KNOWLEDGE MANAGEMENT FRAMEWORK FOR THE MALAYSIAN CONSTRUCTION CONSULTING COMPANIES

(IRPA project vote no. 74320)

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ABSTRACT

This study is aimed to develop a framework that integrates knowledge management (KM) and information technology infrastructure (ITI) capabilities for the Malaysian construction consulting companies. A systematic two-step approach using the Delphi technique followed by a survey questionnaire was able to solicit responses by 19 experts and 122 consultants respectively. A rigorous statistical approach to ascertain data validity and reliability is conducted using factor analysis and Cronbach's alpha respectively. Subsequently, independent sample t-tests were performed to demarcate KM attributes into either 'exploitive' or 'explorative', as well as ITI capabilities into either 'exclusive' or 'standardised'. Through the integration of the findings, a four-quadrant matrix ('exploitive' or 'explorative' KM versus 'exclusive' or 'standardised' ITI capabilities) is finally proposed in this study.

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CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

The world in general and the business world in particular are experiencing a paradigm shift: a shift toward knowledge-based organisations (KBO) and a knowledge-based society (Toffler, 1990; Drucker, 1993). Although we are experiencing it now, this trend has been recognised for over half of a century (Hayek, 1945; Drucker, 1968; Bell, 1973; Holsapple and Whinston, 1987). Today, it is widely claimed by a number of business and academic gurus that in order for the organisations to have a lasting competitive advantage they will have to be knowledge driven (Prahalad and Hamel, 1990; Nonaka, 1991; Drucker, 1993). Peter Drucker in his book *Post Capitalistic Society* writes that, "The basic economic resource is no longer capital, nor natural resources. It is and will be knowledge" (Drucker, 1993, pg. 8).

If knowledge is viewed as a resource that is critical to an organisation's survival and success in the global market, then like any other resource it demands good management. Robert Hiebeler, partner-in-charge, Global Best Practices, at Arthur Andersen, in his article Benchmarking Knowledge Management writes, "Those companies that develop best practices for managing knowledge capital will be the ones that ride this competitive wave" (Hiebeler, 1996). In addition, an article that summarises the developments in the field of knowledge management (KM) asserts that new business and academic initiatives in all domains are approaching a common theme of "transformation of the enterprise – profit or not-for-profit – through knowledge management" (Amidon, 1996, pg. 1). The article analyses collective findings that emerged from recent KM-oriented conferences around the world to identify several recurrent themes: (1) the knowledge management movement is ubiquitous, spanning business, education, and government; (2) an approach needs to be developed to measure knowledge, which is traditionally considered immeasurable; (3) use of technology is integral to a knowledge-based organisation's functioning; and (4) knowledge resources need to be carefully managed rather than being left to serendipity or fate.

The responsibility for productively managing this crucial organisational resource is clearly on the shoulders of all of the organisation's employees, whether they are managers or operational personnel. "It (knowledge productivity) cannot be discharged by government; but it also cannot be done by market forces. It requires systematic, organised application of knowledge." (Drucker, 1993, pg. 190). For many years organisations have formally and explicitly captured and managed knowledge by way of computer systems such as management information system (MIS), decision support system (DSS), and expert system (ES). However, a premise of this report is that such technologies are just a portion of what is possible and what is necessary for effective KM.

Major organisations have appointed chief knowledge officers (CKOs) and chief learning officers (CLOs) to formally initiate and cultivate KM activities in their organisations (Davenport, 1994; Willets, 1996). Such positions are distinct from the more traditional role of chief information officer (CIO). Major consulting firms are directing their attention toward KM consulting activities that focus on issues over and above traditional information systems (e.g., Andersen Consulting, Ernst and Young, and Entovation). Moreover, there are documented cases of organisations that have successfully adopted and implemented a knowledge management culture. Examples include Chaparral Steel, Honda, Canon, Buckman Laboratories, and Skandia (refer Fast Company, 1997; Stewart, 1997; Leonard-Barton, 1995; Nonaka, 1991).

Nevertheless, apart from conventional computing systems, the bulk of organisations still have not approached KM activity formally or deliberately. Yet, such an approach would seem to be valuable and perhaps essential, to effectively function in the emerging knowledge-based economy. Nonaka (1991, pg. 96) points out that, ". . . despite all the talk about brainpower and intellectual capital, few managers grasp the true nature of the knowledge-creating company – let alone know how to manage it." In addition, Zack and Serino (1996) maintain that, ". . . while the business case for knowledge management is becoming widely accepted, few organisations today are fully capable of developing and leveraging critical organisational knowledge to improve their performance."

The cause for this lack of effective management of knowledge could be that most organisations are still struggling to comprehend the KM concept. Anne Stuart senior editor of *CIO* writes, "Many managers would be hard pressed to explain precisely and concisely, what this evolving business trend (KM) means. What they probably do know is knowledge management has been billed as a critical tool for the 21st century corporation ... And they know it is something they just have to get too – even if they don't know exactly what it is" (Stuart, 1996, pg. 1). The reason for this confusion and lack of clarity can be attributed to a gap between the emerging KM phenomena and the current lack of understanding about this phenomenon by researchers and practitioners. To bridge the gap, the fundamental issue of identifying salient characteristics of KM phenomena needs to be addressed. This is a prerequisite for systematic research into the nature and possibilities of KM, as well as for easing the emergence of KM into practice.

As such, changing environment surrounding business organisations during the past decade has forced organisations to look for new ways to compete effectively. One of the key factors of corporate success is the ability to quickly adapt to changing conditions in the environment, innovate continuously, and achieve goals. Organisational knowledge provides this capability. More specially, organisational knowledge provides the capability to understand the market, assess the customer's needs, and translate them into products and services by integrating various organisational resources. As we move from the industrial age into the intelligence age, knowledge has become a central force behind the competitive success of firms. In an economy where everything is uncertain, the one sure source of sustaining competitive advantage is knowledge (Nonaka and Takeuchi, 1995). Thus, KM is a critical concern for creating and sustaining the organisation's core competencies.

KM includes the entire process of discovery, creation, dissemination, and utilisation of knowledge. For successful KM, managers need to understand the various organisational aspects including organisational structure, culture, leadership, and technology especially, information technology (IT) which has become one of the critical factors for effective KM (Junnakar and Brown, 1997; Trussler, 1997; Ruggles, 1998; Syed, 1998; Skyrme, 1999a; Sarvary, 1999; Zack, 1999; Choi, 2000). During the management process, IT is extensively utilised. As the importance of organisational knowledge and the role of IT in KM increase, choosing the right IT for different KM strategies, has become critical than ever.

Many practitioners and researchers have addressed the important issue of applying IT to KM (Rezgui, 2001). To date, these studies have focused only on individual IT applications. However, to truly understand the impact of IT support on KM, it is important for organisations to examine how IT and KM inter-relate with each other. IT applications and KM do not exist in vacuum. It is difficult to separate the IT applications from KM infrastructure components. So far, no empirical study has been carried out on this topic. As such this study investigate the framework between KM and IT infrastructure capability in the construction consulting industry.

1.2 SIGNIFICANCE OF THE STUDY

The significance of this study is based on the uncontested pressure the global economy has placed on the construction consultant industry to speed their technological innovation processes and to exploit the properties of their intangible knowledge assets (Marquardt and Reynolds, 1994; Mann, 1998; Neef, 1998). Unfortunately, although the literature is replete with anecdotes, little empirical research exists on the relationships among knowledge, KM and IT infrastructure (ITI). This lack of research is even more prevalent in the construction consultant industry uses of knowledge management strategies.

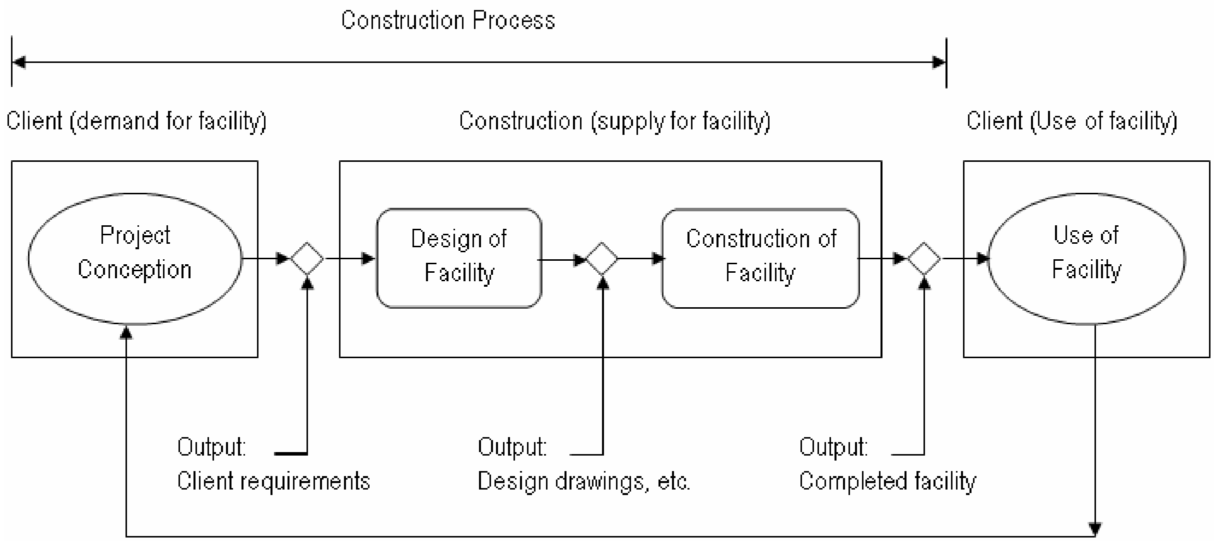
This study hopes to fill the research void by (a) using the existing literature and industry strategies to conceive how the concepts are related, and (b) focusing the research lens on the strategies that enable construction consultant industry to employ KM more effectively. The study leaves the relationship between the effectiveness of KM and the growth of IT to future research efforts. Specifically, by exploring and by further developing a better understanding of the KM-ITI framework construction consultant industry, this report addresses three major goals.

First, it examines, within the context of construction consultant industry, a relatively new area in the field of management and organisational studies at the forefront of scholarly attention. Various cultural, technical, and strategic forces are brought to bear on the management process. As such, there is a trend in current research discovering how these forces enable or constrain the management of knowledge in an organisation (Leonard-Barton, 1995; Cropley, 1998; Davenport and Prusak, 1998; de Jager, 1999; Nijhol, 1999; Russett and Marshall, 1999). However, as previously stated, there is little reported research in the construction consultant industry.

Second, this study not only furthers the existing state of knowledge in KM from a scholarly and academic standpoint, but also brings the practical issues, best strategies, and critical success factors to the surface. In that regard, this study can potentially serve as a reference guide for construction consultant industry wanting to establish a KM system and plan the complementary IT infrastructure.

Third, this study takes existing research on KM, which is currently limited to abstract concepts, ideas, frameworks, models, and anecdotes and adds significantly to both the theoretical and applied fronts of KM research. From a theoretical point of view, this research fills in the gaps by developing a conceptual framework based on the synthesis of existing literature and industry strategies to assess KM and IT infrastructure in the construction consultant industry setting. On the applied front, this study focuses on the operational aspects of the management of organisational knowledge by examining various relationships and generating a list of critical success factors to guide construction consultant industry who wish to use KM within the various stages of the construction process (refer Figure 1.1).

Figure 1.1: Simplified Model of the Construction Process



Source: Kamara et al., 2002)

Finally, KM has been widely touted and discussed; nevertheless, few empirical studies (Bohn, 1994; Nonaka and Takeuchi, 1995; American Productivity and Quality Center (APQC), 1999; APQC, 2000; APQC, 2001; Torraco, 1999; Quinn, 1992) have been done in the manufacturing sector and even fewer in construction consultant industry. Some construction consultant industry have come to face pressures increasingly similar to manufacturing sector organisations and have adopted a variety of management techniques, it seems reasonable to suppose that KM and related strategies might have something to offer to the construction consultant industry.

Moreover, the present and future success of construction consultant industry has come to be based less on the strategic allocation of physical and financial resources and more on the strategic management of organisational knowledge. Therefore, through addressing KM processes and strategies used by construction consultant industry and identifying critical success factors, the consultants will be better equipped to restructure organisational processes, thereby enhancing quality and performance.

1.3 RESEARCH SCOPE

The major focus of this research is to propose a KM-ITI framework for the construction consulting industry. In turn, findings from this study should be interpreted as the organisational issues and they may not be applicable to the individual project level. Information was solicited through Delphi assessment and survey questionnaire using KM best practice implementation derived from the

Construction Industry Institute (CII) Best Practices together with the 25 IT infrastructure services developed by Weil and Broadbent (1998). Applying the research methodology used in this study to a random sample of consultants from the construction industry were based from the Construction Industry Development Board (CIDB) listing may yield different results and thus generalising the results of this study to the whole industry may not reflect the accurate implementation status.

1.4 RESEARCH OBJECTIVE

The overall objective of this study is to examine the relationship between KM and IT infrastructure capability in the construction consulting industry. In the consulting industry, knowledge and its management are primary service products. The consultants sell their expertise and get paid for the solutions they provide to their customers. The expertise and solutions are nothing more than knowledge. If a consultant leaves the firm or retires, then the company may lose a huge amount of money because the person's knowledge goes with him or her.

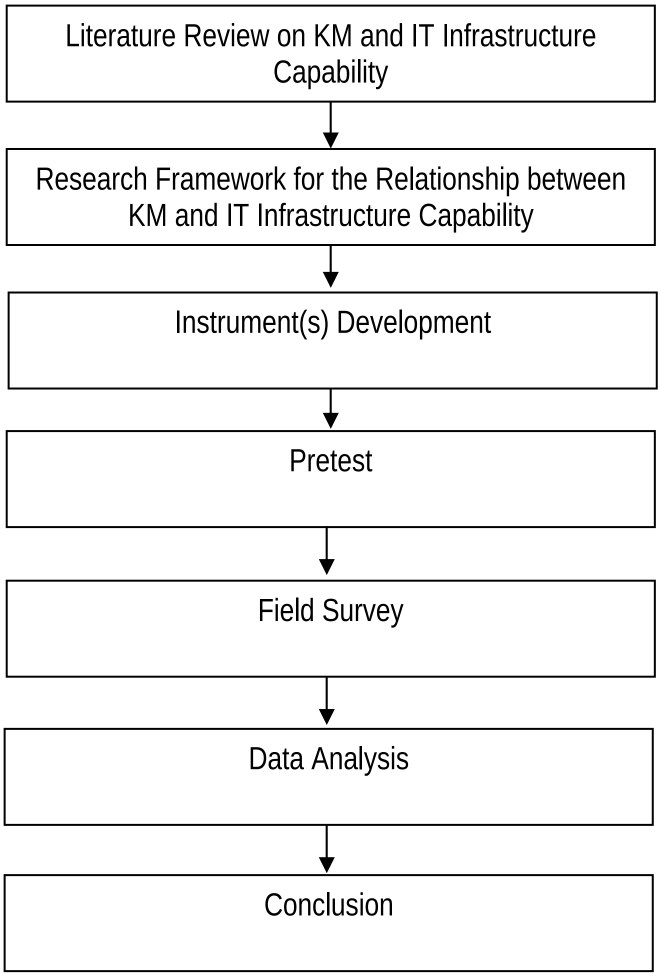
Managing knowledge is one of the key business processes in the consulting industry (Galagan, 1997; Zack, 1999; Sarvary, 1999; Hansen et al., 1999). The industry is also "among the first to aggressively explore the use of IT to capture and disseminate knowledge" (Hansen et al., 1999). Also it has been repeatedly reported that IT and its underlying infrastructure are critical components of successful KM (Junnakar and Brown, 1997; Syed, 1998; Skyrme, 1999b; Choi, 2000). With the growing importance of KM and the role of IT in KM projects in this industry, identification of these relationships helps companies acquire appropriate IT support, plan and priorities IT investment for KM more effectively.

A basic assumption of the research conducted in this report is that management of knowledge is important for both productivity and competitiveness. It not only enables organisations to conduct their business processes in an effective manner (which allows organisations to produce quality products and services), but it is also primary instrument for organisational creativity and innovation. This assertion is supported and reinforced in an industry survey conducted by Computer Science Corporation (CSC). It found that senior Information System (IS) executives perceive knowledge management to be among the most critical technologies that will drive business growth and innovation by the year 2000 (CSC, 1996).

Towards this end, this research involves three steps: (1) development of a conceptual framework for the assessment of KM approaches in the management consulting industry; (2)

presentation of the research model on the relationship between KM and IT infrastructure capability leading to formulating hypotheses; and (3) based on the field survey, the relationship between KM and IT infrastructure capability is measured and tested as shown in Figure 1.2.

Figure 1.2: Overview of the Research Process Flow



A framework is needed to identify and characterise the main elements of KM phenomena and their relationships. A framework provides a perspective for fully understanding as well as organising concepts in a unified fashion. Frameworks are different from theory. A framework describes a phenomenon in the form of key factors, constructs or variables and their relationships for the purpose of theory building (Miles and Huberman, 1994), whereas the purpose of theory is to explain and predict a phenomenon (Kerlinger, 1986).

Although a few frameworks have been posited for KM (e.g., Nonaka, 1991; Wiig, 1993), each framework addresses only certain KM elements. Individually, each fails to adequately describe the full scope of KM phenomena (nor is this the stated intent of any). Collectively, they are not particularly compatible and also appear to overlook KM issues reported elsewhere in the literature. Therefore, there is a need for a more comprehensive framework for characterising KM phenomena. Such a framework can benefit both researchers and practitioners by furnishing an organised foundation for future progress in our understanding and conduct of KM.

1.5 RESEARCH QUESTIONS

There have been numerous studies about KM and IT. However, there have been only a small number of studies about KM and underlying IT components. Furthermore those studies are not empirically based. In order to truly understand the IT capability, it is appropriate to investigate the underlying components of IT because no individual IT application can exist without its infrastructure support.

To maximise the benefits of IT for KM, the relationship between KM and IT infrastructure capability must be established and empirically tested. The purpose of this study is to identify the relationship between KM and IT infrastructure capability. The questions such as "Do different KM approaches need different IT infrastructure capability?" and "Is there are specific IT infrastructure capability needed by a specific type of KM approach?", have critical implications for managers to more effectively plan and implement IT applications for KM projects because answering such questions will allow managers to select right tools for KM. Different KM approaches may require different approaches to leveraging IT. Then, the research question can be stated as follows: What framework could be developed to integrate KM and IT infrastructure capability, especially within the construction consulting industry?

1.6 THE CONSTRUCTION CONSULTING COMPANIES IN MALAYSIA: AN OVERVIEW

The Malaysian construction sector has contributed to no more than 5% of the GDP for the periods of 2001 to 2005 (refer Table 1.1). Though small in percentage, this sector is an important sector as it complements the other sectors through the development of infrastructure from oil and gas structures to highway developments. The importance of the construction sector is illustrated by the sizeable amount of loans approved for construction from 2001 to 2005 which clearly shows that priority given to this sector as an engine for the Malaysian economic growth.

Table 1.1: The Malaysian GDP by Economic Activity at Current Prices (2001-2005)

Economic Activity	2001	2002	2003	2004	2005
Agriculture, Forestry an Fishing (1)	8.2	9.2	9.6	9.5	8.7
Mining an Quarrying (2)	10.1	9.4	10.4	12.6	15.2
Manufacturing (3)	30.4	30.5	31.1	31.4	30.6
Construction (4)	4.2	4.0	3.8	3.4	3.1
Electricity, Gas and Water (5)	3.4	3.4	3.2	3.1	2.9
Transport, Storage and Communication (6)	7.1	6.9	6.8	6.6	6.5
Wholesale and Retail Trade, Hotels and Restaurants (7)	14.6	14.1	13.3	13.0	13.2
Finance, Insurance, Real Estates and Business Services (8)	12.4	12.7	12.0	11.2	10.7
Government Services (9)	7.2	7.6	7.5	7.1	7.0
Other Services (10)	7.1	7.0	6.7	6.2	6.0
Less: Imputed Bank Service Charges	6.6	6.5	6.1	5.5	5.1
Plus: Import Duties	1.7	1.8	1.6	1.4	1.3
GDP at Purchasers' Value	100	100	100	100	100
Service (5+6+7+8+9+10)	51.8	51.6	49.5	47.2	46.3

(Source: www.statistics.gov.my)

Concentrating on technical consultancy serving the construction industry, it can be asserted that the market for technical consultant services in Malaysia is characterised by price competition (usually bids with fixed prices) and low product differentiation. Entrance barriers are low, especially for small assignments, and new kinds of organizations such as staff providers and management consultants compete for some assignments. Many of the large technical consultant firms are therefore trying to move their services in the direction of a more advanced technological content, specialization and services that clearly add value for the customer. The technical consultants appear to respond to this competition by accelerating their development as professional service organizations, something which increases cooperation with customers, suppliers and manufacturers.

The institutions of consulting engineering in Malaysia have been deeply influenced by the colonial past, that is, the British system of engineering education and practice. Malaysian engineering consulting services have drawn on British expertise to provide services to the local construction sector, and this pattern of exploitation of existing knowledge can be seen as a crucial factor for raising quality and efficiency in construction. At the same time, however, engineering firms in Malaysia are now largely staffed with locally born and educated engineers, and they operate in Middle Eastern markets especially Saudi Arabia due to Malaysia's positioning as the Head of OIC as well as in Mainland China and India due to the large number of Chinese and Indians among the Malaysian population. This raises important issues about the potential tensions between a "global" professional culture and the cultural values of the organizations and societies in which consulting engineers carry out projects. Still, a handful of international firms dominate the market for engineering service in Malaysia. In particular, large firms such as Nishimatsu (Japanese) and Sambu (Korean) have a unique culture that promotes innovation, placing specific focus on their human resources. When hiring, the firm tries to look for graduates with different backgrounds to promote diversity. In addition to the normal trainings and professional development routines that engineers go through, Rekayasa (Indonesia) actively tries to arrange for staffs to work in different environment such as oil and gas to enrich their experience. If needed, they could be seconded from one office to another on a project-to-project basis. On top of staff relocation, the firm's internal systems such as skill networks, intranets, and regular publications serve as the backbone on which knowledge is stored and disseminated. These can be regarded as necessary features to supplement the knowledge creation process.

Projects involving advanced engineering design in Malaysia have become increasingly complex during the recent decades. Mega construction projects such as the Putrajaya, Kuala Lumpur International Airport and Mass Transit Railway systems was initiated in the 1990s constituted a highly complex undertaking involving both local and foreign engineering companies. An unusual practice for the construction of the Petronas Twin Towers was the involvement of two main contracting consortiums in the Tower One and Tower Two contracts. The Tower One where Petronas current headquarters situates was handled by Japanese-led Hazama Corp. along with others such as US-based J.A. Jones Construction Co. Ltd., Mitsubishi Corp. Japan, local participating firms consists of MMC Engineering & Ho Hup Construction (All grouped as "Mayjus Joint Venture"; the Tower Two was constructed by SKJ Consortium which comprised of Korean based Samsung Engineering & Construction Co. Ltd. Kuk Dong Engineering & Construction Co Ltd. along with local participation, Syarikat Jasatera and First Nationwide Engineering Sdn Bhd, Malaysia, along with Singapore based Dragages and Bachy-Soletanche. Another 'Malaysian construction milestone' is the complexity of planning and construction of new township and government administration buildings in Putrajaya which presented major challenges to engineering consultants and contracotrs. Although most engineering design projects in Malaysia do not project represents such extreme complexity, the difficulties associated with construction in congested areas, under difficult geo-technical conditions, and with multifarious environmental surroundings are usually challenging.

The reliance on exploitation of preexisting knowledge, which is often embodied in the expertise of employees, has had a tendency to support a pattern of knowledge accumulation that is gradual and often characterized by largely tacit elements in most Malaysian construction onsulting companies. The project team will usually be composed of senior engineers that have built up their specialist knowledge of the design through many years of practice, combined with a group of engineers who are still in the process of learning (Wearne, 1993). The profession also emphasises this aspect of practical experience in the requirements for certification as a chartered engineer. To a large extent, knowledge management in engineering consultancy firms focus on recruitment, training and retaining of engineers who are keen to continue to expand and enhance their knowledge base. Their services rely heavily on their professional expertise, acquired through formal education, continuing professional development, and hands-on experience. Through the design process, for instance, the engineers apply scientific knowledge to solve problems derived from the clients' requirements. Scientific knowledge may entail mathematical calculations, geometric analysis, etc. Subsequently, ideas, concepts and, in some case, analyses are presented in the form of visual interfaces that call for unique computer skills. Materials are engineered such that they perform to the clients' requirements. Knowledge of this kind is often explicit in nature, although it may frequently be presented in a visual form (Henderson, 1999).

1.7 ORGANISATION OF REPORT

This report consists of six chapters; Introduction, Background of the Construction Consulting Industry, Literature Review, Research Design and Methodology, Analysis and Discussions, and Summary and Conclusion. Chapter One has provided a general introduction and brief overview of the research objective, research questions, and the research methodology to be employed. Chapter Two outlines the background of the industry based on the perspective of project management and IT infrastructure. Chapter Three reviews the literature KM and IT infrastructure capability as well as framework development. The first part of this chapter presents a review of KM literature, including various definitions associated with the subject, concepts, and KM approaches in the management consulting industry. The second part provides a review of literature on the IT infrastructure capability to establish a conceptual framework for this study. The third part presents the principles of framework development. Chapter Four presents the research design and methodology employed in this study. It describes a research framework developed through the literature review. All variables used in the research are presented and defined. This chapter also includes discussions on research design, samples and the survey instruments for measuring variables and testing hypotheses. All variables defined are operationalised for measurement purpose. Chapter Five presents the results of the analysis and discussion of the results. This chapter describes the survey procedure employed, including the data collection procedure, sampling, and unit of analysis of the study. It includes a discussion on two important analyses of the measure: reliability and construct validity tests on the instrument employed. Next it presents the results of the analysis. It describes demographic characteristics of the respondents and their companies and also presents a discussion on the results and implications of the results. Chapter Six concludes the study. It presents the summary, limitations and contributions of the study, and the future research needs.

CHAPTER TWO

BACKGROUND OF THE CONSTRUCTION CONSULTING INDUSTRY

Rapid changes in market opportunities, technological advances, and competitive trends are significantly impacting the construction engineering industry. No longer can top management teams do just one thing right. In the marketplace today, many individual components must correctly come together at the right time. Additionally, senior managers must look at their organisations both outward as well as inward in order to achieve long-term corporate growth (Sexton and Seale, 1997).

Today, many executive managers of construction engineering organisations face knowledge limitations with respect to their corporate level responsibilities that include expanding market opportunities, gaining a competitive advantage, and achieving long-term growth. Consequently, top managers rely heavily on traditional short-range project management skills that they have acquired throughout their career progression. The short-term focus of project management permeates nearly every facet of the construction engineering industry. This primary focus on project management is found at: (1) construction job sites where resources must be managed intensively, (2) in corporate offices where critical resources must be balanced among multiple projects, (3) in professional development literature and seminars that provide updated industry techniques, and (4) in graduate-level construction engineering and management programmes that provide industry knowledge.

This heavy emphasis on project management skills has resulted in the creation of a management knowledge gap between the project level focus and corporate level responsibilities within the construction engineering industry. Normally, senior managers move upward in their career progression from project management responsibilities to corporate level responsibilities. However, the concern is that they continue to manage at the corporate level with project management skills. As a result, a management knowledge gap exists for executive leaders charged with corporate level responsibilities.

As corporate managers in the construction industry take on greater organisation level responsibilities, they must accept two key challenges: (1) bridge the management knowledge gap, and (2) develop a long-term strategic management perspective for their organisation. First, executive managers must bridge the management knowledge gap by gaining strategic management knowledge skills needed in order to achieve their corporate level responsibilities. Second, with this new knowledge, executive managers must expand their field of vision from a short-term project focus to a long-term strategic management perspective. To achieve this new perspective for their organisations, senior managers must ask three critical questions:

- Where is our organisation now?
- Where do we want our organisation to be in 5 years?
- Do we know how to get there?

A coordinated effort among the top management team to provide answers to these three critical questions can provide a first step in promoting a long-term strategic perspective for the organisation. In most cases, the construction consulting company knows where they are and where they want to be in the future. But 'how to get there' is a difficult task to determine. The interplay between project management tools to use and what IT infrastructure to develop needs to be planned carefully due to the high cost. This chapter will provide a brief overview of project management and IT infrastructure used within the construction consulting industry. Also included is a brief overview of the Construction Industry Institute – a leading industry-academic consortium developed for the betterment of the construction industry.

2.1 PROJECT MANAGEMENT IN THE CONSTRUCTION CONSULTING INDUSTRY

In modern constructions, a construction project is a unique, complex, custom-built response to client's interests. Most construction projects are large, extensive, expensive, and are subjected to tight schedule and budget. Unlike the manufacturing projects, the construction project is subject to the influence of highly variable and sometimes unpredictable factors. The construction team includes various combinations of architects, engineers, contractors, subcontractors, materials suppliers, equipment providers, inspectors, owner's representative, and other changes from one job to the next. All the complexities inherent to different construction sites, such as soil conditions, surface topography, environmental concerns, weather, transportation, material supply, utilities, and local practices, are an innate part of construction. Table 2.1 shows the major differences in practices between the construction industry and other manufacturing industries.

As a consequence of these circumstances, construction projects are characterised by their complexity and diversity and to certain degree by the non-standardised nature of their production. Despite the use of factory-produced modular units in certain construction practices, it seems unlikely that field construction will ever be able to adapt itself completely to the standardised methods and product uniformity of assembly-line production. Therefore, managing a construction project is an interdisciplinary art requiring professional skills to achieve the maximum performance as required by the project.

Table 2.1: Comparison of Construction and Manufacturing Industries

Views	Construction industry		Manufacturing Industry
	Public	Private	
Initiator	*Federal/local Government*	*Individuals/ Corporations*	*Individuals*
Client	*General public*	*Private group*	*General publics*
Planning/Design	*In-house engineer, architect*		*In-house R&D*
Bid/Contracting	*General procurement laws*	*Owner-contractor Settlements*	*Sale price based on Market*
Type of production	*One at a time*		*Mass-production*
Location	*Uncertain field site conditions, subject to adjacent environment*		*In-house factory, Lab*
Supervisor	*Owner, owner's project representative*		*Production line Manager*
Finance	*Auditory agencies*	*Self management*	*Self management*
Scale	*Large*	*Large*	*Small to Large*
Product life time	*Usually Long*	*Usually Long*	*Usually Short*
Defect corrections	*Hard to replace, correction measures, punch list during finishing stage*		*Replace, refund*

2.1.1 The Project Life Cycle

As projects become more complex and demanding for the owners and participants, the risk and potential for losses require better control. Hence the project management has evolved mainly because of the need to control costs and schedule. It is the art and science of directing human and material resources to achieve stated objectives within the constraints of time, budget, and quality and to the satisfaction of everyone involved (Wideman, 1983).

A construction project is a unique, custom-built response to public or private interest. It involves the execution of a large number of diverse activities by many disciplines and develops in both space and time. A construction project can be divided into several sequential stages, which are usually called the project life cycle. This project life cycle consists of the following phases: conceptual and planning, design and engineering, bidding, construction, commissioning and closeout. In practice, there is no distinct line to distinguish the start and end of each stage. Stages can overlap each other, but it is an easier to manage a project one stage at a time. The following sections will define each of these stages or discuss their importance to the construction.

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2.1.2 Conceptual and Planning

The conceptual phase deals with the evaluation of the project, an analysis of whether this project is feasible or not. This preliminary evaluation includes review of technical and economic feasibility, and the analysis of risk, timeframe and budget for the project. The goal is to develop a plan for the project that will satisfy the owner's needs and requirements as well as establish the project's overall objectives.

The planning phase mainly focuses on the selection of plan alternatives. This phase is to generate plan alternatives, which are combinations of policies, facilities and services. It is designed to measure the alternatives by pre-defined criteria, and then lay out the plan alternatives that maximises the benefit and minimises negative impacts. In this stage, the purpose is to identify the responsible parties (e.g. the project team), methods of project financing and expected time to complete the project. This stage also involves part of the conceptual design for the future project plan.

The construction project begins with a thorough investigation of its technical, environmental, and economic feasibility. After the evaluation, the optimal scheme is chosen that is thought to be the most cost-effective and expected to have the best performance to serve public/private interest. Then the project moves into the design and engineering stage, which involves more interactions between different stakeholders.

2.1.3 Design and Engineering

As the project goes more into detail, the potential barriers may be addressed, and the possible solution may be introduced. This is the stage when ongoing design/revision occurs. This stage includes two major operations; to design the plan, and to detail engineering with the plan elements. The design is the extent of the planning efforts, and the engineering is to make sure the plan comes into reality.

In this stage, more information becomes available on cost and schedule as the design effort proceeds. The schedule and milestone reveals the expected date of operation and completion. When cost estimates combine with this schedule information, the project finance plan can be derived. Also, an accurate estimation of the budget, and the bill of quantities can be refined through detailed engineering efforts. In this stage, the designer or developer prepares the necessary construction documents, which include both drawings and specifications that will be used by potential contractor to bid and construct the project. Major building systems, materials, and the construction methods are identified and evaluated for incorporation into project during this stage. A project is divided into several bid packages according to the scope of work and their technical considerations. This is also the preparation stage for the bidding stage, in which the owner picks qualified contractors who will perform a good job. Some quality measures are also developed in this design stage to ensure the overall work meets the standards. After finishing the design/engineering efforts, the project plan is introduced to potential bidders who seek for a possible opportunity to join the project.

2.1.4 Contracting

Contracting is the stage of major procurement for the project. The bid packages are designed and announced to potential bidders who are interested in participating in the project. The procedure, rules and requirements that pertain to the bidding process followed on public or private construction projects are quite different. Each is controlled by different aspect of law. In private bidding, the procedures are normally conducted by rules and regulations established by the owner, with the advice and assistance of the design professionals. In such a situation, the bidding procedures can be modified, changed, or waived at the discretion of the owner. On the other hand, the public bidding procedures are legislated by various procurement statutes. These statutes direct rules and regulations that must be followed by the public owner. But in general, the public authority does not have the right to change or waive these statutory bidding procedures. It is interesting to note that both the public and private construction bidding processes have their own particular rules to protect their own interests.

In this stage, the construction documents, such as drawings and specifications, are ready for review by potential bidders. The bidders evaluate the bid and develop their estimation price for the bidding. Building quantity, equipment, work force, and direct/indirect costs are major part of the cost estimate items. After carefully examining the plan, the bidders submit their bid prices for a competitive bidding. If necessary, a pre-bid meeting or job site visit is held for bidders. This is to ensure the scope and requirement of the project are clearly addressed and understood by both the owner and potential bidders. This understanding is important because most of the construction disputes and change of works occur during the course of construction due to insufficient information given in the bidding stage.

Through the pre-bid meeting and site investigation, more accurate data can be collected for not only for the bidding, but also for the future construction plan.

2.1.5 Construction

After the bidding stage, the qualified contractors are chosen to participate in following stages of the project. The actual construction of the project takes place during the construction stage. This stage is usually the most expensive, intensive, risky and difficult of the project stages. It consists of a number of inter-related activities and the failure of one activity can disrupt the entire production schedule. Unlike the production plans from other industries, the constructions industry has to deal with the natural environment, so civil engineers require a more flexible approach. In this stage, resources are applied in an orderly manner to complete the project on time, within budget, and meet the specified quality. People from different disciplines contribute their experiences on the construction site and the project manager has to consolidate the diverse forces and direct then into the most critical operations to ensure the maximum success of the project.

Construction activities are those activities that involve the erection, installation or construction of any part of the project. These activities are actually carried out on the job site by the contractor, subcontractors, material suppliers, and equipment vendors. This is different than the manufacturing or fabrication of materials and equipment off site, which is also part of the production process. Activities in this stage include job site layout and control, construction of foundations, forming, reinforcing, structures and so forth.

In addition, there are activities that deal with the control of the project, such as project scheduling, progress/cost control, quality control, project meeting, and administration. All these production activities and managerial activities contribute the overall construction activities, and are critical to the success of the project. In that, it lies in a good communication and coordination scheme among multi-disciplines who work together in a body of whole.

2.1.6 Commissioning and Closeout

The commissioning and closeout stage follows the construction stage. During the commissioning phase, systems incorporated into the project are verified and calibrated. The closeout phase is the phase that the owner satisfies and accepts the final project as substantially complete and ready for its inauguration. Phases of construction project offers overlap as in the case of fast track construction or design-build construction where the design and construction stages of the project are carried out simultaneously. As a result of the additional coordination requirements associated with a fast-track project, there is a greater need for a construction plan than in traditional construction approaches where the design stage is substantially complete prior to the start of construction. Thus, the factors to a successful construction also include good communication and coordination. Before we discuss the importance of communication and coordination, we will review several project management issues.

2.1.7 Managing the Construction Processes

Managing a construction project involves commitments from different disciplines throughout its life cycle. From the stage of conceptual planning to the project closeout, different stakeholders stress their issues of management. There are construction management functions that control the project to ensure the quality of work and timely delivery of services within an estimated budget in order to meet the owner's requirements. With each stage of the project, stakeholders' interests, and the managerial issues constitute a complex web of construction management process (Tables 2.2 and 2.3).

Table 2.2: Summary of Life Cycle Management in Constructions (Planning to Contract)

Stage	*Conceptual and Planning*	*Design and Engineering*	*Contracting*
General Management	• Develop plan and strategy • Feasibility studies and report • Site visit • Logistics and misc. preparations • Start up meeting	• General planning, Develop construction plan • Develop project team, WBS • Laying out job site, field office • Applying site utilities • Permit and occupancy • Develop project control system	• Prepare tender document • Contractor survey and selection • Pre-bid meeting • Distribute specs and drawings to qualified bidders
Schedule Control	• Develop objectives and schedule • Develop master schedule • Evaluation of schedule	• Monitor design schedule • Scheduling and milestones • Schedule for bid packages	• Evaluation of construction schedule for bid packages
Budget Control	• Pre-estimate • Cash flow analysis • Budgeting/ Accounting	• Define scope for bid packages • Detail cost analysis • Value engineering (VE)	• Cost and alternative analysis • Design budget estimate and payment method

Quality Control	• Examine drawing and specifications • Layout design criteria and material standards	• Examine specs, drawings, and design criteria • Develop quality manual • Quality control and assurance	• Evaluation of technical proposal for qualified bidders
Safety Issues	• Risk analysis	• Fire protection Plan • Site sanitary and equipment layout • Develop safety manual • Develop project safety plan	• Evaluation of safety plan
Material/Contract Management	• Work force/resource Planning • Public relations	• Develop procurement and contracting strategy • Material selection and replacement	• Develop contract general/special provisions • Tendering, sign contract • Early procurement of long-lead items • Contract administration

Table 2.3: Summary of Life Cycle Management in Constructions (Construction to Commissioning)

Stage	*Construction*	*Commissioning and Close Out*
General Management	• Preconstruction conference • Traffic Control • Project Administration and documentation • Change order procedure and lines of responsibility • Project meeting, conflict resolutions, project reports • Union Relationship	• Monitoring performance and data collection • Final completion • Final drawing and specs. • Utilities permissions
Schedule Control	• Progress/Cost control plan • Monthly/biweekly schedule • Project progress meeting • Project progress report	• Develop rehabilitation, replacement, expansion plan • Time table for final correction • Propose turn over schedule • Examine final progress and duration
Budget Control	• Progress payment control and difference analysis • Budget estimation and allocation • Cost analysis • VE reports • Project financial statement	• Evaluate service and business plan • Account close out • Final progress payment • Late fee and charge

Quality Control	• Examine drawing, specs • Material testing/inspection • Site inspection • Job quality control, anomaly report, and corrections • Quality bulletin • Punch List	• Punch List • Draft for operation and maintenance manual • Licensing and certifications • Quality assurance • Operator's training
Safety Issues	• Organise safety plan and team • Routine safety exam and insurance • Job safety meeting • Safety bulletin • Project insurance	• Accident report and prevention
Material/Contract Management	• Notice of completion • Change of contract, fee and charge • Contract implementation reports • Inventory Control • Contractor evaluation	• Release of retainage and withholding • Finish commissioning

In constructions, there are manpower, machines/equipment, materials, methods and money dedicated to the production process. The effective construction management relies on dozens of managerial functions, such as schedule, budget, quality, resources, and safety issues. The purpose of these management functions is to profile the complex variables (i.e. manpower, machine/equipment, material, etc.) and output with a schematic methodology to keep the construction processes on track in every stage of project life cycle. Here we discuss these major management functions as follows:

2.1.7.1 Schedule Control

To define the timeline of a project and direct the resources to pour in the production process is the essence of project scheduling. The schedule can be a preliminary schedule in the planning/design stage or the detailed schedule in the construction stage. The format of the schedule report can be accomplished by a variety of methods ranging from a simple bar chart to a sophisticated network schedule. Usually the planning of project schedule is subject to factors of weather, local construction practices, construction methods, and resource availability. Two important procedures in the development of project schedule are identifying the activities and estimating the activity durations. Identification of project activities requires reviews of the project plan, drawings, specifications, and other considerations, such as general requirements and special conditions. The estimation of activity duration is then based on the resource availability to reflect the resource productivity on expected job site conditions.

After the project schedule is developed, this scheduled plan in executed and constantly reviewed by the project team with comparisons to the real project progress to make necessary changes. These monitoring efforts along with the implementation are the keys to the successful management of project schedule.

2.1.7.2 Budget Control

Budget control is another issue in the construction management. Cost overrun is an unfavorable situation just like a project delay. Construction costs break down into different categories, such as labor, material, equipment, and administrations. In fact, the budget plan is closely related to the schedule plan. Along with quantity estimates, the hourly rate is often used as basis to calculate the cost items. Thus, a schedule plan can reveal the potential cost information in the project life cycle. The “S” curve method is frequently used to depict the relation of project schedule and cost. In the “S” curve, one can see whether the project is ahead of the schedule or behind the schedule, and the anticipated expenditure for the project. Once having the project schedule information, it is easy for the owner to develop the project financing schemes.

The cost control and schedule control need constant monitoring of project cash flow against work plan. Whether they are short-term plan, long-term plan, day-to-day, or monthly basis, the basic cost control methodology is analogous to that of schedule control. The only difference is that the cost in business is considered a risk management. If it is unfavorable, none of the party will take the job, since in business, most of the investors are risk-averse.

2.1.7.3 Quality

In every industry, during the past decades, quality is becoming more important. Unlike the mass-production age, the consumers nowadays demand more in goods they purchase. The quality is the way to please customers and the credit of a company to succeed in business. In the past, the quality control focused on the statistical method. It was not until W. E. Deming in the early 1950s, stressed the importance of quality management and established the modern philosophy of quality control. Since then, many industries followed, and the quality issues are considered their strategic opportunity and strength to develop their business plan.

This trend spread into the construction industry. The International Standard Organisation stipulated the ISO 9000s of quality management for the construction industry were soon wide practiced around the world. All these trends indicate that focusing on quality issue will be the key to survive in the future construction industry.

The quality control in construction projects contains three parts: the site control/inspection, the lab control/inspection, and office documentation. It is known as Total Quality Management (TQM) issue. Any one of them should be related and can be traced from one to another. For example, one can find out the concrete strength in the third floor of a commercial building from the site inspection report, lab test data, or the construction document. All of them should be with consistent each other, and all them should meet the building plan, which is thought to be a good quality control and management.

2.1.7.4 Resource Management

Like the cost control, the resource management also works with the schedule plan. The resources here include manpower, materials, machines, methods and money, which are referred to as *5Ms* in construction practices. These resources are used throughout the project life cycle. To manage these resources is an art that requires both knowledge and experience. Along with traditional production planning for resource allocation, communication skill is very important in coordination among multi-disciplines. In modern construction, this communication feature is addressed by the use of computers. We will discuss this issue in the following chapters.

The resource planning and management are vital to the overall construction production process, since any poor resource management can cause serious disruption during the course of the project life cycle, such as cost overrun, project delay or even poor quality product.

2.1.7.5 Safety

Safety is the number one issue in the construction activity. There are many construction accidents every year. To minimise accidents, the safety plan should be enforced in the job site. On the other hand, educating and training for personnel to conduct the right procedure in their works can not only benefit the quality of work but also reduces the unexpected accident.

In addition, the contract management is becoming more important as the projects are becoming complicated and large. More professional disciplines are involved in a single project, and thus, the coordination of work is heavily relies on the clear definition of contract document. In general, a construction contract, though formats are varied, unusually includes definitions of terms, scopes of works, changes of works, responsibilities, certificates and payment, dispute settlement, and contract termination. Without these clear defined obligations, there are often claims and disputes among architect/engineer/construction parties, and the cosy environment of cooperation is destructed, not to mention any future business partnership. To ensure a successful project execution and the future business partnership, it is suggested that all anticipated tasks in each phase of project should be listed in contract document and reviewed by the owner.

Other management issues, such as construction risk, sanitary, document, and information management are also very important. Especially in the information management, people nowadays are trying to use computers to replace part of human activities, such as accounting, CAD drawing, scheduling, and cost estimation. This trend is growing, and the wide deployment of computers in the workplace is the strategic opportunity that will change the ways of construction business practices.

2.1.7.6 Project Communication

As mentioned before, due to the nature of the construction industry, one can conclude that the construction business is extremely information intensive. In the construction site, the most common types of communication used by architect/engineer/construction firms, sub-contractors and the owner are telephones, fax machines, beepers, cellular phones, walkie-talkie radios, and voice display pagers. For a larger project, these devices may also include personal or laptop computers as the tools for construction administration and sending/receiving of e-mail or files. Although participants may share a common goal of completing a particular project, their actual participation is restricted by their organisational objectives. Views of the project may be quite different among different disciplines. The coordination is required through the integration of project information, and communication among different disciplines. And the collaboration is needed to share visions among different parties and maximise team efforts on a particular job.

In recent years, there are several studies in the application of IT that use computers as media for information exchange as well as coordination. Other industries have been very successful in taking advantage of these innovative technologies. In the construction industry, companies are still seeking their best IT solutions. In the following chapters, we will review IT in current construction industry and other industries. We will also review the latest business innovations and philosophies that are due to the technological advancement. To deduce how these change the world and the way we conduct business today. Because it appears that the information and communication are very important to construction industry, the wide use of computer and standardisation are sure continue to dominate this industry's competitiveness and growth.

2.2 INFORMATION TECHNOLOGY CHALLENGES IN THE CONSULTING INDUSTRY

As mentioned before, unlike other industries, a construction project occurs on- site and the construction activities represent a collective effort from specialists who belong to various disciplines. These specialists make autonomous design/construct decisions with respect to their own discipline. Lack of clear definition of roles in the project team and cross-discipline coordination/collaboration in the production process will result in incompatibility errors. These errors are considered risks that discovered during the course of construction phase and generate change orders, construction disputes, cost overruns, time delays, compromise to quality, frustration, and stakeholder dissatisfaction. This potential is heightened when parties that work together have different philosophies regarding the implementation of the project. Engineering and construction personnel simply "speak" different languages (Cleveland, 1994). Views of the project may be quite different among different disciplines. Although participants may share a common goal of completing a particular project, their actual participation is restricted by their organisational objectives.

In construction administration, most of the project information is in paper format and is sometimes circulated around to different parties. This might cause two potential problems: (1) the circulation of the documents among different parties will cause time lags in each party. Fresh information is very difficult to identify if the authorities issuing the documents are not clearly defined in a project team. This will create ambiguities in the middle of project participants who have problems in catching the latest scope and definition of a work. A conflict might occur if parties follow different versions of documents. In this situation, it is not the issue of who is wrong, but that work will be postponed due to the dispute. (2) The circulation of documents might cause inconvenience for personnel in the field office who are at the first line of construction; for example, the field superintendent who has to process piles of documents, such as report and forms, while monitoring the job site. The role of superintendent is supposed to be that of a supervisors who finds the facts about the implementation of a project, instead of a person spending much of his/her valuable time dealing with paper work. It is necessary to rely on the superintendent's expertise to coordinate and monitor the work being carried out by different disciplines in order to ensure the quality of the works.

2.2.1 The Barrier of Technology Assimilation

In recent years, low productivity in the construction industry has increased the cost of building facilities and increased project risks; consequently, the 5% marginal profit is considered low in conducting business in Malaysia. Fragmentation in the construction industry is perceived as one of the major contributors to the reduction of productivity (Meyer et al., 1991). This is partly because the practices and organisational structures of the architect/engineer/construction firms have changed very little over the past few decades. These firms have more conservative attitudes toward technological innovation than firms in other industries as tight budgets restrict funding for R&D programmes. Unlike the manufacturing industry, organisations with less diversity of personnel have the advantage of setting their goals, channeling their communication and integrating their resources to cope with the changing business environment quickly. Especially with the introduction of the microcomputer in the early 1980's, this stimulated revolutionary change in the work environment and initiated evolutionary change in the communication channels used in businesses. The applications of IT in the manufacturing industry improve the manufacturing process, which not only improves the quality of the products but also shortens the time it takes to launch new products into the market. In this case, communication channels are well configured such that members of project teams can actively participate in the design/production of a new product and produce an optimal product by solving problems before they emerge.

However, there is still chance to *"re-engineer"* our industry. A recent research on assimilating information technology innovation in the construction industry by Agarwal who pointed that if a technology is perceived to be *product based*, then the assimilation should focus on influencing an individual's perceptions towards the use of that technology (Agarwal et al., 1997). When an IT innovation is viewed as *process based,* then the focus will shift to convincing all groups of individuals whose task is affected by the technology adopt it. This research aims to provide valuable information for prospective IT developer an entry point to improve the construction industry.

2.2.2 The Islands of Automation

Strictly speaking, the applications of information technology do not produce significant improvements in the performance of construction projects. The construction industry is often criticised for acting slowly in the adoption of IT. However, with the consideration of complex situations in conducting a construction project, there is one important factor responsible for this slow rate of technology assimilation.

Due to the nature of construction practices, the integration of project information, most of today's building information resides in isolated databases contained in hundreds of incompatible software applications from different vendors (Anderson, 1991). The problems of "isolated databases" and "hundreds of incompatible software" are due to computer literature staffs in some firms, which may lack the engineering experience, technical background, and common sense to decide the most appropriate use of a particular programme package. Conversely, engineers with years of experience in the construction industry may not have comprehensive computer-related knowledge to support them to choose the right IT system and configuration to perform their tasks. Besides, unlike other business software, there is not much construction specific software available in the market. These limitations negate the efforts of the firms in developing a universal configuration of IT systems. The result is that the firms have difficulties reaching out to each other to share project information, and the fragmentation problem is further aggravated by a lack of cooperation and coordination among the architech/engineer/ construction parties. This situation was noted as "islands of automation," where organisations are highly integrated inside but loosely connected to the outside environment (Hannus, 1998).

2.2.3 Organisational Culture

It is known that one of the main benefits of IT is its capability to greatly improve the efficiency and quality of communication between several parties. As mentioned before, a construction project needs intensive participation and communication among different disciplines in the project life cycle. Another factor that affects the effective communication is the fear of giving away proprietary knowledge; each party has been doing its job with little contact and little concurrent information is exchanged with the rest of the project team (Bjornsson, 1991). It is believed that the only way the industry will successfully exploit advanced forms of IT and reach its goal of a computer-integrated communication is if a more cooperative atmosphere exits between the different parties involved (Fenves et al., 1990; Teicholz and Fischer, 1993).

The human attitude toward IT is another factor, which influences the successful application of IT. Because of the changing nature of IT, successful applications require continuous learning and adoption by users. In the construction industry, many people still hesitate to use computers and work with computer specialists, and, if they like computers, want to do their work the same way they have done it. Indeed, corporate culture can have a significant impact on a firm's long-term performance (Kotter and Heskett, 1992). As the construction industry slowly incorporates IT, some of these people may see IT as a threat to job quality and security (Agai, 1988; Liker et al., 1992). Also, some architect/engineer/construction firms cannot see the potential benefits that IT can offer and thus do not experiment with it. However, considering the consequential and liquidated damages if a project fails to meet its goal, we can not blindly blame these firms for not experimenting with the application of IT, since the potential problems are just too complicated to experiment.

2.2.4 The Information Overflow

The benefit of technological innovations relating to the IT have provided richer information than ever before in conducting construction projects. However, people of different parties do not necessarily need all the project information. For example, a client should not expect to see the contractor's detailed cost information on a lump-sum project. It is also quite often that the content, structure, and scope of the data produced by the design process are incompatible with how construction people view a project, such that people who work on the construction site are still limited to paper work and mainly conduct face-to-face communication. Construction project information necessary consists of information in various forms including graphical and non-graphical information) which must be communicated unambiguously between members of the project team. This means that paper-based communication of project information is inadequate to cope with the high level of functionality (in terms of speed, accuracy, usability, ease of modification, enhanced visualisation, improved coordination, etc.) required in a collaborative design environment.

It is important to know about the transfer of information between organisations as well as job sites and how construction teams use the information. In addition, these innovated information technologies must be configured to support people of different disciplines working together without conflict. The main goal is to identify what kind of information and communication channels are best for a project management. All these issues need to be further explored in order to find out the best solution.

2.2.5 The Integration of Construction Information

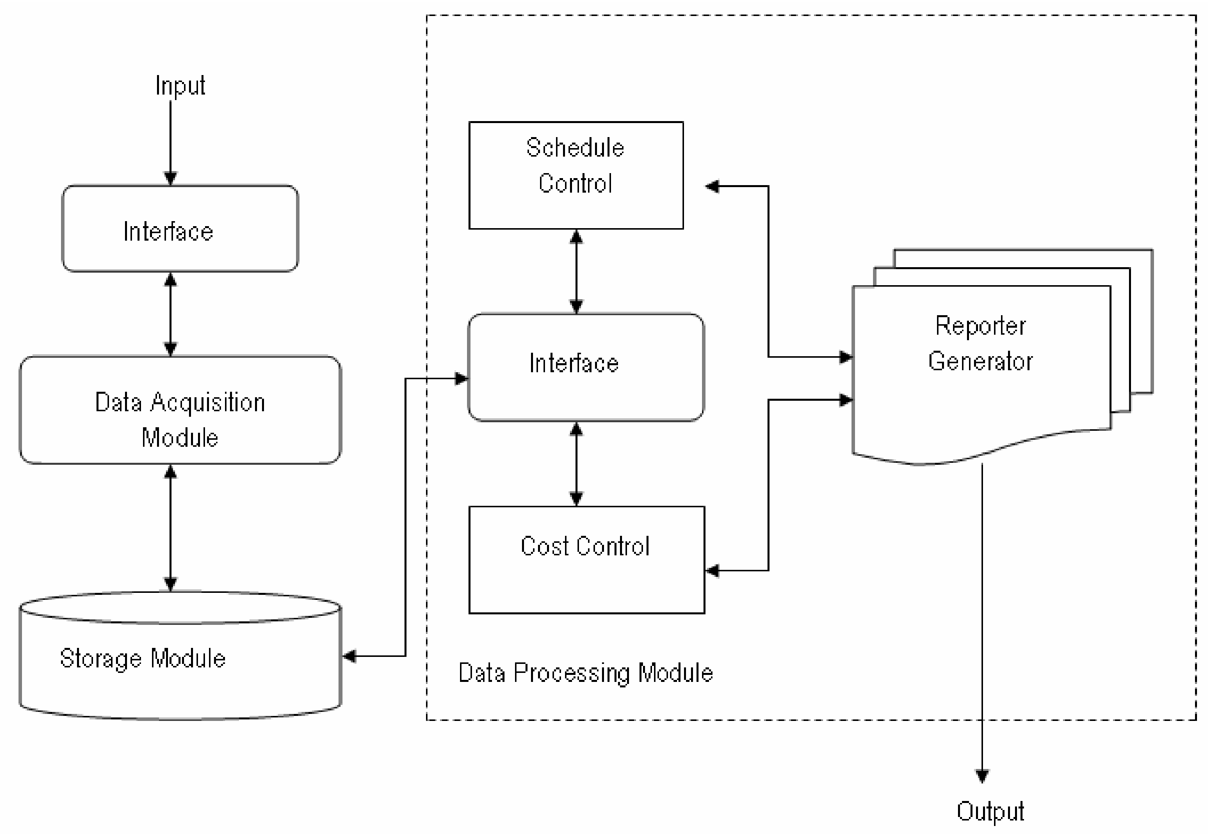
Integration of design and construction has not really changed much: project partners share goals, knowledge, and information in the same way as before. Computer applications still produce traditional documents, such as specification documents, detailed drawings, and bar charts. Humans have to interpret these documents, whether paper or electronic, before the next application can use them. Under these circumstances, it is clear that existing methods of communication are no longer adequate to support collaborative project development. Paper-based communication of design-construction information and face-to-face meetings are inefficient and expensive in terms of time, money and personal inconvenience (Anumba and Evbuomwan, 1997).

There are moves towards integration and more collaborative working in the construction industry, with a view to reducing fragmentation, reducing cost and lead times, improving quality, and achieving greater client satisfaction. An issue regarding the integration of IT in the construction industry primarily focused on the integration of construction cost and scheduling systems since it is the key to improving the quality, efficiency and duration of a project. An early study by Abudayyeh and Rasdorf discusses the use of an automated information management system that integrates cost and scheduling functions on one side while acquiring, storing, and presenting quality data and information in a timely manner on the other, using the work packaging model as an integrated model recommended by Abudayyeh and Rasdorf (1990) as shown in Figure 2.1. In this model, the data is gathered by an automated data acquisition system (bar coding system), and then this automated data acquisition and data storage is combined with the integrated cost and scheduling control concept represented by the work packaging model to provide an automation solution.

Yau has another approach to integrating the scheduling and cost estimation functions within an object-oriented environment (Yau et al. 1991). The object-oriented techniques that originate from structured programming language (such as C), are now widely used for the purpose of integrating construction information because it is excellent at managing complexity with a flexible and efficient way for the design of construction specific IT.

The fundamental feature of the object-oriented approach is that an object conceptually includes both data about itself and the software that controls its behaviour. This is different from the traditional software approach where we view software and data as independent of one another. With the object-oriented techniques, an advanced construction management information system was introduced by Jaafari and Wong who target the establishment of a general database linking to different variety of functions such as time management, cost management and risk management under the Windows platform (Jaafari and Wong, 1994). By now, the object-oriented techniques have increasingly brought advantages to the construction industry to use low-cost microcomputers to perform sophisticated construction managerial functions and to make the portable programmes possible. There are also many studies and third party products target on the integration of the diverse managerial functions, including engineering, contract administration, quality management, accounting and commercial transaction, and reporting on major projects across multi-disciplines entities. However, no there is still no significant and plausible solution due to the complexity of the end result and the inflexibility of the method used by diverse groups of professionals on different projects.

Figure 2.1: Integrated Cost and Schedule Model

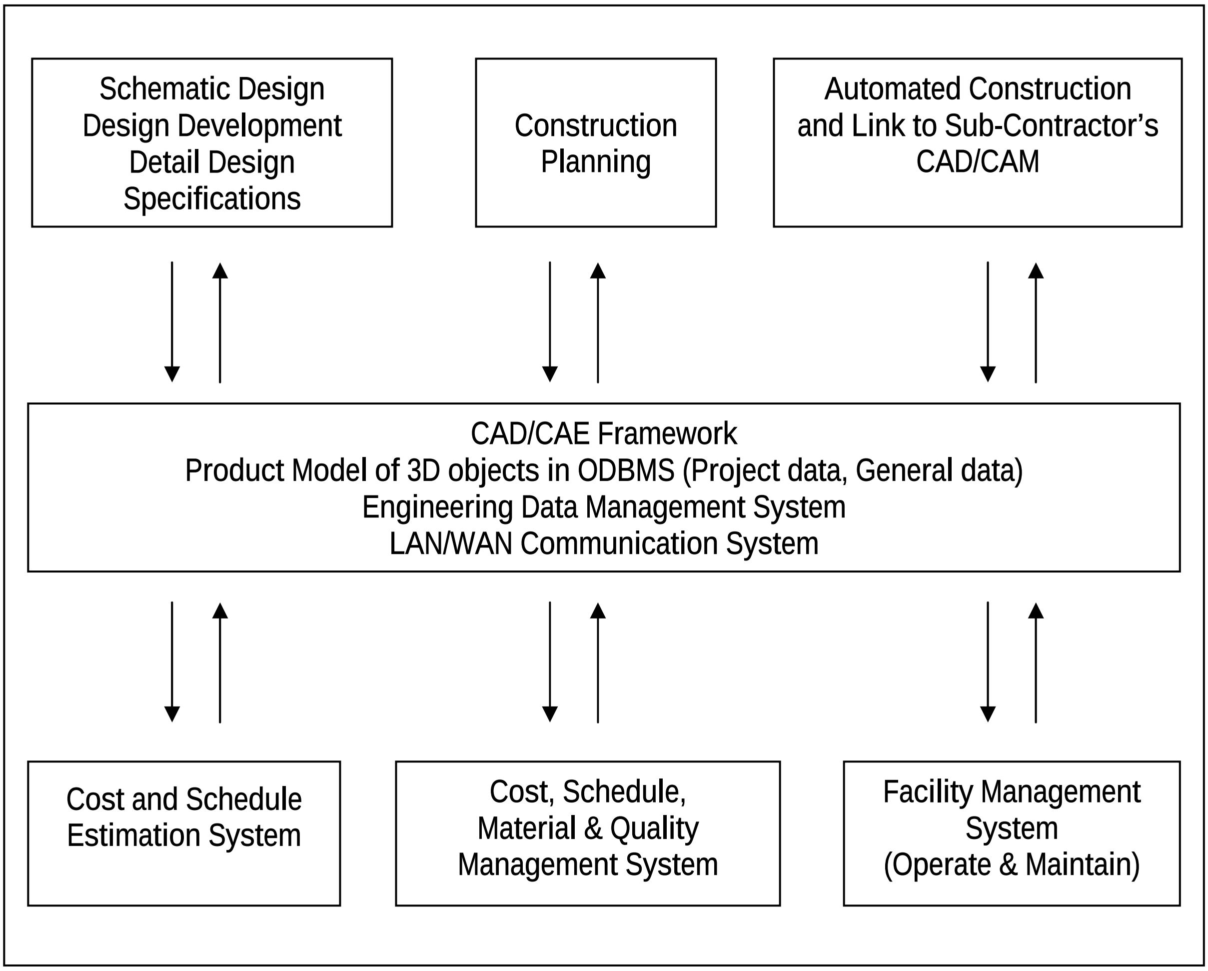


2.2.6 The Computer Integrated Construction

A further step of the integration of IT in the construction industry is the movement of computer integrated construction (CIC). The CIC has recently evolved to maximise the integrated utilisation of information systems throughout the project life cycle and across different business functions (Youngsoo and Gibson, 1999). Therefore, the concept of CIC is a strategic approach that incorporates computers and robotics for linking existing technology and people in order to optimise the business process. It spans the business function along the course of project cycle while maintain corporate strategy, management, and IT internality.

Teicholz and Fischer (1993) proposed the use of a shared object-oriented project as the basis for integration. Networking technology then provides the communication links between project participants and individual application. They propose an overview of the CIC framework on how CIC supports various engineering processes through the use of several technologies (refer Figure 2.2). Under this structure, the engineering data management system integrates the entire process database and the general engineering database.

Figure 2.2: Computer-Integrated Construction Technological Framework



Each member of the project team contributes information to the database, i.e., equipment vendors supply a 3D model and data relevant for their portions of design, materials vendors communicate electronically with the contractors using electronic data interchange (EDI) standard for procurement documents (Harmon, 1992). Another paper discussed the practice of CIC was from

Miyatake and Kangari (1993) who introduced current practice of CIC in Japan. In this paper, the CIC model has one central database and three major systems connecting to it. The three major systems are categorised as the Integrated Design/Construction Planning System, the Factory Automation System, and the Site Automation System. Each system consists of several sub-systems handling particular functions, such as construction planning, working drawing, engineering, schedule and cost control, permanent automated factory, and automatic construction with SMART (Shimizu Manufacturing System by Advanced Robotics Technology).

With the common link to the central database, members of the project team can share information and communicate with other parties. This is a far more advanced prototype. The relevant computer-based technologies support the CIC including: object oriented programming (OOP), knowledge base system (KBS), database management system (DBMS), computer aided drawing/design (CAD), and visual computing, robotics and automated system, computer aided engineering, and local area networking (LAN). In the implementation of communication technology, the transfer of information from one person to other person or computer plays an important role and that is the backbone of CIC implementation.

2.2.7 Other Information Technology Related Applications

As a new medium of communication, the Internet has conquered the world with breathtaking speed, and its worldwide penetration and high level of standardisation contributes to increasing globalisation. Internet technology is presently changing communications to the same degree that PC technology reshaped the computing world twenty years ago. Today, the Internet is thought to be one of the most valuable business opportunities because it often relates to the organisational competitive advantages. Its platform-independent advantage makes it possible to deliver business data and streamlining the business processes across heterogeneous business partners in a flash of second.

Today, the e-business is rapidly expanding into a complex web of commercial activities transacted on a global scale between an ever-increasing number of participants, corporate and individual, known and unknown, on global open networks. With this awareness, there were many studies regarding to the potential usages of Internet technology in the construction practices. One could be optimum to say that the Internet is suitable for the nature constraints of construction practices. The project team needs this kind of technology as a tool to virtually stay together and work on projects collaboratively. Rojas (1997) proposed a web-centric system that facilitates collaborative engineering and combines traditional software development. Whitten and his colleagues used client/server computing architecture and notebook computers to support the capture, storage, and distribution of raw data as well as the production of on-line reports. All of the systems are PC-based which are designed as budget-saving solutions to an organisation (Whitten et al., 1994).

In the past, the client/server scheme was dedicated to mainframe system that forced users to stick with inflexibility proprietary system. Today the focus has shifted form proprietary system to disparate distributed computing system. The client/server computing architecture is the central role of web development. Many developers are trying to take the full advantages of the web-client/server scheme. A study conducted by Han and others who used an integrated web-based client/server architecture and hypertext scheme to develop an automated building code-checking system. This system has a built-in code-checker that resides on a remote server, which examines the IFC (where the Industry Foundation Classes (IFC 1997) is a kind of standard product model) design data and summarises the results in a generated web page. The web page contains a graphical representation of the building model along with “redline” information with hyperlinks to specific comments. When applicable, these comments have hyperlinks to the actual building code document provisions (Han et al., 1998). Nowadays, there are many web-based construction management applications. Among them, the Constructw@re is the leading construction information portal (integrated web site), which is developed by Application Service Provider (ASP) for the construction industry, providing Internet-based project management, collaboration and e-commerce solutions. It is currently being used over 200 firms to actively manage more than $10 billion worth of projects across the U.S, including over 60 of the ENR Top 400 contractors. It is believe that this type of integrated web solution will prevail, and there will be growing numbers of construction companies that will switch from their traditional business practices to embrace this technological innovation.

For the client/server architecture, at present, developers are working on two types of client/server scheme, i.e. the thin-client and thick-client. In the thin-client scheme, the end users’ systems are simple, and typically use a browser (with several plug-in functionalities) to view the business information, or submit forms and reports to the server for server-side processing. The server takes most of the workloads from the client machines and then sends the results back to users. When in the thick-client scheme, the end users’ hardware and software systems should meet the basic requirements laid by the server in order to receive information distributed from the server. The client machines carry out most of the processing and interact with server to get the job done. It is hard to judge which scheme is better because it depends on the strategies of how client-server interact and goals of heterogeneous parties.

In addition to the web applications, there are other IT related applications in the construction industry. For example, the application of bar code technique in the construction industry is a growing trend for data gathering. Bar codes provide the advantage of faster and accurate data entry. Bell and McCullouch (1988) have proposed the application of bar codes in material takeoff, field material control, warehouse inventor, tool and consumable material issue, timekeeping and cost engineering, purchasing and accounting, scheduling, documentation control, and office operations. Additionally as mentioned before, Abudayyeh and Rasdorf (1990) proposed a design for an automated solution to construction information management system that incorporates the use of bar codes. It can be predicted that the bar code technique will be widely practiced in the construction industry in resource management and documentation control just like other industries.

The application of Pen-Based and Notebook computers on the construction site is another trend for the construction industry, especially the pen-based computer. McCullouch and Gunn (1993) discuss various pen-based systems and their applications on the construction site. The Pen-Based computer is suitable for the blue-collar construction field user because it is more portable than the Notebook, and the data entry is performed by printing on the screen with a pen tapping on user designed check-off boxes or calling scrolling lists on the screen and then tapping the correct entries to select them. It is faster and more accurate to pick items off screen lists with pen taps than for the users to remember and enter. The future development of pen-based computer will target the enhancement of its functionality, upgrade ability and better communication with any notebook or desktop computer.

The concepts and practices of IT in construction have become more and more mature during the past few years. And there are many third party products and services that available in the market to support some aspect of construction management processes.

Based on the information technology reviews in this chapter, one can find that there are still opportunities and additional efforts to the development of information technology system for the construction practices: (1) It is evident that there are fragmented technology solutions being implemented. Although there are many information technologies available to various stages of construction management processes, the implementations are not sufficient integrated to provide a comprehensive multi-enterprise solution. Little progress has made to improve the communications of people working on the construction site as well as inter-enterprises business processes. Multi-enterprises' inter-enterprise processes solutions are only beginning to be explored. (2) There is a tendency for the construction operation to develop a "satellite systems" (Burger, 1998). The satellite system is similar to the present supply chain philosophy that transforms the construction partnership into a strategic alliance. In the supply chain practices, the network connectivity enables the supply chain partners to work together almost as if they were one company. Soon, the supply chains, rather than enterprises (architect, engineer, construction contractor, manufacturer, and supplier), will compete with each other in near the future. There will be no isolated islands of automation, and the future of business applications will enable a dynamic "virtual construction team" to fulfil many mission-critical business processes throughout a project life cycle.

Issues regarding to the supply chain integration and the selection of e-supply chain partners extend beyond choosing a trading partner or a contractor and must include configuring the business-to-business collaboration among the partners. We will discuss these in a later chapter. But before we move forward to explore the role of information technology in the construction practices, we will first review what other industries improve their business practices in this information age. The purpose is to learn lessons from other industries and adopt them to improve our construction practices.

2.3 CONSTRUCTION INDUSTRY INSTITUTE (CII)

CII is a research organisation that was formed in October 1983 with the mission of improving the competitiveness of the construction industry (CII, 2001). As a unique consortium of owners, contractors, and academia, CII has produced many research products to help its member organisations find better ways of planning and executing capital facility projects. Member organisations staff CII research teams to provide guidance for specific research activities which are conducted in conjunction with different universities. In order to facilitate effective implementation of CII products and to overcome implementation barriers, a standing committee in late 1995 to address this core value through the development of an 'Implementation Model' to assist organisations wishing to implement CII products. The CII Implementation model contains a foundation and nine recommendations for an organisation to pursue in implementing best practices. Furthermore, the CII Knowledge Structure has recently been developed to organise CII knowledge and products. By using the CII Knowledge Structure, organisations can easily find the right products according to their needs. It also provides an official list of CII Best Practices and a process of screening CII Best Practices. The CII Implementation Model along with the CII Knowledge Structure served as a basis for the development of the survey for this study.

2.3.1 CII Implementation Model

The CII implementation strategy supports comprehensive, effective use of proven CII products by member organisations and the industry in general. Implementation of CII Best Practices is driven by the member organisations and supported by CII. Upon joining CII, each member organisation makes a strong commitment to improve its business performance through the adaptive use of CII products. It is recommended that all CII member organisations use the model to craft their implementation efforts (Gibson and Kim, 2002). To help member companies effectively implement CII products, including best practices, the CII has developed an Implementation Model that specifies the steps of implementing a CII product as illustrated in Figure 2.3.

Figure 2.3: CII Implementation Model

These steps follow the traditional plan-do-check-act continuous improvement model. The foundation and nine building blocks of the implementation model are as follows (CII, 1998a):

1. *A Foundation of CII Products, Support, and Benchmarking and Metrics Data.* CII products include implementation resources, research summaries and educational materials that can be used to assist individuals and organisations in process improvements. The products, those that are including CII Best Practices, are discussed in more detail in the next section. CII also provides support programs such as staff assistance, the experienced user program, and periodic Implementation Champion Workshops to facilitate implementation within and across CII member organisations. The CII BM&M program provides project performance and practice use metrics to

assist organisations in understanding improvement opportunities and the benefits that result from the use of CII practices.

2. *Corporate Commitment.* Any effective corporate implementation effort must begin with a clear and strong management commitment to improve. This commitment may include: (1) a statement from the leadership that clearly informs employees what the company expects relative to implementation of CII Products; (2) Directives to implement specific CII Products into existing processes, procedures and practices within the company; and (3) evaluation of efforts to accomplish or support the implementation of CII Best Practices by incorporating these goals into employee performance reviews with specific usage targets and by using of the Implementation Model as a guide.

3. *Corporate Implementation Champion (IC).* A corporate implementation champion is selected by the leadership, and is provided support and resources to guide and direct implementation of CII products to maximise corporate benefits. Essential duties of the IC include: (1) providing the leadership to identify the greatest corporate improvement needs and the resources to achieve maximum benefits through implementation of CII Best Practices; (2) facilitating communication of implementation benefits, successes, and opportunities; (3) spreading knowledge by enhancing the awareness and availability of CII Best Practices within the organisation; and (4) accomplishing objective measurement of the results of using CII Best Practices.

4. *Self Audit.* Self audits should be performed periodically with the corporate leadership to determine the practices that are done well and those that are done poorly in order to identify opportunities for improvement. Self-audit includes: (1) determine which CII Products have been implemented and the degree to which each has been implemented; and (2) use tools to make the self-auditing process efficient and consistent. (e.g., CII IR 166-3, Implementation of CII Best Practices – Summaries and a Self-Assessment Toolkit).

5. *Implementation Plan & Goals.* In order to implement CII products effectively, an implementation plan should be developed and target goals set to measure success. The plan and goals should: (1) be based on corporate vision, identifying specific corporate goals for the use of CII Best Practices; (2) select strategies and formulate specific implementation steps; and (3) focus on integrating CII Best Practices into company processes, procedures and culture.

6. *Review Boards/Product Champions.* In order to determine which practices and products to adopt, an internal review board facilitates corporate review of CII and other practices. Based on an understanding of the organisation, its goals and culture, the board makes recommendations for adoption of selected practices. Product champions are then assigned to facilitate the implementation of the specific product. The Review Board determines which CII Best Practices (or other practices) are applicable to their company and recommends specific CII Best Practices for application within the company's business process for capital development projects. The Product Champion is selected early in the review process to facilitate the understanding of a CII Best Practice and frequently serves as the overall manager of the implementation process for the selected CII Best Practice.

7. *Product(s) Training.* Effective implementation must be accompanied by training developed specifically for the practice to be implemented. This training should: (1) provide knowledge necessary for successful implementation, including information on company specific processes and practices; (2) include all key stakeholders of the project team(s) selected to implement the Best Practice; (3) use CII resources available to support training; and (4) be adequately resourced to achieve the implementation goal.

8. *Product Implementation.* Next, the product/practice must be implemented. It is recommended that this occur on a pilot application basis on one or more projects with a good mechanism for measurement. Recommendations include: (1) select CII Best Practices for implementation based on potential for improvement in your organisation or project; (2) identify possible barriers and plan the necessary enablers to counter any barriers; and (3) provide leadership, communication, resources and support to make sure that the effort is a fair test of the product or practice.

9. *Measure Results.* As in the case of implementation of any new tool, technique, or product, results must be measured to make sure that the effort is worthwhile. Suggestions include: (1) use the same techniques that were used during the self audit; (2) measure both utilisation of Best Practices and impact of use; (3) participate in surveys conducted by CII Benchmarking Metrics Committee or others – the results will give comparison of its organisational efforts with those of other member organisations.

10. *Celebrate Success.* To effectively integrate the practices into the corporate culture and to inculcate a culture of implementation, celebration of success is an effective tool.

Recommendations include: (1) recognise and publicise successes in the implementation process in order to reinforce the usefulness of the process; and (2) use media such as newsletters, intranet sites, team meetings, and organisational process documentation to get the word out.

Systematically applying these building blocks and using the solid foundation of support that CII provides will improve the organisational implementation efforts. The next section will outline CII products under the CII Knowledge Structure that can provide an excellent starting point to organisations for their implementation efforts. It should be noted that the Knowledge Structure was used extremely in performing this research investigation and thus it is presented in detail in this report.

2.3.2 CII Knowledge Structure

CII has conducted much valuable research since its initiation in 1983. In spite of the tremendous potential of many of its findings, implementation of CII products has been somewhat disappointing. Barriers exist, and CII has worked to identify barriers that inhibit innovation and change and contribute to slow industry progress (CII, 1995). In spite of on-going efforts to improve implementation of CII products, many CII member organisations are still struggling to apply CII products on real world projects. It is especially hard for a new member company to identify appropriate ‘Best Practices’ from CII and guidelines on how to implement them. In addition, many have defined CII Best Practices in different ways even among CII member organisations. Until recently, there was no ‘official’ list of CII Best Practices. Thus, the need for a process to identify CII Best Practices was recently identified as a key development objective by the CII.

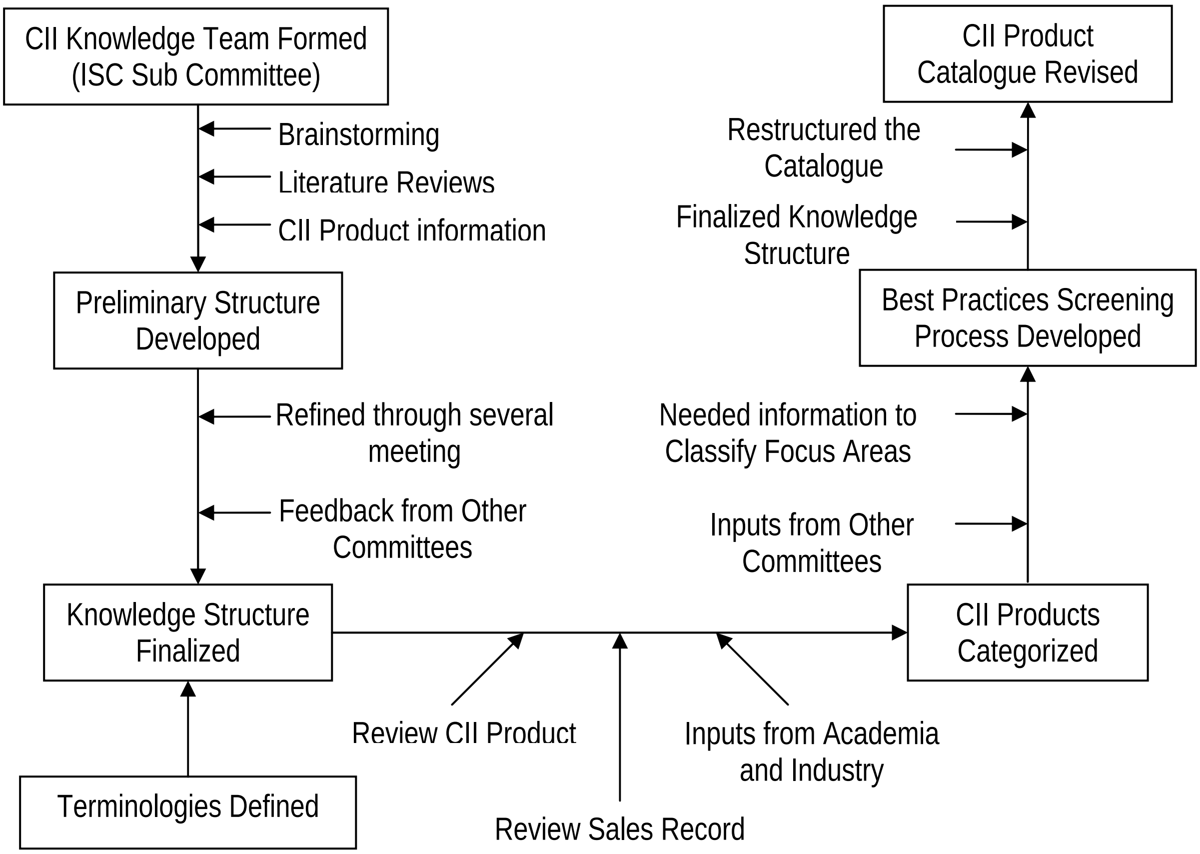
To resolve this problem and increase the level of implementation of CII products, the CII suggested the need for developing a well-organised structure of CII knowledge. As a result, the CII Knowledge Structure was developed in order to support increased implementation. All products developed by CII are included in this knowledge structure including research documents, videos, education modules, and benchmarking reports.

2.3.2.1 CII Knowledge Structure Development Process

In 1998, the CII identified the need to categorise CII studies and products in order to facilitate understanding and the selection of individual practices for implementation. A sub-committee named CII Knowledge Team was formed with representation from CII standing committees and the CII Knowledge

Structure was born through a series of meetings in 1998 and 1999. As interest in the CII Knowledge Structure grew, adding more team members from industry, academia, and CII committees, as well as CII staff enriched the Knowledge Team. The CII Knowledge Structure is the overall body of CII knowledge arranged in topological form (CII, 1998b). It provides an easy mechanism for finding and using CII products. The development process of the Knowledge Structure is shown visually in Figure 2.4.

Figure 2.4: CII Knowledge Structure Development Process



As one of the first steps in the development effort, the team looked at existing literature related to the knowledge structure. The Project Management Body of Knowledge (PMBOK) developed by Project Management Institute (PMI) was one of the first documents reviewed since it contains a knowledge structure which organises project management related knowledge. PMBOK is defined as "the sum of knowledge within the profession of project management, which includes knowledge of proven traditional practices that are widely applied, as well as knowledge of innovative and advanced practices that have seen more limited use, and includes both published and unpublished material" (PMI, 2004). PMBOK consists of nine knowledge areas which are further broken into 39 subdivisions. As shown in Table 2.4, PMBOK is project-specific as well as management oriented. Although the knowledge structure established by PMI was helpful in identifying some of the categories in the CII Knowledge Structure, it was not used as a basis since the target industries of each are different and the CII research covers much broader areas than project-specific and project management related issues, including both organisational and globalisation issues.

Table 2.4: Overview of PMBOK

Knowledge Area	Subdivisions	
1. Project Integration Management	1.1. Project Plan Development 1.2. Project Plan Execution	1.3. Overall Change Control
2. Project Scope Management	2.1. Initiation 2.2. Scope Planning 2.3. Scope Definition	2.4. Scope Verification 2.5. Scope Change Control
3. Project Time Management	3.1. Activity Definition 3.2. Activity Sequencing 3.3. Activity Duration Estimating	3.4. Schedule Development 3.5. Schedule Control
4. Project Cost Management	4.1. Resource Planning 4.2. Cost Estimating	4.3. Cost Budgeting 4.4. Cost Control
5. Project Quality Management	5.1. Quality Planning 5.2. Quality Assurance	5.3. Quality Control
6. Project HR Management	6.1. Organization Planning 6.2. Staff Acquisition	6.3. Team Development
7. Project Communication Management	7.1. Communication Planning 7.2. Information Distribution	7.3. Performance Reporting 7.4. Administrative Closure
8. Project Risk Management	8.1. Risk Management Planning 8.2. Risk Management Identification 8.3. Qualitative Risk Analysis	8.4. Quantitative Risk Analysis 8.5. Risk Response Planning 8.6. Risk Monitoring and Control
9. Project Procurement Management	9.1. Procurement Planning 9.2. Solicitation Planning 9.3. Solicitation	9.4. Source Selection 9.5. Contract Closeout

Source: PMI, (2004)

After several initial meetings, a preliminary structure of the CII Knowledge Structure was developed based on the findings from an extensive literature review and thorough discussion among the Knowledge Team members. The preliminary structure was started from a one- level structure containing 13 different groupings which were later called ‘Knowledge Areas’. A Knowledge Area is defined as a logical grouping of CII topical areas. This structure was refined through several meetings based on the comments from various sources including CII committees. A few knowledge areas were dropped, merged, or replaced with new ones during a review period before the team agreed on the finalised 13 Knowledge Areas. Once the 13 Knowledge Areas were identified, Focus Areas were added under each Knowledge Area where CII publications were actually categorised.

Core terminology was also defined concurrently with completion of the CII Knowledge Structure development, which was subsequently approved by the CII Executive Committee. Associated terminology is provided in Table 2.5.

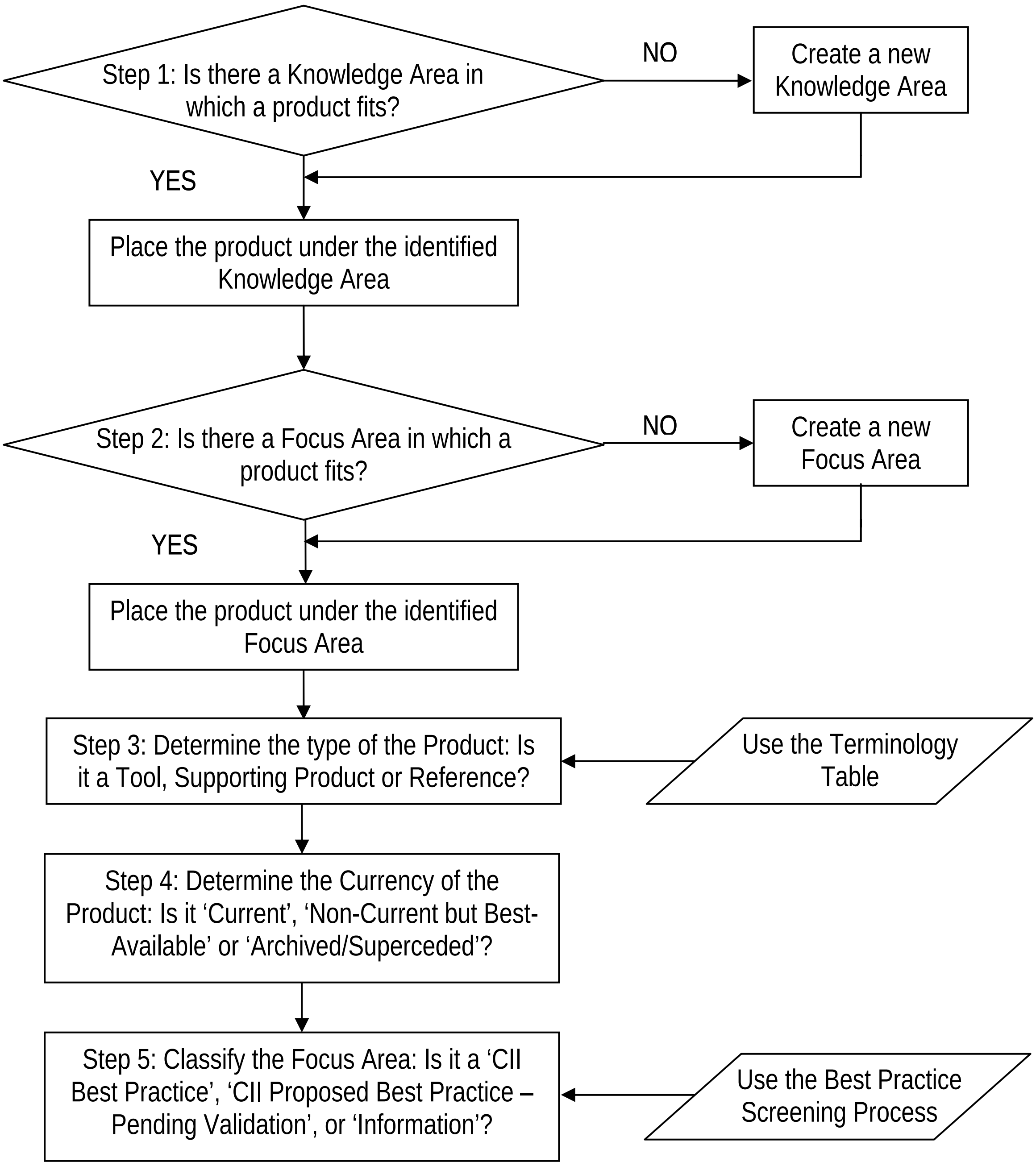
Table 2.5: Definition of Terms in CII Knowledge Structure

Term	Definition
Knowledge Structure	Overall body of CII knowledge arranged in topological form.
Knowledge Area	Logical grouping of CII topical areas. Knowledge Areas reflect project phases or construction issues.
Focus Area	Logical grouping of CII research emphasis that has leaded to research publications/products. A Focus Area is further categorized as a CII Best Practice, CII Best Practice, or Information Area.
Best Practice	A process of method that, when executed effectively, leads to enhanced project performance.
Proposed Best Practice	A process or method that may become a CII Best Practice, but has not provide processes or methods
Information	Investigation results that provide findings and/or reports, but do not provide processes or methods
Tool	A product supporting implementation that requires user interaction and results in decisions, conclusions and/or outcomes.
Reference	Source or background materials that provide information about the topic including research reports and video. Research Reports typify CII Products that are considered References.
Supporting Product	Summaries of research or educational materials that support implementation or understanding of the subject. Research Summaries predominate under this classification.

Once the structure was finalised, the Knowledge Team members started to categorise individual CII products under the CII Knowledge structure. This process involved reviewing over 250 CII publications including their sales record, age, topic, etc., and the process lasted for over six months. Due to the sheer volume of the materials that needed to be reviewed, each member took the responsibility for reviewing a certain number of materials. After reviewing, each member reported and made recommendations to the team at the next meeting. All recommendations were discussed and reviewed again during the meeting as a team before designations of the publications were determined.

The process of placing CII publications within the CII Knowledge Structure involved five steps as summarised in Figure 2.5. The first step was to locate the product within the Knowledge Structure by evaluating fit within existing Knowledge Areas or identifying a new Knowledge Area, which is very rarely done. Then, the product is placed under an existing Focus Area or a New Focus Area within the Knowledge Area. If there was an existing Focus Area where related research had been conducted, the product was placed under the same Focus Area; otherwise, a new Focus Area was created as a distinct area of CII research emphasis.

Figure 2.5: CII Product Categorisation Process



The third step of the process involved the determination of product type. There were three different product types identified including Tools, Supporting Products, and References, and their definitions are provided in Table 2.5. If the product contained method(s) or a process that could assist organisations in actual implementation, it was considered as a tool. A research product containing a summary of research or education material was considered a supporting product. Products providing a source or background materials about a specific topic are categorised as references.

Once the type of the product was determined, the next step was to determine the currency of the product. All products belonged to one of the three categories in terms of their currency and validity. The three categories included are 'Current', 'Non-Current but Best-Available', and 'Archived/Superceded'. If the product was produced within the last five years and the content was applicable to the industry, it was considered as 'Current'. If the product was more than five years old but still contained valid information at the time of evaluation, the product was considered as 'Non-Current but Best-Available'. Finally, products that were outdated or had been replaced by more recent publications were considered as 'Archived/Superceded'.

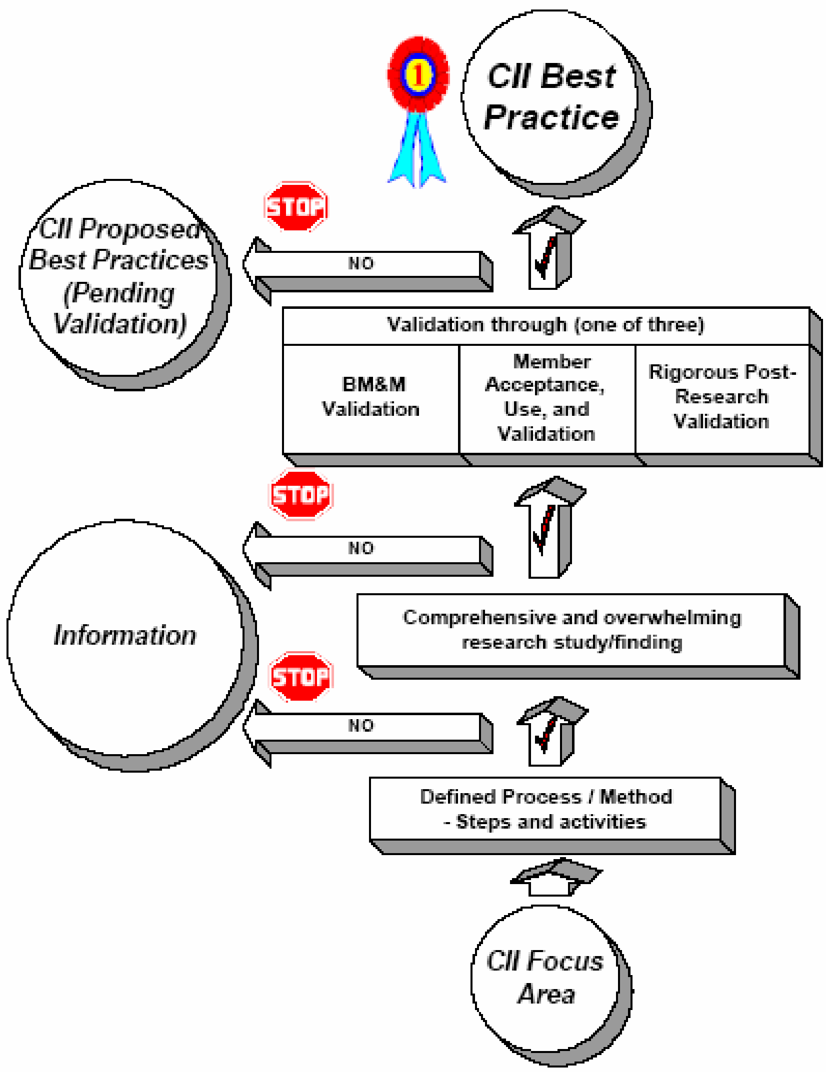
The last step of this product categorisation process was to determine the classification of the Focus Area in which the product was placed. Based on the characteristics of products and information available in a Focus Area, it was classified either as a 'CII Best Practice', 'CII Proposed Best Practice – Pending Validation' or 'Information Area'. Definitions of each of these categories are provided in Table 2.5 and the process of screening a Focus Area to determine its category is provided in Figure 2.6. Categorisation of all the CII products was completed by following the process illustrated in Figure 2.5 and outputs of this process are used in this study, which comprises a list of all CII products with their CII Knowledge Structure breakdown information. During the course of this development effort, the research team coordinated changes and documented their fit into the CII Knowledge Structure.

The best practice screening process starts with investigating whether a Focus Area includes a defined process or a method that describes steps and activities that have been published in CII documents. If not, the Focus Area is categorised under 'Information'. If it includes a process or method, the question of whether there has been comprehensive and overwhelming research study is examined. If the answer is no, it also falls under 'Information'. To become a CII Best Practice, it has to be validated through either one of three criteria. If it passes any one of these criteria, then it is considered a CII Best Practice. Three ways of validating products are: (1) Benchmarking and Metrics (BM&M) validation; (2) Member acceptance, use and validation; and (3) Rigorous post research-validation.

If a Focus Area fails to pass this step, it is categorised under 'CII Proposed Best Practice – Pending Validation'. All Focus Areas falling into this category may become a 'CII Best Practice' or move back to the 'Information' category based on an annual review.

It is important to note that the three categories, CII Best Practices, CII Proposed Best Practices—Pending Validation, and Information Knowledge Areas are related to the extent of development and usage within CII. This characterisation does not diminish the importance of any of the Focus Areas that have been identified. Indeed, each area has been the subject of at least one CII research investigation.

Figure 2.6: CII Best Practice Screening Process



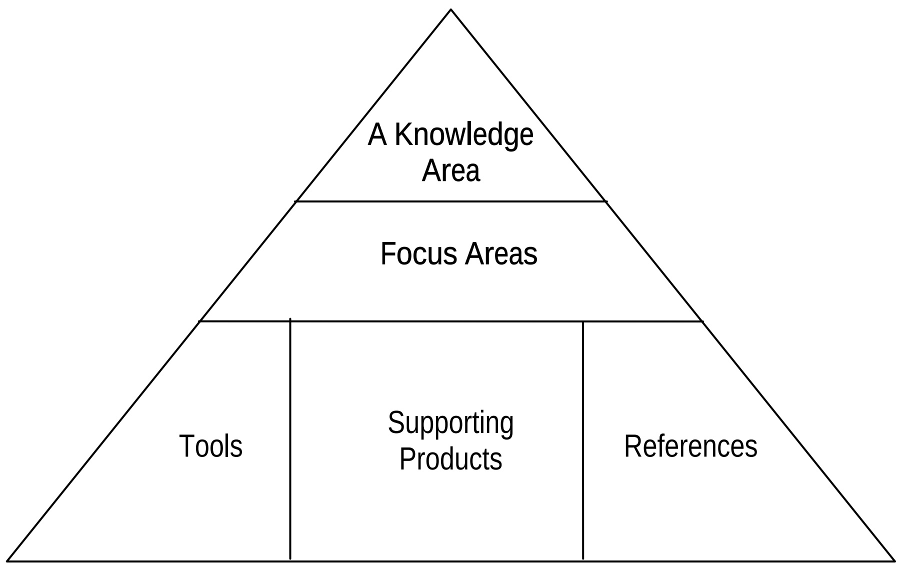
2.3.2.2 Organisation of the CII Knowledge Structure

The CII Knowledge Structure consists of 13 Knowledge Areas at the highest level. A Knowledge Area is defined as a logical grouping of CII topical areas and may be a project phase or specific topic, or project management techniques or issues. The 13 CII Knowledge Areas are:

- Front-End Planning
- Design
- Procurement
- Construction
- Startup and Operation
- People
- Organisation
- Project Processes
- Project Controls
- Contracts
- Safety, Health and Environment
- Information/Technology Systems
- Globalisation Issues

Each Knowledge Area is further broken into Focus Areas and supported by CII products as illustrated in Figure 2.7. A Focus Area is defined as a distinct area of CII research emphasis that has led to research publications/products. All existing CII products including research summaries, research reports, implementation resources, education modules, benchmarking publications, and videotapes are categorised into appropriate Focus Areas under the CII Knowledge Structure.

Figure 2.7: Base Structure of CII Knowledge Structure



As discussed earlier, each Focus Area is generally supported by tools, supporting products, and/or references. Tools are products supporting implementation that requires user interaction and result in decisions, conclusions and/or outcomes. Supporting Products are summaries of research or educational materials that support implementation or understanding of the subject. Research Summaries predominate under this classification. References include source or background materials that provide information about the topic including Research Reports and videos. Research Reports typify CII Products that are considered references. Based on the characteristics and intensity of the previous CII research efforts within a Focus Area, the area may or may not contain all three kinds of publications.

Among the Focus Areas identified, some are more often implemented by CII member companies than others. Accordingly, it can be assumed that those practices that are commonly utilised typically have greater impact on organisational success, at least at present. Therefore, three categories of Focus Areas were established based on product support, usage, and impact.

As discussed earlier, each Knowledge Area is sub-divided into Focus Areas that include Best Practices, Proposed Best Practices – Pending Validation, and Information. A CII Best Practice is defined as a process or method that, when executed effectively, leads to enhanced project performance. Each Best Practice is generally considered a macro-level process and may have many associated/recommended tasks or steps. A CII Proposed Best Practice—Pending Validation is defined as a process or method that may become a CII Best Practice, but has not yet completed the validation process. An Information Focus Area includes investigation results that provide findings and/or reports, but do not provide processes or methods. To determine which Focus Area falls into one of these three areas, the Knowledge Team developed the Best Practice Screening Process that outlines the method of qualifying best practices. This process is explained earlier with Figure 2.6.

Each of the Best Practices and Proposed Best Practices – Pending Validation are supported by tools, products, and references while each Information Focus Area is supported by products and references. In order to implement the Best Practices, an organisation must have access to and an understanding of the associated tools and products. Figure 2.8 graphically illustrates the structure of the CII Knowledge Structure. Each of the 13 Knowledge Areas is supported by Focus Areas that are further supported by tools, products, and/or references.

Figure 2.8: CII Knowledge Structure, Breakdown of Focus Areas

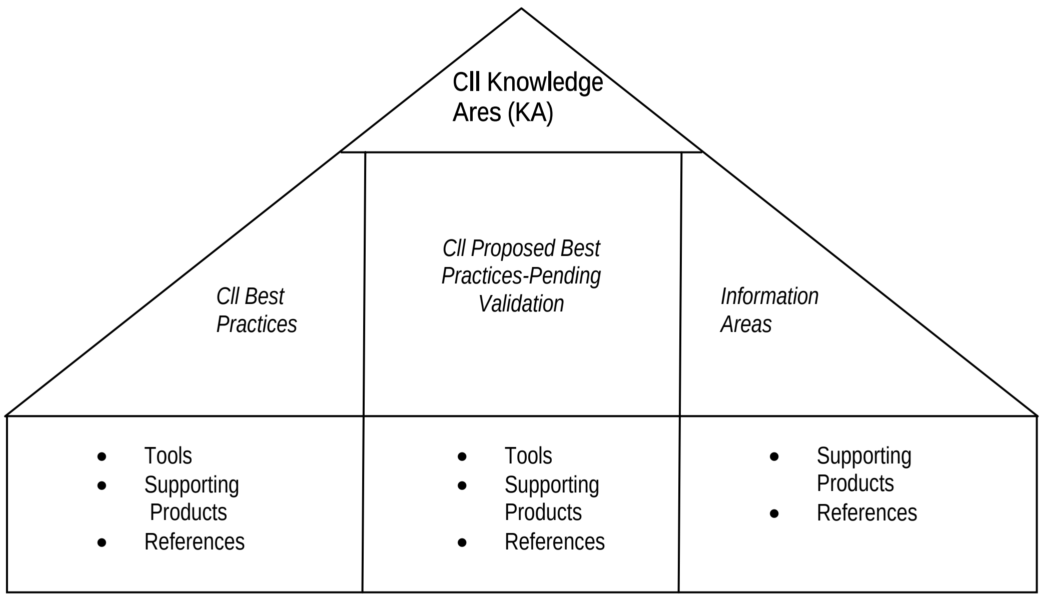
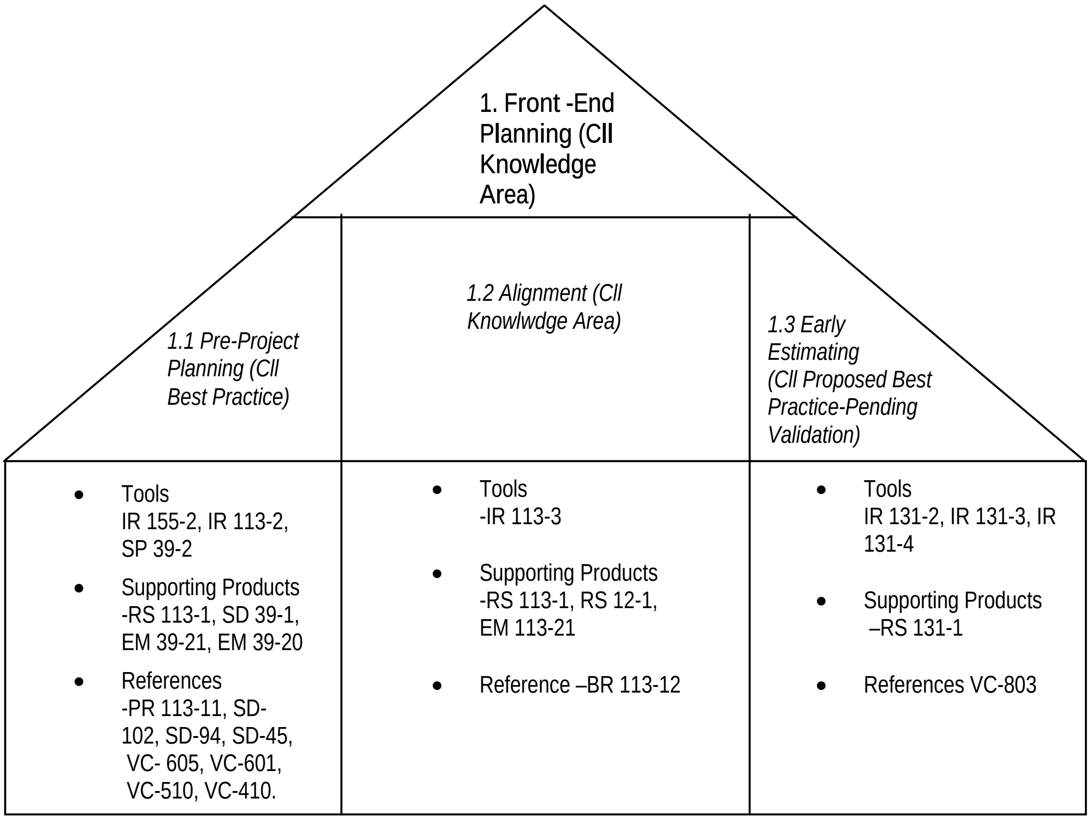


Figure 2.9 gives an example of one of the 13 Knowledge Areas, Front-End Planning. Within each Focus Area, the products are listed in reverse chronological order; that is, the most recently published material is listed first, followed by older materials, in order of publication. If an organisation wishes to implement pre-project planning, for instance, the tools are listed first including process maps, checklists, etc., followed by research summaries and education materials and then any research report and videos. The Implementation Champion or Product Champion can quickly identify useful information to assist with incorporation of the Best Practice by effectively utilising the Knowledge Structure.

Figure 2.9: Example Knowledge Area: Front-End Planning



* Legend: SP/IR	-	CII Special Publication and Implementation Resource
RS	-	CII Research Summary
SD/RR:	-	CII Special Documents or Research Reports
EM	-	CII Education Module
VC	-	Video Cassette

As of March 2002, the CII Knowledge Structure had 13 Knowledge Areas which were broken into 51 Focus Areas: 11 CII Best Practices, 13 CII Proposed Best Practices – Pending Validation, and 27 Information Areas as summarised in Table 2.6. CII Best Practices identified to date are:

- ·Pre-Project Planning
- Alignment
- Constructability
- Design Effectiveness
- Materials Management
- Team Building
- Partnering
- Quality Management
- Change Management
- Disputes Resolution

- Zero Accidents Techniques

The Knowledge Structure will be reviewed annually and revised as appropriate by the Knowledge Committee, which was launched as a standing committee to maintain the CII Knowledge Structure. The revised structure will be maintained as the CII Catalog on the World Wide Web (WWW) at www.construction-institute.org. It is envisaged that the fundamental overall structure will remain the same and only the details will change over time.

Table 2.6: CII Knowledge Structure Summary (As of March 2002)

Knowledge Areas	Best Practices	Proposed Best Practices	Information
1. Front-End Planning	1.1 Pre-Project Planning 1.2 Alignment	1.3 Early Estimating	
2. Design	2.1 Constructability 2.2 Design Effectiveness	See 8.6, 5.2, 11.3	See 12.3 2.3 Piping Design 2.4 Design Standards 2.5 Cost Effective Engineering
3. Procurement	3.1 Materials Management		3.2 Supplier Relationship See 12.1
4. Construction	See 1.2, 2.1, 3.1, 7.1, 7.2, 8.1, 9.1, 10.1, 11.1	See 5.1, 6.1, 6.2, 7.4, 8.2, 8.3, 10.2, 8.6	4.1 Competition See also 3.2, 6.3, 6.4, 6.5, 8.4, 8.5, 9.2, 9.3, 10.3, 10.4, 10.5, 10.6, 12.1, 12.2, 12.3, 12.4, 12.5, 12.6, 13.1, 13.2
5. Start-up and Operation		5.1 Planning for Start-up 5.2 Design for Maintainability	
6. People		6.1 Employee Incentives 6.2 Management of Education and Training	6.3 Attract & Maintain Skilled Workers 6.4 Craft Productivity 6.5 Multi-Skilling 6.6 Engineering Productivity Measurement
7. Organization	7.1 Team Building 7.2 Partnering	7.3 Organization Work Structure 7.4 Leader Selection	7.5 Project Teams
8. Project Processes	8.1 Quality Management	8.2 Implementation of Products 8.3 Lessons Learned 8.6 Work Process Simulation	8.4 Small Projects Execution 8.5 Benchmarking and Metrics
9. Project Controls	9.1 Change Management		9.2 Work Packaging 9.3 Cost & Schedule Control
10. Contracts	10.1 Disputes Resolution	10.2 Managing Workers' Compensation	10.3 Project Delivery Strategies 10.4 Contract Strategies

			10.5 Use of Project Incentives 10.6 Risk Management
11. Safety, Health, and Environment	11.1 Zero Accidents Techniques	11.2 Environmental Remediation Management 11.3 Design for Safety	11.4 Annual Safety Data
12. Information Management/Technology Systems			12.1 Automated Identification 12.2 Electronic Data Interchange (EDI) 12.3 Computer-Aided Design/Drafting 12.4 FIAPP 12.5 Wireless Technology 12.6 Automation and Robotics
13. Globalization			13.1 International Standards 13.2 Global Construction Industry

2.3.2.3 CII Knowledge Committee

In order to maintain and update the CII Knowledge Structure, the Knowledge Committee was newly organised in January 2002 as the successor to the Knowledge Team that developed the CII Knowledge Structure. Members of the committee included representatives of the Strategic Planning, Research Implementation Strategy, Education, and Benchmarking Committees in CII, and two members from CII member organisations at large (CII, 2002). The Knowledge Committee meets at least once per year in early January, to review the CII products from the previous year and to make decisions about the category designations and the relevancy of products represented in the Knowledge Structure. The committee will also review the organisation of the Knowledge Structure and make changes to it if necessary. The defined role of this newly commissioned CII committee is below:

The Knowledge Committee's role is to continue the development of the CII Knowledge Structure, and to maintain the currency of the Knowledge Structure organisation and content. The Knowledge Structure is important because it provides a synthesis of the total knowledge produced by CII and serves to guide the users of CII knowledge to applicable information. The Knowledge Structure also provides a guide in the selection of topics for research and subsequent application of the CII-developed knowledge.

The Knowledge Committee had its first meeting in January 2002 to review the products published in 2000 and 2001. As of now, the Knowledge Committee had categorised all the recently published products and made necessary changes to the Knowledge Structure. As a result, three Focus Areas were added to the structure, and titles of a Knowledge Area and two Focus Areas were modified.

These changes are reflected in Table 2.6 and are used as inputs to the development of instruments of this research, namely the Delphi assessment and the survey questionnaire. Attention was given to 'localise' the inputs to suit the Malaysian construction consulting industry as the CII framework was developed to fulfill the requirements of the American construction industry.

CHAPTER THREE

LITERATURE REVIEW

This chapter presents the literature review on KM and IT infrastructure capability. It consists of three sections. The first section presents a literature review on KM. The second section presents a literature review on IT infrastructure capability where by the concepts of IT infrastructure services that are used to measure IT infrastructure capability are discussed. The third section discussed the criteria for framework evaluation this chapter includes discussions on the findings of the literature review and their implications.

3.1 KNOWLEDGE MANAGEMENT

3.1.1 Knowledge Defined

Francis Bacon once said that knowledge is power. As we move from the industrial age to the intelligence age, knowledge has become a central force behind the success of firms. Especially, with the fast developing IT, the speed of processing information and knowledge has been accelerated. Moore's law states that every 18 month, processing power doubles where costs holds constant. Today even a small desktop computer has more powerful processing capability than that of a mainframe computer decades ago. His law has been true through the years and it appears that it will remain there for the foreseeable future.

With the faster and greater capability to process information, the amount of knowledge has been exponentially utilised by organisation. Organisations try to recognise assets they have that are not being fully utilised (Quintas et al., 1997). Such assets are employees and their knowledge. The assets include human skills, experience, know-how, best practices, databases etc. these assets provide opportunities to cut costs, save design time, and reduce the time to market (Quintas et al., 1997). Knowledge has become a critical corporate asset (Drucker, 1995).

However, knowledge is not a clear concept. It is helpful to distinguish the following terms: data, information, and knowledge for clarification. Data are raw facts that are recorded and stored. Data do not have much meaning. Data must be sorted, grouped, analysed, and summarised to have meaning.

When data are organised and processed, they become information. Information has meaning and value to the receiver. Knowledge consists of data or information that has been organised and processed to give understanding, experience, and expertise in a specific context.

Leonard and Sensiper (1998) define knowledge as “information that is relevant, actionable and based at least partially on experience”. Turban, McLean and Wetherbe (1999) characterise knowledge as “consisting of data or information that have been organised and processed to convey understanding, experience, accumulated learning, and expertise as they apply to a current problem or activity”. O’Dell and Grayson (1998) define knowledge as “what people in organisation know about their customers, products, process, mistakes, and success”. Davenport and Prusak (1998) provide more comprehensive view of knowledge. “Knowledge is a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information” and “it originates and is applied in the mind of the knower”.

Based on various views of knowledge, it is clear that information becomes knowledge when it is combined with context and experience. Due to this context-dependent aspect of knowledge, it is hard to share and transfer knowledge, compared with data and information. For example, when knowledge is transferred, it is interpreted according to the receiver’s capacity. Without an appropriate background, receivers cannot interpret the knowledge will have little value. In this study, knowledge is defined as the combination of information, context, and experience, and is viewed as a core competence of an organisation that can be captured, shared, and utilised for various aspects of business problems.

It should be pointed out that there are two dimensions of knowledge: tacit and explicit. The first researcher who made a distinction between the two was Polanyi (1966). However, it was Nonaka and Takeuchi (1995) who brought its importance to organisational attention. Tacit knowledge is embedded in the expertise and experience of individuals and groups, not yet explicated (Leonard and Sensiper, 1998). Explicit knowledge is codified in organisational rules, routines, and procedures.

Boisot (1995) used the taxonomy of codified knowledge and uncodified knowledge. Codified knowledge can be captured, codified and shared in organisations, while uncodified knowledge cannot be captured, codified and shared. Baker and Baker (1997) described explicit knowledge as formal, systematic, and objective. Explicit knowledge is generally stored in the form of texts (i.e., manual, policy book, database, or even in databases). Tacit knowledge is more intangible. It is difficult to codify and transfer tacit knowledge because it is stored in an individual’s head (i.e., expertise, experience, insights, or know-how). Explicit knowledge is shared through a combination process becomes tacit through internalisation. Tacit knowledge is shared through a socialisation process and becomes explicit through externalisation (Nonaka and Takeuchi, 1995).

3.1.2 Knowledge Management Defined

Knowledge is a core competence of organisations and needs to be managed as such. KM is defined in broad terms and includes all these concepts: knowledge of customers, knowledge of products and services, knowledge of relationships, and knowledge assets (Skyrme, 1999a). According to Metcalfe's law, the usefulness of a network equals the square of the number of users. A knowledge hidden in one single person's head will be useful. However, if it is networked to others and shared with them, the usefulness of the knowledge will be exponentially increased. The effective KM will identify knowledge in one place and allows it to be networked and shared with others, thereby increasing exponentially the usefulness of the knowledge.

Defining KM is difficult because it has multiple interpretations (Choi, 2000). The following definitions are a few examples of the multiple views on KM:

1) "KM is the management of the organisation towards the continuous renewal of the organisational knowledge base - e.g., creation of supportive organisational structures, facilities of organisational members, putting IT instruments with emphasis on teamwork and diffusion of knowledge (e.g., groupware) into place" (Bertel, 1996).

2) "KM is the collection processes that govern the creation, dissemination, and utilisation of knowledge" (Newman, 1997).

3) "KM is the mechanism for building the institutional memory of the firm to better apply, share, and manage knowledge across various components in the organisation" (Choo, 1998).

4) "KM is a strategy that turns an organisation's intellectual assets - both recorded information and the talents of its member- into greater productivity, new value and increased competitiveness; it teaches corporation from managers to employees, how to produce and optimise skills as a collective entity" (Murray, 1997).

5) "KM is the explicit and systematic management of vital knowledge and its associated process of creating, gathering, organising, diffusion, use and exploitation. It requires turning personal knowledge into corporate knowledge that can be widely shared throughout and organisational and appropriately applied" (Skyrme, 1999b).

6) Ruggles (1998) proposed eight major categories of KM activities: "generating new knowledge, accessing valuable knowledge from outside sources, using accessible knowledge in decision making, embedding knowledge in processes, products, and/or services, representing knowledge in documents, databases, and software, facilitating knowledge into other parts of the organisation, measuring the values of knowledge assets and/or impact of KM."

Based on the various definitions, there are five key processes associated with KM: creation, location, organisation, distribution, and sharing of knowledge. KM includes a broad process of creating, organising, locating, distributing and sharing knowledge to achieve the organisations' goals. This is used as the working definition of KM in this study.

3.1.3 Resources Based View of the Firm

The global competitive environment surrounding business organisations has changed drastically during the past decade. The competition has become fierce and relentless. One of the key requirements for corporate success in this competitive environment is, knowing how to sustain competitive advantage. Until the late 1980s, organisations focused on their external environments such as industry competition (Kim and Mauborgne, 1999). Competition had been a key factor in organisational strategy. Most companies focused on how they could build competitive advantage over their competitors. As Kim and Mauborgne (1999) pointed out, this predominant focus on competition has some negative aspects: "strategy driven by competition usually has latent, unintended effects. They are imitative, not innovative, approaches to the market. Companies often accept what competitors are doing and simply strive to do it better. Companies act reactively. Time and talent are unconsciously absorbed in responding to competitive moves, rather than creating growth opportunities." Additionally, "industry boundaries have become fluid and the traditional notion of industry is getting obsolete."

From the late 1980s, a new perspective of strategic advantage emerged. This perspective was called a resource-based view of the firm. Researchers and practitioners of this idea suggested that competitive advantage is not gained only through the combination of product and market based on competition in a given industry, but it was mostly due to differences in organisational resources of different kinds (Prahalad and Hamel, 1990). Because resources cannot always be transferred or imitated, organisations must look inside the firm to find the real sources (Wernerfelt, 1984; Barney, 1986 and 1991; Prahalad and Hamel, 1990; Mahoney and Pandian, 1992; Collis and Montgomery, 1995; Post, 1997; Markides, 1997).

As Wernerfelt (1984) pointed out, “resources are tangible or intangible assets that are tied semi-permanently to the firm.” Core competence is one such resource. It constitutes competitive advantage for a firm (Prahalad and Hamel, 1990; Collis and Montgomery, 1995; Post, 1997; Markides, 1997; Bogner et al., 1999). Such advantage is built up over time and cannot easily be imitated. “Core competencies are the collective learning in the organisation, especially how to coordinate diverse production skill and integrate multiple streams of technologies” (Prahalad and Hamel, 1990). Barney (1991) developed four criteria assessing what kinds of resources would provide sustainable competitive advantage: first, value creation for the customers; second, rarity compared to the competition; third, inimitability; and fourth, substitutability. Knowledge is the resource that meets such requirements. Knowledge is one competitive advantage that is difficult and time taking to imitate. Knowledge has become a core competency.

Knowledge as a core competency does not diminish with use. Physical assets diminish as they are used. Contrarily, competencies such as knowledge increase their values as they are used and shared. Knowledge fades if it is not used. It is a driving force for new product and new business development. The strategies of a company are the result of knowledge about customers, markets, competitors, and its internal capabilities. The strategies of organisations need to be guided by knowledge and not just by the attractiveness of the market because the strategies beyond their capability would not work. In order to sustain competitive advantage, firms need to possess resources which are unique and difficult for competitors to imitate; the organisation’s ability to build, integrate and utilise knowledge is the ultimate source of competitive advantage (Huber, 1991; Nonaka, 1991; Newman, 1997; Teece, 1998; Matusik and Hill, 1998).

3.1.4 Knowledge Management as a Value Creator

The resource-based approach to organisational strategy has highlighted the key role that organisational knowledge plays in creating and sustaining competitive advantage. However, the resource-based view limits the organisation’s opportunity for growth and strategic innovation because its focus is on internal resource. The opportunity of growth and innovation is possible by understanding true needs of customers (who are outside of a firm) and by delivering values to them. The resource-based view does not take customers into a critical consideration as it should. This can be misleading. "Today's business challenges include understanding and satisfying customers' needs; monitoring and staying ahead of competition; determining industry trends and adapting to the challenges; increasing market share; and entering new markets" (Hu et al., 1998).

The ultimate goal of business organisations is to offer products and services that can provide values to customers. Companies of sustained high growth and profit pursue value innovation, and the emphasis on value places the customer at the center of their strategic thinking (Kim and Mauborgne, 1999). Kim and Mauborgne (1999) also pointed out that "value innovation makes the competition irrelevant by offering fundamentally new and superior customer value in existing markets and by of enabling a quantum leap in buyer value to create new markets."

Prahalad and Hamel (1990) gave an analog of a tree to explain core competence, which is a key resource of organisations. Core competence works as the roots of a tree. Every trunk, branch, leaf, flower and fruit flourishes from the roots. However, when the roots can't get sunshine or air from the markets or customers, then the trunk and even the roots can wither away and dry up. Organisations work both ways: from roots to leaves (for water and nourishment) and vice versa (for air and sunshine).

Organisational knowledge provides the capability to understand markets and customers' needs, translate them into products and services. Organisational knowledge can link a market and customers with the resources of the firm. Even though KM has roots in the resource-based view, it can overcome some problems that the view's perspective has. KM integrates a competition-based view and a resource-based view into the more extended and balanced view of the firm.

3.1.5 Knowledge Management Approaches

KM is concerned with the entire process of creating, organising, locating, distributing, and sharing knowledge. While managing organisational knowledge, a firm takes a specific approach. Researchers found that there are two major approaches to knowledge management: exploitive vs. explorative (March, 1991; Jordan and Jones, 1997; Hansen et al., 1999; Sarvary, 1999; Skyrme, 1999a; Zack, 1999). Exploitive approach focuses on reusing exiting knowledge. Explorative approach focuses on creating new knowledge. Of course, companies can take both approaches simultaneously. However, successful companies do not use them to an equal degree. They tend to employ one dominant knowledge management approach (Hansen et al., 1999).

Jordan and Jones (1997) described two dominant knowledge modes within an organisation. Even though they did not term the modes, the two modes represent exploitive approach and explorative approach as summarised in Table 3.1. The framework by Jordan and Jones consists of five broad subordinate categories knowledge modes: knowledge acquisition, problem solving, dissemination, ownership and memory.

Table 3.1: Knowledge Management Modes

Knowledge Acquisition		
Focus	Internal	External
Search	Opportunistic	Focused
Problem Solving		
Location	Individual	Team
Procedure	Trial and error	Heuristic
Activity	Experiential	Abstract
Scope	Incremental	Radical
Dissemination		
Processes	Informal	Formal
Breadth	Narrow	Wide
Ownership		
Identity	Personal	Collective
Resource	Specialist	Generalist
Storage/Memory		
Representation	Tacit	Explicit

(Adopted from Jordan and Jones, 1997)

As Jordan and Jones did, Zack (1999) classified two KM applications: interactive applications and integrative applications. In the integrative applications, knowledge flows from people to computers (i.e., knowledge repository or data warehouse), and vice versa. The repository is the hub for people to place, retrieve and exchange their knowledge. Here the focus is on capturing and storing knowledge for reuse. Explicit knowledge flows into and out of a knowledge repository. "The primary focus tends to be on the repository and explicit knowledge it contains, rather than on the contributors, users, or the tacit knowledge they may hold" (Zack, 1999). In the interactive applications, the primary focus is on supporting interaction among people. The knowledge repository can be utilised, but it is a "by-product of interaction and collaboration" (Zack, 1999). The knowledge used tends to be tacit. Knowledge flows from people to people.

March (1991) called these exploration and exploitation. "Exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation. Exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, and execution" (March, 1991). The exploitation approach is concerned about capturing existing knowledge, codifying it and utilising it. Knowledge is put into a form that makes is accessible to people so that it can be exploited by people. Knowledge is codified so that it can be accessible and applied. By nature, the exploitation approach tends to focus on explicit knowledge. The exploration approach is to explore and generate new knowledge for new challenges. New knowledge is needed to solve new problem and new challenges. Most of the time, there is no knowledge available for these kinds of problem. Collaboration among a group of people, or even with other organisations, is encouraged. The exploration approach tends to focus on implicit knowledge.

3.1.6 Knowledge Management in the Management Consulting Industry

From the perspective of KM, the management consulting industry is a very exciting one. Management consulting is an industry whose core product is knowledge itself. Managing knowledge is the most critical process in the consulting industry (Sarvary, 1999). Consulting firms' core product is knowledge itself. They sell their expertise and experience to customers. The experience and expertise are nothing more than knowledge. Consulting firms get paid for the knowledge that they are providing to the customers. Producing and selling knowledge constitute their core activities. KM is the basic production technology for consulting firms. Recent studies on KM strategies in the management consulting industry also found that there are some specific approaches in the practice of KM as in other industries. There are basically two types of KM approaches: centralised and decentralised (Sarvary, 1999; Hansen et al., 1999).

Decentralised (bottom up approach) KM systems can be observed in generalist strategy firms such as McKinsey, Bain, or Boston Consulting (Sarvary, 1999; Hansen et al., 1999). Such companies are known for their strategy consultancy. Their customers' problems tend to be unique and their recommendation are highly customised and context dependent. Since such knowledge is difficult to codify and standardise, the generalist strategy firms typically put more emphasis on connecting people and collaborating them than on capturing and reusing the available problems and solutions with information technology.

Centralised KM systems (top down approach) can be observed in larger IT consulting firms (i.e., Andersen for its IT consultancy) and the former Big 6 consulting firms (Sarvary, 1999; Hansen et al., 1999). Their customers' problems are operational. Their service often includes highly standardised solutions to the client. Since operational problems have low context dependence, their solutions can be relatively easier to codify and transfer with the methods such as manuals, databases, or knowledge repositories. Centralised systems are heavily dependent on information technology. Information technology has played a critical role in this approach.

Hansen et al. (1999) developed a model for mapping strategy to KM approach. According to their study, companies do not take a uniform approach to managing knowledge. There are two very different KM approaches, depending on business strategies, as shown in Table 3.2.

Table 3.2: Knowledge Management Strategies of Consulting Companies

KM Strategy	Codification	Personalisation
Competitive Strategy	Provide high quality, reliable, and fast information-system implementation by reusing codified knowledge	Provide creative, analytically rigorous advice on high level strategic problem by channeling individual expertise
Economic Model	Reuse Economics Invest once in a knowledge asset; reuse it many items	Expert economics Charge high fees for highly customised solutions to unique problems.
Knowledge Management Strategy	People to documents Develop electronic document system that codifies stores, disseminates, and allows reuse of knowledge.	Person to person Develop networks for linking people so that tacit knowledge can be shared.
Information Technology	Invest heavily in IT; the goal is to connect people with reusable codified knowledge	Invest moderately in IT; the goal is to facilitate conversions and the exchange of tacit knowledge
Human Resources	Hire new college graduates who are well suited to the reuse of knowledge and the implementation of solutions. Train people in groups and through computer-based distance learning. Reward people for using and contributing to document databases	Hire MBAs who like problem solving and tolerate ambiguity. Train people through one to one mentoring. Reward people for directly sharing knowledge with others.

(Adopted from Hansen et al., 1999)

In some companies, knowledge is codified and stored in databases/knowledge bases. Then the stored knowledge can be accessed and reused easily by anyone in the company. They call this "codification" strategy. The other KM strategy is "personalisation" strategy. This strategy focuses on communicating knowledge among people, not storing knowledge. The choice of KM strategy depends on the way the company serves its clients, the economies of its business, and the people it hires. Through the case studies of consulting companies, computer manufacturing companies and medical centres, Hansen et al. (1999) found that emphasising a wrong strategy or trying to pursue both at the same time could quickly undermine a business. They suggest that effective firms need to focus on one of the strategies and use the other in a supporting role (roughly an 80-20 split).

3.1.7 Summary of KM Approaches

Based on the literature review, it is clear that there are two basic approaches to KM. The findings are summarised in Table 3.3.

Table 3.3: Summary of Knowledge Management Approaches

	Approaches	Characteristics
A	- Centralised KM systems - Integrated Applications - Codification strategy - Exploitation	- Provides standardised service - Procedure oriented - Reuse of knowledge - Focus on capturing and utilising knowledge - Use explicit knowledge - Heavy use of IT - Pursue operational excellence.
B	- Decentralised KM systems - Interactive Applications - Personalisation strategy - Exploration	- Provides customised service - Product/service oriented - Create new knowledge - Focus on exploring new knowledge by collaboration of people - Use tacit knowledge - Less use IT - Pursue innovative product/service.

Since one KM approach has different characteristics from the other, organisations need to identify their KM style first before they commit to implementation of the KM projects. Different KM approach will require different methods and different tools.

3.2 IT INFRASTRUCTURE CAPABILITY

In this section, a literature review on IT infrastructure capability is presented. First, IT as an enabler of KM is discussed. Second, the existing studies on IT infrastructure capability are introduced.

Then the concept of IT infrastructure services is presented. IT infrastructure services are to measure the IT infrastructure capability.

3.2.1 IT as an Enabler of KM

As discussed in the previous section, KM is the entire process of creating, organising, locating, distributing and sharing knowledge to achieve organisational goals. During the process, information technology is extensively utilised for knowledge input, processing, repository, flows, and outputs. Information technology has been cited as one of the key enablers of the successful KM (O'Dell and Grayson, 1998; Weil and Broadbent, 1998; Skyrme, 1999b; Choi, 2000). In a survey of 431 U.S. and European companies, Ruggles (1998) found that the four most popular KM projects are related to IT (i.e., Intranet, data warehouse and knowledge repository, decision support tool, and groupware). There is a powerful synergistic relationship between KM and IT; that relationship drives increasing returns and increasing sophistication on both from (O'Dell and Grayson, 1998).

For example, understanding customers' needs is the critical issue. Companies rank knowledge about the customer as most important (Skyrme, 1999a). Organisations want to know about customers to develop new products and to enhance their services. However, in many cases, companies know how much less about their customers. Traditional approaches such as customer surveys do not tell much about customers' underlying needs because sometimes customers do not know what they really need. By developing more effective market scanning systems, companies can get good customer knowledge. By analysing customers' buying patterns and trends, organisations can understand customers' underlying needs and real wishes. All of these can be helped with information technology. Business intelligence systems, customer relationship management (CRM), and data mining are just a few examples of applications of IT to KM to enhance knowledge about the target market customers.

In the KM context, IT includes a broad range of applications. Especially new technologies such as the Internet and groupware have had critical implications for KM. They have reduced the cost and sped up knowledge processing (O'Dell and Grayson, 1998). For example, a Web browser provides an easy to use interface that can access many different types of information. Web pages are easily developed using Web development tools (i.e., Hypertext Market Language) to store organisational information and knowledge. TCP (Transmission Control Protocol)/IP (Internet Protocol) provides a common way of communication between different types of platforms. Group supporting software (i.e., groupware) can provide collaboration support among groups. Information technology is the knowledge enhancer. There is a wide variety of IT applications used for KM.

3.2.2 Information Technologies for Knowledge Management

A data warehouse is a data management technology that integrates information from multiple data pools and makes it easier to explore hidden meaning of data (Chase, 1997; Skyrme, 1999b). With a data warehouse, people can access to large amounts of information that can be analysed from different perspective. This can enhance decision-making quality. When used with appropriate analysis tools (i.e., data mining) or multidimensional data analysis tools (i.e.; OLAP: On–Line Analytical Processing), valuable knowledge can be extracted.

Document management systems can allow people to share knowledge in many applications (Junnakar and Brown, 1997). Document management systems are a “repository of important corporate documents and are therefore important stores of explicit knowledge” (Offsey, 1997). Documents give the users knowledge with more context and details. It can include manuals, best practices, policy books and even drawings.

Another popular technology is a knowledge creation system. This technology can assist thinking and creativity in individuals or in groups. One example is an idea generation tool (i.e., group decision support system or electronic meeting systems). It can help for different creativity activities (i.e., concurrent product development) by allowing groups freely exchange their ideas (Skyrme, 1999a).

Data mining technology is an emerging technology to extract meaningful information from a large pool of data to support business decisions (Mitchell, 1999). Data mining technology finds patterns, trends or relationship in large pools of data and predicts future behaviors from them. These patterns and rules can be used to extract hidden knowledge about customer behavior. Data mining can be used to locate the specific needs of a market or customers.

Knowledge mining is a newer from of data mining. Knowledge mining is a process of extracting previously unknown knowledge from a variety of information sources (Hu et al., 1998). Knowledge mining can drastically improve the power of knowledge search by integrating various information sources. For example, related data and information on the Web can be collected using software agent technology such as Web Crawler or Web Spider. With knowledge mining, information stored outside of the traditional technology (i.e., relational database) can now be utilised.

Search engines play by a key role in making knowledge workers more productive by giving them the information they need in organised way. By using key words or by using directories, users can retrieve matching information. The information can be ranked or sorted according to certain criteria. By using key words, users can retrieve a great amount of matching results in an efficient way.

Intelligent agents (software agents) are “a class of software that operates autonomously, intelligently, and knowledgeable” (Skyrme, 1999b). They are technologies that use “a built-in or learned knowledge base to carry out specific, repetitive, and predictable tasks on the behalf of users” (Syed, 1998). For example, intelligent agent software can travel over the Internet and capture the most appropriate information to the users’ preference. They may monitor incoming e-mails and filter out messages that users would not be interested in.

AI (Artificial Intelligent) technologies such as Case-Based Reasoning Systems and Expert Systems are used to manage narrow domains of knowledge (Davenport and Prusak, 1998). Organisational knowledge can be captured and stored using case-based reasoning systems. In case-based reasoning systems, descriptions of past experiences of human specialists are represented as cases and stored in a case database for a later retrieval. With the technology, users can input characteristics of the problem that they have. Then the system searches for stored past cases with similar characteristics and provides a solution. Unsuccessful solutions are solved by human experts and added to the case database with explanation and human solved solutions. In an Expert System, human expert knowledge can be placed in a machine. An Expert System is a knowledge intensive computer programme that captures the expertise of an expert. It uses a production rule (i.e., If-Then) to represent human knowledge.

Groupware is a technology that can overcome space and time barriers for group interaction. Its focus is to help knowledge workers share that their expertise, particularly in a physically dispersed environment. The purpose of groupware is to support the collaborative works of a group of people. It includes software for information sharing, electronic meetings, scheduling, workflow management, and e-mail network to connect the members of the group.

In the last few years, intranets have emerged as an important KM tool (Ruggles, 1998). They provide several benefits compared with other types of IT applications. It is easy to use (i.e., World Wide Web). It provides a universal access to different platforms by using TCP/IP protocol. At the same time, it allows person-to-person interaction. It can lower the communication cost. Additionally, it prevents outsiders from accessing sensitive information of a company, while linking employees to the outside world. It is widely used to expand an organisation's access to information and knowledge.

IT alone cannot do anything for KM. However, an effective KM project cannot be successful without the support of IT. Sveby (1997) described IT as hygiene factors: "IT is for KM like a bathroom is for a house buyer. IT is essential because without it, the house is not even considered by buyers. But the bathroom is generally not the vital differentiating factor for the buyers. "IT facilitates the rapid dissemination of knowledge and improves communication and collaboration among employees at all levels, all locations, and even with those in other organisations (Weil and Broadbent, 1998).

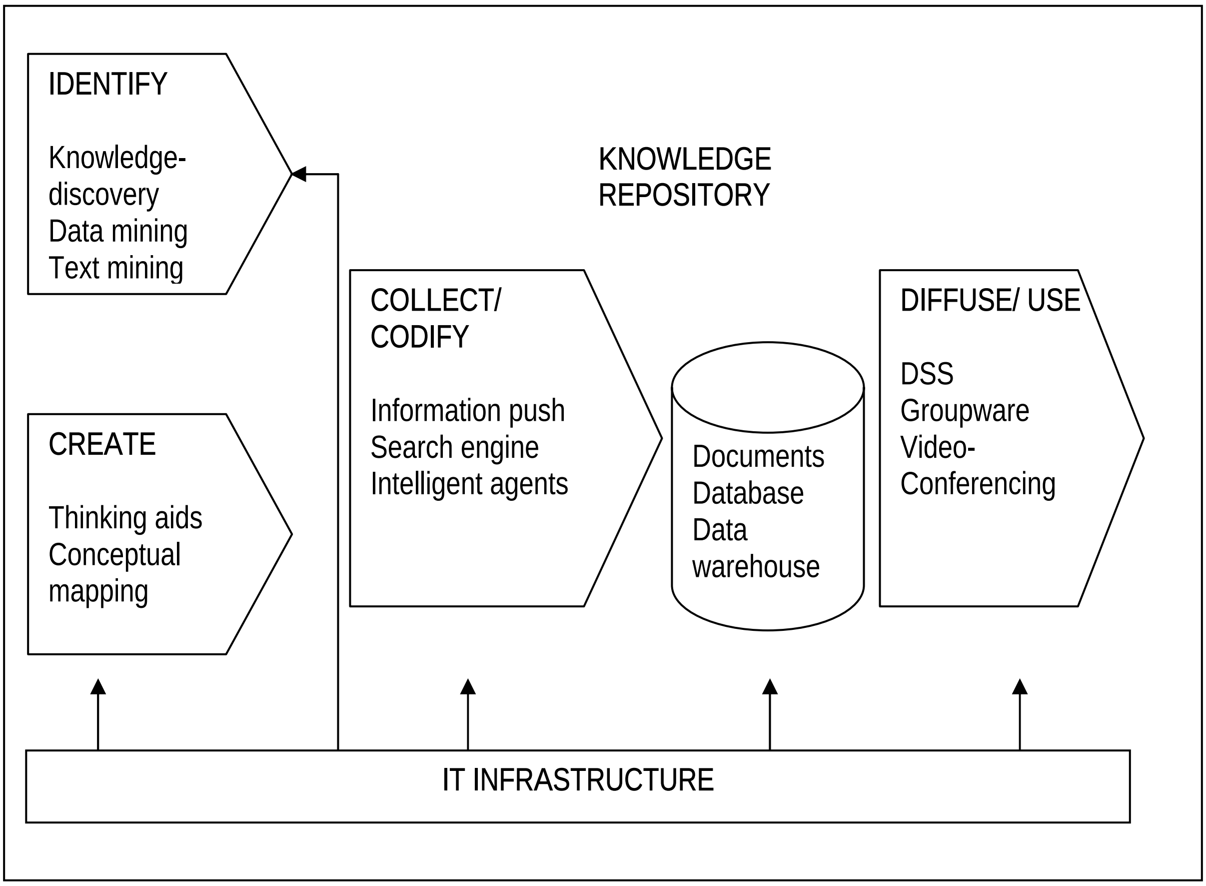
3.2.3 IT and Knowledge Value Chain

As discussed in the previous section, there is a variety of information technologies used for KM. An interesting aspects is illustrated in the IT and knowledge value chain (Skyrme, 1999a). As shown in Figure 3.1, the entire process of KM can be supported by information technology. For example, data mining technology can be used to identify existing knowledge. Intelligent technology can be used to collect knowledge. Data warehouse, technology can be used to store and structure knowledge. No matter what technology organisations are using, the individual technologies interact with the underlying infrastructure. There are some common underlying categories and technologies that organisations can focus on.

This indicates that organisational KM influences IT. This also suggests that organisational knowledge influences IT infrastructure. Organisational KM can be shaped by IT infrastructure capability. The relationships between KM and IT should be examined from an infrastructure view. A KM system itself is the infrastructure necessary for the organisation to implement the KM process. It includes-and for large companies critically depends on–a good IT infrastructure (Sarvary, 1999). In spite of the strong indication of the influence of KM on IT infrastructure there has been no substantial research in this area because knowledge management itself is a new phenomenon and IT infrastructure has started to draw attention only recently (refer to Sveby, 1997; Junnakar and Brown, 1997; O'Dell and Grayson, 1998;

Weil and Broadbent, 1998; Sarvary, 1999; Davenport and Prusak, 1998; Syed, 1998; Hansen et al., 1999).

Figure 3.1: IT and Knowledge Value Chain



(Adopted from Skyrme, 1999a)

3.2.4 IT Infrastructure Capability

KM interacts with and is supported by IT infrastructure capabilities involving a communication network and shared groupware applications (Weil and Broadbent, 1998). KM involves the access, sharing, dissemination, communication and collaboration of knowledge. It is important to understand a firm's information flow so that they can be shared. To manage a firm's knowledge requires a specific set of IT infrastructure capability. Information and knowledge should be easily transferred through a communications network. A well-defined architecture and standard of data and applications ensures enterprise-wide compatibility of systems (Weil and Broadbent, 1998).

IT infrastructure is explained in terms of technology components. For example, Earl (1989) and Niederman et al. (1991) explain IT infrastructure as "a platform technology consisting of the processing hardware and operating system, networking and communication technologies, data, and core data processing applications." However, today's view on IT infrastructure includes IT managerial aspects such as IT planning and control that may affect the design and implementation of technology components (McKay and Bockway, 1989; Dunkan, 1995; Weil and Broadbent, 1998). IT infrastructure "generally describes a set of shared and tangible IT resources that provide a foundation to enable present and future business application" (Dunkan, 1995). IT infrastructure is "the enabling foundation of shared information technology capabilities upon which business depends" (McKay and Brockway, 1989). IT infrastructure also includes IT software and hardware components and combines them into a shared set of capabilities. These capabilities directly support business processes. It is "generally believed to add value to the community in a way that could not be achieved through individual private investment" (McKay and Brockway, 1989).

There are key concepts in IT infrastructure capability to be mentioned. The first concept is integration. Integration refers to "the linking of individual IT components and services for the purpose of sharing software, communications, and data resources" (Keen, 1991). The goal of integration is to ensure that technology components such as hardware, software, information, and telecommunications work together seamlessly enterprise wide. Keen (1991) explains this concept with "Range" or the degree to which information can be directly and automatically shared across systems and services". This represents compatibility. "Incompatibility is diametrically opposed to integration" (Keen, 1991). Architecture and enterprise wide management of information technologies assures the compatibility of IT applications.

The second concept that needs to be mentioned is collaboration. Collaboration refers to mutual efforts by two or more individuals in order to perform certain tasks. People work together on tasks from designing products and to teaching each other. Collaboration capability improves group working and knowledge sharing. Collaboration capability allows for groups of people to work together. Keen (1991) explained this concept with "Reach" which determines the location of people on project to project basis. This capability of IT infrastructure links people and allows collaboration between them beyond space barriers.

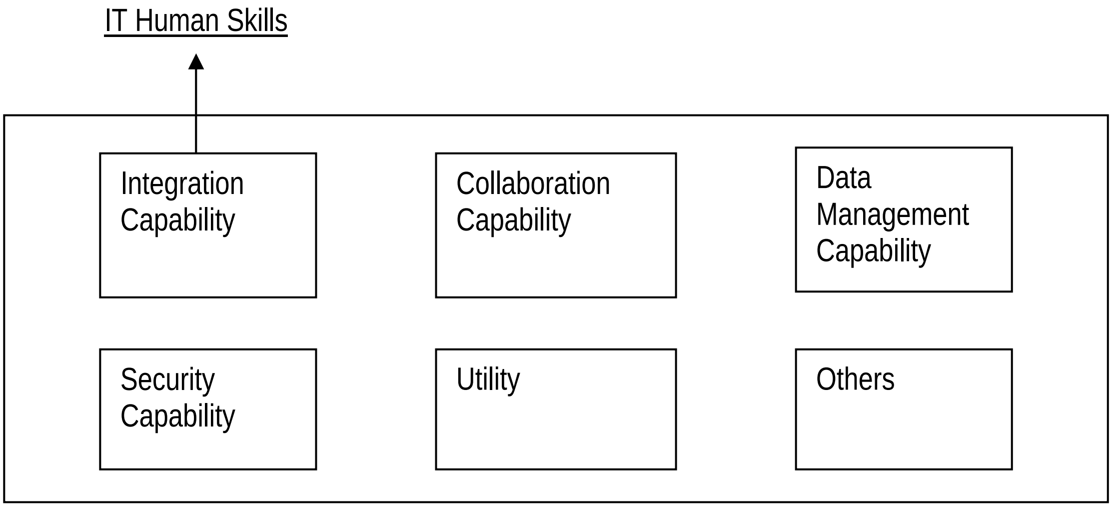
Another concept is data management capability. Data has become an organisational resource. It is the resource shared by multiple users at different levels of management and across various functions. Data is also shared by multiple IT applications. Data resource itself is an integral part of IT infrastructure. The capability to manage the data is an important measure of IT infrastructure capability. The value of an IS is directly related to the quality of the data. Garbage-in-garbage-out is a popular cliché in IS field. The capability to manage the data is an important measure of IT infrastructure capability. Ensuring quality for the data resource has been a continuing concern (Tayi and Ballou, 1998; Wang, 1998; Redman, 1995). The popular knowledge management technologies such as data warehousing, data mining, and knowledge mining can be possible without data captured.

Security is another key concept in IT infrastructure capability. Security refers to the policies, procedures, and technical measures used to prevent unauthorised access, alteration, theft, or physical damage to information systems. Especially, this became a critical issue in IT capability with the advent of the Internet. In a broader sense, security includes disaster management and recovery planning management (Weil and Broadbent, 1998).

Another aspect of IT infrastructure capability is that there are some basic services needed (Weil and Broadbent, 1998). No matter what industry a firm is in, no matter what business a firm is engaged in, no matter what knowledge management approach a firm takes, there are some IT capabilities the firm needs. For example, some capabilities such as IT planning or IT education and training to end-users are needed regardless of their business type or which knowledge management model they are using. Put together, these capabilities can be considered a utility. It works like common public services, such as water and electricity in the public sector.

There are some IT infrastructure capabilities that are difficult to categorise into a specific concept. These capabilities are put in the category of other services in this study. Therefore, IT infrastructure capability consists of the following constructs: integration capability, collaboration capability, data management capability, security capability, utility, and other capabilities. Finally, all these capabilities are combined by IT human skills to provide unique services to organisational processes and IT applications. The human skills are the glue that binds all of them. These capabilities are hard to imitate by competitors. This framework is summarised in Figure 3.2.

Figure 3.2: IT Infrastructure Capability Concepts

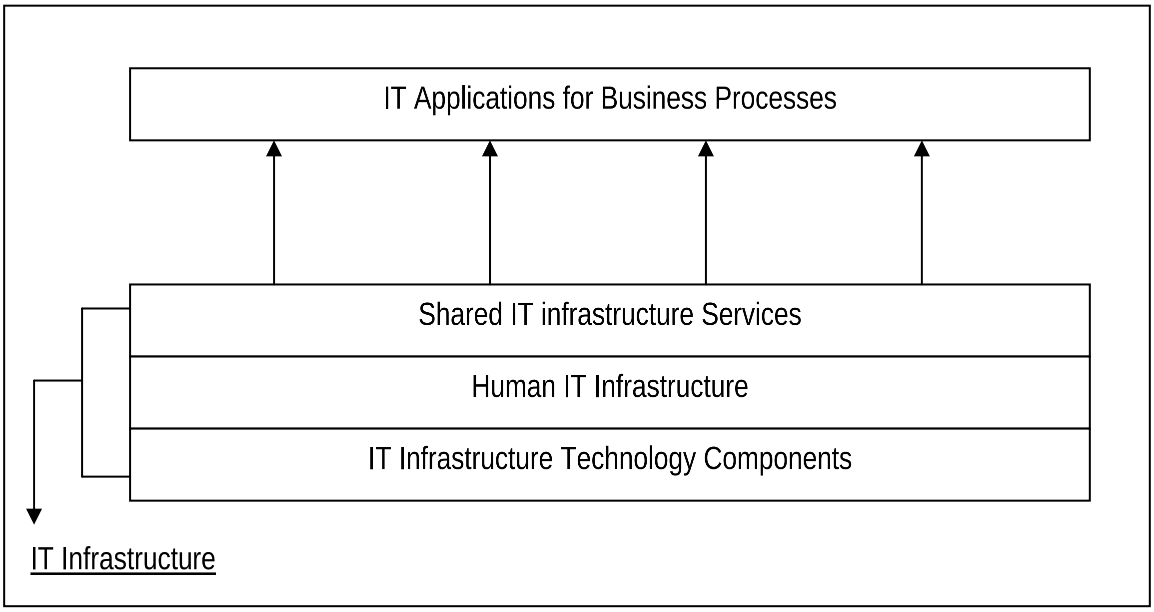


3.2.5 IT Infrastructure Services: A Measurement of IT Infrastructure Capability

IT infrastructure is the foundation of the IT applications. IT infrastructure is shared throughout the firm in the form of reliable services, and is usually coordinated by the IS group (Broadbent, Weil, and St. Clair, 1999). The IT infrastructure capability includes both technical and managerial aspects. One of the measures to assess IT infrastructure capability is the extent of the firm's IT infrastructure services. Broadbent, Weil, and Neo (1996) proposed IT infrastructure services to measure IT infrastructure capability.

To understand IT infrastructure services, it should be mentioned that IT infrastructure consists of four layers (McKay and Broadway, 1989; Weil and Broadbent, 1998). As discussed before, there are technology components (i.e., computers, databases, operating systems, and telecommunication software and hardware) at the bottom layer. At the top of the IT infrastructure there is a set of shared information technology services. The technology components are transformed into useful shared services by a human IT component. This human IT component is shown in the middle layer of Figure 3.3. The services transformed by this layer define the capability of IT infrastructure. This is why organisations can buy the same hardware and software and still provide different IT capability. The infrastructure services "include telecommunications network management and provision of large scale computing (such as Mainframe), the management of shared customer databases, and research and development expertise aimed at identifying the usefulness of emerging technology to the business" (Weil and Broadbent, 1998). These shared IT infrastructure services support shared IT applications. Then these IT applications directly support functional business of organisations.

Figure 3.3: Elements of IT Infrastructure



(Adopted from McKay and Brockway, 1989; Broadbent and Weil, 1999)

"The nature of IT infrastructure can be described from a business perspective using a concept of IT infrastructure services" (Broadbent et al., 1996; Weil and Broadbent, 1998). Weil, Broadbent and Neo originally identified 23 infrastructure services. Later, Weil and Broadbent extended them and suggested 25 services. These 25 services are listed in Table 3.4.

Table 3.4: IT Infrastructure Services

	IT Infrastructure Services
1.	Manage firm-wide communication network services
2.	Manage group-wide or firm-wide messaging services
3.	Recommend standards for at least one component of IT architecture (i.e., hardware, operating systems, data, communications)
4.	Provide security, disaster planning, and business recovery services for firm-wide installations and applications.
5.	Provide technology advice and support services
6.	Manage, maintain, support large scale data processing facilities (i.e., mainframe operations)
7.	Manage firm-wide or business unit applications and databases
8.	Perform IS project management
9.	Provide data management advice and consultancy services
10.	Perform IS planning for business units
11.	Enforce IT architecture and standards
12.	Manage and negotiate with suppliers and outsourcers
13.	Identify and test new technologies for business purposes
14.	Develop business-unit-specific applications
15.	Manage firm-wide or business unit work station networks (i.e., LAN/POS)

16.	Implement security, disaster planning, and recovery for business units
17.	Provide management information electronically (i.e., EIS)
18.	Manage business specific applications
19.	Manage firm-wide or business-unit data, including standards
20.	Develop and manage electronic linkages to suppliers or customers
21.	Develop a common systems development environment
22.	Provide technology education services (i.e., training)
23.	Provide multimedia operations and development (i.e., videoconferencing)
24.	Provide firm-wide intranet capability (i.e., information access, multiple system access)
25.	Provide firm-wide electronic support for groups (Lotus Notes)

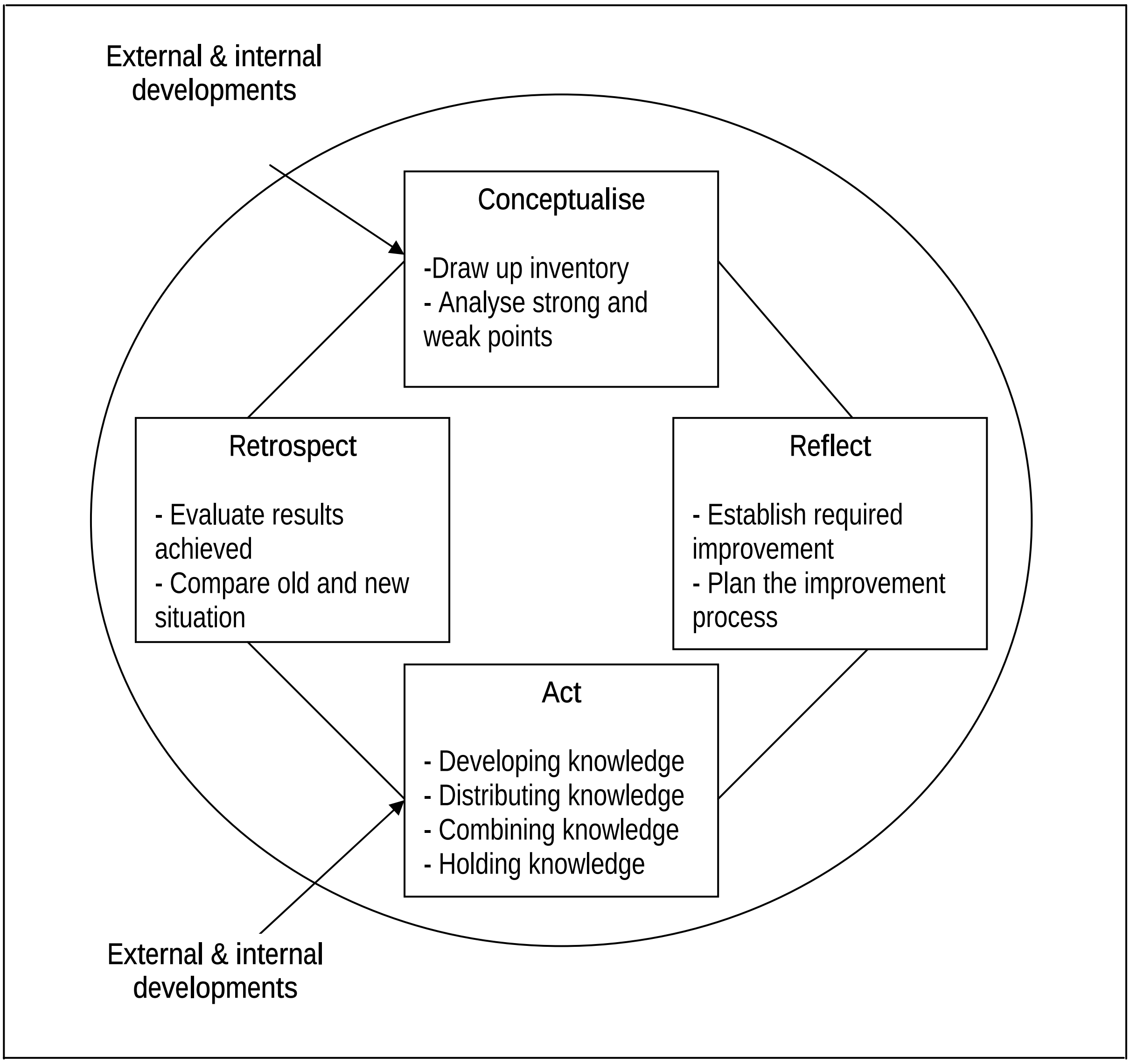
It is important to point out at this juncture that more IT infrastructure services imply better IT infrastructure capability. For example, an organisation that can provide as much of 25 services possible will have IT infrastructures which are more capable.

3.3 FRAMEWORK OF KNOWLEDGE MANAGEMENT STAGES

The framework advanced by Van der Spek and Spijkervet (1997) identifies s cycle of four knowledge management stages: conceptualise, reflect, act, and retrospect. As illustrated in Figure 3.4, these stages control the basic operations on knowledge. The conceptualise stage focuses on gaining insights into knowledge resources. This is achieved through researching, classifying, and modelling existing knowledge. During the reflection stage, the conceptualised knowledge is evaluated using a variety of criteria, required improvements are established, and an improvement process is planned. During the act stage, actions to improve the knowledge are taken. This involves developing new knowledge, plus distributing, combining, and holding this developed knowledge. The last stage, and compares old and new situations.

The configuration of KM stages is oriented toward a problem-solving cycle. Therefore, this configuration can be viewed as one way of coordinating knowledge manipulation activities within a problem-solving episode. The stages in the cycle are impacted by internal and external developments. Internal factors that impact the organisation of the management of knowledge are culture, motivation of employees, organisation, management, and information technology. External factors are recognised as influences, but examples of this factor are not identified in the framework.

Figure 3.4: A Framework of Knowledge Management



(Adapted from Petrash, 1996)

3.3.1 Specific Frameworks

Five examples of specific frameworks related to KM are selected. They are representations of the variety of such frameworks. Two of these frameworks focus on the notion of knowledge as an organisational asset. Two others address the issue of knowledge transfer within an organisation. Another framework depicts the conduct of KM in a specific organisation.

3.3.1.1 Framework of Intangible Assets

Sveby (1997) frames the notion of organisational knowledge as intangible assets. As depicted in Figure 3.5, the framework is comprised of three components: external structures, internal structures, and employee competence. External structures include customer and supplier relationships, brand names, trademarks, and the company's reputation or image. Internal structures include patents, concept, models, computer and administrative systems, and organisational culture. Employee competence consists of skills and knowledge bases of individuals within an organisation. Employees use their skills and knowledge base to act in a wide variety of situations in order to create tangible or intangible assets. When the employees' competencies are directed toward entities outside of the organisation, than they are considered to yield external structures; if those efforts are directed inward, then they are considered to create internal structures.

Figure 3.5: Intangible Asset

INTANGIBLE ASSETS		
EXTERNAL STRUCTURE (brands, customer and supplier relationships)	INTERNAL STRUCTURES (The organisation management, legal structure, manual systems, attitudes, R&D, software)	EMPLOYEE COMPETENCE (Education, experience)

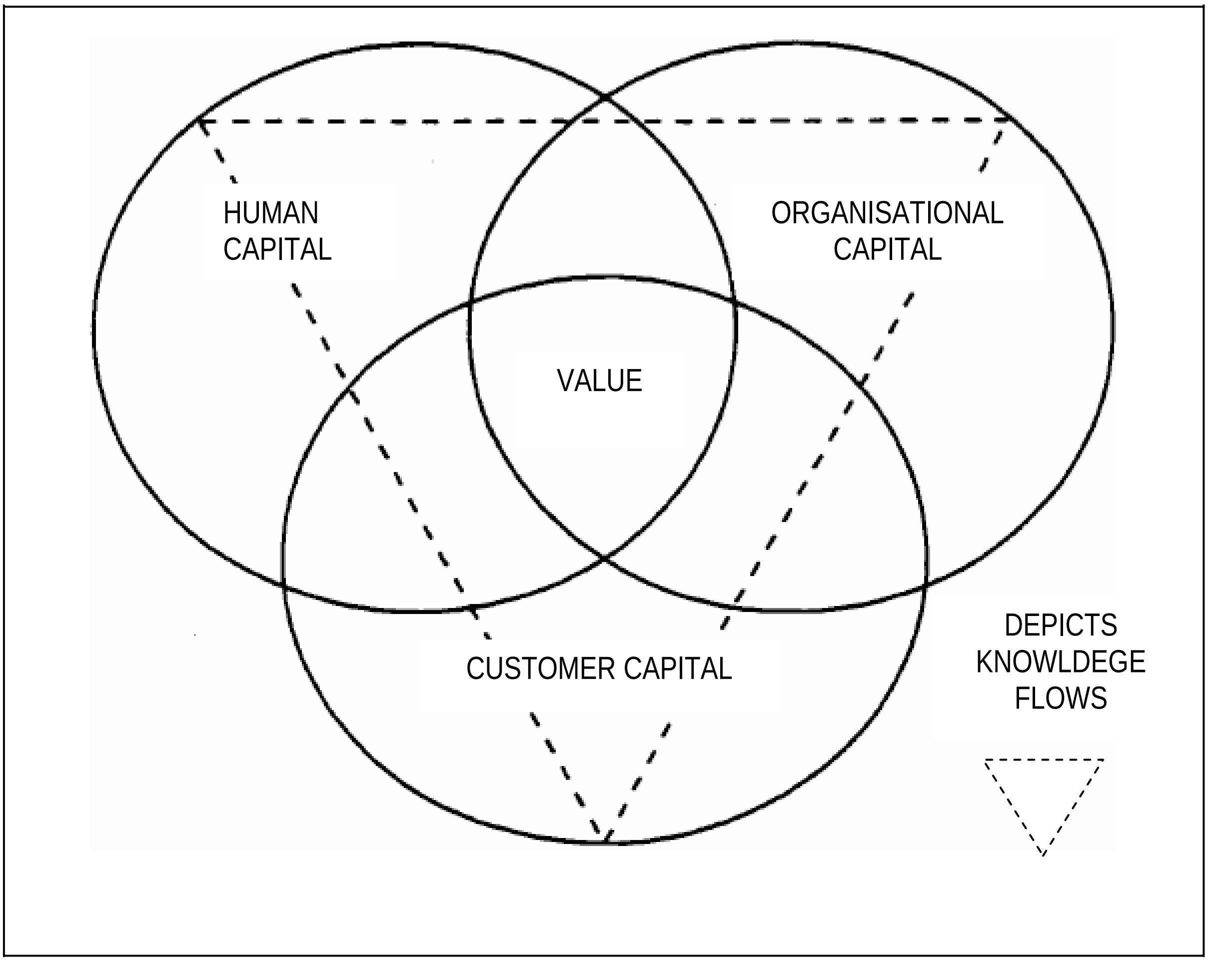
(Adapted from Sveby, 1997)

3.3.1.2 Model of Intellectual Capital

Petrash (1996) has advanced a model involving three types of organisational resources that are referred to as intellectual capital: human capital, organisational capital, and customer capital. Human capital is the knowledge that each individual has and generates. Organisational capital is the knowledge that has been captured/institutionalised as the structure, process, and culture of an organisation. Customer capital "is the perception of value obtained by a customer from doing business with a supplier of goods and/or services" (Petrash, 1996, p.366).

As illustrated in Figure 3.6, this model recognises that relationships among the three major types of intellectual capital lead to financial outcomes (i.e., value). The dotted lines represent the management of intellectual assets. Maximising the interrelationships among the three kinds intellectual capital increases the organisation's "value-creating" space. In Figure 2.7, this is illustrated by creating maximum overlap among the three rings of capital (Bukowitz and Petrash, 1997).

Figure 3.6: Intellectual Capital Model



(Adapted from Petrash, 1996)

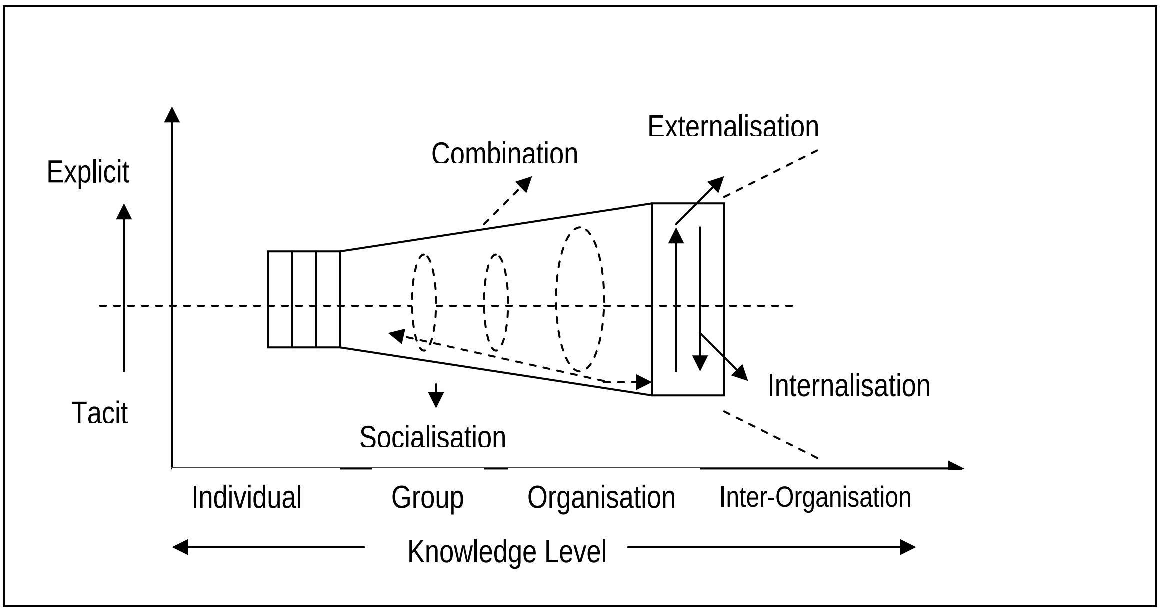
3.3.1.3 Framework of Knowledge Conversions

Nonaka (1991) has advanced a model that identifies four kinds of "knowledge conversion" that drive knowledge creation: socialisation, externalisation, internalisation, and combination. These conversions are base on a dichotomy between the tacit versus explicit modes of knowledge. Tacit knowledge refers to knowledge that cannot be easily verbalised and articulated, and articulated, whereas explicit knowledge refers to knowledge that can be readily verbalised in a formal, systematic language (Polanyi, 1966). The conversion is also based on recognition of distinctions between individual knowledge and collective knowledge.

Socialisation is a process of creating knowledge by converting tacit knowledge from one entity (individual, group, or organisation) to another entity. Combination is a process of creating new explicit knowledge from existing explicit knowledge. The conversion of tacit knowledge into explicit knowledge is called externalisation. The conversion of explicit knowledge into tacit knowledge is called internalisation. Organisational knowledge is created by the interactions among these four conversion processes, and through transferral of tacit/explicit knowledge from individual to group to organisational levels.

Knowledge creation starts with socialisation. This interaction facilitates the sharing of members' experiences and perspectives. Then, successive rounds of meaningful "dialogue" trigger externalisation. Through this dialogue, entities articulate their formerly tacit knowledge to each other. The knowledge that is created through externalisation can be combined with existing knowledge to further refine and extend the knowledge base. This process iterates, with knowledge increasingly taking concrete form through this experimentation of leaning by doing, internalisation takes place. This process of knowledge conversion is illustrated in Figure 3.7.

Figure 3.7: Spiral of Organisation Knowledge Creation



(Adapted from Nonaka, 1991)

3.3.1.4 Model of Knowledge Transfer

Szulanski (2000) has advanced a model for analysing internal stickiness of knowledge transfer, with a focus on transfer of best practices. Internal stickiness refers to the difficulty of transferring knowledge within an organisation. "Intrafirm transfer of best practice is seen as an unfolding process consisting of stages in which characteristic factors not only appear in greater or lesser degree but also in a creation order occurrence" (Szulanski, 1994, p.28). The framework identifies four stages involved in knowledge transfer: initiation, implementation, ramp-up, and integration. It also identifies four factors that impact the difficulty of knowledge transfer: characteristics of knowledge transfer (causal ambiguity and "unproveness"), characteristics of the source of knowledge (lack of motivation and perceived unreliability), characteristics of the recipient of knowledge (lack of motivation, lack of absorptive capacity, and lack of retentive capacity), and characteristics of the context (barren organisational context and arduous relationship).

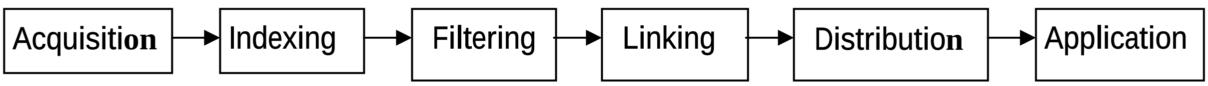
The initiation stage is comprised of all events that lead to the decision to transfer. First, a need for knowledge is recognised which triggers a search for satisfying that need. Once the need and the potential solution to that need are identified then the feasibility of transferring that knowledge is explored. The implementation stage begins once a decision to transfer needed knowledge is taken. In this stage, the knowledge resources flow between the source and the recipient, social ties between the recipient and the sources are established, transfer is customised to suit the needs of the recipient and the sources are established, transfer is customised to suit the needs of the recipient, and care is taken to avoid problems encountered in the previous transfers. These activities cease once the recipient starts to use the received knowledge. In the ramp-up stage a recipient starts using received knowledge. The recipient attempts to identify and resolve unexpected problems that arise while using the new knowledge and meeting (or exceeding) the post-transfer performance expectations. In the integration stage, transferred knowledge gradually becomes routinised and institutionalised.

Data collection to study this model was carried out in a two-step questionnaire survey. in the first round, a feasibility test was conducted to select companies with strong incentives to transfer best practices. Based on the feasibility test, a list of transfers and parties in those transfers (i.e., respondents) were identified for each of the participation companies. For each transfer a questionnaire was sent to the source, the recipient, and a third party to obtain a balanced perspective. The explanatory power of the framework and the relative importance of each barrier was assessed using canonical correlation. The results reveal that the three most important barriers to best practice transfer are lack of absorptive capacity of the recipient, causal ambiguity, and an arduous relationship between the source and the recipient.

3.3.1.5 Model of Knowledge Management Process

This model describes the KM process in a consulting firm, KPMG Peat Marwick (Alavi, 1997). It defines KM as the creation, leveraging, and sharing of know-how and intellectual assets by all individuals across the firm in order to better serve clients. The KM process model developed by KPMG consists of a sequence of six phases as shown in Figure 3.8: acquisition, indexing, filtering, linking, distribution, and application. Acquisition refers to knowledge creation and content development. This is accomplished by distilling experiences and lessons learned from client engagement projects, by collecting, synthesising, and interpreting a variety of information. The next three phases (indexing, filtering, and linking) are referred to as library management activities and include the screening, classification, cataloguing, integrating, and interconnection of content from both internal and external sources. The distribution phase includes packaging and delivery of knowledge in the form of Web pages (e.g., designing knowledge displays, templates, and graphics; creation of multimedia formats). Application refers to using the knowledge that has been collected, captured, and delivered to produce products and services.

Figure 3.8: KPMG Knowledge Management Process



(Adapted from Alavi, 1997)

3.4 CRITERIA FOR FRAMEWORK EVALUATION

The criteria on which the framework is evaluated are: comprehensives, correctness, conciseness, clarity, and utility. Many of these criteria are similar to criteria used for theory evaluation. Comprehensiveness is similar to scope criteria; conciseness relates to parsimony, clarity and correctness relate to construct specification (Bacharach, 1989; Kerlinger, 1986). Each of the criteria is explained below. Each plays a role in guiding the development of the framework as well as in assessing the degree of its success.

3.4.1 Comprehensiveness

Comprehensiveness refers to the extent to which the framework contains the major KM elements and their interrelationships and describes them completely based on the following criteria:

1. The framework should encompass elements within KM-related frameworks currently existing in the literature or practice. In order to ensure this, the framework is mapped against the existing KM frameworks, to verify that it fully accommodates their features.
2. The framework should incorporate major KM-related elements addressed in reference disciplines and reported in practice. In order to accomplish this, framework development involves consideration of KM "best practices" identified by practitioners, KM-related issues raised by practitioners and researchers, elements from reference disciplines that influence KM, and the workings of knowledge-based organisations as defined by practitioners and researchers.
3. Active KM researchers and practitioners are surveyed about the framework's comprehensiveness. The survey contains items to gauge the framework's comprehensiveness.

All three items discussed in connection with comprehensiveness are instrumental in shaping the framework's content during development. Results from items one and three are used for assessing framework's comprehensiveness, whereas, item two does not test comprehensiveness but is a procedure used to help achieve framework comprehensiveness. Therefore, in the report, analysis of item one and results of item three are presented and fully discussed. The set of standards used to accomplish item two, such as a list of "best practices" or list of KM related issues, are not exhaustively enumerated. Rather, they are noted to justify an element's inclusion or illustrate the existence of interrelationships.

3.4.2 Correctness

The elements and their interrelationships within the framework should be accurately defined. Correctness focuses on building descriptive correctness into the framework development rather than prescriptive correctness. The intent is to accurately answer the question "What are KM phenomena in an organisation?" rather than how's and whys about the phenomena. For example, the attempt is to accurately describe each element, its relationships with other elements, and its place in the conduct of KM; no claims are made about how one can effectively handle a specific element or why it is important to handle that element.

In this study, correctness is accomplished by providing theoretical and /or empirical evidence that indicates the accuracy of the framework. This evidence accrues in the development process by drawing on the theoretical and empirical studies of KM phenomena. At the same time, active researchers and practitioners are surveyed to assess the framework's correctness based on specific constructs and items in the survey questionnaire.

3.4.3 Usefulness

The framework should be usable for future research and practice. Utility is demonstrated by the following features: (1) illustrating ways to employ the framework to conduct research, and (2) surveying leading researchers and practitioners about its benefits.

3.4.4 Clarity

The framework's elements and their interrelationships should be clearly defined and described. Clarity is aided by the following examples: (1) using case studies, examples, illustrations, analogies, and metaphors to explain elements and their relationships, and (2) surveying leading researchers and practitioners about its clarity.

3.4.5 Conciseness

Conciseness is fostered by paying attention in development to the following: (1) avoiding redundancy (in terms of elements), and (2) including, among the competing elements, only those elements that are able to adequately describe the KM phenomena with the fewest number of concepts without compromising on other criteria.

CHAPTER FOUR

METHODOLOGY

Quantitative tools utilised for this study comprise of Delphi assessment and survey questionnaire. For the Delphi assessment, a non-parametric analysis using Kendall's coefficient was utilised. For the survey on construction industry consultants, factor analysis as well as a series of reliability tests will be conducted. Subsequently, simple descriptive and inferential statistical analyses were conducted using the .05 level of confidence was used to determine statistical significance.

4.1 DEVELOPING THE DELPHI ASSESSMENT INSTRUMENT

Methods for developing the instrument followed the recommendations of Lindstone and Turoff (1975). A pilot study of the Delphi instrument was conducted among 10 master students for three rounds over three days. After the instruments were ascertained to be reliable, 19 construction experts who were either academicians or professionals with at least eight years of experience and are knowledgeable on the subject issue to become the panel of experts for the study. To achieve an acceptable degree of reliability, we identified the following characteristics as important to the study:

1. Anonymity: The expert participants remain anonymous to one another; they interact only with the research team.
2. Controlled feedback: All information is gathered and redistributed through us.
3. Group response: Individuals contribute information into a group response.
4. Expert opinion: Panelists are selected based on knowledge of the field.
5. Reduced cost and time limitations: The structure of the technique eliminates the need for the participants to arrange costly and time-consuming face-to-face interactions.

The first round of the Delphi assessment, the experts were asked to state their views on the importance of the list of 13 KM factors and components based on the Construction Industry Institute. These thirteen factors namely, front-end planning; design; procurement; construction; start-up and operation; people; organisation; project processes; project controls; contracts; safety, health, and environment; information management and technology systems; and globalisation issues were considered as pertinent to the implementation of KM principles in Malaysia. The responses to this question were analysed from which the second round survey presented a synthesised list of responses from the first round (refer Appendix 1). The experts were asked to rank each factor based on their importance whereby “1” is rated as most important and “13” is rated as least important. In the third round, a separate survey was constructed for each member of the panel by boldfacing factors that differed from the consensus opinion based on each factor's mean rank scores. Each expert was given an opportunity to change his/her response or to present an argument for disagreement. These arguments were incorporated as comments in subsequent sections allowing the experts to look beyond the calculated data. Though the Delphi Assessment has problems in maintaining secrecy among the participating experts as well as possible attrition as the Delphi Assessment progresses, it was an efficient tool to gather quick results. The Delphi Assessment took a maximum of two months to complete.

4.2 SURVEY QUESTIONNAIRE

The first part of the questionnaire was related to KM and was developed by taking into consideration all the variables uncovered in the Delphi Assessment. The second part of the questionnaire was developed by modifying the IT infrastructure capability components identified by Broadbent et al. (1996). Each item of the questionnaire related to KM and IT infrastructures were then anchored with a five-point scale. A final section on demographic information completed the questionnaire. A preliminary version of the questionnaire comprising of 79 items was developed for pilot testing.

Consultants from the construction industry were sent a letter with the questionnaire inviting them to participate in the survey. In accordance with the norm, participation in the study was voluntary and the subjects were free to withdraw at any time without penalty. They were free to decline to answer any questions they did not wish to answer. The subjects were informed that their responses would be anonymous and confidential and that all questionnaires would remain with the research team.

In line with recommendations by Kirkpatrick (1971), the study's data collection instrument is a structured multi-item questionnaire with several open-ended questions (refer Appendix 2). Open-ended questions in the survey questionnaire free the subjects from the limitations of forced choice answers and potentially allow the expression of the subject's personal opinions. Open-ended questions have the potential of bringing out silent factors and can capture idiosyncratic differences (McMillan and Schumacher, 1997).

The questionnaire for the study consists of the following sections: (1) knowledge management; (2) trainee IT infrastructure; and (3) demographic information. Towards the end, the respondents were requested to provide comments to ensure that their personal views could be expressed without being restricted by the five-point scale. Data for the study was collected by a survey questionnaire designed to obtain construction industry consultants' perceptions relating to the relation between KM and IT infrastructure. Research by survey is a typical way to "determine the opinions, attitudes, preferences, and perceptions of persons of interest to the researchers" (Borg and Gall, 1993, p. 219). Investigations are generally conducted for the interrelationships of certain responses, especially those involving demographic information (Krathwohl, 1993, p. 361-362) and attitudinal variables in social science research (Vierra, Pollock and Golez (1998).

Close-ended questions comprised of scales to measure differences in perceptions along a five-point continuum. Likert-like scales provide more information about the respondents' degree of contribution, agreement or necessity, and can provide subtler and deeper ramifications of the perception to be explored (Oppenheim, 1992). The appropriate number of points used in the scale is often debated. Some researchers agree that the optimal length of the scales needs to be determined by the nature of what is to be examined and the extent to which respondents can discriminate among levels (Light, Singer and Willet, 1990). According to Oppenheim (1992), reliability of the five-point scale is good and permits a greater range of answers to respondents than smaller point scales. We followed Oppenheim's recommendation in using the five-point scale as it is good and permits a greater range of answers to respondents than smaller and larger point scales.

4.2.1 Checking Content Validity of the Survey Instrument

To ensure the validity of the survey questionnaire for assessing the relationship between KM and IT infrastructures, three prominent Malaysian professors who are experienced in scale development and quantitative methods were invited to evaluate the content validity of the survey instrument. They were asked to rate on a three-point scale of low, moderate and high relevance in the following three aspects: (1) the proposed eight variables, (2) the subject – construction industry consultants, and (3) the context – construction consulting companies. They were also asked to give their comments in terms of clarity and conciseness, and on any other changes, additions or deletions of items (or attributes) which they felt were unnecessary. Most of the items were rated as high relevant. Based on the recommendations by the 3 professors, the instrument underwent minimal modifications. The modified version with 79 items was produced and deemed as ready for pilot testing.

4.2.2 Developing and Testing the Survey Instrument

After the validation process, a pilot test was conducted for three reasons. Firstly, it helps to pre-test the performance of the scale so as to identify problematic or redundant items. Secondly, it also helps to adjust the length of the instrument. Thirdly, it can also be used for collecting comments from the respondents for further improvements on the instrument.

A pilot study of the questionnaire was conducted by distributing a copy of the questionnaire to a small random sample of thirteen consultants representing all types of the construction industry. They were asked to answer the questionnaire as well as comment on item clarity, understanding and readability. Based upon analysis of the response, the questionnaire was modified and re-piloted for a second time. To further validate item reliability (Nunnally, 1978), a reliability analysis was conducted at the end of the second pilot. All of them were able to complete the whole set of questionnaire within 20 minutes, which was a manageable time for a 4-page questionnaire like the one used in this study.

4.2.3 The Finalised Questionnaire

The questionnaire was able to fit conveniently into four A4-sized pages. A cover page was used to explain the purpose of the questionnaire survey to the respondents. Additionally, a back page was used for them to give additional comments on the questionnaire (refer Appendix 2). The finalised version of the questionnaire to be used for the fieldwork comprises of three sections and 79 items:

Section 1: Knowledge Management comprises of (1) Front-End Planning *(Implementation of pre-project planning at the corporate and project level. Implementation of early estimating in project planning and risk management, Use of modularisation and pre-assembly as a tool at project level);* (2) Design *(Availability of design standard for every project, Implementation of design effectiveness at the project level. Implementation of cost effective engineering for every aspect in project design, Availability of computer-aided to design every project);* (3) Procurement *(Management of supplier relationship, Sharing and transferring knowledge with clients, customers and suppliers, Implementation of material management at project level), Comprehensive material management training programme, Resources are sufficient to implement material management (e.g. time, computer and people), Availability of specific documentation to support the implementation of material management (e.g. file documents, database, etc), Measurement of material management cost and benefits);* (4) Construction *(Control of cost and schedule based on the master plan, Appropriate actions taken based on the cost and schedule control for every project, Implementation of risk management at the project level. Regular updating of* *database of good work practices for risk management, lessons learned and listing of experts, Management of workers' compensation based on regional standard);* (5) Startup And Operation *(Availability of design for maintainability to measure project performances, Management of planning for startup to ease collaboration work of projects or teams that are physically separated (i.e., different work sites));* (6) People *(Availability of formal and informal training to keep employees' skills current, Availability of appropriate tools to measure productivity measurement. Sufficiency of resources to ensure multi-skilling of employees at the project level);* (7) Organisation *(Identification of barriers for implementation of project team, Implementation of appropriate strategies for leader selection for every project, Implementation of comprehensive partnership training programme, Management of the organisational work structure at the project level, Implementation of quality management at the project level, Identification of barriers to the implementation of products and services based on planning and design, Ability to adapt products and services to client requirements, Utilisation of appropriate strategies and experiences to determine benchmark);* (8) Project Control *(Implementation of systems for change management, Resources are sufficient to implement change management (e.g. time, computers, and people), Measurement of costs and benefits of work packaging, There is a written process for work packaging implementation within the project);* (9) Contracts *(Availability of written process for project delivery and contract strategies within the project, Usage of project incentive is implemented at the project level);* (10) Safety, Health, And Environment *(Implementation of zero accident techniques at the project level, Implementation of design for safety for every project);* (11) Information Management And Technology Systems *(Automatic identification of barriers/problems for project processes (design, control, crash programme, etc) using information technology (software application: Primavera, Microsoft project, ETABS, SAP2000, etc), Utilisation of electronic commerce is used to increase number of markets (e.g. wider geographic locations) and to improve client and customer relations (i.e., website, E-mail, etc), Management of fully integrated and automated project using information technology (i.e., database, filing system, sharing data, etc), Utilisation of wireless technology for project processes, Wireless technology is implemented for project processes);* and (12) Globalisation Issues *(Implementation of international standards to improve the competitive advantage, Ability to capture employees' knowledge from other sources (i.e., other business enterprises, industrial associations, technical literature, public research institutions including universities and government laboratories).*

<u>Section 2</u>: IT infrastructure consists of (1) Integration Capability (*Manage communication network service (e.g., phone contact, fax, etc), Manage messaging service (e.g., E-mail, Notice board, etc), Manage business unit workstation networks (e.g., LAN/stand alone PC), Manage business applications (e.g., software applications: Microsoft office, Microsoft Project, Primavera, etc), Recommend standards for IT architecture components (e.g., hardware, operating systems, and communications, Enforce IT*

architecture); (2) Collaboration Capability *(Provide multimedia operations and development (e.g., video conferencing), Provide intranet capability for document management, Provide intranet capability for collaboration (e.g., local resource sharing), Provide electronic support for groups (e.g., documents, tutorials, CD software, etc));* (3) Data Management Capability *(Provide data management advisory and consultancy services, Manage business-unit data, including standards (e.g., oracle, database system), Manage database management system, Manage, maintain and support large scale data processing facilities);* (4) Security Capability *(Provide security for firm-wide database and applications (e.g., file/data backup, anti virus software, etc), Implement disaster planning and recovery system for business units (e.g., backup, disk tools, etc);* (5) Utility Capability *(Provide technological advice and support services for internal requirement, Provide training services for new technologies (e.g., software training, etc), Utilise Information System (IS) for project management, Utilise IS planning of business units, Utilise IS to manage and negotiate with suppliers and subcontractor (by tenders, quotations in buying or dealing));* and (6) Other Capability *(Provide management information electronically (e.g., EIS), Develop and manage electronic linkages to suppliers or customers (e.g., website, E-mail address, etc), Develop a common systems environment).*

Section 3: Demographic Information is made of the following items type of company, company ownership, position, working experience, education level. A request for the respondent's e-mail address was included towards the end of the questionnaire with a promise to send to the respondent the executive summary of the research report. At the same time the inclusion of this request was design to convince respondents that they will get a copy of the report provided they participate by answering the questionnaires.

By making use of the survey instrument developed and validated earlier, the major part of the quantitative study was carried out using postal method for survey of construction industry consultants in Malaysia. Fieldwork commenced from mid January until mid May 2005. Factor analysis and reliability tests were than conducted on the data collected for statistical validity and reliability following which descriptive and inferential analyses were performed to answer the research questions in this study.

4.3 SAMPLING FRAME FOR SURVEY

Listings of the construction industry consultants were obtained from the Construction Industry Development Board. The list is equipped with the address, telephone and fax numbers of the construction industry consultant. From the list of 800 consultants, it turns out that a sizeable number (about 300) of the companies listed cannot be contacted by phone or by fax. Companies with no phone or fax numbers and no e-mail address are deemed 'uncontactable' for the purpose of the survey. We assumed that the 300 companies had either closed down or has moved. From the remaining 500 consultants, the questionnaires were sent with a self-addressed-stamped-envelop. One hundred and twenty two returned questionnaires were collected during a period of five months after several rounds of reminders were sent to companies which did not respond.

4.4 STATISTICAL PROCEDURES

The procedures followed for this phase of this report were as follows:

1) All questionnaires were reviewed for completeness
2) Data was entered into an SPSS 12.0 for Windows database
3) Entry data was independently checked on a random basis
4) Data was analysed by SPSS 12.0 for windows to deliver combinations of statistical information (Bryman and Cramer 1997).
5) Combinations of statistics in Table 4.1 were utilised to interpret survey results.

Table 4.1: Statistics Used in Analysis

Statistic	Description
N	The total number of data within the area of description
Range	The difference between the largest and smallest numbers in the set
Mean	Sum of all responses divided by the number
Standard Deviation	Measure of how values are spread around a mean (are they clustered or widely dispersed)
Variance	Sample standard deviation divided by the square root of the sample size
Independent Sample t-test	Measures the degree to which two variables are related and similar or different
Terrell's transformation	A method used to transform ordinal data representing a particular construct into an index ranging from 0 to 100
Kendall's coefficient of concordance	Used to test if ranking of response is consistent or not
Factor Analysis	Measures statistical validity by forming logical groupings of items
Reliability test	Using Cronbach's alpha to measure statistical reliability

4.4.1 Descriptive Analysis

Descriptive analysis using frequency tables were used to present means and standard deviation as well as frequency counts of the data. Though not powerful enough to make any conclusions, they provide some indicator of the patterns of data behavior.

4.4.2 Kendall's Coefficient of Concordance (W)

Following the completion of the third round of the Delphi Assessment, the Kendall's Coefficient of Concordance (W) was computed for the scored ranking to measure the level of consensus among the experts for the factors proposed with respect to both rounds. The Kendall's Coefficients of Concordance (W) will be tested for statistical significance by observing the p-value and comparing the Chi-square test statistics with the critical value. Kendall's W is a measure designed to determine to which a set of ranked scores agree (Siegel, 1956). A significant W indicates that the participants are essentially applying the same standard in judging the importance of the factors and they are in consensus. As such, what is desired is a high W (close to 1) and a low p-value (less than 0.05) so that the null hypothesis that there is no consistency in response from the experts can be rejected.

4.4.3 Factor Analysis

In order to further study interrelationships and to identify the strongest cluster of questionnaire items related to construction industry consultants' perception on the KM and IT infrastructures, a factor analysis was conducted. Construct validity using factor analysis was used to reduce and summarise data in which redundant items and inappropriate items were deleted (Hair et al., 1998). The study reports only those interrelationships with a correlation coefficient of .60, moderately high, or higher. The factor analysis used a principal component analysis as the extraction method and varimax with Kaiser normalisation rotation method to explain the item variance. Only clusters of questionnaire items organised into components to standard eigenvalue of 1.000 were reported.

4.4.4 Reliability Test

Scale reliability using Cronbach's Coefficient Alpha was used to assess the consistency and homogeneity of items (Cooper and Schindler, 1988). Reliability coefficients were computed for the questionnaire. In assessment of people, researchers recommend a reliability coefficient above .90 for comparisons among individuals and at least .70 for comparison among groups (Fraenkel, Wallen and Sawin, 1999).

4.4.5 Terrell's Transformation

Questionnaire items which are ordinal data will be converted to continuous data using Terrell's transformation technique (Terrell, 2000) based on the following formula:

Transformed Score = [(actual raw score – lowest possible raw score)/possible raw score range] x 100

This technique was used so that construct means could be calculated in order to facilitate other parametric test such as the independent sample t-test.

4.4.6 Independent Sample T-test

The independent-samples t test is used to evaluate whether the mean of a single variable for subjects in one group statistically differs from that in another group. It does this by comparing the difference between the two means with the standard error of the difference in the means of different samples. To be able to perform this test, each case must have at least two variables: the grouping variable and the test variable. Within context of this research, the grouping variable divides the cases into two mutually independent groups or samples (e.g., exploitive or explorative and unique or standardised), while the test variable defines each case on some quantitative measure (the overall mean). The test variable is used to test for a difference between two independent groups on the means of a continuous variable.

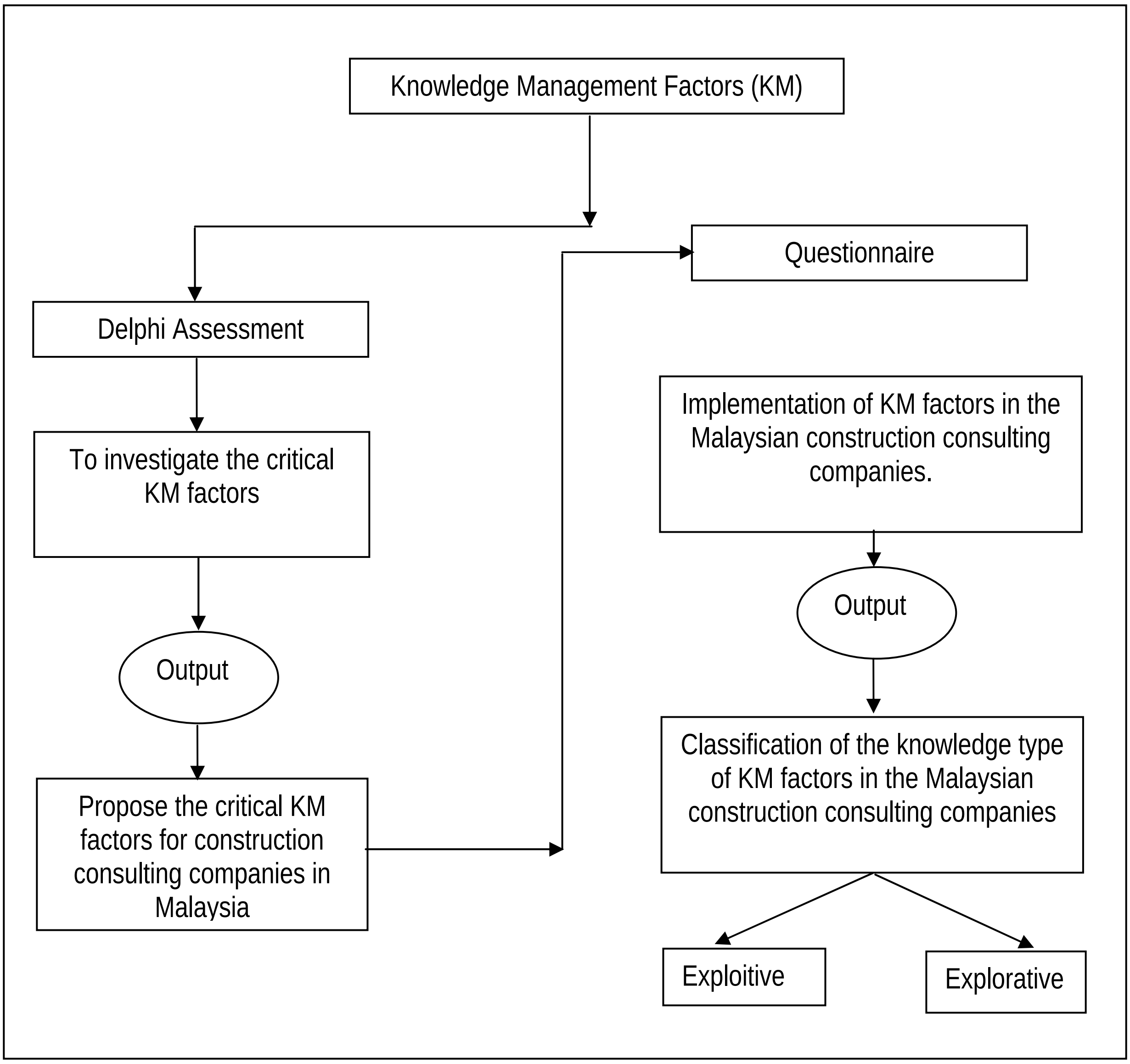
4.5 RESEARCH FRAMEWORK

4.5.1 Knowledge Management Model

As discussed before, consulting firms with different knowledge requirements adopt different KM approaches. Hansen et al. (1999) recommended companies to ask three questions for its KM assessment: "Do you offer standardised or customised products? Do you have a mature or innovative product? Do your people rely on explicit or tacit knowledge to solve problems? "These three questions can be summarised into two concepts: <u>service type</u> and <u>knowledge type</u> used. The KM approaches that the firms adopt depend on their knowledge and service types to serve their customers.

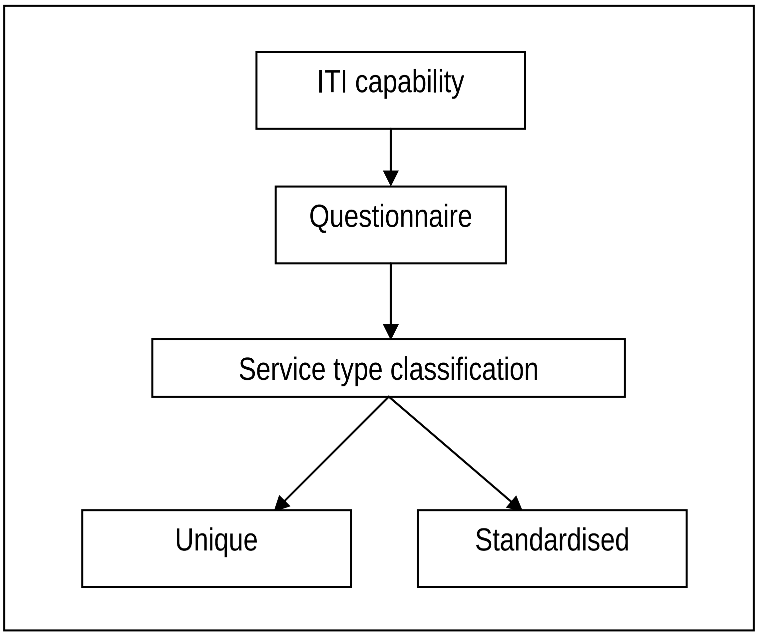
The knowledge type has two dimensions: exploitive or explorative. Knowledge type is "exploitive" when a firm's key concern is to capture explicit knowledge and utilise it by codification. Knowledge type is "explorative" when a firm's key concern is to generate new knowledge, mostly tacit knowledge by collaborative works between people. The processes of identifying knowledge types go through a systematic sequence as shown in Figure 4.1.

Figure 4.1: Knowledge Type Identification Process



The service type has two dimensions: unique or standardised. Service type is "unique" when a firm provides highly customised, context-dependent, and expertise-oriented service to a customer's unique problem (i.e., strategic consultancy). Service type can be "standardised" when a firm provides relatively low context-dependent and procedure-oriented services (i.e., IT consultancy). The processes of identifying service types go through a systematic sequence as shown in Figures 4.2.

Figure 4.2: Service Type Identification Process



4.5.1.1 Knowledge Type

The knowledge type can be exploitive or explorative. The knowledge type determines how explicit the knowledge is. By nature, explicit knowledge is exploitive. Exploitive knowledge can be precisely articulated and codified. It may be in the form of mathematical formulas, databases, manuals, or documents. Therefore exploitive knowledge can be easily transferable to other people. Declarative knowledge (which describes something) and procedural knowledge (which explains how something occurs or is performed) are two examples of exploitive knowledge (Zack, 1999).

On the contrary, explorative knowledge is tacit in nature. Such knowledge is difficult to understand. It is difficult to articulate and codify. Tacit knowledge can be developed from direct experience and interactive conversation. The expert's real expertise tends to be explorative. This type of knowledge is not easily transferred and also very useful to explore and handle new problems and situations. Casual knowledge is an example of explorative knowledge and explains why something occurs (Zack, 1999). If people understand the cause and effect of the something, people can predict what will happen based on the relationship. In another world, this will help us bring new knowledge.

As Jordan and Jones (1997) pointed out, exploitive knowledge can be acquired through a manual or database, but explorative knowledge can be acquired through mostly trial and error.

Exploitive knowledge can be transferred easily (i.e., through classroom lectures or presentations), but explorative knowledge is hard to transfer and can be transferred mostly through coaching or apprenticeship. Exploitive knowledge can be disseminated in the formal and structured ways, but explorative knowledge can be disseminated through more informal ways such as role modeling or daily interaction. In the learning focus, exploitive knowledge tends to be incremental and explorative knowledge tends to be transformative or radical. These are summarised in the Table 4.2.

Table 4.2: Knowledge Type

Variable	Item	Exploitive	Explorative
Knowledge Type	Orientation	Procedure oriented	Expertise oriented
	Application Process	Table look up	Trial and error
	Training Method	Class room	Apprenticeship/coaching
	Ease of Transfer	Difficult	Easy
	Dissemination Process	Formal/ prescribed/ structured	Informal/Role modeling/ daily interaction.
	Scope	Incremental	Transformative

4.5.2 IT Infrastructure Capability

IT infrastructure (ITI) is the enabling foundation of shared information technology capabilities upon which business depends (McKay and Brockway, 1989). IT includes software and hardware components. These technological components are transformed into a set of capabilities that support business. IT infrastructure capability is the combination of the technology components, human skills and management. It supports IT applications and business operations. IT infrastructure capability is a resource that is difficult to imitate because it is created through the fusion of technology and human assets (Duncan, 1995). The overall IT infrastructure capability is the composite capability of integration, collaboration, utility, security, data management and other capabilities.

IT infrastructure should support KM activities. The ideal IT infrastructure is one that provides the capability to link anyone to any application at anytime, anyplace. However, the organisational resource is scarce (i.e., financial or human resources). IT infrastructure investment needs huge financial and human capital. If a firm understands the relationship between IT infrastructure capability or organisational KM, then it can prioritise IT infrastructure investments and distribute resources more effectively and efficiently. Also, this will help managers plan and implement KM projects more effectively with appropriate IT support.

For example, one type of knowledge management model may be more concerned about utilising the pre-existing knowledge and require IT capabilities that can support structuring, organising and storing, and sharing and using knowledge. In this type of model, a great amount of existing knowledge will be stored in a database, knowledge base/repository, document database, or data warehouse. Since then, employees or applications across the entire organisation are allowed to access them. To allow such access, the applications must be compatible so that they can be shared among multiple sources. Then, integrating the capabilities of the IT infrastructure will be critical. A firm-wide management of IT including architecture, standard, centralised management, and policy will be critical issues.

IT infrastructure capability includes integration capability, collaboration capability, utility, security capability, data management capability, and other capabilities.

1. Integrating Capability. Integrating capability refers to the ability of "linking individual IT components and services for the purpose of sharing software, communications, and data resources" (Keen, 1991). The goal of IT integration is to allow physical IT components (such as hardware, software, data, and telecommunications) working together as a integrated resource. Integrating capability of IT infrastructure can assure enterprise wide compatibility among IT components so that IT applications can be accessed and used by employees across the firm.
2. Collaborating Capability. Collaborating capability refers to capability of allowing mutual efforts by two or more individuals in order to perform a specific task. The goal of collaborating capability of IT infrastructure is to provide support for linking people so that they can work together. Collaborating capability allows ideas and opinions to flow freely and new knowledge to be created. To allow collaborative work, people should be connected regardless of their physical locations.
3. Data Management Capability. Today's view of IT infrastructure includes data as a part of it. Data itself has become a part of IT infrastructure. It is the resource shared by multiple applications and users at different levels of management. The value of an IS is directly related to the quality of the data. Data management capability is the capability to manage data. Data

management includes collecting, structuring, storing, transforming and retrieving data. This capability also includes data architecture, database management systems, and database applications.

4. Security Capability. Security is the capability to minimise IT vulnerability and abuse. Security refers to the policies, procedures, and technical measures used to prevent unauthorised access, alteration, theft, or physical damage to information systems. Backup, disaster management, and recovery planning are important components of this capability.
5. Utility. Utility is the basic and common services that every type of IT infrastructure has. No matter what industry a firm is in and no matter what business a firm is engaged in, these capabilities are required. For example, IT planning training, education, and providing support to users are included in the capability.

Even though all of the above 'capabilities' are important, different knowledge management models will need different capabilities in different degrees. A specific KM model will need some capabilities more than others depending on the situation faced by the company. As mentioned beforehand, the service type for a particular KM approach has two dimensions: unique or standardised. Service type is "unique" when a firm provides highly customised, context-dependent, and expertise-oriented service to a customer's unique problem (i.e., strategic consultancy). Service type can be "standardised" when a firm provides relatively low context-dependent and procedure-oriented services (i.e., IT consultancy). As such a better understanding of service types need to be mapped based on the five categories of IT infrastructure capabilities.

4.5.2.1 Service Type

Service type defines what IT service a construction consulting company is providing to its customers. The service type can be unique or standardised. The level of customisation is one of the factors in classifying service type (Davis, 1999). The factor determines how customised service a firm is providing. If their customers have unique problems, then firms need to provide highly customised services. The maturity of their services will determine their service type (Hansen et al., 1999). Highly mature service processes are well understood, while highly innovative services are not. The highly mature service can be provided in more standardised way. The problem structure a consulting deals with will also determine the service type (Hansen et al., 1999). For example, the unique service tends to deal with the unstructured customer's problem. These are summarised in Table 4.3.

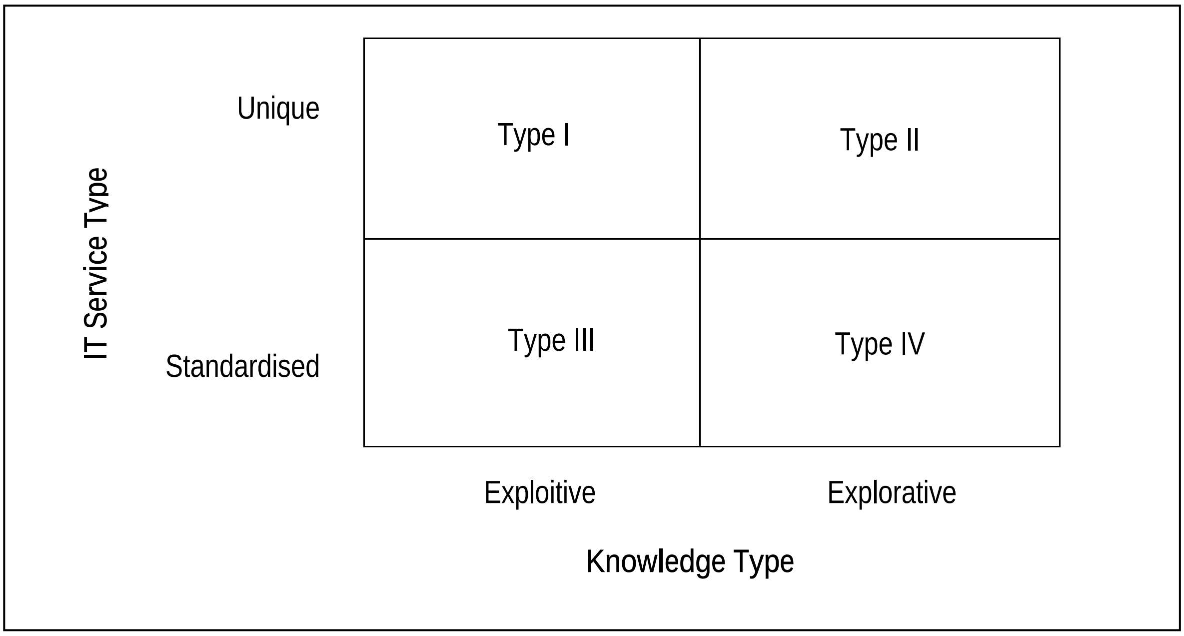
Table 4.3: Service Type

Variables	Items	Standardised	Unique/Exclusive
Service type	Service Concept	How to develop and deliver services	What services to provide
	Maturity	Mature	Innovative
	Focus	Highly reliable/ quality/ fast delivery service	Creative/ totally new type of service delivery
	Customer Problem	Structured	Unstructured
	Standardisation	Standardised	Customised

4.6 THE PRELIMINARY KM-ITI FRAMEWORK

Understanding the service type provided and knowledge type used by construction industry consulting companies is important to categorise the sample consulting companies into one of four different KM models. Each variable has two dimensions, making four cells altogether. Each cell represents one of the four distinct KM models. Together, the two dimensions form four different types of KM models: unique service with exploitive knowledge, unique service with explorative knowledge, standardised service with exploitive knowledge, and standardised service with explorative knowledge. These four distinct models are termed as Type I, Type II, Type III, and Type IV in this study. The classification is reproduced in Figure 4.3.

Figure 4.3: The Preliminary KM-ITI Model



The vertical axis describes a firm's service type. The horizontal axis describes the knowledge type that a firm mainly uses to deliver the service. For the firms positioned in the top half (Type I and Type II), services are characterised as highly customised. The requirements of their customers tend to be unique. Their customers' problems are highly context dependent. Such problems are usually unstructured. A firm should provide highly customised solutions to customers' unique problems. The key here is on providing creative, innovative and totally new types of services. Their consultancy focuses on service itself: WHAT service is provided.

For the firms positioned in the left half (Type III and Type IV), services are characterised as highly standardised. The problems of their customers are low context dependent compared with Type I and Type II models. Such problems tend to be less structured or structured. Here the key is on providing highly reliable and quality services. Their consultancy focuses on the operational side of the solutions: HOW the service is delivered.

For the firms positioned in the left half (Type I and Type III), the knowledge type used is characterised as exploitive. The knowledge used is explicit and procedure oriented. This type of knowledge is easy to codify in the database, manuals, or knowledge repository. The knowledge initiative is to know what the firm already knows. The firm may already have the knowledge required for service somewhere in the organisation. However, the firm may not know that it knows. Or even though the firm knows that it knows, it may not know where it is located. Therefore, the knowledge is recreated again and again. Organisations need to know how to share the existing knowledge. Many firms underutilise much of their existing knowledge because its existence is unknown to those who need it. The focus is to capture and store knowledge in the knowledge repository and utilise the stored knowledge repeatedly. This achieves the economies of scale for knowledge reuse.

For the firms positioned in the right half (Type II and Type IV), the knowledge type used is characterised as explorative. The knowledge used tends to be tacit and expertise oriented whereby most of the time such knowledge exists in people's brain. The KM focus is to know what a firm does not know because it is hidden in people's head or it does not have it. This can be achieved through encouraging creative thinking and free exchange of ideas. Throughout the process, ideas continually flow between people. Locating source of knowledge, connecting them, and collaborating with them are critical. Such collaborative work encourages creativity and idea generation. These eventually will be translated into new knowledge.

CHAPTER 5

FINDINGS

This study deployed a two-level sequential method to identify the critical components of KM principles deemed as important to the construction industry consultants based on a Delphi assessment. Findings from the Delphi assessment were tested for consistency using Kendall's coefficient of concordance. Subsequently, the input from the Delphi assessment was incorporated into a survey questionnaire. Descriptive statistics were derived from the questionnaire data followed by the conduct of factor analysis and reliability tests to ascertain statistical validity and reliability.

5. 1 THE FIRST LEVEL OF THE KM RESEARCH

The first level of KM research commenced with a three-round Delphi assessment. In the first round of the Delphi assessment, thirteen factors considered as being critical components of KM principles was adopted from Construction Industry Institute (CII, USA), United State of America. These thirteen factors namely, front-end planning; design; procurement; construction; start-up and operation; people; organisation; project processes; project controls; contracts; safety, health, and environment; information management and technology systems; and globalisation issues are accepted as standards within the construction industry worldwide and are considered as pertinent to the implementation of KM principles in Malaysia (refer Table 5.1).

Table 5.1: List of KM Factor and Component

No	KM factor	Component
1	Front-End Planning	- Pre-project planning - Early estimating - Modularisation/Pre-assembly
2	Design	- Design standard - Design effectiveness - Cost effective engineering - Computer-aided
3	Procurement	- Supplier relationships - Material management
4	Construction	- Cost and schedule control - Risk management - Managing worker compensation
5	Startup and Operation	- Design for maintainability - Planning for start-up

6	People	- Management of education and training - Productivity measurement - Multiskilling
7	Organisation	- Project teams - Leader selection - Partnering - Organisation work culture
8	Project Processes	- Quality management - Implementation of products - Benchmarking
9	Project Controls	- Change management - Work packaging
10	Contracts	- Project delivery and contract strategies - Use of project incentive
11	Safety, Health and Environment	- Zero accident techniques - Design for safety
12	Information Management	- Automatic identification - Electronic commerce - Fully integrated and automated project process - Wireless technology - Automation and robotics
13	Globalisation Issues	- International standards

Source: Construction Industry Institute (2004)

In the second round, nineteen experts comprising of professionals who are knowledgeable on the subject matter were invited to become the panel of experts for this stage. The experts were asked to "agree" or "disagree" to each component of KM factor. Table 5.2 shows the results of the second round.

Table 5.2: Results of the Second Round Delphi Assessment

KM FACTOR	Agree	Disagree	No Answer
Front-End Planning			
Pre-project planning	19	-	-
Early estimating	18	1	-
Modularisation/Pre-assembly	16	3	-
Design			
Design standard	15	4	-
Design effectiveness	17	2	-
Cost effective engineering	18	1	-
Computer-aided	18	1	-
Procurement			
Supplier relationships	15	4	-
Material management	19	-	-
Construction			
Cost and schedule control	19	-	-
Risk management	16	3	-
Managing worker compensation	16	3	-

Startup and Operation			
Design for maintainability	17	2	-
Planning for startup	18	1	-
People			
Management of education and training	15	4	-
Productivity measurement	15	4	-
Multiskilling	13	6	-
Organisation			
Project teams	18	1	-
Leader selection	16	2	1
Partnering	15	3	1
Organisation work culture	18	1	-
Project Processes			
Quality management	19	-	-
Implementation of products	17	1	1
Benchmarking	14	5	-
Project Controls			
Change management	12	7	-
Work packaging	14	4	1
Contracts			
Project delivery and contract strategies	18	1	-
Use of project incentive	16	3	-
Safety, Health and Environment (SHE)			
Zero accident techniques	14	5	-
Design for safety	17	2	-
Information Management			
Automatic identification	13	5	1
Electronic commerce	12	6	1
Fully integrated and automated project process	12	6	1
Wireless technology	12	7	-
Automation and robotics	9	9	1
Globalisation Issues			
International standards	12	6	1

As shown in Table 5.2, the automation and robotics component of information management factor was recommended to be excluded, as nine experts disagreed on the importance of this item, while nine other experts considered this item to be included and one expert did not answer. Due to attrition, in the third round only fifteen experts participated in the ranking of each factor based on their importance whereby "1" was rated as most important and "13" was rated as least important. Following the completion of the third round of the study, Kendall's coefficients of concordance (W) were calculated to assess the level of consensus among the experts. Kendall's W is a measure designed to determine the level of agreement for a set of ranked scores (Siegel, 1956). A significant W indicates that the participants are applying essential the same standard in judging the importance of the factors and that they are in consensus which is reflected by a high W and a low p-value (less than 0.05), so that the null hypothesis that "there is no consistency in response from the experts" can be rejected. The results for the third round are presented in Table 5.3.

Table 5.3: Results of the Third Round Delphi Assessment

Knowledge Management Factor	Mean Rank	Rank
Front-End Planning	3.73	1
Organisation	4.00	2
Design	4.80	3
Construction	4.93	4
Contracts	5.53	5
Startup and Operation	6.53	6
Procurement	6.93	7
People	7.07	8
Project Processes	7.20	9
Project Controls	8.33	10
Safety Health and Environment	9.40	11
Information Management and Technology System	10.27	12
Globalisation Issues	12.27	13
Kendall's W =0.424, p-value = 0.000		

As shown in Table 5.3, the third round of the Delphi assessment produced mean and ranking for all the factors. The output of the third round was found to be statistically significant (p-value < 0.05) and consistent. The order of ranked importance for these factor as components of KM principles is as follows: front-end planning; organisation; design; construction; contracts; startup and operation; procurement; people; project processes; project controls; safety health and environment; information management and technology system; globalisation issues. These thirteen factors were considered as the basis for the development of a questionnaire which is the second level of the research.

5.2 THE SECOND LEVEL OF THE KM RESEARCH

After completing the first level of the research, a questionnaire was developed taking into consideration all of the KM components identified. Each item of the questionnaire was then anchored with a five-point scale. A finalised version of the questionnaire comprising of 47 items representing KM attributes, 25 items representing IT infrastructures and 5 demographic related questions was developed after a series of pilot testing (refer Appendix 2).

5.2.1 Demographic Findings

One hundred and twenty two practitioners from the construction consulting companies were randomly selected to form the sampling frame. Table 5.4 presents the characteristics of the samples. Overall, slightly more than half (83) of the practitioners were working in civil engineering companies. The bulk of practitioners (96.7%) were from companies which are 100% owned by Malaysians. However, 76 practitioners have position as civil engineers and 15 practitioners as quantity surveyors and architects. Furthermore, 55 practitioners have working experience more than 10 years, 40 practitioners have less than 5 years working experience and 27 practitioners have 5-10 years working experience. In terms of education level, most of the practitioners have a bachelor degree. The aforementioned breakdown of respondents are reflective of the population characteristics obtained from the CIDB listing thus ensuring the sample used was a fair representation of the population parameters.

Table 5.4: Demographic Background of the Practitioners

Demographic Information	Frequency	Percent	Valid Percent	Cumulative Percent
Type of Company				
Quantity Surveyor	10	8.2	8.2	8.2
Civil Engineering	83	68.0	68.0	76.2
Architecture	10	8.2	8.2	84.4
Others	19	15.6	15.6	100.0
Company Ownership				
100% Malaysian ownership	118	96.7	96.7	96.7
Joint venture with foreign company	3	2.5	2.5	99.2
100% Foreign ownership	1	.8	.8	100.0
Position				
Quantity Surveyor	15	12.3	12.3	12.3
Civil Engineer	76	62.3	62.3	74.6
Architecture	15	12.3	12.3	86.9
Others	16	13.1	13.1	100.0
Total	122	100.0	100.0	
Working Experience				
Less than 5 years	40	32.8	32.8	32.8
5-10 years	27	22.1	22.1	54.9
More than 10 years	55	45.1	45.1	100.0
Education Level				
Diploma	9	7.4	7.4	7.4
Bachelor's degree	99	81.1	81.1	88.5
Others	14	11.5	11.5	100.0

5.2.2 KM Related Findings

Descriptive statistics based on percentages of responses for the KM related items are presented in Table 5.5. Upon further analysis, a preliminary conclusion could be derived that most of the respondents are concerned about KM and practice KM principles within their consultancy projects since most of the response for items are biased towards “a little effective, effective and very effective”. In most cases, a majority would rate “effective” as compared to other responses.

Table 5.5: Descriptive Statistics of KM Attributes

KM Attributes	Very Ineffective	Ineffective	A Little Effective	Effective	Very Effective
Implementation of pre-project planning at the corporate and project level	.8	0	26.2	49.2	23.8
Implementation of early estimating in project planning and risk management	.8	1.6	27.9	46.7	23.0
Use of modularisation and pre-assembly as a tool at project level	4.9	13.9	36.9	34.4	9.8
Availability of design standard for every project	.8	3.3	15.6	49.2	31.1
Implementation of design effectiveness at the project level	.8	22.1	58.2	18.9	.8
Implementation of cost effective engineering for all aspect in project design	5.7	25.4	49.2	19.7	5.7
Availability of computer-aided to design every project	1.6	2.5	13.1	40.2	42.6
Management of supplier relationship	.8	7.4	32.0	41.8	18.0
Sharing and transferring knowledge with clients, customers and suppliers	0	4.1	27.9	46.7	21.3
Implementation of material management at project level	2.5	5.7	34.4	41.0	16.4
Comprehensive material management training programme	5.7	15.6	35.2	39.3	4.1
Resources are sufficient to implement material management (e. g., time, computer and people)	.8	10.7	32.8	40.2	15.6
Availability of specific documentation to support the implementation of material management (e. g., file documents, database)	0	5.7	26.2	50.0	18.0
Measurement of material management cost and benefits	1.6	9.0	23.8	46.7	18.9
Control of cost and schedule based on the master plan	1.6	4.1	31.1	42.6	20.5
Appropriate actions taken based on the cost and schedule control for every project	1.6	4.9	26.2	46.7	20.5
Implementation of risk management at the project level	4.9	11.5	35.2	39.3	9.0
Regular updating of database of good work practices for risk management, lessons learned and listing of experts	3.3	13.9	36.9	32.0	13.9

Management of workers' compensation based on regional standard	4.1	14.8	36.1	38.5	6.6
Availability of design for maintainability to measure project performances		12.3	41.0	41.8	4.9
Management of planning for startup to ease collaboration work of projects or teams that are physically separated (i e , different work sites)	2.5	12.3	44.3	33.6	7.4
Availability of formal and informal training to keep employees' skills current	3.3	11.5	27.9	41.8	15.6
Availability of appropriate tools to measure productivity measurement	4.1	12.3	37.7	39.3	6.6
Sufficiency of resources to ensure multiskilling of employees at project level	1.6	11.5	30.3	39.3	17.2
Identification of barriers for implementation of project team	1.6	11.5	30.3	39.3	17.2
Implementation of appropriate strategies for leader selection for every project	2.5	11.5	25.4	46.7	13.9
Implementation of comprehensive partnership training programme	4.1	20.5	42.6	27.0	5.7
Management of the organisational work structure at the project level	2.5	6.6	38.5	35.2	17.2
Implementation of quality management at the project level	1.6	4.9	33.6	47.5	12.3
Identification of barriers to the implementation of products and services based on planning and design	.8	9.8	34.4	45.1	9.8
Ability to adapt products and services to client requirements	9.0	22.1	0	57.4	11.5
Utilisation of appropriate strategies and experiences to determine benchmark	.8	13.1	32.0	40.2	13.9
Implementation of systems for change management	3.3	9.0	44.3	33.6	9.8
Resources are sufficient to implement change management (e. g., time, computers and people)	.8	8.2	30.3	48.4	12.3
Measurement of cost and benefits of work packaging	1.6	12.3	41.0	38.5	6.6
There is a written process for work packaging implementation within the project	5.7	10.7	41.0	34.4	8.2
Availability of written process for project delivery and contract strategies within the project	1.6	8.2	34.4	41.8	13.9
Usage of project incentive is implemented at the project level	4.1	8.2	41.8	37.7	8.2
Implementation of zero accident techniques at the project level	1.6	17.2	34.4	22.1	24.6
Implementation of design for safety for every project	2.5	10.7	32.8	30.3	23.8
Automatic identification of barriers/problems for project processes (design, control, crash programme, etc) using information technology (software application: Primavera, Microsoft project, ETABS, SAP2000, etc)	4.9	9.0	35.2	35.2	15.6

Utilisation of electronic commerce is used to increase number of markets (e g , website, E-mail, etc)	4.9	14.8	43.4	27.9	9.0
Management of fully integrated and automated project using information technology (i. e. , database, filing system, sharing data, etc)	3.3	13.9	33.6	33.6	15.6
Utilisation of wireless technology for project processes Wireless technology is implemented for project processes	8.2	19.7	38.5	27.0	6.6
Implementation of international standards to improve the competitive advantage	4.9	12.3	28.7	43.4	10.7
Ability to capture employees' knowledge from other sources (i. e., other business enterprises, industrial associations, technical literature, public research institutions including universities and government laboratories)	2.5	12.3	34.4	44.3	6.6
Ability to protect from loss of knowledge due to worker's departures	3.3	13.1	36.1	36.1	11.5

5.2.2.1 Factor Analysis and Reliability Test for KM Attributes

As shown in Table 5.6, the high value of 0.847 for the Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the low p-value of 0.00 for the Bartlett's test for sphericity indicate that the analysis is significant for subsequent factor analysis.

Table 5.6: KMO and Bartlett's Test for KM Attributes

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.847
Bartlett's Test of Sphericity	Approx. Chi-Square	3256.991
	df	1081
	Sig.	.000

The factor analysis using Varimax with Kaiser Normalisation method, was able to generate nine KM factors as shown in Table 5.7. These eight factors are compared with the original groupings identified from the first level of the research (see Table 5.1). Furthermore, in order to ensure that the data was statistically reliable and valid, the internal consistency method was employed using Cronbach alpha reliability coefficient. Based on Table 5.7, the Cronbach alpha values for the KM components range from 0.757 to 0.923 thus implying that the data is very statistically significant (Nunnally, 1978).

Table 5.7: KM Factors, its Components and Reliability Coefficients

No	KM Factor	Component	Reliability Coefficient
I	Organisation and People	1. Availability of design for mantainability to measure project performances. 2. Management of planning for startup to ease collaboration work of projects or teams that are physically separated (i.e., different work sites. 3. Availability of formal and informal training to keep employees' skills current. 4. Availability of appropriate tools to measure productivity measurement. 5. Sufficiency of resources to ensure multiskilling of employees at the project level. 6. Identification of barriers for implementation of project team. 7. Implementation of appropriate strategies for leader selection for every project. 8. Implementation of comprehensive partnership training programme. 9. Management of the organisational work structure at the project level. 10. Implementation of quality management at the project level. 11. Identification of barriers to the implementation of products and services based on planning and design. 12. Utilisation of appropriate strategies and experiences to determine benchmark.	0.923
II	Construction	13. Implementation of cost effective engineering for every aspect in project design. 14. Implementation of material management at project level. 15. Comprehensive material management training programme. 16. Measurement of material management cost and benefits. 17. Control of cost and schedule based on the master plan. 18. Appropriate actions taken based on the cost and schedule control for every project. 19. Implementation of risk management at the project level. 20. Regular updating of database of good work practices for risk management, lessons learned and listing of experts.	0.878
III	Project Control	21. Use of modularisation and pre-assembly as a tool at project level. 22. Management of workers' compensation based on regional standard. 23. Implementation of systems for change management. 24. Measurement of cost and benefits of work packaging. 25. There is a written process for work packaging implementation within the project.	0.826

IV	Operation Management	26. Implementation of zero accident techniques at the project level. 27. Implementation of design for safety for every project. 28. Automatic identification of barriers/problems for project processes (design, control, crash programme, etc.) using information technology (software application: Primavera, Microsoft project, ETABS, SAP2000, etc). 29. Utilisation of electronic commerce is used to increase number of markets (e.g., website, E-mail, etc). 30. Management of fully integrated and automated project using information technology (i.e., database, filing system, sharing data, etc).	0.862
V	Globalisation Issues	31. Utilisation of wireless technology for project processes. Wireless technology is implemented for project processes. 32. Implementation of international standards to improve the competitive advantage. 33. Ability to capture employees' knowledge from other sources (i.e., other business enterprises, industrial associations, technical literature, public research institutions including universities and government laboratories). 34. Ability to protect from loss of knowledge due to worker's departures.	0.849
VI	Front-end Planning	35. Implementation of pre-project planning at the corporate and project level. 36. Implementation of early estimating in project planning and risk management.	0.849
VII	Contract	37. Availability of written process for project delivery and contract strategies within the project. 38. Usage of project incentive is implemented at the project level.	0.757
VIII	Design and Procurement	39. Availability of design standard for every project. 40. Implementation of design effectiveness at the project level. 41. Availability of computer-aided to design every project. 42. Resources are sufficient to implement material management (e.g. time, computer and people). 43. Availability of specific documentation to support the implementation of material management (e.g. file documents, database, etc.). 44. Resources are sufficient to implement change management (e.g. time, computers, and people). 45. Management of supplier relationship. 46. Sharing and transferring knowledge with clients, customers and suppliers. 47. Ability to adapt products and services to client requirements.	0.780

Subsequently, mean and group rank for all factors were calculated to enable the KM factors to be ranked in terms of priority whereby each raw score was converted to an index using Terrell's transformation technique.

Table 5.8: Transformed Scored and Group Rank for KM Factors

KM Factor	N	Transformed Score	Rank
Design and Procurement	122	70.81	1
Construction	122	64.68	2
Front-end Planning	122	62.40	3
Organisation and People	122	61.89	4
Operation Management	122	61.31	5
Contract	122	60.86	6
Project Control	122	58.07	7
Globalisation Issues	122	57.89	8

Based on the data in Table 5.8, the order of ranked importance for KM factors is as follows: Design and Procurement; Construction; Front-end Planning; Organisation and People; Operation Management; Contract, Project Control; and Globalisation Issues. Based on the results from the factor analysis, these eight factors are compared with the original ranking identified from the results in the third round of Delphi assessment (see Table 5.3). The comparison for KM factor's ranking is shown in Table 5.9.

Table 5.9: The Ranking Comparison for KM factors

No	Ranking Based on CII Listing	Ranking Based on Questionnaire
1	Front End Planning	Design and Procurement
2	Organisation	Construction
3	Design	Front-end Planning
4	Construction	Organisation and People
5	Contract	Operation Management
6	Startup and Operation	Contract
7	Procurement	Project Control
8	People	Globalisation Issues
9	Project Process	
10	Project Controls	
11	Safety, Health and Environment	
12	Information Management and Technology System	
13	Globalisation Issues	

As shown in Table 5.9, there are significant changes in ranking for KM factors. In the first study, identification of KM factors is based on the list from CII which originates from USA. However, in the second study, the Malaysian construction consultants tend to use eight KM factors as the tools in construction process and operation. It can be argued that the cultural and behavioral difference can possibly influence the mechanism process and operation in the construction industry. According to Hofstede (1991), there is no such thing as a universal management method or management theory across the globe. Even the word management has different origins and meanings in countries through out the world. Management is not a phenomenon that can be isolated from other processes taking place in the society. In this case, in order to understanding KM factors in Malaysia, there is a need to make construction industry aware that Malaysian construction consulting companies may need to focus on these eight KM factors.

5.2.2.2 Classification of KM

To assess the KM types, the overall mean score of the KM questionnaire was used. The respondents whose scores are less than the overall mean score are classified as "exploitive" while those whose scores are equal or greater than the overall mean score are classified as "explorative". Table 5.10 shows the descriptive statistics for this study.

Table 5.10: Descriptive Statistics for KM Classification

No	KM component	N	Mean
1	Implementation of pre-project planning at the corporate and project level.	122	3.95
2	Implementation of early estimating in project planning and risk management.	122	3.89
3	Use of modularisation and pre-assembly as a tool at project level.	122	3.30
4	Availability of design standard for every project.	122	4.07
5	Implementation of design effectiveness at the project level.	122	3.95
6	Implementation of cost effective engineering for every aspect in project design.	122	3.83
7	Availability of computer-aided to design every project.	122	4.20
8	Management of supplier relationship.	122	3.69
9	Sharing and transferring knowledge with clients, customers and suppliers.	122	3.85
10	Implementation of material management at project level.	122	3.63
11	Comprehensive material management training programme.	122	3.20
12	Resources are sufficient to implement material management (e.g. time, computer and people).	122	3.59
13	Availability of specific documentation to support the implementation of material management (e.g. file documents, database, etc.).	122	3.80
14	Measurement of material management cost and benefits.	122	3.72
15	Control of cost and schedule based on the master plan.	122	3.76
16	Appropriate actions taken based on the cost and schedule control for every project.	122	3.80
17	Implementation of risk management at the project level.	122	3.36
18	Regular updating of database of good work practices for risk management, lessons learned and listing of experts.	122	3.39
19	Management of workers' compensation based on regional standard.	122	3.29
20	Availability of design for maintainability to measure project performances.	122	3.39

21	Management of planning for startup to ease collaboration work of projects or teams that are physically separated (i.e., different work sites).	122	3.31
22	Availability of formal and informal training to keep employees' skills current.	122	3.55
23	Availability of appropriate tools to measure productivity measurement.	122	3.32
24	Sufficiency of resources to ensure multiskilling of employees at the project level.	122	3.59
25	Identification of barriers for implementation of project team.	122	3.57
26	Implementation of appropriate strategies for leader selection for every project.	122	3.58
27	Implementation of comprehensive partnership training programme.	122	3.10
28	Management of the organisational work structure at the project level.	122	3.58
29	Implementation of quality management at the project level.	122	3.64
30	Identification of barriers to the implementation of products and services based on planning and design.	122	3.53
31	Ability to adapt products and services to client requirements.	122	3.71
32	Utilisation of appropriate strategies and experiences to determine benchmark.	122	3.53
33	Implementation of systems for change management.	122	3.38
34	Resources are sufficient to implement change management (e.g. time, computers, and people).	122	3.63
35	Measurement of cost and benefits of work packaging.	122	3.36
36	There is a written process for work packaging implementation within the project.	122	3.29
37	Availability of written process for project delivery and contract strategies within the project.	122	3.58
38	Usage of project incentive is implemented at the project level.	122	3.38
39	Implementation of zero accident techniques at the project level.	122	3.51
40	Implementation of design for safety for every project.	122	3.62
41	Automatic identification of barriers/problems for project processes (design, control, crash programme, etc.) using information technology (software application: Primavera, Microsoft project, ETABS, SAP2000, etc).	122	3.48
42	Utilisation of electronic commerce is used to increase number of markets (e.g., website, E-mail, etc).	122	3.21
43	Management of fully integrated and automated project using information technology (i.e., database, filing system, sharing data, etc).	122	3.44
44	Utilisation of wireless technology for project processes. Wireless technology is implemented for project processes.	122	3.04
45	Implementation of international standards to improve the competitive advantage.	122	3.43
46	Ability to capture employees' knowledge from other sources (i.e., other business enterprises, industrial associations, technical literature, public research institutions including universities and government laboratories).	122	3.40
47	Ability to protect from loss of knowledge due to worker's departures.	122	3.39
Overall mean			3.55
Standard deviation			0.25

As illustrated in Table 5.10, the overall mean and standard deviation of the 47 KM attributes are 3.55 and 0.25 respectively. By comparing the mean Km for each of the 122 respondents, a total of 55 practitioners were classified as “exploitive” and 67 practitioners were classified as “explorative”. The results are illustrated as shown in Table 5.11.

Table 5.11: KM Classification

Exploitive (< 3.55)	Explorative (≥ 3.55)
55 practitioners	67 practitioners
Mean: 3.08	Mean: 3.94
Standard Deviation: 0.39	Standard Deviation: 0.30

5.2.2.3 Tests Between Overall KM Programme and KM Types

A one sample T-test was used to determine whether there are differences between overall KM programme and KM types (i.e., exploitive and explorative). The independent sample T-test results are presented in Table 5.12. Based on the mean differences, it is apparent that KM exploitive has a mean below the overall mean of 3.55 as indicated by a mean difference of -0.47327. KM explorative has higher mean than the overall mean as shown by a mean difference of 0.38776. What is more important is that both of exploitive KM and exploitive KM recorded p-values at 0.000 implying that there are significant differences between exploitive KM as well as exploitive KM based on the overall mean. Thus, the null hypothesis that there are no differences between KM types (i.e., exploitive and explorative) and overall KM programme is rejected at the 0.05 level of significance.

Table 5.12: Independent Sample T-Tests

KM type	Test Value = 3.55					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Exploitive	-9.104	54	.000	-.47327	-.5775	-.3690
Explorative	10.683	66	.000	.38776	.3153	.4602

5.2.3 ITI Capability Related Findings

Descriptive statistics based on percentages of responses for the ITI Capability related items are presented in Table 5.13. Upon further analysis, a preliminary conclusion could be derived that most of the respondents are concerned about ITI Capability within their consultancy projects since most of the response for items are biased towards “quite important, Important and very important”. In most cases, a majority would rate “effective” as compared to other responses.

Table 5.13: Descriptive Statistics of ITI Capability Attributes

ITI Capability Attributes	Very Un-important	Un-important	Quite Important	Important	Very Important
Manage communication network service (e.g., phone contact, fax, etc)	2.5	2.5	13.9	27.0	54.1
Manage messaging services (e.g., E-mail, Notice board, etc) and business unit workstation networks (e.g., LAN/stand alone PC)	2.5	2.5	21.3	35.2	38.5
Manage business unit workstation networks (e.g., LAN/ stand alone PC)	1.6	7.4	25.4	39.3	26.2
Manage business applications (e.g., software applications: Microsoft Office, Microsoft Project, Primavera, etc)	1.6	4.1	18.9	31.1	44.3
Recommend standards for IT architecture components (e.g., hardware and communications)	2.5	5.7	35.2	36.9	19.7
Enforce IT architecture	2.5	8.2	38.5	33.6	17.2
Provide multimedia operations and development (e.g., video conferencing)	2.5	21.3	45.1	25.4	5.7
Provide intranet capability for document management	3.3	13.1	30.3	35.2	18.0
Provide intranet capability for collaboration (e.g., local resource sharing)	3.3	13.1	28.7	41.0	13.9
Provide electronic support for groups (e.g., documents, tutorials, CD software, etc)	3.3	9.0	36.1	35.2	16.4
Provide data management advisory and consultancy services		12.3	36.9	41.0	9.8
Manage business-unit data, including standards (e.g., oracle, database system)		11.5	50.0	31.1	7.4
Manage database management system		9.8	46.7	33.6	9.8
Manage, maintain and support large scale data processing facilities		9.8	44.3	34.4	11.5
Provide security for firm-wide database and applications (e.g., file/data backup, anti virus software, etc)	2.5	3.3	22.1	32.0	40.2
Implement disaster planning and recovery system for business units (e.g., backup, disk tools, etc)	2.5	4.1	22.1	27.0	44.3
Provide technological advice and support services for internal requirement	.8	6.6	36.9	41.8	13.9
Provide training services for new technologies (e.g., software training, etc)	1.6	6.6	33.6	41.0	17.2
Utilise Information System (IS) for project management	1.6	3.3	45.1	40.2	9.8
Utilise IS planning of business units	1.6	6.6	47.5	34.4	9.8
Utilise IS to manage and negotiate with suppliers and subcontractor (by tenders, quotations in buying or dealing)	1.6	4.9	52.5	32.0	9.0
Provide management information electronically (e.g., EIS)	1.6	16.4	45.1	28.7	8.2
Develop and manage electronic linkages to suppliers or customers (e.g., website, E-mail address, etc)	.8	11.5	42.6	32.8	12.3
Develop a common systems environment	4.1	8.2	42.6	37.7	7.4

5.2.3.1 Factor Analysis and Reliability Test for ITI Capability Attributes

One hundred and twenty-two practitioners from the construction consulting companies were randomly selected to form the sampling frame. As shown in Table 5.14, the high value of 0.910 for the Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the low p-value of 0.00 for the Bartlett's test for sphericity indicate that the analysis is significant for subsequent factor analysis.

Table 5.14: KMO and Bartlett's Test for ITI Capabilities

Kaiser-Meyer-Olkin Measure of Sampling Adequacy			.910
Bartlett's Test of Sphericity	Approx. Chi-Square	2301.609	3256.991
	df	276	1081
	Sig.	.000	.000

The factor analysis using Varimax with Kaiser Normalisation method was used to determine statistical validity and was able to generate five ITI capability components as shown in Table 5.15. In addition, in order to ensure that the data is statistically reliable and valid, the internal consistency method was employed using reliability coefficient known as the Cronbach's alpha. Based on Table 5.15, the Cronbach alpha values for the components range from 0.843 to 0.914 implied that the data is very statistically significant (Nunally, 1978).

Table 5.15: ITI Capability Factors, its Components and Reliability Coefficients

No	ITI capability	Cronbach's Alpha
I	Data Management Capability 1. Provide data management advisory and consultancy services. 2. Manage business-unit data including standards (e.g., oracle, database system). 3. Manage database management system. 4. Manage, maintain and support large-scale data processing facilities. 5. Utilise Information System (IS) for project management. 6. Utilise IS planning of business units.	0.914
II	Integration Capability 7. Manage communication network service (e.g., phone contact, fax, etc). 8. Manage messaging service (e.g., E-mail, Notice board, etc) and business unit workstation networks (e.g, LAN/stand alone PC). 9. Manage business unit workstation networks (e.g., LAN/ stand alone PC). 10. Manage business applications (e.g., software applications: Microsoft Office, Microsoft Project, Primavera, etc). 11. Recommend standards for IT architecture components (e.g., hardware, operating systems, and communications). 12. Enforce IT architecture.	0.893

III	Collaboration Capability 13. Provide multimedia operations and development (e.g., video conferencing). 14. Provide intranet capability for document management. 15. Provide intranet capability for collaboration (e.g., local resource sharing). 16. Provide electronic support for groups (e.g., documents, tutorials, CD software, etc).	0.898
IV	Utility Capability 17. Utilise IS to manage and negotiate with suppliers and subcontractor (by tenders, quotations in buying or dealing). 18. Provide management information electronically (e.g., EIS). 19. Develop and manage electronic linkages to suppliers or customers (e.g., website, E-mail address, etc). 20. Develop a common systems environment.	0.864
V	Security and Other Capability 20. Provide security for firm-wide database and applications (e.g., file/data backup, anti virus software, etc). 21. Implement disaster planning and recovery system for business units (e.g., backup, disk tools, etc). 22. Provide technological advice and support services for internal requirement. 23. Provide training services for new technologies (e.g., software training, etc).	0.843

5.2.3.2 Classification of ITI Capability

To assess the ITI capability types, the overall mean score of the KM questionnaire was used. The respondents whose scores are less than the overall mean score are classified as "standardised" and the respondents whose scores are equal or greater than the overall mean score are classified as "exclusive". Table 5.16 shows descriptive statistic for this study.

Table 5.16: Descriptive Statistics for ITI Capability Classification

ITI capability component	N	Mean
Manage communication network service (e.g., phone contact, fax, etc).	122	4.28
Manage messaging service (e.g., E-mail, Notice board, etc) and business unit workstation networks (e.g., LAN/stand alone PC).	122	4.05
Manage business unit workstation networks (e.g., LAN/ stand alone PC).	122	3.81
Manage business applications (e.g., software applications: Microsoft Office, Microsoft Project, Primavera, etc).	122	4.12
Recommend standards for IT architecture components (e.g., hardware, operating systems, and communications).	122	3.66
Enforce IT architecture.	122	3.55
Provide multimedia operations and development (e.g., video conferencing).	122	3.11
Provide intranet capability for document management.	122	3.52
Provide intranet capability for collaboration (e.g., local resource sharing).	122	3.49
Provide electronic support for groups (e.g., documents, tutorials, CD software, etc).	122	3.52
Provide data management advisory and consultancy services.	122	3.48
Manage business-unit data, including standards (e.g., oracle, database system).	122	3.34
Manage database management system.	122	3.43
Manage, maintain and support large scale data processing facilities.	122	3.48
Provide security for firm-wide database and applications (e.g., file/data backup, anti virus software, etc).	122	4.04
Implement disaster planning and recovery system for business units (e.g., backup, disk tools, etc).	122	4.07
Provide technological advice and support services for internal requirement.	122	3.61
Provide training services for new technologies (e.g., software training, etc)	122	3.66
Utilise Information System (IS) for project management.	122	3.53
Utilise IS planning of business units.	122	3.44
Utilise IS to manage and negotiate with suppliers and subcontractor (by tenders, quotations in buying or dealing).	122	3.42
Provide management information electronically (e.g., EIS).	122	3.25
Develop and manage electronic linkages to suppliers or customers (e.g., website, E-mail address, etc).	122	3.44
Develop a common systems environment.	122	3.36
Valid N (listwise)	122	
Overall mean		3.61
Standard deviation		0.30

As shown in Table 5.16, the overall mean of the twenty-four ITI capability attributes is 3.61. Upon further analysis, a total of 59 practitioners were classified as "standardised" and 63 practitioners were classified as "exclusive". The results are illustrated as shown in Table 5.17.

Table 5.17: ITI Capability Classification

Standardised (< 3.61)	Exclusive (≥ 3.61)
Total: 59 practitioners	Total: 63 practitioners
Mean: 3.14	Mean: 4.05
Standard deviation: 0.49	Standard deviation: 0.35

5.2.3.3 Tests Between Overall ITI Capability and ITI Capability Types

A one sample T-test was used to determine whether there is difference between overall ITI capability programme and ITI capability types (i.e., standardised and exclusive). The independent sample T-test results are presented in Table 5.18. Based on the mean differences, it is apparent that ITI capability (standardised) has a mean below the overall mean of 3.61 as indicated by a mean difference of -0.47068. ITI capability (exclusive) has higher mean than the overall mean as shown by a mean difference of 0.44460. What is more important is that both p-values of ITI capability (standardised) and ITI capability (exclusive) are 0.000 implying there are significant differences between ITI capability (standardised) as well as ITI capability (exclusive) and the overall mean. Thus, the null hypothesis that there is no difference between ITI types (i.e., standardised and exclusive) and ITI capability overall programme is rejected at the 0.05 level of significance.

Table 5.18: Independent Sample T-Tests

ITI capability type	Test Value = 3.61					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Standardised	-7.396	58	.000	-.47068	-.5981	-.3433
Exclusive	9.967	62	.000	.44460	.3554	.5338

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

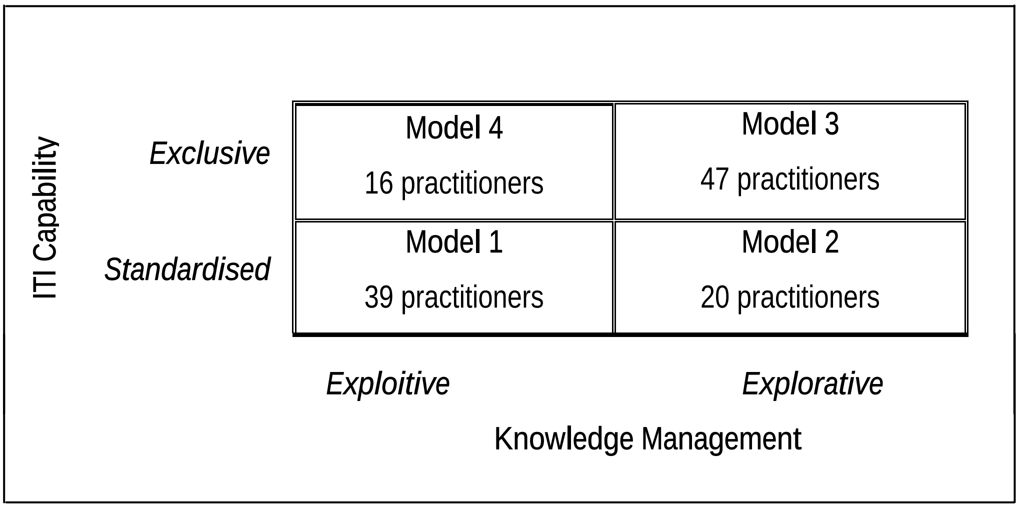
The purpose of this study was to integrate KM principles with ITI capabilities to support the construction consulting industry. After a series of rigourous testing and analyses, the study was able to demarcate KM factors and ITI capabilities into two distinct and independent components. The KM-ITI Capability Matrix Framework based on the quantitative analyses conducted will be presented in this chapter followed by the limitations of this research and its main contribution. Finally, a section on recommended further studies is included towards the end of this report.

6.1 KM AND ITI CAPABILITY MATRIX FRAMEWORK

Based on Figure 6.1, a combination matrix framework was developed taking into consideration the classifications of KM and ITI capability. Upon further scrutiny, the following demarcations were identified:

- Model 1 can be categorised as exploitive KM type and also standardised ITI capability type.
- Model 2 can be classified as explorative KM type and standardised ITI capability type.
- Model 3 can be categorised as explorative KM type and exclusive ITI capability type.
- Model 4 can be categorised as exploitive KM type and also exclusive ITI capability.

Figure 6.1: KM-ITI Capability Matrix Framework



It is apparent that the perceptions among the practitioners tend to be biased towards Model 3 and Model 1 and only few practitioners to fall into Model 2 and Model 4. Based on this framework, it is concluded that the Malaysian construction consultants prefer to deploy exclusive ITI capability to complement explorative KM type implying the construction industry consultants have preference to use specialised knowledge to support their highly technical IT skills.

6.2 LIMITATIONS

The objective of this research is not to prove or disprove theories that have some bearing on ITI capabilities and KM. The focus is purely on relevant concept and interrelationship identification and definition:

- This research does not focus on the philosophical meaning of knowledge; in other words, it does not dwell on epistemology. Rather, its focus is on devising an action-oriented knowledge characterisation that can be used in organisations.
- Perspectives, methods, concepts, and techniques that have a bearing on KM and ITI capabilities are noted and considered. However, these are not discussed in detail.
- We assume that an organisation's knowledge grows over time. An organisation may not be aware of it, may not be making best use of it, or may not be managing well in order to enhance those activities that lead to efficient and effective knowledge growth. Therefore, the focus is not on how and why an organisation "knows", or ways of "knowing", but rather on developing a framework that allows one to understand KM and ITI capabilities inter-relate.
- Response analysis and synthesis is subject to our perceptions and interpretations of how to accommodate respondents' comments.

The primary objective of this framework is to stimulate further KM and ITI research, including perhaps the introduction of newer frameworks that may be more comprehensive or concise than the one presented here. To the extent that improvements on the current framework are fostered, then the framework will have served its main purpose.

During the course of the research, some potential limitations of this study in terms of methodology and data collection were expected. The primary limitation was related to sample selection. Nineteen participants participated in the Delphi study which faced problems of attrition during the later rounds while 122 construction consultants participated in the survey questionnaire. The respondents were based on the CIDB listing, though there are in reality many more construction consultants which we found were not listed in the CIDB directory. As such, generalising the results of this study to the whole industry in not reasonable since the results may not represent industry as a whole.

The second limitation is related to the nature of the subject. The main objective of this study was to assess the IT-KM framework which covers a very broad range of issues within a construction consulting organisation. However, the survey was sent to only one individual within an organisation and it may be unrealistic to expect him/her to know the right answers for all the questions asked in the survey. Although it was recommended for survey participants to get help from others in answering the questions where they did not have enough knowledge, limited time availability and the length of the survey might have prevented them from gathering all the needed inputs. In addition, many questions were subjective and could have been answered differently if asked of someone else within the same organisation. Another limitation relates to the data which are “snapshots” of organisational implementation at the time of the survey completion. Considering how fast the industry is evolving, the comparison between survey data then and reviewing the situation right now might not have produced very accurate comparison results.

6.3 CONTRIBUTIONS

The research efforts in this report will provide expected contributions to three primary areas: (1) professional literature and seminars, (2) academic programmes, and (3) construction engineering organisations. The conclusions developed in this paper are expected to provide information on KM and ITI topics that can be used to fill the current gap that exists in professional development. At the same time, the conclusions in this paper are expected to provide a full curriculum of KM and ITI topics that can be used to develop classroom and distance learning programmes of study. Finally, the conclusions in this paper are expected to provide information on how to plan and integrate KM principles and ITI within the construction consulting organisations. This is important as KM will not function properly as a competitive strategy until IT infrastructure capabilities that support it are available. Numerous studies have shown how information technology infrastructure is acknowledged to be essential in knowledge management efforts as one of the enablers of KM (APQC, 2001; Davenport and Prusak, 1998; McDermott, 1999).

6.4 FUTURE RESEARCH

Through the course of this research effort, several areas have been identified as potential areas for further study. We have identified five areas where follow-up research based on this study could be conducted. The five areas are: (1) to conduct comparative studies; (2) to use of structural equation modeling; (3) to develop typology of construction consultants based on their scope of services; (4) to conduct complementary qualitative study to get an in-depth understanding of the construction consulting companies' application of KM-IT tools; and (5) to integrate the KM-ITI framework on construction project performance.

6.4.1 Conduct Comparative Studies

In this study, the sample was chosen from the construction consulting companies in Malaysia. Further comparative works could be conducted with other construction consulting companies from other countries. Comparisons with construction consulting practices adopted in other countries can help us to understand the requirements of different IT competencies across transnational boundaries, so that similarities and differences could be identified. At the same time, good management practices could also be identified.

6.4.2 Use of Structural Equation Modelling

We believe that it is desirable to apply structural equation modelling techniques for future research alongside the conceptual model including confirmatory factor analysis and path analysis. As Hair et al. (1998) suggested, these techniques are distinguished by, firstly, their ability to estimate multiple interrelated dependence relationships between KM factors and IT infrastructures through series of structural equation than separate equations, and secondly, their ability to represent unobserved concepts in these relationships and account for measurement errors in the estimation process. These advantages allow further research for estimating the conceptual model as a whole. By using structural equation modelling, it is also easier to estimate the goodness-of-fit for different alternative models, so that a "better-fitted" one can be identified. Further, confirmatory factor analysis can be applied to the competency instrument to provide further support for modifications or confirmation of the factor pattern within the instruments.

6.4.3 Typology of Construction Consultants Based on Their Scope of Services

By classifying the consultants into different categories, it is possible to identify and develop a more focused KM-IT framework for each different type of construction industry consultant. For example, a civil engineer's KM-IT framework may or may not be similar to those from the architect and civil engineer's perspective. This issue could be answered by getting a bigger data set for subsequent studies.

6.4.4 Conduct Complementary Qualitative Study

Qualitative research is frequently used as a generic term under which a number of research strategies reside (Bogdan and Biklen, 1984). These strategies include case methods, naturalistic inquiry, and phenomenological or ethnographic research, to name a few. Many different research procedures are used in qualitative research, including interviews, observations and analysis of documents all of which will be employed in this study. By conducting a qualitative study, a better understanding of the reasons (why) and the building block process (how) in planning and operating a KM-IT infrastructure in a typical construction consulting company would be uncovered. The combination of the qualitative results with the quantitative findings of this research, a process known as mixed method would enrich our understanding of the subject matter as Greene et al. (1989) listed four purposes for the use of mixed methods, including (1) complementary (examining overlapping and different facets of a phenomenon), (2) initiation (discovering paradoxes, contradiction and fresh perspectives), (3) development (using the methods sequentially, such that results from the first methods inform the use of the second method), and (4) expansion (mixed methods adding breadth and scope to a project).

6.4.5 Integrate KM-ITI Framework With Project Performance

Construction consulting projects are characterised by their complexity and diversity and to certain degree by the non-standardised nature of their processes. Therefore, managing a construction project is an interdisciplinary art requiring professional skills to achieve the maximum performance as required by the project. As discussed in earlier chapters, knowledge, information, and communication are crucial for effective performance and key to the ability of any organisation to respond to change (Dhillon, 2001). Moreover, according to Coukos-Semmel (2002), many observers feel that in a knowledge-based economy, KM is the critical element of a business strategy that allows an organisation to improve its operational processes and accelerate the rate at which it handles new challenges and opportunities. It does so by leveraging its most precious resources-collective know-how, talent, and expertise. It is interesting to note that most researches focused on themes related to KM and IT infrastructures. Little quantitative research exists on how the KM and IT infrastructures impact project (PP) performance. The vacuum needs to be addressed through a follow-up research to develop a KM-ITI-PP framework for the construction consulting companies.

6.5 CONTRIBUTIONS

This research investigation contributes to the management body of knowledge by providing a way of assessing the KM-ITI relationship within the construction consulting industry. Recent research investigations in many different industries have emphasised the importance of effectively managing IT infrastructures and implementing knowledge to take the maximum benefit to the organisation. In correspondence to these research efforts, this study contributes to the body of knowledge in the following areas:

- First study of its kind in the construction consulting industry focusing on KM-ITI framework; thereby it provides a solid foundation for future research studies with similar scopes,
- Development of a well-established knowledge structure to effectively organise and manage construction-related knowledge and also to increase accessibility of research findings,
- Development of research instruments to assess the organisational implementation status, which can be used as an internal self assessment tool or an external auditing tool.

To date, there has been positive feedback from the industry representatives who participated in this study. In addition, the survey instrument developed for this study is planned to be used by some organisations as a way of measuring their KM and IT infrastructures on a continual basis.

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APPENDIX 1

The Delphi Assessment

DELPHI ASSESSMENT DOCUMENTATION

ROUND 1

DELPHI ASSESSMENT TO IDENTIFY KNOWLEDGE MANAGEMENT FRAMEWORK FOR THE CONSTRUCTION CONSULTING COMPANIES

Dear Sir/Madam

We have identified you as a member of the panel expert for our Delphi Assessment entitled: Knowledge Management (KM) Framework for the Construction Consulting Companies. We are using the reknowned American Construction Industry Institute as a reference (refer page two of this letter). There will be several rounds of follow-ups to solicit your feedback of the responses obtained from other experts.

For the purpose of this study we would appreciate if you could either agree or disagree the importance of the KM attributes listed on pages two and three. Please answer the following question and return to me by e-mail by 22nd June, 2004. We wish to emphasise that your participation is entirely voluntary and you do not have to respond to every item or question. Your identity will remain anonymous and confidentiality will be maintained throughout this study. Also we plan to distribute to you a copy of the executive summary of the report once it is completed.

Thank you for agreeing to participate in this study.

Assoc. Prof. Dr. Amran Md. Rasli
amran@ruc.dk

Please tick (✓) in the appropriate boxes:

Importance Of KM Factor To The Malaysian Construction Consulting Companies	Agree	Disagree	Not Applicable
Front-End Planning			
Pre-project planning			
Early estimating			
Modularization/Pre-assembly			
Design			
Design standard			
Design effectiveness			
Cost effective engineering			
Computer-aided			
Procurement			
Supplier relationships			
Material management			
Construction			
Cost and schedule control			
Risk management			
Managing worker compensation			
Startup And Operation			
Design for maintainability			
Planning for startup			
People			
Management of education and training			
Productivity measurement			
Multiskilling			
Organisation			
Project teams			
Leader selection			
Partnering			
Organization work culture			
Project Processes			
Quality management			
Implementation of products			
Benchmarking			
Project Controls			
Change management			
Work packaging			
Contracts			
Project delivery and contract strategies			
Use of project incentive			
Safety, Health And Environment (SHE)			
Zero accident techniques			
Design for safety			

Information Management			
Automatic identification			
Electronic commerce			
Fully integrated and automated project process			
Wireless technology			
Automation and robotics			
Globalization Issues			
International standards			

ROUND 2

DELPHI ASSESSMENT TO IDENTIFY KNOWLEDGE MANAGEMENT FRAMEWORK FOR THE CONSTRUCTION CONSULTING COMPANIES

Dear Sir/Madam

Thank you for your prompt response to our request for you to either agree or disagree the importance of the CII factors and attributes. The views of all the experts are presented under the 1st round Delphi findings column and we were wondering if you would like to reconsider your views by filling in the last column.

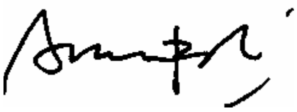
Please type A for ‘agree' and D for ‘disgaree' in the last column:

KM Factor	1st round Delphi findings			My reconsideration
	Agree	Disagree	No Answer	
Front-End Planning				
Pre-project planning	19	-	-	
Early estimating	18	1	-	
Modularization/Pre-assembly	16	3	-	
Design				
Design standard	15	4	-	
Design effectiveness	17	2	-	
Cost effective engineering	18	1	-	
Computer-aided	18	1	-	
Procurement				
Supplier relationships	15	4	-	
Material management	19	-	-	
Construction				
Cost and schedule control	19	-	-	
Risk management	16	3	-	
Managing worker compensation	16	3	-	
Startup And Operation				
Design for maintainability	17	2	-	
Planning for startup	18	1	-	
People				
Management of education and training	15	4	-	
Productivity measurement	15	4	-	
Multiskilling	13	6	-	
Organisation				
Project teams	18	1	-	
Leader selection	16	2	1	
Partnering	15	3	1	
Organization work culture	18	1	-	

Project Processes				
Quality management	19	-	-	
Implementation of products	17	1	1	
Benchmarking	14	5	-	
Project Controls				
Change management	12	7	-	
Work packaging	14	4	1	
Contracts				
Project delivery and contract strategies	18	1	-	
Use of project incentive	16	3	-	
Safety, Health And Environment (SHE)				
Zero accident techniques	14	5	-	
Design for safety	17	2	-	
Information Management				
Automatic identification	13	5	1	
Electronic commerce	12	6	1	
Fully integrated and automated project process	12	6	1	
Wireless technology	12	7	-	
Automation and robotics	9	9	1	
Globalization Issues				
International standards	12	6	1	

We would appreciate if this document could be returned to me by e-mail by 15th July, 2004. We wish to emphasise once again that your participation is entirely voluntary and you do not have to respond to every item. Your identity will remain anonymous and confidentiality will be maintained.

Thank you for agreeing to participate in this study.



Assoc. Prof. Dr. Amran Md. Rasli
amran@ruc.dk

ROUND 3

DELPHI ASSESSMENT TO IDENTIFY KNOWLEDGE MANAGEMENT FRAMEWORK FOR THE CONSTRUCTION CONSULTING COMPANIES

Dear Sir/Madam

Again we would like to thank you for taking time from your busy schedule to assist us with this research. This third round is perhaps the most important stage of this study whereby we need you to rank the KM factors identified from the American Construction Industry Institute to ascertain their relevance to the Malaysian construction consulting companies. Please abide by the specific instruction given.

Please rank the the importance of following KM factors in the construction consulting industry based on the following scale:

1 3 5 7 9 11 13

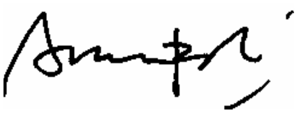
most important ... least important

You should use each number only once for each factor.

Knowledge Management Factor	My ranking
Front-End Planning	
Organisation	
Design	
Construction	
Contracts	
Startup and Operation	
Procurement	
People	
Project Processes	
Project Controls	
Safety Health and Environment	
Information Management and Technology System	
Globalisation Issues	

We would appreciate if this document could be returned to me by e-mail by 15th August, 2004. We wish to emphasise once again that your participation is entirely voluntary and you do not have to respond to every item. Your identity will remain anonymous and confidentiality will be maintained. Once again we would like to reiterate our plan to distribute to you a copy of the executive summary of the report once it is completed.

Thank you for agreeing to participate in this study.



Assoc. Prof. Dr. Amran Md. Rasli
amran@ruc.dk

APPENDIX 2

The Survey Questionnaire

January 15, 2005

Dear Sir/Madam

SURVEY ON KNOWLEDGE MANAGEMENT AND IT INFRASTRUCTURE

We would like to invite you to participate in a survey to obtain your perceptions of Knowledge Management and IT infrastructures. For your information, this survey is part of a project funded by the Ministry of Science, Technology and Innovation.

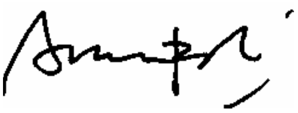
The attached survey questionnaire and information obtained from this survey will be kept anonymous and completely confidential. All questionnaires will remain with the researcher. Only findings in aggregate form will be submitted to the relevant authorities. The identification number on the questionnaire will be used for follow-up purposes only, so that reminder requests are sent only to those who have not returned their questionnaires and to cut fieldwork costs.

Your participation in this survey is completely voluntary, and you are free to withdraw at any time and for any reason. You are also free to decline to answer any questions you do not wish to answer. A copy of the final will be housed in the university library.

I would like to convey our appreciation for your cooperation in completing this questionnaire. If you have any questions about this research project, please call me at 07-5537564 or 017-7710535 or e-mail at amran@ruc.dk

Thank you in advance for your participation and assistance with this project. Your input is much appreciated.

Sincerely yours



Amran b. Md. Rasli
Project Leader IRPA 74230

Part A. Knowledge Management

Directions: Please respond to each item by circling a number based on the following 5 point scale:

1 = Very Ineffective, 2 = Ineffective, 3 = Quite Effective, 4= Effective, 5 = Very Effective

	Please indicate your views on the effectiveness of the implementation of the following Knowledge Management Factors that you find most appropriate to your company based on the following items.	Very Ineffective		A Little Effective		Very Effective
	Front-End Planning					
1.	Implementation of *pre-project planning* at the corporate and project level.	1	2	3	4	5
2.	Implementation of *early estimating* in project planning and risk management.	1	2	3	4	5
3.	Use of *modularization and pre-assembly* as a tool at project level.	1	2	3	4	5
	Design					
4.	Availability of *design standard* for every project.	1	2	3	4	5
5.	Implementation of *design effectiveness* at the project level.	1	2	3	4	5
6.	Implementation of *cost effective engineering* for every aspect in project design.	1	2	3	4	5
7.	Availability of *computer-aided* to design every project.	1	2	3	4	5
	Procurement					
8.	Management of *supplier relationship.*	1	2	3	4	5
9.	Sharing and transferring knowledge with *clients, customers and suppliers.*	1	2	3	4	5
10.	Implementation of *material management* at project level.	1	2	3	4	5
11.	Comprehensive *material management* training program.	1	2	3	4	5
12.	Resources are sufficient to implement *material management* (e.g. time, computer and people).	1	2	3	4	5
13.	Availability of specific documentation to support the implementation of *material management* (e.g. file documents, database, etc).	1	2	3	4	5
14.	Measurement of *material management* cost and benefits.	1	2	3	4	5
	Construction					
15.	Control of *cost and schedule* based on the master plan.	1	2	3	4	5
16.	Appropriate actions taken based on *the cost and schedule control* for every project.	1	2	3	4	5
17	Implementation of *risk management* at the project level.	1	2	3	4	5
18.	Regular updating of database of good work practices for *risk management*, lessons learned and listing of experts.	1	2	3	4	5
19.	Management of *workers' compensation* based on regional standard.	1	2	3	4	5
	Startup And Operation					
20.	Availability of *design for maintainability* to measure project performances.	1	2	3	4	5
21.	Management of *planning for startup* to ease collaboration work of projects or teams that are physically separated (i.e., different work sites).	1	2	3	4	5
	People					
22.	Availability of *formal and informal training* to keep employees' skills current.	1	2	3	4	5
23.	Availability of appropriate tools to measure *productivity measurement.*	1	2	3	4	5
24.	Sufficiency of resources to ensure *multi-skilling* of staff at the project level.	1	2	3	4	5
	Organisation					
25.	Identification of barriers for implementation of *project team*.	1	2	3	4	5
26.	Implementation of appropriate strategies for *leader selection* for every project.	1	2	3	4	5
27.	Implementation of comprehensive partnership training program.	1	2	3	4	5
28.	Management of the *organizational work structure* at the project level.	1	2	3	4	5
29.	Implementation of *quality management* at the project level.	1	2	3	4	5
30.	Identification of barriers to the *implementation of products and services* based on planning and design.	1	2	3	4	5
31.	Ability to adapt *products and services* to client requirements.	1	2	3	4	5
32.	Utilisation of appropriate strategies and experiences to determine *benchmark*.	1	2	3	4	5

	Project Control					
33.	Implementation of systems for *change management*.	1	2	3	4	5
34.	Resources are sufficient to implement change management (e.g. time, computers, and people).	1	2	3	4	5
35.	Measurement of costs and benefits of *work packaging*.	1	2	3	4	5
36.	There is a written process for *work packaging* implementation within the project.	1	2	3	4	5
	Contracts					
37.	Availability of written process for *project delivery and contract strategies* within the project.	1	2	3	4	5
38.	Usage of *project incentive* is implemented at the project level.	1	2	3	4	5
	Safety, Health, And Environment					
39.	Implementation of *zero accident techniques* at the project level.	1	2	3	4	5
40.	Implementation of d*esign for safety* for every project.	1	2	3	4	5
	Information Management And Technology Systems					
41.	Automatic identification of barriers/problems for project processes (design, control, crash program, etc) using information technology (software application: Primavera, Microsoft project, ETABS, SAP2000, etc).	1	2	3	4	5
42.	Utilisation of *electronic commerce* is used to increase number of markets (e.g. wider geographic locations) and to improve client and customer relations (i.e., website, E-mail, etc).	1	2	3	4	5
43.	Management of *fully integrated and automated project* using information technology (i.e., database, filing system, sharing data, etc).	1	2	3	4	5
44.	Utilisation of *wireless technology* for project processes. Wireless technology is implemented for project processes.	1	2	3	4	5
	Globalisation Issues					
45.	Implementation of *international standards* to improve the competitive advantage.	1	2	3	4	5
46.	Ability to capture employees' knowledge from other sources (i.e., other business enterprises, industrial associations, technical literature, public research institutions including universities and government laboratories).	1	2	3	4	5
47.	Ability to protect from loss of knowledge due to worker's departures.	1	2	3	4	5
48.	Additional comment (if any) :					

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<u>Part B. IT Infrastructure</u>

<u>Directions:</u> Please respond to each item by circling a number based on the following 5 point scale:

1 = Very Unimportant, 2 = Unimportant, 3 = Quite Important, 4= Important, 5 = Very Important.

	Please indicate your views on the importance of the following items that you find most appropriate to your company's IT infrastructure.	Very Unimportant		Quite Important		Very Important
	Integration Capability					
49.	Manage communication network service (e.g., phone contact, fax, etc).	1	2	3	4	5
50.	Manage messaging service (e.g., E-mail, Notice board, etc).	1	2	3	4	5
51.	Manage business unit workstation networks (e.g., LAN/stand alone PC).	1	2	3	4	5
52.	Manage business applications (e.g., software applications: Microsoft office, Microsoft Project, Primavera, etc).	1	2	3	4	5
53.	Recommend standards for IT architecture components (e.g., hardware, operating systems, and communications).	1	2	3	4	5
54.	Enforce IT architecture.	1	2	3	4	5

	Collaboration Capability					
55.	Provide multimedia operations and development (e.g., video conferencing).	1	2	3	4	5
56.	Provide intranet capability for document management.	1	2	3	4	5
57.	Provide intranet capability for collaboration (e.g., local resource sharing).	1	2	3	4	5
58.	Provide electronic support for groups (e.g., documents, tutorials, CD software, etc).	1	2	3	4	5
	Data Management Capability					
59.	Provide data management advisory and consultancy services.	1	2	3	4	5
60.	Manage business-unit data, including standards (e.g. database system).	1	2	3	4	5
61.	Manage database management system.	1	2	3	4	5
62.	Manage, maintain and support large scale data processing facilities.	1	2	3	4	5
	Security Capability					
63.	Provide security for firm-wide database and applications (e.g., file/data backup, anti virus software, etc).	1	2	3	4	5
64.	Implement disaster planning and recovery system for business units (e.g., backup, disk tools, etc).	1	2	3	4	5
	Utility Capability					
65.	Provide technological advice and support services for internal requirement.	1	2	3	4	5
66.	Provide training services for new technologies (e.g., software training, etc).	1	2	3	4	5
67.	Utilize Information System (IS) for project management.	1	2	3	4	5
68.	Utilize IS planning of business units.	1	2	3	4	5
69.	Utilize IS to manage and negotiate with suppliers and subcontractor (by tenders, quotations in buying or dealing).	1	2	3	4	5
	Other Capability					
70.	Provide management information electronically (e.g., EIS).	1	2	3	4	5
71.	Develop and manage electronic linkages to suppliers or customers (e.g., website, E-mail address, etc).	1	2	3	4	5
72.	Develop a common systems environment.	1	2	3	4	5

73. Additional comment (if any) :

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Part C. DEMOGRAPHIC INFORMATION

Directions: Please tick (✓) in the relevant boxes.

74. Type of Company:
    - Quantity Surveyor ☐
    - Civil Engineering ☐
    - Architecture ☐
    - Others ☐ ____________________

75. Company Ownership
    - 100 % Malaysian ownership ☐
    - Joint venture with foreign company ☐
    - 100% Foreign ownership ☐ ____________________

76. Position:
    - Quantity Surveyor ☐
    - Civil Engineer ☐
    - Architect ☐
    - Others ☐ ____________________

77. Working Experience:
    - Less than 5 years ☐
    - 5 – 10 years ☐
    - More than 10 years ☐

78. Education Level:
    - Diploma ☐ Area : ____________________
    - Bachelor's degree ☐ Area : ____________________
    - Others ☐ ________________________

79. E-mail address (for us to send you the executive summary of this research): ________________________

THANK YOU FOR COMPLETING THIS SURVEY