to draw conclusions about New Zealand construction supply chain management needs. To ensure a logical and consistent research design, the research in this study drew on the work of other studies in construction supply chain management in other country. This study also extended those studies in the investigation of aspects of partnering and ICT adoption. Action research was also used and the researcher's experience and involvement in BlueSky was drawn upon.

I accept that in using my own experiences to develop the theory that I am taking an interpretative approach as described by Lincoln and Guba (1995). In effect I, as the researcher, have become the research instrument. I believe that I am unbiased but none-the-less what I might believe to be reality could be challenged as being merely my perception of reality. Such a challenge would usually be on the grounds that I was emotionally involved. Bevan (2000), for exampl, describes her experiences of being a researcher at the same time that she was acting as a change agent (her research topic being managing change) and how she was challenged on the grounds of lack of distance from research subjects. Her reply was that she was aware of the need and to maintain a professional and objective detachment, and was able to do so McCutcheon and Meredith (1993) aslo warn against the dangers of losing objectivity in case study research.

This research applied Design Science Information System Research Framework introduced by Hevner et al. (2004) and also used Design Science Research Process (DSRP) presented by Peffers and Tuunanen (2006) as a guideline. A case study incorporating field study and a structured questionnaire were selected as the methodology and the rationale for this choice is included in this chapter.

The research question is:

- How can Information and Communication Technology (ICT's) facilitate the synthesis of supply chain management in the New Zealand construction industry?

The research question is composed of the following three questions:

- Identify problems inherent in supply chain management and partnering in the New Zealand construction industry.
- Identify how ICT might be used within the supply chain to facilitate benefits for the construction industry.
- What kinds of benefits and potential risks are brought by ICT based Construction Supply Chain Management System---“BlueSky” ?

2.2 Research paradigm

Hevenr (2004, p. 76) states that “there are mainly two paradigms which characterize the research in the information systems discipline, which are behavioral science paradigm and design science paradigm.” According to Hevner (2004, p. 76) the behavioral science paradigm is more focused on the “development and verification of theories that explain or predict human or organizational behavior.” On the other hand, the design science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts (Hevner et al., 2004, p 75). In this research context, a new concept of an ICT driven Construction Supply Chain Management System (BlueSky) is explored and evaluated.

Action research is another research paradigm which is employed in this study. Action research allows the researchers to develop knowledge and understanding as part of practice. It allows research to be done in situations where other research methods may be difficult to use (McCutcheon & Meredith, 1993). For example, it is often used when you must remain flexible, or you wish to involve the people in the system being researched, or you wish to bring about change at the meanwhile or the situation is too ambiguous to frame a precise research question. In short, action research is a useful way of doing qualitative research if the researcher is a practitioner who wishes to improve his understanding of practice. Also, it can be used by activists who wish to engage the client as co-researchers, especially in preliminary or pilot research (Mankin & Cohen, 2004). In short, action research is a research paradigm, a set of research methods composed by a certain set of principles and a certain style.

Cohen & Manion (1994, p. 186) define action research as ‘small scale intervention in the functioning of the real world and a close examination of the effects of such intervention’. Essentially, action research is a procedural design ‘to deal with a concrete problem located in an immediate situation’ (Cohen & Manion, 1994, p. 192). In this research the immediate situation would equate to the integrating ICTs with supply chain management process in construction enterprises, and the session-by-session observations and recording of activities would be the step-by-step monitoring necessary in action research. However, action research is a recursive procedure. The last point is not appropriate to this research since no attempt is made to further refine the model in order to return to the cycle. Such action could be the subject of a future study.

Therefore, this study is mainly applies the design science paradigm and follows the framework in the following developed by Hevner et al. (2004, p. 80) for Information Systems research and also the Action research (Cohen & Manion, 1994) as the research paradigm.

- Environment--- the research first looks into the corporate environment to search for the business needs in terms of people, enterprise and technology, which frames the research problem. Structured questionnaires were distributed aimed to identify the current issues in the New Zealand Construction Industry Supply Chain and also examined the attitude of the practitioners towards adoption of ICTs in their daily jobs.
- Case Study --- based on the business needs and problems identified from the environment, case study will be performed to measure how well the pilot sites use BlueSky system, focused on the key problems obtained from literature review,

participant observation, and the questionnaire. Usability testing will also be used to justify and evaluate BlueSky system.

- Theory Base--- included literature from Supply Chain Management, Partnering of construction supply chain and the existing BlueSky model, and constructs frameworks from the above mentioned literatures.

2.3 Research methodology

2.3.1 Structured Questionnaire

Structured questionnaire played an important role in this research. Survey and questionnaire are normally used as one of the primary research strategies employed by behavioral and social scientists to identify the human behaviors and beliefs. (Saunders et al, 2003) In this research, a structured medium length, multi-part questionnaire was used to determine the current New Zealand construction industry supply chain management situation and ICT adoption rate and trend. It contained both open-ended and close-ended questions. Some of the questions which measured attitudes and perceptions used the Likert-scale. This flexible format was used to solicit the most accurate and complete responses from the construction practitioners' representatives. The questionnaire consisted of 25 questions designed to elicit information for the current New Zealand construction industry supply chain environment. The questionnaire was developed into four sections: section A was designed to asked for basic information about the practitioner and their organization; section B was aimed to explore what software and system is used by the industry; Section C was designed to picture the current New Zealand construction supply chain management situation and Section D was to elicit the respondents' attitude towards adopting ICTs into the organization supply chain management. Moreover, in this research, some of the questionnaires were sent to the employees in BlueSky pilot sites and an interview followed by interviews.

As noted above, the questionnaire captures information from the New Zealand construction industry and the information gathered will assist in further development of BlueSky ICTs. The questionnaire is shown at Appendix 1.

2.3.2 Case Study

Robson (1993, p. 5) defines case study research as ‘a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence’.

The methodology used in this case study and presented followed the recommendation of Yin (1994) and has four stages:

1. Design the case study,
2. Conduct the case study,
3. Analyze the case study evidence, and
4. Develop the conclusions, recommendations and implications.

Case study is an ideal methodology when a qualitative, in-depth investigation is needed (Feagin, Orum, & Sjoberg, 1991). Case studies have been used in varied investigations, particularly in sociological studies, but increasingly, in instruction. Yin, Stake, and others who have plenty of experience in this methodology developed powerful research procedures. Following these procedures, the researcher should follow the methods and also develop and test in the scientific field. Whether the study is experimental or quasi-experimental, the data collection and analysis methods are known to hide some details (Stake, 1995). On the other hand, case studies are designed to bring out the details from the viewpoint of the participants using multiple sources of data.

Case study is also known as a triangulated research strategy. Snow and Anderson (1991) affirmed that triangulation can be composed by data, investigators, theories, and even methodologies. Stake (1995) stated that the paradigm that is used to ensure accuracy and alternative explanations are called triangulation. The requirement of triangulation arises from the ethical need to confirm the validity of the processes. In case studies, this could be done by using multiple sources of data. (Yin, 1984) The problem in case studies is to establish meaning rather than location.

The issue of generalization has appeared in the literature with regularity. It is a frequent argument of case study research method that the results are not widely applicable in the “real” world because it is always specific. Yin in particular argued that by presenting a well constructed explanation of the difference between analytic generalization and statistical generalization: "In analytic generalization, previously developed theory is used as a template against which to compare the empirical results of the case study" (Yin, 1984).

Yin (1994) presented at least four applications for a case study model:

1. To explain complex causal links in real-life interventions
2. To describe the real-life context in which the intervention has occurred
3. To describe the intervention itself
4. To explore those situations in which the intervention being evaluated has no clear set of outcomes.

Information technologies involve all four of the above categories, but this study will only report on the first two. There has been very little literature relating to the pace of acquisition of information technology at New Zealand construction industry supply chain management. For this reason, this research used a case study after consulting with experts in the field and with senior case researchers. Their recommendation was to conduct an in-depth study of the pilot sites of BlueSky system using case methodology. This study used a single case study on the nature of information technology acquisition in construction supply chain management.

Single case may be used to confirm or challenge a theory, or to represent a unique or extreme case. (Yin, 1994) Single-case studies are also ideal for revelatory cases where an observer may have access to a phenomenon. These studies can be holistic or embedded the latter occurring when the same case study involves more than one unit of analysis.

This is not to be confused with sampling logic, where a selection is made out of a population, the two pilot sites of BlueSky system. Each individual pilot site case study consists of a "whole" study, in which facts are gathered from participant observation and usability testing.

As in all research, consideration must be given to management the validity, including internal validity, external validity, and reliability. (Yin, 1989) Levy (1988) established construct validity using the multiple-case exploratory design, and internal validity using the multiple-case explanatory design. Yin (1994) suggested using multiple sources of evidence as a useful method of constructing validity. The current study used multiple sources of evidence; survey instruments, interviews, and documents. The specification of the unit of analysis also provides the internal validity as the theories are developed and data collection and analysis test those theories. External validity is more difficult to attain in a multiple-case study. Yin (1994) suggested that external validity could be obtained from theoretical relationships and from these generalizations could be achieved. It is the development of a formal case study protocol that provides the reliability that is required of all research.

The design of this case study closely follows that of the Levy study. The methodology selected by Levy (1988) was based on the seminal work by Yin (1984) and confirmed by Feagin et al. (1991). The "pattern matching" (Yin, 1984) of acquisition and use established in other environments may be shown to be applicable in construction industry supply chain management studies. Yin (1994) listed six sources of evidence for data collection in the case study protocol:

1. Documentation,
2. Archival Records,
3. Interviews,
4. Self administrated questionnaire,
5. Participant Observation, and
6. Physical Artifacts.

For this case study, a single case study method was used but also added to in the field by examination of aspects of adoption rate of ICT in construction enterprises and the knowledge base of supply chain in the industry.

Specific questionnaire items covered these areas. These categories were also employed in the case analysis.

1. Technological adoption rate,
2. Structural Arrangements,
3. Knowledge background,
4. Economic Environment (partnering), and
5. Benefits/Problems.

The questionnaires were distributed at two New Zealand Construction Industry conferences. This data gathering activity was co-sponsored by the Technology and Education Community (TEC).

2.4 Research Design

2.4.1 Research Plan

Overall, this research studies different disciplines and synthesizes and develops a new conceptual model to solve the problem in integrating ICTs with construction supply chain management effectively.

The literature review in information system (IS) subfields (seen in Chapter 3) identifies the current issues remaining in the strategic information systems literature. It strives to look for solutions from supply chain management and partnering management literature, and gains a conceptual idea of the solution by synthesizing the literatures. All the key concepts are abstracted from supply chain management (SCM), information and communication technology (ICT) and partnering subfields after the literature review.

Secondly, the specification of construction supply chain management system (CSMS) is based on supply chain management (SCM) literature, specifically the ICT driven SCM literature. CSMS applies ideas from ICT to the construction supply chain management and partnering domain, and in addition, takes ICT as a unique resource into the system, which is based on the conceptual framework derived from the application of ICT in SCM and Partnering. At this stage, a fully constructed conceptual system framework of CSMS is completed.

Finally, the research evaluates the BlueSky system by applying the case study on two pilot sites to see whether the result implies that the system can solve the identified problems and answer the research questions. The overall result of the BlueSky system and future research directions are then discussed.

Figure below shows the plan for conducting the research.

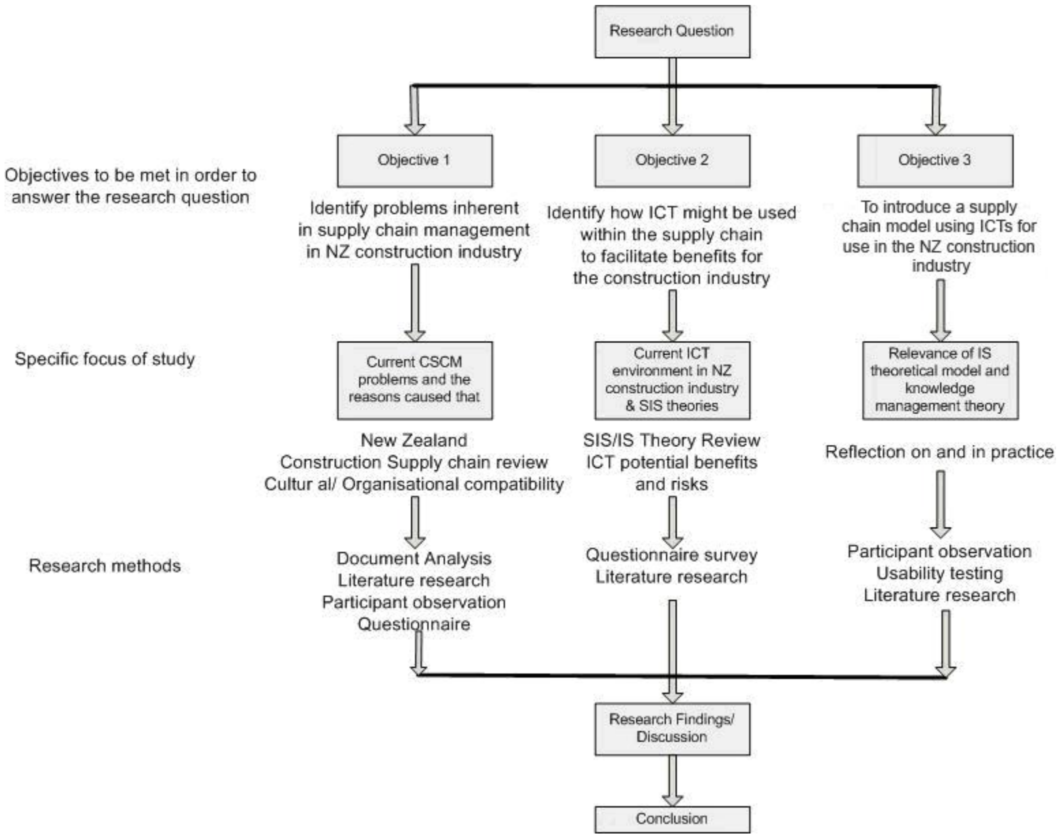

Figure 1: Research plan

2.4.2 Case Description

The purpose of this case study is to examine the effects of using BlueSky system in two pilot sites, and the effect of use of BlueSky on productivity, cost, time consuming, and communication in the two sites and their supply chain partners and their partner relationships were also examined. The two pilot sites are one architectural design company (site A) and one master contractor company (site B).

In order to address the research question and meet the objectives, the study needed to specifically identify:

- How was the value added to the pilot site by utilizing BlueSky system
- Were the benefits and risks realized by the practitioners?

The criterion for success in this study is:

- The utilization of BlueSky system added value to the construction enterprise supply chain management by establishing better information flow and effective communication among supply chain, reducing time consuming and cost, and better productivities.

The ability to measure the level of success was derived primarily from participant observation and usability testing.

2.4.3 Theory development

The case study shows why the utilization of BlueSky system in pilot sites can add significant benefits to construction supply chains.

2.4.4 Unit of Analysis

The unit of analysis for this study is the project, as described later in chapter 5. This is a single case study, providing holistic study of the benefits of supply chain process and communication.

2.4.5 Data Collection

Triangulation is a research technique wherein multiple methods are used to analyze the same theoretical question. This means that case studies allow researchers to understand the nature and complexity of processes by using multiple sources of data. (Yin 1981) Yin (2003) identified six primary methodologies for case study research: documentation, archival records, interviews, direct and participant observation and physical artifacts. All are not essential in every case study, but the importance of multiple sources of data to the reliability of such studies has been well-established. (Stake 1994; Yin 1994) This study employed the following key methodologies—Action research, which included participant observation, usability testing and literature review on construction supply chain management. It is important to note the findings are by no means generalizable, and will purely be used to refine the model for future study.

Structured questionnaire is another mean to collect data in this research. Questionnaires were distributed to collect general New Zealand construction industry practitioners' attitude towards the adoption of ICTs into New Zealand Construction Supply Chain Management. This can provide a comparatively general view of the whole construction industry supply chain management. The information gained from observation and usability testing was primarily the specific aspects of utilization BlueSky system into pilot site A and B.

2.5 Summary of Research Methodology and Design

By grounding the research within a qualitative paradigm and by combining structured questionnaire and case study as a research methodology, the study proposes that following a design of participant observation and questionnaire, the benefits and risks of utilization of BlueSky system to improve the construction supply chain performance. It is contended that the findings provide insights to the adoption of ICTs into New Zealand Construction Industry Supply Chain Management. The influences of time, cost, communication, and the accuracy and efficiency of the information flow among the chain are identified.

CHAPTER 3: LITERATURE REVIEW

3.1 Introduction

The literature review chapter reviews several streams of literature that underpin the research problem. The literature stream of Supply Chain Management (SCM) will be reviewed first, followed by the Strategic Information Systems (SIS) literature stream.

In the SCM literature, sub-fields such as Construction Supply Chain Management (CSCM) and Partnering will also be discussed. The organization of this chapter is outlined below.

- ü The literature review begins with a revision of SCM measures that are germane to the research problem; in particular those measures that are relevant to construction supply chain management, as a specification for a ICT based Construction Supply Chain Management System is the output of this thesis (Section 3.2).
- ü Discusses the unique features of Construction Supply Chain, how these features may affect creating value to business and generate business competitive advantage over competitors (Section 3.3).
- ü Strategic Information Systems Planning (SISP) is then discussed, which deals with the alignment between IS knowledge and business knowledge. (Section 3.4).
- ü Partnering as an essential issue is then discussed. It will help to better understand the relationship among the Construction Supply Chain components. (Section 3.5)

3.2Supply Chain Measures

The welfare of any business entity in the supply chain directly depends on the performance of the others, according to their willingness and ability to harmonize. This can be considered to be the essence of supply chain management. Harland (1996) has identified four main uses of the term “supply chain management”.

- ü an internal supply chain integrates business functions;
- ü dyadic (two-party) relationships with immediate suppliers;
- ü a chain of businesses, which include the customer and supplier, as well as their customers and suppliers, and so on;
- ü a network of interconnected businesses involved in the ultimate provision of a product or service;

An important factor in supply chain design and analysis is the establishment of appropriate performance measures (Yonghui et al, 2000). A performance measure, or a set of performance measures, is used to determine the efficiency and/ or effectiveness of the existing supply chain management systems. Performance measures are also used to design proposed systems, by determining the values of the decision variables that yield the most desirable level(s) of performance. (Chopra & Meind, 2004) There are plenty of references in the literatures indicating how important the measures are in the evaluation of supply chain effectiveness and efficiency. These measures, described in this section, may be categorized as either qualitative or quantitative.

3.2.1 Qualitative performance measures

Qualitative performance measures are those measures for which there is no single direct numerical measurement, although some aspects of them may be quantified (Simchi-levi et al., 2002). These objectives have been identified as important here:

Customer satisfaction: The degree to which customers are satisfied with the product and/or service received and may apply to internal customers or external customers. (Christopher, 1994) Customer satisfaction includes three elements:

1. Pre-transaction satisfaction: satisfaction associated with service elements occurring prior to product purchase.
2. Transaction satisfaction: satisfaction associated with service elements directly involved in the physical distribution of products.

3. Post-transaction satisfaction: satisfaction associated with support provided for products while in use (Simchi-levi et al., 2002).

- Flexibility: The degree to which the supply chain can respond to random fluctuations in the demand pattern.

- Information and material flow integration: The extent to which all functions within the supply chain communicate information and transport materials.

- Effective risk management: All of the relationships within the supply contain potential risk. Effective risk management describes the degree to which the effects of these risks will be minimized.

- Supplier performance: With what consistency suppliers can deliver raw materials to production organizations on time and in a good condition.

3.2.2. Quantitative performance measures

Quantitative performance measures are those measures which can be directly described numerically. Quantitative supply chain performance measures may be categorized by: (1) objectives that are based directly on cost and (2) objectives that are based on some measure of customer responsiveness.(Nicolini, Holti & Smalley, 2001)

3.2.2.1. Measures based on cost

- Cost minimization: The most widely used objective. (Wright & Race, 2004) Cost is typically minimized for an entire supply chain (total cost), or is minimized for particular business units or stages.

- Sales maximization: Maximize the amount of sales dollars or units sold. (Alter & Hage, 1993)

- ü Profit maximization: Maximize revenues less costs.

- ü Inventory investment minimization: Minimize the amount of inventory costs (including product costs and holding costs) (Alter & Hage, 1993)

- ü Return on investment maximization: Maximize the ratio of net profit to capital that was employed to produce that profit.

3.2.2.2. Measures based on customer responsiveness

- ü Fill rate maximization: Maximize the fraction of customer orders filled on time.

- ü Product lateness minimization: Minimize the amount of time between the promised product delivery date and the actual product delivery date. (Wright & Race, 2004)

- ü Customer response time minimization: Minimize the amount of time required from the time an order is placed until the time the order is received by the customer. (Bjork, 2002) It usually refers to external customers only.

- ü Lead time minimization: Minimize the amount of time required from the time a product has begun its manufacture until the time it is completely processed. (Wright & Race, 2004)

- ü Function duplication minimization: Minimize the number of business functions that are provided by more than one business entity. (Chopra, 2002)

3.2.3. Performance measures used in supply chain modeling

As mentioned above, an important element in supply chain modeling is the establishment of appropriate performance measures. The case study in Chapter 5 seek to optimize one or more measures of supply chain performance, given a set of physical or operational system constraints. Table 1 below summarizes the performance measures used in previous research.

Basis	**Performance measure**
Cost	**Minimize cost**
	Minimize average inventory levels
	Maximize profit
	Minimize amount of obsolete inventory
Customer	**Achieve target service level (fill rate)**
Responsiveness	**Minimize stock out probability**
Cost and customer responsiveness	**Minimize product demand variance or demand amplification**
	Maximize buyer-supplier benefit
Cost and activity time	**Minimize the number of activity days and total cost**
Flexibility	**Maximize available system capacity**

Table 1 : Performance measures used in supply chain modeling (Wright & Race, 2004)

3.2.4 Decision variables in supply chain modeling

In supply chain modeling, the performance measures (such as those described in 3.2.1, 3.2.2 and 3.2.3) are described as functions of one or more decision variables. These decision variables are then chosen in such a way as to optimize one or more performance measures. (Wright & Race, 2004) The decision variables used in the previous supply chain models are listed as below:

- Production/distribution scheduling: Scheduling the manufacturing and/or distribution.

- Inventory levels: Determining the amount and location of every raw material, sub-assembly, and final assembly storage.

- Number of stages: Determining the number of stages (or echelons) that will comprise the supply chain. This involves either increasing or decreasing the chain's level of vertical integration by combining (or eliminating) stages or separating (or adding) stages, respectively.

- Distribution Center (DC) - customer assignment: Determining which DC(s) will serve which customer(s). The number and location of DC's also needs to be known.

- Plant- product assignment: Determining which plant(s) will manufacture which product(s).

- Buyer- supplier relationships: Determining and developing critical aspects of the buyer-supplier relationship.

- Product differentiation step specification: Determining the step within the process of product manufacturing at which the product should be differentiated (or specialized).
- Number of product types held in inventory: Determining the number of different product types that will be held in finished goods inventory. (Simchi-Levi et al., 2002)

3.3 Construction Supply Chain

The term supply chain refers to the linkages among the enterprise and its suppliers, manufactures, and customers. In construction industry, a supply chain refers to linkages of those parties participating in a construction project. Construction supply chain management offers new approaches to reduce the cost of and increase the reliability and speed of facility construction.(Akintoye et al., 2000) Supply chain management takes a systems view of the production activities of autonomous production units (subcontractors and suppliers in construction) and seeks global optimization of these activities. Applications of supply chain management techniques in manufacturing environments have saved hundreds of millions of dollars while improving customer service. (Arntzen et al., 1995) As subcontractor and supplier production comprise the largest value of project cost, supply chain approaches may have similar benefits. Limited studies in construction suggest that poor supply chain design regularly increases project cost by ten percent (Bertelsen, 1993), and this estimate is probably conservative. Project duration may be similarly affected.

3.3.1 Features of Construction Supply Chain

According to existing relevant literature, in terms of structure and function, the features of construction supply chain are listed as following:

1. Convergence: The supply chain is converging in construction industry. (Agaoiou et al., 1998) All materials are clustering and then transporting to the construction site. In the traditional supply chain as in manufacturing, various products go through the factory and then are distributed to the customers. Compared with that, the construction supply chain is special since the "construction factory" is built around the single product (Vrijhoef& Koskela, 2000).
2. Momentary: Another feature of construction supply chain is momentary. It is a temporary supply chain producing one-off construction projects through duplicated reconfiguration of project organizations (Vrijhoef & Koskela, 2000). Therefore, the construction supply chain shows characters like instability, fragmentation, and the separation between the design and the construction of the built object.
3. "Make to order": It is a representative "make-to-order" supply chain. Normally, there is little repetition. For particular kind of projects, the processes are very similar (Wright & Race, 2004).

3.3.2 Roles of Construction Supply Chain

The features discussed above affect the construction supply chain management significantly. Vrijhoef and Koskela (2000) have mentioned that there are four major roles of SCM in construction, dependent on whether the focus is on the supply chain, the construction site or both of them.

First of all, the focus is the influence of the supply chain on site activities. The goal is to reduce costs and improve efficiency of site activities. (Brown, 2005) From this point of view, the first thing need to be considered is to build up effective material and labor flows on the site to achieve successive workflow. To achieve that, we need to focus on the relationship between the site and direct suppliers. (Building and Construction Industries Supply Chain Management, 2006) The contractor is in the best position to adopt this focus since they are interested in site activities.

The focus of the second role is on the supply chain itself which is reducing costs.

The third role is focus on the delivery activities from the site to earlier stages of the supply chain. It can avoid the lower conditions on site and can also improve concurrency between activities. (Changchien, 2002) It can also reduce the total costs and duration. Suppliers or contractors may initiate this focus.

Fourthly, the focus may be on the integrated management and improvement of the supply chain and the site production. (Hong-Minh et al., 1999) Consequently, site production can be classified into supply chain management clients. Suppliers or contractors may initiate this focus as well.

Roles listed above are not reciprocally exclusive, but often used jointly. (Lambert et al., 1998; Love et al., 2002; O’Brien et al., 2002) All the four roles of SCM are adopted at the same time in order to improve both the efficiency and the effectiveness of the supply chain. Indeed, contractors, clients who have sufficient construction volume are able to initiate major improvements in the construction supply chain.

Construction supply chains have characteristics that are different from other industries' supply chains. One of the most extraordinary features is the truth that the supply chain is designed for each individual construction project (Dainty et al., 2001). The current trend of the construction supply chain development is greater specialization, especially when talking of construction approaches. There are quite a few construction companies who are signing contracts with only one supplier, which can include all or some of the components of the supply chain. (Ellram, 1991) This provides remarkable savings in cost and time and other advantages, for example, better control of the outsourcing approaches and the possibility of centralizing the organization's resources in its core business (Jung & Hans, 2004).

3.3.3 Construction Supply Chain Structure

As a result of the characteristics of construction operation activities, the construction supply chain can be defined as a functional network composed by all the organizations which are involved in the processes of construction project life circle: start from the project generation, include project definition, project financial, project design, project put into effect, project completion, project quality control, project delivery and project maintenance to project rebuild or extend or demolish. It is all based on the proprietor's requirements. (Jones & Riley, 1985) From an operational perspective, the supply chain in the construction industry begins with the developers' requirements, and includes master contractors, suppliers, building materials manufacturers, sub contractors, designers and architects, and the eventual owners. According to Ling (2003), there are two types of construction supply chain:

Basic supply chain: Considered the supply, transportation and warehousing of the building materials, the flows in the supply chain should include materials, information, and funds, and the logistics and channels of such flows. (Ling, 2003) The node enterprises of this kind of supply chain are building material manufacturers and suppliers. It is easy to convert.

Support supply chain: The node enterprises include project investor, product supplier, building component manufacture, land developer, subcontractors, master builder, architectural specialist (designer and consultants), and quantity estimators. (Ling, 2003; Jones & Saad, 2003) This type of supply chain operates to match different project demands. Supply chain management focus on conducting the support nodes and their relations. Construction supply chain structure is shown as following.

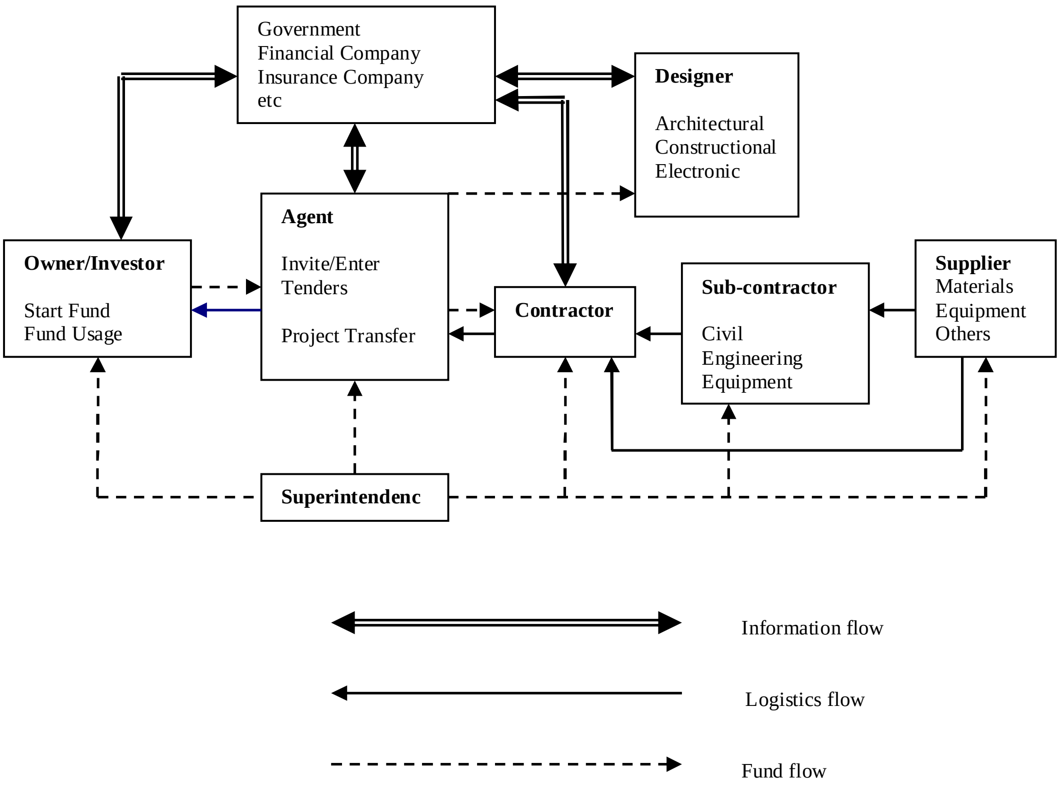

Figure 2: Construction supply chain model (Ling, 2003)

Because of the particular characteristics of the construction sector, the supply chain is different for each construction project. The principal criterion to establish the relations and structures is the initial identification of each particular project. There are three key factors of the model: the project, the participants and the relations between them. (London & Kenley, 2000) Each project involves the demand for an infrastructure or building by the client's organization. The structure of a construction supply chain is shown in Figure 2, in which the contractor, as a central organization, is the equivalent to the large assembler in the traditional supply chain models in the automobile sector (Ling, 2003). This challenges the general assumption of many authors that the main contractor is the equivalent to the assembler.

Compared with traditional manufacturing industry supply chain, construction supply chain has three distinct features: network, attitude and cooperation (Jung & Hans, 2004). Network refers to the organization network or relationship which is built when contenting the owner's demand (London, 2001). Attitude indicates that the behavior of the organization or individuals within the chain will seriously influence each others. Cooperation points out that there must be a long term strategy to achieve the competition advantages of the whole chain (Ling, 2003). The detail results of the comparison are listed in the table below.

Construction Industry Supply Chain	Manufacture Industry Supply Chain
A typical supply chain model according to the order	A supply chain model according to the market estimate
The "onetime" and irreversible feature of the construction industry production	The products can be produced in batch and can also be duplicated easily.
All materials are assembled on the project site.	Different parts of the products can be produced in different location.
The suppliers are chosen by inviting or entering a tender.	The suppliers are chosen by negotiations.
The relationship between chain members is temporary.	The relationship between chain members is a long term relationship.
The responsibility of each chain member is separated. It is one of the causes of the fragmentation of the supply chain.	The chain members are related together tightly because of the customer's requirement.
The construction project life circle is too long and there are always some unstable changes. It is not easy to share information within the chain. The chain members do not want to share information.	The product life circle is normally stable and there are seldom changes. The chain members can easily trust each other because of the long term cooperation. It is easy to share information among the chain members.

Table 2: Comparison of Construction Industry Supply Chain and Manufacture Industry Supply Chain features Resourced from Ling, 2003

3.3.4 Problems in Construction Supply Chain

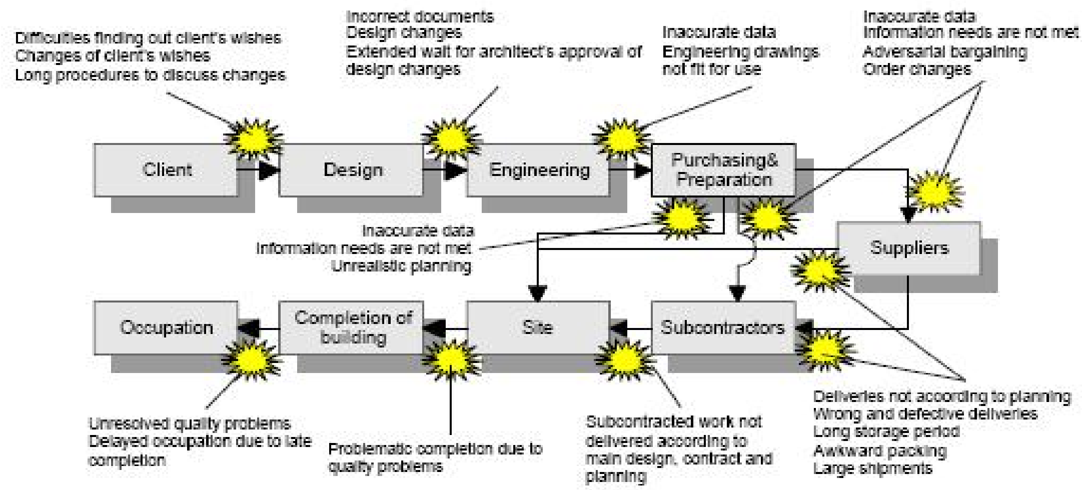

Figure 3: Problems of construction supply chain management (Sobotka, 2000)

The status of construction supply chains does not seem to have changed much in the last few decades. Peansupap and Walker (2006) observed that: "… any lack of cohesion and co-ordination is less the result of ill-will or malignancy on the part of any groups or individuals, but more the result of forces beyond the control of any individual or group and which are affecting all"(p.329).

From previous research, three main conclusions can be drawn as to the current status of construction supply chains (Vrijhoef & Koskela 2000). First of all, the construction supply chain has a great deal of waste and problems. Secondly, most of these waste and problems have a bad effect in other stages of the construction supply chain than where it is recognized. Last but not least, waste and problems are because of the antiquated and short sight control of the construction supply chain and also the independent control of each stage of the chain.

1. Waste and problems in construction supply chains: Sobotka (2000) found in his study on construction material flows that the value-added time of materials flow is only 0.3-0.6% of the total flow time. Only for the interface between the main contractor and the supplier has an average cost reduction potential of 10% (of material costs) through improved logistical procedures been shown (Sobotka, 2000). The waste can be even higher when taking the whole supply chain into consideration.

2. Root caused of waste and problems in former stages of the construction supply chain: Sobotka (2000) found that "incomplete planning and information on the amount of necessary material are characteristic for materials purchasing in construction component manufacturing" (p.188), Vrijhoef and Koskela (2000) found that the construction component orders are always made according to the incomplete and wrong design data. In another study on the supply of concrete façade component, Roy (2003) found that several of the problems in the factory were caused by external chain partners. The design documents are often insufficient and most of the issues are not described in detailed. Changes are

caused by unavailable, late, wrong and incomplete information and are often not well communicated. On the other hand, the factory may bring problems for other chain partners as well. When trying to improve its activities it supplied elements in a different order. The factory needed to have all drawings at the same time because of its own inadequate scheduling of its information needs.

3. Myopic control of the construction supply chain: It was shown that the purchasing price is the primary criterion for supplier selection (DTI Internet, 2006). O' Brien (2002) found that subcontractors are always selected according to price. Roy (2003) found that decision making on the improvement of supply chain is often limited by those solutions one has experience of. It is customary to use material inventories as buffers against disruption. Similarly, Marsh and Finch (1998) found that nearly all supply chain partners add a time buffer to their schedule, and it will increase the time cost.

According to those previous researches, it can be seen that waste and problems in construction supply chains are extensively present and persistent. As a result of interdependency, the occurrence of waste and problems in interrelated with causes in other stages of the supply chain (Peansupap & Walker, 2006). What is more, myopic control of the construction supply chain enlarges waste and problems and makes things even worse. It is obviously that those uncontrollable forces and their organizational aftereffects hindered the development of construction supply chain. A part of the new model, such as open building system, sequential procedure, the new construction mode, design/build and partnering, have directly attacked this lack of cohesion and co-ordination. There are several other examples: generic initiatives, like re-engineering, time compression, quality and information technology (Ward, 2005). These have been recently implemented in construction. However, only few of them succeed.

What may be the reason for the failures? One possibility is pointed out by Peansupap and Walker (2006) who compared a time compression program in construction with a corresponding program in manufacturing. They conclude that for builders with their project culture it is easier to implant renewal efforts (Peansupap & Walker, 2006). However, at the same time this means that a fundamental mental change was hardly needed in implementing the construction time compression program, and thus its cultural and mental influence was limited.

In another research, it shows that communication perspective provide a useful conceptual basis for analyzing construction supply chains (Tsemg et al., 2005). In this study, the author showed primary evidence for the relevance of communication and the construction supply chain waste and problems.

The one way construction supply chain can be understood as a network of commitments, which are emerged from continuous conversations for action just like other kinds of business (Dainty et al., 2001). These conversations and commitments are regularly carried out in the critical phases of a construction supply chain: design, materials procurement and logistics and site coordination.

In Vrijhoef and Koskela's study on design management, the central problems found were defined as follows: "… the involved persons perceive uncertainty on what has to be done, who has to do it and when it has to be ready. The actors in the design project organization have no common and clear understanding on what should be designed" (Vrijhoef & Koskela, 2000, p.174). They pointed out that conversations for action were either ineffective or missing in the coordination of design.

Vrijhoef and Koskela (2000) found that there are different supply chain management problems in different stages of the construction supply chain. Many of the problems are caused directly or indirectly by insufficient coordination, communication, and these commitments lead to wrong inform about schedule changes, late confirmation of deliveries, and lack of feedback procedures.

From site coordination point of view, Dainty (2001) mentioned in his paper that "… the specialists [contractors] are just thrown together and told to sort things out between themselves” (p.845). These kinds of phenomena which always happened in the supply chain are always the causes of misunderstanding. It shows a complete lack of coordination and structure in the communication and collaboration on site.

Naim and James (2001) study of quality defect costs in construction found ‘that the majority of causes for defects are related to various forms of ambiguity, such as ambiguity about clients’ (e.g. concerns, interests and requests), ambiguity about organizational structure and responsibilities (e.g. agreements and promises) and ambiguity in drawings (e.g descriptors of conditions and clients responsibilities)”.(p597)

The construction supply chain is triggered by material flow

The material flow is one of the fatal factors which can highly influence the supply chain in every industry. Things are the same in construction supply chain. However, there is a serious challenge of the construction project management during the material delivery process currently. The key point is how to ensure the material timely delivery for the project tasks without any additional and unnecessary cost. As discussed above, this requires effective and proper communication with the suppliers and also needs a precise project time table. Therefore, the most recent project schedule from the last planner approach will be required as the reference of communication between the project site and building material suppliers (Goodman & Chinowsky, 1996).

From the last planner’s perspective, project tasks are assigned on the newest time table. There is a material limitation on each construction project (Goodman & Chinowsky, 1996). It will not be removed until the necessary materials are available. After all the constraints are removed, the tasks are then allowed to move to the workable list. Otherwise, because the forthcoming tasks are also allocated on the newest time table, the information can also be used to communicate with the suppliers in advance about delivery requirements (Agapiou et al., 1998). This is definitely the most accurate material requirements information because that this newest timetable from the last planner will be continuously updated to ensure the most reliable timing information of the project tasks.

Hence, it could describe the progress of the project to an inch. If the suppliers are given visibility of the forthcoming material requirements, they will be able to forecast the information of the projects and can consider the potential delivery problems in advance. Therefore, the task time table can be then calibrated.

Furthermore, according to the changes which have been made in the task sequence orders, the supplier will be then given notice of delayed or advanced material requirement information (Agapiou et al., 1998). Then the newest project timetable can be used to ensure the suppliers to better deal with the changes in the required deliver dates of the relevant project material.

The efficiency of the operations of the planner can be increased by getting rid of the need for frequent material orders from the order list. If the forthcoming material requirements are heralded directly to the suppliers, for example, by email or fax, the suppliers will be able to move to deliver the materials which are needed for the project tasks in advance (Arbulu et al., 2003). The suppliers can be given the responsibility to deliver the materials to project site on time for each individual construction project task. When talking about this kind of advanced material delivery, an extra parameter could be added to the task time table. It is defined as “project buffer time”. The project buffer time is used to make sure the necessary materials arrive early enough for the tasks that are going to be moved into the workable list (Jones & Saad, 2003). Consequently, the relevant material suppliers are given a material needs list on which the requirements are labeled by the number of the project buffer time. For instance, the project planner has decided that the necessary project relevant materials should be available for the project tasks which are going to be performed for the following three days. A supplier with a two-day‘s delivery time should have to send out the materials required by a particular task in five days before the task will be started (London & Kenley, 2000). The material requirement of the forthcoming tasks would be shown as a forecast to make sure that suppliers are able to prepare to send materials according to the time table.

The chain is full of waste as well as ineffective communications.

Construction industry is full of waste and problems which are mainly because of timeworn, bleary-eyed control of the construction supply chain which are different as a result of independent control of each stage of the chain. Construction supply chain management provides a possible solution of the integration of the traditional gaps between partners in construction supply chain (Jones & Saad, 2003). It will be able to reduce time and cost.

In these days, the construction industry is facing an ongoing challenge to improve the current work practices and become more client-oriented. This trend is generated by a number of factors, including greater performance expectations by clients, globalization of the economy, increased competitions between contractors, continued restructuring of work practices, industrial relations, and industry's need to implement information and communication technologies (Weippert, Kajewski & Tilley, 2003). Although the construction project is different from each other and has its individual feature, it involved quite a few of participants, such as clients, designers, consultants, contractors, subcontractors, and suppliers. These participants worked as an entity but perform various roles and responsibilities (Goodman & Chinowsky, 1996). Practice errors and time delays are significantly reduced through sharing up-to-the-minute information among chain participants. As a result, the more effective and efficient productivity has been achieved. What is more, the collaboration, cooperation and teamwork within the supply chain partners have been improved. However, current construction industry is facing costly progress delays as a result of the inaccurate and untimely communications among project team members. Sometimes the fetal information is lost so that the information needs to be re-entered; hardcopy manuals and drawing documents need to be re-produced to achieve rapid access to the required information to perform some of their tasks (Weippert, Kajewski & Tilley, 2003). The rapid development of mobile information technologies, Internet, and other Information and Communication Technology have generated the opportunities of revolution of on-line business solution and electronic-commerce (e-commerce). Both of them are aimed to provide support for not only information flow but also work flow control, and process management as well as the improvement of the communication (Weippert Kajewski & Tilley, 2003). However, until recently, there is still little research concerning successful applications of new ICTs in the construction supply chain. For this reason, the following paragraphs will focus on the current applications of new ICTs within the construction supply chain. The specific issues which will be further discussed include the objectives, benefits, barriers of using new ICTs. These relevant researches explored the promotive factors and the need such as learning, training, and knowledge sharing for better applications of new ICTs and provide suggestions for better utilization of these modern communication and management tools.

3.4 Strategic Information Systems

Business process re-engineering (BPR) of construction supply chains is hardly a new topic. In contrast to the other market sectors, the construction industry has arguably lagged in BPR, particularly with regard to supply chains (Latham, 1994). At first this seems to be a paradox since “the process approach” is endemic within many construction activities. But there is less inclination to spread this message to manage business interfaces to effective supply chains. That is, to use procedures exploited in “the what” of construction to “the how” of construction. As Powell (1993), who has re-engineered many automotive and electrical businesses, has argued that the organization which operates using a systems approach delivers better engineering throughout all its activities. Essentially it involves applying engineering ideas and concepts to the “how” of business as well as to the “what” of the enterprise. Importantly, this methodology can be transformed into a toolkit suitable for use in the construction sector (Scheer, 1998; Wiseman, 1988).

3.4.1 Nature of Strategy

Strategy is said to be at one end of the management activity continuum, followed by tactic and operation at the other end (Powell, 1993). Powell (1993) also recognizes management activities as a hierarchy; strategy sits above tactics to provide guidelines and tactics bind and direct the operational issues. “Strategy is a framework within which tactical moves are made”, “strategy comes first, tactics implement strategy and operations implement tactics” (Powell, 1993).

On the other hand, strategy is made based on what operations have achieved, therefore, strategy “encompasses the definition of the business, products and markets to be served, functions to be performed, and major policies needed for the organization to execute these decisions to achieve objectives” (Powell, 1993). Strategy is a long term objective the organization wants to achieve, which guides long term investments in projects that can support the business at the operational level and which achieve the objective with the recognition of environmental changes.

Overall, the nature of the strategy sets a long term objective for the organization, based on the available resources of the organization and the way in which the organization meets environmental changes in the industry (Baets, 1992). The organizational resources it is based on include the products the organization has, the technologies the organization is able to deploy, and the functions the organization can perform to support business operations (Bergeron, Buteau & Raymond, 1991). These resources are actually the knowledge of the organization, which is what the organization knows and what it can do. The knowledge resides at the operational level, which in turn will affect the strategy made by the organization. In other words, strategy closely relates to what the organization has at an operational level, particularly knowledge.

3.4.2 The Strategic Role of IS/IT

The strategic role of IS/IT in an organization implies that the use of such IS/IT should be strategic; however, not all IS/IT in the corporate world are used strategically so they are not performing in the strategic role (Brancheau, Janz & Wetherbe, 1996).

As mentioned in the previous section, strategy and operation influence each other (Goldsmith, 1991). Therefore, the use of IS/IT should be guided by strategy to support operations and the result from using the IS/IT should feedback to the strategic decision making process.

This use of IS/IT could be recognized as strategically used and the IS/IT is in the strategic role. This point is supported by Galliers (1993) who stated “strategic aspects of IT are best explained in terms of their influence on business results, such as changes in market share, improved product quality, increased market penetration, higher profit margins and enhanced customer service”

These results at the operational level will require changes in strategy. Lincoln (1990) also perceives “strategic IT as the support to the fundamental business goals and objectives” (p. 215).

In a more detailed view, the purpose of using IS/IT is to gain competitive advantages for the organization. Bergeron et al. (1991) pointed out that “the competitive advantages generated from IS/IT are those that incorporate the fundamental objectives of the organization and have a significant impact on its success” (p. 91), which again supports the statement made above. The impact could be realized by the use of different strategies, including product differentiation strategy, market segmentations and low-cost strategy. If the use of IS/IT could result in impacts such as raising entry barriers, creating customer loyalty, offering innovative products and services, changing the bargaining power of suppliers/customers and setting the rules of competition (Powell, 1993), the IS/IT can be classified as strategic. Liang and Tang (1991) also identified three characteristics of SIS:

- ü Environmental-oriented to affect competition;
- ü Provide linkage to various parties;
- ü Bring direct benefits to those parties within the pre-settled environment.

Ciborra (1991) states that system which can contribute towards gaining the competitive advantages for an organization can be considered as strategic.

Overall, the IS/IT could be classified as strategic only when IS/IT aligns with strategy by supporting the operations guided by the strategy and the result from the use of IS/IT gains competitive advantage to the organization.

In the following sections, detailed discussion will be given on the IS/IT contribution to business strategy.

3.4.3 IS Contribution to Business Strategy

This section aims to illustrate practical understanding of the use of information systems in traditional organizations and to reflect the relationship between the use of IS/IT and business strategy. It begins by presenting types of popular strategies used in the corporate world, and discusses how information systems support these strategies. Table 3 presents four types of strategies proposed by Ansoff (1965).

Markets / **Products**	**Existing**	**New**
Existing	Market Penetration	Product Development
New	Market Development	Diversification

Table 3: The Ansoff Model (Ansoff, 1965)

The Ansoff model has two dimensions, products and markets, each with two sub dimensions to specify alternative strategies. The model tries to demonstrate that the organization can choose to either continue to sell the existing products or innovating new products, and the products can be sold in existing markets or in a completely new market. The following four strategies will be used in the following discussions to demonstrate the use of information systems to support these strategies.

Firstly, market penetration strategy requires the organization to take steps to reduce costs and build long term customer relationships. Organizations could use information systems, such as computer aided design systems or manufacturing systems (CAD/CAM), to reduce production lead time or to improve product quality. Once the lead time is reduced, production costs are lower; or if the product quality increases, the customer will be more willing to purchase. In this way, the information systems support the market penetration strategy.

Secondly, market development strategy tries to expand the existing product into new markets, which may require market identification and careful planning, with different sets of IT and skills to support this strategy (King & Teo, 1996). Information systems such as high-level management or executive information systems (EIS) could enable fast identification of potential new markets and serve the market quickly.

Thirdly, product development strategy has been adopted by many building construction companies. For example, companies search for new products to satisfy customers in an existing market (Cheng et al., 2001). These companies use sophisticated software, which is usually developed in– house, to locate and assess new lots which may be available. Interestingly, some builder companies have the belief that the use of proprietarily systems can gain a strategic advantage over competitors.

Finally, diversification strategy is adopted when an organization tries to find new products to serve customers from new markets (King & Zumd, 1981). Much of the diversification occurs by merging and acquisition of other organizations, rather than through the organic growth of organizations. An information system could still be the enabler of a successful diversification, especially when the existing information system of the organization could not handle operations in a newly acquired business. Cibra (1991) pointed out that this could be one of the reasons for why organizations start outsourcing the IS function to third parties. Furthermore, it is important to correctly align or match the IS/IT strategy with the business strategy, because it might degrade the achievement of the business strategy if the IS/IT strategy is not congruent with that business strategy.

The discussion above reveals how information systems are used in a traditional way to support business strategies (King, 1978; Lederer & Garduner, 1992; Lederer& Sethi, 1996). However, the organization aims to use information systems for data processing functions, rather than to gain competitive advantage.

Recently, this perspective has changed and organizations have realized that the aim of using information systems is to gain competitive advantage for the organization, which refers to Ciborra's (1991) definition of strategic information system. Early information systems improved the efficiency and effectiveness of the business operations in some way and created a competitive advantage to the organization.

However, a competitive advantage gain early on is not sustainable, as competitors can catch up very easily (Lederer & Mendelow, 1993). One of the reasons is because the information systems are not used strategically. The following sections will look at the changes in business perspective on the role of information systems, which leads to discussion on the creation of competitive advantage by using information systems.

3.4.4 Shifting Focuses of IT Strategy

The perspective of the use of IS/IT has changed in different stages. As technology develops, the use of IS/IT has been endowed with higher expectations in the corporate world (Levary, 2000). The nature of the use of IS/IT has been defined as being different from its earlier use. This section aims to illustrate the changes in definition from earlier to recent times and tries to understand what the strategic IS/IT should be in a business perspective.

Figure 4 shows the changing nature of information systems strategy as one key information system management issue.

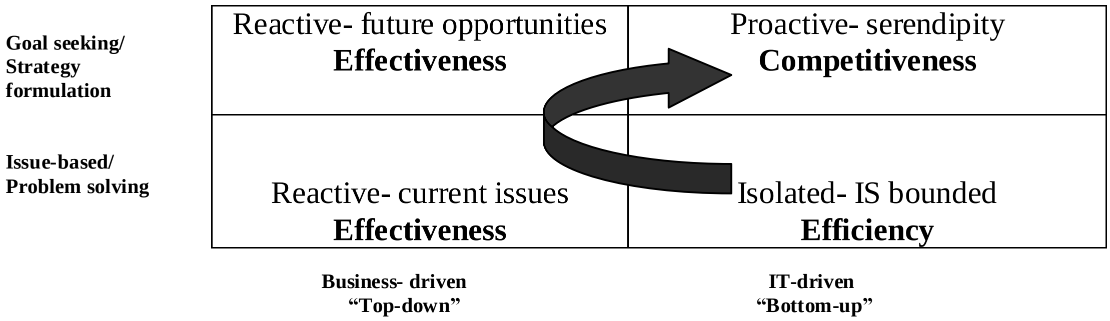

Figure 4: The shifting focus of IT strategy: from technological efficiency to business competitiveness (Galliers, 1993)

In its early stages, IS/IT is isolated from the corporate world. Organizations tend to use information systems to support some of their business operations, such as data processing and electronic file storage, to accelerate operational efficiency (Galliers, 1993). It is said to be the IT-driven strategy of the use of IS/IT, because organizations look at what information systems can do and apply this to part of the operations.

Since IS/IT technology develops rapidly, and information systems can do many things, organizations start to use information systems to solve current issues in their operations (Galliers, 1993). If an organization realizes there is a problem in the operational process, it applies an existing information system or builds a new system to solve the problem. This strategy is business driven and organizations seek for effectiveness by using IS/IT.

In the third stage, organizations try to identify future benefits or opportunities that information systems can generate (Galliers, 1993). Organizations have existing information systems to support and solve some issues at the operational level; these information systems facilitate the organization to look for future opportunities in a reactive fashion (Lederer & Salmela, 1992). At this point, the focus is extended to external matters of the organization, and considerable amount of attention is paid to business process reengineering and redesign.

Organizations start to use information systems to compete with other organizations and move the strategy of use of information systems into a goal seeking or strategy formulation stage.

More recently, organizations have adopted a proactive style to gain competitive advantage in the market place (Galliers, 1993). Based on results produced from using information systems at an operational level, organizations take into consideration internal issues associated with processes and structures, together with external issues associated with collaboration and competition to formulate new strategies that will guide future operations (Lederer & Salmela, 1996). It is hoped that this will generate competitive advantage in the future.

It is clear that the main focus of using information systems is to gain competitive advantage, which requires alignment between the use of IS/IT and business strategy to achieve competitive advantage. However, the process of trying to align the IS/IT world and the business world is another important issue. In the following section, the strategic alignment process and the important concepts that can be obtained is discussed.

3.4.5 Strategic Alignment Process

This section discusses the general approach to the strategic alignment process. Two IS strategy alignment models that are complementary to each other are combined and used in this section. These are MacDonald's (1991) 'Strategic Alignment Process' model and Parker, Benson and Trainor's (1988) 'Enterprise-wide Information Model'.

The modified model is referenced from Baets' (1992) work on aligning information systems with business strategy and is shown below.

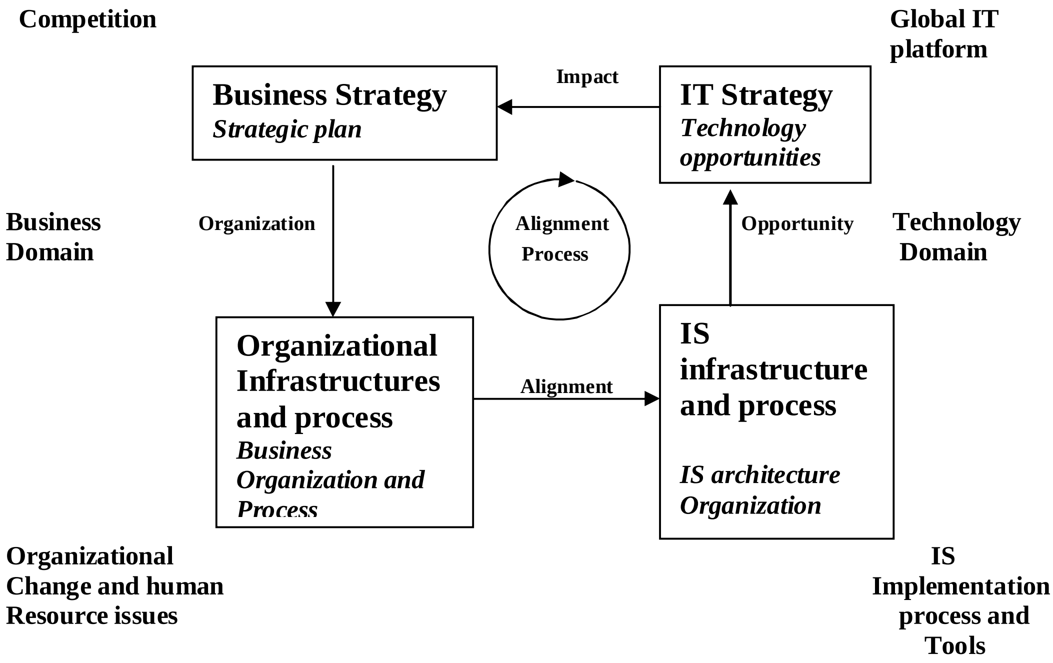

Figure 5: Strategic Alignment Process (Baets, 1992)

A number of methodologies are introduced in the literature, each having its own strengths and weaknesses. However, their alignment processes are somewhat similar to each other, but they are different in the place where they start the alignment process (Baets, 1992). MacDonald's (1991) 'Strategic Alignment Process' model and Parker, Benson and Trainor's (1988) 'Enterprise-wide Information Model' are complementary to each other, with similar processes. After combining the two models, the new model shows a reasonably complete process for alignment, as described in Baets' paper (1992). For this thesis, it is important to identify the resources to consider when trying aligning IT strategy with the construction supply chain management strategy, so that the case study could support the alignment process by offering precise resources and hence produce a better CSC. This section sets the foundation for the discussion of CSCMS. However, the thesis does not focus on the strategic alignment process and hence it discusses only one general methodology from the literature.

Some of the models in the literature begin from the IT strategy and then attempt to integrate business strategy; others argue that the process should start from a business strategy while defining the IT strategy in parallel (Lederer & Salmela, 1996). However, the conventional approach is to start from a business strategy and then try to integrate IT strategy within it (Teo and King, 1996). Because the alignment methodology is not the main focus of this thesis and the conventional approach would take similar resources into consideration when starting the alignment process, as do the other extended methodologies, the conventional approach is sufficient for the discussion.

The model starts from the business strategy, represented by a business plan. The business plan sets the guideline for future business operations to meet competitors in the market place and the objective is to create competitive advantage (Teo and King, 1997). From the business plan, further investigation is required into the business domain the organization is operating in.

When trying to incorporate information systems into the operational processes, the organizational structure and the existing processes need to be considered. It is important to know the infrastructures and processes of an organization, so that proper information systems can be deployed to suit the infrastructures (Lederer & Salmela, 1996). Sometimes, the organization may need to alter some of the processes and structures to fit the information systems being deployed. At this point, an organization needs to know what processes at the operational level are the best practices to produce the most efficiency and effectiveness (Powell, 1993). For example, a production line process may produce high quality products that competitors cannot match. Such processes need to be kept, and there is also a need to seek improvements on the process in the future. After the investigation on an organization itself, consideration of what information systems could be deployed could be taken.

The organization then needs to investigate the existing IS infrastructure and processes within the organization to see whether existing information systems are still compatible with the business operations and processes (Powell, 1993). It needs to consider whether the IS function should be outsourced, or if new information systems are required (Teo and King, 1996). If new information systems are needed, decisions have to be made on whether to develop a system in house or whether a commercial system should be purchased.

Organization also considers what tools and technologies are available in the organization to build the new information systems and other IS related issues. From here, it looks for opportunities to use information systems to create competitive advantage.

The last step is to formulate the IT strategy about what to build, how to build and so on and obtain a plan (Bryd et al., 1995). This stage and the previous stage are more focused on the technology domain to seek technology opportunities, as the first two stages are more focused on the business domain to analyze the internal and external business environment. IT strategy seeks opportunities to better support business operations that meet environmental changes in business (Ching, Holsapple, Winston, 1996). Finally, the IT strategy used to support the operational level impacts on the future business strategy, as shown in Figure 4. This gives credit to the discussion in the previous section on the nature of strategy and the role of strategic IS/IT.

As discussed in Section 3.4.4 on the shifting focus of IT strategy, information systems need to create competitive advantage to the organization to be strategically used. This is also the purpose of aligning the IT strategy with the business strategy. Competitive advantage created by information systems has been a major issue discussed in the literature for many years. As Ciborra (1991) stated, information systems are considered strategic only when they create a sustainable competitive advantage to the organization.

There could be a competitive advantage created if the IT strategy aligned with the business strategy (Lederer & Salmela, 1996). However, here comes an issue: how can IT/IS strategy adopted into the whole construction supply chain entities whose relationship is not good? To solve this problem, in-depth understanding of partnering of construction industry will be essential. In the following section, discussion will focus mainly on the quality relationships among construction supply chain entities.

3.5 Partnering

It is important to review the different definitions that exist for the term “partnering” by identifying the main characteristics usually present in any definition. As the previous literatures out put identified, the relationships between the different disciplines involved in a construction project cannot be described as being good; they tend to be adversarial with an evident lack of trust and commitment. The problems developed from this kind of “mind-set” include:

- Communication/information problems: as the different trading partners cannot completely trust each other, they try to limit the exchange of information as much as possible (Johnston and Lawrence, 1988). Consequently, due to a lack of co-ordination they often have insufficient or incorrect information to complete their work and thus do not respect each other’s deadlines.

- Win-lose relationship: companies try to procure benefits out of their relationships and often finish with a “lose-lose” relationship. Contracts are often fallback used to gain recompense when problems arise (Ward, 2005).

- Poor quality/late completion: as a result from a lack of commitment between trading partners, the work is often of a poor quality due to a time consuming checking process (Sobotka, 2000). In the same way, the companies can not complete their work on time and therefore will not fulfill their professional obligation and meet the agreed deadlines.

One solution to these problems, which can be summarized under the term changing the “mind-set”, can be achieved through what some people call partnering. As Roy and Gaze (2003) have defined it, “partnership is … very much an attitude of mind and one that requires fundamental changes in the behaviors that characterized the construction industry for the last 25 years”, a literature review provides many different definitions of partnership. The most frequently exercised definition proposed by the Construction

Industry Institute's Partnering Task Force and the National Economic Development Council: partnering is a long term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources (Veeramani et al, 2002). Partnering requires changing the traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based upon trust, dedication to common goals, and an understanding of each other's individual expectations and values (Ward, 2005). Excepted benefits include improved efficiency and cost effectiveness, increased opportunity for innovation, and continuous improvement of quality products and services.

Partnering has to be a mechanism employed as a means of satisfying the end-user (Wood & Ellis, 2003). This means that companies must co-ordinate their efforts to embrace a coordinated supply chain approach. Co-ordination begins with definition of the customer's needs, translation of those needs into a product/service requirement, and the procurement of raw material through to the delivery of the finished product/service (house, building, road, bridge, etc.) to the end customer (Wong, 1999). To achieve co-ordination trust, mutual commitment, and an understanding of each other's individual expectations, open exchange of information is required from the various members of the supply chain.

The various examples in the literature review refer to the use of partnering within the construction industry as well as in other industries (Ward, 2005). These examples answer the fundamental questions why and how partnering is used, and what benefits can be expected through its implementation by companies willing to enter into a partnership.

Ellram and Krause (1994) have carried out an interesting and important study comparing manufacturing and non-manufacturing companies. This study refers to "supplier partnering" (SP) being defined as "an ongoing relationship between organizaitons which involves a commitment over an extended time period, and a mutual sharing of information and the risks and rewards of the relationship" (Ellram and Krause 1994). The study was undertaken using an in-depth survey sent to a variety of companies including chemical and related products, electronics and electronic equipment, industrial equipment and machinery, banks and banking services, air transportation, trucking and warehousing.

Ellram and Krause's study indicates that non-manufacturing companies have has longer relationships with their trading partners than manufacturing firms (Ellram and Krause 1994). In the same way, they identified the same characteristic within their own group of compose companies. Non-manufacturing companies (including client and architect) have tended to have longer business relationships with their "partners" (customers and suppliers) than the manufacturing companies.

The Ellram and Krause (1994) survey presents the main reasons why companies enter into a partnership. One of the principal motives for entering into a supplier partnering: relationship for non-manufacturing companies is the delivered price of the item/product class. Another factor that is worth considering is a reduction of internal procurement procedures and its resulting costs, which is ranked third by the non-manufacturing firms, In the case of the construction industry, partnering has been promoted as a means of avoiding the tender procedure.

Finally, Ellram and Krause (1994) indicate the estimated improvement resulting from SP. Both manufacturing and non-manufacturing companies showed considerable reduction of incoming defects (by from 6.4 to 21.2%), percentage on time delivery (from 22.9 to 25.6 % improvement), cycle time reduction (from 7 to 24.7 days) and percentage of orders received complete (from 15.6 to 16.8% improvement). This survey provides us with good insight of the reason why companies move towards partnering and the benefits these companies have enjoyed since entering a partnership relationship. To establish a strategy construction supply chain management system, partnering of construction supply chain is one of the issues which can not be ignored.

3.6 Summary Literature Review

The current materials management and control procedures are unsatisfactory because they are labor intensive, inaccurate and error prone. This leads to the waste and superfluous use of material, delays, decrease in productivity and lack of real time information regarding the status of purchase orders, inventory and other negative effects.

The literature shows that the construction industry is full of waste and problems which are usually caused by lack of co-ordination of the construction supply chain. There are several measures to evaluate the performance of supply chain management categorized as qualitative and quantitative measures. These measures are the criterions of the further research of the New Zealand construction supply chain management situation. Moreover, according to the previous literature of partnering, the commitment and cooperation from all chain members becomes increasingly important to enable a complete implementation of supply chain management for the success of construction project. To ensure all the chain members to be able to achieve the timeliest and properly information from others, there is a growing need of developing a new strategic supply chain management model which allows all participants to communicate and interact with each other in a just-in-time way. Consequently, some of the leading companies started to introduce strategic supply chain management information system into their supply chain management processes to obtain benefits such as time and cost reduction, competitive advantages, improvement of document and information quality, and better customer satisfaction. It found that it is not easy to establish a strategic information system to meet different organization’s perspective.

CHAPTER 4: QUESTIONNAIRE FINDINGS

4.1 Introduction

This chapter provides the results of the analysis factors that may influence integrating ICTs with Construction Supply Chain Management in New Zealand. It also provides findings regarding Construction Industry practitioners' perception of supply chain management and their expectations regarding the use of ICTs in construction supply chain management.

The questionnaire was arranged in four sections: A, B, C and D. In Section A, information pertaining to personal characteristics of respondents such as age, job title, education, experience was collected and analyzed. Section B provides an analysis of respondents' opinions regarding their daily job Computer usage. Section C focuses on the respondents' experience of supply chain management issues. Section D solicited responses concerning what factors influence them to employ ICTs into construction supply chain management.

Questionnaires were distributed over a three week period beginning 17th July 2007 to participants at two construction conference meetings one in Auckland and one in Wellington. The results were tabulated using the Statistical Package for Social Science (SPSS), version 12th and analyzed using the exhibit of mean and frequency of agreement (in percentage). In Section C and D the questionnaire was designed so that respondents had to choose answers for each question using a Likert Scale.

A total of 280 questionnaires were distributed to practitioners in New Zealand Construction Industry including Architectural Design Companies, Building Component manufacturers, Suppliers, Master contractors and Subcontractors. Out of the 280 questionnaires distributed, 200 (71.4%) responses were received.

4.2 Data Analysis of Questionnaire

The data analysis was based on raw data collected from the structured questionnaire (Appendix 2) completed by 200 respondents. The respondents were randomly selected among the people attending the two architectural conferences Year 2007. They were chosen on the basis of the fact that they were pursuing a job in the New Zealand construction industry.

The analyses focused on two measures: the mean and percentage of agreement. The scale mean is useful for analyses where continuous measures are important and percentage agreement represents the group of respondents. Scale means are the averages of the item rating for the five groups of items making up the scale. The percentage agreement refers to the average across the item based on of respondents agreeing or strongly agreeing with the item.

4.3 Questionnaire Analysis Results

4.3.1 Section A: Respondents' Demographic Background

This section provides an analysis of the responses to question in Section A, concerning the job title, organization type, organization range, experience and education background.

The respondents were distributed averagely among building manufacture, supplier, contractor, architectural design and other types of construction industry firms. The building manufacture and supplier organizations are normally larger than other organization types. Most of the respondents have computer using experience in their daily job. It was found that the architects and administration officers use computers much more frequently than builders, plumbers and other subcontractor job positions. In summary, this section provides a basic demographic analysis towards the respondents. Detail table and analysis are shown in Appendix 2.

4.3.2 Section B: What Software and System are used by the industry currently?

A chi square statistic was used to investigate whether distributions of categorical variables differ from one another. Basically categorical variable yield data in the categories and numerical variables yield data in numerical form. In section B, chi square test was used to analysis the relationship between the respondents' job titles and what kind of software they normally use in their daily job. In this section, bar chart and two-way cross table are exhibited to help reveal the relevance between certain software and respondents' job title (shown in Appendix 2).

This section includes two main parts: the cross analysis of job title and how many hours did the respondents use per day on different kind of software application, and the organization types and what kind of computer systems the respondents' organization are using. Some of the usage of software application like general accounting, job costing or estimating software, project management software, general internet use and other software (CAD, ArchitectCAD and so on) are highly dependent on what position the respondents are holding but other kinds of software are not. On the other hand, most of the computer systems uses also depended on the kind of organization. These results can be used as a guideline of further computer based supply chain management system development. It was found that most people prefer to remain with systems that they are familiar with.

4.3.3 Section C: Current New Zealand Construction Supply Chain Management Situation.

This section provides analysis of the responses concerning the current New Zealand Construction Supply Chain Management situation.

This section focused on the analysis of the current New Zealand construction industry supply chain management situation. It focuses on how the respondents experience supply chain related issues in their daily jobs. The majority of the respondents felt dissatisfied with the current communication situation, supply information, estimating or quoting costs to job, managing costs to budget, and the number of mistakes made on the project. Although the respondents are satisfied with some of the supply chain factors, there are some significant problems in current New Zealand construction supply chain management scenario. Majority of the respondents stated that they wasted 8 to 16 hours on any particular construction project. Also the respondents ranked the five important supply chain features as the following: “No mistake”, “Fast response”, “Low cost”, “Easy of use” and “Happen on time”. This section also indicated that the majority of construction firms select the same partners or from an existing “partner pool”. This showed that the partner relationship is normally steady in the construction supply chain.

4.3.4 Section D: The Respondents’ Attitude towards Adopting ICT

In this section, the respondents responded concerning their usage of computer in daily job.

According to the analysis results listed in Appendix 2, the respondents’ showed a positive attitude to adoption of ICTs but some of them especially the builders and subcontractors are not confident when faced with changes to system.

4.4 Summary of Questionnaire Findings

The questionnaire findings are summarized as below:

- Architects and administrators use computers more frequently than builders, plumbers and subcontractors.

- The majority of respondents, irrespective of job role prefer to remain with systems they are familiar with.

- There is considerable dissatisfaction evident with inefficiencies in the construction supply chain. Problems are in communication, information flow, estimating costs, managing costs to budget, and high error level.

- It was found that the five most important requirements of a construction supply chain in order of importance are:
  1. No mistakes
  2. Fast response
  3. Low cost
  4. Easy of use
  5. Happen on time

- It was found that partnership relationship is generally steady. Although dissatisfaction of overall performance is high the preference is not to change partners.

- Overall respondents showed a positive response to the use of ICTs. However, builders, plumbers and other subcontractors expressed a lack of confidence (in their own ability).

CHAPTER 5: BLUESKY CASE STUDY AND FINDINGS

5.1 "BlueSky" System Introduction

5.1.1 Background Information of the Company

BISCO, the building integration software company, was established at the beginning of 2005 but the partners: "the two Nicks" have been working on this software for nearly 10 years. They both worked for Carter Holt Harvey spending three years researching and developing an application based on ArchiCAD to enable the design, engineer, and cost processes within one system. The target for this system was residential house construction and kitchen joinery manufacturing. The system was developed to the point where a number of customers were using the first release and were almost complete on a house design and costing version. Due to a change in strategic direction, CHH decided not to continue investing in the project. After having a good think about it they decided that the real value was not the code that was cut, but what they have realized about the process so they decided to start again from a clean sheet of paper. This has proven to be very worthwhile, as they obviously knew a lot more about the subject than what they did when they first started and they have taken these lessons into BlueSky. They started development of the BlueSky suite at the beginning of 2005 and the system has been installed several sites.

5.1.2 Overview Concept of BlueSky System

Research by the US national research estimated that poor communication amounts to a cost of $US15.8 billion in the US capital facilities industry, other estimates say that 3% of all construction costs is waste (Roy et al., 2003). It is hypothesized that the cost percentages may be similar in all developed economies, such as in New Zealand.

According to the literature review and supported by results from the questionnaires, it is found that the construction industry supply chain lacks effective communication and therefore lack of effective information flow. Traditionally, the communication among the chain partners is by paper. The process generally starts in an electronic format, e.g. a CAD design and an MS Word specification, but the builder mostly gets the information they need by reading it off paper then enters it into their costing system. The builder also gives paper to their suppliers, like frame and truss plants, who enter the information into their systems. This manual replication of the original plan is time consuming and also brings plenty of opportunities for human errors to occur. The more changes in a project, the higher the cost is. The largely hidden impact, beyond the waste from mistakes, is the restricted ability for the designer and owner to alter the design of their building. By reducing the cycle time of the analyze, design, and verify process it is possible to understand the impact of design changes on cost and utility before becoming too committed to a particular path.

The purpose of BlueSky is to establish an industry supply chain management platform allowing users to set up modules and real services around it. Modules include: job costing, scheduling, integration to accounting systems, mobile communication tools, connection to production machinery, and providing training and implementation services. This software is aimed to streamline the building industry business processes including design, building, costs planning and materials transportation. It aims to change the chaotic situation of supply chain management in construction industry significantly. The core target market for BlueSky in NZ is medium to larger architects and builders. There are also some other potential users: building owners, suppliers and raw material manufactures for instance. These users are quite different: different level of computer literacy, different education background, different work condition and so on. All of these “differences” lead to complicated user requirements.

BlueSky will support extracting information from several architectural CAD applications: Autodesk ADT 2007, Revit 9.0, GraphiSoft ArchiCAD 10, and others in the future, and automatically reprocessing and storing it for other all users to use when required for their jobs in one integrated system. The following details the functions of BlueSky:

- ü Exporting CAD Model Component – It extracts a CAD model from a CAD application and processes the output data by mapping between the raw data and the Bisco template model which defines list of architectural element items and their properties for use of the other service components in the BlueSky system.

- ü Service Components – There are some service components are developing for various purposes by Bisco. There are four main service components which are under-developing and planning other components of the system. These components are described in detail below.

    - Estimating Component (creating budget or detail level costs) – It allows estimating cost through Active Based Cost pricing methodology driven by the features of the elements from a CAD model or through manual input. It may include details of materials, tasks, resource requirements, and any other budget related items.

    - Replica Model Component – It saves a replica of the CAD model and can be used for visualizing elements in 3D view and displaying related information from the database. It is not intended to be a photorealistic or exact replica of the original CAD model but is geometrically accurate for use as a means of visually navigating the data held in the BlueSky building model.

    - Specification Component – It allows the user to manage the specifications of an item such as a product, a task, an inspection, a resource, and pretty much anything. It has specific user interface that present the data in an appropriate manner.

    - Planning Component – It allows user to manage the plan of a project and track time spent on project task. Each task is performed using the details of budget and production commitments.

- Other Service Components – Bisco are planning to develop many other components which are also related to the building life-cycle processes, such as purchasing order, producing invoice, recording work, managing document, communicating, etc.

ü Database – Bisco database provides a platform to store, organize, and retrieve the entire project data used in BlueSky.

ü Bisco Communication Protocol – It provides information sharing between Bisco servers in several areas such as architect, city council, builders, fabricators, and so on. It allows communication over the Internet connection after encryption of the data to secure the information using HTTPS communication protocol.

To ensure integrity of the process the system manages all of the businesses information in a way that enables easy locator, secure storage, and is available to both network and mobile users. Its unique solution also solves a common issue of building, which is mobility. People need to be able to work from home or on site and have all the information that they need without the risk of somebody else making a change back at the office.

Moreover, the BlueSky system is designed to be modular so that different type of organizations can implement the functionality they need. Furthermore, it allows organizations which have already established solutions for parts of process to take what they need from BlueSky.

5.1.3 "BlueSky" system structure and functions

5.1.3.1 BlueSky System Architecture Diagram

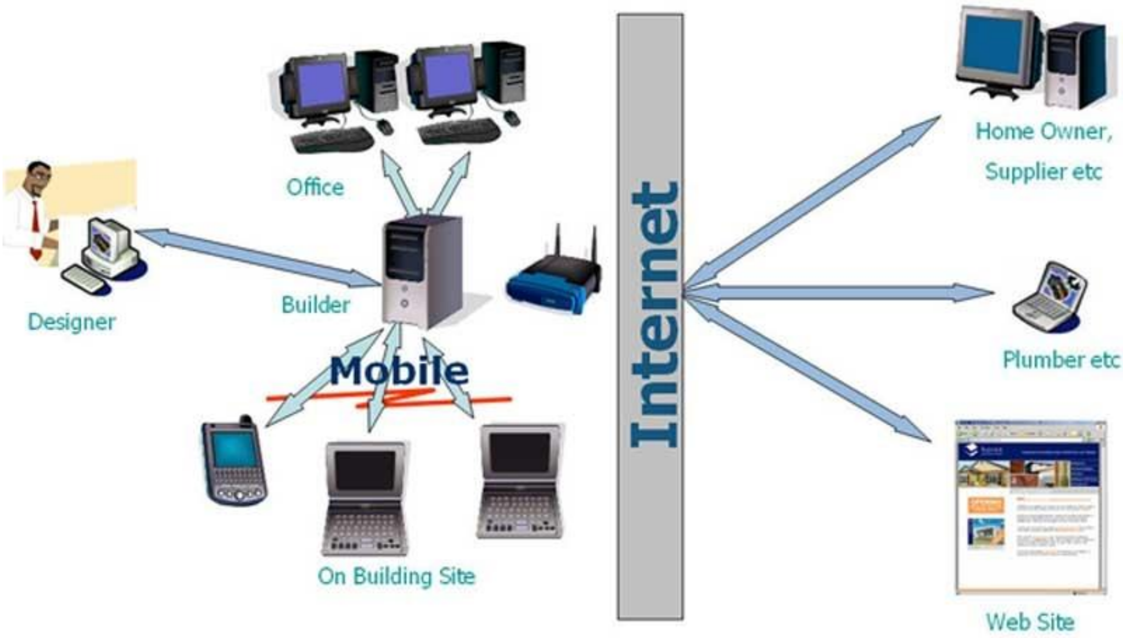

Figure 6: BlueSky system architecture diagram

The above diagram shows the way in which information flows through the building industry supply chain with BlueSky according to BISCO. This is well advanced. Automatically unlocking the information currently held in 3D CAD models is the key. It uses information technology to improve communication within the building industry. The potential system users include all participants of the construction supply chain: the builders (master builder and subcontractors), architectural designers (architects and engineers), land developers, quantity estimators, building component manufactures, products suppliers and anyone who needs to know what is going on with a project. The following Use requirement diagram shows the interaction between the primary actors (the system potential users listed former) and the system (BlueSky).

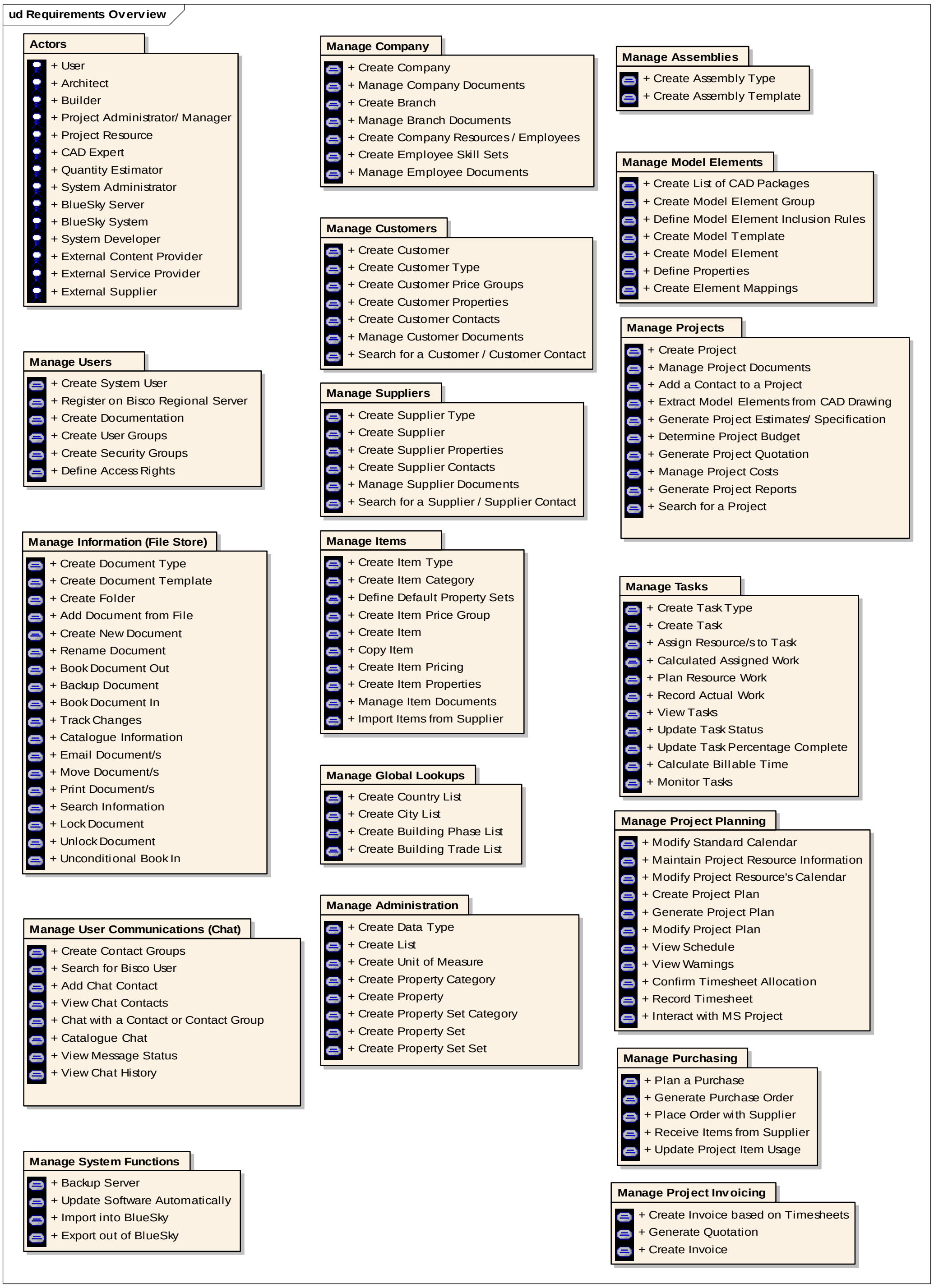

Figure 7: BlueSky Use Requirement Diagram

5.1.3.2 Current BlueSky System Function Lists

BlueSky system provides multiple functions dealing with construction supply chain management issues. These functions are listed below:

BlueSky Estimating- Automated Construction Costing

BlueSky system provides direct linkages among CAD model and estimating processes. Users can choose what is included in the estimate and the level of detail required so that the estimate is appropriate for the phase of the project. This allows the users to calculate materials, labour, sub trades, hire equipment, in fact any type of resource required for a building project. Price and cost update are automatically generated by the system for the suppliers or quantity estimators after they changed the project related information. Also, the selected products will be ready for purchasing from selected supplier.

What is more, BlueSky Estimating interface exposes all of the available properties from the CAD database and appends any additional information required to ensure accurate estimation of the design. Once the users have the information from the CAD model in a standardized format they can use it for further processing.

The estimating methodology is a technology developed by BISCO team called Feature driven Activity Based Intelligent Costing (fABC or Faebic). This methodology uses information from 3D CAD models to identify features that drive changes in cost and then use traditional Activity Based Costing to estimate the cost of these features. It can capture the decision-making knowledge of the estimator and uses the information from the CAD application to connect this to the costs for building different components to determine the cost of complete structures.

BlueSky Estimating also includes manual estimating inputs so users do not have to use only a 3D model as the input but can also input via a manual form or an Excel spreadsheet.

BlueSky Office - Information Process Management

BlueSky Office can let the users keep all the information "on hand". It ensures the users have accesses to all files they need when they are away from the office and also ensures others can't change them. Also the system can manage all of the business documentation and store it in an easy access and safety way. The system includes all MS Office file types such as Outlook and any other document format so that the users can use on their computers.

BlueSky Office can not only manage documents but any other information relevant to the users' business: Suppliers, customers, products, whatever can be defined electronically. Every item is catalogued and is easy to located using search algorithms. The system also record time spent working on projects and tasks. Moreover, it provides tools to allow users to work away from the office either on-line or offline while all the time maintaining version control, automatically backing changes up, and keeping document integrity.

When a user decides to access a document, the system copies it onto their local drive and opens the document from there with the system ensuring the maintenance of document integrity. This means the performance of the document is the fastest possible. The system also manages all supporting data like X-Ref and libraries so it means that once a document is booked out, either read only or exclusive, the user can disconnect from the network and still has complete access to the document. This is ideal for on site workers, traveling people, or staff working from home.

The system is client server when running on a network, but the client operates as a standalone application when disconnected from the server. This means users can carry on working when not connected to the network. It also automatically backs up any exclusively booked out documents when the user connects to the server. The user can also connect over the internet to update or book out documents when working away from the office using our secure SSL connection technology.

BlueSky Project – Automated Project Planning

The BlueSky Project can create a project plan directly based on what is in the CAD model. As the user adds more elements the project plans update. When the user changes an element, there rise up a need of more time or resources. This is automatically fed into the plan. This system comes with an internal project plan user interface but connects seamlessly to MS Project to allow the users to visualize and edit their plan. The users can view and edit resource allocations and resource loadings across all projects they are working on. The users are also allowed to view and edit task sequences and time estimates. Moreover, project dates can be fed back into the 3D CAD model so that the model can be time based, something called 4D Modeling.

BlueSky Specification- Automated Specification Generation

BlueSky specification generation system uses the features of the design to determine what information should be included in the specification document. When the users add a 3D new element into a design, or change an element, the generation process will automatically update the specification document.

It creates specification documents built clause by clause based directly on what is contained in the CAD model with the ability to edit manually if required. The BISCO team is currently negotiating with content providers to have their specification information as the master data for the process. A clause can include text and graphics allow for easy inclusion of items like flashing details or nailing patterns that are much easier to explain as drawings.

The clause selection process uses the features output directly from the CAD model then applies artificial intelligence rules to these to select the required clauses from the master data. This means not only very precise documentation but also a minimal data maintenance overhead while delivering huge flexibility. The users do not have to define specification sections for every permutation though every permutation is possible, meaning that the system is very flexible.

Therefore, the BlueSky Specification system supports fully formatted text and graphics so that the users can add bullet points, tables, and pictures into their specification at will.

And they also can publish the finished document in multiple formats, MS Word, PDF, HTML, XML, RTF, etc

BlueSky Studio- Project Communication

The BlueSky Studio system is a free to distribute standalone application which the users can give to the people they wish to deal with. The user can even give it to the building owner so that they can see the building progress updates via web camera.

The system allows the user to receive and view project information including specification, quantities, project plans, pictures, and a simplified replica of the original 3D CAD model. Furthermore, the communication system allows the project export and user security functions allow the users to control who gets to see what.

BlueSky Studio system can record notes against any item. Users can send instant messages between Bisco users that are in context with project information. The communication is secured using bank quality encryption. It includes free word processing and spreadsheet tools that can print or export to MS Word or Excel.

5.2 Case Study Findings

The above detailed the benefits of BlueSky as seen by the two Nicks (the principals of BISCO). This section reveals the research results of participant observation, usability testing of pilot sites and interview with some of the employees at the two sites.

5.2.1 Business Process of Pilot Sites Description

5.2.1.1 Pilot Site A Supply Chain Process Description

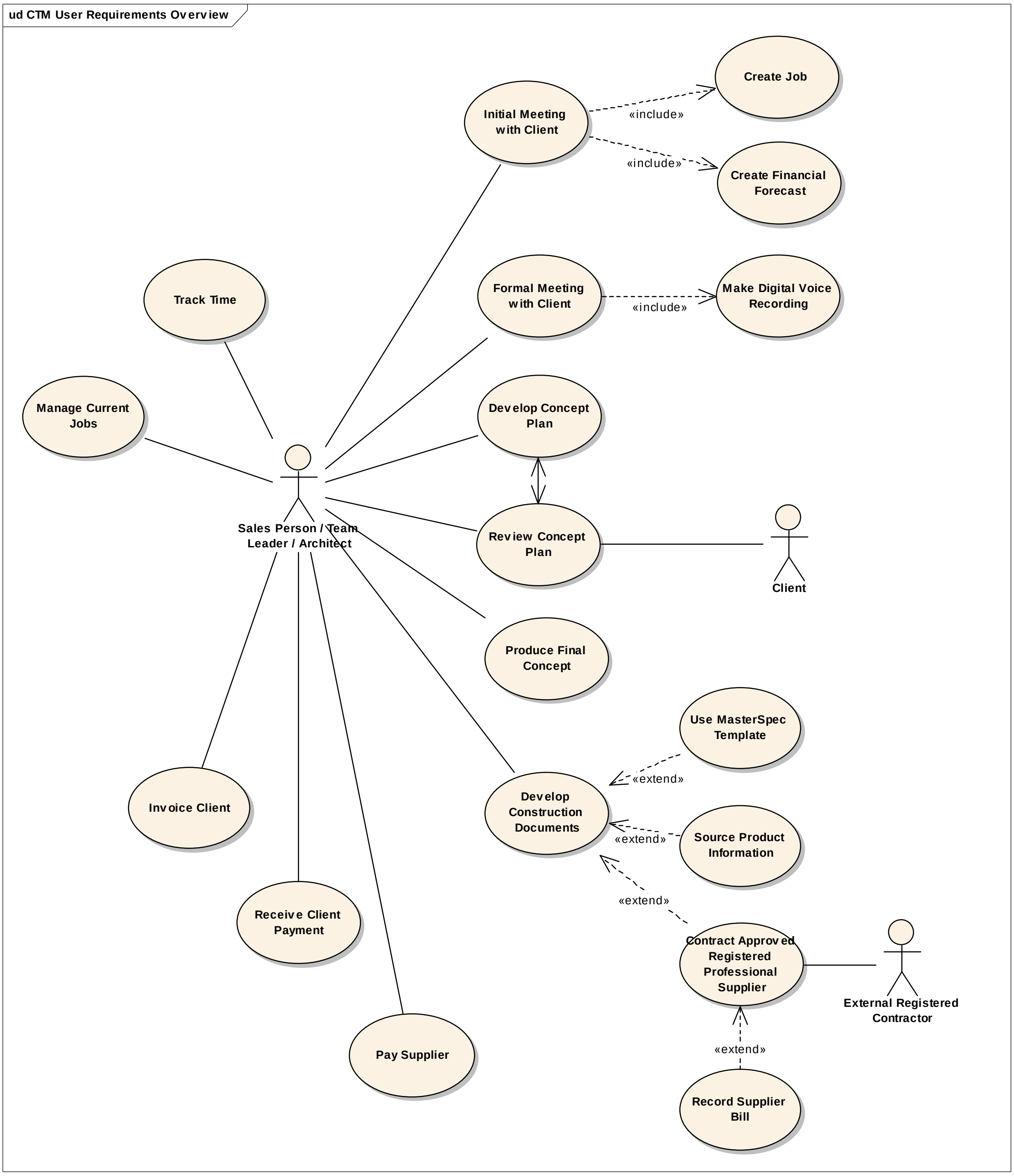

Figure 8: Pilot site A business process diagram

Pilot site A is an Architectural firm located in Pukekohe, Auckland and has been in business for more than 8 years. It has 8 fulltime employees including 6 architects (3 registered architects), 1 office administrator (secretary), 1 principle design director who is also the owner of the company. Site A is based in Auckland and focused on providing design services that are highly tailored to client needs. Their commitment is to addressing the key aspects of the client's brief with sensitivity and subtlety, whilst ensuring that quality of details is maintained in project realization. Their practice concentrates on two areas of work: Residential architecture and Public and institutional architecture. They have maintained a focus on residential architecture since the launch of practice and have completed a number of new houses and large residential alteration projects.

Site A performed nearly 150 projects last year and it has a long term partner relationship with Housing New Zealand. This firm receives most of its business from client referrals. Costumer relationship has consequently become one of the vital issues of their business development. All the customers' contact information is stored in a custom developed Access Database which doesn't work very well and errors occur very frequently.

The architectural designers at Site A are clients focused and they prepared design images and technical drawings using the most up-to-the-minute professional software. This allows for the creation of realistic three-dimensional imagery at an early concept stage which can be used to provide detailed consent documentation later. All the project information including project detail information, contact information, updates for project in progress, relevant documents which are received from city council are stored in a customised Access database which they said is not stable and errors occur very frequently. Therefore, although they have an electronic project record, it is still not easy for them to get the right information for a particular project.

They also provide their clients with cost estimates upfront and bill on actual time and materials on completion of the job. Time keeping is therefore an essential component of their business. Phone calls and other billable interruptions are often overlooked and so may not be accurately billed. They currently use hard copy diaries to record their time. A secretary enters these diary entries into an administration software application at the end of each day. They receive approximately 40 incoming phone calls a day. The secretary receives all emails then routes them to the relevant resource, thereby reducing wasted time. Some projects require the use of professional services such as engineers that incur external costs for site A that the customer must pay for.

Site A invest considerable time in establishing the design brief from the client and turning this into a concept plan, something that may require three to four iterations. Once the design is established, a review of the business processes highlighted that the bulk of the project work is the development of the required construction documentation. Additional work may be required due to the impact of building regulations, changing customer requirements, or any unforeseen changes late in the process create much more additional work. Site A often absorb the extra time required by resources thereby reducing their profit margins. Changes in the building act and greater council requirements have increased the amount of documentation by 50% but the competition limits how much of additional costs can be passed on. As a result, effective communication is called for to improve their productivity.

They are currently using various software tools to assist them in their business, including a custom developed Access database, Office Auto and Cash Manager for their accounting needs. They use Vector-Works and Chief Architect (consultants) for their design work.

5.2.1.2 Pilot Site B Supply Chain Process Description

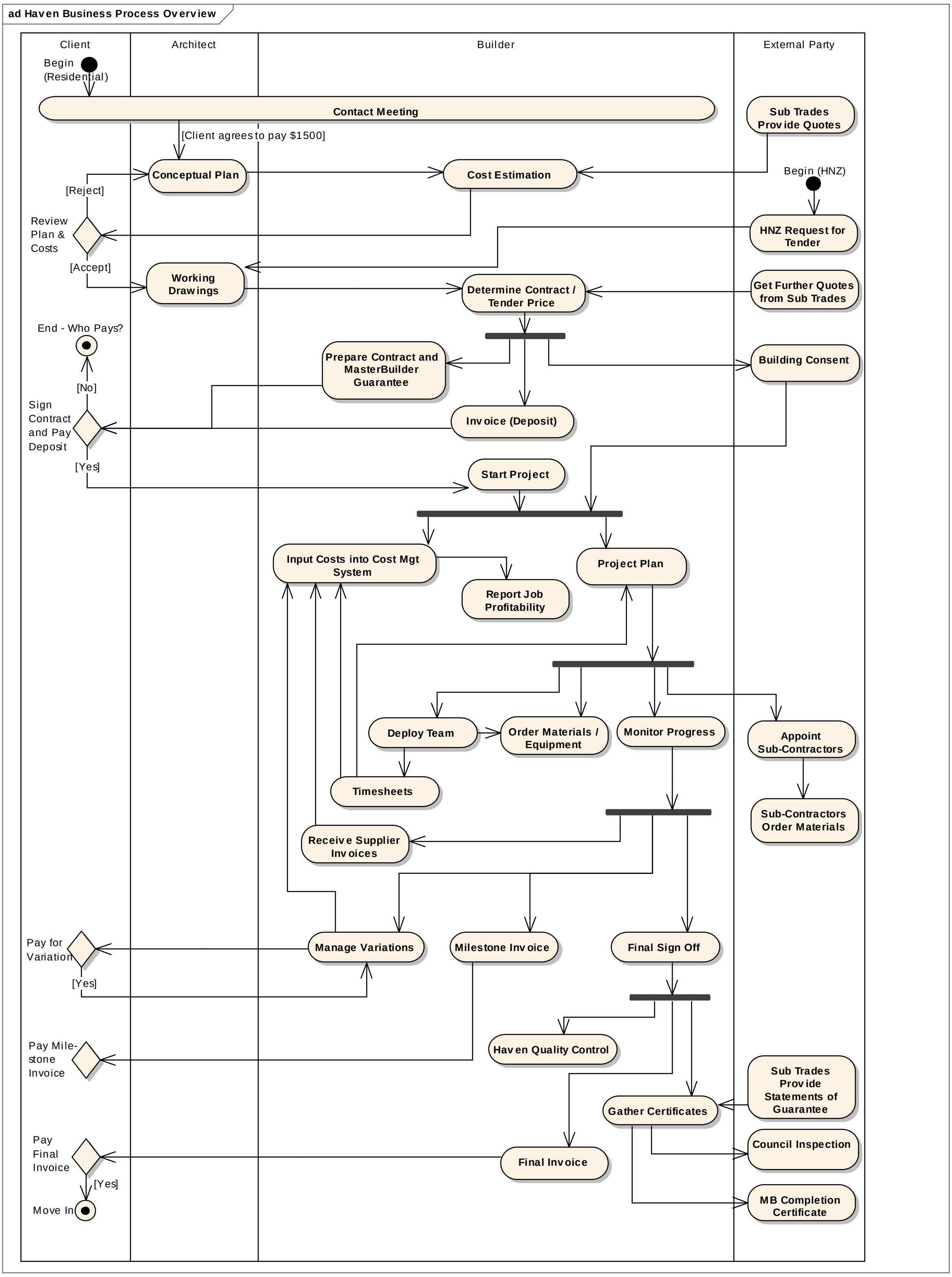

Figure9: Pilot site B Business Process Diagram

Established in 1995 as Franklin Builders Limited, Site B entered a fresh new era in 2002 with the launch of a new brand. The new brand was a progressive step for the company that has a project history spanning Auckland, the Franklin District, and the Coromandel peninsula. Under the guidance of the Managing Director, the company employs over 30 builders and trades people. An expert team of Builders, Craftsmen and professionals offers maintenance and repair work, electrical, plumbing, flooring, decorating, design consultation, architecture and landscaping services. As Registered Master Builders, Site B could offer clients the security of a comprehensive 7-Year Guarantee on new homes. In addition, Site B has specialized in constructing Firth Masonry Villa's over the last 10 years. Site B team aim to create 'distinctively different' homes, and are committed to providing innovative design solutions and quality workmanship to each client. They focus on two main areas: Residential developments and Housing New Zealand developments. HNZ developments provide constant, steady income whilst Residential projects offer greater challenges, risks and potential profit. It specializes in the custom design and build of new residential homes with an emphasis on providing a unique solution for the design preferences, lifestyle and budget of each individual client. The design process involves an experienced team of architectural drafting men, spatial designers and builders collaborating with the client. The Site B team prides itself on understanding the individual needs of clients and working in close partnership to achieve the desired result. The company's commitments to excellence and leading-edge design and construction capabilities have been recognized in the Registered Master Builders House of the Year Awards consistently since 2001. The exceptional level of service offered by Site B includes a 'Tool Box' of support services, readily available to clients.

Site B has their own in-house project managers, site foremen and building teams, and they also make extensive use of sub-contractors for their developments. They have established relationships with many sub-contractors and have a list of preferred suppliers that they use. They have also established relationships with preferred architects and interior design consultants.

A key process in their business is the estimation of the building cost. This figure is provided to the client at the beginning of the project and forms the basis of the contract. It is essential that this estimate is accurate, as it will determine the profitability of the project. Another key process is the accurate recording of actual costs for the job. This will provide good data for trend analysis, giving them the ability to understand their costing. This will be invaluable in the continual refinement of the estimate process.

Variations form a large part of their residential projects and are currently a high-risk area. By their very nature variations are extremely difficult to cost and manage effectively. Some thought needs to go into a streamlined process that will work in the books as well as practically on site. Some suggestions are covered later in this paper.

Site B currently makes use of a cost management software application for accounting purposes. Their other processes and tools are mostly manual at this stage. They store the construction project related data including customer information, project information, supplier information, and project documents on the paper in the office. Due to the limitation of space, they destroy the documents of projects after 7 years. Overall, it is difficult for them to find information they need for a particular project.

The business process of Site B is complex and full of unexpected factors. Residential projects for example, involves the homeowners themselves and therefore have the potential to be harder to manage. They have more risk associated to them, but also offer potentially higher margins. The process begins with a client meeting where the client's requirements are discussed in detail. This usually involves input from the client, architect, builder and interior design consultant. The lot (land) is reviewed at this point as well. Thereafter, the architects draw up a conceptual plan based on the decisions taken in the contact meeting. The cost of plans for the client is $1500, and the cost for Site B is between $800-$1200 depending on the complexity of the plan. Plans are only drawn up once the client agrees to pay this initial cost.

Site B uses the conceptual plan to determine a physical estimation of the costs involved. This estimate is presented to the client. If the costs presented are not acceptable to the client, the conceptual design is revisited by the architects. The client is charged for this process at the architect's charge out rates. On average this review process is done about three to four times per project. Furthermore, in order to calculate an accurate cost estimate, sub-contractors are sourced and asked to provide quotations. The office manager and project manager determine the number of sub-contractors required for the project, based on the plans / working drawings. They make photocopies of the drawings for each preferred sub-contractor. The costs incurred during this process may be high, and in general are not recovered. These costs include phone costs, photocopy / paper costs as well as labour costs to oversee this process (which may take up to three weeks). On average, 3 to 4 pages are provided to each sub-contractor, but in some cases 200 pages need to be photocopied for 20 sub-contractors. In these cases, the sub-contractors will be charged $150 for a copy of the plans.

The office manager will then chase up the quotes, receiving them mostly by fax. The figures are all collated once all quotes have been received and an estimate for the project is determined. This process could be resource intensive and may cause a massive drain on certain resources to oversee to completion. Once the review process is complete and the client is satisfied with the costing, the architects proceed with the working drawings. The costs involved for this process are incorporated in the contract price of the project.

On the other hand, Housing New Zealand (HNZ) provides Site B with constant work at steady margins. These projects are unemotional and easier to manage. For these projects, Site B needs to tender for the project. In case of that, Site B determine the contract / tender price for the project. This should be within approximately 5% of the cost estimate. Sub-contractors may again be asked to provide quotations based on the working drawings.

For both residential and HNZ projects, the office manager need to prepare the necessary documentation to present to the client for signature. This includes a contract as well as the Master Builder Guarantee. Also an invoice for the initial deposit is prepared and presented to the client with the contract. Whereafter, the necessary documentation is submitted for building consent. It takes about 4 weeks on average to get building consent.

Once the client has paid their initial deposit and signed the contract, the project begins. The project budget is entered into the cost management system and figures are allocated according to cost centres. And then a site foreman and team of 2-3 builders are assigned to site. The site foreman will manage all day-to-day issues on site and raise any concerns with the project manager. The project manager or site foreman will then order the materials and equipment required for the project. The job name is always supplied when placing orders. Bonus schemes are in place to provide incentives for the site foreman to minimise costs. For example, freight charges might apply to each order, so the foreman can plan the orders well so that larger quantities are ordered less frequently to minimise the freight costs etc. In general, only about 10% of orders they place will not be against a formal quotation. This reduces the risk to the company. Equipment required will be ordered from equipment suppliers such as Mitre 10. They arrange for onsite delivery of the equipment. To conduct the project progress, timesheets are required to be submit weekly by the team onsite and input into the cost management system against pre-defined labour cost centres for the job, e.g. Concrete Floor, Framing, Cladding, etc. The project plan should also be updated with the progress made during the week.

In meanwhile, sub-contractors will be contacted to let them know that the project has begun and that they have been awarded the job. Site B might provide them with an estimated time line but generally expect their preferred suppliers to be ready when needed. In some cases the sub-contractor will be required to order materials. For example, painters will need to order the paint.

On the supplier's side, the invoices are received and allocated to the appropriate cost centre for the project. Some suppliers allow you to add items to an open invoice. Others (e.g. Mitre 10) require separate invoices for each order. Usually supplier invoices are per project, only rarely will an invoice span multiple jobs.

It is quite common to have many variation orders raised throughout development of residential projects. Variations are potential risks as they are generally not fully understood and often produce costly domino effects that are not easily identified up front. Ideally variation orders should be carefully costed and signed off by the client before proceeding. However, in a lot of cases the job cannot be held up by this and the variation is implemented before sign off. This can lead to arguments and even arbitration as the client may refuse to pay after the work has already been done. There are some common examples of variations. For instance, provisional sums for colour, kitchen etc. may be provided upfront. On implementation the kitchen supplier may invoice the balance after the provisional sum has been consumed. This is raised as a variation. The client may change their mind on the make of bricks they want. The new bricks may cost 4c extra per brick. This cost is raised as a variation. Variations may also need to be raised due to environmental factors. Variations should be invoiced at the time of implementation, instead of at the end of the job.

To milestone the invoice, Housing New Zealand projects are simple. The progress of the job is estimated at the end of each month and invoiced accordingly. This is currently a manual process and could be automated. HNZ will send a Valuer to check progress and payment is generally received within 5 days. However, residential projects are much more complex. The contract ensures a payment schedule for the project. As pre-defined milestones are achieved, an invoice needs to be sent to the client. At this stage, Site B experiences major delays in collecting payment from clients due to the fact that the process is complex. Payment terms are 7 days, and often by the time the process is complete they will only receive payment after 25 days.

When a project is nearly completed, Site B will enter their Final Sign Off process. This includes:

- Internal quality control. This takes place onsite with the project manager and site supervisor.

- ü Gathering of statements of guarantee from sub-contractors e.g. electricians, water proofers, tilers, etc. These are generally received via fax and it takes approximately 1 week to arrange.

- ü Application for coding compliance. This is submitted to council together with all the statements of guarantee.

- ü Council final inspection. This is done onsite with the project manager.

- ü Master Builders completion inspection certificate. They will sometimes do an onsite check, but mostly don't.

- ü Final invoice. This can be complex to calculate as variations need to be considered and milestone payments reconciled.

The client cannot move into the house until final payment has been received.

5.2.2 Problems Found in Pilot Sites' Supply Chain Process

The researcher started a field study from August 2006 with site A (from 13th August to 15th October) and site B (from 18th September to 24th November). The participant observation and interviews have been performed to identify problems in both sites' business processes. Followed by those supply chain measures listed in the literature review, this section summarizes the problems found in participant observation and interviews.

5.2.2.1 Pilot Site A Supply Chain Process Problems

According to the business process described in section 5.2.1.1, several problems have been found and listed as following:

- **Variations brought high waste.**

During the field study in Site A, it has been found that the construction projects frequently finish late in terms of contract dates, programmed durations and consequently client expectations. There are generally many variations in each project: customers changed their minds during construction, the council required further changes, and the builders or engineers found errors on site. As a result, the client disappointment will result from failure to achieve unrealistic expectations due to those variations. Sometimes it even brings legal arguments when the architect cannot execute the deadline. Furthermore, these variations also have the risks to cause loss in profits because of the unexpected time consuming and human costs. Therefore, a well documented process is required to conduct the work flow to reduce the crisis of these unexpected variations.

- **High cost of estimation phase**

According to the interview and meeting with the employees, high costs are existed in the current estimating phase. First of all, paper and photocopy costs may be high because they need to print out conceptual plans and working drawings for sub-contractor to use on site. Therefore, when there are any changes need to be done, they have to reprint the plans and drawings. Secondly, labour costs are very high to manage this process. They normally call DHL to deliver the documents to their subcontractors and customers which cost even more money on delivery. Thirdly, as discussed previously, there may be unexpected variations through the construction project. Therefore, the architects and designers may have to spend more time on their jobs to meet every variation than they expected. These variations can happen at any moment so it is really difficult to forecast and to estimate the costs. Due to above reasons, it is hard to perform accuracy and effective estimation phase.

- **Invoicing systems inefficient**

Site A has employed some information systems and software to assist their daily job. For example, they use Cash Manager and Auto Office as accounting system, a costumer developed Access Database as project management software and Microsoft Project Manager as time sheet. However, these systems and software work as "isolated electronic island". In another words, there is no connection among these systems therefore the information flow in Site A is still scrappy. Consequently, there is no way to generate accurate, immediate and automatically invoice based on their actual work records. For instance, the designer needs to report their progress to the admin staff every day before they leave, but sometimes they forgot to do that. It means the admin staff cannot send out the invoice on time. This will further affect cash flow.

- **Cash flow dependent on external parties**

According to the participant observation and interview results, the cash flow of Site A sometimes depends on external parties such as owners, master builders, engineers and subcontractors. Once an invoice has been sent to a client, the payment of that invoice is in the hands of those external parties who don't really share your urgency to receive payment. However, the admin staff can not remember all of the unpaid invoices because she had to check the invoice and change the invoice status manually.

- **Limited early indicators**

Early indicators can be used to conduct possible cost issues and project task progress. However, there are limited early indicators in Site A. What happens in their daily work is that the principal designer assigned jobs to the admin staff and then the admin staff sent out a rough time plan to the architects. Therefore, the principle director and admin staff have no idea how the project is going and when each tasks could be finished. What is more, since the accounting system is separated from the job planning, this is no way to know which invoice needs to send out recently or what cost is going to be paid. It is difficult to describe the comprehensive, monthly cost and schedule tracking system used on the project without early indicators. Furthermore, because of the limited early indicators, issues which may benefit the project cannot be flagged for early implementation, and also issues which may have negative impacts cannot be rigorously studied and corrected at the earliest possible time. Therefore, extra time and money will be spent to correct the mistake.

ü Poor project management

Conducting the design phases of construction projects is complex in Site A. The main responsibility of the principle director is organizing, accessing and sharing files, scheduling multiple jobs running concurrently, and communicating information to the right person at the right time. He needs to organize and conduct resources to make sure the project could be completed within defined scope, quality, time and cost constraints. Currently in Site A, the identify tasks are recorded by the assigned architects on their individual timetable. They have to update their current progresses to the principle director and need to record their performance every day on their own paper based timetable which was distributed by the admin staff or on their own computers. As a result, it is difficult for the principle director to know the latest status of a particular task because the assigned person sometimes may forgot to update the progress information. Therefore, the principal director cannot conduct the project effectively because of the demoded and imprecise information. Moreover, because the accounting system is separated, the visibility of purchasing commitments and invoicing commitments are very poor. This leads to inefficiency of forecasting cash flow and cost estimation, also it caused late invoice for external parties.

ü Lack of effective communication

Unfortunately, the communication between the clients and Site A is not very effective. They use a recorder to record their conversation with the clients and save it in both in tapes and in digital. And then they will refer to the records when they are not sure about the clients' requirements or when there is an argument about the design. However, it is difficult to track conversational information: who it was discussed with, when it happened, which project it is related to and what topic it is about. Furthermore, the clients sometimes contact the architect by phone or mobile phone which is impossible to record. Moreover, it is also difficult to find a perfect time to discuss the project when every person who is involved is free. Therefore, the architect has to spend unexpected time on waiting for all parties come together to discuss even a simple point. In terms of that, the customers sometimes feel impatient and distraught to communicate via this kind of ineffective communication. This will potentially damage the customer relationship. It is a fatal problem because Site A receives most of its business from client referrals, which has been mentioned previously.

- **Rough-and-tumble documentation management**

Although the firm is using customer developed Access Database to maintain the project documents, it is not used in an effective way. Project information and documents should be stored a set in order to facilitating ease of search. The main problem in Site A with the documentation management system is that documents are not linked to each other in an intelligent way. For example, the communication files haven't been stored under related project and client. This makes search project information is quite difficult and slow.

5.2.2.2 Pilot Site B Supply Chain Process Problems

According to the participant observation and interviews with the staffs, there are some significant problems in the current business process of Site B:

- **Variations are hard to be conducted**

Changes made to schedule or scope is happened very frequently in construction projects, even in those well-run projects. With residential project for example, variations happen all time since the owner may change their mind at any time. The variations always start with the building owner, and then move to the architect or engineer, then to the builder or fabricator and ultimately end with an invoice to another party. Therefore, due to the changes in schedule and scope as seen in the Site B case, unforeseen variation in production schedules on-site becomes a general issue. And because when the variation happens, it sometimes may require shifting resource allocation on some of the suppliers and subcontractors. This could be one of the most essential drivers of project costs overtop the budget. Moreover, the variations bring significant time wasting. Whenever there is a change made on the project, the project manager needs to spend more time on communicating with the other supply chain parties. Furthermore, variations may cause the delay of the project and as a consequence bring complaints from the client which will damage the customer relationship of Site B.

ü Poor project management

The current project management performance is very low. The office manager won't have any idea of the project progress until the project manager and the foreman reported to him every week on the project meeting. What is more, the office manager can not present a collaboration project work flow since he can not conduct the staff working on the same project in parallel as he has no idea of who will or who has already finished what or when. Therefore, he can not conduct the project effectively on a real time base unless he goes to the construction site. Furthermore, the cost brought by the variations can not be conducted effectively because of the difficulty of communication. Several change orders can not be approved in advance by the owner because some project managers or foremen are not doing their required paperwork timely. As a consequence, the project manager can not have the right products on site and it will cause delay of the progress. More broadly, the cost management system cannot provide detailed information and reports which will be use to analyze to determine the job's profitability. The budget cannot be compared to the actual costs automatically therefore the manager cannot determine areas of possible improvement for future projects. This may account for the failure of managers on Site B project to explore lower cost alternatives to their acceleration.

ü Fragments in information flow of the supply chain

On the other hand, construction contracts always penalize for problems and contact separately for particular work. It leads to the unwillingness of information sharing. Therefore, the supply chain parties can not explore costs and capabilities in a dynamic environment. This may be the reason why the delay of construction material was not known in advance. It also explained the lack of examination of alternatives by the general contractor. Therefore, there comes a problem that the integrated analysis across the entire supply- chain (from supplier to subcontractor) can not be performed because of the fragments of information flow. Furthermore, the information flow is not rigorous because most of the documents are paper based and need to process manually therefore there are too many chances to make mistake. Moreover, the information cannot be updated “just-in-time”. An example is an irate subcontractor who called threatening to walk off a job unless they got paid for work completed two weeks ago but the account manager did not know they had finished. Increases in costs and supplier costs are greatly influenced by the degree of uncertainty in the unit-order system. A systems perspective is required to evaluate performance.

ü **Ineffective project communication**

Communication is a big problem. First, the internal organizational communication is not effective. The project manager and foreman are always on the construction site and can only be reached by mobile phone. However, they are weighed down with picking up documents from the office or taking notes of the variations the clients just notice the office manager. Secondly, it is difficult to track the communication of particular project with the external parties such as the owner, Housing New Zealand, the architect, the inspector, and the subcontractor. Currently, phone call and fax are the main method to communicate with their customers. They can not record any conversation on the phone and cannot relate it to the particular construction project. Therefore, they can not track the previous discussion or agreement on a particular project.

ü **Poor document management performance**

There is no computer based document management system in Site B. They store the documents on the paper and each project has a folder. And the project which is more than 7 years will be destroyed due to the limitation of space. However, there are still thousands of documents which can not be destroyed since Site B has promised a 7-year quality guarantee to their clients. The documents are not cross referenced by customers, supplier, manufacturer, project manager, and even subcontractor. It is difficult for the staff to search related documents in bulky folders. Therefore, the project information and documents cannot be located quickly and accurately.

- ü **Poor cost control**

The original budget to complete a construction project is usually different from the actual costs. It will always be higher or lower due to unforeseeable variations happened in the project process. Therefore, the project manager should be able to control the current on a project's cost by maintaining a reliable and accuracy information received from supplier and also the progress of the project progress. In Site B case, the office manager and the project manager can only estimate cost of a particular project based on their own previous experience. However, the changes in labor wages, productivity, labor shortages and the variations of the cost of materials, delays of deliveries, accidents, and even weather and site conditions may affect the cost, as well as the initial job plan. As discussed previously, because the office manager and account manager can not exchange the real time information with the on site project manager, the costs cannot be conducted and recorded. Therefore, it is difficult to learn lessons from previous projects and it is difficult to forecast the cost in next project. Furthermore, Cost control accounting and progress estimating are completely separated in Site B. Bookkeeping, including the recording of accounts receivable, accounts payable, payroll, taxes and other financial accounts, all these functions are highly depended on the information from the construction site. Consequently, the invoicing and ordering system are not effective due to the poor quality of information the account manager receives.

In conclusion, there are some relations among these problems, no matter in site A or B. Ineffective communications may lead to variations and then bring redundant costs. It can also result in poor project management therefore induce poor estimation and cost control, including human resource cost, capital cost and time cost. On the other hand, the fragments in information flow lead to inefficient invoicing, poor cost control and also poor project management. Consequently, the problems are correlative, and ineffective communication and information flow are the root causes behind those problems.

5.2.3 Benefits Brought by Adoption BlueSky

This section will recapitulate the main opportunities which eventuated from the adoption of ICTs in the form of BlueSky at both pilot sites.

5.2.3.1 Benefits Brought by Adoption of BlueSky in Site A

Pilot Site A has adopted BlueSky since September 2006 and there are considerable changes brought by the system listed as following

- **Better project process conduction**
  According to the administration staff and the principle director's user experience, the project process management has been improved significantly. BlueSky provides tools for recording and tracking time spent on project tasks. Timers can start automatically when a document is opened and tasks can be recorded as soon as it begins. BlueSky system automatically creates a diary for each employee, which allows the users to create or navigate their actual and planned activities of a particular task. Every user can plan or record their time so can represent future or historical activities. The admin staff and the principle director can see all the diaries of the firm so that they can conduct the project progress in real time. They also can add new tasks or activities into the others' diary for their future work plan and the user can see it from their own diary when they log in. Moreover, the principle direct can assign architect to projects or tasks and it is possible to plan when these assigned person will perform work on the task which will then appear in the person's diary. Furthermore, there is a reminder in the system which will alert the user when there is a task, an invoice or a purchasing needed in a preset up time.

- **Better communication**
  The effectiveness of the communication between Site A and its clients has been improved through an instant messaging system provided by BlueSky. This instant messaging system allows users to communicate with each other within the bisco

framework. BlueSky Chat is similar in concept to Skype or Msn Messenger except that it allows the messages to be stored in a context. This allows the user to review the history of discussions about any aspect of a project or other entity when required. BlueSky Chat does not require both parties to be online at the same time as it can store a message on a server until it is delivered to the target party. It makes the communication much more flexible than before because the parties needn't to be online at the same time. They can view and reply the information when they are free. Furthermore, BlueSky Chat provides record functions as well and the audio file will save in the history folder so that the user can review it when required just like those textual chat history. Also they can communicate directly with Valuers and clients, perhaps sending photo to confirm progress. Moreover, the user can categorise the chat history into project or task. This allows the user to search the information more easily.

- **Integrate information flow through the supply chain**

The fragments in Site A supply chain information flow has been integrated by BlueSky system. As a project centric system, BlueSky integrates the activities required by the project together. These activities include job planning and recording, communication, invoicing and purchasing. Job cost will be generated automatically according to preset up criteria and the invoice will be automatically sent to external parties.

- **Better cost estimation and payment control**

The principle director can keep accurate records of all costs using BlueSky Estimation system. One function he really liked is the system allows him to highlight the possible changes required in the estimating process and to identify high risk areas and implement more 'red flags'. Moreover, the system provides a progress payment timetable based on the project plan so that the admin staff can be automatically 'reminded' to follow up with the principle director when milestones are due to be completed. It also provides full records of cost of work in variation and invoice variations and enables immediate on approval with 7-day payment terms. Therefore, BlueSky system reduces the time taken for estimates and the amount of follow up effort required by its unique project generated cost function.

ü **Better documentation management**

According to the feedback of the interview with Site A staff, they are very satisfied with BlueSky FileStore function. First of all, they suggested that BlueSky has provided multiple accesses to the documents they need. They can access the document from a particular client, project, diary, chat topic, and job cost. It can provide a location where any type of file is stored and managed effectively. Furthermore, the core function of the FileStore is the booking process which provides both security and flexibility for the user. It allows the user to copy the file onto their machine and also allow the others to view the file at the same time by different book status they chose. This function can let more than one person view the document but only one of them can change it. It avoids the unexpected and unauthorized changes to documents.

ü **Better security**

BlueSky system provides better security for the firm. It is necessary to have a user account to log into the system and the account only can be created by the principle director. The principle director can create different user groups so that different user groups can only view the project information which has been assigned to them. This can pretend business secrete and copy rights.

5.2.3.2 Benefits Brought by Adoption BlueSky in Site B

Pilot Site B has begun to use BlueSky system since September 2006. There are benefits brought by adoption of the system:

ü **Lower administration and communication costs**

According to the participant observation in Site B, the administration and communication costs of conducting multiple parties involved in one particular project is very high. However, the costs have been significantly reduced after they start to use BlueSky system. Firstly, BlueSky system provide digital document and varies functions which allow them to exchange project information without paper. BlueSky FileStore function, for example, allows the different project parties share information on the FileStore Server. Consequently, the scattered information across Site B, which cause an inefficient and lack coordination process, can be collected together and therefore improved both internal and external communications. Secondly, the office manager can conduct the project progress simultaneously from the office. BlueSky Project also provides a diary for each user so that they can record their daily activities which could be browse and traced by the project manager and the office manager. Therefore, the previous cost of phone calls can be saved. Thirdly, the time control of each project team member can be performed easily through the time recorder in BlueSky system. The entire project time cost will be calculated automatically by the system according to the actual work record. Therefore, the project manager needn't spend extra energy on time tracing.

ü **Better cost control**

BlueSky provides an effective job costing control system which can help Site B to improve its competitive advantages and win the tendering. It offers an ideal cost system for both bidding and accounting purposes. It can capture the changes in a project progresses. If construction costs are running higher than the estimate, or are different from schedules, corrections can be made when the project is still in progress. Therefore, Site B can achieve financially success. Furthermore, BlueSky system provides an integrated system which is comprise of estimating, project management and cost control. The account manager can set up job cost codes and budgets automatically from the estimating modular. Furthermore, BlueSky helps Site B to keep the expenses under control. Cost budgets can be setup for material, labor, equipment and other categories which can be easily tracked estimated towards actual. The system use "tasks" to represent activities to be undertaken on a project and if a task is billable can have a budget work, cost and sell prices and these feed through to capture actual job cost. What's more, Site B also takes advantage of BlueSky Project to track labor hours or equipment running time. BlueSky allows workers to enter hours into a time sheet from jobsite, home or main office. These can be reviewed or approved by the project manager to conduct the employee wages.

- **Time savings**

After using BlueSky system, Site B saved a lot of time on a particular project. First, BlueSky helps the project manager save a lot time on project conducting, communication with the clients, subcontractors, suppliers and other project parties. For example, the project manager can take a photograph of the completed milestone and send it online to the Valuer from Housing New Zealand and attach the invoice and copy it to the clients. Secondly, some project progress can be done by automatically by the system. For instance, total time costing can be calculated by the system automatically after the project has been completed. Also, the project parties save a lot of time on communication as well. This will be discussed later in this paper.

- **More project control and security**

BlueSky system led an effort in developing comprehensive construction functions that incorporates the best practices of construction project control which has been proved in the participant observation and the interview with the project managers. BlueSky Project can bring estimators, project managers and accounting staff together to work as a team on its electronic platform. For example, BlueSky can quickly turn estimates into contracts, subcontracts, change orders and purchase orders. What is more, BlueSky "Ghost Model" can replicate the original CAD model and every element represented in the model can be related to database record. Therefore, the system can automatically determine how many sheets are required to manufacture a project. Furthermore, BlueSky Estimating system can help the project manager get the all-sided picture and profitability by providing a real time information flow. As a result, the managers can analyze cost, hour and revenue budgets. BlueSky system allows the project team members to be able to track due dates and tasks in order to prevent workflow disruptions. BlueSky system also provides an effective way of cost control. For example, when the timesheets are captured in the system and the project plan is updated, triggers are set up against these pre-defined milestones in the project plan and a reminder will be highlighted to generate an invoice.

The information can be shared in a convenient and safe environment by using BlueSky. First, the user must have a user account to log into the system. They need a valid user name and password to browse the information. Also there are different user groups in the system and different groups have different secure level which means they can only browse the information their user group is allowed to. Secondly, BlueSky Office (FileStore functions) allows the user to share information safely and easily. The cores function of the FileStore the booking process. This process copies the file onto the user's local machine ensuring fast access to the file and the ability to use the file offline. And it provides different users' rights with the file. For example, an Exclusive Book Out means the user can edit the file and all other users are prevented from accessing the file while he is editing.

ü **Enhanced project communication**

BlueSky system provides successful communication between construction parties and achieves significant success on particular construction project for Site B. It provides cross discipline communication by integration the documents transfer process with accurate, real time and collaborative information flow. Site B has replaced paper based documents of compatible electronic format by adoption BlueSky system. Furthermore, it provides a safe information sharing method among the project team members, both internal and external. Therefore, the scope of co-operation among project parties is widely extended. And the communication process between project partners has been improved by the use of electronic document management system. Moreover, BlueSky system offered an effective way of searching relevant project information in a time saving method. As a result of that, the communication on project argument has been improved. What is more, BlueSky "Chat" function offered a real time communication among the project parties. The users can communicate with each other by sending instant messages and these messages will be stored in the database for future reviews.

CHAPTER 6: DISCUSSION AND RECOMMENDATION

6.1 BlueSky Benefits Bring into the Pilot Sites

According to the participant observation and usability testing results of BlueSky pilot sites, there are several benefits brought by BlueSky system:

- **Considerable time saving and better communication:** Neither Pilot site A or B had effective document management system before implementing BlueSky. Site B, for example, had to transfer paper based project documents through the project life cycle. Therefore, according to the pre interview with some of the staffs, they wasted significant time on project communication: the architect finished the initial project plan and then he called the project manager who in charge of this project. They had to discuss the design for several times face to face and sometimes the developer or owner will be involved. This kind of communication had to meet the participants' timetable: owner, architect and project manager. Therefore, the architect or the project manager had to wait until the other has spare time to discuss. After using BlueSky system for a while, they started to enjoy the benefits brought by the online communication and file store function which allow them to view, edit or delete project related file stored on BlueSky sever. In terms of that, all the previous interviewee said they saved a lot of time and achieve more effective communication.

- **Error reduced:** Since both of the pilot sites were mostly using paper based project document including project plans, construction diagrams, primary and secondary elements diagrams, there were avoidable mistakes throughout the project process. For example, the architect in pilot site A sent the initial plan to the project manager in pilot site B, but after a while he changed a detail and sent another diagram to the project manager. Unfortunately, the project manager had already gone to the construction site and talked with the builders on site. He didn't realize the change until he was back to the office. This kind of mistake happened all the time. However, things have been changed after they started to use BlueSky. According to interviews with some of the staff, most of them think the accuracy of the information they received has been increased because of the real time communication and automatic estimating function of the software.

- ü **Lower administration costs:** Pilot site B is a master contractor company which used to spend a lot of money on project management and administration. Every Monday morning, the office administration lady sent out printed out time table to each staff and they had to report what they had or hadn't finished to the relevant people. If one of them forgot to report or make a wrong report, the others were tampered with their mistake. "It is really tough. Things can be a mess." After implementing BlueSky Project, the project manager can browse other team member's calendar in real time and conduct the project progress easily. Also, once implemented the system alert function will notice the person there is an assignment going to due or over due.

- ü **Tendering and procurement efficiency:** According to the pre interview with pilot site B manager, the organization had their own supplier and sub contractor pool. They called or emailed each supplier or sub contractor to inquire price list and then selected a suitable one to deal with. However, things have been significant changed after they kicked off with BlueSky: all the suppliers' and other partners' information including their price list has been stored in BlueSky server and they can generate orders directly from BlueSky Estimating system. Therefore, the procurement has been more effectively.

6.2 ICT Benefits for NZ Construction Supply Chain Management

The literature shows that some research has been carried out overseas to examine on application of Information and Communication Technology in the construction industry. Veeramani et al. (2002), on behalf of CII (Construction Industry Institute in USA) carried out a research named "state of practice of strategy information system in the American construction industry" through literature search, survey (with 49 responses) and 19 in-depth interviews with CII member organizations as well as four in-depth case studies. Based on this research, they concluded that the owners are the initiators of the implementation of Internet-based technologies including email communication and buyer/supplier integrated pooled procurement packages. They also found that use of ICTs can reduce the time required to complete the different stages of procurement (Veeramani et al, 2002).

The IT Construction Forum (2004) based in UK also held a survey called "IT in construction – use, intentions and aspirations" of 373 construction organizations of different business types, including contractors, specialists, designers and consultants, and sizes. There are five key findings in this survey, which are described as following: Firstly, it is widely used among UK construction organizations. Secondly, most of the construction organizations use the Internet to transport information of construction products. Email is used most frequently, for communication and product orders mainly. There are around 50% of the organizations which are using online purchasing. Thirdly, it is generally accepted that the speed of work has been significantly increased by using new ICTs. Fourthly, most of the organizations are seriously considering their investment of adoption of ICTs recently. They suggested that the investment should be the same or even better than their major competitors. They want to keep more competitive advantages than their competitors in the adoption of ICTs. What is more, they can also keep timely in touch with their clients through new technologies such as email and mobile information technology. Last but not the least all the examined organizations said they need professional advice on the costs and risk management of wise investment on ICT. They also need recommendation on how to design a suitable ICT strategy for themselves.

BlueSky as a leading strategy New Zealand local construction supply chain management system can offer various benefits to local construction organizations. Based on previous questionnaire results and the participant observation and usability testing results, there are considerable potential benefits that BlueSky can bring into New Zealand construction supply chain management.

6.2.1 Better Partnership among Construction Industry Supply Chain

The BlueSky system can build up a stronger and more effective partnership among New Zealand construction industry supply chain members. The effects are not easy to quantify, but there was a strong feeling that by providing participants with correct just in time information updates, the whole culture of project information exchange will be changed from restricting the flow of information on the ground of commercial sensitively to a culture of sharing and trust (Wood & Ellis, 2003). According to the questionnaire results, majority of the businesses in New Zealand construction industry are moving onto an increasingly information-intensive platform. Information technology is used to improve the management of their core business process and their management of supply chains, especially those large organizations. Moreover, New Zealand construction industry already has base of knowledge of what is good practice utilizing information technology. Majority of the respondents think that ICTs can help with improving construction supply chain performance and are willing to have such kind of supply chain information management system in their organizations. As a construction supply chain management information system, BlueSky needs to be judged in the context of its wider impact in enabling business process reengineering, the opportunities it offers for exploiting information, and the challenge of its implementation through supporting applications. Information and communication technology is an important requirement for building better performance of all supply chain partners in the construction process and BlueSky information and document management system (BlueSky Studio and BlueSky Office especially) is seen as a substantial step towards achieving greater business benefits.

6.2.2 Enabled Pooled Procurement

It has been shown that through global integration of procurement information over multiple projects, pooled procurement leads to efficiency in material manufacturing and distribution, decreased material costs to contractors and owners, and reduced transaction costs (Wright & Race, 2004). In the previous section, the possibilities of BlueSky pooled procurement for reducing prices, without creating damaging monopolies have been explored. In brief, BlueSky system helps the construction organizations play a more pro-active role in ensuring long-term availability of key cheap products, at the lowest possible price and of assured quality. It can help the New Zealand construction organizations to establish more healthy and smoother supply chain management system via BlueSky Estimating to generate orders, procurements, and bills directly from CAD models and to select better supply chain partners via BlueSky partner pool which is established for particular users or shared by all the users depends on their requirements. Therefore, BlueSky system can add considerable supply chain competitive advantages for New Zealand Construction Industry by its unique pooled procurement function.

6.2.3 Significant Time and Cost saving

As stated in the questionnaire analysis section and previous literature review, Information and Communication Technologies have generated great effects within the construction processes. The first type of effects is more efficient information-related activities such as creation, recovery, delivery of information and effective communication, which could be able to offer significant time saving. Another type of effects is the activities related to efficient material-handling in information processing through the use of Information and Communication Technology. Majority of the questionnaire respondents agreed that the new ICTs provide inventory reduction and also the decrease in the number of rebuilding as results of accurate design information and production of energy efficient buildings.

By the applications of BlueSky system in the construction supply chain, pilot organizations can achieve great benefits from the reduction of transaction costs, labor requirements and project lifecycle. It could decrease the inventory levels and gain higher degree of job transparency. The successful adoption of BlueSky system offers provision of information of demand which provides more frequent and intense use of it. Moreover, it also can provide efficient connection to operations across organizational boundaries, enlarge the span of effective control and co-ordination, and improve in the quality of decision-making processes. Except all of the above, BlueSky system also improve the communication and collaboration between supply chain partners and organizations.

6.2.4 Create Integrated Construction Supply Chain

In agreement with the literature, the construction supply chain is always fragmented and full of chaos. According to the questionnaire analysis results, majority of the respondents indicated that ineffective communication among project partners and high mistake rates are the most headachy problems in their daily job. Most of the respondents suggested that their actual working time has been double due to those problems on per construction project. Designed to counter this point, BlueSky system provides several functions to solve these problems: designers provide project architectural drafting and planning, builders receive any changes in real time whenever and wherever they are; project managers conduct project time plan, generate project budget directly from the architectural diagrams, and they also align the actual cost to the estimated cost as the process going, the suppliers upload their price list on BlueSky server and are paid directly into their bank account, bills, documents and specifications are generated and sent automatically and the owners investigate the construction project site without leaving their home by online communication and even web cam in real time. Therefore, the New Zealand construction supply chain cycle will be integrated as a whole by using BlueSky system.

6.2.5 Act According to Actual Circumstances

There is a great deal of construction software in the market such as ArchiOffice, developed by the US and focused on document management, and Risk Manager, developed by an Australia company named Red Gravel. But these types of software are designed for different construction market and are focused on different supply chain needs (Bjork, 2002). According to the literature, different countries have different construction specifications, building codes and market situations. Although Australia and New Zealand construction industry are sharing the same building code, the participant organizations' type, range and ICT situation are completely different. Therefore, the foreign construction software can not be fully aligned with the New Zealand local construction industry. As local designed software, BlueSky system can meet local conditions. BlueSky Specification system, which is still in development, can generate specification directly and automatically from popular architectural design software such as AutoCAD, Skechup, ArchiCAD and Revit. Since the system is designed to adjust to New Zealand local construction industry conditions, BlueSky can provide more benefits than other kinds of construction supply chain management software.

6.2.6 Summary

The following table shows that the adoption of BlueSky system within the New Zealand construction industry supply chain management can provide unique benefits for each branch of the construction supply chain, and also offer great potential for enhanced performance of the whole chain.

Branch of construction supply chain	**Potential Benefits of BlueSky system (strategy construction supply chain management system)**
Owners/Developers	• Improved project efficiency • Reduced construction costs, chance of errors, and the need for rework • Compressed construction programme
Designer	• Time savings • Improved communication • Increase accuracy and speed of specification
Master builders and subcontractors	• Lower administration and communication costs • Tendering and procurement efficiencies • Time savings • More project control and security • Enhanced project communication
Suppliers	• Lower inventory • Lower cost of serving customers
Building components manufacturers	• Reduced channel costs • Improved access to information • Cost-effective access to actively purchasing and specifying customers

Table 4: Potential Benefits of BlueSky to Supply Chain Members Resourced from Capo et al. (2002)

All in all, adoption of ICTs will improve the efficiency of the building industry by managing the flow of information across the industry ensuring process and data integrity. It is a platform that allows the transfer of information between different parts of the building industry electronically eliminating re-keying errors and reducing processing costs. What is more, ICTs such as BlueSky transform information from one format to another for use in various functions. This could be extracting data from 3D CAD models and transferring it to estimating databases, project planning tools, or accounting systems

6.3 BlueSky Potential Problems in the Pilot Sites

There are also some problems and potential risks of using BlueSky found on pilot sites:

- **BlueSky system problems**: Several usability problems have been found during BlueSky usability testing on pilot site: (1) the system has so many functions that some of the staff think it is not easy to use; (2) the route of getting needed information is complex; (3) the system is not very reliable; (4) sometimes the response is not fast enough.

- **People and organization culture issues:** Compared with pilot site A (architectural design company), there are some human nature risks in pilot site B (master contract company). One of the project manager said he didn't trust the electronic project document because he cannot "feel" it. He seemed to refuse this new technology although he admitted that the system did bring "some benefits".

- **Software training issues:** From observation by the researcher on both pilot sites, the computer literacy levels of the employees of site B are lower than site A. It is more difficult to provide software training in site B as most of their employees are builders and project managers who need to work on the project site. They claim, due to pressure on the job not to have time to attend training courses. As a result they take longer to become competent with new, and/or changes to software.

6.4 BlueSky Potential Problems in New Zealand Construction Supply Chain Management

Although ICTs can bring significant competitive advantages, many companies have failed to effectively enjoy the benefits enabled by ICT because of the misunderstanding of the relationship between factors and process which influence ICT implementation **(**Peansupap& Walker, 2006). In Peansupap and Walker's research, they recorded the results of a recent qualitative ICT implementation research among three construction contractors. The findings of their study provides deep insights and useful practical experience of lessons learned which can be broadly implanted within the construction industry. These research results also provide an ICT innovation organizational level framework with perspectives of how it can be used to improve ICT adoption at different implementation stages for the construction industry. They suggest that strategic ICT implementation planning needs to consider those issues of risk management support, technical support and also the characteristics of construction industry ICT users so that the ICT framework may be effectively applied.

According to the participant observation and usability testing in BlueSky pilot sites, and also the questionnaire analysis results, challenges of using BlueSky system were revealed in the documentation and standardization of purchasing processes and workflow processes. It can be concluded that some organizations especially most of the contractors, were unwilling to adopt BlueSky as they thought that there are too many uncertainties and concerns. They also found that the reluctance to using ICTs or BlueSky system is not only generated from the internal culture but also from business partners within the construction industry and its supply chain.

This section will summarize potential risks and problems when adopting BlueSky system into New Zealand construction industry supply chain management process.

6.4.1 Information Management Methodology

BlueSky system as an example, the new ICTs have the potential to generate an enormous wealth of data which leads to information overload. The sharing and transferring of information predominates supply chain partner’s activities, which is seen as a core function of the supply chain. However, as a result of the fragmentation of information from different communication channels, effective information management to have the purposive information approachable when required have become toilful and time-consuming activities, and inefficient management of information have reduced the benefits of using new ICTs. In addition, the potentially enormous data collected from both internal and external communication points involves significant information management load in security, filtering, consistency checking, data cleaning, storing, knowledge discovery, and knowledge integration backups etc, which is challenging for information management and knowledge integration.

6.4.2 Legacy Enterprise Policy

The adoption of new technology such as supply chain management systems for example, BlueSky, can impact all of the operations within organizations significantly, and this requires adaptation of a new underlying operation and management philosophy (Elliman & Orange 2003). This change affects core component of organizations both management and employees, such as goals, technology, vision, training, policies, culture, mission, and business strategy. The implementation should be undertaken in a top-down hierarchical approach. Starting from top management, further implementation then move to the middle management, and then to lower management. Step by step, change operation can be introduced to influence all the employees to support the new mindsets and the application of new ICTs (Cheng et al., 2001).

6.4.3 People and Enterprise Culture Issues

An organization may not possess appropriate skills to manage new innovation technology, which may not be embedded with an underlying supportive culture (Wood & Eliis, 2003). Organizational culture contributes a significant part in implementation of innovation that involves different professionals working together to meet the project objectives and enhance performance, which requires 'no-blame' culture to encourage people to experiment with new concepts (Ling, 2003). Furthermore, contribution by staff in task execution and management is crucial and their performance can significantly affect the success and failure of the organization (Cheng et al., 2001). It is impossible to implement new work process into an organization when the current working environment is not ready for it. When adapting new ICTs, it needs careful and critical evaluations to decide the degree of change which includes the internal efficiency of the business, budget, availability of highly skilled people, economical situation, market conditions, political systems, capability of internal staff, and regulations with external partner.

6.4.4 Knowledge Management in Construction Enterprise

Training staffs can assist to improve resilience, trust, and pride by them, because without the commitment of staff, innovative technology cannot be aligned with the organization's goals and objectives (Cheng et al., 2001). Knowledge sharing is recognized as a channel for industry to address its need for innovation and improved business performance. However, frequently, organizations rely heavily on people and assume that they will transfer their learning and experiences to other employees, which can make organizations vulnerable if and when there is a high staff turnover. People-based knowledge transferring system may not incur much cost commitment to organizations, but such approach is considered ineffective, unproductive and expensive when compared with the loss of knowledge that is inevitable when liable staffs leaves the organization, resulting in possible difficulty in case of expansion (Kamara et al., 2002). Walker (2004) further comments that current information and communication technology such as knowledge repository can provide great value, but it is essential that employees have competent skills to fully utilize this application.

6.5 Recommendation

BlueSky system has been developed for 3 three years and has successfully run on several pilot sites. However, for BlueSky to be fully effective more ICT component need to be added.

6.5.1 Employ Mobile construction RFID (Radio Frequency Identification)-based Supply chain management portal system

The current BlueSky system focuses on how to obtain real-time information effectively and how to improve inter-organization performance by utilizing information sharing and communication among involved project participants to reduce construction conflicts, project delay time and total costs. However, the system can not work efficiently on project sites since it is not always convenient to use a PC notebook in such a harsh environment as a construction site. At the same time, paper-based documents of site processes are ineffective and can not transfer the quick response between the office and project control center. Promising integration information technologies is radio frequency identification (RFID) technology for improvement the effectiveness and convenience of information flow in construction supply chain management systems (Acar et al. 2005). Radio frequency identification is appropriate for several construction applications, providing cost savings through increased speed and accuracy of data entry. Ling (2003) demonstrates the effectiveness of a RFID-based supply chain management application in construction projects. It is called the Mobile Construction RFID-based Supply Chain Management System which can offer efficient responds and can improve the information flow between offices and sites in a construction supply chain environment. This kind of advanced system can not only enhance the efficiency and productivity of work for on-site engineers, but also can provide a visual control system for project participants to monitor the whole project. Moreover, in his paper, Ling also presents generic system architecture and implementation guidelines.

There are already some successful examples in other countries. Ping et al. (2005) presents a similar construction supply chain management system using personal digital assistant (PDA) and BAR codes. The results of questionnaire analysis have indicated the importance of obtaining effective real-time and proper information for the construction supply chain management performance. To satisfy the potential users (questionnaire respondents), bar code scanning is appropriate for several construction applications, providing cost savings through increased speed and accuracy of data entry. By utilizing the latest mobile information technologies such as personal digital assistants (PDA), bar code scanning, and data entry mechanisms, the BlueSky system should be able to dramatically improve the effectiveness and convenience of information flow among the chain. It can ensure both the speed and the quality of the project information transformation among offices and project sites. What is more, it has been successfully demonstrated that the effectiveness of a bar-code-enabled PDA application construction supply chain management system.

Therefore, BlueSky system should be able to be improved by employing this kind of technology to achieve even better efficiency and performance of conducting the delivery of the building components and ensuring the location of each component ordered.

6.5.2 Reorganized BlueSky Functions to Match Different Organization's Needs

According to the field study and questionnaire results, different kinds of organizations have different requirements of supply chain management system. For instance, the architectural design company needs effective communication and high accrues, but the builders are looking for effective procurement, project management and better communication. However, current BlueSky system is categorized by different functions as above. It cannot meet different customers' needs. Therefore, BlueSky functions should be reorganized and packaged for particular types of construction operations.

6.5.3 Employed Web Application

E-supply chain management is one of the hottest topics in all kinds of industry and all over the world including New Zealand construction industry. BlueSky system can contain a real-time information visualization tool for construction supply chain management. It can utilize the Web Services and computer agents' technology for building a virtual construction supply chain (Arbulu et al., 2003). Having real-time information available at any time can increase information transparency, which in turn, makes it easier for project managers to identify potential risks. However, it is not an easy task since the information only can be retrieved from heterogeneous system. On the other hand, the process of achieving information is intractable. In order to increase information transparency within the construction supply chain management, BlueSky can employed web application to construct a virtual supply chain seamlessly.

6.6 Limitations

The limitations imposed by the time and scope of this research are listed blow:

- ü The BlueSky system does not incorporate the function for strategic construction supply chain management system in Chapter 2.

- ü The questionnaires are sent out during the architectural conference. As a result of that, the samples of the respondents are not random so that the questionnaires results are not general features of New Zealand Construction Industry.

- ü The participant observations of BlueSky pilot site are not complete since the researcher are not supposed to be on site everyday.

- ü Some of the BlueSky functions haven't been used by pilot sites, for example, BlueSky Specification. In terms of that, there is no outcome for this part of the system.

6.7 Lesson Learnt from This Research

The development of a case study research is very challenging; however, throughout the research, the ability of framing the concepts from the existing literature and obtain new knowledge from them has been extensively exercised. Much of the new knowledge was gained from the literature review.

The design science case study and qualitative research process are very powerful guides that can consistently and precisely guide and direct the researcher throughout the research. Particularly in the case study research process, the BlueSky system was consistently assessed and refined. The applicable key concepts are accurately obtained and applied to the review of BlueSky system, which gives rigors to the research.

6.8 Future Research

The BlueSky system can be improved further to include the mobile information technology, web application and knowledge share pool, such as facilitating the generation of a precise system future plan. The architecture of BlueSky uses a layer design; a more advanced service-oriented design can be applied to enhance the usability of the system.

Currently, the usability of BlueSky is being partly tested; however, the functions haven't been categorized and packaged for each type of construction organizations. In addition, an intact BlueSky system can be built using available technology, based on the foundation work of this research.

CHAPTER 7: CONCLUSION

7.1 Summary of Research Findings

The findings of the research are detailed below in relation to their relevance in addressing the research objectives and informing the theoretical model.

7.1.1 Objective 1. Identify problems inherent in supply chain management and partnering in the New Zealand construction industry.

The current New Zealand construction sector is huge, diverse, extremely fragmented and arguably the least developed of all the sectors in terms of supply chain management and the integration of core business processes in the construction supply chain. Overruns are the rule rather than the exception and poor project execution due a lack of co-ordination between disparate trades' people results in considerable amounts waste (re-building, re-working and repairing). This has been also proved in previous questionnaire results. Therefore, there are signs of change, with public sector construction tenders increasingly demanding evidence of partnership agreements between major contractors and sub-contractors to ensure efficient, effective and timely delivery of construction projects, but there is huge scope for improvement. According to the previous questionnaire responses, there is a trend of calling for utilizing ICTs to improve CSC effectiveness.

The construction industry in general is highly fragmented with significant negative impacts – perceived low productivity, cost and time overruns conflicts and disputes, and resulting claims and time-consuming litigation. These have been acknowledged as the major causes of performance-related problems facing the industry. The legacy of this high level of fragmentation is that the project delivery process is considered highly inefficient in comparison with other industry sectors.

Some of the consequences of the fragmentation problem include:

- Inadequate capture, structuring, prioritization and implementation of client needs;
- The fragmentation of design, fabrication and construction data, with data generated at one location not being readily re-used downstream;

- ü Development of sub-optimal design solutions;
- ü Lack of integration, co-ordination and collaboration between the various functional disciplines involved in the life-cycle aspects of the project; and
- ü Poor communication of design intent and rationale, which leads to unwarranted design changes, inadequate design specifications, unnecessary liability claims, and increases in project time and cost.

The application of Supply Chain Management is a means of developing vertical integration in the design and production process and operation to link the process into a chain, focusing on maximizing opportunities to add value while minimizing total cost. As this application requires a significant shift in the mind-set of the participants toward collaboration, teamwork and mutual benefits, it is hardly surprising that only few sophisticated applications have been reported in the construction industry.

7.1.2 Objective 2. Identify how ICT might be used within the supply chain to facilitate benefits for the construction industry.

Although most supply chain issues are strategic by nature, there are also some tactical problems. These include inventory control, production/distribution coordination, order consolidation and ineffective communication. According to the questionnaire feedbacks, most of the response organzations believed in ICT can solve these problems and are willing to utilize ICTs to improve their supply chain effectiveness and efficiency of supply chain management in construction industry. Although at present only large organizations have expensive software, there is a clear business opportunity of improving the ability to accept and satisfy occasional needs within medium and even small scale organizations. The ICT opportunities are listed as below:

- ü Synchronized conversation execution (Just in time communication)
- ü Coordinating teamwork in a virtual supply chain
- ü Automatic orders and invoice through individual project
- ü Effective document management system

- ü Decrease overall cost including time cost and human cost

Although at present only large organizations have expensive software, there is a clear business opportunity of improving the ability to accept and satisfy occasional needs within medium and even small scale organizations.

7.1.3 Objective 3. To propose a supply chain model using ICTs for use in the New Zealand construction industry.

This study explored the benefits of utilizing ICTs to improve construction supply chain efficiency in New Zealand. It is based on a case study of a New Zealand local software---BlueSky system, examined the software performance on two pilot sites: one is architectural design company and the other is master builder who is a partner of the architectural design company.

According to the case study result, the system helped the two pilot sites improve their supply chain performance significantly. The benefits were reduced cost, increased the accuracy of the information flow, provided an effective document management method and better communication, and time saving. However, there are also potential risks arising from human issues such as understanding the systems and procedures (for example, back ups and recovery etc.)

In conclusion, information and communication technology (BlueSky as an example) is offering a new wave of technology for supply chains which could offer more convenience, better productivity and more competitive advantages to all industries including construction industry. Every company should consider adopting ICTs into their legacy supply chain management processes to achieve more benefits. On the other hand, every company should be aware of the problems and pitfalls that can arise if ICTs are not carefully conducted.

All in all, this research makes a number of contributions to both theory and practice based on case study, participant observation, usability testing and questionnaire.

- ü Takes a knowledge perspective on the issue of strategic construction supply chain information systems;
- ü Identifies strategic and knowledge aspects of Construction supply chain management;
- ü Conclude the questionnaire feedbacks of New Zealand Construction supply chain management
- ü Help to address the issue of CSCMS

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Appendix 1: Research Questionnaire

The first part of this questionnaire is about the current use of computers and information systems in your organisation. Please provide answers to each question based on your own experience.

1. Do you use a computer in your daily job?

    ☐ Yes ☐ No

    If "no" go to question 3.

2. What are the computer systems you currently use: (use as many as required) and how many hours per day do you use them: Please write :A. up to 1 hour B. up to 3 hours C. more than 3 hours.

System	Hours per day
General Accounting	
Job Costing or Estimating software	
Project Management, Planning, or Scheduling software	
Microsoft Excel based tools	
Custom Developed Database tools (like MS Access)	
Project collaboration software on the internet	
General internet use, searching, information gathering etc	
Email (MS Outlook, web mail, etc)	
Word processing (Like Microsoft Word)	
Others (Please specify)	

3. What accounting software does your business mainly use?
4. Does your company have any software systems to manage these functions of your business automatically and how satisfied are you with them? (Score each function but use 0 if your company does not have software for the function)

Function	Satisfaction
	Very Unhappy OK Very Happy
Customer Relationship Management (CRM)	0 1 2 3 4 5
Timesheets or time management	0 1 2 3 4 5
Shared or collaborative project planning with other companies on projects (internet or internal)	0 1 2 3 4 5
Project planning or scheduling for your company	0 1 2 3 4 5
Estimating job costs	0 1 2 3 4 5
Capturing Actual Job Costs (Back costing)	0 1 2 3 4 5
Placing purchase orders electronically or by automatic fax/email	0 1 2 3 4 5
Creating Purchase Orders automatically from the Job Requirements	0 1 2 3 4 5
Software for managing document versions for drawings, contracts, etc	0 1 2 3 4 5

If you have answered with a 1 or 2 for a function please provide a comment as to why.

Continue on separate sheet if required

This part is about the how you or your organisation current manages your relationships with suppliers or other project collaborators. Please provide answers based on your own experience.

5. Think about the current systems (computerised or otherwise) for performing the following functions, how satisfied are you with them. (Please score each function)

Function	Satisfaction
	Very Unhappy OK Very Happy
Getting the information that I need to do my job	1 2 3 4 5
Supplying information to others	1 2 3 4 5
Estimating or quoting my costs for the job	1 2 3 4 5
Managing my costs to my budget	1 2 3 4 5
Knowing when suppliers are going to deliver the products or services that the job requires	1 2 3 4 5
Managing project variations	1 2 3 4 5

6. Thinking about a recent building project that you were involved with, how would you rate the following aspects? Please score from 1 -5 and use 0 if the aspect is not relevant for you.

Function	Satisfaction
	Very Poor OK Very Good
The time taken to get the information you wanted	0 1 2 3 4 5
How well the various parties communicated	0 1 2 3 4 5
The accuracy of the information you received	0 1 2 3 4 5
The amount of information you received	0 1 2 3 4 5
The time you spent communicating on the project	0 1 2 3 4 5
Did the right products turn up on site	0 1 2 3 4 5
The amount of time you spent waiting for others	0 1 2 3 4 5
What it cost you to do your part of the project	0 1 2 3 4 5
The number of mistakes made by you or others on the project	0 1 2 3 4 5

7. How much time do you think you waste on a typical project due to the above issues:

A	B	C	D	E
Less than 1 hours	1 to 4 hours	4 to 8 hour	8 to 16 hours	More than 16 hours

8. The amount of time it takes you to complete your paperwork on a typical project has:

A	B	C	D	E
Almost gone	Halved what it was	Not changed	Doubled from what it was	More than doubled

9. The following are features of a supply chain, please rank them in order of importance to you

from the most important to the least

Feature	Example	Your Rank
Happens on time	1	
No mistakes	2	
Fast response	3	
Low Cost	4	
Is easy to use	5	

To descript the usage of computer in your daily work, how much do you agree (or not) with each of the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree	No opinion
10. Managing the supply chain is one of the most important issues in construction industry.	☐	☐	☐	☐	☐
11. Computer based supply chain management could improve efficiency.	☐	☐	☐	☐	☐
12. Computer based supply chain management can reduce costs. (Order, delivery and project life cycle costs).	☐	☐	☐	☐	☐
13. Computer based supply chain management system will be a pain to put into the building industry.	☐	☐	☐	☐	☐
14. Computer based supply chain management system can reduce the time and work involved in the building consent process has to happen.	☐	☐	☐	☐	☐
15. The last thing that I need in my job is more computers.	☐	☐	☐	☐	☐
16. Computer based supply chain management system can improve accuracy of information flow and material flow.	☐	☐	☐	☐	☐
17. Computer based supply chain management can improve communication among supply chain participants.	☐	☐	☐	☐	☐

18. Please circle the statement that most commonly applies to your business when selecting project partners.

A. We deal with pretty much the same partners on our projects

B. We have a pool of people that we deal with and choose from them for each project

C. We tender each project and choose the best deal at the time

D. We generally have no say over whom we deal with

E. We don’t have any partners

Finally, could you give us some information about yourself so that we can put your other replies in greater context? We promise the information you provide will only be used for research purpose and will remain confidential.

19. How many employees are there in your organization?
☐ Less than 5 ☐ 6 to 15 ☐ 16 to 40 ☐ More than 40

20. What kind of organization are you working for?
- ☐ Building components manufacturer
- ☐ Supplier
- ☐ Architectural Design
- ☐ Master Contractor/ Subcontractor
- ☐ Other (Please specify)

21. What is your job?
- ☐ Builder
- ☐ Manufacturer
- ☐ Architect/Designer
- ☐ Plumber
- ☐ Electrician
- ☐ Drain layer
- ☐ Supplier
- ☐ Accounts/ Administrator
- ☐ Other (pleaser specify)

22. Which age group do you belong?
☐ Under 20 ☐ 21 to 30 ☐ 31 to 40 ☐ 41 to 50 ☐ Above 50

23. How long have you been involved in the construction industry?
☐ Less than 2 year ☐ 3 to 5 years ☐ 6 to 10 years ☐ more than 10 years

24. What kind of qualification do you hold?
- ☐ College or high school
- ☐ Degree or Diploma
- ☐ Trade qualification

25. Do you have any other recommendations for using ICTs to improve the supply chain and partnering?

***Section A: Question 1 and Question 19 to 24**
Section B: Question 2 to 4
Section C: Question 5 to 9 and Question 18
Section D: Question 10 to 17

Appendix 2: Questionnaire Analysis Result

Section A: Respondents Demographic Background and Analysis Results

This section provides an analysis of the responses to question in Section A, concerning the job title, organization type, organization range, experience and education background.

Exhibit 1: Organization Range

Organization Range	Frequency	Percent
less than 5	25	12.5
6 to 15	85	42.5
16 to 40	73	36.5
more than 40	17	8.5
Total	200	100.0

The result indicates that 12.5%, 42.5%, 36.5% and 8.5% of the respondents were from organizations have less than 5, 6 to 15, 16 to 40, and more than 40 employees respectively. This shows that there more medium size construction organizations (6 to 40) than big organizations or small organizations.

Exhibit 2: Organization type

Organization type	Frequency	Percent
Building components manufacturer	50	25.0
Supplier	43	21.5
Architectural Designer	28	14.0
Master Contractor/Subcontractor	69	34.5
Others	10	5.0
Total	200	100.0

In terms of the organization types, 34.5% of the organizations were contractors which can be categorized further into Master Contractor or subcontractors. Only 5% of the respondents were coming from "others" organizations which include Engineering and also students whose major is relevant.

Exhibit 3: Organization Range * Organization type Cross tabulation

Organization Range	Organization type					Total
	Building components manufacture	Supplier	Architectural Design	Master Contractor/ Subcontractor	Others	
less than 5	1	2	5	13	4	25
6 to 15	12	17	16	37	3	85
16 to 40	21	23	7	19	3	73
more than 40	16	1	0	0	0	17
Total	50	43	28	69	10	200

Exhibit 3 showed than Architectural Design and Contractor organizations are normally smaller than Building components manufacture and Supplier categories are always bigger.

Exhibit 4: Job title

Job title	Frequency	Percent
builder	10	5.0
manufacturer	13	6.5
designer	28	14.0
plumber	7	3.5
electrician	10	5.0
drain layer	12	6.0
supplier	17	8.5
Admin	65	32.5
others	38	19.0
Total	200	100.0

The respondents' major job position was Administrator (32.5% of the sample) including accounts and project managers while the second largest job title group was others (19.0% of the sample) including purchasing staffs from Supplier organizations, Quality control and manufacturers from manufacture organizations. Other respondents categorized as plumber, electrician and drain layers included 14.5 % of the sample. It can be concluded that administrations are the major position category. It may be because that the samples are collected mainly from the two big architectural conferences.

Exhibit 5: Age

Age group	Frequency	Percent
under 20	1	.5
21 to 30	34	17.0
31 to 40	109	54.5
41 to 50	45	22.5
above 50	11	5.5
Total	200	100.0

The majority of the respondents (54.5) were between the ages of 31 to 40 years old, while 22.5% of the respondents were between the ages of 41 to 50. Only one respondent were under 20 and 11 are above 50. Respondents aged between 21 to 30 years old are made up the remaining 17%. Basically, more construction practitioners are between age 31 to 50 (78%). These things also suggest that the practitioners may have plenty of work experiences.

Exhibit 6: Experience

Experience	Frequency	Percent
less than 2 years	1	.5
3 to 5 years	20	10.0
6 to 10 years	67	33.5
more than 10 years	112	56.0
Total	200	100.0

As shown in Exhibit 6, 56% of the respondents have been in construction industry for more than 10 years, 33.5% has 6 to 10 years' experience, 10% of the respondents have 3 to 5 years' relevant work experience, and only one respondent has been working in this industry for less than 2 years. This is consistent with the findings in age group.

Exhibit 7: Qualification

Qualification	Frequency	Percent
college or high school	36	18.0
Degree or diploma	77	38.5
trade qualification	87	43.5
Total	200	100.0

According to the respondents, 43.5% of them are holding trade qualifications and 38.5% of them have degree or diploma. While another 18% only has a college or high school qualification. This indicated that most of the respondents (82% of the sample) have had vocation relevant training. This may affect the adoption of the ICT adoption rate due to the education level of the participants.

Exhibit 8: Use of Computer

Use of Computer	Frequency	Percent
Yes	168	84.0
No	32	16.0
Total	200	100.0

In terms of the use of computer in daily job, the findings show that 84% of the respondents do use computer in their daily job, while still 16% of them did not use computer in their jobs. In case of that, majority of the respondents have computer use experience so they should be able to provide an accurate expectation of utilization of ICTs in their supply chain management.

Exhibit 9: Job title * Use of Computer Cross tabulation

Job title	Use of Computer		Total
	Yes	No	
builder	4	6	10
manufacturer	12	1	13
designer	28	0	28
plumber	1	6	7
electrician	2	8	10
drain layer	4	8	12
supplier	17	0	17
Admin	63	2	65
others	37	1	38
Total	168	32	200

Exhibit 9 indicated that the use of computer in daily job is relevant to the respondents' job title. Most of the builders, plumbers, electricians and drain layers' job do not use computer in daily grind but all designers and suppliers (including architect and engineer) use computer everyday. This also reveals that most of administration and other construction relevant jobs are highly computer-depended job. This creates less challenge for the integration of ICT with designer and supplier positions.

Section B: what kinds of software and system is the industry using currently?

A chi square statistic is used to investigate whether distributions of categorical variables differ from one another. Basically categorical variable yield data in the categories and numerical variables yield data in numerical form. In section B, chi square test will be used to analysis the relationship between the respondents' job titles and what kind of software they normally use in their daily job. In this section, bar chart and two way cross table will be exhibited to help reveal the relevance between certain software and respondents' job title.

Exhibit 11: General Software and Job title Bar Chart

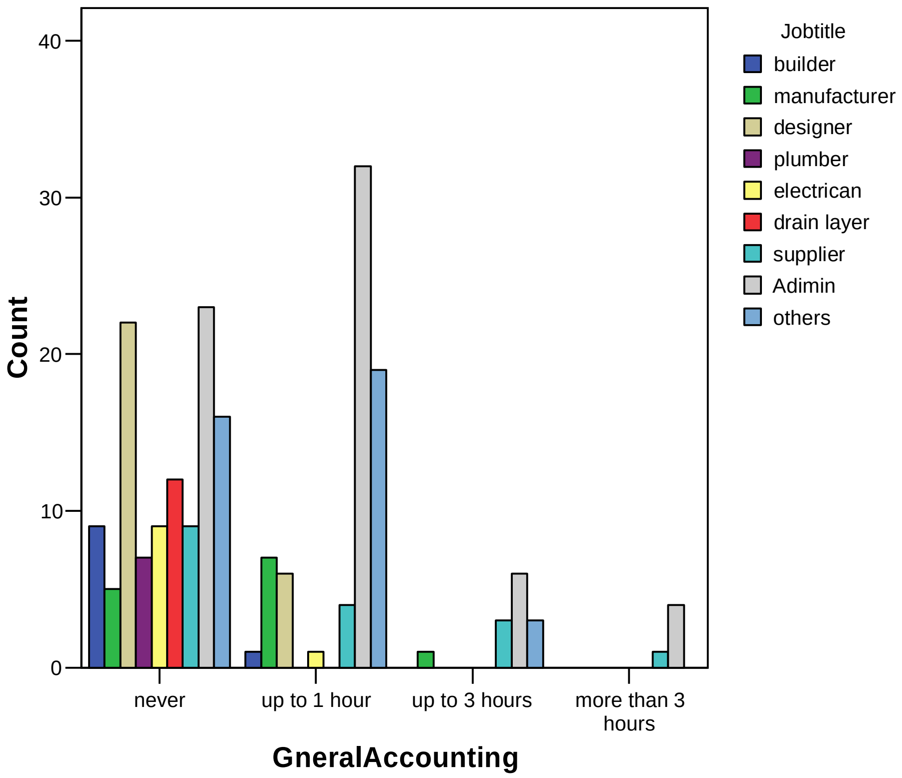

Exhibit 12: Job title * General Accounting Cross tabulation

Job title	General Accounting				Total
	never	up to 1 hour	up to 3 hours	more than 3 hours	
builder	9	1	0	0	10
manufacturer	5	7	1	0	13
designer	22	6	0	0	28
plumber	7	0	0	0	7
electrician	9	1	0	0	10
drain layer	12	0	0	0	12
supplier	9	4	3	1	17
Admin	23	32	6	4	65
others	16	19	3	0	38
Total	112	70	13	5	200

Exhibit 13: Chi-Square Tests of General accounting software and Job title

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	55.779(a)	24	.000
Likelihood Ratio	66.970	24	.000
N of Valid Cases	200		

a 24 cells (66.7%) have expected count less than 5. The minimum expected count is .18.

According to the chi-square test, the P value is .000 which is less than 0.05, which indicates that the usage of general accounting software is highly depending on the respondents' position. Shown as Exhibit 12, more than half of the administration staffs (42 out of 65) use general accounting software everyday, categorized as 32 up to 1 hour, 6 up to 3 hours and 4 more than 3 hours per day. Other functionary respondents seldom use this kind of software.

Exhibit 14: Job costing software and Job title Bar Chart

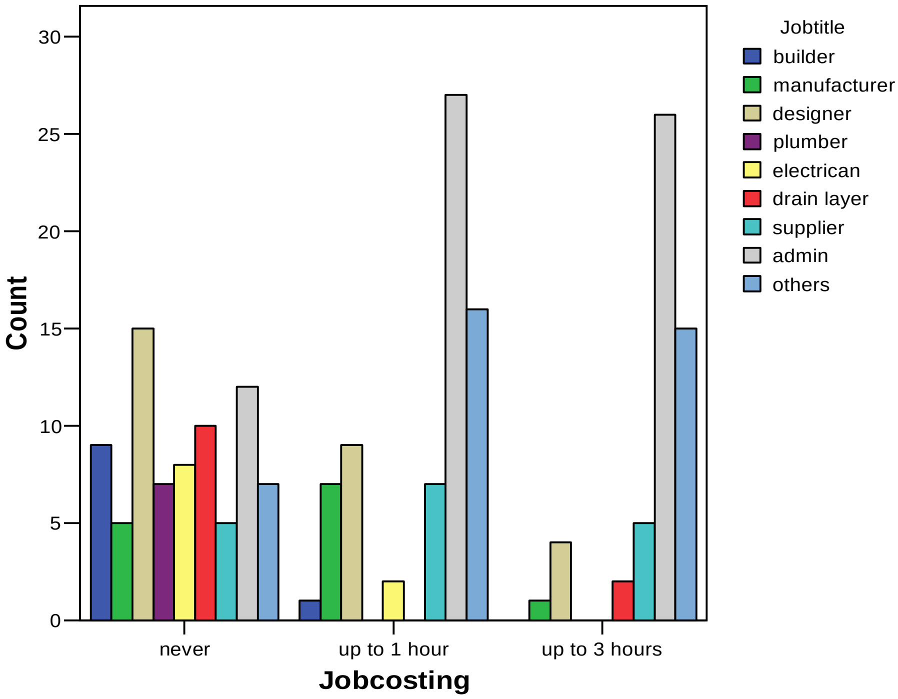

Exhibit 15: Job title * Job costing Cross tabulation

Job title	Job costing			Total
	never	up to 1 hour	up to 3 hours	
builder	9	1	0	10
manufacturer	5	7	1	13
designer	15	9	4	28
plumber	7	0	0	7
electrician	8	2	0	10
drain layer	10	0	2	12
supplier	5	7	5	17
admin	12	27	26	65
others	7	16	15	38
Total	78	69	53	200

Exhibit 16: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	66.781(a)	16	.000
Likelihood Ratio	77.343	16	.000
N of Valid Cases	200		

a 15 cells (55.6%) have expected count less than 5. The minimum expected count is 1.86.

P value of the chi-square test shows that the use of Job costing software is depended on what kind of job the respondent is doing. None of the positions use Job costing software more than 3 hours per day but some of the positions (manufacturer, designer, supplier, administrator and others) use it more than others (builder, plumber, electrician and drain layer).

Exhibit 17: Project Management Software and Job titleBar Chart

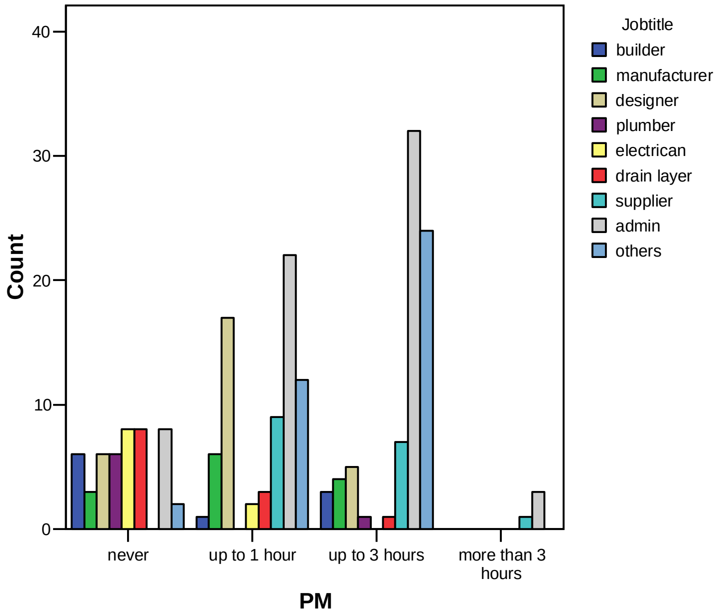

Exhibit 18: Job title * PM Cross tabulation

Job title	PM				Total
	never	up to 1 hour	up to 3 hours	more than 3 hours	
builder	6	1	3	0	10
manufacturer	3	6	4	0	13
designer	6	17	5	0	28
plumber	6	0	1	0	7
electrician	8	2	0	0	10
drain layer	8	3	1	0	12
supplier	0	9	7	1	17
Admin	8	22	32	3	65
others	2	12	24	0	38
Total	47	72	77	4	200

Exhibit 19: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	90.550(a)	24	.000
Likelihood Ratio	91.838	24	.000
N of Valid Cases	200		

a 24 cells (66.7%) have expected count less than 5. The minimum expected count is .14.

All the suppliers and most of the administration staffs (57 of 67) use project management software in their everyday job. On the other hand, plumber, electrician and drain layers seldom use this kind of software. The p value (.000) shows the high dependence between the use of PM software and the respondents' job categories.

Exhibit 20: MicroExcel and Job title Bar Chart

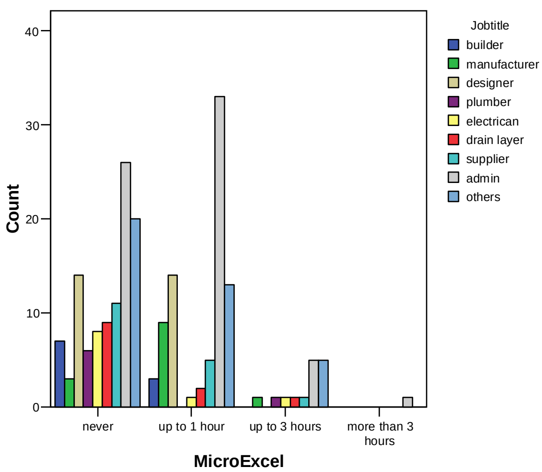

Exhibit 21: Job title * Micro Excel Cross tabulation

Job title		Micro Excel: never	up to 1 hour	up to 3 hours	more than 3 hours	Total
	builder	7	3	0	0	10
	manufacturer	3	9	1	0	13
	designer	14	14	0	0	28
	plumber	6	0	1	0	7
	electrician	8	1	1	0	10
	drain layer	9	2	1	0	12
	supplier	11	5	1	0	17
	admin	26	33	5	1	65
	others	20	13	5	0	38
Total		104	80	15	1	200

Exhibit 22: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29.551(a)	24	.200
Likelihood Ratio	35.799	24	.057
N of Valid Cases	200		

a 23 cells (63.9%) have expected count less than 5. The minimum expected count is .04.

According to the chi-square test of the relevance between the use of Micro Excel and the job title of the respondents, the P value is 0.200 which reveals that these two variables are not depended. Only one respondents use this software more than 3 hours per day and more than half of the respondents (104 out of 200) never use Micro Excel in their job.

Exhibit 23: Custom Database and Job title Bar Chart

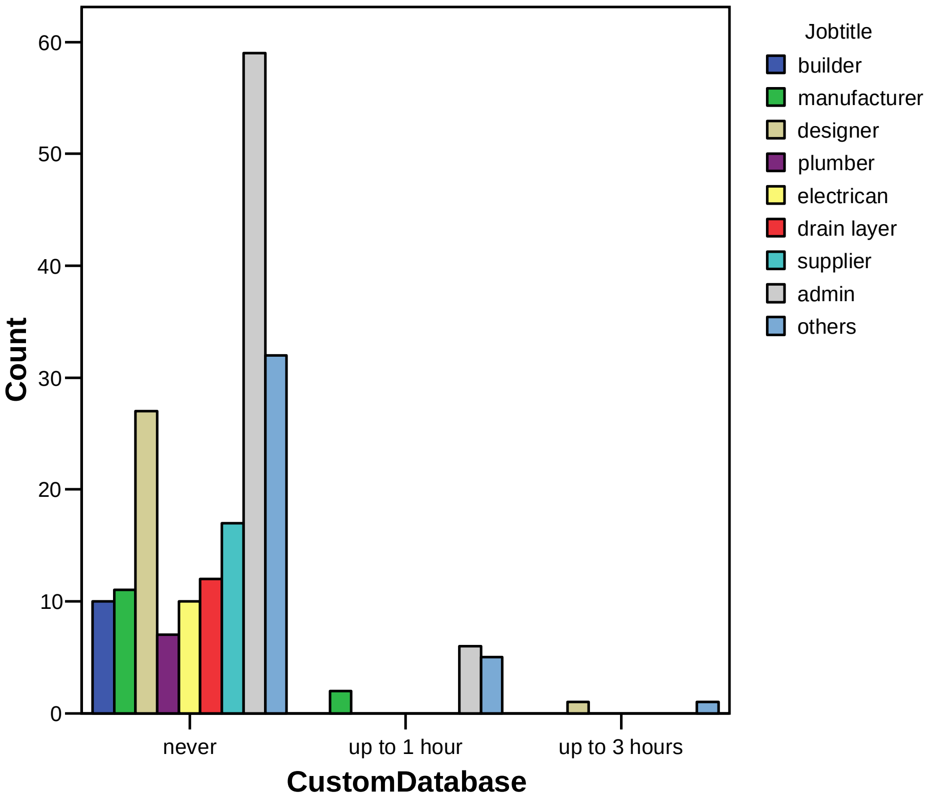

Exhibit 24: Job title * Custom Database Cross tabulation

Job title	Custom Database			Total
	never	up to 1 hour	up to 3 hours	
builder	10	0	0	10
manufacturer	11	2	0	13
designer	27	0	1	28
plumber	7	0	0	7
electrician	10	0	0	10
drain layer	12	0	0	12
supplier	17	0	0	17
admin	59	6	0	65
others	32	5	1	38
Total	185	13	2	200

Exhibit 25: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.357(a)	16	.499
Likelihood Ratio	19.968	16	.222
N of Valid Cases	200		

a 18 cells (66.7%) have expected count less than 5. The minimum expected count is .07.

In terms of the chi-square test of the relevance between the use of Custom Database and the respondents' job title, the P value is 0.200 which shows that there is no dependence relationship between them. 185 of the total 200 respondents never use this kind software in their daily job.

Exhibit 26: Project Collaboration Software Bar Chart

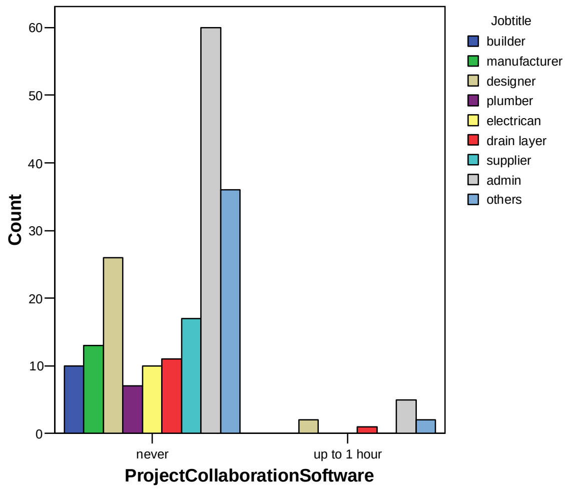

Exhibit 27: Job title * Project Collaboration Software Cross tabulation

Job title		Project Collaboration Software		Total
		never	up to 1 hour	
	builder	10	0	10
	manufacturer	13	0	13
	designer	26	2	28
	plumber	7	0	7
	electrician	10	0	10
	drain layer	11	1	12
	supplier	17	0	17
	admin	60	5	65
	others	36	2	38
Total		190	10	200

Exhibit 28: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.549(a)	8	.805
Likelihood Ratio	7.187	8	.517
N of Valid Cases	200		

a 9 cells (50.0%) have expected count less than 5. The minimum expected count is .35.

The findings show that the use of project collaboration software on the internet has no relationship with the position of the respondents because the P value of the chi-square test is 0.805 which is much more than 0.05. It can be seen from Exhibit 27 that nearly all of the respondents (190 of the 200 sample) has never used this kind of software in their work.

Exhibit 29: General Internet use and Job title Bar Chart

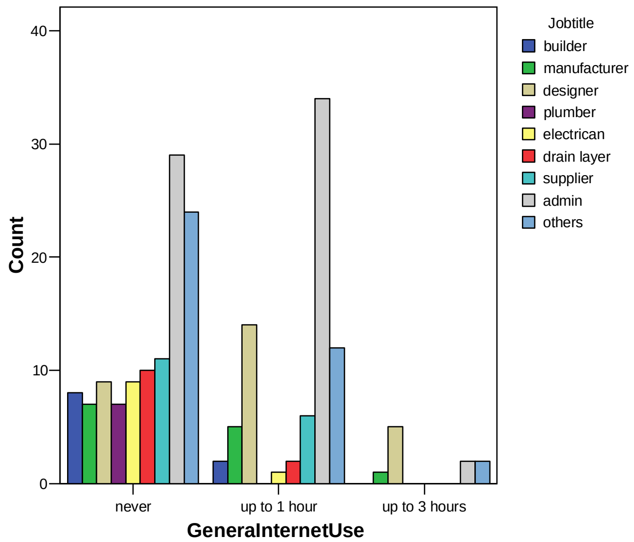

Exhibit 30: Job title * General Internet Use Cross tabulation

Job title	General Internet Use			Total
	never	up to 1 hour	up to 3 hours	
builder	8	2	0	10
manufacturer	7	5	1	13
designer	9	14	5	28
plumber	7	0	0	7
electrician	9	1	0	10
drain layer	10	2	0	12
supplier	11	6	0	17
admin	29	34	2	65
others	24	12	2	38
Total	114	76	10	200

Exhibit 31: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.559(a)	16	.002
Likelihood Ratio	39.034	16	.001
N of Valid Cases	200		

a 15 cells (55.6%) have expected count less than 5. The minimum expected count is .35.

The p value (0.002) in this chi-square test shows that the general internet use depends on which position the respondent is. The analysis result in exhibit 30 shows that the designer, administration staffs and “other” positions use more internet than other job categories such as builder, manufacturer, plumber, electrician and drain layer.

Exhibit 32: Email and Job title Bar Chart

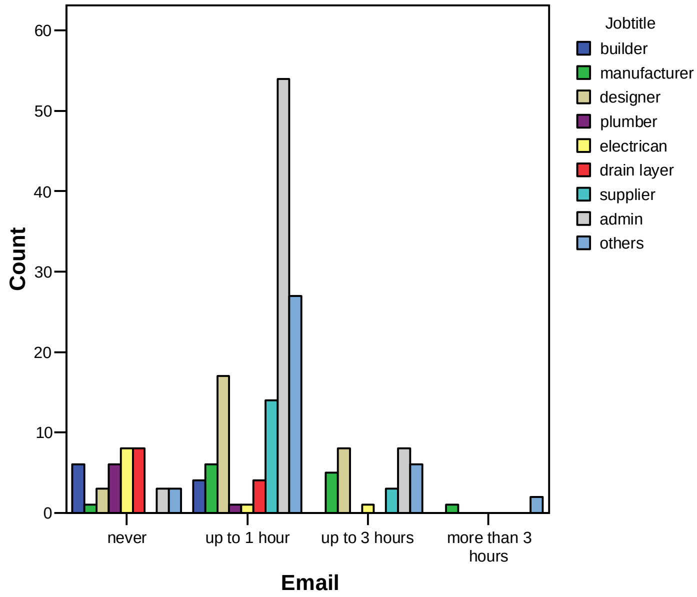

Exhibit 33: Job title * Email Cross tabulation

Job title		Email never	up to 1 hour	up to 3 hours	more than 3 hours	Total
	builder	6	4	0	0	10
	manufacturer	1	6	5	1	13
	designer	3	17	8	0	28
	plumber	6	1	0	0	7
	electrician	8	1	1	0	10
	drain layer	8	4	0	0	12
	supplier	0	14	3	0	17
	admin	3	54	8	0	65
	others	3	27	6	2	38
Total		38	128	31	3	200

Exhibit 34: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	111.169(a)	24	.000
Likelihood Ratio	99.031	24	.000
N of Valid Cases	200		

a 23 cells (63.9%) have expected count less than 5. The minimum expected count is .11.

According to the analysis, the use of Email depends significantly on what kind of job the respondent is doing because the p value of this chi-square test is 0.000 which is much less than 0.05. Most of the respondents (162 of 200 respondents) use Email in their daily job and most of them are designer, supplier, administration staff and "other" staff.

Exhibit 34: Word processing software and Job title Bar Chart

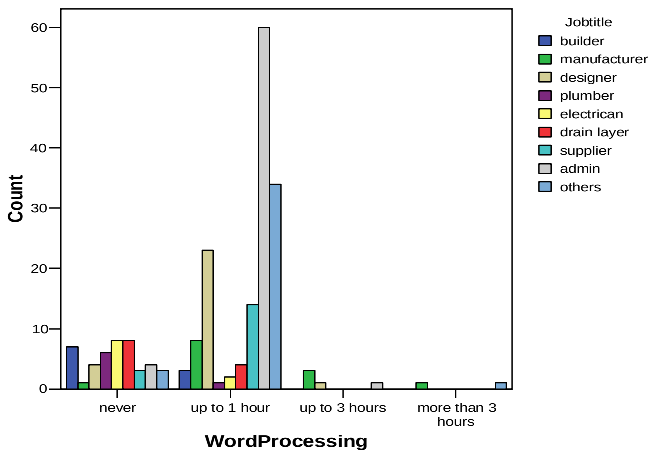

Exhibit 35: Job title * Word Processing Cross tabulation

Job title		Word Processing				Total
		never	up to 1 hour	up to 3 hours	more than 3 hours	
	builder	7	3	0	0	10
	manufacturer	1	8	3	1	13
	designer	4	23	1	0	28
	plumber	6	1	0	0	7
	electrician	8	2	0	0	10
	drain layer	8	4	0	0	12
	supplier	3	14	0	0	17
	admin	4	60	1	0	65
	others	3	34	0	1	38
Total		44	149	5	2	200

Exhibit 36: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	112.937(a)	24	.000
Likelihood Ratio	88.751	24	.000
N of Valid Cases	200		

a 24 cells (66.7%) have expected count less than 5. The minimum expected count is .07.

The P value which is .000 (less than 0.05) indicates that this is a significant dependence relationship between the use of word processing software and the job title of the respondent. According to the results shown in Exhibit 35, the plumbers, electricians, drain layers and suppliers never use word processing software more than one hour per day in their daily job.

Exhibit 37: Other Software and Job title Bar Chart

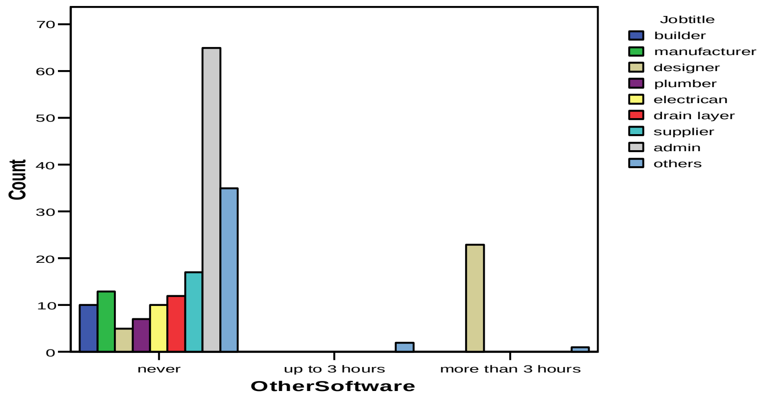

Exhibit 38: Job title * Other Software Cross tabulation

Job title		Other Software			Total
		never	up to 3 hours	more than 3 hours	
	builder	10	0	0	10
	manufacturer	13	0	0	13
	designer	5	0	23	28
	plumber	7	0	0	7
	electrician	10	0	0	10
	drain layer	12	0	0	12
	supplier	17	0	0	17
	admin	65	0	0	65
	others	35	2	1	38
Total		174	2	24	200

Exhibit 39: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	160.289(a)	16	.000
Likelihood Ratio	117.571	16	.000
N of Valid Cases	200		

a 17 cells (63.0%) have expected count less than 5. The minimum expected count is .07.

The chi-square test shows that the use of other software is highly depended on what job title is held by the respondent because the P value is .000 which is much less than 0.05. According to the feedback of the questionnaires, the other kinds of software include mainly Auto CAD, 3D MAX, Sketch up, and Archi CAD. Shown as Exhibit 38, only designers and "other" positions like engineers use these kinds of software and most of them use it more than 3 hours per day.

Exhibit 40 CRM satisfaction and Organization Type Bar Chart

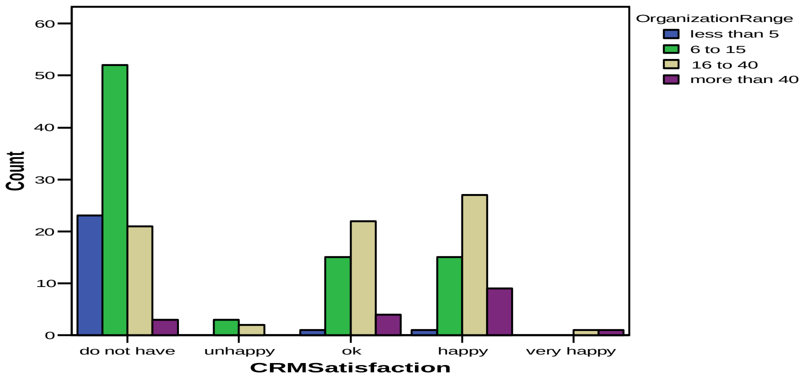

Exhibit 41: CRMSatisfaction * Organization Range Cross tabulation

CRM satisfaction	Organization Range				Total
	less than 5	6 to 15	16 to 40	more than 40	
do not have	23	52	21	3	99
unhappy	0	3	2	0	5
ok	1	15	22	4	42
happy	1	15	27	9	52
very happy	0	0	1	1	2
Total	25	85	73	17	200

Exhibit 42: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	49.886(a)	12	.000
Likelihood Ratio	52.894	12	.000
Linear-by-Linear Association	43.091	1	.000
N of Valid Cases	200		

a 10 cells (50.0%) have expected count less than 5. The minimum expected count is .17.

According to the analysis, nearly half of the respondents' organizations do not have CRM software. Most of those who have CRM were satisfied with it. Only 5 of the respondents felt unhappy with it and according to the respondents' feedback it is because CRM systems are usually not easy to use. The Exhibit 42 shows that the CRM satisfaction is significantly depended on the range of the organization that the respondent comes from. Seen from Exhibit 41, most of the organizations (23 of 25) which has less than 5 employees do not have CRM systems while most of those have more than 40 employees do have one and feel satisfied with it.

Exhibit 43: TimeManagement Satisfaction & Organization Range Bar Chart

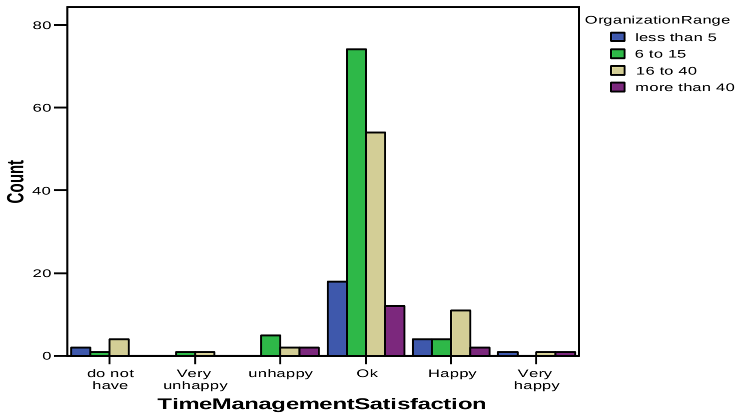

Exhibit 44: Time Management Satisfaction * Organization Range Cross tabulation

Time Management Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
	do not have	2	1	4	0	7
	Very unhappy	0	1	1	0	2
	unhappy	0	5	2	2	9
	Ok	18	74	54	12	158
	Happy	4	4	11	2	21
	Very happy	1	0	1	1	3
Total		25	85	73	17	200

Exhibit 45: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19.355(a)	15	.198
Likelihood Ratio	21.302	15	.127
N of Valid Cases	200		

a 18 cells (75.0%) have expected count less than 5. The minimum expected count is .17.

The findings shows that there is no a significant dependence relationship between organization range and the satisfaction of Time Management software (P value=0.198 > 0.05). Most of the organizations have time management systems and most of the respondents are satisfied with it.

Exhibit 46: PM satisfaction & Organization Type Bar Chart

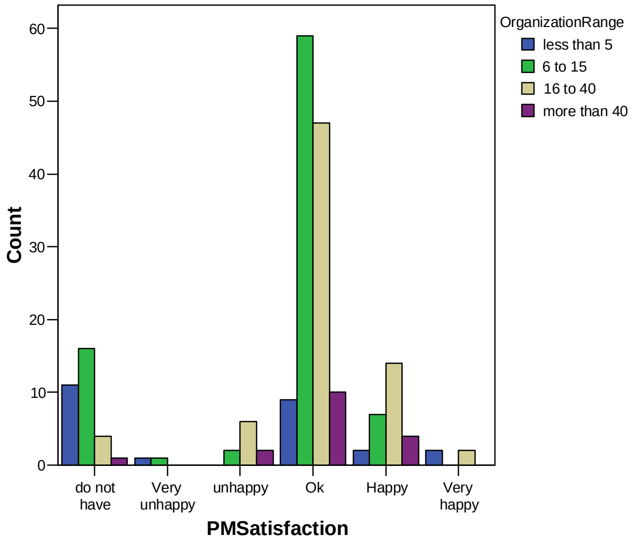

Exhibit 47: PM Satisfaction * Organization Range Cross tabulation

PM Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
	do not have	11	16	4	1	32
	Very unhappy	1	1	0	0	2
	unhappy	0	2	6	2	10
	Ok	9	59	47	10	125
	Happy	2	7	14	4	27
	Very happy	2	0	2	0	4
Total		25	85	73	17	200

Exhibit 48: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	43.090(a)	15	.000
Likelihood Ratio	42.443	15	.000
N of Valid Cases	200		

a 16 cells (66.7%) have expected count less than 5. The minimum expected count is .17.

The result of chi-square test shows that there is a significant dependence relationship between PM satisfaction range and the range of the respondents' organization. 11 of 25 smallest organizations do not have such kind of system but nearly all of the largest organizations have it and 14 of the sample feel satisfied with using it.

Exhibit 49: Shared Project Planning Satisfaction & Oranganization Range Bar Chart

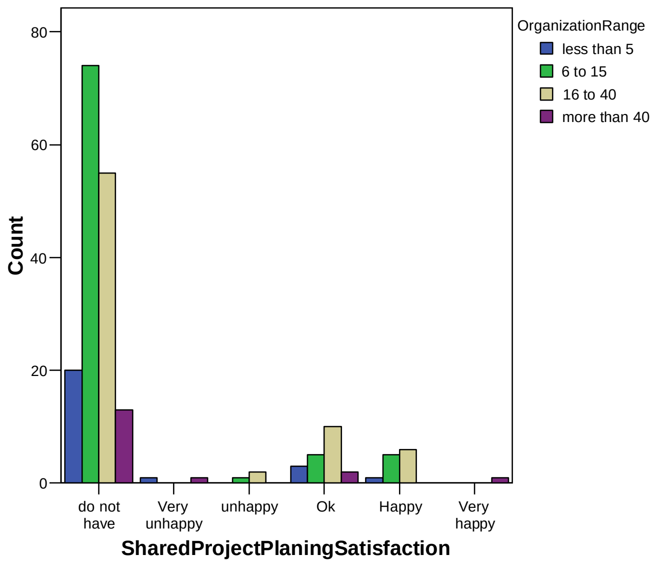

Exhibit 50: Shared Project Planing Satisfaction * Organization Range Cross tabulation

Shared Project Planning Satisfaction	Organization Range				Total
	less than 5	6 to 15	16 to 40	more than 40	
do not have	20	74	55	13	162
Very unhappy	1	0	0	1	2
unhappy	0	1	2	0	3
Ok	3	5	10	2	20
Happy	1	5	6	0	12
Very happy	0	0	0	1	1
Total	25	85	73	17	200

Exhibit 51: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	25.185(a)	15	.048
Likelihood Ratio	19.388	15	.197
N of Valid Cases	200		

a 17 cells (70.8%) have expected count less than 5. The minimum expected count is .09.

Based on the responses, 162 of the 200 samples do not have shared or collaborative project planning with other companies on projects. According to the chi-square test, satisfaction of using shared project planning system is depended on how big the organization is. Shown as Exhibit 50, the bigger the organization is, the more satisfied the organizations are. That may be because the computer literacy is higher.

Exhibit 52: Estimating Job Cost Satisfaction Bar Chart

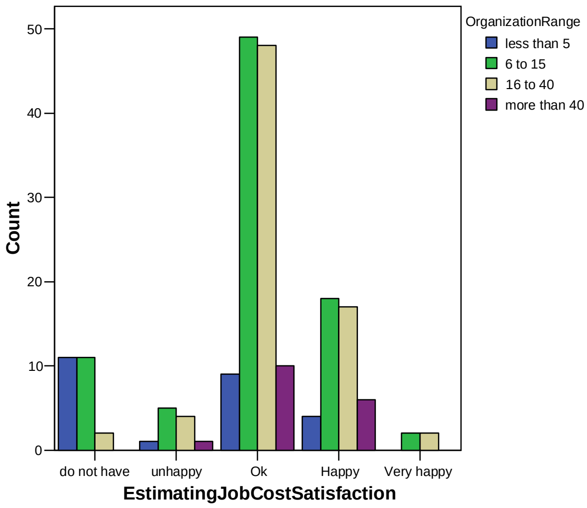

Exhibit 53: Estimating Job Cost Satisfaction * Organization Range Cross tabulation

Estimating Job Cost Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
do not have	Expected Count	3.0	10.2	8.8	2.0	24.0
	% of Total	5.5%	5.5%	1.0%	.0%	12.0%
unhappy	Expected Count	1.4	4.7	4.0	.9	11.0
	% of Total	.5%	2.5%	2.0%	.5%	5.5%
Ok	Expected Count	14.5	49.3	42.3	9.9	116.0
	% of Total	4.5%	24.5%	24.0%	5.0%	58.0%
Happy	Expected Count	5.6	19.1	16.4	3.8	45.0
	% of Total	2.0%	9.0%	8.5%	3.0%	22.5%
Very happy	Expected Count	.5	1.7	1.5	.3	4.0
	% of Total	.0%	1.0%	1.0%	.0%	2.0%
Total	Expected Count	25.0	85.0	73.0	17.0	200.0
	% of Total	12.5%	42.5%	36.5%	8.5%	100.0%

Exhibit 54: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	34.514(a)	12	.001
Likelihood Ratio	31.192	12	.002
N of Valid Cases	200		

a 11 cells (55.0%) have expected count less than 5. The minimum expected count is .34.

Again, the research result indicates that there is a significant dependence relationship between Estimating Job Cost Satisfaction and organization range. According to the results shown in Exhibit 53, the medium sized organizations (6 to 15 and 16 to 40) are satisfied with this kind software while smallest size (less than 5) and largest size (more than 40) organizations are not as satisfied as the medium sized organizations.

Exhibit 55: Actual Job Costing System and Organization Range Bar Chart

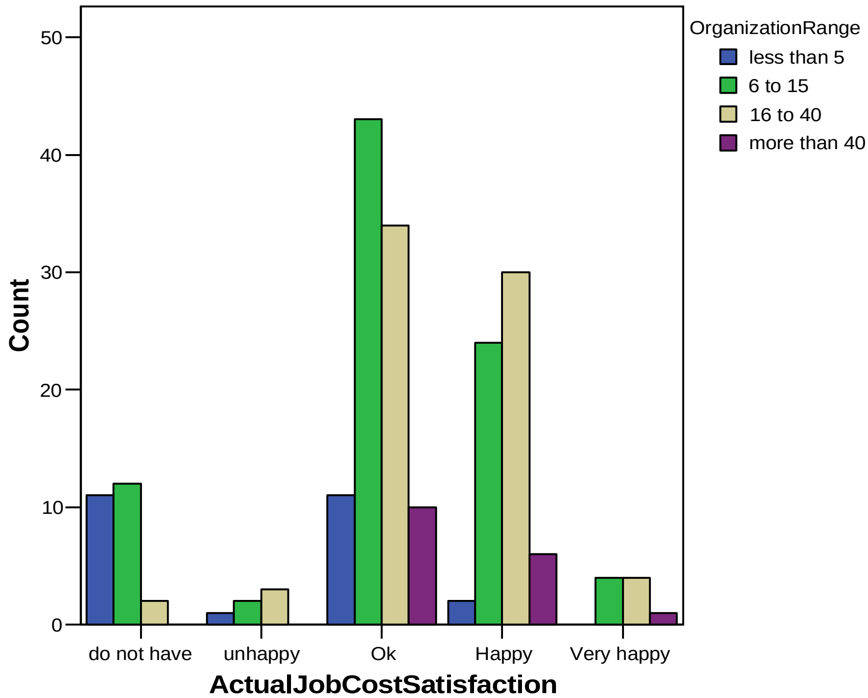

Exhibit 56: Actual Job Cost Satisfaction * Organization Range Cross tabulation

Actual Job Cost Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
do not have	Expected Count	3.1	10.6	9.1	2.1	25.0
	% of Total	5.5%	6.0%	1.0%	.0%	12.5%
unhappy	Expected Count	.8	2.6	2.2	.5	6.0
	% of Total	.5%	1.0%	1.5%	.0%	3.0%
Ok	Expected Count	12.3	41.7	35.8	8.3	98.0
	% of Total	5.5%	21.5%	17.0%	5.0%	49.0%
Happy	Expected Count	7.8	26.4	22.6	5.3	62.0
	% of Total	1.0%	12.0%	15.0%	3.0%	31.0%
Very happy	Expected Count	1.1	3.8	3.3	.8	9.0
	% of Total	.0%	2.0%	2.0%	.5%	4.5%
Total	Expected Count	25.0	85.0	73.0	17.0	200.0
	% of Total	12.5%	42.5%	36.5%	8.5%	100.0%

Exhibit 57: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	37.654(a)	12	.000
Likelihood Ratio	37.645	12	.000
N of Valid Cases	200		

a 10 cells (50.0%) have expected count less than 5. The minimum expected count is .51.

Based on the p value response of 0.000, it is clear that the relationship between Actual Job cost System and organization range is significantly depended. Most of the medium size organizations' respondents feel this kind of system is ok, happy or very happy.

Exhibit 58: Eorder Satidfaction & Organization Range BarChart

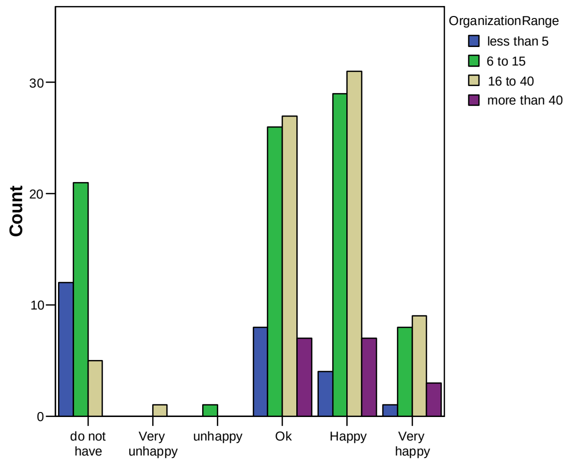

Exhibit 59: E order Satisfaction * Organization Range Cross tabulation

E order Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
do not have	Expected Count	4.8	16.2	13.9	3.2	38.0
	% of Total	6.0%	10.5%	2.5%	.0%	19.0%
Very unhappy	Expected Count	.1	.4	.4	.1	1.0
	% of Total	.0%	.0%	.5%	.0%	.5%
unhappy	Expected Count	.1	.4	.4	.1	1.0
	% of Total	.0%	.5%	.0%	.0%	.5%
Ok	Expected Count	8.5	28.9	24.8	5.8	68.0
	% of Total	4.0%	13.0%	13.5%	3.5%	34.0%
Happy	Expected Count	8.9	30.2	25.9	6.0	71.0
	% of Total	2.0%	14.5%	15.5%	3.5%	35.5%
Very happy	Expected Count	2.6	8.9	7.7	1.8	21.0
	% of Total	.5%	4.0%	4.5%	1.5%	10.5%
Total	Expected Count	25.0	85.0	73.0	17.0	200.0
	% of Total	12.5%	42.5%	36.5%	8.5%	100.0%

Exhibit 60:Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	31.324(a)	15	.008
Likelihood Ratio	34.384	15	.003
N of Valid Cases	200		

a 12 cells (50.0%) have expected count less than 5. The minimum expected count is .09.

E-order system is to place purchase orders electronically or by automatic fax or email. The finding shows that 19% of the respondents' organizations do not have an E-order system that means most of the organizations have such kind of system and are satisfied with using it. When establishing an E-order system for the construction enterprises, the current E-order system can be used as a good sample. Also, the chi-square test showed that there is a dependence relationship between these two variables.

Exhibit 61: Auto Order Satisfaction & Organiztion Range Bar Chart

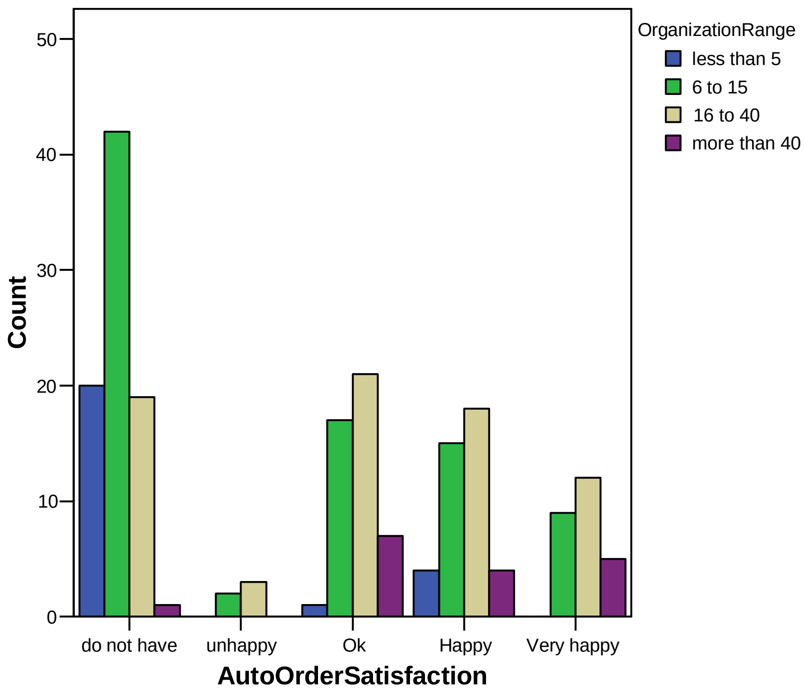

Exhibit 62: Auto Order Satisfaction * Organization Range Cross tabulation

Auto Order Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
do not have	Expected Count	10.3	34.9	29.9	7.0	82.0
	% of Total	10.0%	21.0%	9.5%	.5%	41.0%
unhappy	Expected Count	.6	2.1	1.8	.4	5.0
	% of Total	.0%	1.0%	1.5%	.0%	2.5%
Ok	Expected Count	5.8	19.6	16.8	3.9	46.0
	% of Total	.5%	8.5%	10.5%	3.5%	23.0%
Happy	Expected Count	5.1	17.4	15.0	3.5	41.0
	% of Total	2.0%	7.5%	9.0%	2.0%	20.5%
Very happy	Expected Count	3.3	11.1	9.5	2.2	26.0
	% of Total	.0%	4.5%	6.0%	2.5%	13.0%
Total	Expected Count	25.0	85.0	73.0	17.0	200.0
	% of Total	12.5%	42.5%	36.5%	8.5%	100.0%

Exhibit 63: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	38.507(a)	12	.000
Likelihood Ratio	44.677	12	.000
N of Valid Cases	200		

a 8 cells (40.0%) have expected count less than 5. The minimum expected count is .43.

Auto order system is aim to generate orders through tasks. Shown as Exhibit 62, nearly half (41.0%) of the respondents' organizations do not have an auto order system and 2.5% of the respondents are not satisfied with their current auto ordering system. According to that, there is a challenge of establishing such a system in construction organizations. What is more, due to the p value is 0.000, there is a significant dependence relationship between auto ordering system and organization range. In terms of that, the ranges of the organizations need to be concerned when integrating such a system with the construction industry.

Exhibit 64: Document Management Satisfaction & Organiztion Range Bar Chart

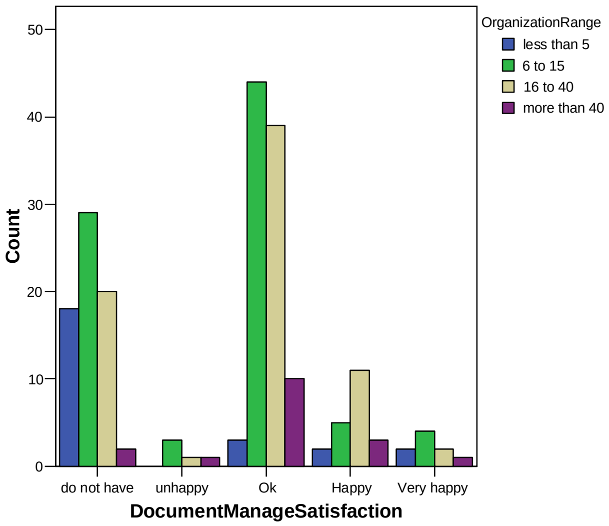

Exhibit 65: Document Management Satisfaction * Organization Range Cross tabulation

Document Management Satisfaction		Organization Range				Total
		less than 5	6 to 15	16 to 40	more than 40	
do not have	Expected Count	8.6	29.3	25.2	5.9	69.0
	% of Total	9.0%	14.5%	10.0%	1.0%	34.5%
unhappy	Expected Count	.6	2.1	1.8	.4	5.0
	% of Total	.0%	1.5%	.5%	.5%	2.5%
Ok	Expected Count	12.0	40.8	35.0	8.2	96.0
	% of Total	1.5%	22.0%	19.5%	5.0%	48.0%
Happy	Expected Count	2.6	8.9	7.7	1.8	21.0
	% of Total	1.0%	2.5%	5.5%	1.5%	10.5%
Very happy	Expected Count	1.1	3.8	3.3	.8	9.0
	% of Total	1.0%	2.0%	1.0%	.5%	4.5%
Total	Expected Count	25.0	85.0	73.0	17.0	200.0
	% of Total	12.5%	42.5%	36.5%	8.5%	100.0%

Exhibit 66: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29.224(a)	12	.004
Likelihood Ratio	31.028	12	.002
N of Valid Cases	200		

a 10 cells (50.0%) have expected count less than 5. The minimum expected count is .43.

Documentation management system is aimed to manage project documents including costumer information, project status, timetable and diagrams. The research finds that these two variables are significantly depended. According to Exhibit 65, there are 34.5% of the respondents' organizations do not have such kind of software this shows a potential possibilities to improve or establish such kind of system within the organizations.

Section C: Current New Zealand Construction Supply Chain Management situation.

This section provides analysis of the responses concerning the current New Zealand Construction Supply Chain Management situation. There were 18 questions in this section. It will be analyzed and listed as below.

Mean and frequency for question 1-6

Question	1	2	3	4	5	6
Mean	3.30	2.83	2.89	2.99	2.93	2.84
Frequency of satisfaction	85.5%	62%	65.5%	70%	65%	64.5%
1=Very Unhappy 2=unhappy 3=ok 4= happy 5= very happy						

Q1: Getting the information that I need to do my job.
(Mean= 3.30& Frequency of satisfaction = 85.5%)

According to the analysis, the majority of the respondents (45%) feel ok with their current state of getting the information they need to do their job. The mean (3.30) indicated a positive response towards this question and this suggests that the respondents are satisfied with getting job related information.

Q2: Supplying information to others.
(Mean= 2.83& Frequency of satisfaction = 62%)

The findings show that quite a few of the respondents were not confident with supplying sufficient information for their job partners. This is based on 38% of the respondents providing a negative response to the question, and the mean of 2.83 illustrates the same point. The result also highlights that there were a number of respondents (39.5%) who were satisfied with the information they give to their partners even though the mean is negative.

Q3: Estimating or quoting my costs for the job.
(Mean= 2.89 & Frequency of satisfaction = 65.5%)

Some of the respondents (34.5%) provided a negative response to this question, while 40% felt ok about it. The mean was 2.89 and the frequency of agreement is 65.5%. This shows that the respondents felt not too bad about estimating or quoting their costs for their job.

Q4: Managing my costs to my budget.
(Mean= 2.99& Frequency of satisfaction = 70%)

The majority of the respondents (70%) felt more than ok of managing their costs to their job budget while 30% of them are not satisfied. The mean average (2.99) showed a slightly negative response about this statement.

Q5: Knowing when suppliers are going to deliver the products or services that the job requires.
(Mean= 2.93& Frequency of satisfaction = 65%)

Based on the survey results, 35% of the respondents provided a negative response to this question, which indicates that quite a few of the practitioners have no idea when the suppliers are going to deliver the products or services which their job requires. Only 5.5% of the respondents felt very happy with the notice of delivery. With a mean average of 2.93 the majority of respondents (65%) stated that there is a slightly negative response of this question.

Q6: Managing project variations.
(Mean= 2.84& Frequency of satisfaction = 64.5%)

Based on the responses of the practitioners, the mean and the frequency regarding this question are similar to Q5. Even though 41% of the respondents felt ok with the management of project variations, it suggests that there is still a trivial negative tendency of this question.

Mean and frequency for question 7-15

Question	7	8	9	10	11	12	13	14	15
Mean	3.20	1.95	2.81	2.98	2.10	2.65	2.15	3.08	3.22
Frequency of satisfaction	84.5%	20.5%	67.5%	75%	29%	61.5%	31.3%	76.5%	82%
0= not related 1 =Very poor 2=poor 3=ok 4= good 5= very good									

Q7. The time taken to get the information you wanted.
(Mean= 3.20& Frequency of satisfaction = 84.5%)

84.5% of the respondents revealed that they did not spend too much time on colleting job relevant information. It indicated that most of the responses were satisfied with the time spending on getting information in a particular project. The results were strongly supported by the mean of 3.20 and the frequency of satisfaction of 84.5%, which indicated a positive response from the respondents.

Q8. How well the various parties communicated
(Mean= 1.95& Frequency of satisfaction = 20.5%)

The findings showed that only 20.5% of the respondents felt that it is easy to communicate with the various parties involved in the same project. The mean response of 1.95 indicated that the respondents provided a strongly negative response regarding the question concerning the communication through the project. This result is accordant with the literature review which also indicated that communication is one of the inducements of the problems in construction supply chain management.

Q9. The accuracy of the information you received.
(Mean= 2.81& Frequency of satisfaction = 67.5%)

The findings show that 67.5% of the respondents are some extended satisfied with the accuracy of the information they received. With a mean reported of 2.81, this indicates that practitioners who involved in a specific project are slightly dissatisfied with the information accuracy.

Q10. The amount of information you received.
(Mean= 2.98& Frequency of satisfaction = 75%)

The mean of 2.98 indicated that most respondents are satisfied with the amount of information they received. This suggests that the ideal computer based supply chain management system should also be able to provide a certain amount of information.

Q11. The time you spent on communicating on the project.
(Mean= 2.10& Frequency of satisfaction = 29%)

The majority of the respondents (71%) provided a negative response to this question, while 2% were claimed that they needn't communicated with others on the project. It was not surprising to see the proportion of the respondents who felt that they have wasted a lot of time on communication. This result was also supported by Q8.

Q12. Did the right products turn up on site?
(Mean= 2.65 & Frequency of satisfaction = 61.5 %)

More than half of the respondents (38.5 %) stated that the right products didn't turn up on site. This may have been due to the communication problems which have been proved in Q8, Q11 and also in literature review. Although the mean (2.65) indicated that the respondents provided a negative response to this question, the trend is more like towards positive.

Q13. The amount of time you spent waiting for others.
(Mean= 2.15& Frequency of satisfaction = 31.3 %)

The mean average of 2.15 and frequency of satisfaction of 31.3% indicated that most of the respondents are not satisfied with the time spending on a specific project.

Q14. What it cost you to do your part of the project?
(Mean= 3.08& Frequency of satisfaction = 76.5%)

The mean (3.08) and frequency of satisfaction (76.5%) indicated that the respondents were satisfied with the time costing to finish their part of the project. Compared with the result of Q13, the mean reason of negative response of Q13 may be also the communication problem when working on the project.

Q15. The number of mistakes made by you or others on the project
(Mean= 3.22& Frequency of satisfaction = 82%)

Although the mean 3.22 indicated that the respondents were "ok" with the number of mistakes made by them or others on the project, there are 20% of the respondents felt dissatisfied with the accuracy of the project. That means there is a need of improve the accuracy.

Q16. How much time do you think you waste on a typical project due to the above issues?

Exhibit 67:Histogram

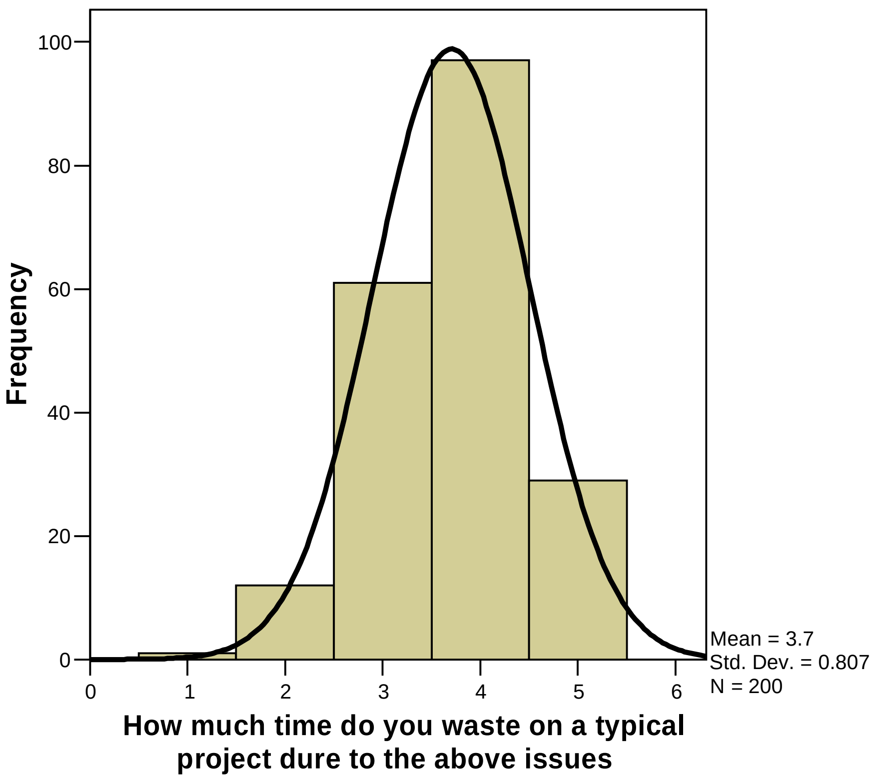

Exhibit 68: How much time do you waste on a typical project due to the above issues?

	Frequency	Percent
less than 1 hour	1	.5
1 to 4 hours	12	6.0
4 to 8 hours	61	30.5
8 to 16 hours	97	48.5
more than 16 hours	29	14.5
Total	200	100.0

According to the results shown in Exhibit 68, nearly half of the respondents (48.5%) thought they have wasted 8 to 16 hours on a typical project due to the above issues. Anther 30.5% of the respondents suggested 4 to 8 hours time wasting and 14.5% indicated than they wasted more than 16 hours.

Q17. Rank the supply chain features.

Exhibit 69: Rank of the supply chain features

Features	**Happens on time**	**No mistakes**	**Fast response**	**Low cost**	**Easy of use**
Mean	2.06	3.47	3.42	3.18	2.89

According to Exhibit 69, “no mistake” is the most important feature of construction industry supply chain, following by “fast response”, “low cost”, “easy of use”, and “ happen on time” in order.

Q18. How did your business select project partners?

Exhibit 70: Partner Selection

Total	200	100.0
Valid	Frequency	Percent
same partner	84	42.0
select from a pool	68	34.0
different each project	40	20.0
have no say over whom we deal with	2	1.0
no partners	6	3.0

The result indicates that majority of the respondents' organization (42%) deal with pretty much the same partners on their project and 34% of them have a pool of people that they deal with and choose from them for each project. 20% of the organizations tender each project and choose the best deal at the time. These results are consistence with the previous literatures how construction industry organizations choose their supply chain partners.

Section D: The respondents' attitude towards adopting ICT

In this section, the respondents responded concerning their usage of computer in daily job. This section consists of 9 statements.

Mean and frequency for statement 1 to 9

Statement	1	2	3	4	5	6	7	8
Mean	3.46	3.41	3.07	2.25	2.79	2.31	3.12	3.34
Frequency of agreement	100%	95.5%	83%	30%	68.5%	33.5%	93.5%	96.5%
1= Strongly disagree 2= Disagree 3=Agree 4= Strongly agree								

S1. Managing the supply chain is one of the most important issues in construction industry.
(Mean= 3.46 & Frequency of agreement = 100 %)

All of the respondents provide a positive response to this statement. Every respondent thinks supply chain management is one of the most important issues in construction industry. 45.5% of the respondents strongly agreed with this statement. This result reveals that all the respondents call for an effective supply chain management system.

S2.Computer based supply chain management could improve efficiency.
(Mean= 3.41 & Frequency of agreement = 95.5 %)

Although the mean (3.41) indicated that the respondents were slightly negative of this statement, there are some of the respondents (4.5%) do not think that computer based supply chain management system could improve efficiency. That means although most of the respondents may be willing to introduce ICT into the supply chain management, there may be some humanistic issues when integrating ICT with construction supply chain management.

S3.Computer based supply chain management can reduce costs. (Order, delivery and project life cycle costs)
(Mean= 3.01 & Frequency of agreement = 83 %)

The majority of the respondents (83%) agreed with the statement about the possibility that computer based supply chain management system can reduce project relevant costs. The mean also indicated an agree response with the figure of 3.01.

S4.Computer based supply chain management system will be a pain to put into the building industry.
(Mean= 2.25 & Frequency of agreement = 30 %)

The mean average of 2.25 indicated a disagreed response from the respondents regarding the bad effects may be brought by ICT into the building industry. According to the frequency, the majority of the respondents (70%) stated their disagreement about this statement; however, still 30% of them think that ICT may be a pain to put into the building industry.

S5.Computer based supply chain management system can reduce the time and work involved in the building consent process has to happen.
(Mean= 2.79 & Frequency of agreement = 68.5 %)

The majority of the respondents (68.5%) agreed that computer based supply chain management system can reduce the time and work involved in the building consent process has to happen. Although the mean (2.79) indicated a slight negative response, the figure tends towards agreement.

S6.The last thing that I need in my job is more computers.
(Mean= 2.31 & Frequency of agreement = 33.5 %)

The mean average of 2.31 indicated a strong disagreement response from the respondents regarding the possibilities of employing more computers in their organization. According to the frequency, the majority of the respondents (66.5%) stated their requirements of using more computers. This suggests that the desires of using computers.

S7.Computer based supply chain management can improve accuracy of information flow and material flow.
(Mean= 3.12 & Frequency of agreement = 93.5 %)

93.5% of the respondents stated their agreement with this statement. The mean was 3.12 and the high frequency level (93.5%) indicated a positive response the statement. This clearly shows that the respondents believed that computer based supply chain management can improve accuracy of information flow and material flow.

S8.Computer based supply chain management can improve communication among supply chain participants.
(Mean= 3.34 & Frequency of agreement = 96.5 %)

With a mean average of 3.34 the majority of respondents (96.5%) believed that computer based supply chain management can improve communication among supply chain participants. It indicated that practitioners would be happy to use ICTs to improve the performance of supply chain communication.