DEVELOPMENT OF KM MODEL FOR KNOWLEDGE MANAGEMENT IMPLEMENTATION AND APPLICATION IN CONSTRUCTION PROJECTS

by

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ABSTRACT

Knowledge management (KM) is now becoming a vital issue in the business strategies of any construction organisations and it is a complement to the organisational business activities. Lessons learned from the construction industry have proved that reusing and sharing knowledge can enhance construction projects successfully by decreasing cost and time of completion and improving the whole competitiveness of the organisation. The challenge to KM implementation in construction organisations is the lack of systematic procedures for developing and applying knowledge management systems (KMSs). Various KM models have been developed to support KM activities. However, the existing KM models and tools may have some problems in many circumstances, which cannot be used efficiently and effectively. This research aims to develop a new KM model that overcomes such problems and provides an effective and efficient way for managing knowledge in the construction industry.

An extensive review and analysis of KM models has been carried out and a KM model was developed to fill the gaps and overcome the disadvantages of previous KM models used for construction projects. Interviews with KM practitioners have been conducted to evaluate and enhance the KM model. A questionnaire survey has been conducted to improve the developed KM model by investigating KM initiatives, activities and tools of current KMSs in construction organisations and exploring environmental factors and activities that can be critical for successful implementation and application of KM in the construction industry. A final KM model has been set to provide an effective solution and useful guidance for successful implementation and application of KM in the construction projects.

Two case studies in the construction industry have been carried out to investigate KM implementation and application in two companies. These provide useful examples of KM procedures and approaches to show how applying KM to create, capture and share knowledge can be very useful for the construction organizations. Furthermore, the problems that may stop or delay a successful application of KM procedures and tools have been investigated and discussed. The case studies also aimed at evaluating the applicability and validity of the proposed KM model and how the proposed KM model can be used to improve the existing KMSs and the industry KM performance. The results indicated that the proposed model can effectively facilitate the process of implementation, development and application of KM in the construction organisations. Recommendations are given and future research works are suggested in order to improve the implementation and application of KM in the construction organisations.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

CCC	Consolidated Contractors Company Group
CoP	Community of Practice
CRM	Customer Relationship Management
HRMS	Human Resource Management System
ICT	Information and Communication Technology
IDEF0	Integrated Definition Function Modelling, Level 0 (zero)
IT	Information Technology
KM	Knowledge Management
KMS	Knowledge Management System
KPI	Key Performance Indicators
SMEs	Small and Medium Enterprises
TQM	Total Quality Management
VBC	Visual Byblos Cyberspace

CHAPTER ONE

INTRODUCTION TO KNOWLEDGE MANAGEMENT

1.1 Introduction

Knowledge management (KM) is now considered as one of the most important parts of any organization and a complement to the organization's business activities. With new economy increasingly becoming a more knowledge-based economy, knowledge is becoming the most important asset for organisational success among other assets such as capital, materials, machineries, and properties (Kelleher & Levene, 2001; Fong & Wong, 2005).

Many organisations claim to have large savings from the adoption of KM techniques in their companies (Jennex, 2005a). Through successful knowledge capturing, sharing, and creation, industrial companies can improve the process of organisational learning to enhance the performance and create more possibilities to gain competitive advantages for the organisations (Li & Gao, 2003; KLICON, 1999; Ahmad & An, 2008). Companies were encouraged to adopt KM techniques to maintain their competency against other companies. An organisation's competitive advantages depend on the organisation ability to learn faster than its competitors. The organisational learning process depends on the ability of the organisation to collect and use knowledge, skills and behaviours which have the potential to enhance learning of its members and improve the organisational future performance (KLICON, 1999).

The overall aim of this thesis is to develop an integrated KM model to help construction organisations to improve knowledge management implementation and application in their construction projects. The thesis includes seven chapters. Chapter 1 aims at providing required background of knowledge and knowledge management to help to conduct and understand the research. Chapter 2 describes the objectives of the research and the methodologies that will be adopted to fulfil these objectives. Chapter 3 provides review and analysis of existing KM models in the literature in order to develop a KM model version that fills the gaps and solve problems of previous models. Chapter 4 provides details and results of interviews and questionnaires conducted in the research in order to help improving the KM model versions into a final enhanced KM model. Chapter 5 describes the details and advantages of the final proposed KM model components. Chapter 6 provides evaluation of the proposed KM model in terms of its usability and usefulness through conducting two case studies in the construction industry. Finally, Chapter 7 summarizes the final main conclusions, achievements and recommendations of the conducted research.

This chapter (Chapter 1) aims at providing review of knowledge and knowledge management (KM) concepts to investigate the different areas of KM, identify the subject of interest that has shortcomings and gaps to fill, and provide conceptual background that helps to develop and understand the research KM model. The chapter commences with reviewing various definitions of knowledge in the KM literature, stressing its differences with data, information and wisdom, identifying knowledge categorisation methods used by different researchers, and describing relationships between the different types of knowledge. After that, the concept of KM will be described. Motivations that may encourage organisations and people to apply and use KM will be discussed. Challenges and difficulties in implementing and applying KM will be explained. Finally, examples of KM methods, techniques and evaluation methods currently used in construction organisations will be presented.

1.2 Knowledge

1.2.1 Definition of Knowledge

Knowledge can be defined as the facts, skills and understanding that one has gained, especially through learning or experience, which enhance ones ability of evaluating context, making decisions and taking actions (Awad & Ghaziri, 2004; Tserng & Lin, 2004). Because knowledge combines information with experiences, by using KM organisations can provide their people with the ability to find and use methods and procedures that were created or used by others previously to solve similar problems, and to learn from past experiences, while maintaining the new created experiences to be used in the future (Tiwana, 1999; Davenport & Prusak, 1998; Baker *et al*., 1997). Many definitions have been developed in the KM literature to help understanding of knowledge and distinguish it from other forms of contents such as data and information. Examples are given in Table 1.1.

Table 1.1: Definitions of knowledge in the literature

References	Definitions
Davenport and Prusak (1998)	"A fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms."
Davenport *et al*. (1998)	"Knowledge is information combined with experience, context, interpretation, and reflection. It is a high-value form of information that is ready to apply to decisions and actions."
Nonaka and Takeuchi (1995)	"Information anchored in the beliefs and commitment of its holder."
Bath (2000)	"a changeable reality created through interaction and information exchange"
KLICON (1999)	"Knowledge is a body of information, coupled with the understanding and reasoning about why it is correct. ……Knowledge is the cognitive ability to generate insight based on information and data…… Knowledge is typically gained through experience or study."
Tiwana (1999)	"Actionable (relevant) information available in the right format, at the right time, and at the right place for decision…… An understanding of information based on its perceived importance or relevance to a problem area."
Bennet and Bennet (2004)	"Knowledge is the capacity (potential or actual) to take effective action in varied and uncertain situations."
McInerney (2002)	"Knowledge is the awareness of what one knows through study, reasoning, experience or association, or through various other types of learning."
(Merriam Webster's Collegiate Dictionary, 2009)	"acquaintance with or understanding of a science, art, or technique."
(Oxford English Dictionary, 2009)	"knowledge" as meaning "acknowledging . . . recognizing- . . . inquiring . . . being aware . . . understanding . . . cognizance . . . intelligence . . . information acquired through study, and learning."

1.2.2 Data, Information and Knowledge

Although the terms data, information and knowledge are extremely related, they should not be used interchangeably (Blumentritt & Johnston, 1999; Kakabadse *et al*., 2001; Logan & Stokes, 2004). In most literature the concepts of knowledge and information were used synonymously and inaccurately (Alondeiene *et al*., 2006). According to Davenport *et al*. (1998), Probst *et al*. (2000), and Awad and Ghaziri (2004), data, information and knowledge have different attributes that can be summarised and illustrated in Figure 1.1.

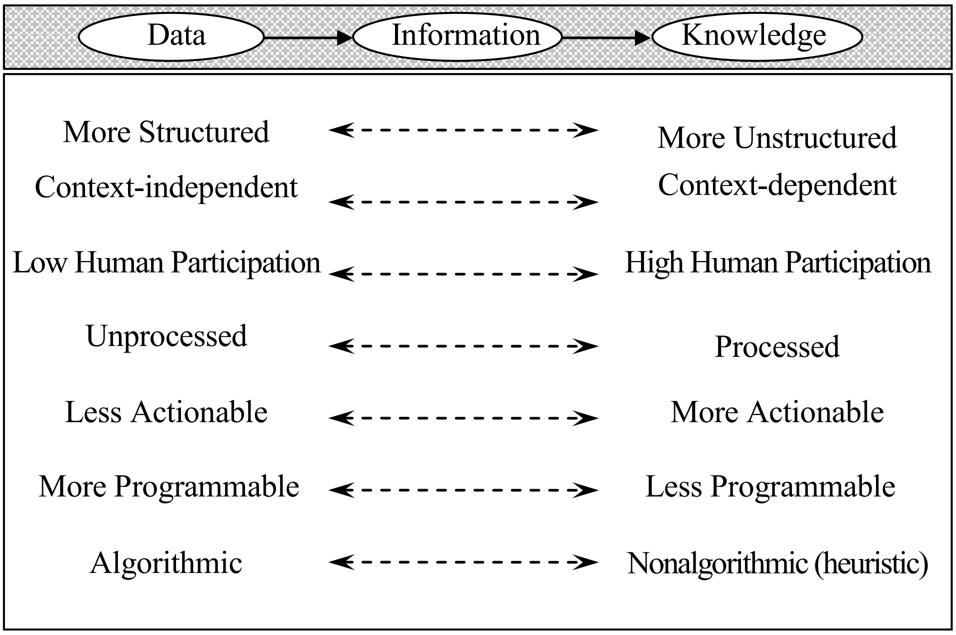


Figure 1.1: Data, Information and Knowledge Attributes (Davenport *et al.*, 1998; Probst *et al.*, 2000; Awad & Ghaziri, 2004)

Data refers to raw facts without any processing, organizing or analysis, so it has little meaning and few benefits to managers and decision-makers. According to KLICON (1999) Data is un-interpreted material on which a decision is to be based and depends on facts which may include any thing known to be true or exist.

Information refers to data that has been processed and shaped to be of more meaning to users. KLICON (1999) argues that information results from the interpretation of data in a given context. So, a single content of data may produce different information contents if the context is different (KLICON, 1999). Information comprises facts that are organized in a structured way, whereas knowledge incorporates values, beliefs, perspectives, judgments, and know-how (Blumentritt & Johnston, 1999).

Knowledge is the most useful form of contents for problem solving and decision making since it has more meaning than data and information. Therefore, knowledge is more than data and information in that it combines information with experiences to show methods and procedures used by others, which can be reused in the future to solve similar problems (Tiwana, 1999; Davenport & Prusak, 1998; Baker *et al*., 1997).

Studies found that a useful way to differentiate between the three concepts is by representing them in a hierarchy where knowledge is represented at the top with the most value and meaning for the end-users, and data is represented at the bottom with the least value and meaning to the end-users but with the most availability and programmability in the organisation (Awad & Ghaziri, 2004; NDR, 2003; Bierly *et al*., 2000). This can be represented as shown in Figure 1.2.

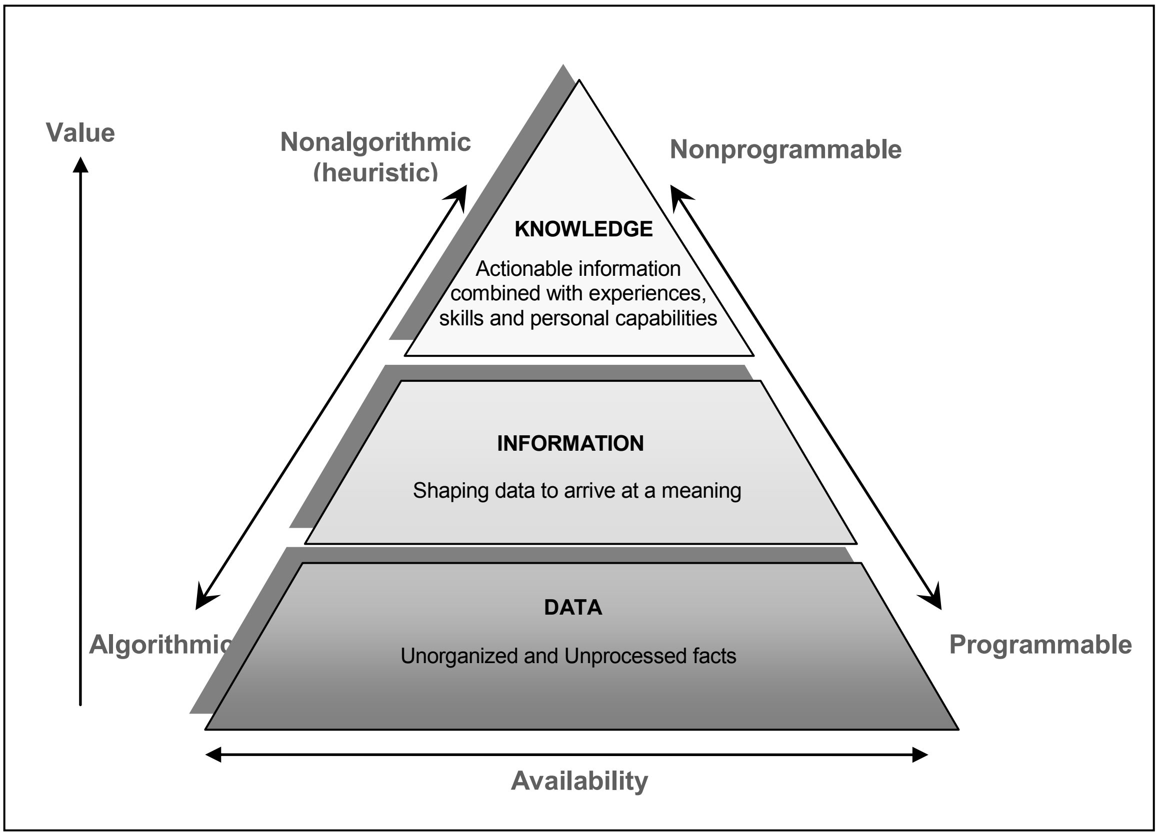


Figure 1.2: Data, Information and Knowledge (Awad & Ghaziri, 2004; NDR, 2003; Bierly *et al*., 2000)

1.2.3 Knowledge Classification Methods

Knowledge can be considered in a variety of ways. Classifying knowledge helps organizations to identify the different types of knowledge with different nature that may need different procedures, tools and activities to process and manage (Tserng & Lin, 2004; Lin *et al*., 2006). Hence, classifying knowledge is an important issue to help the organizations to manage important and available knowledge resources successfully.

1.2.3.1 Explicit and Tacit Knowledge

Explicit knowledge can be expressed in formal and systematic language, and shared in the form of scientific formulae, specifications, manuals and such like. Explicit knowledge is easy to be captured, retrieved, shared and used because it can be expressed in words and numbers that can be managed more easily. In project contexts, explicit knowledge may include project-related contents such as specifications, contracts, reports, drawings, changing orders and data (Lin *et al*., 2006). KLICON (1999) described explicit knowledge as being 'readily available', recorded, codified and/or structured in a way that makes it easily transmissible and available to be retrieved and used, which can be found in a range of diverse sources, such as human resources data, meeting minutes and the Internet.

Tacit knowledge is the most valuable type of content since it combines information with experiences, skills and understanding of people, which can help people to find best solutions and reduce opportunities of repeating mistakes (Awad & Ghaziri, 2004; Baker *et al*., 1997; Davenport & Prusak, 1998; Gupta *et al*., 2000; Tiwana, 1999; Tserng & Lin, 2004). In project contexts, tacit knowledge may include work processes, problems faced, problems solved, expert suggestions, know-how, innovations and experiences (Lin *et al*., 2006).

Tacit knowledge is highly personal and hard to be managed, shared or formalised since it includes experiences, know-how and perceptions, which normally reside in individuals' heads and memories (Nonaka, 2007; Lin *et al*., 2006). According to KLICON (1999) tacit knowledge cannot be easily articulated with formal language since it is a personal knowledge that is embedded in people experiences and involves intangible factors such as personal beliefs, perspectives, and values. The best way for utilizing tacit knowledge is by using methods and tools that encourage and facilitate collaboration and knowledge sharing among the people of the organisation, such as applying e-messaging and e-meeting tools (Nonaka, 2007; Lin *et al*., 2006).

However, some tacit knowledge can be captured, mobilized and turned into explicit knowledge by using KM tools, such as knowledge capturing, publishing, categorising and editing tools. These help to transfer knowledge into more available and accessible forms that may help the organisation to progress rather than requiring its members to relearn from the same stage all the time (Gore & Gore, 1999).

Although a complete tacit-explicit split cannot be achieved (Nonaka & Takeuchi, 1995; Inkpen & Dinur, 1998), it is a useful way to understand the different characteristics and nature of different types of knowledge that require different processing, procedures and tools to be managed and dealt with. Figure 1.3 represents a hierarchy that has been developed to provide a useful way to understand the differences and relationships among data, information explicit knowledge, tacit knowledge and wisdom (Davenport *et al*., 1998; Probst *et al*., 2000; Awad & Ghaziri, 2004; Bierly *et al*., 2000; NDR, 2003). This representation helps to understand the different characteristics and values of the different types of contents and how these contents can be transformed from one type to another. Blumentritt and Johnston (1999) suggested that in order to gain competitive advantages, organisations need to enhance the information-knowledge balance through the implementation of IT-based improvements to enhance information management and socially-based mechanisms to enhance knowledge management.

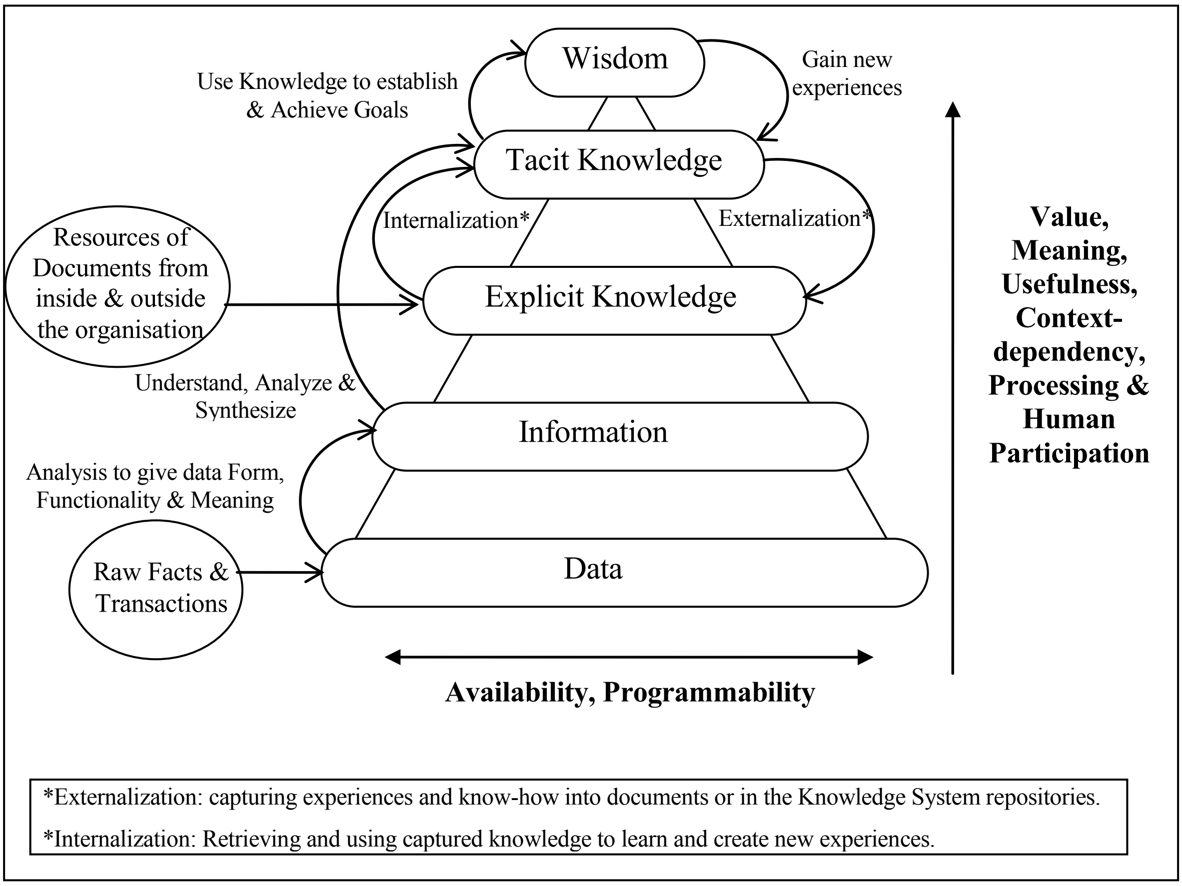


Figure 1.3: Data, Information, Explicit Knowledge, Tacit Knowledge, and Wisdom (Davenport *et al.*, 1998; Probst *et al.*, 2000; Awad & Ghaziri, 2004; Bierly *et al.*, 2000; NDR, 2003)

Tacit knowledge according to Nonaka and Takeuchi (1995) can be further categorized into technical knowledge and cognitive knowledge. Technical knowledge depends on the experiences of individuals, which has been developed with time, so it can be captured in the form of "know-how", while cognitive knowledge depends on mental models, perspectives and beliefs therefore cannot easily be articulated (Nonaka, 2007). Technical knowledge contains many shapes of knowledge, such as descriptions of problems and solutions, experience notes and procedures. Cognitive knowledge includes ideas, viewpoints and innovations.

Although tacit knowledge is difficult to capture simply by normal tables, they can be captured and stored in forms similar to articles including those attached descriptions, pictures and videos that provide more details and clarifications to the knowledge contents. Another useful method is by encouraging sharing such knowledge through direct contacts, such as face-to-face meetings, e-chatting, video conferencing, etc., and indirect contacts, such as e-messaging, e-discussions, e-commenting, etc. Although these methods have been proven more convenient in the collection and sharing of tacit knowledge, it needs more effort to follow procedures that encourage people to capture and share their knowledge, and to provide classification and searching techniques that facilitate knowledge retrieving and reusing.

1.2.3.2 Explicit, Implicit and Tacit Knowledge

Although many studies have used the terms tacit and implicit knowledge synonymously, some other studies have differentiated among three knowledge dimensions, including explicit, implicit and tacit, emphasizing that tacit and implicit knowledge have significant differences and cannot be used interchangeably (Alonderiene *et al*., 2006; Nickols, 2003; Newman & Conrad, 1999; Bennet & Bennet, 2008). Nickols (2003) introduced a representation that provides a useful way to distinguish among explicit, implicit and tacit knowledge as shown in Figure 1.4.

Explicit knowledge consists of knowledge that has already been articulated or codified in the form of text, tables, diagrams, drawings, photos, audios, videos, etc., so they can be directly and completely captured, used or shared, such as documented articles, books, reports, best practices, manuals, specifications and standards (Nickols, 2003; Newman & Conrad, 1999).

Implicit knowledge is the knowledge identified that it can be articulated and turned into explicit in the future but has not yet been articulated. This can be caused by various reasons such as if the codification or capturing process has not been completed or even started yet, if the company has not decided to capture this form of knowledge yet or if the company has decided that they do not currently need to capture this form of knowledge.

Tacit knowledge refers to knowledge that people have, but they cannot articulate, express using language or make explicit, because articulating them will fail to capture its essence (Nickols, 2003; Polanyi, 1997; Alonderiene *et al*., 2006). Examples include people skills and experiences that cannot be easily described, such as how to deal with different people and read the reaction on their faces or the ability and speed to work under time pressure, solve problems, provide ideas and innovate.

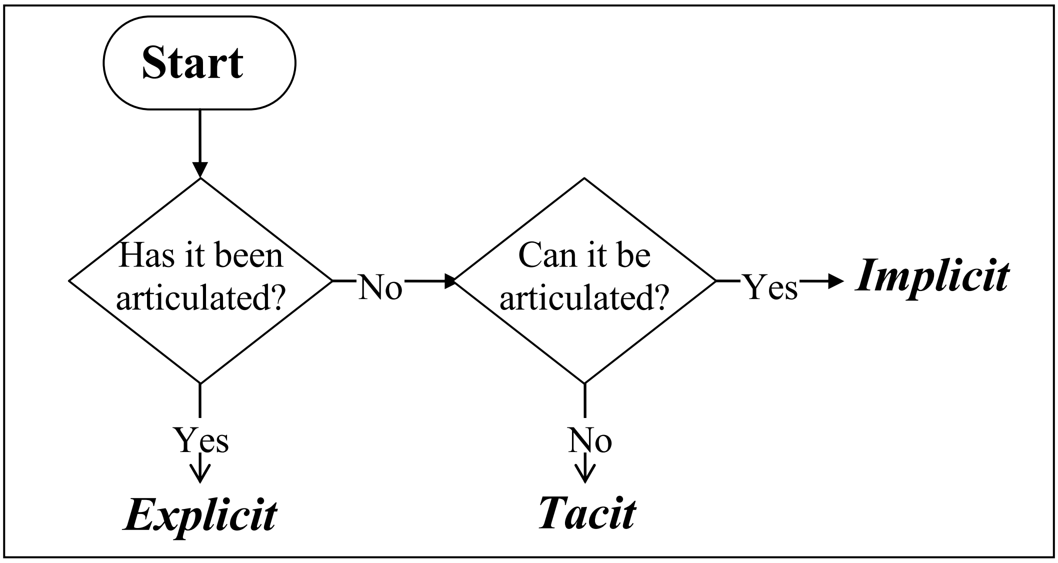


Figure 1.4: Distinguishing among Explicit, Implicit and Tacit Knowledge (Nickols, 2003)

The research by Bennet and Bennet (2008) discussed the differences and relationships among explicit, implicit and tacit knowledge and pointed out that explicit knowledge can be described accurately by words and/or visuals, while implicit knowledge is more complicated and not readily accessible. It is the knowledge that individuals do not know they have, but they discover it through questions, dialogues, reflective thoughts, or as a result of an external event. Once this knowledge has emerged, the individual can have the ability to capture it in the form of explicit knowledge, or may not have this ability and so the knowledge remains as tacit. Finally, tacit knowledge is the knowledge that even if individuals know they have it, they still cannot put it into words or visuals that can be useful for others to use and to create new knowledge.

Tacit knowledge has been studied in the research conducted by Bennet and Bennet (2008) in terms of four aspects; embodied, intuitive, affective and spiritual, where each of these aspects represents different tacit knowledge sources with different characteristics, as presented in Figure 1.5 along with explicit and implicit knowledge.

Embodied tacit knowledge relates to the movement of the body, such as knowing a craft or how to use a tool, and the five human senses such as knowing the quality of a material or a finished work from its appearance. This kind of knowledge can be learned through practicing and behaviour skill training and through time it becomes embedded in memory and retrieved automatically when needed.

Intuitive tacit knowledge is the knowing that may affect decisions and actions that comes from the individuals' sense and the actor cannot explain (unconscious) the reason for taking this action. Intuitive knowledge has developed in people's minds as a result of continuous learning through meaningful experiences that can be built up by practicing making decision and actions, collecting feedback on these decisions and actions, and interpreting this feedback. These practices will help people to develop intuitive skills such as developing the ability to evaluate situations quickly and to predict the consequences of such situations (Klein, 2003).

Affective tacit knowledge refers to people feelings that may have impact on behaviours, thoughts and responses. Thus, affective tacit knowledge is related to other types of knowledge because feelings as a form of knowledge can influence decisions and actions, such as feeling fear or upset that could prevent the decision-maker from taking an action.

Finally, ***spiritual tacit knowledge*** can be described as the animating principles of human life such as its moral aspects, the emotional part of human nature and mental abilities, which may affect thoughts and actions.

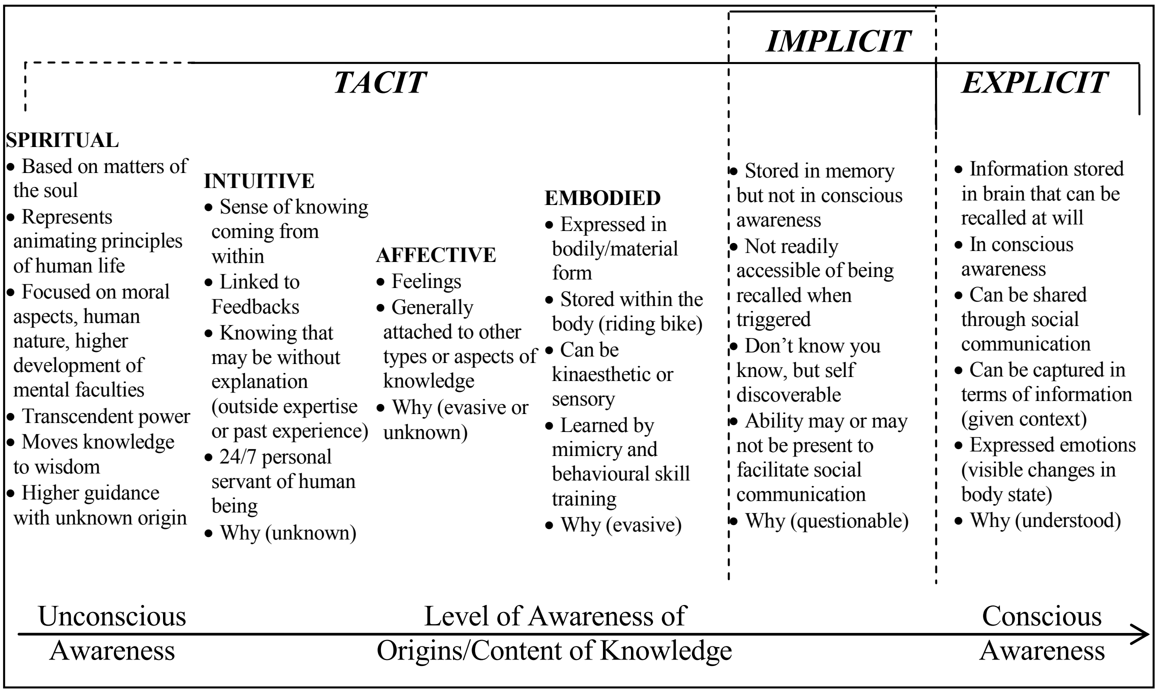


Figure 1.5: Continuum of Awareness of Knowledge Source/Content (Bennet & Bennet, 2008)

1.2.3.3 Other Methods

Many methods for categorizing knowledge have emerged and been used within the KM literature as a response to the growing interests in managing knowledge and growing awareness of its usefulness and importance. Those methods of knowledge classification have been proposed to enhance managing and processing knowledge in the organizations by adopting KM techniques. For example, Musgrave (1993) proposed a method to distinguish among three different kinds of knowledge, i.e. knowledge of things and objects, knowledge of how to do things, and knowledge of statements or propositions.

Collins (1993) provided a different way of classification by distinguishing between codified and non-codified knowledge, and proposed four categories of knowledge including Symbolic-type knowledge that can be transferred without loss such as books and documents, Embodied knowledge that cannot be easily transferred because it is held within the body of humans, Embrained knowledge which normally held within the brain, and Encultured knowledge which relates to society and social groups.

For management purposes a number of classifications have been proposed to overcome the difficulty and inaccuracy of older methods. Lundvall (1996), for example, proposed four knowledge categories, i.e. Know-what that is described as the knowledge that can be easily codified, Know-why that includes principles and laws, Know-how that refers to skills and capabilities to perform a given task successfully, and Know-who which includes details about who knows how to do what.

Furthermore, Blumentritt and Johnston (1999) categorized knowledge into four types by distinguishing between codified knowledge and other forms of what is called in that research 'real' forms of knowledge. The knowledge types proposed by that research are: Codified knowledge, which refers to knowledge captured or written in an explicit transferable format; Common knowledge, which includes routines and practices learned through working in a particular context without capturing them in formal explicit formats; Social knowledge refers to cultural issues and interpersonal relationships such as cooperation and coordination; and lastly, Embodied knowledge, which includes experiences, skills and backgrounds of individuals that affect the way a person deal with a given set of information to build and create appropriate knowledge to solve problems.

1.3 Knowledge Management (KM)

1.3.1 Definition of Knowledge Management (KM)

There are many definitions and interpretations of the term 'knowledge management' (KM) that have been used in the literature. Examples of important definitions of KM in the literature are provided in Table 1.2. However, KM is defined in this thesis in a way that copes with the aim of this study of developing a KM model that presents structured procedures, methods and techniques, important and useful for successful management of knowledge in the construction projects.

The term of KM used in this thesis is defined in general as a set of distinct and well-defined processes and techniques, which include systematic procedures based on technologies and practices, that motivate effective creation, capturing, organisation, distribution, use and sharing of both useful tacit and explicit knowledge, to enable individuals of the organisation to be more effective and productive in their work in order to generate value for the projects and the organisations. KM provides the tools and services for end-users to capture, share, reuse, update, and create new experiences, problem solutions and best practices to aid employees in processes such as problem solving, decision making and innovation without having to spend extra time, effort and resources on reinventing solutions that have already been invented elsewhere in the organizations (Ahmad *et al*., 2007).

Table 1.2: Definitions of knowledge management

References	Definitions
Jashapara (2004)	"The effective learning processes associated with exploration, exploitation and sharing of human knowledge (tacit and explicit) that use appropriate technology and cultural environments to enhance an organization's intellectual capital and performance."
Wiig (1997)	"It is a set of distinct and well-defined approaches and processes. The overall purpose of knowledge management is to maximize the enterprise's knowledge related effectiveness and returns from its knowledge assets and to renew them constantly."
Teece (2000)	"It can be used to describe the panoply of procedures and techniques used to get the most from a firm's knowledge assets. The knowledge management requires the development of dynamic capabilities and the ability to sense and to seize opportunities quickly and proficiently."
Davenport and Prusak (1998)	"It consists of processes to capture, distribute, and effectively use knowledge."
Carlucci *et al*. (2004)	"The KM is a managerial paradigm which considers knowledge as a resource at the basis of a company's competitiveness. It identifies the capabilities to generate value for a company's stakeholders with the explicit and systematic implementation of approaches, techniques and tools for the assessment and management of intellectual capital."
Ruggles (1998)	"It is an approach to adding or creating value by more actively leveraging the know-how, experience, and judgment resident within and, in many cases, outside of an organization."
Lee and Yang (2000)	"It is an emerging set of organizational design and operational principles, processes, organizational structures, applications and technologies that helps knowledge workers dramatically leverage their creativity and ability to deliver business value."
McInerney (2002)	"Knowledge management (KM) is an effort to increase useful knowledge within the organization. Ways to do this include encouraging communication, offering opportunities to learn, and promoting the sharing of appropriate knowledge artifacts."
Quintas *et al*. (1997)	"It is the process of continually managing knowledge of all kinds to meet existing and emerging needs, to identify and exploit and acquire knowledge assets and to develop new opportunities."
Beijerse (2000)	"It is the management of information within an organization by steering the strategy, structure, culture and systems and the capacities and attitudes of people with regard to their knowledge. It is the achievement of the organization's goals by making the factor knowledge productive."

1.3.2 Definition of Knowledge Management Systems (KMSs)

The term 'system' is normally used in different disciplines to refer to a group of interrelated components that work together by way of some driving process that can often be visualized or modelled as component blocks that have connections drawn between them (Pidwirny, 2006; Merriam Webster's Collegiate Dictionary, 2009).

The term of 'knowledge management system' (KMS) has been used in different meanings through the literature. In KM literature, the terms of KMS and knowledge systems are used synonymously to refer to the technological or software components of the KM (Abdullah *et al.*, 2002). For example, Alavi and Leidner (2001) defined KMSs as "IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application". Furthermore, Gupta *et al.* (2000) defined it as "A class of information systems applied to managing organizational knowledge, which helps organisations to find, select, organise, disseminate and transfer important information and expertise necessary for activities such as problem solving, dynamic learning, strategic planning and decision making".

However, other researches have expanded those definitions by incorporating strategy, services, processes and users' components to the KMS, not just the IT components (Jennex & Olfman, 2004; Jennex, 2005b). Because, as mentioned previously, the term 'system' should include all the interrelated components with their driving processes and relations, then all the components, processes and relations important for successful implementation and application of KM should be included in the KMS definition of this study. So, the terms of KMS and knowledge system in this research are used to refer to the technological and/or non-technological components of KM that may include KM software, hardware, networks, individuals, groups, organisations, resources, tools, services, activities, procedures, methods and other environmental factors and activities that may compose, relate to or affect KM in an organisation.

1.3.3 KM Importance and Motivations

Knowledge management (KM) is now becoming more vital for successful management of construction projects and a complement to the business activities of organisations. With the new economy increasingly becoming a more knowledge-based economy, knowledge is becoming the most important asset for organisational success among other assets such as capital, materials, machineries, and properties (Kelleher & Levene, 2001; Fong & Wong, 2005). The research by Gupta *et al*. (2000), which discusses practices and challenges of KM in a number of selected organisations, argues that KM is the only competitive advantage for companies in the 21st century.

Construction projects are in knowledge-intensive environments where many interrelated components work together in a complex manner. A main benefit by adopting KMSs in construction work is to enable the industry companies to complete the projects with reduced cost and time while improving quality of projects. By reusing and sharing previous experiences and knowledge, employees can find solutions for their problems without spending extra time, efforts and resources on reinventing solutions that have already been invented elsewhere in the organization (Ahmad *et al*., 2007).

With the successful capturing, sharing, and creation of useful knowledge, industrial companies can improve the process of organisational learning to enhance performance and create more possibilities to gain competitive advantages for the organisation (Li & Gao, 2003; KLICON, 1999; Ahmad & An, 2008). Li and Gao (2003) argue that industrial companies can enhance organisational learning through knowledge generation combined with successful knowledge sharing, which will not only lead to enrich the knowledge of employees and organisations, but also will lead to more strategic innovations. Improving organisational learning means enhancing the ability of the organisations to collect and use knowledge so that members exploit it to improve the organisations' performance (KLICON, 1999). Organisational learning can create possibilities to gain competitive advantages, which involve the ability of a company to perform projects and activities at lower cost and time combined with higher quality of projects than other competitors. The benefits from the application of KM in an organisation which have been discussed previously can be summarised and represented as shown in Figure 1.6.

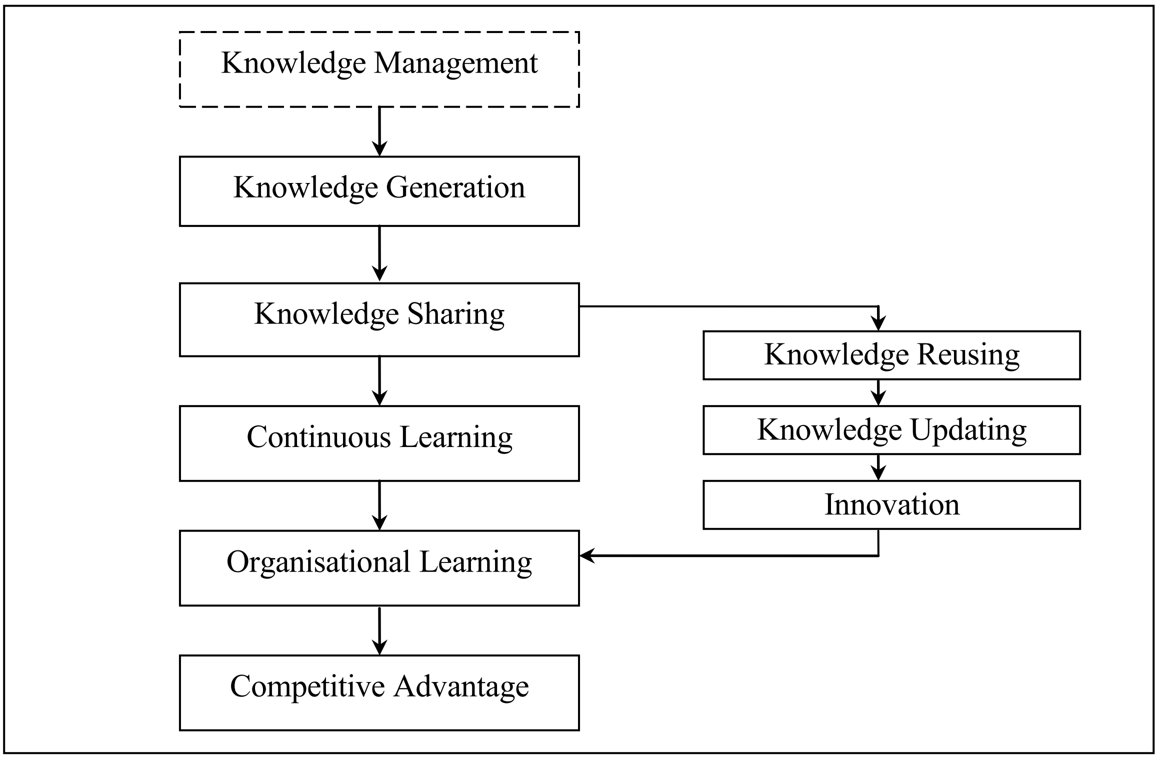


Figure 1.6: Knowledge Generation and Sharing Leading to an Organisational Competitive Advantage (Li & Gao, 2003; KLICON, 1999; Ahmad & An, 2008)

The current interest in KM has been motivated by the need for continuous changes and improvements to enhance the construction process that has benefited from the remarkable developments in computer technology which provide people with ability to digitally capture, search and transmit knowledge and electronically contact other people (KLICON, 1999; Carrillo *et al*., 2000; Blumentritt & Johnston, 1999). The construction organisations have shown an increased awareness of KM as a necessary prerequisite for improved quality, innovations, business performance, efficiency of project delivery, and relationships with partners, suppliers and clients to gain competitive advantages (Egan, 1998; Kamara *et al*., 2002; Love *et al*., 2003). KMSs provide the tools and services for end-users to capture, share, reuse, update, and create new experiences, problem solutions and best practices to aid employees in processes such as problem solving, decision making and innovation, and so to enhance the total performance of the organisation (Ahmad *et al*., 2007).

1.3.4 Challenges and Factors Affecting KM

Many challenges to KM implementation in the construction industry, for example, the complexity of industry, diversity of work players, adversarial relationships encouraged by the strategy of contracting and the project nature with pressure to complete and non-repetitive nature of work, are all causes for much "knowledge wastage" and difficulties in accessing important knowledge (KLICON, 1999). The complex nature of knowledge and construction context increases the difficulty for organisations to plan and implement formal KM initiatives.

While much of the literature has been concerned with discrete projects, project integration proved to be a major challenge for construction management that goes beyond conventional systems integration, which is largely concerned with technical integration of software, hardware and communication protocols etc., to the coordination and management of the different activities necessary for the successful completion and delivery of the project as a whole (Winch *et al*., 1998; Rudolph, 1998; Alderman *et al*., 2001).

The challenges for KM become more difficult when dealing with tacit knowledge because individuals normally regard tacit knowledge as a source of strength and personal rather than organisational property (Carrillo *et al*., 2000). A vast amount of knowledge in the project-oriented organisations resides in the heads of numerous individuals who may belong to different companies with different professional backgrounds and many of these companies are unstable and can be completely changed during the period of the project life cycle, which causes difficulty for people to collect, share and manage their knowledge within limited time and budget of the construction projects (Carrillo *et al*., 2000).

Employees of the organisations are still reluctant to share their knowledge with others, while changing this people's behaviour is not easy (Egbu *et al.*, 2004; Lin *et al.*, 2006; Nonaka, 2007). Many individuals regard their knowledge as a personal property and source of strength and most of typical existing construction organisations find difficulty to encourage the culture of sharing knowledge (Carrillo *et al.*, 2000). For example, a medium sized UK construction company, called Wates Group, stated that it took more than four years before staff accepted the concept of sharing knowledge (Carrillo *et al.*, 2000). Case studies conducted by Carrillo and Chinowsky (2006) in six engineering design and construction organisations showed that employees resistance to knowledge sharing is one of the top barriers for KM within these organisations. Reasons, such as the lack of trust among employees, lack of time, lack of KM awareness, lack of openness to new ideas, intolerance of management for creative mistakes and refusal of solutions from people in lower positions, can negatively affect knowledge sharing process (Davenport & Prusak, 1998).

With the increased pressure from customers to improve the quality of projects while reducing cost and time of work completion, the construction industry faces many challenges of how to implement and apply a successful KMS that provides desirable results and benefits (Chinowsky & Meredith, 2000). A successful KM implementation requires a major change in organisational culture and commitment at all the organisational levels (Gupta *et al*., 2000).

The lack of employees' and management's awareness of the importance and future benefits of KM to their organisations is an important challenge to KM application in the construction industry (KLICON, 1999). Some empirical studies proved that construction companies, especially small and medium enterprises (SMEs) which comprise about 99 percent of construction firms in the UK, suffer many problems of applying KM and lack awareness of many important issues associated with knowledge capturing and its benefits for construction organisations (Hari *et al*., 2005).

The difficulty of KM implementation for many construction organisations is caused not only by the complicated nature of KM operations, but the fact that the implementation of KM initiatives has often been unplanned and informal. A study conducted by Robinson *et al*. (2004) based on leading construction organisations showed that these organisations lack a strategy to KM implementation and co-ordination, and a high percentage of them have not appointed a knowledge manager or a team to implement their KM strategy, with the fact that small and medium organisations are less successful than large counterparts in KM implementation. Other studies argued that UK construction companies with domestic operations are less successful in KM implementation of their international counterparts, because they lack the adoption of well formulated KM strategies and implementation plans, and KM alignment with business strategy of the organisation (Robinson *et al*., 2005).

A survey carried out by Carrillo *et al*. (2004), investigated the main barriers to implementing KM strategies such as work processes, employees time, organizational culture, expenses, employees resistance and poor IT infrastructure. It indicated that the most significant barrier to KM implementation in the UK construction organisations is the lack of standard work processes, such as having too many different procedures to perform similar activities and the lack of systematic procedures for collecting and reusing lessons learned and best practices. Although previous studies attempted to select or to develop an appropriate KM strategy for the construction industry, those studies are still far from enough, and managerial courage is required to face the previous challenges and achieve changes.

Unrepeated nature of the construction projects is an important challenge to the management of knowledge in the construction organisations. A problem solution or best practice in a project may confuse other users having similar problems in different projects with different characteristics and contexts. KMSs need to be designed to help users to find problem solutions rather than providing the ultimate solutions for their problems. The research by Fong and Wong (2005) argues that, despite the importance of KM in reducing the risk of "reinventing the wheel", it is sometimes difficult for people in a project to re-use and re-apply knowledge of other projects. The reason is that it is difficult for employees in a project to understand the context and the reasons for decisions that have been made in other projects simply by using reports or drawings kept after the completion of those projects (Fong & Wong, 2005).

The ability of KM initiatives to deliver desirable results for individuals and organisations can be affected by environmental factors, such as organisational culture and management support (Burgess & Singh, 2006). Davenport *et al.* (1998) argue that, in order to obtain successful KMSs, organisations need not only to improve KM processes and technological contents but they also need to enhance the knowledge environment through practices attempting to change behaviours of employees that relate to knowledge such as building KM awareness and cultural acceptability.

Egbu and Botterill (2002) studied the use of IT-tools for KM in construction organisations, and concluded that IT is more useful for the transmission of explicit knowledge while face-to-face interaction and verbal conversation are more efficient in sharing and transferring tacit knowledge. This IT inefficiency in sharing and capturing tacit knowledge can be due to the effect of environmental factors such as the lack of employees' awareness of the potential benefits of IT-tools, the lack of a formal strategy to apply the KMS, the short-term nature of projects that cause difficulties with building teams, 'Communities of Practice' and trust among employees, and finally, the human nature for preferring familiarity of using the old routine of doing jobs over having to learn new methods of applying and using new technologies (Egbu & Botterill, 2002).

Ahmad and An (2008) discussed environmental factors that can influence KM design, implementation and use. The research has categorised these factors into groups to simplify representing and understanding them such as individual factors, organisational factors, technological factors, economical factors, customer factors and regulation issues. The study also highlighted the importance of management support and the role of KM teams to maintain and improve the KMS in the organisations. However, some factors may hinder the process of knowledge coordination and sharing among employees in different construction projects of the organisation that may cause every project to work as a separated unit, and so this may cause failure of using knowledge of other projects and learning from past mistakes and experiences (Carrillo *et al.*, 2000).

The research by Davenport and Prusak (1998) indicated that some individual behaviours (cultural frictions) can negatively affect the KM process. They suggested a set of solutions to reduce the influence of these factors and encourage knowledge creation and sharing in the organisations by applying some procedures and approaches such as providing incentives, accepting and rewarding creative errors, providing times and places for learning, meeting and sharing knowledge, and encouraging relationships and trust among employees (see Table 1.3).

Table 1.3: Examples of cultural frictions and the solutions (Davenport & Prusak, 1998)

Frictions	**Possible Solutions**
Lack of trust	Build relationships and trust through face-to-face meetings.
Different cultures, vocabularies, and frames of reference	Create common ground through education, discussion, publications, teaming, and job rotation.
Lack of time and meeting places; narrow idea of productive work	Establish times and places for knowledge transfers: fairs, talk rooms, and conference reports.
Status and rewards go to knowledge owners	Evaluate performance and provide incentives based on sharing.
Lack of absorptive capacity in recipients	Educate employees for flexibility; provide time for learning; hire for openness to ideas.
Belief that knowledge is prerogative of particular groups, not-invented-here syndrome	Encourage non-hierarchical approach to knowledge; quality of ideas more important than status of source.
Intolerance for mistakes or need for help	Accept and reward creative errors and collaboration; no loss of status from not knowing everything.

An and Ahmad (2010) discussed and represented the influence of environmental factors and the way they affect the ability of KM methods, tools and activities in delivering desirable outcomes for individuals and organisations, as shown in Figure 1.7, to simplify understanding their effects and enhance awareness of their importance in KM implementation and application.

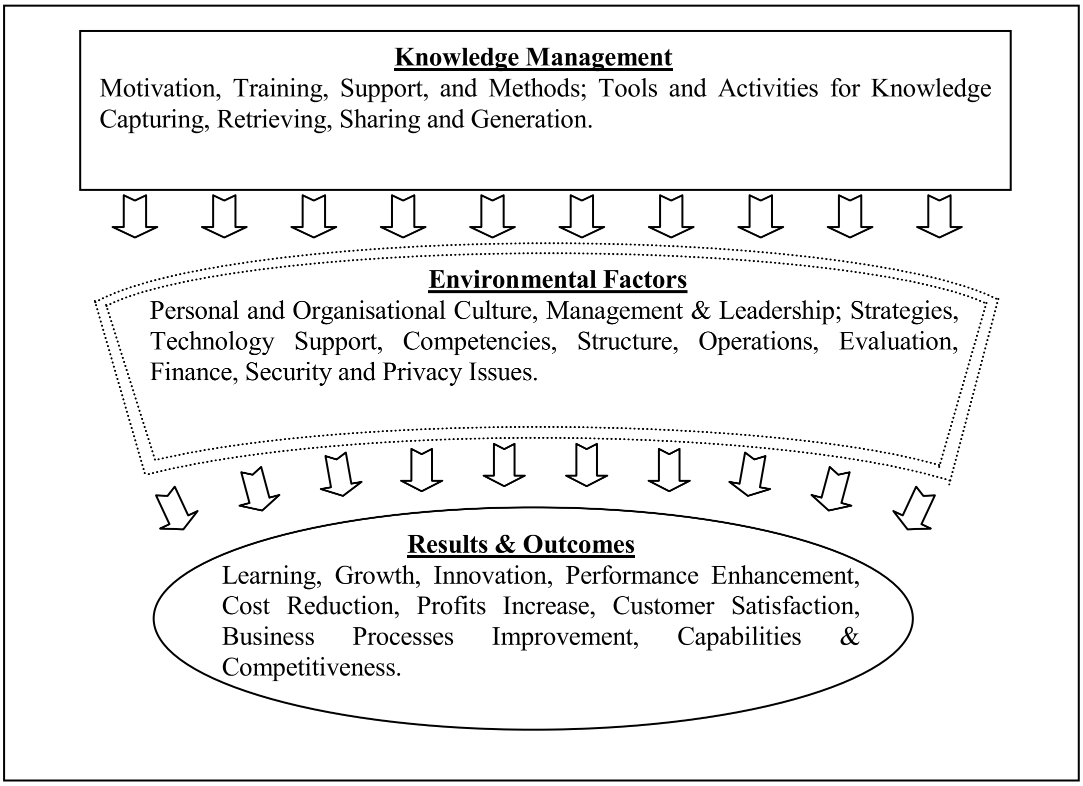


Figure 1.7: Influence of Environmental Factors on KM Outcomes (An & Ahmad, 2010)

The challenges and barriers discussed earlier that may affect the successful management of knowledge cause the need for a more coherent and structured approach for utilising and managing knowledge in construction organisations. Therefore, it is essential to develop a new KM model which can be used as a navigation aid for managing knowledge to satisfy the needs of the industry. This study addresses this problem by developing a KM model that can deal with available and important knowledge in the construction projects more efficiently and effectively. Case studies conducted in the construction industry are used to demonstrate how the proposed KM model can be useful to improve the industry KM performance.

1.3.5 KM Methods and Techniques

Many techniques have been developed and used in the construction organisations to enhance KM implementation and reduce the effect of knowledge barriers. For example, by using network knowledge maps, users can improve their ability to discover what knowledge exists and what knowledge is missed in a certain area or project (Lin *et al*., 2006).

Dynamic knowledge maps proposed by Woo *et al*. (2004) is a technique that facilitates searching for experts with relevant knowledge and communicating with them by using instant messaging, e-mail, telephone, Internet conferencing or other internet technologies.

Another technique is the use of modelling methods that can be used to develop and manage KMSs. Models are used to help people to understand the complexity of real systems by representing the main features and dividing the large systems into its parts, to simplify understanding and managing (Abdullah *et al*., 2002).

A successful technique in construction KM is the use of Activity-Based KMSs where information and knowledge from projects are categorized and saved in units related to the projects' activities so that these information and knowledge can be easily retrieved and reapplied (Tserng & Lin, 2004).

Another technique of knowledge categorization and organization is the use of Ontology-based systems. Ontology is an explicit specification that provides formal representation to show what knowledge of a domain exists in a knowledge-based system, which enhances searching capabilities, enabling the segregation of knowledge and reducing the overlapping topics between different discussion groups (Gruber, 1993; KLICON, 1999). Ontology-based systems provide a mechanism to classify domain knowledge items into inter-related components, in the form of hierarchical structure and semantic relationship, in which knowledge can be accessed based on meaning, better enabling computers and people to exchange these knowledge (El-Diraby & Kashif, 2005).

The research by Gupta *et al*. (2000), which discussed practices and challenges of KM in selected organisations, shows that the two major trends currently used when applying KM are measuring the intellectual capital by developing measurement ratios and benchmarks, and mapping knowledge that includes capturing and disseminating knowledge of individuals, mainly through information technology. This research also shows the importance of data mining tools in transforming the organisation's existing data into "answers-knowledge" available to employees, anywhere in the organisation at anytime.

Many of the existing KM techniques and ongoing research need a more structured coherent approach to KM and a better alignment of KM to business goals in the construction organisations. Although, many of the existing KM techniques and tools can only deal with explicit knowledge, many studies have approved that tacit knowledge is playing an important role of KM in the organisations. Therefore, it is essential to develop a new KM model that can be used as a navigation aid to explicit and tacit knowledge to satisfy the needs of the industry. This study addresses these problems by developing a new KM model which provides a structured method for KM that can deal with both explicit and tacit knowledge and align with the specific characteristics of construction projects.

1.3.6 KM Evaluation Methods

To convince senior management to undertake the decision of implementing or enhancing KM in their organisations, business benefits and competitive advantages compared to cost of implementation of KM need to be demonstrated (Davenport *et al*., 1997; Robinson *et al*., 2004). Many research have studied the relationship between KM and supply chain management (SCM) to show how KM affects the performance of organisations and how it can improve the speed of learning, improving and decision making for players in the supply chain. Burgess and Singh (2006) argued that knowledge, infrastructure and corporate governance, can work together to produce innovations that lead to desirable improvements in the organisation performance, only if the social environment support this transformation.

Most of the organisations normally use general business performance management models to evaluate their KMSs and to assess the influence of the KMSs on their business performance. Carlucci *et al*. (2004) reviewed the role of KM in the business performance management models such as the Balance Scorecard (Kaplan & Norton, 1992), the Business Excellence Model (EFQM, 1999) and most recently the performance prism (Neely *et al*., 2002). The study depended on the classification of knowledge assets , using a method developed by Marr and Schiuma (2001), into four asset groups (i.e. knowledge of human resources, management or stakeholder relationships, physical infrastructure and virtual infrastructure) to conclude that KM processes will lead to enhancements in competencies, effectiveness and efficiency of organisational processes, business management abilities and business performance. That will finally lead to an increase in value generation for the whole organisation.

Measuring the value of intellectual capital can also be assessed by using tools and techniques such as “cause-and-effect map” that measures contribution of KM initiatives to the strategic objectives of the organisation, “evaluation roadmap” which is an interactive tool that guides users to select the most appropriate technique based on a set of structured questions to measure the impact of each KM initiative on the user business performance, “cost and benefit checklists” that compare costs of each KM initiative to its potential tangible and intangible benefits, and “priority matrix” that prioritize KM initiatives of users based on effectiveness and efficiency of performance (Robinson *et al*., 2004).

Other KM evaluation methods used in the construction industry are by using "verification tests" that use questionnaires to collect users' feedback to determine whether the system operates according to the required design and specifications, and "validation tests" that use questionnaires to collect users' feedback about the usefulness of the system (Lin *et al*., 2006).

Furthermore, Gupta *et al*. (2000) suggested that two major trends which can be used in evaluating KMSs in the organisations are by developing measurement ratios and benchmarks. Although there were various measures in practice, the research argued that there was still no absolute measurement matrix in the literature to measure the success of a KM effort. The research recommended that there is a need to develop accounting procedures for valuing intangible assets of organisations. The research suggested that evaluating KM efforts can be achieved through evaluating aspects related to KM, such as customer satisfaction, financial outcomes, effectiveness of business processes, ability to sustain innovations and changes, improvements resulting through enhancing organisational learning, and finally through quantifying critical success factors (Gupta *et al*., 2000).

Although all of these methods can help organisations to obtain better views of the performance and usefulness of their KMSs, there are still no precise ways to evaluate the return on investment in knowledge and the impact of KM on business performance (Robinson *et al*., 2004; Carlucci *et al*., 2004; Chong *et al*., 2000; Gupta *et al*., 2000). This study will help to provide a practical and structured method to evaluate the existing KMS of an organisation and suggest important modifications and enhancements.

1.3.7 Definition and Importance of KM Modelling

KM modelling is a technique that uses graphical and textual presentations to describe the real system of KM in order to describe the KMS features, components, inputs, outputs, tools, processes, practices and other factors that can impact the organisational knowledge and/or the KMS (Davenport & Prusk, 2000; Abdullah *et al*., 2002). KM models are used in organisations to provide guidance for implementing and applying KM efficiently and effectively. It can provide a procedural and structured plan that directs KM efforts through the stages of designing, building, evaluating and enhancing the KMSs of organisations.

KM models can be used to evaluate successfulness of existing KMSs in organisations and help to decide and achieve required improvements (Robinson *et al*., 2004; Axelsson & Landelius, 2002). It can also help to coordinate the work of the different people and/or groups who work on developing the KMS or applying various activities of the KM processes, by providing details about the different work phases and activities to be implemented and the roles of the people who apply these activities.

KM models help to enhance awareness of organisations, management and people about KM and its activities, tools and procedures, which may encourage management and employees to apply KM more successfully. It helps organisations to decide the overall objectives of applying KM and required strategies to achieve them. Using modelling techniques in KM to help people understand the complicated large systems leads to reducing the implementation and development costs of KMSs (Abdullah *et al*., 2002). This thesis presents a proposed KM model that addresses these issues and provides an effective and efficient way for managing knowledge in the construction industry.

1.4 Summary

This chapter aimed at providing required background of knowledge and knowledge management (KM) related to the objective of the research to develop a model for KM implementation and application in construction projects. The chapter started with discussing the importance of KM to the organisations and its positive effects on organisational learning and competitive advantages. Then, the chapter reviewed knowledge definitions in the literature and showed how knowledge is different from and more valuable than data and information. Furthermore, the chapter reviewed important methods for classifying knowledge in the literature that is important to help organisations to identify the methods and processes required to manage the different types of knowledge successfully. The review of knowledge classification methods highlights two important methods, i.e. classifying knowledge into explicit and tacit knowledge, and into explicit, implicit and tacit knowledge.

In the following section of this chapter, various definitions of KM and KMS from the literature were reviewed and a definition of KM and KMS were provided in the research that complies with the research aim of developing a KM model to provide a structured comprehensive method for KM implementation and application in construction projects. Then, factors and benefits that motivate applying KM in the construction industry were reviewed in the literature. Also, problems and challenges that cause difficulties in KM implementation and application, and possible solutions to reduce the influence of these factors were discussed. Methods and techniques developed and used in the construction organisations to enhance KM adoption were reviewed. In addition, methods developed and used to evaluate KMSs in terms of their effect on business performance, their compliance with the required design and specifications, and the usefulness of these systems to the people and the organisations, were reviewed. Finally, a definition of the KM modelling technique was introduced and the importance of KM modelling in providing procedural guidance to design, build, evaluate and enhance KMSs was discussed.

In this chapter, a general review of different KM aspects was provided to assist as a starting point in this research to investigate the different areas of KM, identify the subjects of interest that require more research work, and to provide required background that simplify understanding and developing the KM model. The following chapter will discuss the main objectives of the research and the research methods followed to achieve the desirable results.

CHAPTER TWO

RESEARCH METHODOLOGY

2.1 Introduction

This chapter aims at describing the research methodologies adopted in this study to commence, develop, enhance and evaluate the research proposed KM model. This chapter starts with an overview of the motives and problems in the KM domain and literature that encouraged conducting more subject-related research to develop a KM model for construction organisations. Then, the objectives of the research are detailed and the research methods used in this study to fulfil these objectives are described. Finally, limitations that may affect the adoption and results of the research methodologies will be described. The following chapters will be dedicated to describe the adoption and application of these methodologies in addition to a description of the research final developed KM model.

This chapter highlights the importance and need to conduct more research to pinpoint and improve the application of KM in modern construction organisations. The research in general has been motivated by the current growing number of KM adopter and the increased awareness of its importance and benefits to the business work (Jennex, 2005a). The current interest in KM has also been motivated by the improvements achieved in data processing and communication capabilities (KLICON, 1999). This chapter will describe the shortcomings of other research on KM, the aim and objectives of the research, and the research methods to achieve desirable results.

2.2 Problem Description

As stated in chapter 1, construction projects are in knowledge-intensive environments where many of interrelated components are working together in a complex manner. In many circumstances, knowledge in the construction industry is mostly tacit knowledge and highly based on individuals' experiences and perceptions, which increase the difficulty of capturing and reusing it. These situations call for a method for managing knowledge to solve problems and achieve higher quality construction projects.

Various KM models have been developed to support KM activities. However, many of the existing KM models only provide a communication platform or a repository for data and/or explicit knowledge, and much KM efforts still lack structured methods of implementation and alignment with business objectives and strategies of the organisations.

Most recent literature classifies knowledge within an organisation into two categories, i.e. explicit knowledge and tacit knowledge. Explicit knowledge is normally easy to capture, retrieve, share and use because it can be expressed in words and numbers that can be managed more easily, while tacit knowledge is personal and exists in the individuals' memories in the form of experiences and know-how that is not easy to capture, share and manage. However, tacit knowledge can be captured, mobilized and turned into explicit knowledge, which can be accessible to others in the organisation to enable the organisation to progress, rather than requiring its members to relearn from the same stage all the time and repeating mistakes that have been learnt how to solve and avoid in previous projects (Gore & Gore, 1999).

Many studies have confirmed that tacit knowledge plays the most important role of KM in the organisations (Burgess & Singh, 2006). However, many of the existing KM techniques and tools can only deal with explicit knowledge. Knowledge generated in construction projects, especially tacit knowledge, can be lost from the company due to many reasons, such as when people with experiences leave the company or when knowledge saved in unsearchable filing systems (Carrillo *et al*., 2000). This represents a lost opportunity for the organisation, in that if its competitors succeed in sharing and leveraging similar knowledge efficiently, then they may gain competitive advantages (Zack, 1999).

These challenges and barriers that may affect the successful management of knowledge cause the need for a more coherent and structured approach for utilising knowledge in construction organisations. Therefore, it is essential to develop a new KM model which can be used to satisfy the needs of the industry to successfully manage organisational knowledge. This study addresses this problem by developing a KM model that can deal with knowledge more efficiently and effectively in construction projects.

2.3 Goals and Objectives of the Research

The overall aim of this research is to develop an integrated KM model to help construction firms to make better use of knowledge in their organisations and to improve construction management performance. It is anticipated that this will aid the implementation and application of KM that may have an economic impact by eliminating wasteful time and resources of reinventing solutions that have already been invented elsewhere in the organization. It will also have a social impact, as KM will act as a catalyst for improving organizational culture and promoting sharing and teamwork. Specific objectives have been formulated and methodologies have been followed in order to achieve the stated aim. The specific objectives of the research are as follows:

1. To review current practices of KM in the construction industry. A critical review of important KM literature is carried out to highlight technological, cultural and managerial aspects of KM implementation and application in the context of construction projects and organisations.

2. To analyse and evaluate existing models of managing knowledge in the construction industry, and discuss problems those negatively affect the successful implementation and application of KM in the construction context.

3. To develop a new KM model that enables ideas and suggestions of employees to be captured and shared, and deals with creating value from construction operations. The KM model will provide practical help to firms for taking the first step into applying new KMSs and improving their existing systems. The proposed KM model formulates a strategic framework and a stage-by-stage approach to develop and apply KM in construction organisations. This model will also help organisations to identify what knowledge is important for their organisations, where it can be found, and how it can be shared among employees or stored in the KMS repositories for future reuse.

4. To develop a guidance that can help organisations to identify important KM resources, processes, tools and procedures for successful implementation and application of KMSs in the construction organisations.

5. To validate the proposed KM model by applying a chosen research methodology. Questionnaire surveys and interviews approaches are used to enhance the proposed KM model and case studies are conducted to evaluate the final developed model in

terms of its ease of use, usefulness, importance and credibility to the construction industry.

6. To provide recommendations for the future development of KM implementation and application at both organisational and industrial levels within the construction industry.

2.4 Research Methodologies

A combination of quantitative and qualitative research methods has been adopted in this research to investigate KM critical success factors, tools and activities, and KM implementation and application in the construction industry, in order to develop, enhance and evaluate the proposed KM model. The main methodologies adopted in this research are:

2.4.1 Literature Review

The research depends on the understanding and analysis of various recent KM literature to provide a foundation for this study. Review of literature helps to support the research work with other research on the KM domain to provide more understanding and strength to the research topic and provide other examples of KM models to make the research more credible. Existing KM models in the construction industry and some other general models will be reviewed and analysed. The advantages and disadvantages of the current KM models will be studied in order to search for appropriate solutions of problems. This provides a theoretical basis for developing a new KM model that fills gaps of other KM models and present enhanced KM model for the construction industry.

2.4.2 Interviews

The interview is probably the most common research method in qualitative research, because it provides an easy flexible method that can be used to capture important ideas and detailed opinions to enrich the research (Bryman & Bell, 2003).

Interviews with KM academics and practitioners in the construction industry and in-depth study of the initial proposed model will help to modify and improve the KM model to enable the developed version to be used more effectively and efficiently in the construction organisations. Interviewees will be asked to provide general opinions and important aspects that need to be considered when developing a KM model, and also to evaluate and discuss the components of the proposed KM model and provide opinions and suggestions.

The interviews follow semi-structured approach, which means that a procedure, shown in Appendix 1, will be used in the interviews, but the interviewees will be given flexibility to refer to and discuss their opinions and interests in the KM field. This also means that questions that are not included in the questions' list can be asked regarding details and description on things mentioned by the interviewees (Bryman & Bell, 2003). This method may help to encourage the interviewees to provide more important, valuable and detailed responses to the interview questions (Kendall & Kendall, 2002).

2.4.3 Questionnaire Survey

A questionnaire survey has been conducted to capture the initiatives for KM and investigate the critical success factors for implementing KM in the construction industry. The questionnaire seeks the importance of KM activities, procedures and tools for successful implementation and use of KMSs, and investigates which activities and methods are currently used in construction organisations to manage their knowledge. The questionnaire survey helps the research to reach to a final enhanced version of the KM model that can help to successfully manage knowledge in the construction industry.

The questionnaire survey is one of the tools used by researchers to confirm, deny or enhance what was already believed or known. Survey methodology is important and popular because of its ability to define and detail various characteristics of key issues that can be important and interesting for certain readers and organisations (Chauvel & Despres, 2002). A questionnaire survey also has the ability to provide results that can be quantified and so can be easily treated and analysed statistically. It provides the ability to extend the results obtained from a sample of respondents to a larger population when it is not practical and efficient to work with the entire population. It also provides fast and straightforward results compared with other research methods to allow researchers and practitioners to act in a relatively quick and intellectually respectable manner (Chauvel & Despres, 2002).

2.4.4 Case Studies

Case studies of two international large sized construction companies interested in KM application have been conducted. The case studies have been carried out to investigate KM application in construction organisations, evaluate the KM model in terms of its usability and usefulness and demonstrate how the developed model can be used to improve performance of KM processes.

Among the tools that were used in the case studies are conducting interviews, observation, and investigating hard data. This research has utilised the knowledge of people whose jobs are related to computer and information systems, such as IT managers, knowledge managers, and frequent users.

The case studies also aimed to ascertain the advantages and disadvantages of KMSs in use and sought to find appropriate solutions for problems. The research studied areas for KM processes in the construction companies, such as implementing or building the KMS, applying or using the KMS to capture, create and distribute knowledge, and impediments that may negatively influence the processes of managing knowledge.

Case study approach is one of several strategies of doing research that has particular advantages and disadvantages compared with other ways, such as experiments, surveys, histories and the analysis of archival information. A common feature of a case study is that it aims to clarify the reasons why a decision or a set of decisions has been adopted, the procedures of implementing the decision and the results for applying such decision (Schramm, 1971).

According to Yin (2003), a case study is an empirical inquiry that investigates a phenomenon and studies its contextual conditions, especially which might be highly relevant to the phenomenon of study. In general, case studies are the preferred strategy when the researchers are dealing with “how” and “why” questions, having little control over events, and investigating a contemporary phenomenon within some real-life context (Yin, 2003).

The case study is a comprehensive research strategy that benefits from the prior development of theoretical propositions to guide the design, data collection and data analysis approaches and techniques (Stoecker, 1991). Since this research aims to investigate why and how construction organisations adopt and apply KMSs, this method has been chosen to fulfil the purpose.

2.5 Research Stages

The methodologies and stages followed during the research life-cycle are represented in Figures 2.1 and 2.2.

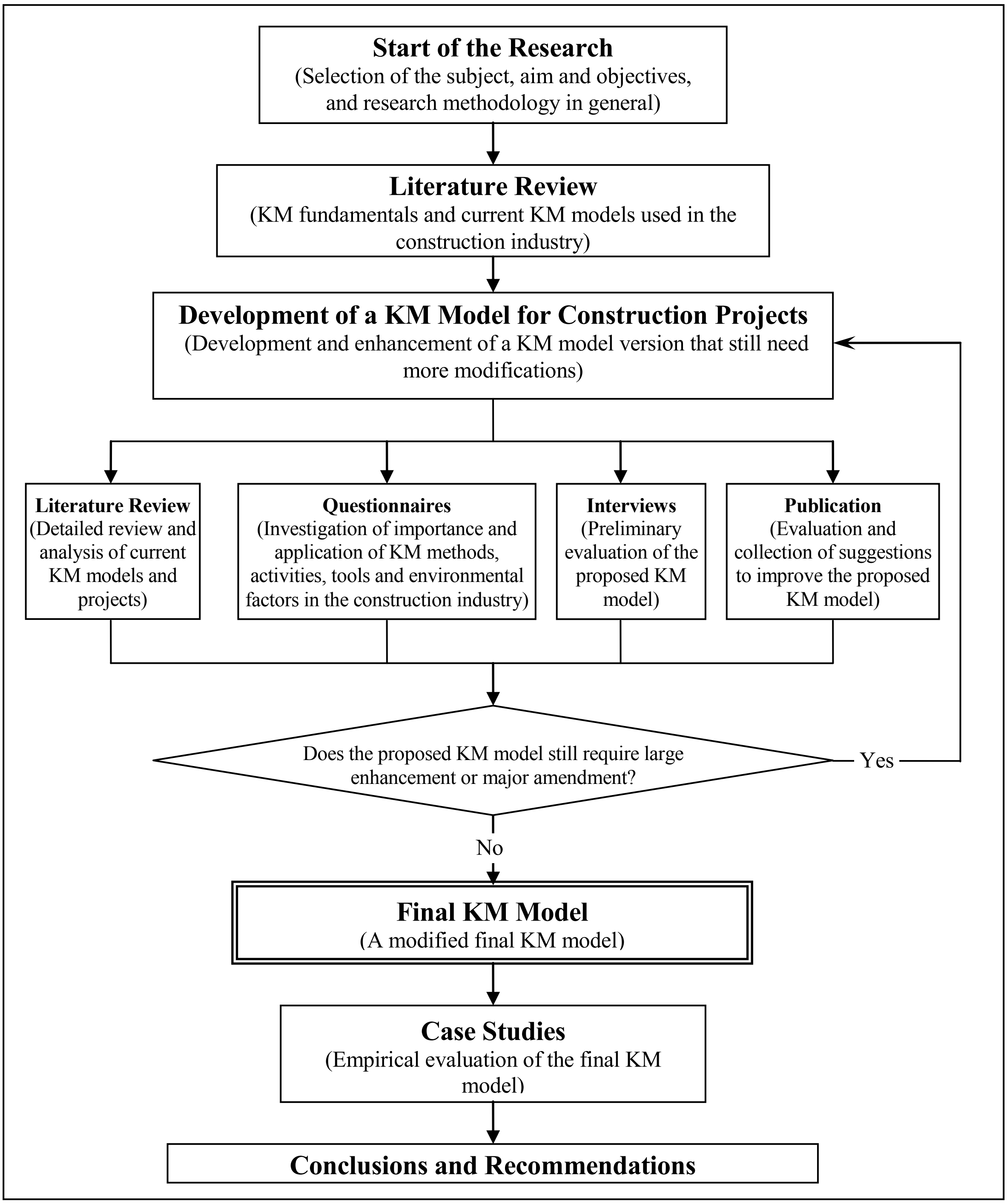
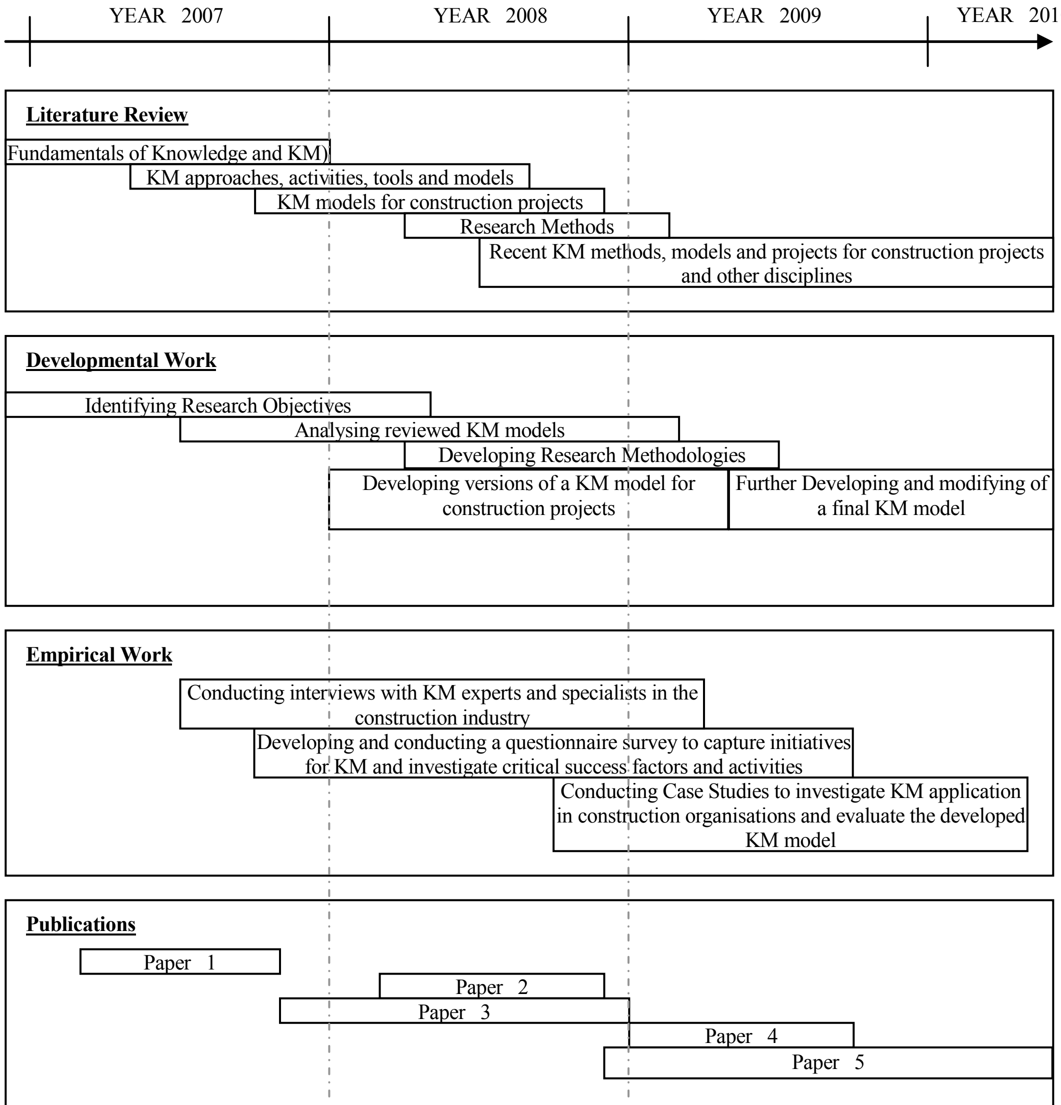


Figure 2.1: Research Model



1. Ahmad, H.S., An, M. and Gaterell, M. (2007) 'Development of KM model to simplify knowledge management implementation in construction projects', *Proceedings of the 23rd Annual ARCOM Conference, Association of Researchers in Construction Management*, Belfast, UK, 3–5 September, pp.515–525.
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Figure 2.2: Research Stages and Methodologies

As shown in Figure 2.1, the KM model has been developed and enhanced from its first version into a final improved KM model through continuous reviewing of literature and projects, conducting questionnaire survey with KM practitioners, organising interviews with people from the KM domain and construction industry, and presenting and publishing the achieved results in scientific journals and at conferences.

These methods have been used to investigate KM tools, processes, methods and environmental factors, and to collect experts' and practitioners' feedback and ideas for further improvement of the proposed KM model. This helped the research to identify key parts of the KM model, evaluate the appropriateness of the proposed KM model, identify important characteristics that should be included in the development of the model, and finally to decide required amendments and improvements that might be useful to enhance the developed KM model.

Examples of the various versions of the KM model proposed, developed and evaluated during the life-cycle and stages of the research are shown in Figures 2.3 to 2.7. The first developed version of the KM model depended mainly on the review of existing KM modelling techniques and KM models, especially those developed for construction projects. These include KM models and techniques that developed by Abdullah *et al.* (2002), Nonaka and Takeuchi (1995), McInerney (2002), Wetherill *et al.* (2002), O'Dell and Grayson (1998), Tserng and Lin (2004), Lin *et al.* (2006), Robinson *et al.* (2004), Jashapara (2004), Wiig *et al.* (1997), IDEF0 (1993), Tiwana (1999), Davenport and Prusak (1998) and Wong and Aspinwall (2004).

Every KM model version went through an evaluation process through extensive study of the model details, an in-depth review of recent KM literature and capturing feedback from the research participants. Therefore, limitations of the developed versions and recommendations to enhance them were concluded and applied.

In general, while the research was developing the KM model from one version to a more enhanced one, the research started to receive more positive feedback, less negative comments and less required improvement to the proposed KM model. Chapters 3 and 4 provide more details of how the adopted methodology of the research helped to develop and improve the KM model to be more practical and useful for KM implementation and application in construction projects.

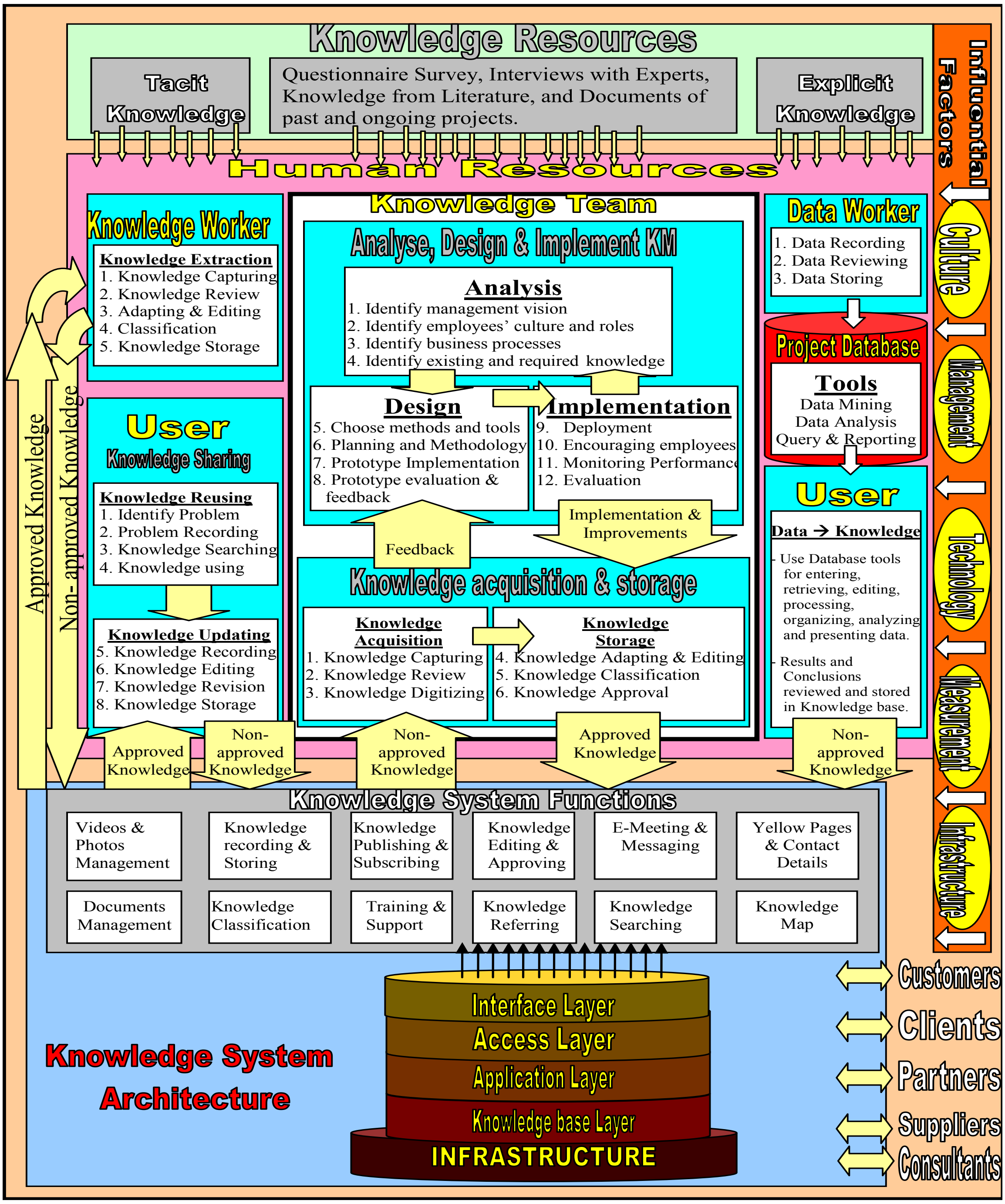

Figure 2.3: Version 1 of the KM Model Developed During the Research Stages (Details are available in Appendix 4.1) (Abdullah et al., 2002; Nonaka & Takeuchi, 1995; McInerney, 2002; Wetherill et al., 2002; O'Dell & Grayson, 1998; Tserng & Lin, 2004; Lin et al., 2006; Robinson et al., 2004; Jashapara, 2004; Wiig et al., 1997; IDEF0, 1993; Tiwana, 1999; Davenport & Prusak, 1998; Wong & Aspinwall, 2004)

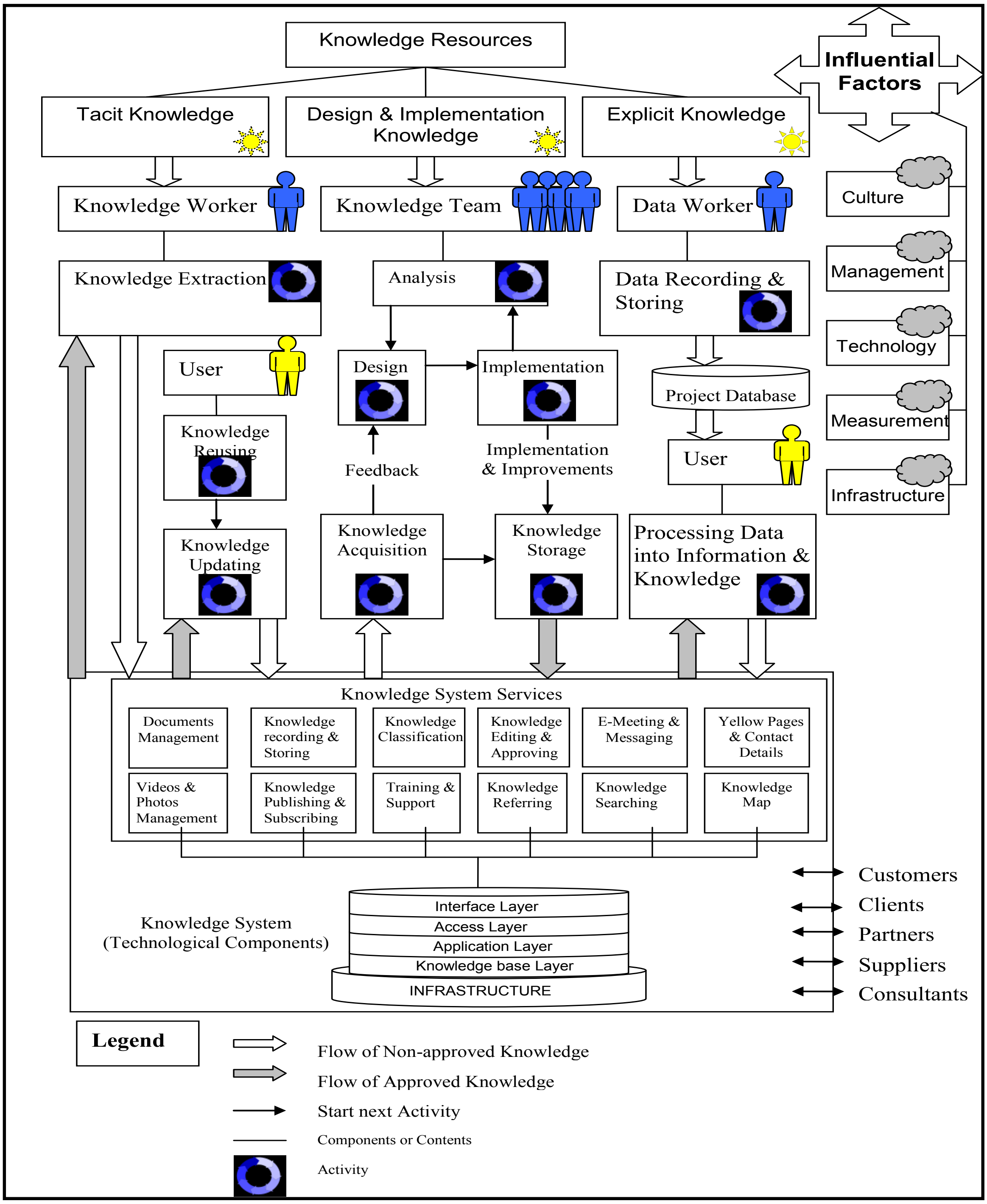

Figure 2.4: Version 2 of the KM Model Developed During the Research Stages (Details are available in Appendix 4.1)

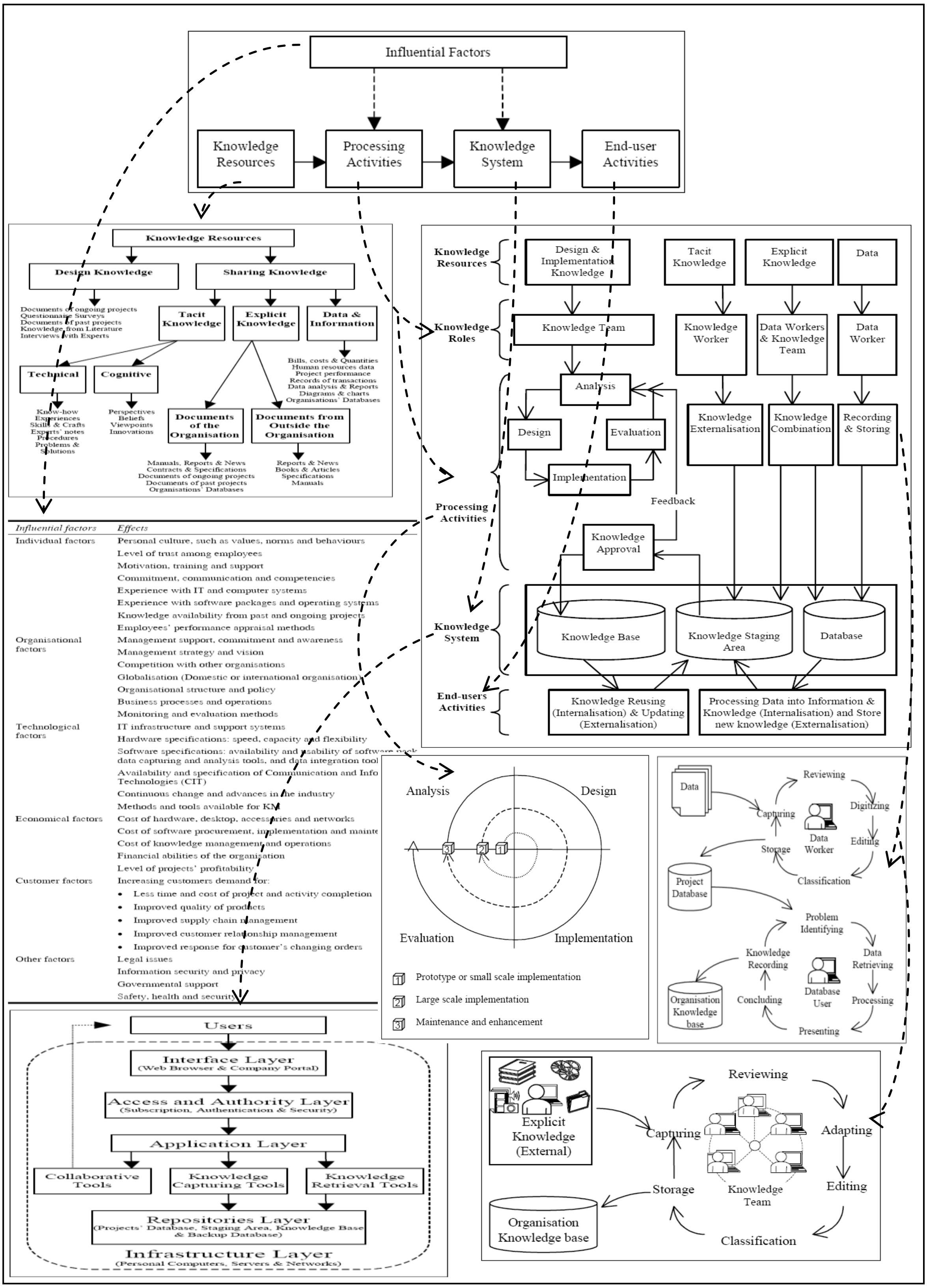

Figure 2.5: Version 3 of the KM Model (Details are available in Appendices 4.2 and 4.3)

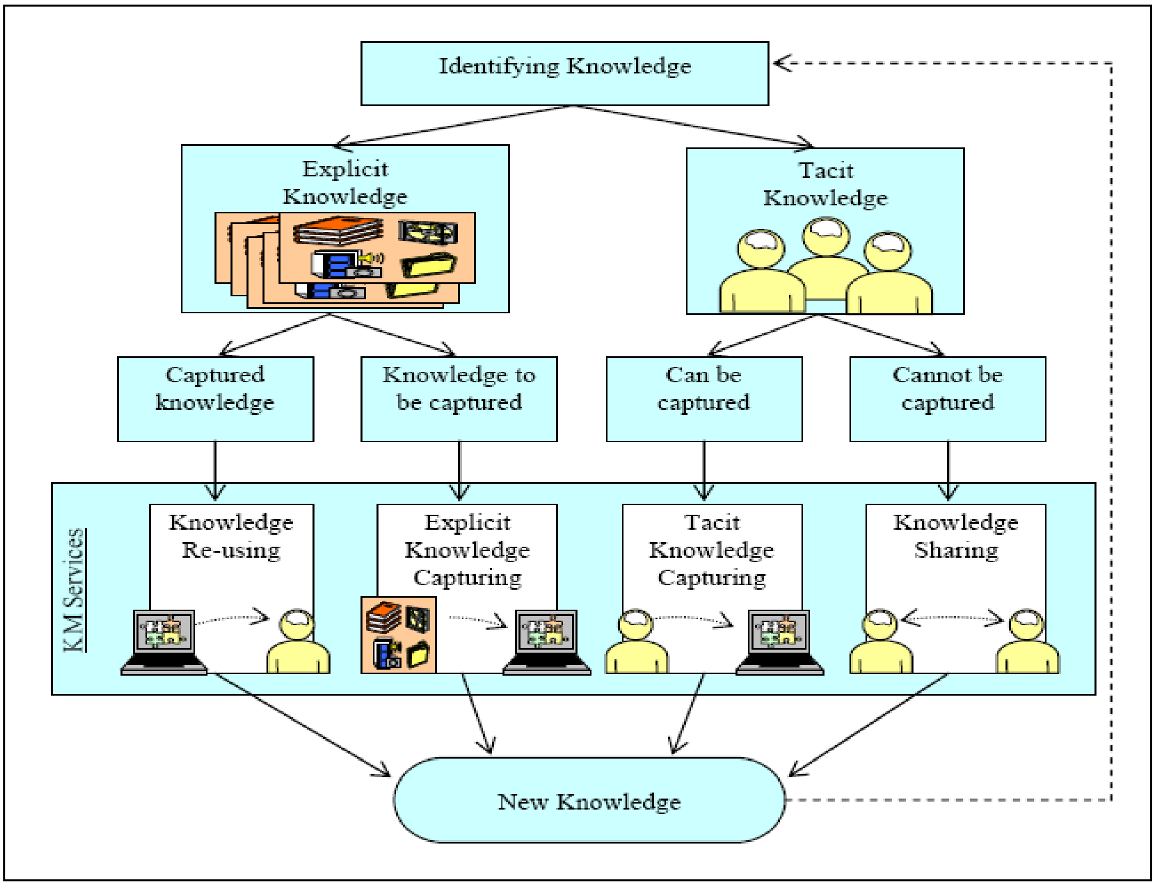

Figure 2.6: Version 4 of the KM Model Developed During the Research Stages (Details are available in Appendix 4.4)

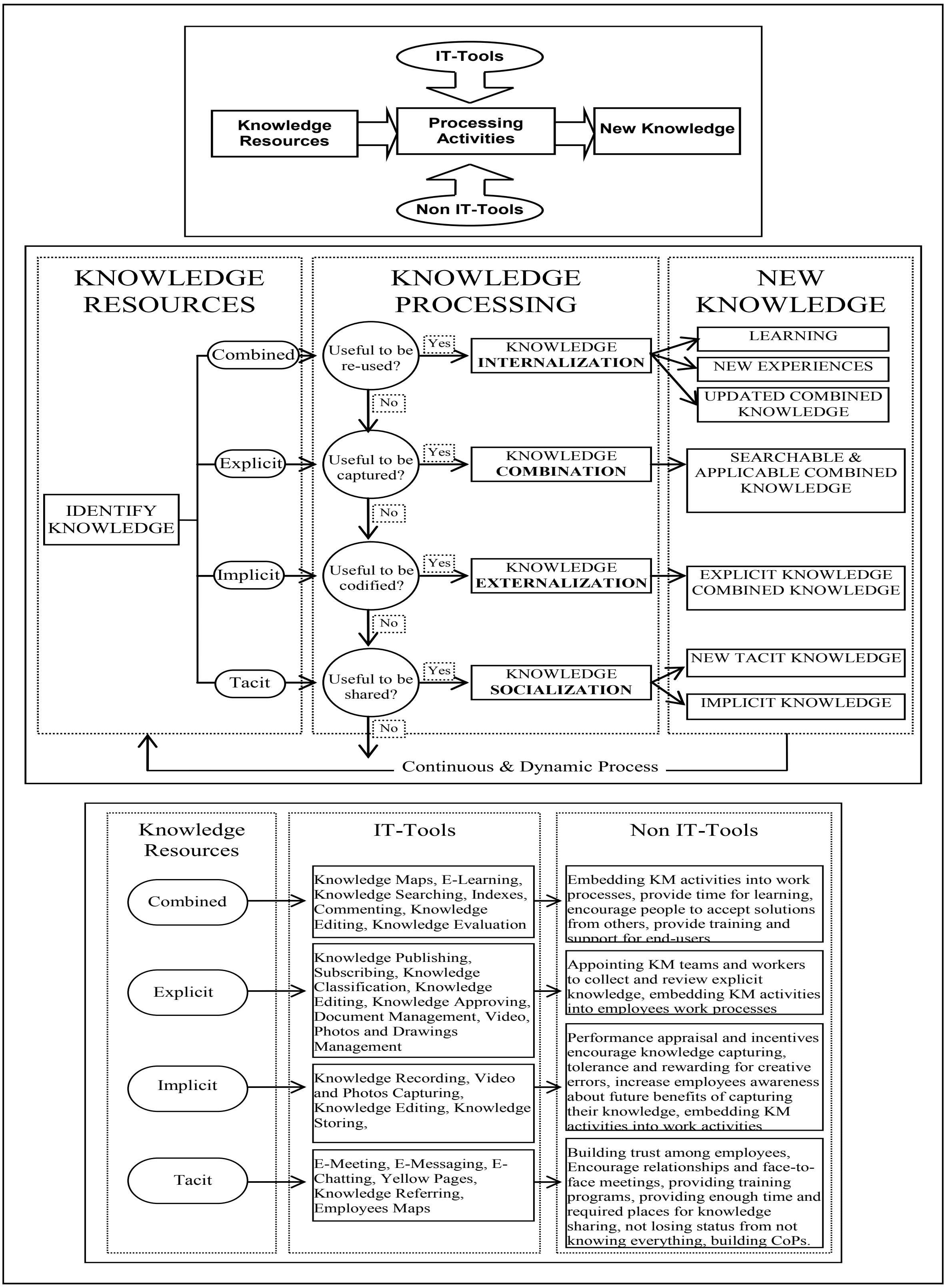

Figure 2.7: Version 5 of the KM Model Developed During the Research Stages (Details are available in Appendix 4.5)

2.6 Limitations

Building and implementing a new KMS in an organisation is a complicated task because it can involve fundamental changes, such as organisational culture, work practices and technological infrastructure. This requires a considerable amount of time (perhaps years) to be accomplished, and substantial courage from organisational management. Thus, this cannot be achieved within the limited time extent of this research.

Another limitation to the research is that most of the employees in the construction industry feel they lack the time to provide details about the existing knowledge system in their organisations due to the limited time of projects and the pressure to finish projects before specific deadlines. Furthermore, some employees feel they lack the authority to provide such details due to the restrictions of privacy and confidentiality regulations. The details related to the design and implementation processes of the KMSs cannot be effectively investigated in the construction organisations because most of these processes are normally provided by external IT specialised companies.

2.7 Summary

This chapter highlighted the importance and need to conduct more research to pinpoint and improve the application of KM in modern construction organisations. KM modelling is an important method that can help to manage knowledge within the complex environment of construction projects. However, more research work is needed to fill gaps and solve problems of existing KM models. The research aims at developing a KM model that fills the gaps of previous models to better deal with tacit knowledge, provide structured methods of KM implementation and application, and ensure alignment of KMSs with business objectives and strategies of the construction organisations.

Research methods were adopted in this thesis in order to satisfy the research aims and objectives, beginning with an extensive review of KM literature and existing KM models. The advantages and disadvantages of these models were analysed to provide a theoretical basis for the development of a new KM model.

Interviews with academics and practitioners of KM in the construction industry were conducted to evaluate and improve the proposed KM model of the research. Furthermore, a questionnaire survey was used to investigate critical success factors, activities and tools for KM implementation and application in the construction projects. This helps to highlight important KM practices in order to evaluate and enhance the proposed KM model.

Finally, two case studies were carried out to investigate the applicability of the proposed KM model and to evaluate it in terms of usability and usefulness to the construction organisations. The methodologies, stages and limitations of the research were reviewed and discussed in this chapter, while the application and results of these methodologies will be discussed in the following chapters.

CHAPTER THREE

LITERATURE REVIEW

3.1 Introduction

This chapter aims at providing a detailed review of various KM models in the literature, especially those developed for construction projects. Insights gained from analysing the construction KM models will be highlighted and findings will be presented to provide an important background for the development of a new KM model.

The lack of standard processes and systematic procedures, combined with the lack of awareness of the importance and future benefits of KM, causes the need for a more coherent and structured approach for managing and utilising the different types of knowledge within organisations (Hari *et al*., 2005; Carillo *et al*., 2004; Robinson *et al*., 2005). A method used to overcome challenges, and develop and manage knowledge systems successfully is by using KM modelling.

Models are used to help people to understand the complexity of real systems by representing the main features and dividing the large systems into its parts, which will simplify understanding and managing (Abdullah *et al*., 2002). Models help to provide a more structured approach to understand, implement, apply and evaluate KMSs. Many researchers have developed KM models to help organisations in implementing and applying KM successfully. However, it can be argued that most of those models have disadvantages that limit the organisations to achieve successful KM in the construction projects.

3.2 General KM Models

Many methods, techniques and tools have been developed in the literature to enhance the management of knowledge and reduce the effect of KM barriers. Examples can include knowledge maps (Lin *et al*., 2006; Woo *et al*., 2004), SECI model (Nonaka and Takeuchi, 1995), KM models (Abdullah *et al*., 2002), Activity-Based KMSs (Tserng & Lin, 2004) and Ontology-Based KMSs (Gruber, 1993; KLICON, 1999; El-Diraby & Kashif, 2005). However, these KM techniques and many other ongoing research need a more structured, coherent approach to KM and a better alignment of KM to business goals in the construction organisations.

Nonaka and Takeuchi (1995) suggested that knowledge is created through continuous interactions between tacit and explicit knowledge to form four modes presented in the SECI (Socialization, Externalization, Combination and Internalization) model as shown in Figure 3.1. Nonaka (1991) argued that to create new knowledge there should be a non-stop process to re-create the company and everyone in it by making the creation of new knowledge a non-specialised activity where everyone in the organisation acts as a knowledge worker. He explained that new knowledge always begins with the individual and that individual's personal knowledge can be transformed into valuable organisational knowledge, such as when an employee uses his experiences to enhance work processes or provide innovations.

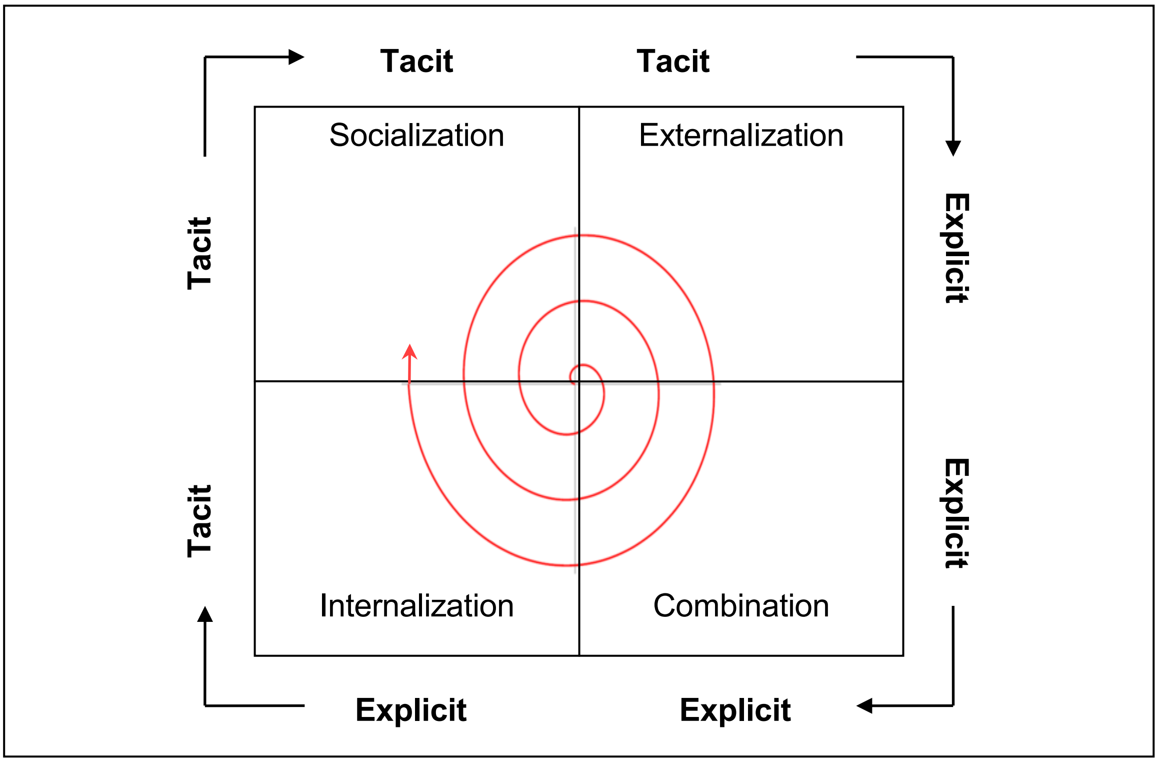

Figure 3.1: The SECI Model (Nonaka & Takeuchi, 1995)

The spiral represents the continuous movement between different modes of knowledge creation, and the increase in the spiral radius shows the movement and diffusion of knowledge through organizational levels.

Socialization is to share or acquire others experiences or tacit knowledge through meetings, direct conversations, observation, practicing, training, etc. Through socialisation, an engineer can learn from an expert or senior engineer the tacit secrets of solving a problem in the construction projects (tacit to tacit).

Externalization is to transform tacit knowledge to explicit knowledge to enable its communication. Through externalization, a senior engineer can translate his tacit knowledge such as experiences, ideas, know-how and perceptions into explicit in the format of reports, specifications, articles, procedures, descriptions, etc that is easy to be understood, captured, shared and reapplied (tacit to explicit).

Combination of various related elements of explicit knowledge to form new explicit knowledge is the third form of knowledge creation. Through combination, a report can combine explicit knowledge with other related knowledge to provide more analysis and understanding of valuable explicit knowledge available for employees (explicit to explicit).

Finally, *Internalization* indicates the process of developing new experiences by learning from, reusing and reapplying the existing explicit knowledge to produce new tacit knowledge that if successfully externalized can help to update and revalidate the existing explicit knowledge. Through internalization, the available explicit knowledge can be reapplied by employees to learn and produce new experiences and tacit knowledge (explicit to tacit). This new tacit knowledge can be shared among individuals through direct contacts (Socialization) to start a new iteration of the continuous spiral.

Li and Gao (2003) studied the fundamental points of tacit knowledge on the basis of Nonaka's SECI model regarding knowledge creation and its constraints. They underlined the importance of the spiral-type model in providing an analytical framework for knowledge activities in business management. The study relied on Polanyi (1996) to categorise the tacit knowledge into two parts: implicit and real tacit.

Implicit knowledge indicates the ability of people to express and articulate knowledge, but they may be unwilling to do that because of specific reasons under certain settings (such as behaviour, culture or organizational style). However, it is of great value for an organisation to arrange activities to help to transform implicit knowledge of employees into explicit through suitable incentive schemes to make this knowledge available for other employees across the organisation (Li & Gao, 2003). According to Polanyi (1996) it is hard for real tacit knowledge to be communicated among people with different levels of knowledge and it is useless and costly for an organisation to try to manage it for sharing.

McInerney (2002) argued that to effectively manage knowledge and successfully transfer tacit knowledge into explicit accessible formats in any organisation, there should be a clear understanding of the dynamic nature of knowledge. He defined explicit knowledge as the knowledge that has been explained, recorded or documented, while tacit knowledge is the rest of other forms of knowledge that, if it has not been represented and made explicit, there could be lost opportunities of competitive advantages.

According to McInerney (2002), knowledge can also be a disadvantage for organisations if it is incorrect or misleading, if it is inhibiting or discouraging, or if it is not aligned with or does not satisfy an organisation's mission or strategy. Knowledge is considered to be dynamic because it is constantly changing in individuals through experiences and learning, and in organisations through the movement of knowledge to be transferred or shared. That requires keeping knowledge stored in the knowledge repositories current and updated, while keeping knowledge systems flexible enough to deal with continuous updates and changing requirements from all sectors of the organisation.

McInerney (2002) suggested that instead of investing efforts in the initiatives of extracting knowledge from the employees, it might be more productive for organisations to invest efforts in creating a knowledge culture that encourages learning and sharing of knowledge using procedures such as establishing small group meeting rooms, conducting on-site seminars, rewarding those who continuously practise learning and who teach others what they know, offering informal "water cooler"-type meeting places throughout the workplace, encouraging trust, dialogue and collaboration among employees, etc. His study illustrates how tacit knowledge and explicit knowledge interact through internal and external processes within and among people in an organisation using a graphical representation of a KM model as shown in Figure 3.2. Having a static collection of knowledge is not enough, but continuous knowledge creation is essential to manage knowledge more effectively and to keep organisations healthy and innovative (McInerney, 2002).

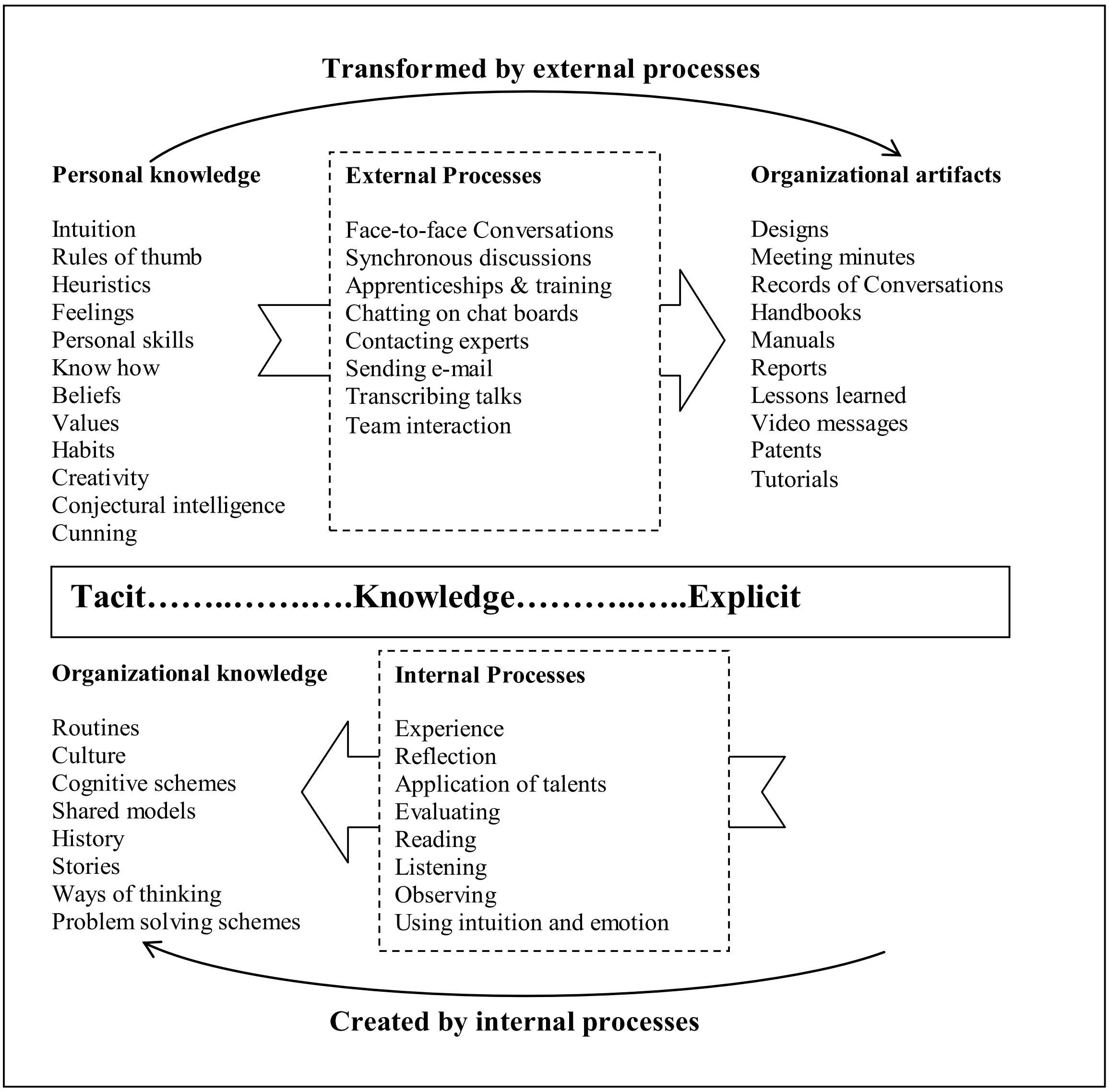

Figure 3.2: Tacit-Explicit Knowledge Continuum (McInerney, 2002)

3.3 KM Models in the Construction Industry

In this context, some recent research in KM for the construction industry have been reviewed and analyzed by enumerating their advantages and disadvantages that have been identified. This study aims to build up a foundation for developing a new KM model that fills gaps of other methods and simplifies KM implementation and application in the construction industry.

A KM model developed in the E-Cognos project aims at promoting consistent KM within collaborative construction environments (Ferneley *et al*.,2002; Lima *et al*., 2005). E-Cognos is a European R&D project for electronic consistent KM across projects and between enterprises in the construction domain.

The consortium includes an IT and KM service provider: Arisem; European leading construction companies: OTH, YIT, Taylor Woodrow and Hochtief; and European leading research centres and academic: CSTB and Information Systems Institute of University of Salford.

According to the research by Ferneley *et al*. (2002), the E-Cognos platform presents the first comprehensive ontology-based portal for KM in the construction domain that provides adequate search and indexing capabilities and allows for formally documenting and updating organizational knowledge. The proposed approach is described by Wetherill *et al*. (2002) as a cyclical approach as shown in Figure 3.3, that consists of eight phases: preparation of organisation for KM implementation, understanding and modelling core business processes, case study definition, capture KM practice, specification of KM solution and building KM strategy, implementation of KM solution, KM solution trial, and evaluation of KM solution, which can provide feedback that promotes for a new iteration of the KM phases that lead to refining and improving KMS.

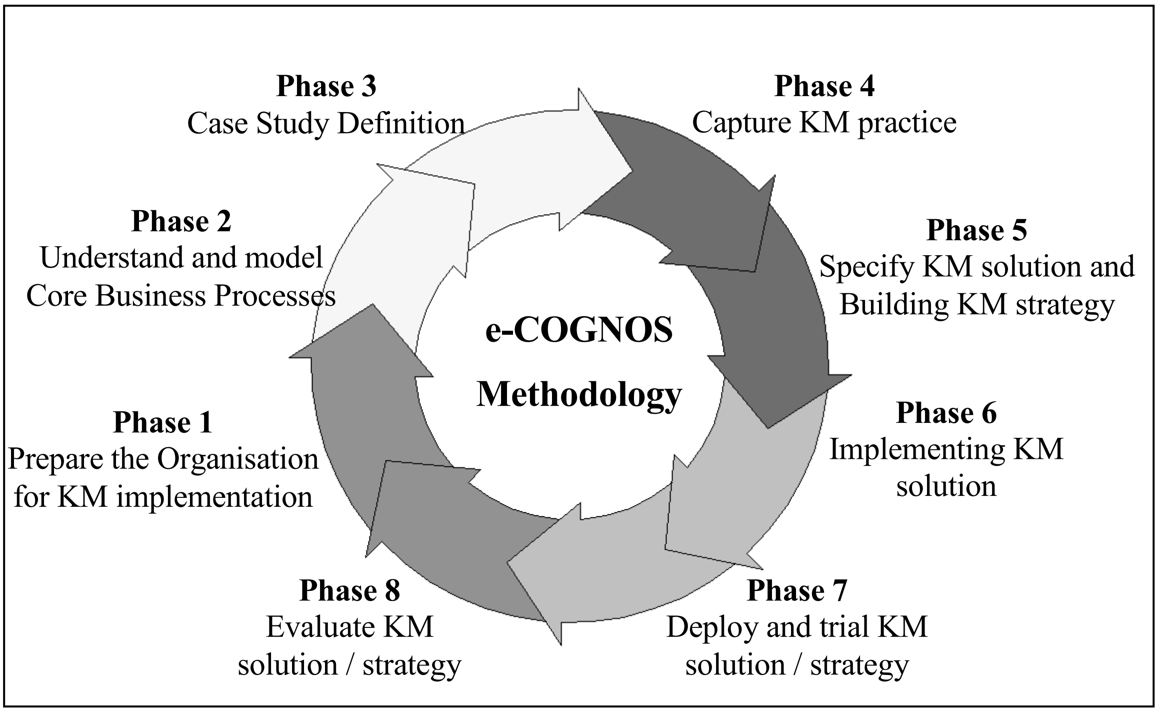

Figure 3.3: The e-COGNOS Methodology (Wetherill *et al*., 2002)

Phase 1 aims to prepare the prospective user of KMS for the implementation and use of the new system and handle the problems that may arise from the management and employee resistance to implement or use the KMS. Therefore, this stage tries to introduce and explain the activities and tasks, which accompany the implementation and use of the KMS to managers and staff of the organisation by using tools such as brochures, posters and sessions. This stage also aims to assess risks related to implementation and use of the new system, and learn from past experiences in implementing KMSs both successful and unsuccessful, in the organisation and in other organisations.

Phase 2 aims to model the core “high-level” business processes of each prospective user of the KMS. This stage involves reviewing the current and future company strategy, the structure of the organization, the culture of the organization, and the current systems in use, such as rules, procedures, guidelines, software and hardware systems. This stage should be implemented by internal consultants of the organisation with support from academic and research institutions in order to encourage employees to respect and cooperate with consultants, and to help secure ownership of the KM process.

Phase 3 aims to concentrate on a specific process or business unit of the organisation by identifying success factors, preparing extensive descriptions of the KM-related practices, and specifying KM metrics appropriate to evaluate the KM practice in the business unit or process.

Phase 4 aims to determine a suitable method that requires the design of questionnaire and interviews with staff to evaluate the effectiveness of KM practices in the process / business unit that has been selected in phase 3.

Phase 5 depends on the evaluation results of KM practices in phase 4 to prepare a plan for the KM solution in a wide range in the organisation and defines the appropriate KM strategy for the organisation.

Phase 6 aims to implement the plan and follow the strategy from phase 5 to build the recommended KMS for the organisation.

Phase 7 aims to put the implemented system in the use of employees of the organisation. The implemented system should be tested to ensure that it operates correctly according to the design and specification.

Finally, phase 8 aims to evaluate the usefulness of the KMS for the employees and organisation, and its impact on their performance. This last stage provides a feedback that promotes a new iteration of the KM phases that lead to refining and improving the existing system.

The main focus of the continuous research and development work at Skanska Group (one of the world's largest construction companies who works in more than 60 countries with about 56,000 employees and a leading position in a number of home markets in Europe, the United States and Latin America) that started in 2000, is to link together knowledge-bearers at business units or external specialists with Skanska's project organizations (Skanska, 2007). A Knowledge Network has been established, in which knowledge maps were applied, to facilitate the exchange of experiences, reduce risks in development, and enhance the performance in each business stream through knowledge exchange between different business units and different geographic markets (Skanska, 2007). Axelsson and Landelius (2002) reviewed how Skanska Group enhanced knowledge transfer through its Knowledge Network by using O'Dell and Grayson's (1998) KM model. This model consists of seven steps comprising: information identification, information collection, information organisation, information sharing, knowledge adaptation, the use of knowledge, and creation of new knowledge, as shown in Figure 3.4.

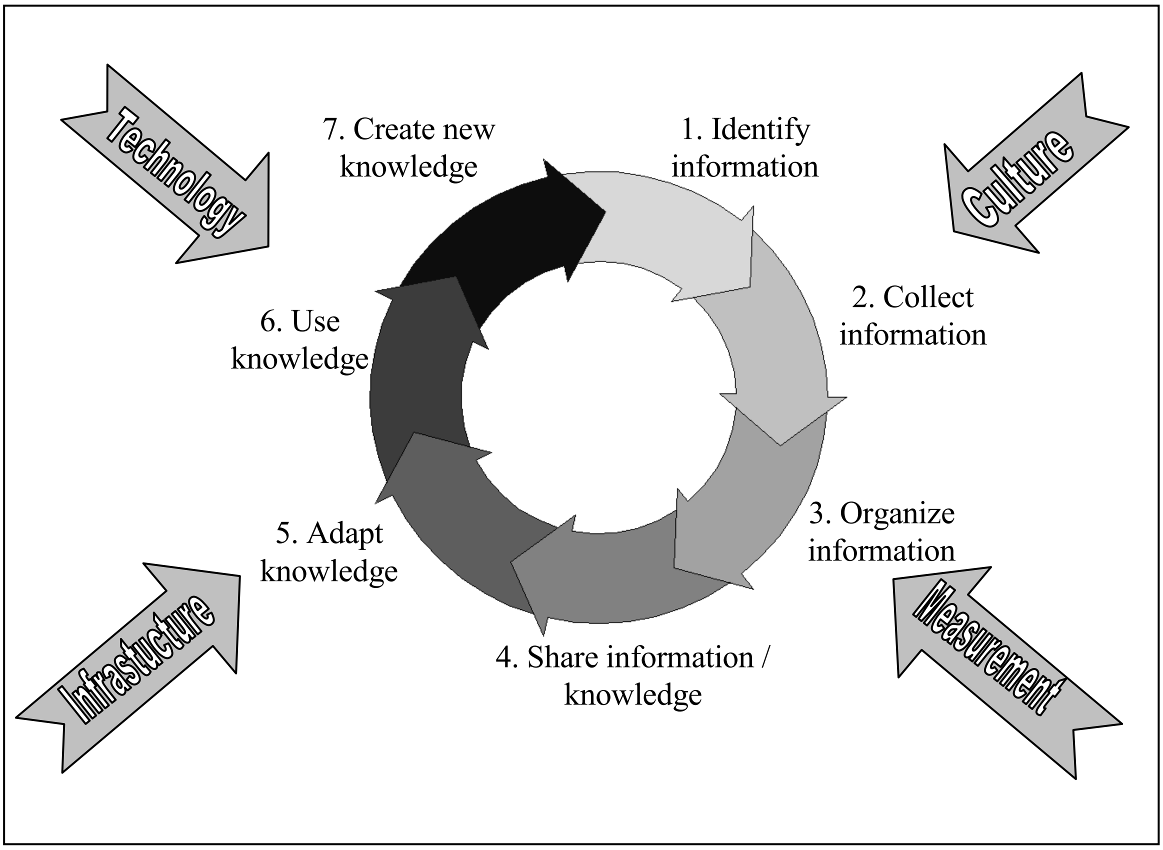

Figure 3.4: Steps in the Knowledge Transfer Process in a Knowledge Transfer-enabling Environment (O'Dell & Grayson, 1998).

Figure 3.4 shows that KM efforts and processes require the support of four enablers in order to work successfully. This means that in order to successfully capture knowledge, share experiences and know-how among users, and reuse captured and shared knowledge in practice to update content and create new valuable knowledge, the organisation should maintain and support environmental factors. For example, the organisation can motivate knowledge sharing by maintaining and motivating a culture that encourage knowledge sharing and discourage knowledge hoarding behaviour. This can be motivated through training and awareness courses and through financial and recognition rewards. Also, the organisation can enhance KM efforts through providing required tools, technologies and financial and human resources that support effective and efficient knowledge capturing, sharing and reusing. The KM initiatives will face problems if these enablers are poorly understood and managed.

The first enabler presented in the model is culture, where the existence of some behaviours such as hoarding knowledge from others and resistance of using others' knowledge can cause a major problem to apply KM initiatives. Such behaviours should be dealt with otherwise they can cause system failure.

The second enabler is technology, for which an appropriate choice is very important for KM initiatives. The choice of inappropriate technology may result in additional costs and/or inefficiency of the system.

The third enabler is infrastructure, which implies the use of the new support systems and relevant personnel to support KM initiatives in order to achieve the desired result.

The fourth enabler is measurement, which involves the choice of appropriate evaluation methods and tools needed to ensure system and business improvements.

The model of O'Dell and Grayson (1998) consists of seven steps that according to the authors are important to ensure successful transfer and management of knowledge.

The first step in this model aims to identify existing knowledge, their uses and their sources in the organisation. It is important to decide which information is useful for the organisation, as collection of unimportant and meaningless information is non-productive for any organisation (Davenport & Prusak, 1998).

The second step aims to collect the information and knowledge which are identified in the first step. Selecting appropriate methods of collecting and storing knowledge is very important to simplify the future re-use and sharing of knowledge. Using knowledge maps is a method that provides a systematic presentation of knowledge that helps users to identify what knowledge exists and what knowledge is absent in the KMS.

The third step aims to organize the collected items of information and/or knowledge by classifying them according to specific characteristics. Choosing appropriate methods for organizing knowledge is essential in simplifying knowledge retrieval and subsequent knowledge reuse.

The fourth step in the model aims to share the organized knowledge that is the output of the third step. Even if individuals in the organisation realise where knowledge may be found, it is still important for KMSs to ensure that valuable knowledge is systematically shared among the organisation's employees and/or groups or across organisational borders (Axelsson & Landelius, 2002).

The fifth and sixth steps go hand in hand with each other and aim to support employees to adapt and use knowledge of the organisation. Adapting knowledge aims to transform organisational knowledge, especially which is invented elsewhere in the organization, and put it into context of knowledge users.

The final step aims to create new knowledge when using old knowledge of the organisation. When employees use knowledge to solve a problem or to improve a process, new knowledge will be created that should be collected and stored to be re-used in future problems and improvements.

These steps will continue to identify knowledge of interest, and collect, organize, share, adapt and use them to create more new knowledge.

Tserng and Lin (2004) researched into the application of KM to construction projects and proposed a construction activity-based KM model for contractors. 'Activity-Based' means that information and knowledge from all projects are classified and stored as activity units similar to project scheduling. The main aim of this model is to simplify the way of collecting and reusing knowledge in construction projects. This model represents activities and processes that are necessary for a successful implementation and use of KMSs.

This research uses the IDEF (Integrated DEFinition function) modelling method to provide a prototype used for KMSs in construction projects. IDEF is a series of techniques developed during the 1970s by the U.S. Air Force in a programme to increase manufacturing productivity through application of computer technology (IDEF0, 1993). This method is composed of techniques including IDEF0 that is used to provide a structured representation of the functions, activities and processes within a system; IDEF1 that represents the structure and semantics of information within a system; and IDEF2 that represents the time-varying behavioural characteristics of a system (IDEF0, 1993).

IDEF0 consists of a hierarchical series of diagrams and text that includes a top-level diagram divided into more detailed lower level programmes. Tserng and Lin (2004) have used this modelling method to represent activities and processes that are necessary for a successful implementation and use of KMSs. It also shows inputs, controls, outputs and relationships among the various activities. Figure 3.5 presents the top-level IDEF0 context diagram that represents five main activities of KM. Each one of these main activities is sub-divided into more detailed sub-divisions and presented by using lower levels of IDEF0 diagrams.

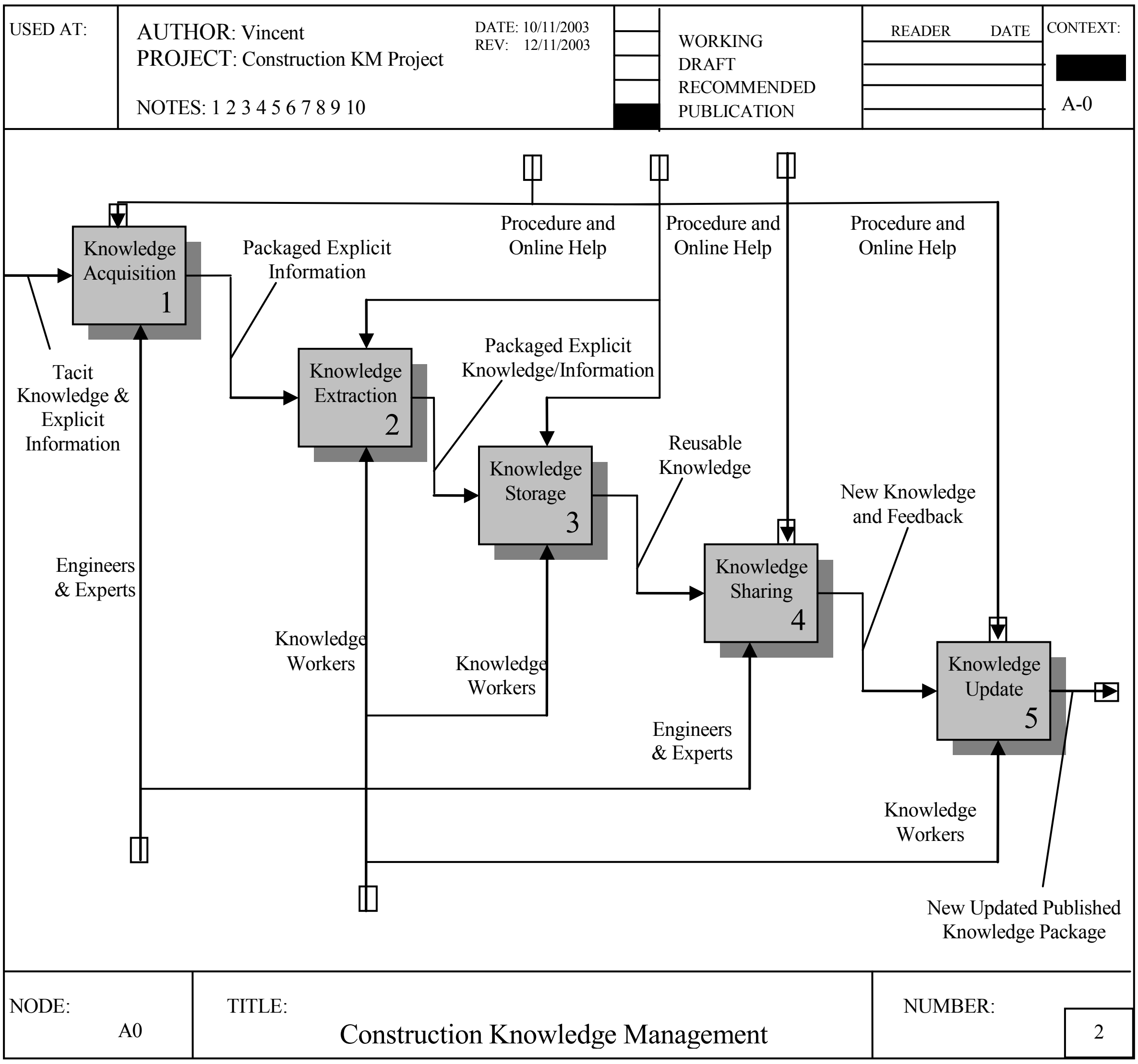

Figure 3.5: An IDEF0 Diagram Showing Top Level of Construction Knowledge Management (Tserng & Lin, 2004)

According to the research, *Knowledge Acquisition* contains all activities that are important for collecting data and information concerning a typical project. *Knowledge Extraction* is the second phase and contains all activities needed to translate data and information into knowledge. Third phase is *Knowledge Storage,* which is about storing the knowledge in a centralized and safe environment. *Knowledge Sharing* is the phase that enables people to use and share the stored knowledge. The final phase, *Knowledge Update,* is about collecting the feedback from various users to update the existing knowledge. The definitions and descriptions of top-level and sub-level phases for the Construction Activity-Based KM are shown in Table 3.1.

Table 3.1: Top-level and sub-level phases of the Activity-Based KM (Tserng & Lin, 2004)

Top-level Phases	Sub-level Phases	Description
Knowledge Acquisition		Knowledge Acquisition is the collection of data, information and knowledge that is important and useful for the organisation and projects.
	1. Collect Information	Collect all paper-based and electronic documents, information and data.
	2. Digital Information	Transform collected paper-based information and documents into digital information.
	3. Edit Information	Add details, descriptions, and comments to the original digital document / information.
	4. Package Information	Attach related files that contain descriptions, comments or notes to clarify the explanation or present an example of shared information.
	5. Submit Information	Submit a package that includes a description, comments and attached files with photos.
Knowledge Extraction		Knowledge extraction is the process of transforming data and information into knowledge.
	6. Record Operation and Event	Record information of construction operating events in a digital format.
	7. Edit Knowledge	Add descriptions, notes, comments, videos and photographs to clarify the recorded information.
	8. Manage Knowledge	Manage the knowledge community and collect the grouping meeting records.
	9. Package Knowledge	Package the related descriptions, notes and comments with the attached files that provide the explanation of knowledge or provide other examples.
	10. Submit Knowledge	Submit the package that includes description, notes, comments, and the attached files.
Knowledge Storage		Knowledge storage is the process of storing knowledge in a centralized and secure environment.
	11.Approve Knowledge	Approve the Knowledge Package which submitted in phases 5 and 10 before being saved in the system.
	12.Classify Knowledge	Classify knowledge package before being saved in the system.
	13.Store Knowledge	Store the approved and classified knowledge in the knowledge system.
	14.Backup Knowledge	Make another copy of the knowledge package to another knowledge base for safety.
	15.Publish Knowledge	Publish knowledge package for auto-distributed within the certain community groups for reuse and application.
Knowledge Sharing		Knowledge sharing enables users of the system to share the knowledge stored in the system by using the internet or intranet.
	16. Search Knowledge	Find knowledge or experience by using keywords or a domain expert search.
	17. Refer Knowledge	Refer knowledge to the original source and exam the past knowledge that has stored in the system.
	18. Modify Knowledge	Modify the original knowledge package based on the new projects or other current projects.
	19. Apply Knowledge	Apply the modified existing knowledge packages to other projects.
	20. Collect Feedback	Collect the feedback based on the application of original or modified knowledge package.
Knowledge Update		Knowledge update is the process of using the feedback from users to update the knowledge stored in the system for reuse.
	21. Collect Knowledge	Collect all paper-based and electronic documents, information and data.
	22. Renote Knowledge	Note the new or updated description, comments and notes based on the original knowledge package.
	23. Repackage Knowledge	Repackage the new or update description, comments and notes with attached related files based on the original knowledge package.
	24. Approve Knowledge	Approve updated knowledge package to be processed accurately before saving it in the knowledge system.
	25. Republish Knowledge	Republish knowledge package for auto-distributed within the certain community groups for reuse and application.

On the basis of activity-based KM model, Lin *et al*. (2006) introduced an approach to capture and present knowledge for the construction projects by using network knowledge maps. A knowledge map is a graphical or diagrammatic representation that shows what knowledge is available and what knowledge is missing in a KMS in a clear and simple way. It can clarify vague knowledge, enabling users and learners to easily find desired knowledge.

In this KM model, knowledge gained from previous projects is connected to knowledge map units of similar activities of new projects, as shown in Figure 3.6. The Knowledge of each project is represented with a node, which includes sub-nodes to represent the captured knowledge of each activity in the project and linkages to indicate the relationships among knowledge. Every Knowledge Map Unit (Sub-node) is connected to Knowledge Map Units of similar activities for other projects. In the Knowledge acquisition phase a knowledge worker collects knowledge and saves it in project map units that include both tacit and explicit knowledge. In terms of explicit knowledge, project-related information or knowledge generally includes specifications, contracts, reports, drawings, change orders and data. By contrast, tacit knowledge may include process records, problems faced, problems solved, expert suggestions, know-how, innovations and experience notes.

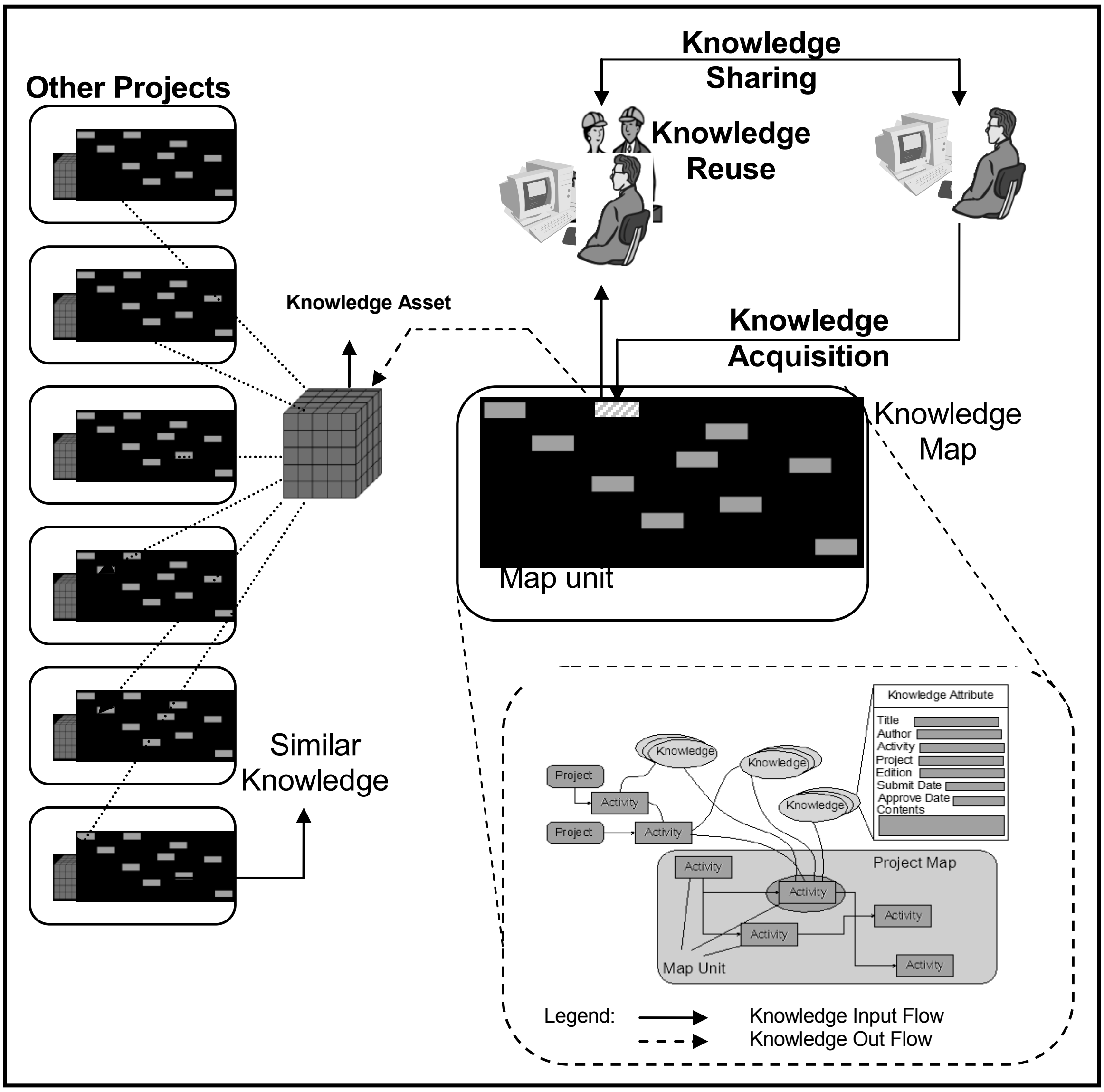

Figure 3.6: The Application of Network Knowledge Map with Knowledge Management (Lin *et al*., 2006)

Tserng and Lin (2004) and Lin et al. (2006) have proposed an architecture to describe the technological components of KMSs by distinguishing among four different layers, as represented in Figure 3.7.

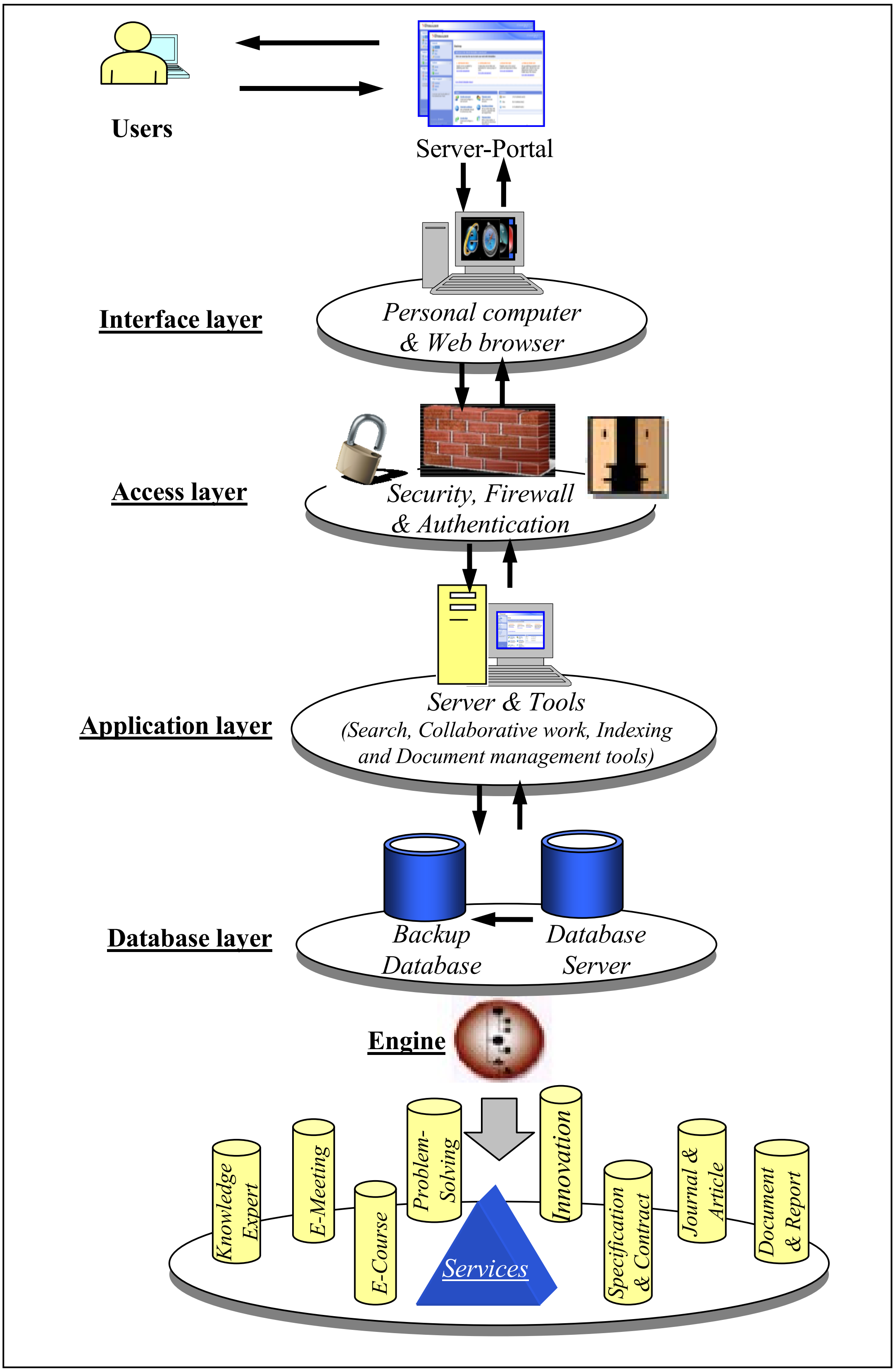

Figure 3.7: KM System Architecture (Tserng & Lin, 2004; Lin *et al.*, 2006)

Robinson *et al*. (2004) presents the IMPaKT model (Improving Management Performance through Knowledge Transformation), a three-stage approach which is represented in Figure 3.7. Stage 1 of this model aims to study the strategic context of business problems and their knowledge management implications. Stage 2 aims to plan and adapt KM strategy to address business problems or objectives. Finally, stage 3 aims to evaluate the impact of KM on business performance.

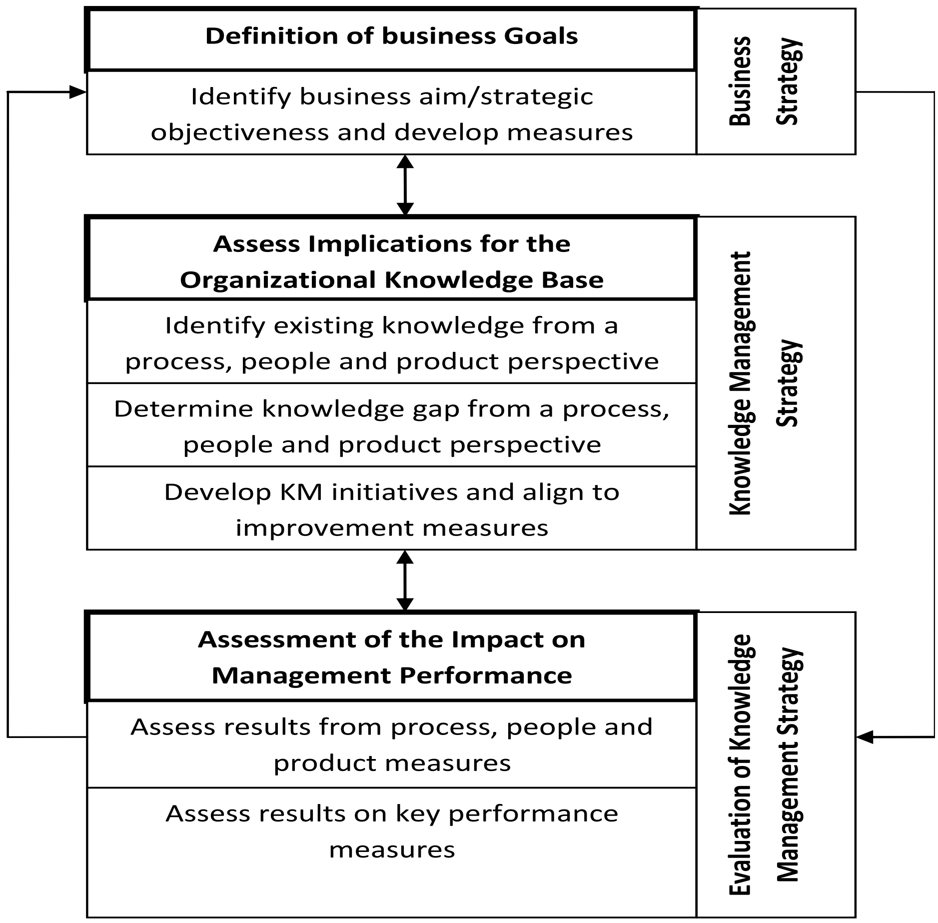

Figure 3.8: IMPaKT Model (Robinson *et al*., 2004)

In the IMPaKT model, stage 1 provides a structure for formulating a business improvement plan. The steps involved at this stage are shown in Table 3.2 supported by detailed guides such as a sample of performance measures, metric definitions and expected benefits. The glossary of key terms supports the entire framework, particularly in formulating the business plan in Stage 1. The outcome of Stage 1 is a business improvement plan with measurable indicators and performance benchmarks to assess progress.

Table 3.2: Business improvement plan (Robinson *et al*., 2004)

	Stage 1 steps	**Supporting guide**
1.1	Choose a business problem with a knowledge dimension	Glossary of key terms
1.2	Place the business problem in a strategic context by relating it to your external business drivers, strategic objectives and critical success factors	Glossary of key terms
1.3	Select measures to monitor progress towards achieving your strategic objectives, and identify the business processes they relate to	Performance measures
1.4	Identify current and target scores for various measures and establish the performance gaps	Metric definition

Stage 2 clarifies the knowledge problems identified in stage 1 to develop specific KM plans to address the business problems and objectives as shown in Table 3.3.

Table 3.3: KM and transformation plan (Robinson *et al*., 2004)

	Stage 2 steps	**Supporting guide**
2.1	Clarify the knowledge dimension of your business problem by identifying the KM process(es) involved	Problem diagnostic questionnaire
2.2	Develop specific KM initiatives to address the business problem/objectives	Problem diagnostic questionnaire
2.3	Select tools to support the KM process(es) identified and the implementation of the KM initiatives	KM tool selector
2.4	Prepare an Action Plan and identify change management and resources required	Readiness audit checklist
2.5	Identify relationships between KM initiatives and performance measures and show how they relate to the strategic objectives	Cause-and-effect map

The diagnostic questionnaire (step 2.1) aims to identify the KM sub-processes relating to the business problems such as locating and sharing knowledge which are shown in table 3.4. This provides the context for developing KM initiatives in step 2.2. The KM tool selector (step 2.3) therefore identifies appropriate mechanism for KM implementation based on the KM sub-processes identified in step 2.1 and the additional characteristics of the KM initiatives developed in step 2.2.

Organizational readiness to implement KM needs to be assessed in terms of the resources required, the reform needed and a result monitoring mechanism. The Readiness Assessment Checklist consists of a set of statements reflecting key criteria using a scale from low to high level of preparedness. The ‘overall readiness’ or output is a ‘traffic light’ system colour-coded, depending on aggregate scores, with statements reflecting the actions required (action plan) prior to implementing KM. The outcome of Stage 2 is a KM strategic and transformation plan with a set of initiatives, implementation tools and an action plan to support business improvement.

Table 3.4: KM problem diagnostic questionnaire (Robinson *et al*., 2004)

Sub-Process	Diagnostic Questions
Locating knowledge	Do employees face problems in identifying where knowledge exists? (e.g. which people have the knowledge, internet, software systems or database) Is there a need to catalogue and index knowledge sources? Do employees need new software and/or hardware to search for knowledge? Do employees know-how to use different search methods to find knowledge?
Capturing knowledge	Is there a need to codify knowledge that exists within the organisation? (e.g. tacit knowledge about people, processes and products etc) Is there a difficulty in codifying or representing tacit knowledge that exists within the organisation? Is there a difficulty in obtaining and representing external knowledge? Do you have problems in identifying tools for capturing knowledge?
Sharing knowledge	Is there a difficulty in sharing tacit knowledge between people across the organisation? Is there a need to transfer explicit knowledge between people, software applications and paper documents? Is there a problem in the learning process across the organisation?
Modifying knowledge	Is the knowledge-base within your organisation getting too large to maintain? Do you have a formal procedure for maintaining the knowledge-base? Is there a problem with identifying individuals or groups who should validate any modifications to the content of the knowledge-base? Do employees face risk of using outdated knowledge stored in the knowledge-base?
Creating new knowledge	Is there a requirement to elaborate or combine existing explicit knowledge to generate new knowledge? Is there a need to re-use existing information to produce new knowledge? Do you need to encourage employees to generate new knowledge? Do you need to obtain knowledge creating tools other than those already in place?

Stage 3 provides a structure for evaluating the impact of KM initiatives on business performance using the outcomes from stages 1 and 2. This stage is supported by the cause-and-effect map, evaluation roadmap, cost and benefit checklists, and a priority matrix (Table 3.5). The outcome of stage 3 is a KM evaluation strategy and an implementation plan with an appreciation of the impact of various KM initiatives on business performance in terms of effectiveness and efficiency.

Table 3.5: KM evaluation strategy (Robinson *et al*., 2004)

	Stage 3 steps	**Supporting guide**
3.1	Use the cause-and-effect map to assess the likely contribution of the KM initiatives	Cause-and-effect map
3.2	Assess the probability of success of your KM initiative in improving your performance measures (effectiveness measure)	Readiness audit checklist
3.3	Choose an appropriate method to assess the impact of each KM initiative on your business performance	Evaluation road map
3.4	Identify the cost for each KM initiative and the possible benefits (efficiency measure)	Cost and benefit checklists
3.5	Prioritize your KM initiatives based on the measures of performance	Priority matrix

Hari *et al*. (2005) studied knowledge capture in small and medium enterprises (SMEs) in terms of processes, challenges and benefits, taking into consideration both tacit and explicit knowledge. The research has developed a computer-based awareness tool on knowledge capture underpinned by Kolb's experiential learning theory, which provides a useful computer tool for the owners and/or managers, particularly, in the SMEs, to enable them to raise awareness and embed knowledge capture strategic issues in their organisations.

Most recently, Maqsood *et al*. (2007) applied Soft System Methodology (SSM) to a case study to show how knowledge-pull from external knowledge sources could systemize knowledge exchange as a KM initiative. The results indicate that by using this SSM technique a construction contractor can receive many benefits from a chosen approach, for example, to participate in external knowledge activity, for delivering significant benefit from diffusing an external developed innovation. Seven sequential steps of the developed SSM model aim to explore problematic situations that arise in human activities by learning from the different perceptions that exist in the minds of the different people who are involved in these situations. However, the research only focused on human knowledge exchange.

A research study in the C-SanD project (Creating, Sustaining and Disseminating Knowledge for Sustainable Construction: Tools, Methods and Architecture) carried out by Shelbourn *et al*. (2006) aims to develop practices in the construction sector that promote knowledge creation for subsequent sharing and re-use, along with the tools to support such a process. The work focuses on the promotion of sustainable development in the construction industry, especially in areas such as the minimisation of waste, material recycling and energy conservation in the design, construction and operation of buildings. The research developed a "Sustainability Management Activity Zone" (SMAZ) as an activity zone within the Generic Design and Construction Process Protocol (GDCPP). The process protocol is a process map that provides a framework for the management of processes on any given construction project through eight activity zones comprising: development of project, resources, design, production, facilities, health & safety, statutory and legal, and process management.

There are other KM models in the literature. Although some KM models have been developed which help construction organizations to embrace KM, most of the available approaches are not targeted to explicit and tacit knowledge, which leads to difficulty during KM implementation and application (Wethrill *et al.*, 2002; O'Dell & Grayson, 1998; Robinson *et al.*, 2004). The disadvantages of these KM models are investigated and discussed in the following section.

3.4 Analysis and Discussion of the Existing KM Models

This section discusses advantages and disadvantages of existing KM models, which form a basis for developing a new KM model that will benefit from the advantages and overcome shortcoming of current KM models.

3.4.1 e-COGNOS Model

The KM model developed by Wetherill *et al*. (2002) based on the e-COGNOS project aims at specifying and developing an open model-based and web-based infrastructure, and a set of tools that promote KM within a collaborative construction environment. The research developed a KM model in which the knowledge is divided into three categories: domain knowledge, which is available for all users of the web-based KMS; organizational knowledge, which is available for any user in the organisation; and project knowledge, which includes knowledge about a project that is only available for the people of that project. The research aims to address the knowledge requirements of end-users and support their existing practices while taking into account the contractual, legal, intellectual property rights, security and confidentiality constraints. Another objective of this research was to develop an adaptive mechanism that can organize documents ranging from unstructured to highly structured according to their contents and interdependencies.

The e-COGNOS method uses tools such as ‘Class Diagrams’, ‘Use Case’ and ‘Sequence Diagrams’ to show the details of how the user interacts with the system and the way the system will be used. They also help in discovering the required system components. The e-COGNOS consortium conducted a detailed investigation into existing and required technologies, which is useful in the process of implementing the infrastructure of the KMS. As a result of this investigation, a set of technologies and a technical architecture has been adopted, which aims to form the basis for the ongoing implementation and development of the e-COGNOS infrastructure (Wetherill *et al*., 2002; Ferneley *et al*.,2002; Lima *et al*., 2005).

On the other hand, the e-COGNOS method lacks important components. Although it shows the activities included in developing a KM solution, it does not show the important factors that affect these activities and how to deal successfully with them, such as employees' culture and management strategy. Although this method includes the activities of building management understanding and explaining the KM project to company staff, there is a need to identify the management strategy and staff culture (O'Dell & Grayson, 1998; Davenport & Prusak, 1998; Robinson *et al*., 2004). If this can be included, it will help to identify the appropriate methods and techniques that are suitable for the organization.

Another disadvantage in the e-COGNOS method is that it does not show the importance and the role of the knowledge staff including knowledge team and knowledge workers in KM. The role of the knowledge team/knowledge worker is vital to the success of KM efforts (Tserng & Lin, 2004).

Also this method ignores some important KM activities like knowledge acquisition, classification, storing, reusing and updating. These activities are very important in order to benefit from the collected knowledge and to create new knowledge from the old one (Lin *et al*., 2006). The e-COGNOS method also has a disadvantage in that it shows that KM activities work in sequence. This creates a conflict with the fact that it is possible for two activities or more to work in parallel (Ahmad & An, 2008). For example, an organisation can work on applying improvements on existing components of their KMS and at the same time it can work on designing and implementing new KM components. However, an advantage of this method is the classification of knowledge into three different categories (Wetherill *et al.*, 2002). These categories are: the domain knowledge that is available to all companies and users; the organizational knowledge that is company specific; and the project knowledge that is specific for projects and can be created by interaction between firms. This classification is important but not sufficient. There is a need to identify two types of knowledge, i.e. tacit and explicit knowledge. This is important because each type of knowledge needs different methods, tools and processes to capture, manage and use (Nonaka & Takeuchi, 1995; Tserng & Lin, 2004).

3.4.2 O'Dell and Gayson's (1998) KM Model

The study by Axelsson and Landelius (2002) aims to evaluate the existing KMS and find out how to facilitate and support the internal knowledge transfer process within Skanska Group. Evaluating Skanska Knowledge Network depends on Knowledge Transfer Process developed and introduced by O'Dell and Grayson (1998). This method shows four types of enablers that represent the effect of the company's environment on the Knowledge Transfer Process and the steps included in the knowledge transfer process. This research encourages the use of knowledge maps to facilitate searching for knowledge within a particular area.

This method shows steps in the knowledge transfer process. However, this method does not contain the steps included in designing, implementing and enhancing the KMS and the relation of these steps with those of collecting, sharing, and creating new knowledge (Wetherill *et al.*, 2002; Ferneley *et al.*, 2002). Also, performing knowledge identification at the first step should be followed by some steps such as identifying the required methods and tools, before commencing in knowledge collection steps (Robinson *et al.*, 2004; Wetherill *et al.*, 2002). This method also does not show the important classification of knowledge into tacit and explicit knowledge that needs different methods to deal with for a successful management of knowledge (Nonaka & Takeuchi, 1995; Tserng & Lin, 2004). It also does not differentiate between the terms of information and knowledge that appears to be used synonymously in the research (Blumentritt & Johnston, 1999; Kakabadse *et al*., 2001; Logan & Stokes, 2004). Another disadvantage in this method is that it does not show the importance of knowledge teams, the existence of which, especially in large companies, is vital for monitoring the use of the applied KMS and the performance of end-users in capturing and storing knowledge (Davenport & Prusak, 1998; Wenger & Snyder, 2000; Tserng & Lin, 2004). Furthermore, this method does not show the activities that could be applied in parallel (Ahmad & An, 2008). It shows that all activities can only be applied in sequence.

An advantage of this method is that it shows the importance of supporting employees to adapt and use knowledge (O'Dell & Grayson, 1998). But on the other hand, it does not show the major role of the management in supporting KM efforts. The management strategy in the organisation is a major factor that affects the implementation and use of knowledge. There is a need to convince senior management and stakeholders of the organisation before implementing any KM solution (Robinson *et al.*, 2004). Furthermore, a major disadvantage of this method is that it does not show the importance of system architecture and components (Tserng & Lin, 2004; Lin *et al.*, 2006; Jashapara, 2004). The system that is evaluated by the KM model consists only of parts like project databases, yellow pages and contact information, but cannot guarantee that knowledge can be shared, adapted, used and created (Axelsson & Landelius, 2002). Without appropriate and adequate components the system will not be able to serve the required activities of capturing, sharing and creating knowledge. The lack of appropriate components that provide the system with the ability to store, process and transmit knowledge successfully in Skanska Knowledge Network led the researchers of this study to conclude that this system is not a successful KMS and that it is more precise to describe it as an information system rather than a knowledge network (Axelsson & Landelius, 2002).

3.4.3 Activity-based and Map-based KM models

Tserng and Lin (2004) and Lin *et al*. (2006) are two researches complementing each other. Their researches aim to propose a Construction Activity-Based Knowledge Management system with the help of tools such as knowledge maps and web technology. The first research uses the IDEF (Integrated DEFinition function) modelling method to provide a prototype to be used for designing construction KMSs (IDEF0, 1993). The second research proposes a knowledge map network consisting of components and procedures. The second research also shows how to use the knowledge map to enhance the Construction Activity-Based KMS that was proposed in the first research.

One advantage of these researches is that they show the importance of classifying knowledge into tacit and explicit knowledge and emphasise each type must be managed differently (Nonaka & Takeuchi, 1995; Tserng & Lin, 2004). They also give knowledge resources and where explicit and tacit knowledge can be found. The two researches provide important method for categorising and storing knowledge as "activity" units by referring each activity to similar activities in past projects. This simplifies the process of collecting and retrieving knowledge from past projects that relate to a particular activity or specific subject to be reused in solving similar problems (Lin *et al.*, 2006).

IDEF0 (top-level of Integrated DEFinition function modelling) is used to represent the top-level of KM activities, and inputs and outputs. There are five general activities, and each can be decomposed into five sub-activities. This gives a high level of details about the required KM activities that simplifies understanding and applying them in the construction organisations (Tserng & Lin, 2004). The researches also show the importance of providing details of the system architecture and components for a successful implementation and use of KMSs, and how these architecture details are important in ensuring the security and validity of the system (Tserng & Lin, 2004; Lin *et al.*, 2006; Jashapara, 2004). The researches also discussed the important roles of knowledge workers, senior engineers, experts and junior engineers in implementing KM activities successfully (Davenport & Prusak, 1998; Wenger & Snyder, 2000; Tserng & Lin, 2004).

Although the two researches represent a KM model that contains many advantages, it also has some disadvantages. Similar to the methods discussed earlier, the IDEF0 model shows that the activities are applied in sequence. It does not show the availability of parallel activities (Ahmad & An, 2008). It shows that some KM activities such as sharing knowledge or capturing experiences and problem solutions depend entirely on completing other activities, such as capturing data and transferring it into knowledge, which is not very precise.

Although the two researches have used knowledge categorization and classification methods in order to manage knowledge in construction organizations, some terms like information and explicit knowledge were not differentiated and their terms were used interchangeably in many circumstances (Blumentritt & Johnston, 1999; Kakabadse *et al.*, 2001; Logan & Stokes, 2004; Alondeiene *et al.*, 2006). Also, the researches do not show the importance of the environmental factors that can affect the application of KM activities such as employees' culture and management strategies. These factors are of high importance and should be monitored and dealt with during the application of KM activities (Davenport & Prusak, 1998; O'Dell & Grayson, 1998). Furthermore, the two researches do not show many of activities that are required in KM. They only show activities of knowledge acquisition, extraction, storage, sharing and updating. They do not show activities associated with designing, implementing and maintaining the KMS, and they do not show the links between the proposed activities and the process of enhancing the KMS (Wetherill *et al.*, 2002; Ahmad & An, 2008).

3.4.4 IMPaKT Model

The IMPaKT method (Improving Management Performance through Knowledge Transformation) by Robinson *et al.* (2004) is a three-staged approach that concentrates on the importance of organisation's management and the need to convince senior management and other stakeholders about the business benefits to justify a KM strategy. This approach aims to formulate a business improvement plan, a KM strategic and transformation plan, and a KM evaluation strategy and implementation plan. This approach involves studying and understanding the external and internal forces that affect the business environment and KM efforts (Davenport & Prusak, 1998; O'Dell & Grayson, 1998). The external forces according to the research could be technological (e.g. the need for innovation), market or structural (e.g. expansion/downsizing). The internal forces include customers, employees, shareholders and nature of services or products. This approach shows the importance of using measures to evaluate KMSs from different sides of view by using different evaluation methods such as cause-and-effect map, evaluation roadmap, cost and benefit checklists, and priority matrix (Robinson *et al.*, 2004).

However, there are some disadvantages in this approach. The model does not show details of KM implementation and application activities, inputs, outputs and the factors that affect their implementation such as employees' culture (O'Dell & Grayson, 1998; Tserng & Lin, 2004). It also does not show the important roles of knowledge teams and knowledge workers (Davenport & Prusak, 1998; Wenger & Snyder, 2000; Tserng & Lin, 2004). This model also does not highlight the importance of identifying the different types of knowledge resources and the different procedures and system components needed (Nonaka & Takeuchi, 1995; Tserng & Lin, 2004). For example, the method does not show the importance of classifying knowledge into tacit and explicit knowledge and how they need different methods and techniques to capture and process. Furthermore, the model does not propose technological architecture in order to satisfy security and privacy issues in the KMS (Tserng & Lin, 2004; Lin *et al.*, 2006; Jashapara, 2004).

The other models reviewed or found in the literature normally are general, i.e. they do not provide enough details to ensure effective and efficient use in the construction KM application (Tserng & Lin, 2004). Many of these models only provide a method for either KM implementation or KM application but do not show the relationship between the two processes (Wetherill *et al.*, 2002; Ahmad & An, 2008). Many of the KM models ignore the effect of important environmental factors and the critical role that people can provide for successful implementation and application of KM (Davenport & Prusak, 1998). Some models do not stress the importance of having a continuous method for enhancing KMSs and ensuring recent and updated contents stored in the repositories (Wetherill *et al.*, 2002; Tserng & Lin, 2004; Lin *et al.*, 2006). Although much of the KM literature highlighted the importance of categorising knowledge into different types with different natures, most of the developed KM models ignored the importance of showing how these types may require different activities, procedures and tools to manage successfully (Nonaka & Takeuchi, 1995; Tserng & Lin, 2004; McInerney, 2002). Recent research has proved that construction organisations still lack the adoption of structured methods to implement and apply KM (Robinson *et al.*, 2004; Robinson *et al.*, 2005; Carrillo *et al.*, 2000). Therefore, more research works are needed to provide coherent and structured methods for KM implementation and application in construction projects.

3.5 Summary

Previous studies which investigated practices and developed models for KM implementation and/or application are still far from sufficient and many of them lack important characteristics that may limit KMSs to be applied efficiently and effectively in the construction organisations. These KM models do not consider the special characteristics and situations of the project-oriented construction organisations. The environment of construction projects increases the difficulty of applying KM successfully. Identifying, summarizing and discussing gaps of KM models is important to provide critical background that helps in the process of proposing and developing a new KM model that provides a structured method to fill the gaps of the existing models for KM in the construction projects. Disadvantages and gaps of current KM models can be summarized as follows:

- Many of general models lack details to satisfy the needs of the construction industry and help to enhance KM awareness in this industry sector. Many of the construction KM models may lack alignment with the special characteristics of project-oriented organisations, for example, lack of details about the nature of construction knowledge resources, lack of the categorisation methods for knowledge that can be useful in project contexts, lack of detail of activities and sub-activities that can be adopted to manage and process knowledge in construction projects, lack of the contextual factors of the construction project environments etc.

- Most construction KM models only handle one of two main KM processes, i.e. KM implementation or building, and KM application or use. The relation between the two processes, how KM implementation affects the use of KMSs, and how the use of KMSs can affect the development and enhancement of the KMSs are not included and discussed in these KM models.

- Most KM models only discuss KM activities without referring to other environmental factors or enablers that may affect KM efforts, such as employees' culture and management support and strategy. Many of these factors may negatively affect KM application if not being dealt with carefully. Many activities and procedures need to be applied to encourage KM application and reduce the negative impact of environmental hinders.

- Most KM models may provide KM activities without presenting and discussing technological structures required in supporting the KM activities while maintaining contractual, legal, intellectual property rights, security and confidentiality issues and regulations. Presenting KM architectures can help organisations to identify existing and needed system components and technologies, and to decide the required infrastructure in order to support a successful implementation and application of KMSs. A KMS that lacks important components and technologies may fail to help capturing and transferring knowledge among its users.

- Many KM models do not provide useful methods for categorising knowledge resources and/or to differentiate knowledge from data and information. Identifying different types of knowledge resources available in projects will help organisations to identify the different activities, procedures and tools to process and manage knowledge. Furthermore, this will also help organisations to classify knowledge stored in the repositories of the KMSs to simplify and encourage finding and using it. Categorising knowledge resources can help to differentiate contents that require different authority definitions to ensure delivering knowledge to the right people. Categorising knowledge can also help organisations to organise knowledge in the system repositories in order to identify knowledge available, knowledge missed and knowledge needed to be included in the KMSs.

- The roles of KM teams, knowledge workers, data workers, Communities of Practices (CoPs) and KM end-users, are missed or not sufficiently detailed in most of the KM models.

- Most of the existing KM models show that KM activities and processes can only work in sequence, i.e. before next activity starts, the first activity must be completed. This is not always true; in fact many of KM activities can work in parallel, such as working on the process of enhancing the existing KMS while practising other KM processes such as capturing and sharing knowledge.

- Many KM models do not present methods for evaluating KM processes and tools in terms of validity, applicability and usefulness, and these models do not provide feedback-collection mechanisms to discover problems so that the KMSs can be improved.

- Most KM models do not highlight and benefit from the dynamic nature of knowledge that requires organisations to encourage a continuous process of creating new knowledge, updating and validating existing knowledge, removing outdated and invalid knowledge, and discovering new opportunities to capture and share new knowledge. However, this process is important to ensure the validity of the KMS in use and to overcome problems that may take place because of sharing and using outdated knowledge.

Reviewing previous studies and analysing their gaps and shortages help to identify the major characteristics, relationships and components that can compose a more appropriate, comprehensive, practical and useful KM model for KM implementation and application in construction projects.

The design of the proposed KM model of the research has been adopted to ensure overcoming shortages of the existing models and to provide practical method for implementing and applying KM in construction organisations. Preliminary study has developed a KM model for construction projects which addresses the key characteristics and components for a successful KM. This model overcomes the disadvantages as summarized previously. In the model, new components and characteristics are introduced and improvements are implemented to ensure it is more practical and comprehensive. Other methods of interviews and questionnaires are conducted to help to enhance the developed KM model as will be described and discussed in the following chapter.

CHAPTER FOUR

INTERVIEWS AND QUESTIONNAIRES

4.1 Introduction

The effective implementation and application of KM in organisations is controlled and facilitated by KM activities, methods, tools, and environmental factors. Organisations need certainly to encourage the application of KM activities, the use of KMS tools, and the improvement of environmental factors (or what is described in literature as Critical Success Factors (CSFs)), in order to apply KM more effectively and ensure a more successful competitive performance (Rockart, 1979; Saraph *et al*., 1989).

CSFs include factors for the successful implementation and application of KM such as the alignment of KM to business strategy, the appropriateness and flexibility of system architecture, the support and motivation of management, the support of knowledge-friendly culture, the adequacy of technology and infrastructure, the desire and ability of learning, and the efficiency of KM activities and tools (Skyrme & Amidon, 1997; Davenport *et al*., 1998).

Although previous studies have tried to study KM processes, tools and CSFs, most of these studies do not consider the special characteristics and features of construction projects that can affect KM efforts. Furthermore, many of these studies lack the adoption of a systematic way and suffer from a lack of empirical studies for the particular business sector of the construction industry. This chapter studies KM activities, methods, tools and environmental factors in a systematic way to enhance the proposed KM model so that it can be easily and effectively used by construction organisations for successful KM implementation and application.

Firstly in this chapter, the aims and objectives of the interviews conducted for this research are discussed. Then, the responses of the participants are reviewed and analysed. Secondly, the objectives and design of the questionnaire survey used in the research are presented. The findings from the questionnaire survey are analysed and presented. Finally, the results of the interviews and questionnaires are discussed to show how they affect the development and improvement of the KM model. By incorporating the results of the interviews and questionnaires into the proposed KM model a more structured and comprehensive KM model has been developed for KM implementation and application in construction projects.

4.2 Interviews

4.2.1 Aim and Objectives of Interviews

As part of the research effort to evaluate and improve the KM model to develop a more comprehensive and appropriate version of the model interviews were conducted with experts of KM in the construction industry. The aim of the interviews is to investigate respondents' evaluation and understanding of the KM model in terms of its ease of use, usefulness, comprehensiveness, applicability, feasibility and structure.

Many people, including practitioners and academics from the construction industry known for having experience and/or published work in the KM domain, were chosen and asked to participate in interviews for the purpose of this research. A description of the KM model, combined with general questions about KM and the participants' backgrounds (see Appendix 1), were sent to the people who showed interest in participating in the research.

Interviews were conducted with six people who agreed to participate in the research. The interviewees include two academics with wide experiences in KM research and publishing, two KM managers with more than seven years experience in IT and KMS applications, one knowledge worker with more than 5 years experience and 1 senior manager with more than 12 years experience in the construction projects and a wide experience in the KM domain. The interviewees were chosen regarding their experiences and background in the KM domain and their willing and interests on participating.

However, the responses and results were filtered to insure the exclusion of unnecessary irrelevant outcomes. Also, the respondents were given the opportunity to review their responses in order to edit contents and provide comments. In some occasions, opinions from respondents were discussed with other respondents to collect feedback, refine results and improve outcomes. Also, some face-to-face discussions were arranged to encourage discussion and solve problems.

Adopting semi-structured interviews with questions of an open-ended nature was the method adopted by the research interviews to encourage respondents to provide useful detailed opinions and ideas, and to identify and discuss important topics, which enabled the research to identify issues that can be important for the development of a KM model for construction projects.

4.2.2 Analysis of the Responses

The comments and discussions provided by the interviewees reflect their opinions, perspectives, ideas and evaluations about the proposed KM model in terms of its characteristics, such as ease of understanding and use, comprehensiveness, applicability, feasibility, structure, usefulness, etc. In general, the respondents gave positive comments, and agreed that the developed KM model is useful, relatively comprehensive and appropriate, especially for the latest versions. The comments given by the respondents are discussed in the following paragraphs.

The comments received in the early stages of the development of the KM model (Version 1 in Figure 2.3) described the KM model as interesting and informative, and stated that it addressed the important issues of KM within the construction management research. However, the graphical presentation of the model is difficult to understand and follow, and needs to be improved and explained better. This motivated the author to enhance and develop the KM model into a clearer version (Version 2 in Figure 2.4).

Version 2 was found by respondents to be easier to understand and applied than the previous version. However, respondents found some difficulties in following the different stages of the proposed KM model. Respondents suggested improving the proposed KM model by dividing it into its main components, where every component can be represented and explained more clearly. By using this method, an enhanced KM model (Version 3 in Figure 2.5) was developed to provide better details for KM adoption in construction projects.

Version 3 divides the KM method into five major components and provides details for each component. All of the respondents agreed that the proposed KM model is properly developed, looks relatively simple, easy to understand and follow, and includes the elements needed for the successful implementation and application of KMSs. They stated that the proposed KM model successfully shows the relationships and the flow of knowledge among the different components. Respondents believed that the proposed KM model makes the implementation and application of KM in construction projects easier, more structured and more effective. However, some concerns were raised by respondents regarding modifying and adding more details to the proposed KM model.

Suggestions were given to add more details about the influential factors that affect KM adoption by presenting procedures or activities to deal with them successfully. Some cultural frictions were referred to by interviewees, such as unwillingness to share knowledge and a belief that sharing knowledge means losing the power accompanied with it. Environmental activities were recommended by interviewees to deal with cultural frictions such as rewarding knowledge sharing, encouraging trust among employees, and providing time and places for employees to learn. Privacy, confidentiality and copyright issues are also examples of the influential factors that have been referred to by the interviewees to be dealt with in the development and application of KMSs.

Concerns were given about the effort and cost required to capture and share explicit and tacit knowledge by the KMS users. Recommendations were provided about exerting more efforts to identify knowledge resources of high importance to the organisation to decide what knowledge needs to be captured, to be shared, and what needs to be ignored in the KMS.

An important issue discussed with the interviewees was the need to review and approve captured knowledge by experts and/or KM team members before making it available to the users of the KMS. Some of the interviewees recommended that a successful KMS should be open, where everyone in the organisation can add and edit the knowledge contents. They argued that the existence of processes to review and approve knowledge before making it available for the KMS end-users delays the participation of many of the employees and causes a loss of opportunities to view important content and gain valuable knowledge. The interviewees stressed the importance of allowing any participation from people in the company to encourage adding to the system

Other interviewees recommended that the existence of rules, restrictions and reviewing processes protect the system from being overloaded with too many contents that may confuse the searchers and negatively affect the system's performance. They argued that it is important to filter knowledge and exclude unimportant contents from the system before overloading it with unrelated and low quality contents. An interviewee gave an example from his experience of a leading UK company where KMS had the problem of having too much knowledge in its repositories that caused the low performance of the system and complexity in finding required knowledge. This caused a very low level of usage for the system.

A mechanism to review, adapt, edit and approve captured knowledge was suggested and encouraged in the proposed KM model. However, the proposed KM model suggests finding a balance in the process of reviewing and approving the knowledge contents. Too much reviewing of the contents will result in delays, and discourage knowledge capturing and sharing, while overloading the system with too many unimportant contents. This will negatively affect the performance of the users and the system. Hence, it is important to define the required purposes and roles of the KMS to align with the strategy of the organisation.

Comments were also provided by interviewees on enhancing the effectiveness of the proposed KM model in dealing with tacit knowledge. The interviewees suggested adding more details to the KM model to better deal with the special characteristics of tacit knowledge. This suggestion was dealt with by categorising knowledge resources into more types that require different procedures, methods and tools to manage and deal with them, as will be described in the final version of the developed KM model.

The development of the final KM model will take into consideration the useful comments and suggestions provided by the interviewees, combined with other results of the questionnaire survey that will be detailed and discussed in the following section.

4.3 Questionnaire Survey

KM researchers have applied survey methodology in the construction industry to investigate a variety of objectives. Egbu and Botterill (2002) conducted a questionnaire survey in order to investigate the role of IT for KM in the construction industry. The results revealed that traditional technologies, such as the telephone, are used more frequently to manage knowledge, than other knowledge sharing tools, such as Groupware or video conferencing. The researchers recommended a greater implementation of knowledge sharing tools supported by sufficient training and education to achieve more potential benefits for KM.

Carrillo *et al*. (2004) conducted a questionnaire survey on the UK construction organisations to examine the importance of applying KM in these organisations, to investigate the resources used to implement KM strategies and to investigate the main barriers to implementing KM strategies. The results showed that the main motive for implementing KM is the need to share the tacit knowledge of employees' experiences and best practices. The resources allocated for KM by the respondent companies, in terms of staff and budget, were investigated. The research found that the main barrier for implementing KM in the UK construction organisations is the lack of a standard work process.

Robinson *et al*. (2005) carried out an exploratory questionnaire survey to investigate the perception of KM in the UK's leading construction organisations. The findings indicated that over 75 % of respondents are aware of the importance of KM and intended to apply KM in the future, while over 45 % intended to appoint a person or group with responsibilities for KM.

Lin *et al*. (2006) applied the questionnaire method to evaluate an existing KMS by collecting the feedback of its users. The questionnaire aimed to investigate whether the system operated according to design specifications and to assess the usefulness of the system. The results showed that the KMS helps to find required knowledge easily and effectively. The results also highlighted the primary benefits of using the KMS, such as identifying key knowledge that is most strategic and critical to the projects, and providing assistance for users to find the required knowledge easily and effectively.

4.3.1 Aims and Objectives of Questionnaire Survey

The main aim of the research survey is to capture the initiatives for KM and investigate the critical success factors for implementing KM in the construction industry. The questionnaire includes four main sections as shown in Appendix 2.1.

Section 1 asks for general information about the participants and their companies. These will be used to describe characteristics of the questionnaire respondents. Section 2 is dedicated to investigate both the usage and importance of activities, procedures and tools of KM in the participating companies. Section 3 investigates KM environmental activities and factors (Critical Success Factors, CSFs) by listing statements that relate to the CSFs. Respondents are asked to provide their opinions regarding how much those statements describe the KMSs in their organisations and the importance of the different statements for a successful implementation and application of KM in the construction industry. Also, motivations, challenges and required specifications to KM will be investigated in terms of their importance and influence on the organisations according to the participants' opinions. Section 4 of the questionnaire is for non-knowledge adopters to investigate the reasons of not applying KM in some of the construction companies.

The responses of the questionnaire represent respondents' opinions that depend on their judgements and affected by their own experiences in the construction and KM domains. By involving practitioners and those with knowledge of KM implementation and application from the construction industry in the survey, important perceptions and results will be gained to strengthen the proposed KM model and achieve more accurate and comprehensive results.

The second aim of the questionnaire survey is to investigate the importance and applicability of the different parts of the KM model in order to identify the areas and subjects that need further investigation and improvement. For example, if the results show that specific areas or activities have received high importance but low levels of application in the organisations, this indicates a need to provide details in the KM model to improve awareness and encourage application in the required areas. So the questionnaire helps to evaluate the proposed KM model and encourage applying improvements and providing details to reach to a final KM model for construction projects.

The results of the questionnaire help to build sets of important KM activities, tools and environmental factors in the KM model to enable organisations to plan and manage their KM efforts successfully. The results evaluate importance and influence of different KM issues in order to help organisations manage resources and efforts successfully to obtain required results and potentials. Hence, addressing the results of the questionnaire into the KM model is necessary in helping construction organisations to identify the key factors, that if effectively adopted can make the implementation and application of KM more successful.

4.3.2 Questionnaire Design and Development

The questionnaire was designed to investigate the KM methods, procedures, activities, tools and environmental factors which are important to shape a more useful and comprehensive model for successful and effective KM implementation and application in the construction projects. During the research stages, the questionnaire has been developed and enhanced in shape, design and content. The contents of the questionnaire relied on the developed KM model (mainly on version 3 in Figure 2.5). The questionnaire was checked and evaluated through a pilot study and so was corrected and enhanced in terms of structure, content and format.

The questionnaire was designed to search opinions from KM or IT managers, workers and team members, senior and junior engineers, or any employee who may have good experience in implementing or applying KMSs in construction organisations. The questionnaire asks participants to provide their evaluation for the importance of different components, characteristics and activities of KM and KMSs according to their experiences and perceptions.

The questionnaire was split into four main sections as shown in Appendix 2.1. Section 1 seeks general information about the respondents and their companies, such as the profession of the respondent, the size of the company, the type of the company's business and the year the company started to implement KM. The responses for this section will be used to define the characteristics of the respondents and their companies.

Section 2 asks respondents to evaluate, according to their experiences and opinions, the extent of application and the level of importance of activities for KM implementation (building and development) and application (use), and KM technological tools (see Table 4.1).

In Section 3, the respondents were asked to provide their evaluation about the importance of statements that describe environmental factors and activities that affect KM and to indicate how much these statements describe the KM environmental activities in their companies (see Table 4.2). Furthermore, section 3 investigates the importance of drivers, system specifications and challenges that may affect KM efforts in the construction projects, and asks respondents to indicate how much these statements describe the KM application in their companies (see Table 4.2).

Sections 2 and 3 were designed to provide a tool for evaluation of statements that describe activities, procedures, tools and factors that may affect KM implementation and application in construction projects. The statements used in Sections 2 and 3 were carefully formulated and categorized on the basis of the preceding research work that includes reviewing and analysing of relevant KM literature, interviewing KM experts and practitioners, and developing, evaluating and modifying the KM model. Participants were asked to provide two responses for each statement organised into two columns as shown in Appendix 2.1.

The first column is to evaluate the extent of implementation of the statement by using a 3-point scale. In Section 2, level 1 refers to non implementation, 2 refers to prototype or small scale implementation, and 3 refers to large scale implementation. In Section 3, level 1 indicates that the statement does not describe the KMS in the respondent's organisation, 2 moderately describes and 3 extremely describes it.

The second column of response in Sections 2 and 3 asks participants to rate the level of importance of the statements to the success of KMSs in the construction projects. The responses evaluate the importance of the listed activities, tools and environmental factors according to the respondents' experiences, opinions and perceptions. This evaluation uses a 6-point Likert scale where 1 means not important at all, 2 means slightly important, 3 is moderately important, 4 is important, 5 is very important and, finally, 6 means extremely important. The respondents were asked to leave boxes blank if they did not know or were unsure of the response, or if their companies did not practice KM. Using a scale with an even number of 6 points and asking participants not to answer when they were not sure helped to avoid problems of "Leniency" and "Central tendency" by encouraging respondents to show whether they lean more towards the "important" or "not important" directions of the scale rather than choosing the midpoint (Kendall & Kendall, 2002; Albaum, 1997; Trochim, 2006).

Two other questions were included in section 3 of the questionnaire, asking the participants to give their evaluation of the KMSs in their organisations and to evaluate the success of the activities, methods, tools and factors listed in sections 2 and 3 of the questionnaire. Comparing results of the two questions can be used to indicate the usefulness of applying the activities, tools, and procedures included in the questionnaire. Since the questionnaire statements depend on the contents of the KM model developed at that stage of the research (Version 3 in Figure 2.5), the comparison of the responses to the two questions provides a general evaluation for the contents of the KM model and their usefulness to implement and improve KMSs in the construction organisations.

Finally, Section 4 asks non-adopters of KM to give their opinions about the main reasons for not applying KM in their organisations to date and whether or not they intended to implement a KMS in the future. A feedback section was included at the end of the questionnaire to encourage respondents to participate in other stages of the research. This section allows respondents to provide comments about the questionnaire survey and invites more opinions and suggestions on how to improve KM in the construction projects.

Table 4.1: KM implementation activities, application activities and technological tools investigated in the questionnaire survey

SECTION 2: KM ACTIVITIES AND TOOLS	
KM Implementation Activities	**A1. System Analysis** 1. Conducting questionnaires and/or interviews with employees 2. Identifying business processes and procedures 3. Identifying data & knowledge available and important for the organisation 4. Identifying what tools are appropriate for KMS **A2. System Design** 1. Defining aims and objectives for KM 2. Using KM models to represent KM activities, methods, and components 3. Preparing an action plan and guidelines for KM implementation **A3. System Implementation** 1. Implementation of a Prototype before applying wide range KMS 2. Appointing KM offices to provide training and support to employees 3. Embedding KM activities into employees' work processes and activities **A4. System Maintaining and Monitoring** 1. Collecting feedback from end-users regarding improvement requirements 2. Observing the differences in operations after implementing KM 3. Monitoring the system performance and showing bottle necks 4. Monitoring the environmental factors such as management strategy, employees culture and technological factors **A5. System Evaluation** 1. Investigating business process improvements 2. Evaluating the system correctness and Alignment with design specifications 3. Evaluating the system usefulness, ease of use, and applicability
KM Application Activities	**A6. Knowledge Capturing and Storing** 1. Recording problem solutions & experiences in electronic repository 2. Referring knowledge to its sources (experts, books, articles or websites) 3. Recording new ideas and perceptions of experts and engineers 4. Attaching pictures, videos, and text files to clarify knowledge contents **A7. Knowledge Reusing and Sharing** 1. Using the intranet to share and transfer knowledge 2. Using searching tools to find required knowledge 3. Showing contact details and experiences of the employees **A8. Knowledge Reviewing and Approving** 1. Using the intranet to publish and edit knowledge 2. Reviewing knowledge contents by experts or a knowledge team 3. Classifying knowledge to facilitate knowledge searching functions **A9. Using Databases to create Knowledge** 1. Capturing data and information of projects in electronic repository 2. Using Data Mining, Data Analysis, and Reporting tools 3. Recording knowledge and information concluded by using previous tools
KM Technological Tools	**A10. System Tools** 1. User manuals and help desk 2. Data Mining, Analysis and Reporting 3. Document Management 4. Photos and/or Videos Management 5. Training and Support (E-learning) 6. Knowledge Searching 7. Knowledge Map (graphical presentation provides overview and sometimes links to existing knowledge and domain experts) 8. Yellow Pages and/or Contact Details 9. Subscribing and/or Password Interring to define authority level 10. E-Meeting, Messaging, Chatting and Discussion board/forum 11. Decision support systems and/or Intelligent agents

Table 4.2: KM environmental factors, drivers, system specifications and challenges investigated in the questionnaire survey

SECTION 3: KM Influential Factors	
Environmental Factors and Activities	**F1. Culture** 1. A culture that values knowledge seeking and problem solving 2. Providing time to employees to perform knowledge related activities 3. Encouraging collaboration and teamwork among employees 4. Updating employees and other users about the changes in KMS 5. Building up awareness and providing training on use of the KMS **F2. Management leadership and support** 1. Management establishes the necessary conditions for KM 2. Leaders encourage and support knowledge creation, sharing and use 3. Knowledge managers constantly search for new approaches to KM 4. Development of a KM strategy with clear objectives and goals 5. Sufficient financial resources for building up a technological system **F3. Information technology** 1. Matching the KMS with KM objectives and user's needs 2. Utilisation of the intranet and internet 3. Ease of use of the technology 4. Protecting knowledge from unauthorised exposure or being stolen 5. Ability of the system to capture and store tacit knowledge 6. Appropriate categorization and updating of knowledge 7. Application of technological tools (collaborative tools, searching tools, indexing, document management etc) **F4. Measurement** 1. Measuring benefits per unit of investment 2. Monitoring the system performance and showing bottle necks 3. Developing indicators for measurement of KM **F5. Organisational infrastructure** 1. Appointing of a knowledge leader and/or knowledge team or workers 2. Ensure of sufficient human resources to support KM initiatives 3. Specifying activities, tasks and processes for performing KM 4. Specifying roles and responsibilities for performing KM tasks 5. Recruiting and hiring of employees to fill knowledge gaps
KM Drivers	**F6. Drivers for KM** 1. Building up and maintaining employees' expertise and skills 2. Sharing employees' expertise and perceptions 3. Identifying internal and/or external best practices 4. Reducing cost and/or time to solve problems in projects 5. Enhancing work quality of projects 6. Providing competitive advantages to the company 7. Helping senior engineers and managers to avoid many problems' causes 8. Presenting accurate and timely knowledge to facilitate decision making 9. Providing an effective tool to train junior engineers 10. Enhancing relation and coordination with customers, partners and suppliers 11. Encouraging continuous improvement and/or new products and services 12. Reducing rework and save time of solving repeated problems
KMS Specifications	**F7. Specifications of the KMS** 1. The knowledge system is easy to use 2. It is easy for users to find useful information for problem solving 3. The system Collects knowledge that is important for the organisation 4. The system Ignores knowledge that is not important for the organisation 5. The system facilitates knowledge sharing between company's employees 6. The system maintains good relationships with customers and other partners 7. The role of knowledge team and knowledge workers is very important
KM Challenges	**F8. KM Barriers and Challenges** 1. The nature of construction projects (e.g. non-repetitive work, no standard procedure for activities, pressure to complete on schedule, changing employees in different phases, etc.) 2. Lack of organisational culture for knowledge creation and sharing (e.g. build trust among employees, establish times and places for knowledge transfer, provide incentives, accept and reward creative errors, etc.) 3. Lack of structured procedures and processes to implement KM 4. Lack the adoption of well formulated KM strategies and implementation plans 5. Lack of knowledge manager or a team to implement KM strategy 6. Lack of awareness of the importance of KM in construction organisations 7. Lack of training and support 8. Lack of technology and techniques for knowledge capture and sharing 9. Lack of leadership support 10. Lack of resources in term of a budget, staff, and IT infrastructure 11. Employee resistance to share their knowledge 12. Lack of post-project reviews and project documentation

4.3.3 Characteristics of Selected Construction Companies

In order to select construction companies for the survey, the FAME (Financial Analysis Made Easy) database was used to generate a list of the UK construction companies. This list contains construction companies' names, latest number of employees, last turnover, contact details, web sites and E-mail addresses, which provides useful information for the questionnaire survey.

A method recommended by the National Science Foundation (NSF, 2006) is used to classify organisations into 10 groups based on the total number of employees. The NSF method is used in the research to ensure that the chosen list of companies is homogeneous and diverse, i.e. it is distributed in the different size categories and so provides better representation of the existing construction companies in the UK.

Another method widely used in the UK survey-based researches is by using European Commission (EC) recommendations that classify organisations into four groups based on the number of employees and turnover (EC, 2004; EC, 2005a; EC, 2005b; OECD-APEC, 2006; SBS, 2001). The EC recommendations are used in the analysis of the questionnaire responses to simplify understanding the results of the respondents' characteristics (Section 1 of the questionnaire).

The two methods are compatible and can be used together in the questionnaire. Figure 4.1 shows similarities in the two methods, where small and micro companies groups according to EC relate to Groups 1 and 2 of NSF, the medium companies group relates to Groups 3 and 4, while the large companies group includes Groups 5 to 10. Appendix 2.2 shows an example of the UK construction companies' population lists that was generated by using the

FAME database and categorised in separate sheets for the different size groups based on the NSF recommendations for size categorisation.

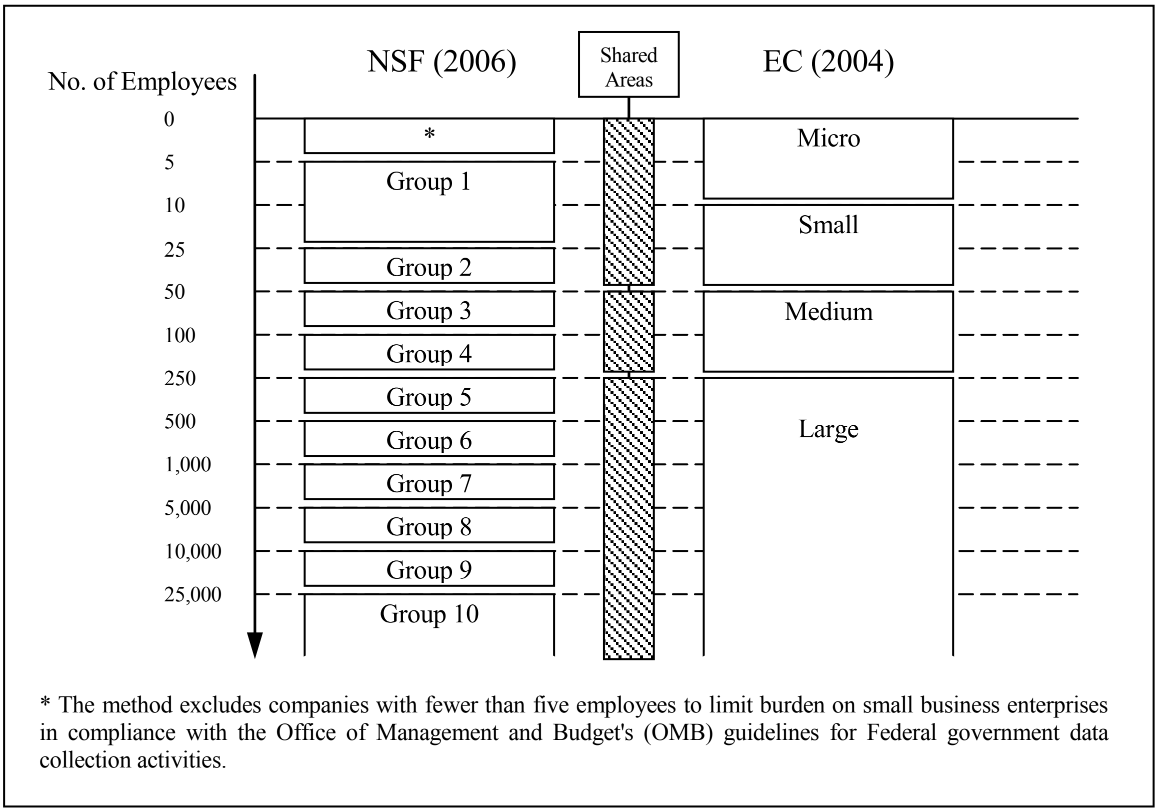

Figure 4.1: The Classification Methods of Companies Adopted by the Research (NSF, 2006; EC, 2004)

Companies were randomly selected from the list of the UK construction organisations, from each of the different size groups, especially those for which the web-site and/or e-mail address are provided, and those who provided details about a selected director or contact whose position is related to KM, IT or construction domain as shown in Appendix 2.3. The data of the chosen companies were carefully checked to ensure they are correct and up-to-date. E-mail addresses of employees whose positions are related to KM were also searched through the companies' web-sites to ensure that the questionnaire survey can reach people with required experiences and knowledge. Finally, e-mail messages were sent to a total of 300 construction companies inviting the targeted people to participate in the questionnaire survey, explaining its purposes and importance, providing link to the questionnaire web-site, and asking to forward the message to any employee in their organisation who may have useful experiences for the purposes of the research. Follow-up messages were also sent to the companies in order to improve the response rate. Example of the sample message used to contact the construction companies and the Follow-up message are shown in Appendices 2.4 and 2.5.

4.3.4 Reliability and Validity of the Questionnaire Results

Testing the reliability and validity of the questionnaire results is very important before conducting any further analysis. Reliability tests are used to provide an indication of the degree to which the measures used to evaluate the same thing are homogeneous and consistent (Saraph, 1989; Black, 1999; Antony *et al*., 2002).

In order to assess the reliability of empirical measurements, four methods can be used: (1) the retest method, (2) the alternative form method, (3) the split-halves method, and (4) the internal consistency method (Nunnally, 1967; Sellitz *et al*., 1976). The first three methods have major limitations (particularly for field studies) such as requiring two independent administrations on the same sample or the need for two alternate forms of the measuring instrument (Nunnally, 1967). That made the fourth method the most used form of reliability estimation for the field type of studies (Saraph *et al*., 1989). Hence, the internal consistency method was adopted for this research.

The ***internal consistency method*** estimates the degree to which items in a set are homogeneous by calculating a reliability coefficient called Cronbach’s alpha (Cronbach, 1951). In this study, Cronbach's alpha was computed by using the SPSS (originally, Statistical Package for the Social Sciences) reliability programme to perform an internal consistency analysis for the responses of sections 2 and 3 of the questionnaire. Examples of reliability results provided by using the SPSS programme are shown in Appendix 2.6. Generally, Cronbach's alpha refers to a sufficiently homogenous elements if its value is greater than 0.7 (Cronbach, 1951). However, when Cronbach's alpha is less than the value 0.7 the reliability can be maximized by eliminating an item or more from a sub-section. The analysis was performed for each activity or factor separately and the values for Cronbach's alpha were recalculated if any of the items were deleted from the sub-sections as shown in Appendix 2.6.

Table 4.3 summarises the original alpha values associated with all the items included in each sub-section, the items that should be removed from the original sets if alpha is less than 0.7 to maximize its value, and the final computed alphas for the reduced sets. This is important to ensure that all the activities and factors that will be analysed in the following sections of this study have high internal consistency, and are thus reliable.

The results in Table 4.3 show that all the calculated Cronbach's alpha values for the sections and sub-sections of the questionnaire results, excluding sub-sections A6, A7 and A8, are greater than the value 0.7. This indicates that the responses for the items in these sections and sub-sections are homogenous, and having high internal consistency. So, the results of these sections and sub-sections can all be included in the analysis of the questionnaire responses in the following sections.

However, the calculated Cronbach's alpha for sub-sections A6, A7 and A8 are less than 0.7 as shown in Table 4.3, which means that the responses for these sub-sections are not reliable, and thus cannot be used in its existing format for the following analysis of the questionnaire results. But as discussed previously, the value of Cronbach's alpha can be maximized by eliminating an item or more from the sub-sections. By using SPSS programme, it has been found that eliminating the items A6.4, A7.1 and A8.3 from subsections A6, A7 and A8 increases Cronbach's alpha into values greater than 0.7 as shown in Table 4.3. So, excluding these items makes their sub-sections sufficiently homogenous and reliable. Consequently, the items A6.4, A7.1 and A8.3 will be excluded from the analysis calculations in the following sections of this study.

Table 4.3: Reliability Analysis Results

Questionnaire Sections		No. of original items	Original alpha value	Item for deletion	Alpha if item deleted
SECTION 2	**KM Processing Activities and Tools**				
A1 to A5	**KM Implementation Activities**	**17**	**.867**	_	**.867**
A1	System Analysis	4	.834	_	.834
A2	System Design	3	.865	_	.865
A3	System Implementation	3	.892	_	.892
A4	System Maintaining and Monitoring	4	.824	_	.824
A5	System Evaluation	3	.753	_	.753
A6 to A9	**KM Application Activities**	**13**	**.845**	_	**.845**
A6	Knowledge Capturing and Storing	4	.681	A6.4	.797
A7	Knowledge Reusing and Sharing	3	.590	A7.1	.793
A8	Knowledge Reviewing and Approving	3	.606	A8.3	.905
A9	Using Databases to create Knowledge	3	.714	_	.714
A10	**KM Technological Tools**	**11**	**.905**	_	**.905**
SECTION 3	**KM Influential Factors**				
F1 to F5	**Environmental Factors and Activities**	**23**	**.863**	_	**.863**
F1	Culture	5	.776	_	.776
F2	Management leadership and support	5	.941	_	.941
F3	Information technology	7	.928	_	.928
F4	Measurement	3	.848	_	.848
F5	Organisational infrastructure	3	.919	_	.919
F6	**Drivers for KM**	**12**	**.958**	_	**.958**
F7	**KMS Specifications**	**7**	**.836**	_	**.836**
F8	**KM Barriers and Challenges**	**12**	**.929**	_	**.929**

Validity tests aim at evaluating the extent to which a measure is testing what is intended to be measured (Saraph *et al*., 1989). The two tests, i.e. content validity and criterion-related validity, are usually used in literature for an approximately similar number of responses to test validity of the questionnaires' results. ***Content validity*** can not be evaluated numerically but it depends on evaluations and judgements by the researchers on whether the instrument or the questionnaire contains items that cover all aspects of each variable being measured (Nunnally, 1967; Saraph *et al*., 1989; Badri *et al*., 1995; Yusof and Aspinwall, 2000).

In this study, because the selection of all the measurement items in the questionnaire was based on in-depth review of the KM literature, and these items were reviewed, edited and detailed according to feedback and evaluations from KM academicians and practitioners, the questionnaire measures developed in this study can be judged as having content validity. Furthermore, an evaluation by practitioners and academicians indicated that the items included in each sub-section are relatively comprehensive and well represented to evaluate and measure presented activities, tools or factors.

Criterion-related validity refers to the extent to which a measuring instrument is related to an independent measure of a relevant criterion (Yusof & Aspinwall, 2000). Since the questionnaire is measuring the importance of a set of activities, tools and factors for a successful implementation and application of KM, the results for sections 2 and 3 can be related to a question that asks respondents to evaluate the success of the questionnaire items to deliver a successful implementation and application of KM in the construction industry. For this purpose, a question was included in the questionnaire (See question 11 in Appendix 2.1) that requires respondents to evaluate the success of the KM activities, tools and factors by using 6 levels where 1 refers to unsuccessful at all and 6 refers to extremely successful.

To determine the extent of the relationship between the 'average importance score' for each factor given by each respondent (independent variables), and his/her evaluation to the level of success of the KM activities, tools and factors, a multiple regression analysis was carried out by using SPSS programme and the results were presented as shown in Appendix 2.7. The adjusted R-square value (adjusted coefficient of determination) resulting from this analysis was 0.783 when the KM activities, tools and factors were taken into account. This indicates that the KM activities, tools and factors have a high degree of criterion-related validity and a high degree of predictive capability.

4.3.5 Analysis of the survey responses

In order to define the response characteristics and to evaluate the importance and level of implementation of KM activities, tools and procedures in the participating construction companies, the responses to sections 1, 2, 3 and 4 of the survey need to be analysed. The response characteristics are investigated by calculating the numbers and percentages of occurrence of responses from Section 1 in the questionnaire. The level of implementation and importance of KM activities, tools and factors are investigated in Sections 2 and 3 of the questionnaire through calculating the mean scores and the number and percentage of occurrence for the respondents' ratings. Calculating numbers and percentages of occurrence of the responses in Section 4 investigates the reasons of not adopting KM in some of the participating companies.

4.3.5.1 Section 1: Response Characteristics

From the 300 companies contacted, a total of 34 questionnaires were received, representing 11.3% response rate. However, only 27 of them confirmed that their companies have implemented and practiced KM, representing a usable 9% response rate which is adequate to satisfy the survey objectives and acceptable when compared to surveys carried out in the KM field.

An example is a study by Moffett *et al*. (2003) that used a questionnaire survey to address the relationship between the cultural and technological aspects of KM. The survey was distributed to over 1,000 organisations in the UK concentrated across three industrial sectors, namely, engineering, retailing and technology. The response rate for the survey was 9 percent of the population. The results of that research indicated that a strong relationship exists between KM technologies and organisational culture.

A second example is a study by De Pablos (2002) that used a questionnaire survey to investigate areas of KM strategies, organisational learning and organisational performance in the Spanish manufacturing industry. The questionnaire survey was sent to 2,136 firms and the perceived response rate was about 6 percent. The results of the questionnaire showed that different KM strategies have different effects on organisational learning, performance, capabilities and competitive advantages.

Furthermore, a study by Wong and Aspinwall (2004) applied a questionnaire survey to investigate the critical success factors (CSFs) for adopting KM in small and medium-sized enterprises (SMEs). The questionnaires were distributed to a total of 300 SMEs in the UK and 100 contributors from academics, consultants and practitioners in the KM field. The response rates were 8.7 percent and 18 percent respectively from the two groups. The survey aimed to integrate the results of the two groups of respondents in order to generate a prioritised list of CSFs in order of their importance for implementing KM.

Finally, the numbers of respondents and/or response rates of the surveys of KM in the construction industries reviewed earlier are: 40 respondents from the construction industry for the study conducted by Egbu and Botterill (2002); 53 respondents, giving a response rate of 31.2 percent for the study conducted by Carrillo *et al*. (2004); and 15 respondents to evaluate an existing KMS in the study conducted by Lin *et al*. (2006).

It is difficult to evaluate the percentage of companies in the construction industry that can be classified as KM adopters. There is a lack in the literature for a precise definition that can differentiate KM organisations from non-KM organisations. Although some construction companies have announced that they adopt formal KMSs in their organisations, some research shows that these companies may only apply some KM tools that cannot insure successful application of KMSs (Axelsson & Landelius, 2002).

In this research, the items and practices included in the proposed KM model and in the developed questionnaire survey, shown in Tables 4.1 and 4.2, which refers to the important KM implementation, application and environmental activities and KM technological tools, will be used to define the characteristics of KM organisations.

Figure 4.2 shows the percentages of responses that indicate large scale implementation for the KM practices and tools proposed in the questionnaire survey. The results show, for example, that about 50% of the respondent companies only apply less that 10% of the items proposed in the research.

These results are affected by the fact that most of the respondent companies are from large construction companies who already have interests in KM, and the fact that the questionnaires were sent and more contacting were conducted to organisations that were recognised, through their contacts and web-sites, of being interested with computer systems. The detailed percentages of companies implementing each of the items that are proposed in the survey are presented in Figures 4.5, 4.8, 4.11 and 4.22. The results compares favourably with other research in the KM literature.

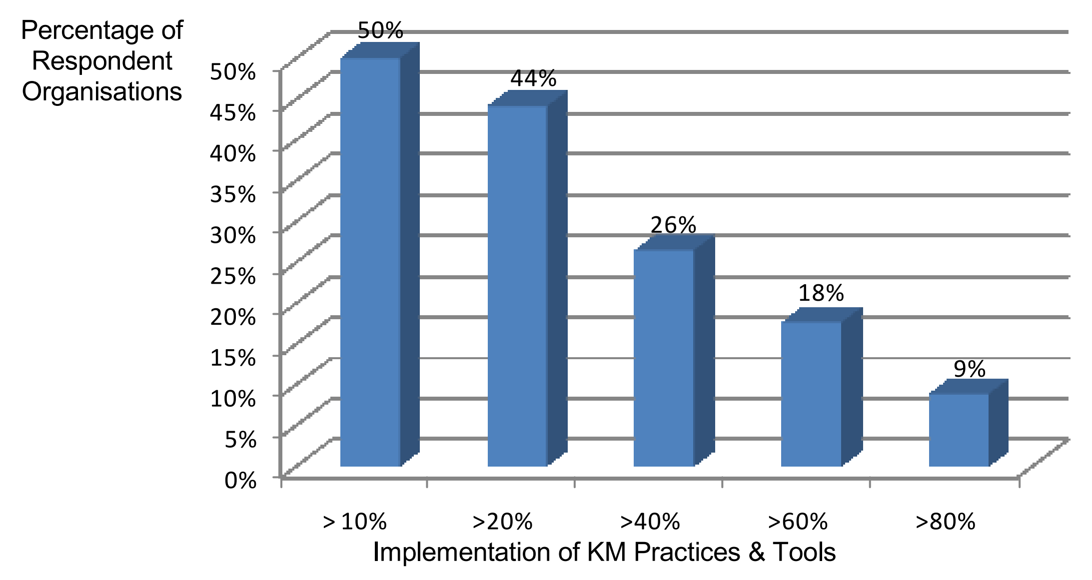

Figure 4.2: Percentages of Companies Implementing KM Practices and Tools

For example, a recent questionnaire survey conducted by Carrillo *et al.* (2004) was sent to 170 managers and directors of leading construction organisations in the UK. The response of 53 organisations, indicating a response rate of 31.2%, shows that over three-quarters of the respondents are aware of KM benefits, about 42% of the organisations already have a strategy for KM, while another 32% plan to have a strategy in the short term and the rest of 26% do not have any plans to have a KM strategy in the short-term.

Also, the results of to the questionnaires have shown that 63% of the respondent organisations consider their KM efforts to be "ad hoc", with high lack of integration and coordination, while the rest of 23% of the responses showed that their organisations may have at least a managed approach or process to KM and the remaining 14% are somewhere between "ad hoc" and "managed" (Carrillo *et al.*, 2004). The results showed that 45.3% of the organisations indicated that they have established roles of responsibility to employees to implement their KM strategy, and 22% of the organisations have introduced reward schemes to motivate KM application.

An investigation, by the same research, on the application of KM tools showed that percentages of using non-IT tools such as conferences, communities of practice, brainstorming sessions, research collaboration and job rotation, ranges between 8% and 38% of the respondent organisations. The responses also indicated that the main IT-tools, which are used to support the implementation of their KM strategies, are: the intranet with response rate of 73.6%, while extranets were only identified in limited cases; database systems with 62.3% response rate; document management systems with 37.7% response rate; electronic discussion forums with 15.1% response rate; and no responses for the use of data mining or data warehousing tools.

The research confirms that KM adoption is still new and in its early stages in most construction organisations (Carrillo *et al.*, 2004). This research only addresses the use of KM practices in the UK leading construction organisations and does not address the difficulties often associated with managing tacit knowledge (Carrillo *et al.*, 2004). Another survey by Martin (2002) that investigated KM practices across leading companies in all industrial sectors showed that the majority of organisations fall in the "add hoc" level and only 9% can be considered as having "managed" KM.

The design of a web-based questionnaire survey rather than using other forms helped to make the participation easier and the response rate more acceptable, while it also made collecting and organising the responses easier and faster. Responses from companies that did not participate in the questionnaire survey showed that the reasons for not participating include issues such as not practicing KM, low level of awareness about KM and its practices, lack of adopting formal KMSs and lack of time and/or resources to respond to the questionnaire survey.

Statistical analysis of the responses to Section 1 in the questionnaire is performed to show the descriptive statistics of the 27 respondent companies of the KM adopters. This shows characteristics of the respondent companies and people in terms of size of the company, business area, time of KM implementation and respondents' occupations as shown in Table 4.4.

The results show that the jobs of respondents are spread among different occupations that may help to capture the different opinions of the different specialities related to KM implementation and application. The results also show that about 81% of the respondent companies are large companies with 250 or more employees. The business areas of the respondent companies are diverse, but the consulting companies represent the major respondents with about 59% of the total. This may reflect the importance of KMSs to consulting companies where their competency and success depend on their abilities to develop, use and sell knowledge and know-how.

The results also show that most of the respondents claim that their companies have started to apply KMSs from between 4 and 7 years with an average of 5.2 years for the total respondents. This information may provide an indication about the involvement of the respondent companies in KM and show in general that the importance of applying KM has been widely recognised in the construction industry during the last decade, especially the last 7 years.

However, the low response level from the new adopters of KM who have applied KM from less than 4 years can be as a result of that their systems are still in early stages of application and they may still lack sufficient experience to recognise the different aspects about the applied systems and to evaluate its importance and success.

Table 4.4: Profile of respondents (Adopters of KM)

Job title of the respondents			**Size of the company**					**Business area**			**Start of KM implementation**		
Position	Number	Percentage	Category	Category	Number	Percentage	Percentage	Category	Number	Percentage	Number of Years	Number	Percentage
Design engineer	4	14.81%	Small and Micro	Less than 24	1	3.70%	7.41 %	Design-and-build Firm	2	7.41%	2 Years	1	3.70%
Site engineer	5	18.52%		25 to49	1	3.70%		General Contractor	6	22.22%	3 Years	2	7.41%
Project manager	2	7.41%	Medium	50 to 99	3	11.11 %	11.11 %	Coordinated-general Contractor		0.00%	4 Years	6	22.22%
Expert or Specialist	2	7.41%		100 to 249		0.00%		Sub Contractor		0.00%	5 Years	7	25.93%
Manager	2	7.41%	Large	250 to 499	4	14.81 %	81.48 %	Owner as General Contractor	2	7.41%	6 Years	4	14.81%
Knowledge worker	3	11.11%		500 to 999	2	7.41%		Consultant	16	59.26%	7 Years	6	22.22%
Knowledge team member	2	7.41%		1,000 to 4,999	7	25.93 %		Research Institution	1	3.70%	8 Years	1	3.70%
Knowledge manager	2	7.41%		5,000 to 9,999	5	18.52 %							
Data worker	2	7.41%		10,000 to 24,999	3	11.11 %							
Consultant	3	11.11%		25,000 or more	1	3.70%							
Total	27	100.00%	Total		27	100.00 %	100.00 %	100.00%	27	100.00%	Total	27	100.00%

4.3.5.2 Section 2 (A1 to A5): KM Implementation Activities

The results of sub-sections A1 to A5 are analysed to evaluate the importance and level of implementation for activities of KM implementation in the respondents' construction organisations. The activities in sub-sections A1 to A5 are proposed in the developed KM model of the research to define activities and processes of KM implementation in the construction projects. The average rating of importance for the activities listed in sub-sections A1 to A5 are summarised and represented in Figure 4.3. As can be seen, 88.1% of the responses indicate that the KM implementation activities are important, very important, and extremely important. This indicates that, in general, the activities included in sections A1 to A5 are of high importance for the successful implementation or building of KMSs in the construction companies.

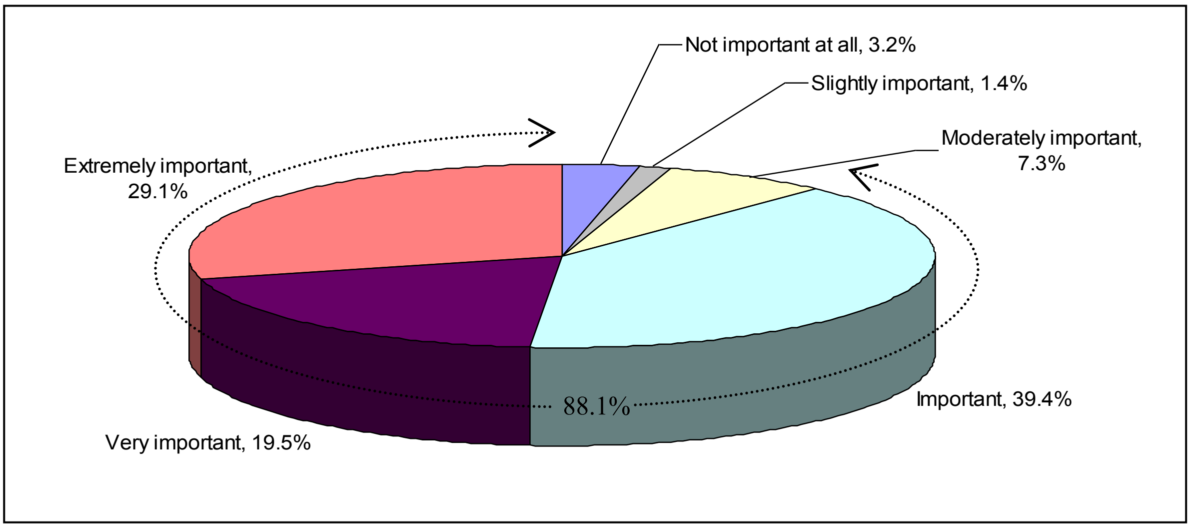

Figure 4.3: Evaluation for Activities of KM Implementation Presented in the Research

The average of the rating values for each activity in sub-sections A1 to A5 are calculated and represented to create a comparison among the perceived importance of the activities in the opinions of the questionnaire participants as shown in Figure 4.4. The mean values are in the range from 3.81 to 5.27 that fell within the range of 'Important' and 'Very important' activities with a total average of 4.59 for all the KM implementation activities. So, it can be concluded that all of the KM activities included in the questionnaire sub-sections A1 to A5 were perceived by the respondents as playing a key role in KM implementation.

The highest scores were provided for system evaluation activities with an average score of 4.96. Receiving higher importance levels for system evaluation, system analysis and system monitoring activities refer to the high involvement of the employees in the construction organisations in these activities. That shows the importance of capturing feedback from end-users in the early and late stages of the development of the KMS in an organisation in order to implement the required KMS. Lower importance levels for the design and implementation activities refer to the fact that employees of the construction organisations have less involvement in these processes compared to other activities where most of these activities are carried out by specialised IT companies.

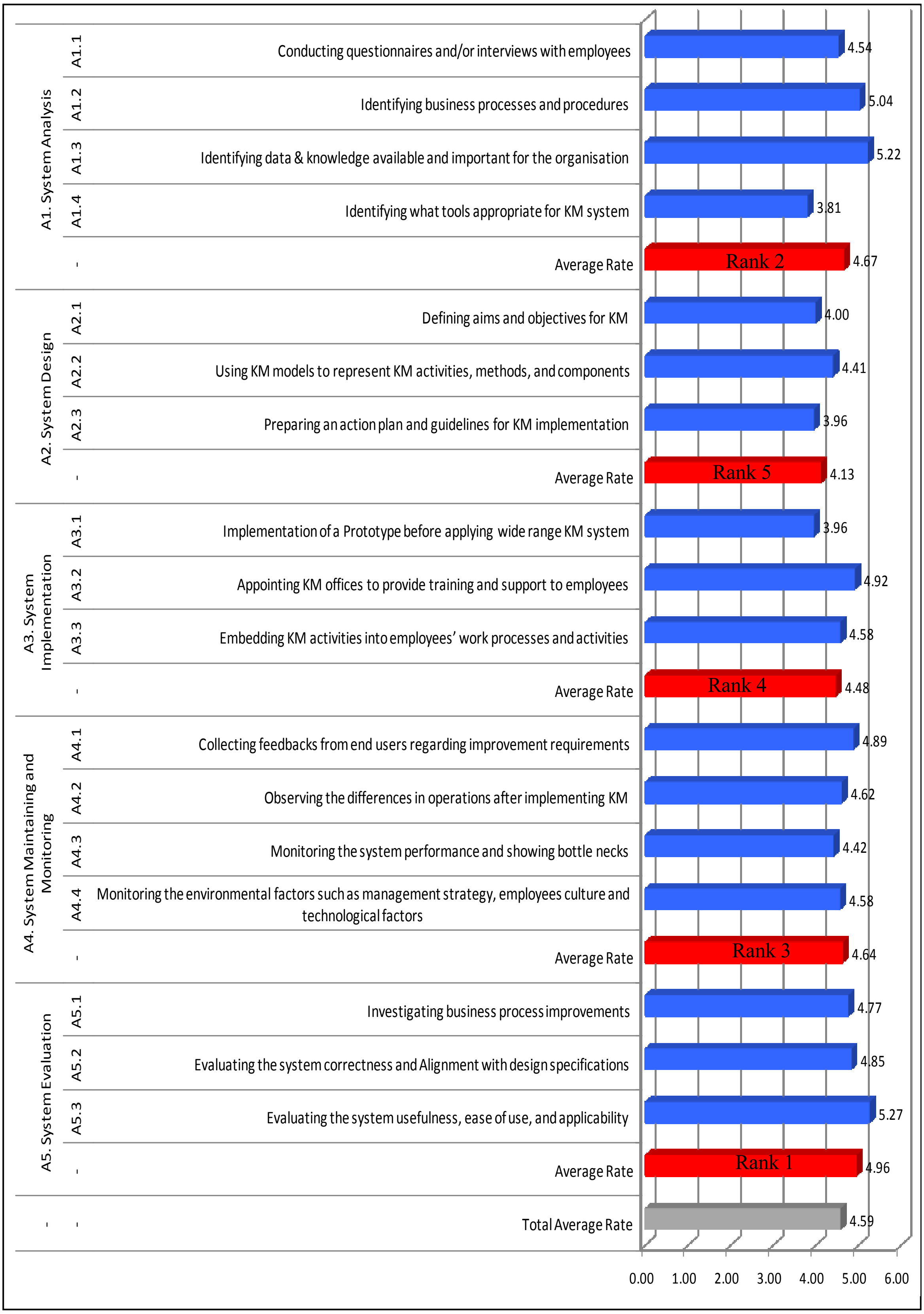

Figure 4.4: Importance Analysis of Sub-sections A1 to A5

The analysis of the respondents' opinions about the level of implementation of the activities in sub-sections A1 to A5 shows that an average of 43.0% of responses indicated large scale implementations of the listed KM activities. The levels of implementation include three scales of implementation, i.e. non implementation, prototype or small scale implementation, and large scale implementation. Non implementation of an activity or tool means that the organisation has not planned to apply it or it has planned to apply it put has not started yet. The prototype or small scale implementation of a KM activity or tool means that the application of it is still under testing so it is applied in a small area of the organisation, such as in a department or in a number of projects, to enable the organisation to evaluate and modify it before starting the large scale implementation. A large scale implementation means that the activity or tool is approved by the organisation to be applied widely and to be available in all the areas it is designed for. Figure 4.5 summarises the percentages for each activity of KM implementation listed in the questionnaire.

The results show that, among other KM implementation activities, the system analysis activity is the largest one to be implemented in the participating companies. This refers to a high level of awareness in the construction companies about the importance of this activity, which may include sub-activities such as investigating existing business processes and procedures, identifying available and important knowledge resources, capturing opinions and feedback from end-users about KM issues, and investigating required KM activities and tools to satisfy business and end-users needs. Conducting detailed analysis at the early stages of KM implementation before starting the other stages plays an important role to ensure more successful, reliable and effective design, implementation and application of KMSs.

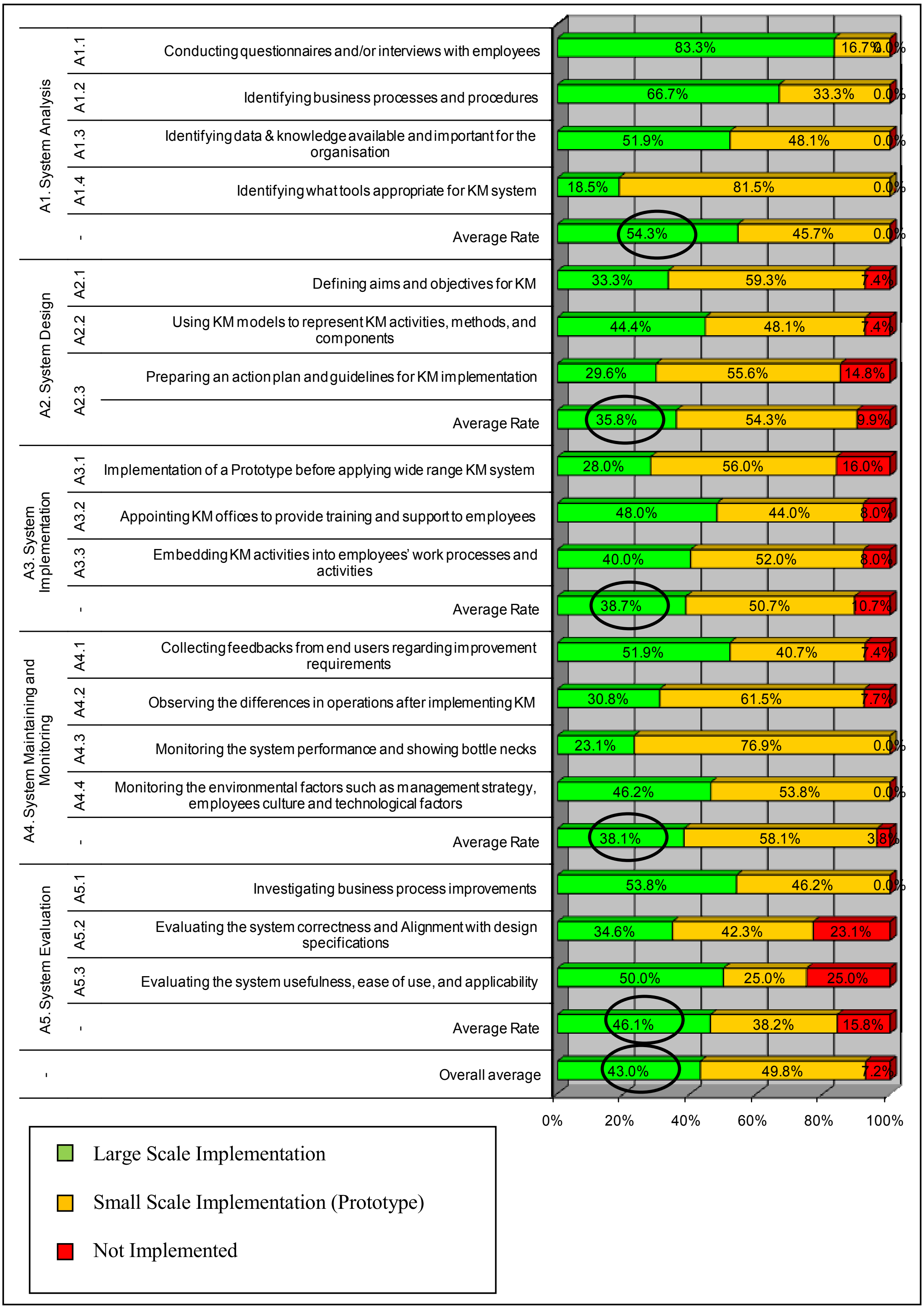

Figure 4.5: Percentages of Implementation Rates for Activities of KM Implementation

4.3.5.3 Section 2 (A6 to A9): KM Application Activities

In order to evaluate the activities of using KMSs in construction projects, the questionnaire survey includes questions to rate these activities. The proposed activities of KM application are in the questionnaire sub-sections A6 to A9. The percentages of the responses are calculated for all of the KM application activities. The results show that about 94.1% of responses believe the activities included in sub-sections A6 to A9 to be 'Important', 'Very important' or 'Extremely important'. This demonstrates that the adoption of the listed activities is important for a successful application and use of KMSs in construction projects as shown in Figure 4.6.

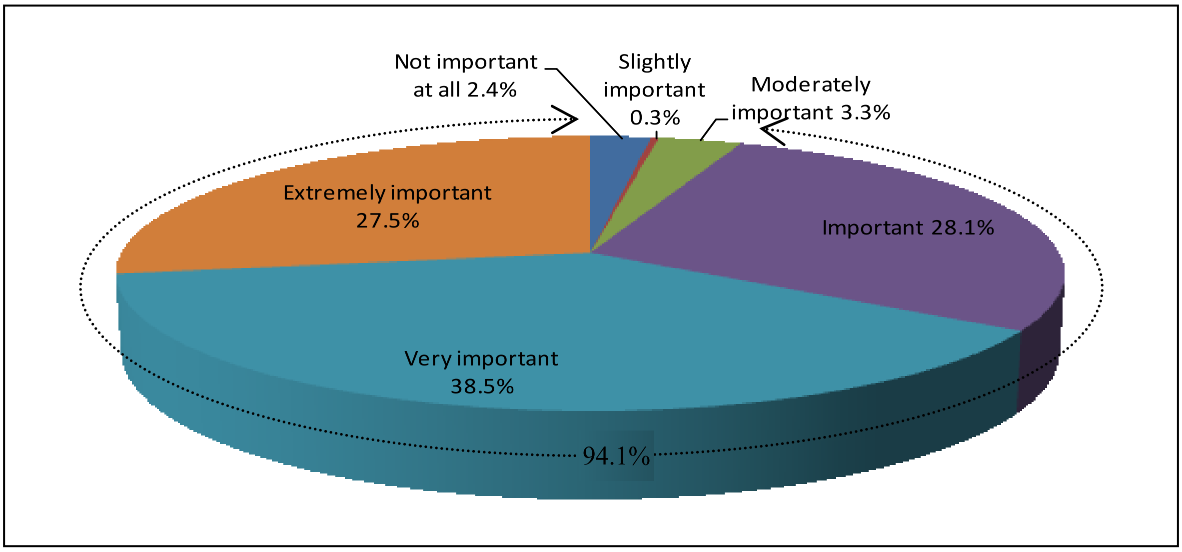

Figure 4.6: Importance Evaluation of Activities of KM Application Proposed in the Research

In order to provide an overview about the perceived importance of each proposed KM application activity, the averages of the rating values are calculated and represented in Figure 4.7. As can be seen, the averages of the perceived importance fell in the range of 4.08 to 5.19 with a total average of 4.75 for all the activities. This shows that all of the KM application activities proposed in the research are perceived by the respondents as key activities for the successful application of KM. The results also show that the most important group of activities of KM application are the activities of knowledge reviewing and approving with an importance average rate of 5.09.

The most important activity within the groups, and perhaps the main reason for people to practice and use KMSs, is the use of the company's intranet and collaborative tools to share and transfer know-how and experiences among employees. Furthermore, the lowest importance of the activity groups of KM application is the activities of using the companies' databases to create knowledge, with an average of 4.49. The least important within this group is the activity of capturing and recording the knowledge concluded by using the company's databases and data mining tools, with an average importance rate of 4.08. This shows the need to enhance the awareness of people and organisations in the construction industry about the important role of data and information in creating knowledge as will be discussed in the final proposed KM model of the research. For example, a captured problem solution, best practise or innovation may need to be supported with data and information to show that it is cost efficient, time efficient and practical, before it is made available for the KMS end-users.

The total average rate for the proposed KM application activities is 4.75, which is higher than the total average of KM implementation activities of 4.59. This can refer to the fact that for a successful adoption of KM in an organisation, it is not enough merely to have a well designed and implemented KMS, but it is also important to follow procedures and processes to encourage and enhance the use of the KMS.

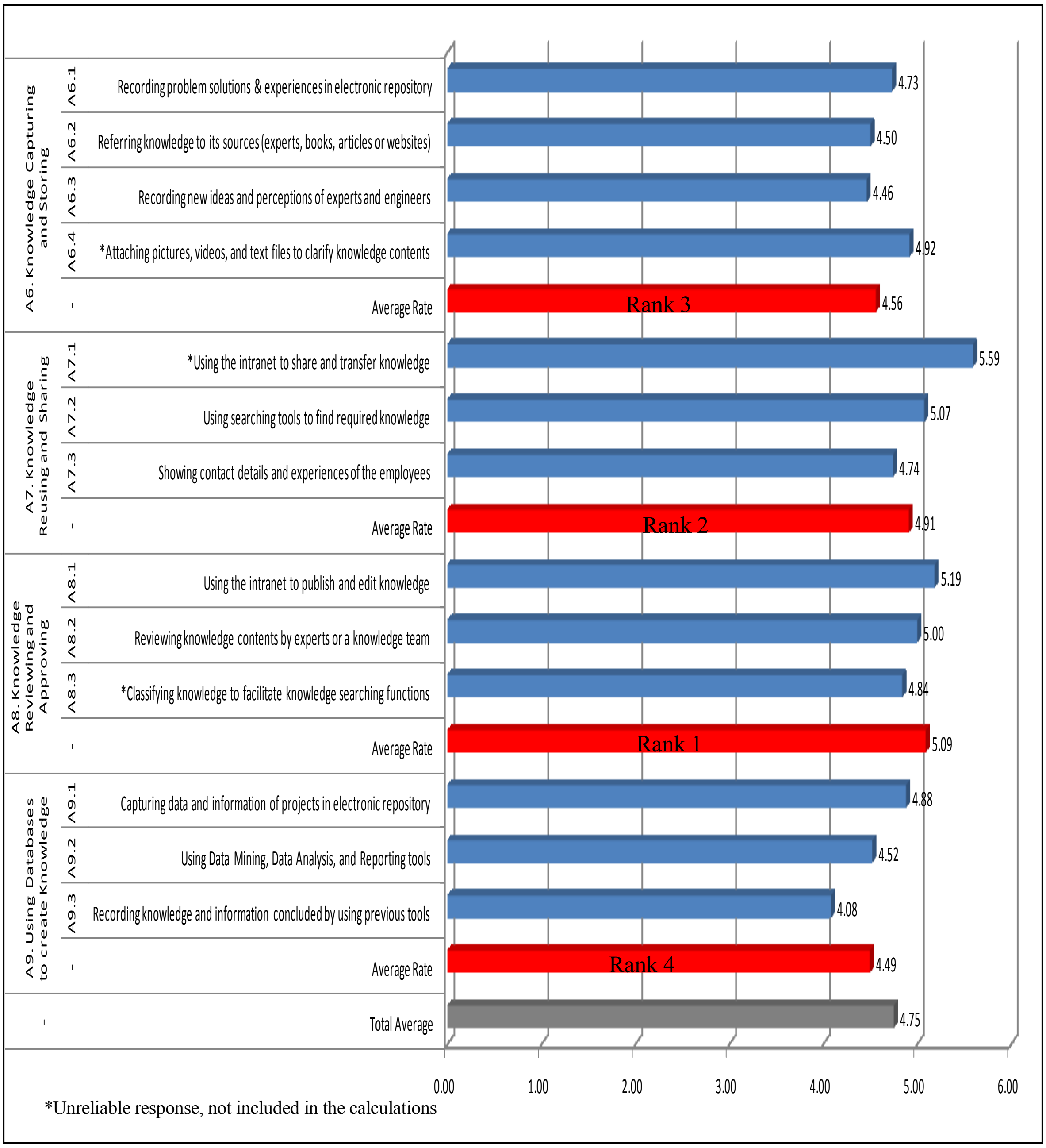

Figure 4.7: Averages of the Perceived Values of Importance for the KM Application Activities

The analysis of the implementation part in subsections A6 to A9 shows 39.8 % of the responses from the companies adopting KM claiming that they have already adopted a wide range implementation of the KM application activities listed in the questionnaire. The level of implementation of KM application activities are represented in Figure 4.8.

The results show that the highest large scale implementation level is for knowledge reusing and sharing activities (A7) with an average rate of 64.2%. The most implemented activity within this group is the activity of using KMS to share and transfer knowledge with an average rate of 85.2%. The activities of using the organisational databases to create knowledge, as discussed previously, are perceived as the least important among the KM application activities. Also, the level of implementation of the same activities is also the minimum in the KM application activities with only a 24.0% rate for the large scale implementation.

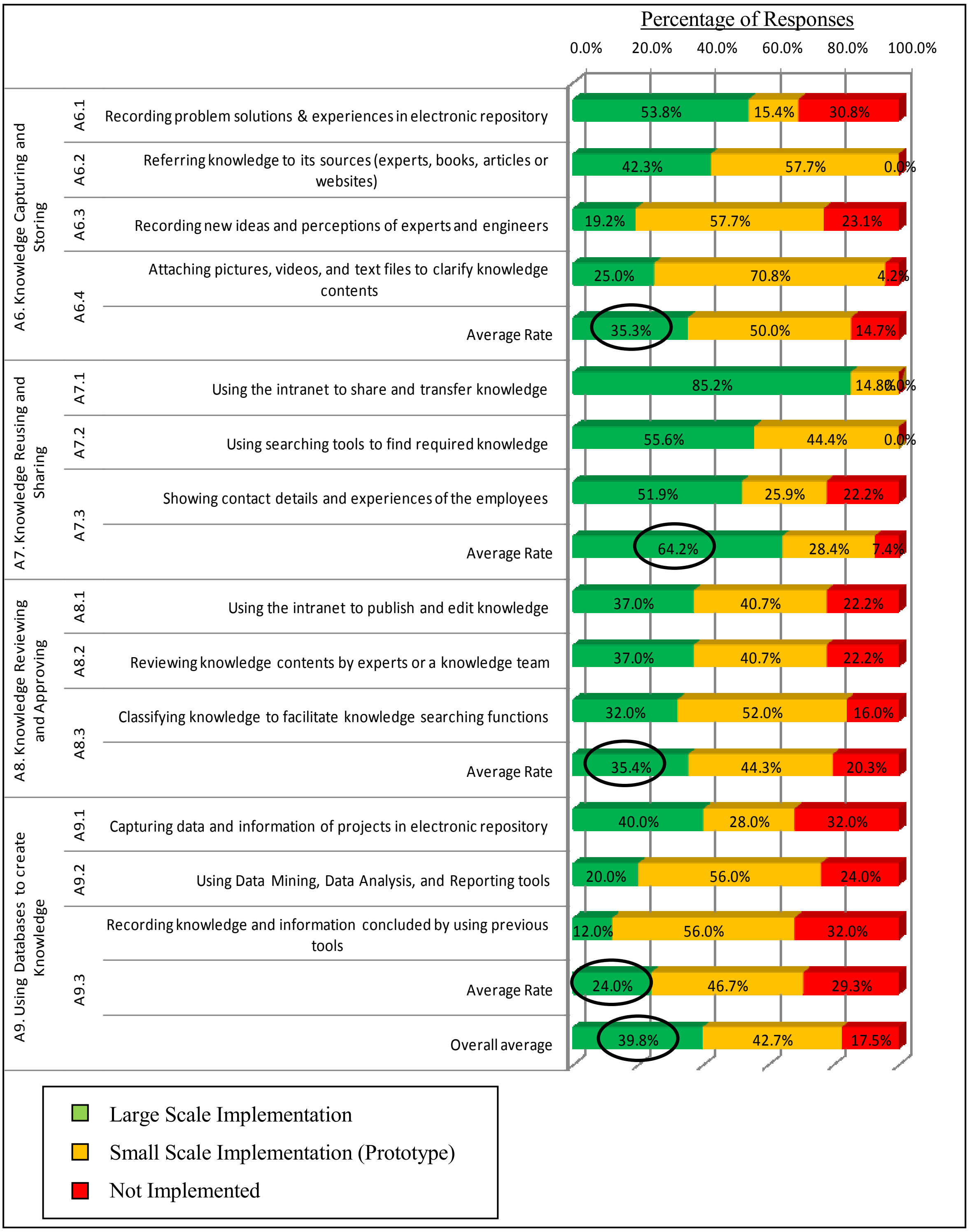

Figure 4.8: Percentages of Implementation for Proposed Activities of KM Application

4.3.5.4 Section 2 (A10): KM Technological Tools

An analysis to a list of KM technological tools (section A10) was carried out to investigate the implementation of these tools in the construction companies and to evaluate their importance for the successful application of KM. The percentages of the responses for each importance level for the proposed tools are represented in Figure 4.9. The results show that 81.1% of the responses indicate that the KM technological tools are 'Important', 'Very important' or 'Extremely important', which shows that the adoption of such tools is a key issue for a successful application and use of KMSs.

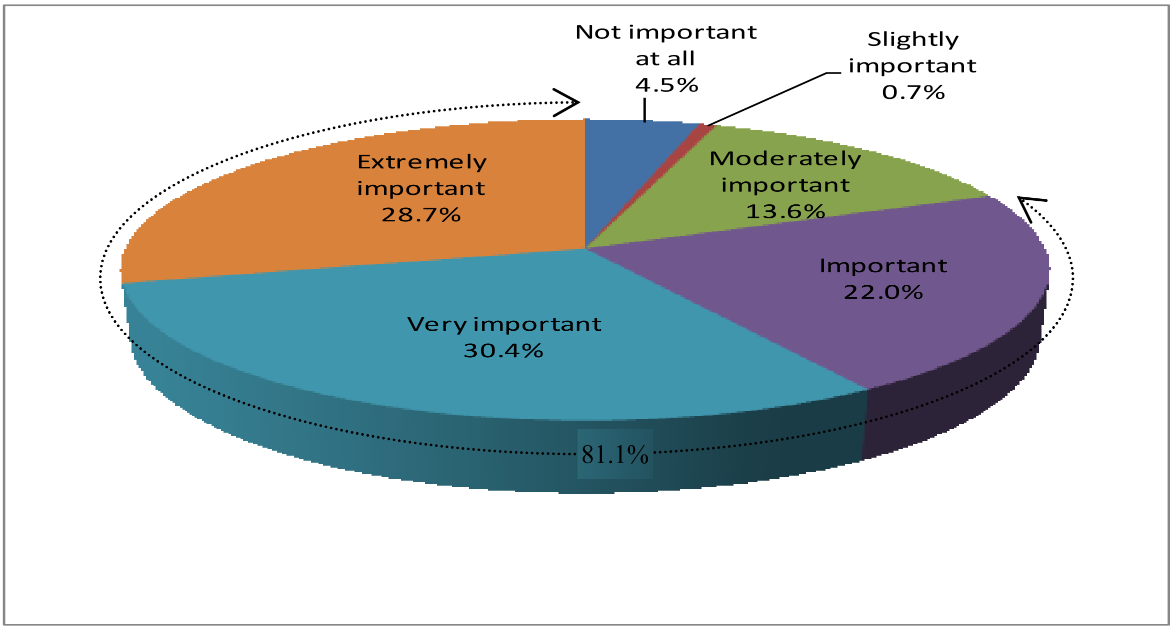

Figure 4.9: Evaluation of Importance of KM Technological Tools Proposed in the Research

The averages of the rating values for each KM technological tool are shown in Figure 4.10. Average ratings fall in the ranges of 'Important', 'Very important', and 'Extremely important' with a total average of 4.59. This indicates that those tools are very important for a successful adoption of KM in the construction organisations.

The results also show that the technological tools of capturing and retrieving explicit knowledge, such as documents, drawings, photos and videos management tools, received the highest importance ratings among other KM technological tools. Other tools, such as knowledge maps and yellow pages, which can help users to navigate and find required contents and people, are known to be very useful in processes such as problem solving and decision making. However, these tools received the lowest importance rating values. This shows that there is still a need from the construction companies and KM literature to enhance the awareness of people about the importance of applying and using such tools, and to encourage providing more support and motivation to use them.

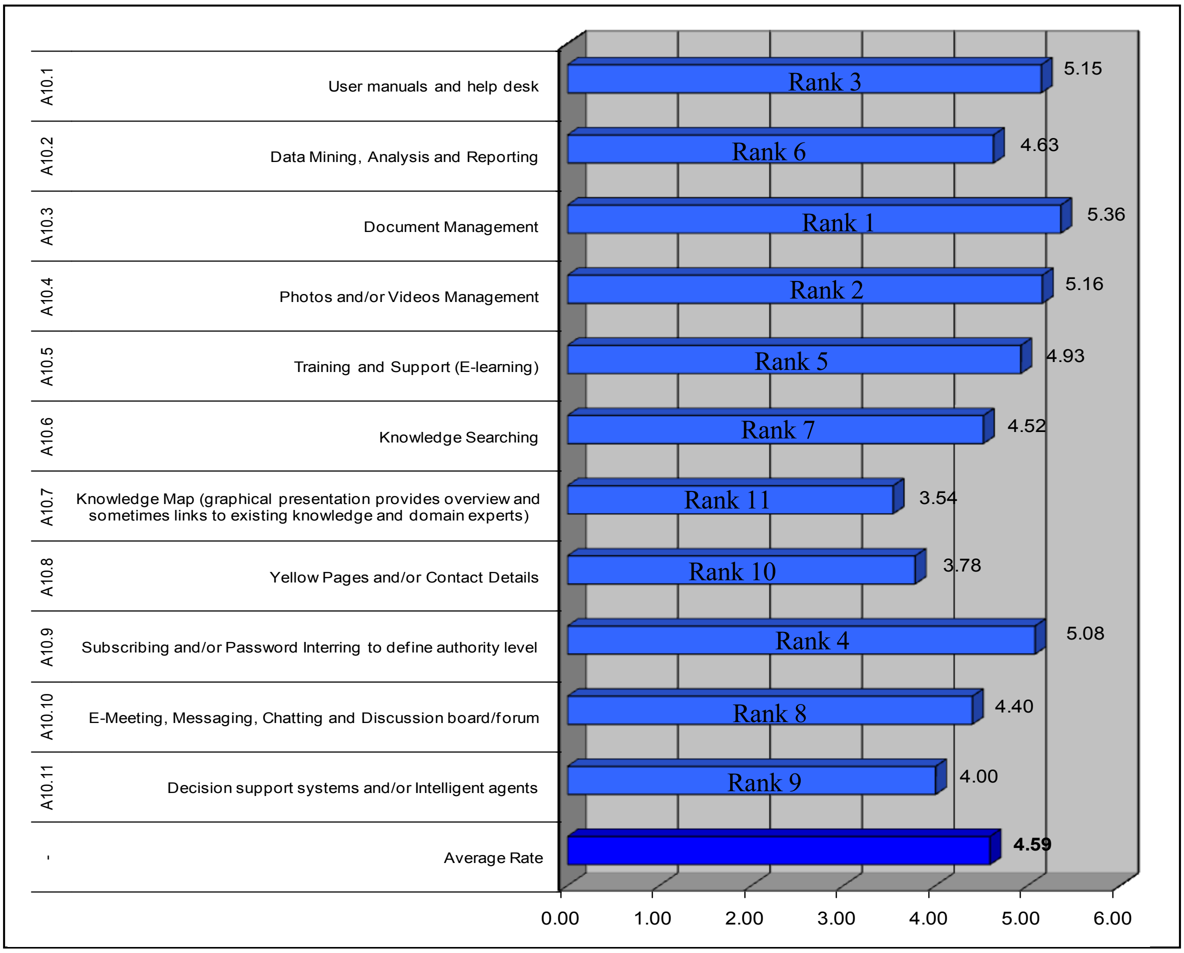

Figure 4.10: Average Rates of Importance for Proposed KM Technological Tools

An analysis of the level of implementation of KM technological tools was carried out to investigate the implementation and application of these tools in the respondent construction companies as shown in Figure 4.11. The results show that an average of 35.2% of the responses indicates that the responding companies have applied these technological tools in a wide range implementation, while 46.8% of the responses indicates that they have applied them only in a small scale implementation, and 18% of the responses shows that they have not started implementing and applying the tools.

The results also show that the most common tools used in these companies are document management tools, user manuals and help desk, while the least implemented tools are knowledge maps and yellow pages. However, the importance of adopting knowledge maps and yellow pages in the processes of capturing, retrieving and sharing knowledge has been confirmed by much of the KM literature.

Knowledge maps can help organisations to identify available and missing knowledge types in the KMS and to decide what types of knowledge may need more efforts and support to capture in the system. It also helps to categorise captured knowledge available for end-users. Providing yellow pages and contact details in the KMS helps users to find and contact people who have the required experiences. Knowledge maps and yellow pages have been widely used in managing knowledge in the organisations (Lin *et al*., 2006; Woo *et al*., 2004). However, this study shows that there is still much effort needed to enhance the awareness of people and organisations about the importance and future benefits of adopting knowledge maps and yellow pages in the organisations in general and in the construction companies in particular.

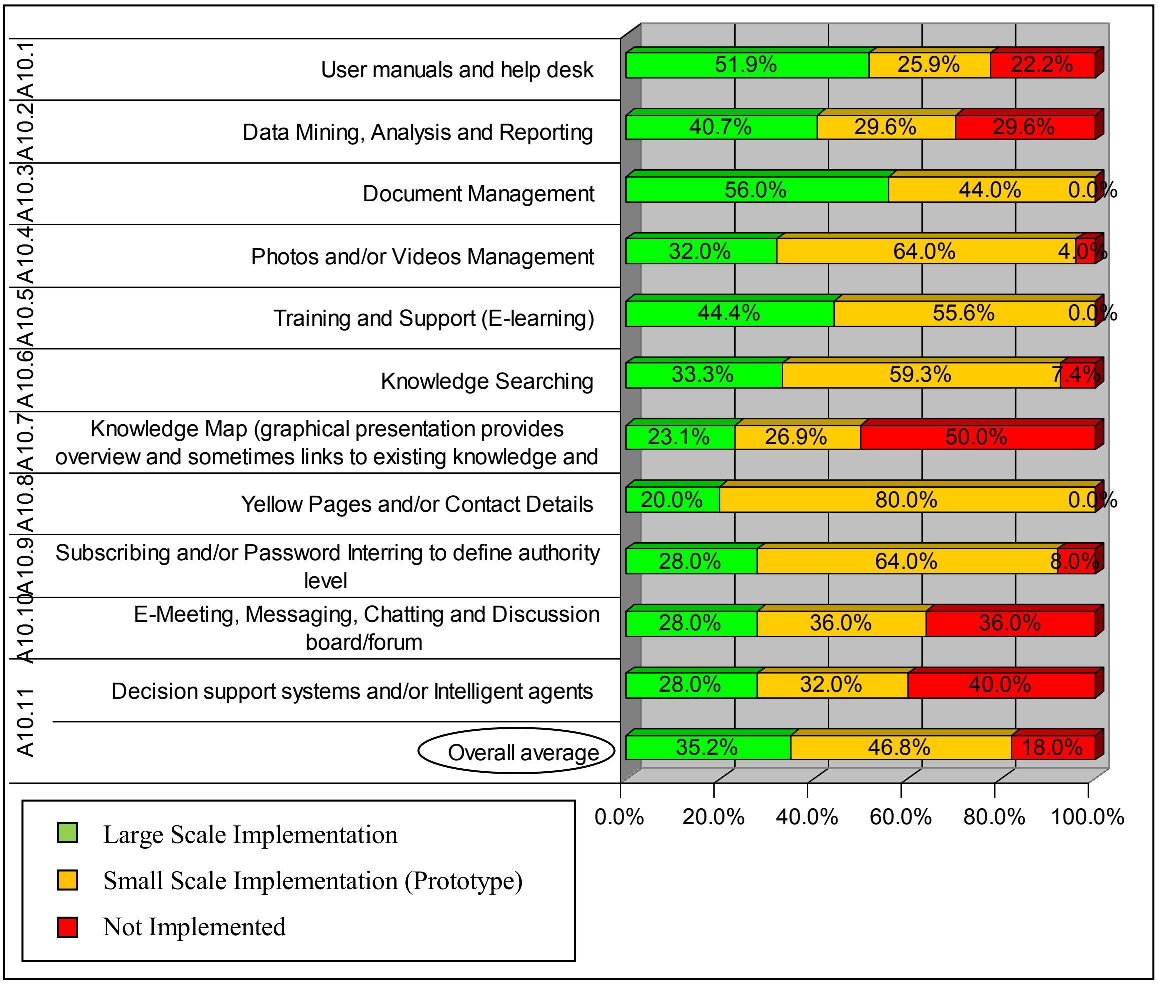

Figure 4.11: Percentages of Responses Indicating the Implementation level for KM Technological Tools Proposed in the Research

4.3.5.5 Section 3 (F1 to F5): Environmental Factors and Activities

Subsections F1 to F5 in the questionnaire survey are to investigate the opinions of KM practitioners in the construction industry about the importance and the level of implementation of KM environmental activities. The aim is to examine key activities to deal with environmental factors that may affect the successful implementation and application of KM in the construction projects. The results are represented in Figure 4.12. It should be noticed that 88.8% of the responses refers to the high importance of the proposed activities according to the opinions and experiences of the questionnaire respondents. As can be seen, the environmental activities in the proposed KM model have been ranked as highly important for a successful adoption of KMSs in the construction companies.

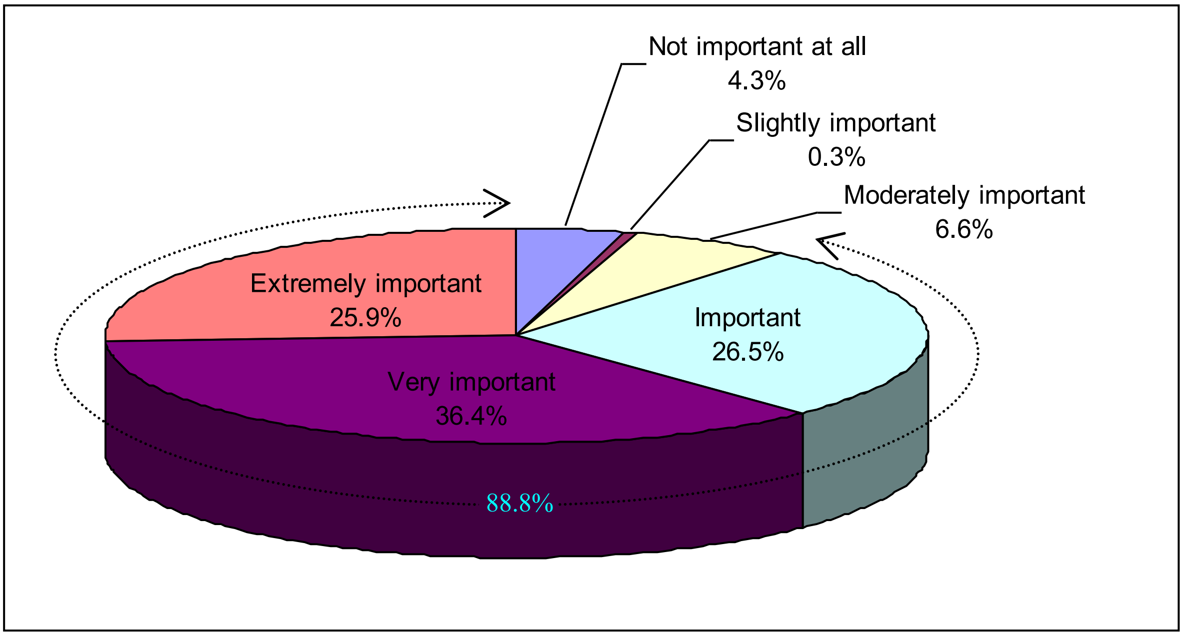

Figure 4.12: Evaluation for Environmental Activities of KM Adoption Proposed in the Research

The average rating values for the subsections F1 to F5 and for the activities within each subsection, as represented in Figure 4.13, fell in the range from 4.07 to 5.41, as 'Important' and 'Very important'. The overall average was 4.68, which indicates that the activities included in the proposed KM model to define the environmental activities are highly neccessary to deal with KM environmental factors and play key roles for the adoption of KM in the construction organisations. The highest evaluation averages are given regarding the activities and procedures related to information technology. This indicates that KMS should be easy to use; be available for end-users through intranet and internet; include tools and components that satisfy organisational and individual needs; and allow users to capture, share, retrieve, reuse, update and protect knowledge. Although the environmental activities are evaluated to be very important for a successful adoption of KM in the construction projects, those activities cannot work successfully if the existing KMS is not easy to use, lacks the required components, does not consider privacy and copyright regulations, and lacks effective and efficient performance.

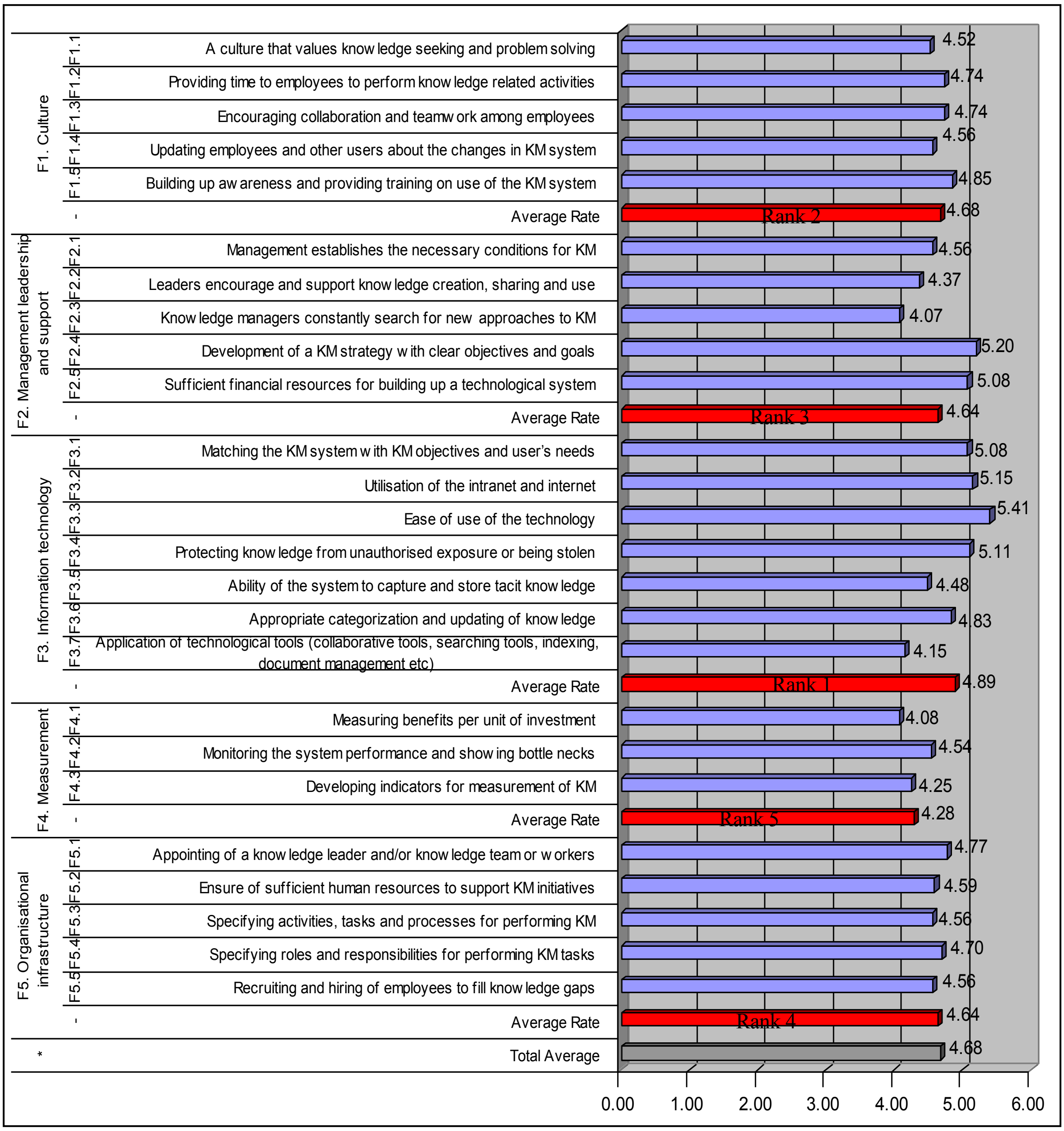

Figure 4.13: Importance Evaluation of Environmental Activities

The levels of implementation to the environmental activities in the participating companies according to the respondents are shown in Figure 4.14. The results show an overall average of 34.4%, which indicates that the environmental activities are extremely implemented in the participating construction companies. Among these proposed environmental activities, the highest level of implementation is related to information technology. Knowing that these activities have also received the highest importance rates according to the respondents' opinions, these construction organisations seem to have a high awareness level about their importance and usefulness to their KM efforts.

Furthermore, the results show that the construction organisations still lack a high level of implementation to the evaluation and measurement methods, which also received the lowest importance rates. These methods are to evaluate the success of existing KMSs and their effect on business performance. This result indicates that there is still a need to develop more effective and useful evaluation methods, and to investigate more measurement indicators to evaluate the success of KM efforts and their effect on business performance.

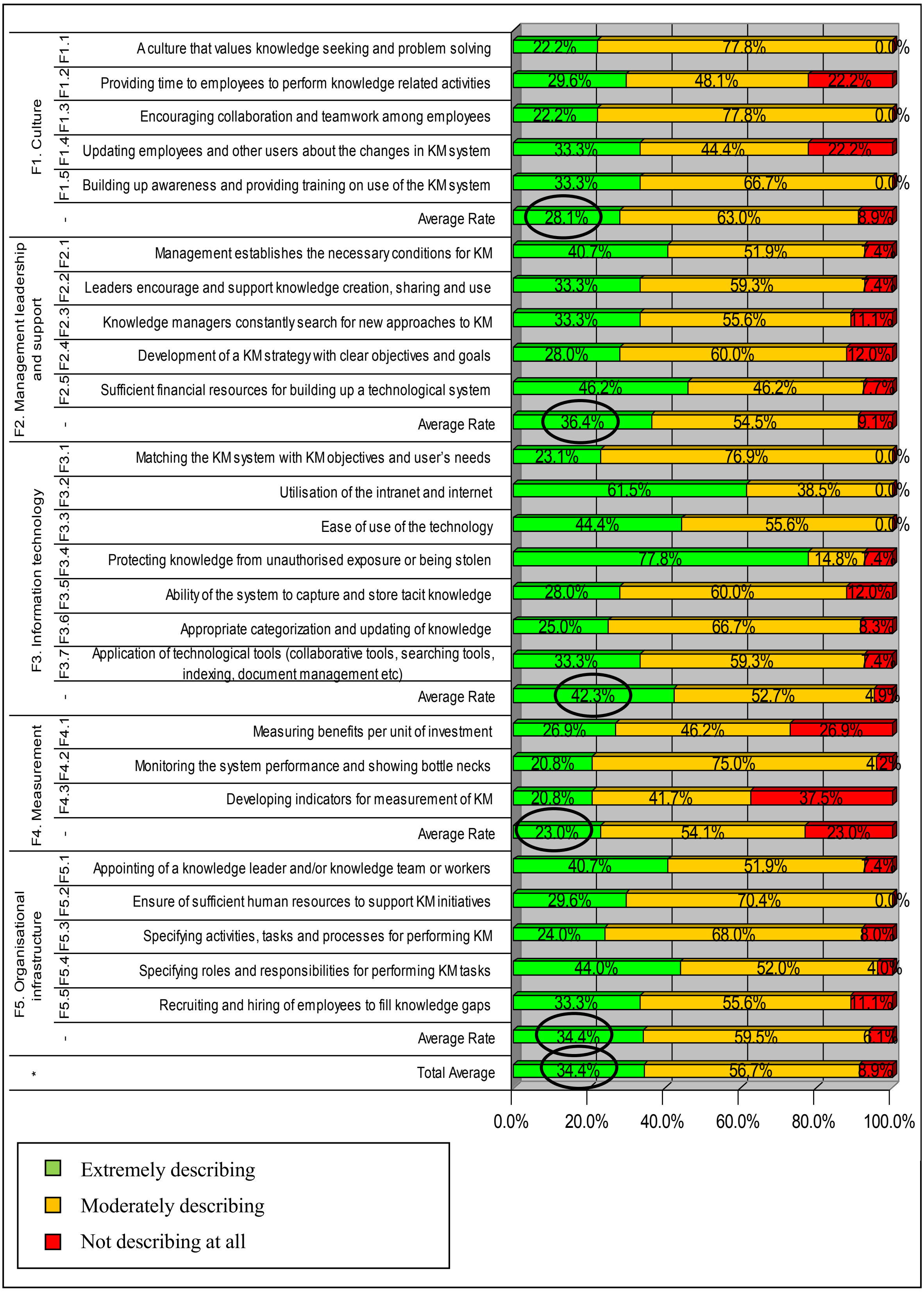

Figure 4.14: Percentages of Implementation Rates for Environmental Activities

4.3.5.6 Section 3 (F6 to F8): KM Drivers, Specifications and Challenges

Subsections F6, F7 and F8 are designed in the questionnaire survey to ask for respondents' opinion about the importance of drivers, specifications and challenges that may encourage or hinder the efforts for adopting KM in the construction organisations. Figure 4.15 shows the results of these sections, which indicate that 'Important' to 'Extremely important' responses are 93.1% for KM drivers, 92.6% for KMS specifications, and 96.0% for KM challenges. This indicates the need of construction organisations to investigate drivers that encourage their KM efforts, specifications that are required to support their KM activities, and challenges that they need to avoid and deal with by applying special KM methods and procedures.

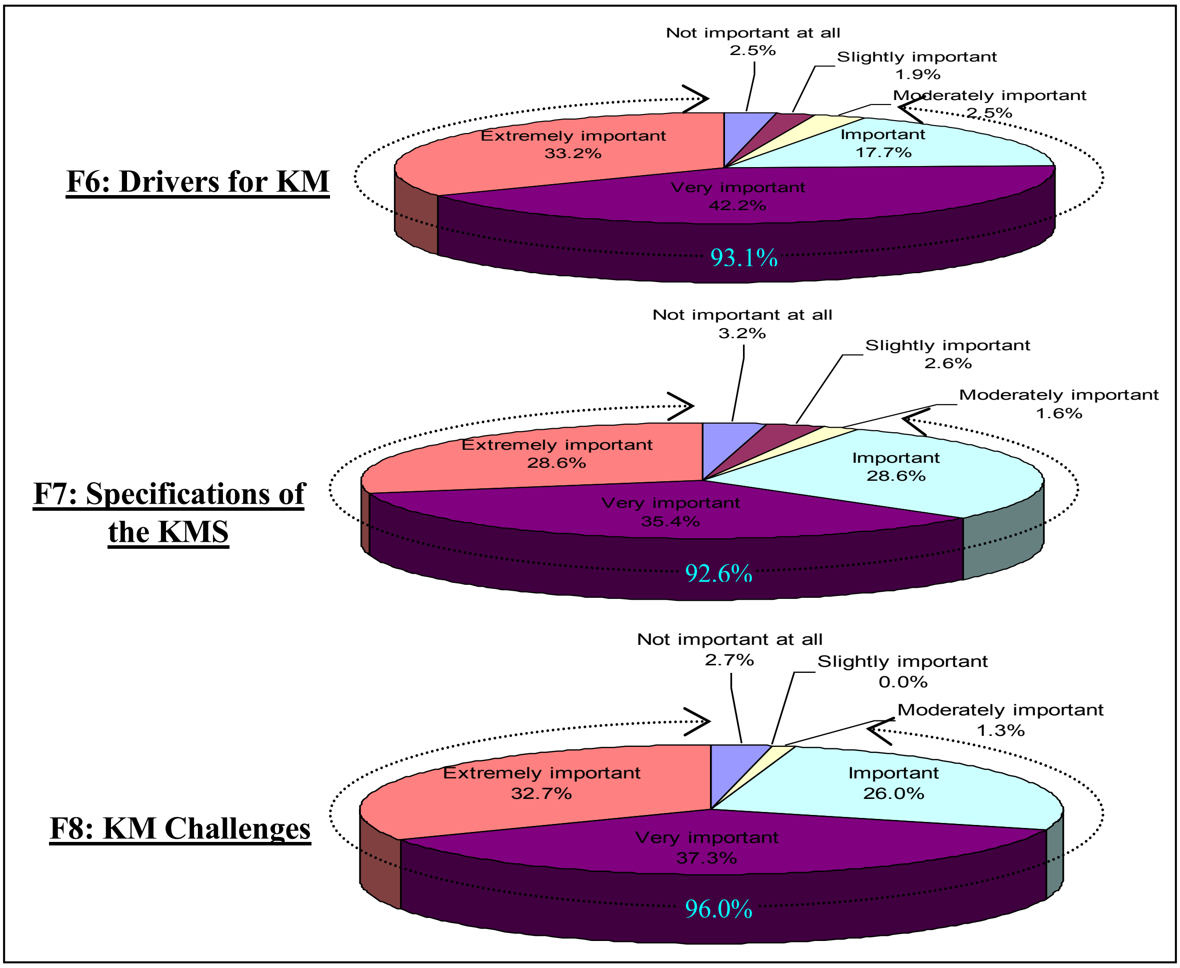

Figure 4.15: Evaluation for KM Drivers, Specifications and Challenges

Figures 4.16 to 4.21 show the responses' results in terms of mean ratings of importance and average percentages of implementation of each item used to describe KM drivers, system specifications and KM challenges. It should be noted from Figures 4.16, 4.18 and 4.20 that all importance means are in the range from 4.07 to 5.52 which refers to the 'Important', 'Very important' and Extremely important' evaluation levels. This indicates that all the factors in the questionnaire are crucial for a successful adoption of KM in the construction projects. Therefore, for successful implementation and application of KM, these factors should be investigated, managed and dealt with effectively in the construction organisations.

As can be seen in Figures 4.16, the most important driver that encourages the construction organisations and people to adopt and apply KM is to enhance the quality of work processes and products in the construction projects. Other factors that received high importance levels include enhancing relations with customers, partners and suppliers; and reducing time, money and efforts required to find problem solutions, best practises and decisions. Figure 4.17 shows that the questionnaire respondents believe that by using KMSs the companies enhance work processes and products, accelerate learning processes, improve risk management application and help gain competitive advantages.

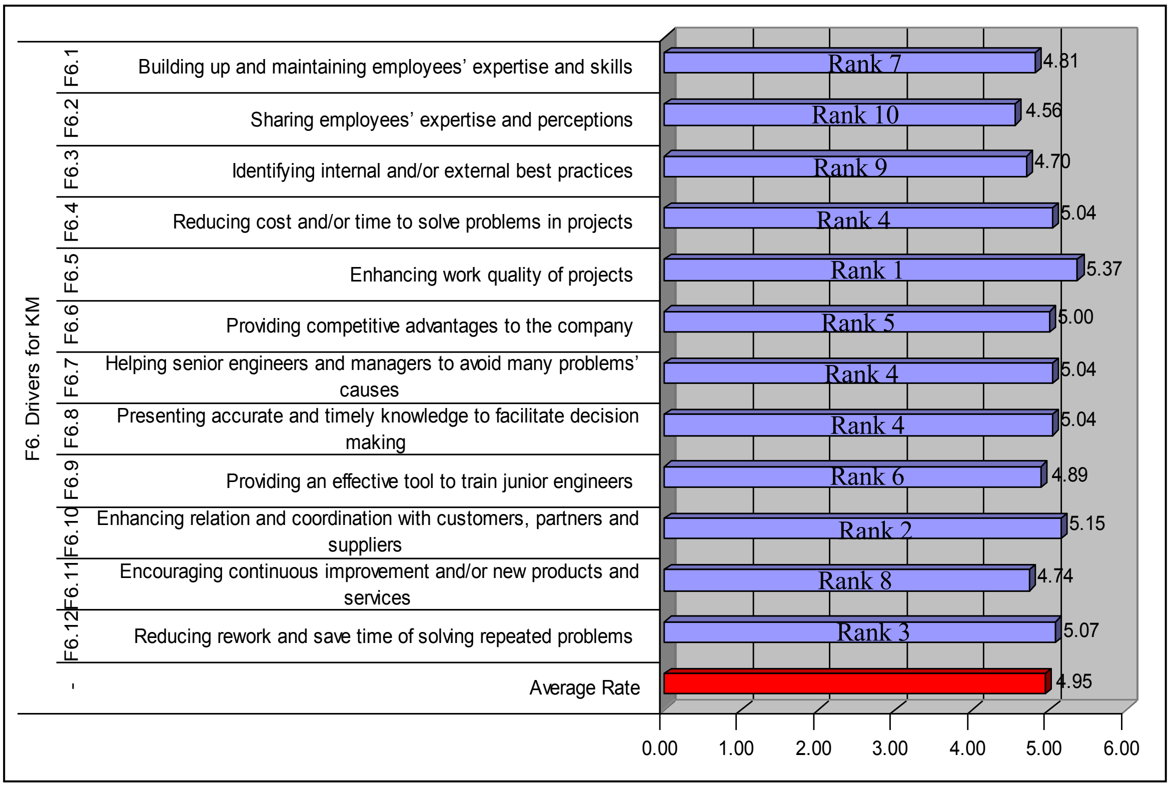

Figure 4.16: Importance Evaluation of KM Drivers

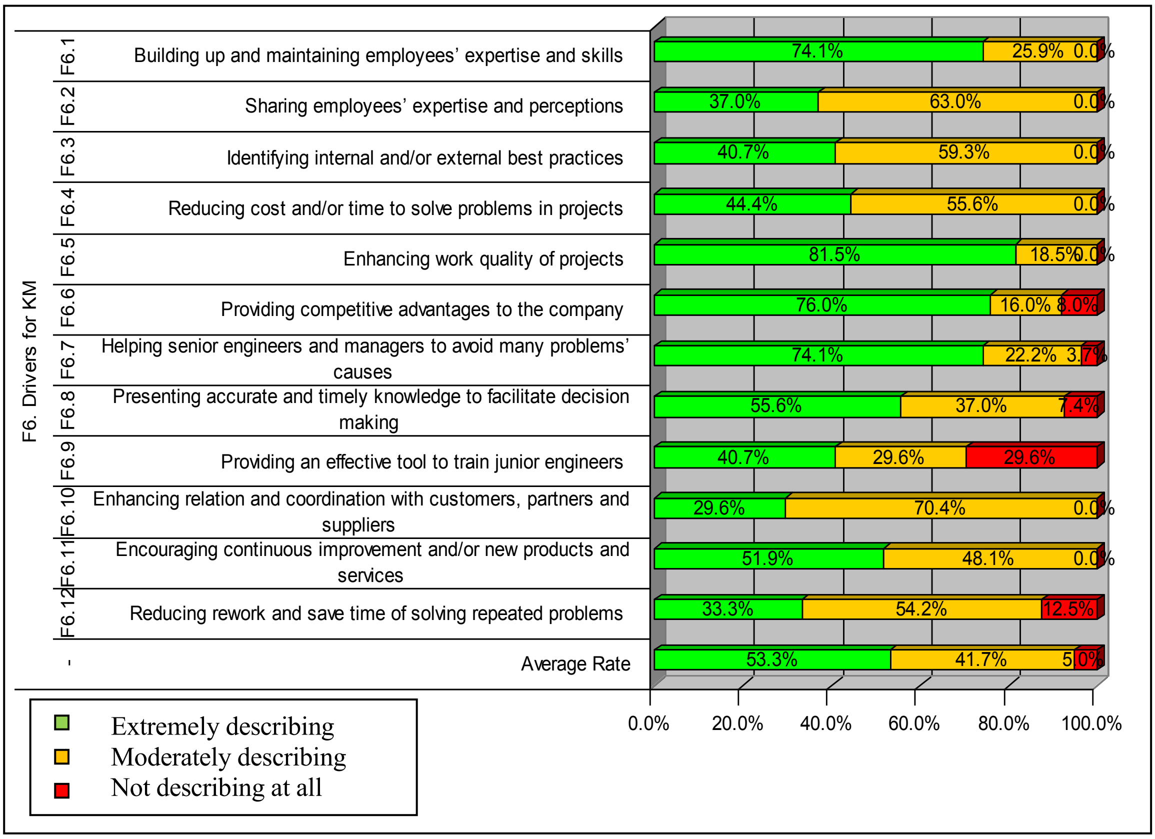

Figure 4.17: Description Evaluation of KM Drivers

The results of subsection F7, shown in Figure 4.18, demonstrate the most important specifications required for a successful adoption of KMSs. These include KMS characteristics such as providing services and knowledge to partners, suppliers and customers; appointing KM teams and/or workers; providing user friendly services and interfaces, and ensuring the collection and availability of useful and valid knowledge. Furthermore, the results shown in Figure 4.19 indicate that the respondents think these specifications highly describe the KMSs applied in their organisations.

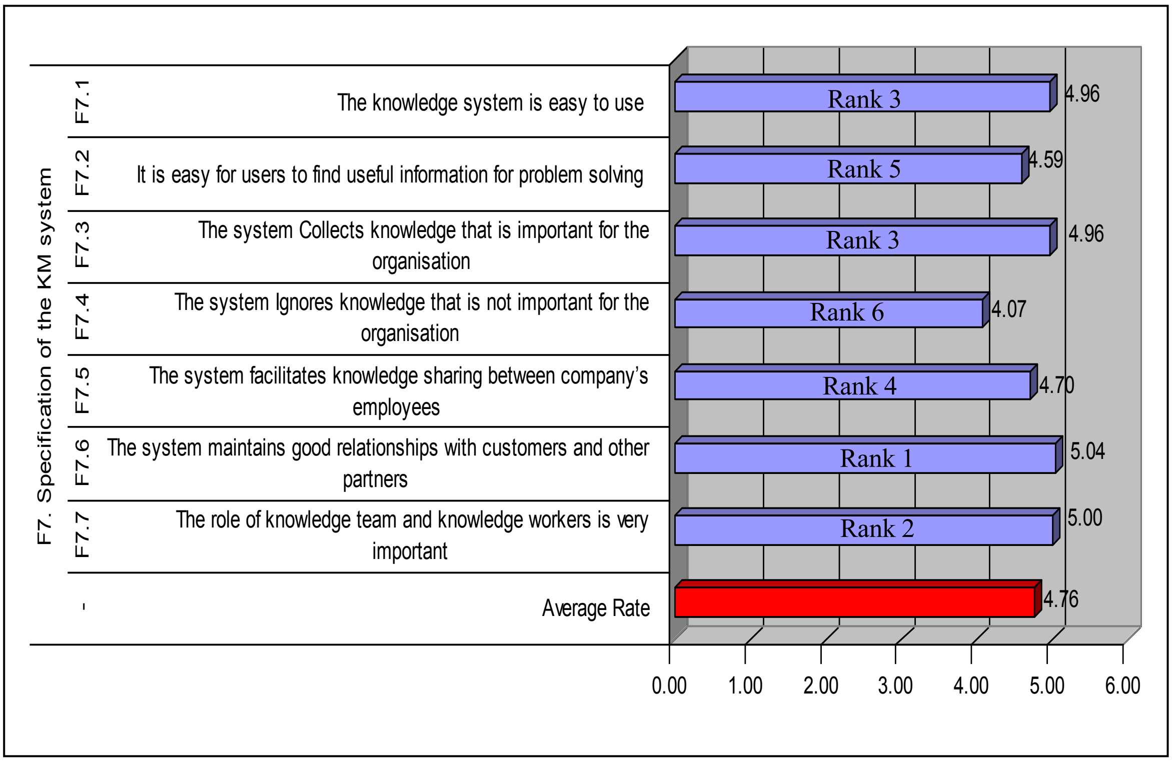

Figure 4.18: Importance Evaluation of KMS Specifications

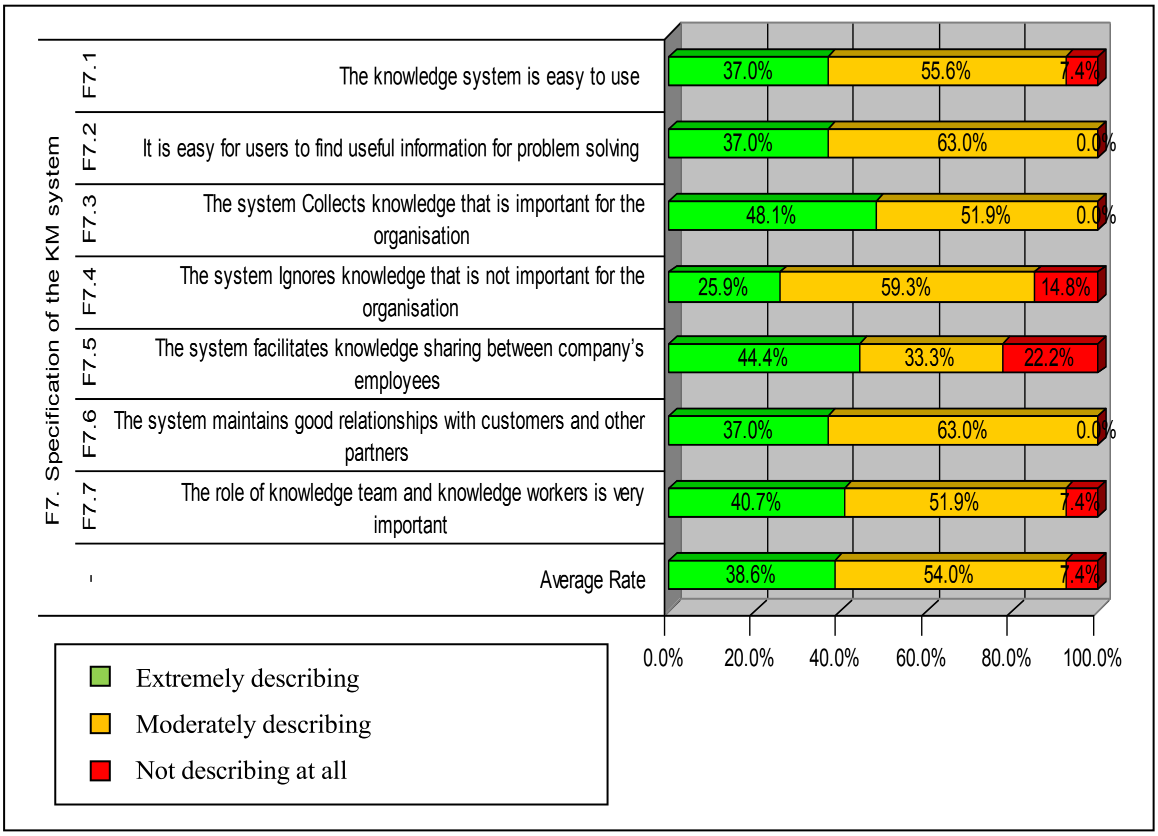

Figure 4.19: Description Evaluation of KMS Specifications

Figure 4.20 shows that the most important challenge to the success of KM in the construction organisation is the lack of knowledge teams or KM roles to deal with KM processes, activities and strategies. However, this challenge does not widely describe what actually exists in the responding companies. The results represented in Figure 4.21 show that the biggest challenge describing the condition in the participating construction companies is the lack of a structured method to implement and apply KM procedures and methods. This research deals with this challenge by developing a practical structured method to simplify and manage the adoption of KM in construction projects.

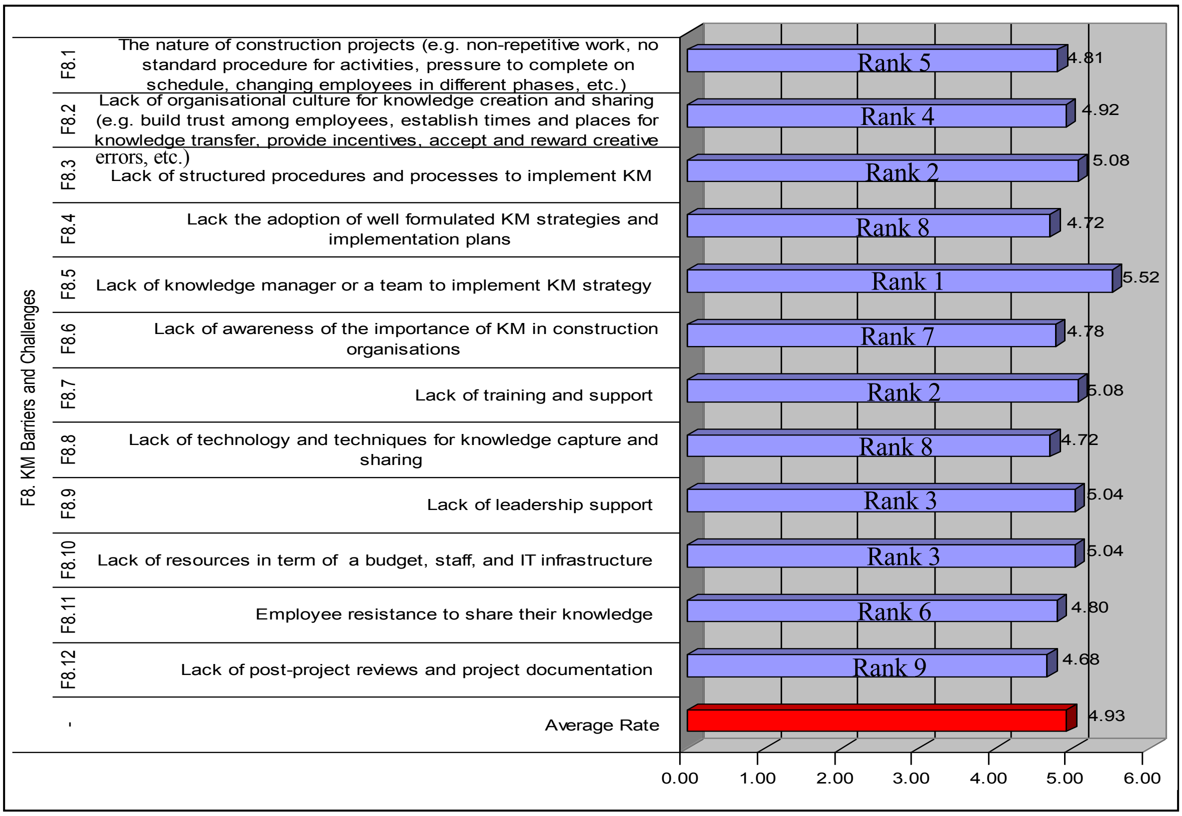

Figure 4.20: Importance Evaluation of KM Challenges

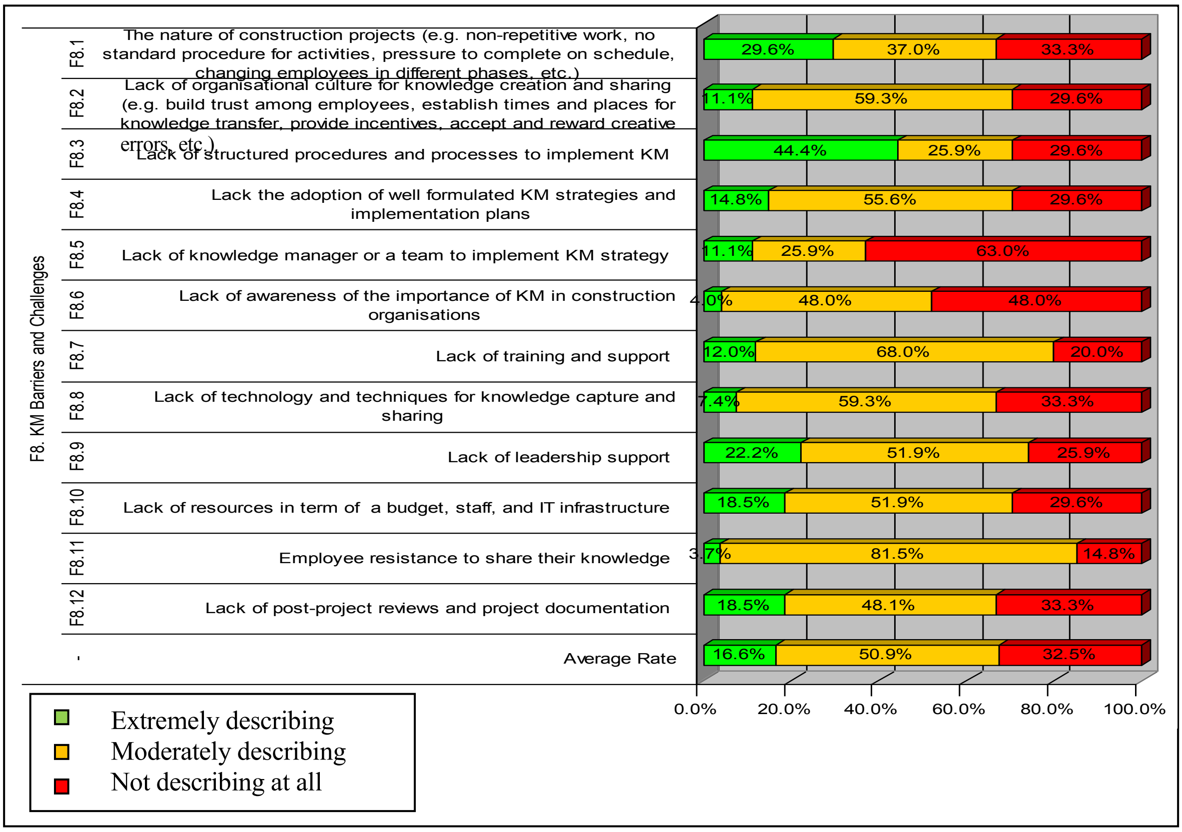

Figure 4.21: Description Evaluation of KM Challenges

4.3.5.7 Sections 2 and 3: Comparison of Results

Figure 4.22 shows a comparison among KM implementation activities (sub-sections A1 to A5), KM application activities (sub-sections A6 to A9), KM technological tools (sub-section A10) and KM environmental activities (sub-sections F1 to F5) in terms of the perceived importance and the evaluation of their implementation.

The results show that the KM application activities (subsections A6 to A9) have the highest importance rates among other activities and tools. However, the results show that the KM application activities have a lower implementation percentage than for the KM implementation activities. This indicates that there is still a need to encourage adopting KM activities that enhance the use and application of KMSs in the construction organisations. An effective method to achieve that is by embedding KM activities into the routine work procedures of the people in the organisation. The results also show high levels of importance and implementation of the environmental activities in the respondent construction companies. This emphasizes the need to apply procedures and methods that deal with environmental factors to encourage the useful factors and reduce the negative influence of KM barriers.

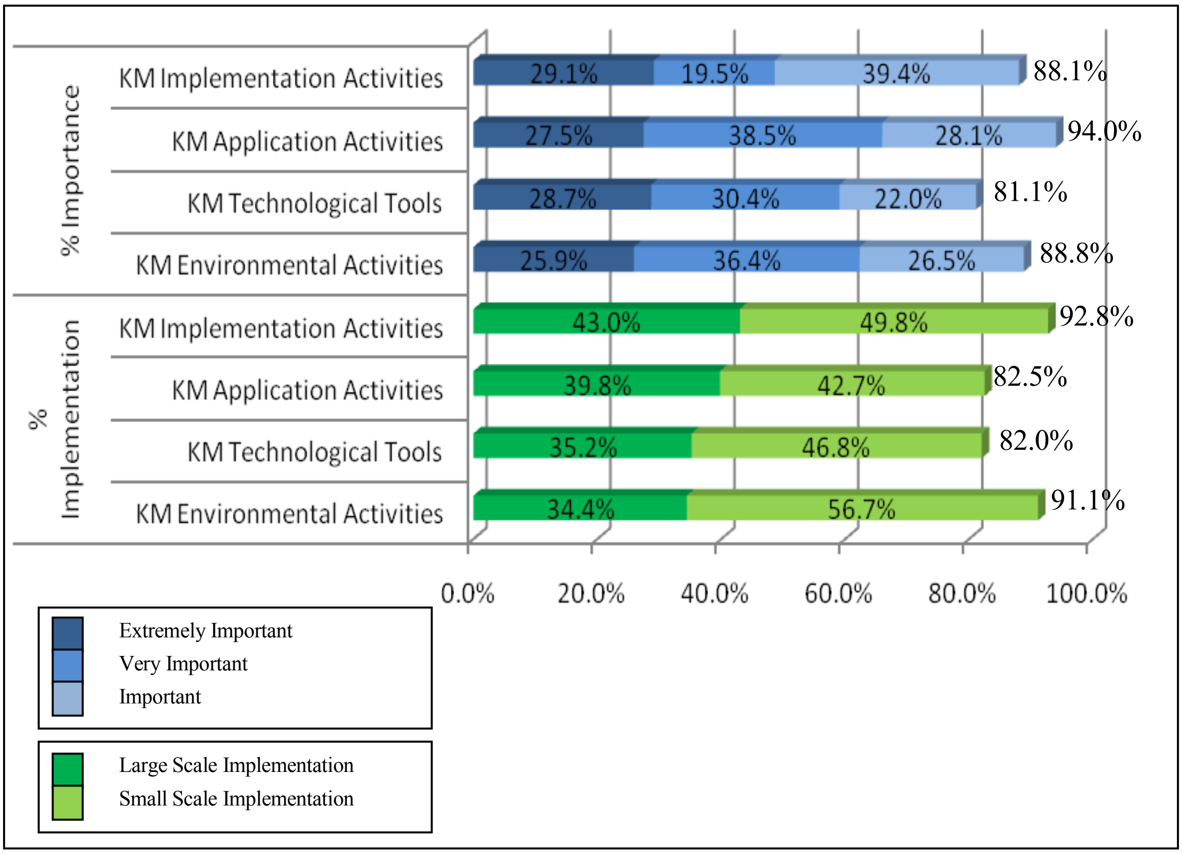

Figure 4.22: Comparison of Importance and Implementation Evaluation for KM Activities and Tools Proposed in the Research

4.3.5.8 Section 4: KM Barriers for Non-KM Adopters

This section investigates the reasons of not adopting KM in the construction organisations. The section requires respondents from organisations that do not adopt KM to choose one or more of the main reasons for not adopting KM in their organisations. The number of respondents to this section is 7 respondents provided 19 responses. The results represented in Figure 4.23 show that the main reason for not adopting KM is the lack of financial and human resources to implement and apply KM. Other major KM barriers are the lack of awareness about KM benefits and the lack of methods to evaluate the actual benefits of KMSs in the construction organisations. More barriers to KM implementation are described by respondents. A major barrier described by the respondents is that the organisations planning to adopt KM need to apply major changes in terms of work procedures and organisational culture which require considerable time, effort and managerial courage to be implemented and applied.

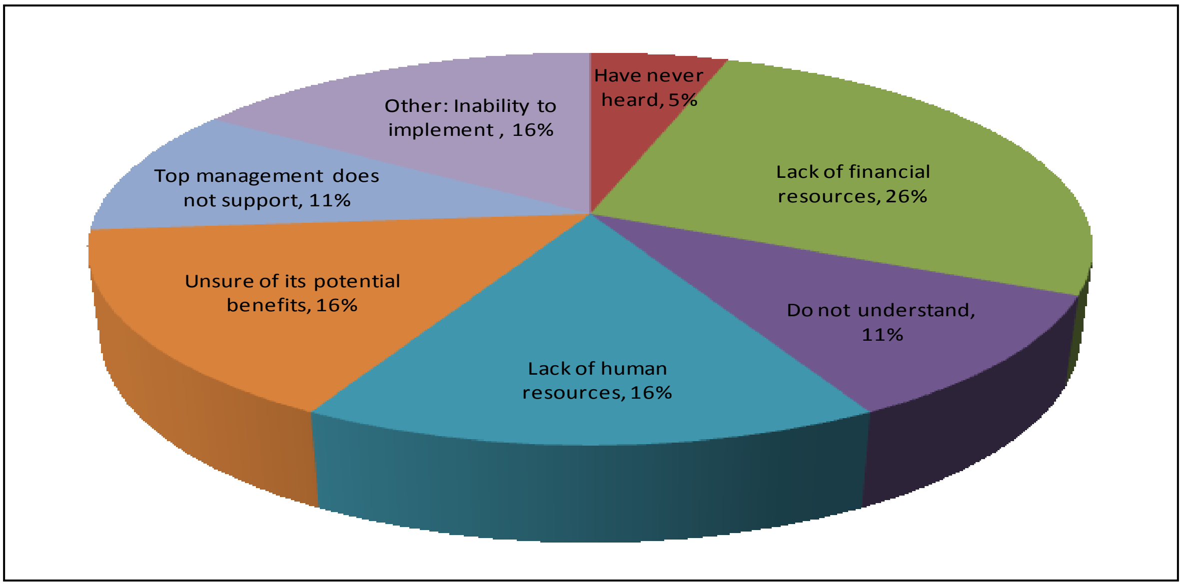

Figure 4.23: Response Rates of KM Barriers for Non-KM Adopters

4.4 Summary of Findings

The suggestions, recommendations, opinions and experiences provided by the respondents to the research interviews and questionnaires had a great effect on the development and enhancement of the KM model of this study in order to achieve a final version of a KM model for KM implementation and application in the construction projects. The results of the interviews and the questionnaire survey have been supported by a continuous review of recent KM literature and projects' reports to develop a practical KM model that is useful in the context of construction projects. The final results of the interviews and questionnaires have important effects on the research developed KM model and encourages for more development and refinement of the model to achieve the desired consequences. The final results concluded from the conducted interviews and questionnaires which have positive impact on the development of the KM model can be summarized as follows:

- The results of the interviews and questionnaires have shown a high importance of the contents proposed in the KM model and their usefulness for a successful adoption of KM in the construction organisations. However, the results highlighted the importance of developing the KM model in a way that is easy to understand and follow.

- The results of the interviews have shown that it is very useful to provide enough details and descriptions to the proposed KM model that may help to simplify its understanding and adoption.

- It has been found from the results of the interviews and questionnaires that it is highly important to include details in the KM model about the environmental factors that may affect KM efforts in the construction organisations. It is also important to provide and suggest procedures and methods that can be useful in reducing the negative influence of the environmental factors and encouraging successful KM efforts. The results of the questionnaires and interviews showed the importance of environmental factors that relate to information technology, people culture and leadership support, and that it is important to deal with these factors for successful applications of KMSs.

- The results of the interviews and questionnaires have shown the importance of applying more efforts during the early KM implementation and development stages, such as in the analysis and design stages, in order to achieve a system design that better aligns with business objectives and procedures and to reduce time and effort wastage caused by design errors and reworks.

- It can be concluded from the interviews' results that it is important to find a balance in the process of reviewing and approving captured knowledge before making it available for end-users in order to encourage the processes of knowledge capturing and sharing without overloading the KMS with unimportant, unrelated or outdated contents. Furthermore, the results of the questionnaires showed a high importance of adopting procedures for knowledge reviewing and approving to ensure that the knowledge stored in KMSs repositories is useful, searchable and applicable.

- Since many of existing KM models do not provide sufficient details to successfully deal with and manage tacit knowledge, and because the construction projects are in knowledge intensive environments where most of the important knowledge is tacit knowledge, recommendations were provided by interviewees to include more details in the proposed KM model to better deal with the special characteristics of tacit knowledge in the construction projects.

- The results of the questionnaire responses showed the importance of applying evaluation and monitoring mechanisms by using techniques such as capturing end-users' feedback about the system use, or developing evaluation measures to ensure a continuous process of system maintenance and improvement. However, the results showed a low level of implementation for evaluation methods in the construction industry. This indicated the need to develop more evaluation methods to help organisations to better estimate the success of their KM efforts and the effect on business performance.

- The results of the questionnaire survey showed that one of the construction organisations' main objectives for adopting KM is to encourage knowledge sharing and transfer to enhance the process of organisational learning and gain competitive advantages.

- The results of the questionnaire survey showed that it is not enough to implement a KMS with its technological tools to ensure a successful adoption of KM in an organisation, but it is more important to follow procedures and methods to encourage successful use of the system to capture and share experiences and know-how.

- The results of the questionnaire showed a need to enhance the awareness of the people and organisations in the construction industry about the importance of using data and information of the organisational database to create new knowledge and to show efficiency and practicality of captured knowledge.

- The results of the questionnaires showed the importance of the KM technological tools provided in the research, especially those that can help to capture knowledge and retrieve it from the systems' repositories.

- The results of the questionnaires showed a need to enhance awareness of people and organisations in the construction industry about the importance of applying knowledge maps and yellow pages to help in categorising captured knowledge, finding required knowledge and people, and providing idea of available and missing knowledge in the system repositories.

- According to the questionnaires results, the most important drivers that may encourage construction organizations to adopt KM are to enhance work processes and products in the construction projects, maintain relationships with customers, partners and suppliers, and saving time, cost and effort of rework and solving repeated problems.

- The results also showed that the most important specifications for KMSs required by end-users includes characteristics such as allowing the organizations to maintain good relationships with customers, suppliers and partners, availability of knowledge teams and/or knowledge workers to handle some KM tasks and to provide training and support for other users, providing easy to use interfaces and services, and finally allowing end-users to easily collect and share important knowledge.

- Finally, the questionnaire results showed that the most important challenges that negatively affect KM application include factors such as lack of a knowledge manager or a team to implement KM strategies, lack of structured procedures for KM implementation and application, lack of sufficient training and support, lack of management support, and lack of financial, human and IT resources. However, the results showed that the most important challenge that describes the actual condition in the construction companies is the lack of a structured method for KM implementation and application, which will be dealt with in this research by developing a KM model that provides a structured method for KM adoption in the construction projects.

This chapter has discussed the application and results of methodologies used in this research to develop and enhance a KM model for KM implementation and application in construction projects. The next chapter will present the final enhanced version of the developed KM model proposed in this research to help to achieve successful adoption of KMSs in the construction organisations.

CHAPTER FIVE

DEVELOPMENT OF A KM MODEL FOR KNOWLEDGE MANAGEMENT IMPLEMENTATION AND APPLICATION IN CONSTRUCTION PROJECTS

5.1 Introduction

On the basis of the conducted questionnaires, interviews, and literature review, it is essential to develop a KM model to manage knowledge effectively and efficiently in construction projects. The proposed KM model should include KM resources, initiatives, roles, system specifications, system architectures, and influential factors for construction projects. This model should also take into consideration the need to integrate project information and knowledge in the organization to avoid and minimize the existence of many pieces of knowledge that contradict each other.

The KM model proposed in this research and the items proposed in the model and the questionnaire survey, shown in Tables 4.1 and 4.2, provide a definition of KM procedures and tools that should be adopted by an ideal KM organisation to achieve successful implementation and application of KMS. However, the application of all the items included in the KM model may require the organisations to apply wide range changes that require the consumption of time, cost and efforts, which might be not easy by many organisations. The KM models developed in the literature, in addition to the KM model of this research, can be best used to evaluate existing KM systems, identify shortcomings and apply improvements (Axelsson & Landelius, 2002; Wetherill *et al.*, 2002; Tserng & Lin, 2004).

Although some literature may help to provide methods for managing knowledge, there is still a need to develop more comprehensive structured methods for KM implementation and application in construction projects. The KM model should make use of the dynamic nature of knowledge to ensure the continuation of new knowledge creation through the transformation of knowledge from its shape into a more useful and valuable form of knowledge. This dynamic and continuous process is used in KMSs to update, re-validate, and add value to the stored knowledge, which will be discussed in more details in the following sections. This chapter presents the final version of the proposed KM model.

Finally, the advantages of the proposed KM model and how the new, modified model fills the gaps of other previous models will be discussed to illustrate its importance and usefulness.

5.2 Components and Descriptions of the KM model

Firstly, a framework of KM for construction projects was proposed to represent the main components of the KM model to facilitate its understanding and to show the relationships among the different parts. The proposed KM framework consists of five phases as shown in Figure 5.1.

Phase 1 starts the KM process with identifying KM resources which are available and useful for the organisation.

Phase 2 refers to identifying environmental factors that may affect activities and components of the KMS, and deciding the required procedures and methods to successfully deal with these environmental factors.

Phase 3 covers deciding processing procedures and activities to handle and manage every type of knowledge resources.

Phase 4 helps choosing and applying the required system specifications and IT tools that enhance and support the KM activities.

Finally, Phase 5 seeks to identify new KM resources created by using the KMS and define methods for updating and revalidating knowledge contents.

Each phase of the proposed KM model will be described and detailed in the following sections.

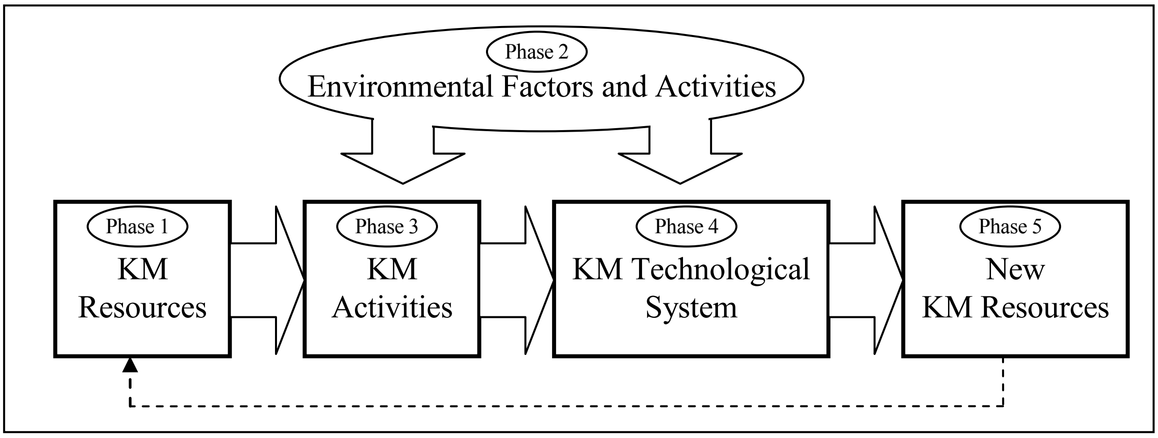

Figure 5.1: Components of the New Proposed KM Model for Construction Projects

5.2.1 Phase 1: KM Resources

This section of the KM model is dedicated to describe types of resources needed in the organisation that can be processed, captured, shared and transferred through the organisational KMS. This knowledge represents the real intellectual asset of an organisation that through the use of KMSs can be developed into more valuable asset that may help the organisation to gain competitive advantages.

Two main categories of KM resources are distinguished in the KM model, i.e. implementation resources and application resources, as shown in Figure 5.2. Although many types of knowledge and KM resources have been described in the literature, the KM model will highlight knowledge types which are useful for the organisations and can be managed through KMSs. The proposed KM model starts with processes such as collection, organization and review of knowledge that can be used in the design and implementation of the KMS (Implementation Resources), followed by processing knowledge for capturing, retrieving and sharing through the KMS (Application Resources).

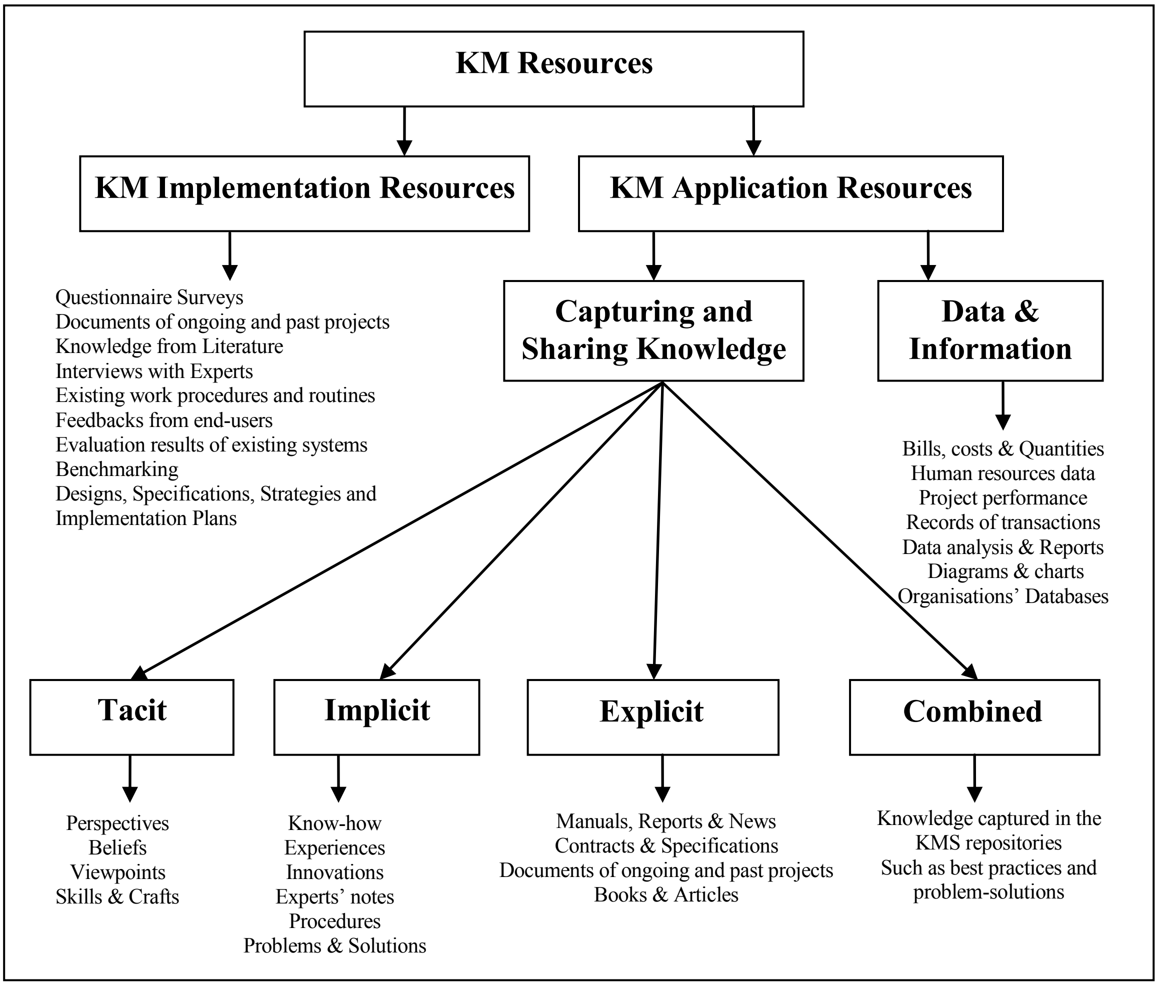

Figure 5.2: KM Resources in Construction Projects

Design and implementation knowledge is collected from resources, such as documents, data, information and knowledge from past and ongoing projects. Furthermore, knowledge from literature and feedback of interviews and questionnaire surveys with experts and senior engineers can be a major source of knowledge to be used in the process of analysis, design, implementation and evaluation of KMSs.

KM application resources can be classified into two types, i.e. knowledge resources, which includes resources that directly provide knowledge in its different forms, and data and information resources, which are useful resources for creating new knowledge or for supporting and approving other existing knowledge. For example, by analysing data of costs, quantities and human resources related to a knowledge content, it can be decided which methods provide effective and practical solutions for problems and what procedures can be considered as best practices.

Although most of KM literature has adopted the method of classifying knowledge into tacit and explicit knowledge, a more useful method has been proposed in this research by distinguishing among four different types of knowledge that can be available and useful in an organisation. The reason for such a classification is that it differentiates among four types of knowledge with different nature and formats that require different procedures, tools and technologies to capture, share and/or re-apply.

The first type of knowledge proposed in the research is '*Combined knowledge*', which refers to the type of knowledge resource that has been captured, categorized and adapted, and made searchable and available to end-users of the KMS. This type is the product of combining related contents to produce valuable and applicable knowledge stored in the KMS repositories.

'*Explicit knowledge'* is the second type of knowledge proposed in the KM model. This represents the type of resource that has been codified in documents. This knowledge can be found either in an electronic format or in a paper-based format. It can usually be found either inside the enterprise in the form of manuals, specifications, contracts, reports, photos, drawings, electronic files and documents stored in the database; or can be found outside the organisation in the form of books, journals, news and regulations. This type of knowledge has not yet been made available and cannot be easily searched and re-used by end-users, but can often be easily transformed from its resources to be available and searchable in the KMS.

The third is '*Implicit knowledge'*, which is a type of tacit knowledge identified by the organisation and/or people, that can be transformed and articulated into formats similar to explicit knowledge, such as experiences, know-how and problem solutions, which can be captured into articles, reports, memos and/or other types of electronic or paper-based documents. Implicit knowledge is more difficult to store and formalise than explicit knowledge, because it requires more processing and effort to be managed. However, the resultant of the implicit knowledge processing is more valuable and useful for the company, since it includes people's experiences, problem solutions, lessons learned, best practices and innovations, which may help the organisation to improve the quality of business processes and work products.

Finally, '*Tacit knowledge'* refers to the rest of knowledge that the people cannot capture and turn into explicit knowledge due to various reasons, such as that articulating it fails to deliver the meaning and the context influence; that capturing past experiences may oppose privacy, confidentiality and security regulations; or that some people may be unaware of having such knowledge or feel that it is personal, so it cannot be made available to other employees throughout the organisation. Furthermore, tacit knowledge can result because organisations may decide not to capture all available knowledge of their employees. This could be reasons of protecting their KMS repositories from being overloaded with knowledge. Overloading the KMS with unimportant knowledge can negatively affect the KMS performance and confuse people searching for required knowledge with many irrelevant and invalid choices. Tacit knowledge can be more useful if the organisation encouraged sharing it through direct contacts, such as face-to-face meetings and conversations, or through collaborative tools, such as e-messaging, e-chatting and e-meeting.

Nonaka and Takeuchi's SECI model (Nonaka, 1991; Nonaka & Takeuchi, 1995; Nonaka, 2007), discussed in chapter 3, can be used and adapted to show how new knowledge can be created through continuous interactions between the four proposed modes of knowledge, as shown in Figure 5.3. The spiral represents a continuous movement between different modes of knowledge creation, with the increase in the spiral radius showing the movement and diffusion of knowledge through organizational levels (Nonaka & Takeuchi, 1995).

Socialisation is the process of sharing or acquiring others' experiences and know-how either through direct methods, such as meetings, conversations, observation, practicing, and training, or via indirect methods, such as e-messaging, e-meeting, e-chatting, and e-learning. It represents how engineers can learn tacit secrets for solving a problem from other engineers, then applying, testing and supporting this knowledge by experiences in the construction projects. Socialisation helps to transform tacit knowledge into a more useful shape of knowledge that is available to be captured in an explicit format (tacit to implicit).

Externalisation is the process of transforming implicit knowledge into a coded format (explicit knowledge) to simplify and encourage its transfer. Through externalization, an engineer can translate the implicit knowledge he has gained through socialisation and experiences into an explicit format that is easier to be retrieved, understood and reapplied by others (implicit to explicit).

Combination is the process of gathering various elements of explicit knowledge. It represents how related explicit knowledge contents can be combined and stored in the repositories and supported with tools and services to be available for end-users of the KMS (explicit to combined).

Finally, *Internalisation* means that the combined knowledge can be retrieved, learned from, reapplied and retested, and so help to create new experiences and know-how (combined to tacit). The new generated tacit knowledge can be shared and discussed among individuals (tacit to implicit), recorded in an explicit formats (implicit to explicit), combined with new related resources (explicit to combined) and used (combined to tacit) to update or replace older knowledge in the KMS repositories, in a new iteration of the continuous process of knowledge creation.

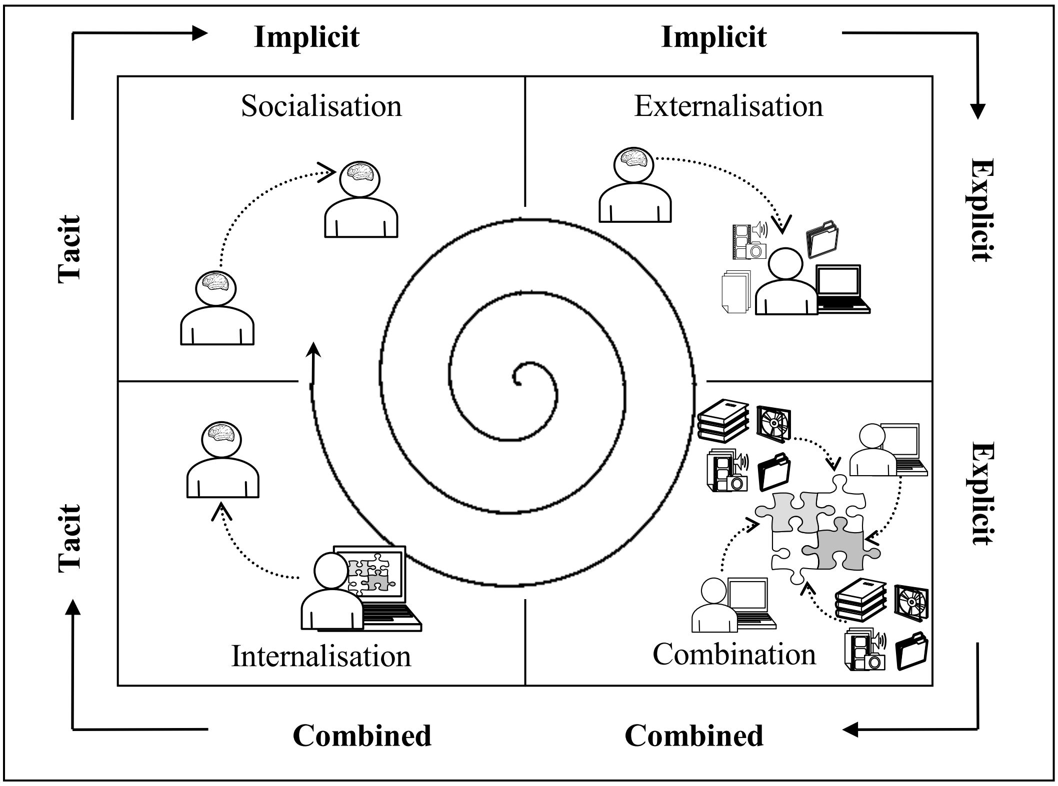

Figure 5.3: Knowledge Creation Process (Adapted from SECI Model (Nonaka & Takeuchi, 1995))

5.2.2 Phase 2: Influential Factors

Before discussing other components of the proposed KM model, it is important to identify the factors that may affect KMS components and activities of knowledge processing and using within the organisations. These factors can be either incentives or barriers for KM adoption, and they can affect the effectiveness, efficiency and the overall performance of the KMS.

A literature search carried out in this research indicated that the important influential factors can be classified into six categories: i.e., customers, partners and suppliers' demands; technological factors; individuals' culture and background factors; organisational and management factors; financial factors; and finally, factors of regulations and rules.

Table 5.1 is used to provide examples from each category of environmental factors that can affect KMSs, and suggests possible environmental activities and procedures that can be applied to deal with these factors and encourage KM implementation and application in the construction organisations. The aim of this table is to provide examples to help construction organisations being aware of factors that may affect their KMSs and to help them identify possible procedures and solutions required to enhance their KM performance. The proposed categories of the influential factors are ranked according to their importance that was investigated through section 3 of the questionnaire survey conducted during this research and discussed in chapter 4.

Table 5.1: KM Environmental Factors and Activities

<table>
<tr><th>Environmental Factors</th><th>Environmental Activities</th></tr>
<tr><td colspan="2">Customers, partners and suppliers Factors</td></tr>
<tr><td>Increasing demand for :
• Reduced efforts, time and cost of projects and activities completion
• Improved quality of products
• Improved supply chain management
• Improved customer relationship management
• Improved response to customer’s changing orders
• Improved reputation of the organisation</td><td>• Enabling them to use the KMS with predefined authorities
• Providing important knowledge
• Providing required services and tools
• Coordinating between partners
• Increasing awareness about KM usefulness and importance</td></tr>
<tr><td colspan="2">Technological Factors</td></tr>
<tr><td>• IT infrastructure and support systems
• Hardware specifications: speed, capacity and flexibility
• Software specifications: availability and usability of software packages, data capturing and analysis tools, and data integration tools
• Availability and specification of communication and information technologies (CIT)
• Continuous change and advances in the industry
• Methods and tools available for KM</td><td>• Applying technologies that is easy to use
• Using advanced technologies with high performance
• Ability to use technologies anytime from almost anywhere
• Ability to find related useful knowledge
• Removing outdated knowledge
• Providing tools for knowledge capturing and sharing
• Providing IT help, support and training</td></tr>
<tr><td colspan="2">Cultural and individuals Factors</td></tr>
<tr><td>• Personal Culture, such as values, norms and behaviours
• Level of trust among employees
• Commitment, Communication and Competencies
• Experience with IT and computer systems
• Experience with software packages and operating systems</td><td>• Encouraging knowledge sharing and seeking
• Providing time and places for knowledge sharing
• Encouraging collaborations and team working
• Building trust among employees
• Providing training and support
• Providing incentives, rewards and recognition
• Accepting and rewarding creative errors
• Building Communities of Practises (CoPs)</td></tr>
<tr><td colspan="2">Organisational and Management Factors</td></tr>
<tr><td>• Management support, commitment and awareness
• Management strategy and vision
• Motivation, training and support
• Knowledge availability from past and ongoing projects
• Employees’ performance appraisal methods
• Competition with other organisations
• Globalisation (Domestic or international organisation)
• Organizational structure and policy
• Business processes and operations
• Monitoring and evaluation methods</td><td>• Providing necessary condition for KM
• Increasing managers awareness about KM importance and usefulness
• Development of KM strategy with clear objectives that align with objectives of the organisation
• Applying evaluation and monitoring methods to the KMS
• Specifying KM activities and embedding the KM activities into the work processes
• Adopting structured method for implementing and applying KM (KM model)</td></tr>
<tr><td colspan="2">Financial and resources Factors</td></tr>
<tr><td>• Cost of hardware, desktop, accessories and networks
• Cost of software procurement, implementation and maintenance
• Cost of knowledge management and operations
• Financial abilities of the organisation
• Level of projects’ profitability
• Financial benefit assessment of adopting the KMS</td><td>• Providing sufficient financial and human resources to build or enhance the KMS
• Finding cost effective tools and solutions
• Appointing KM manager, team and/or workers
• Recruiting employees to fill KM gaps</td></tr>
<tr><td colspan="2">Regulation Factors</td></tr>
<tr><td>• Legal issues
• Knowledge security and privacy
• Governmental support
• Safety, health and security</td><td>• Providing contents to enhance awareness
• Providing privacy and security protection
• Providing different authority levels for different users
• Respecting regulations in the KMS</td></tr>
</table>

Demands of customers and other partners and suppliers are, according to the survey results, the most important environmental pressures that can significantly affect KM and its application in the construction organisations. A major purpose of the KMS in construction organisations is to be flexible enough not only to meet the changing demands of customers but also to exceed their expectations. Results from the conducted questionnaire survey showed that the most important drivers for adopting KM in the respondent companies include factors relate to customers, partners and suppliers' demands such as the need to improve quality of processes and products, and the need to enhance relations, coordination and services provided to customers, partners and suppliers.

The results of the questionnaire survey also showed that the most required specification of the KMS is to have the necessary tools and services to maintain and encourage good relationships with customers and other partners. An explanation for this result can be that recent large construction companies tend to implement their projects through managing and directing a network of many small and medium partners and suppliers. So, KMSs can play a major role in such types of companies in order to manage and coordinate the different partners by providing timely required knowledge and services.

Continuous growth in technology also affects KMSs. The results of the questionnaire survey showed a high importance of activities and procedures related to information technology such as providing technological tools and services which are easy to use, ensuring and protecting private and sensitive knowledge, aligning KM services with organisational and personal needs and objectives, and enabling end-users to use the KMS to find useful knowledge and to do required work at anytime from almost everywhere through using intranet and internet technologies.

KMSs should be designed and regularly improved to satisfy the changes and improvements in construction and IT technologies. Availability of advanced KM tools and services can encourage the use of the system and enhance the performance of end-users. The unavailability of services and tools with required specifications can cause low performance and complexity of the KMS that may stop the KMS from being used effectively. Knowledge contents need also to be regularly revised to remove outdated and invalid knowledge before confusing end-users with many contents of unrelated unimportant knowledge.

Some cultural behaviours of individuals, such as seeing knowledge hoarding as strength, lack of trust among employees, unwillingness to show mistakes, refusal to accept solutions from other departments or from people at lower positions, and resistance to any changes that may affect the routine operations of work, can negatively affect the KM processes in an organisation. In order to reduce the effects of these individual factors, the management of organisations have to encourage knowledge creation and sharing through organisational rewarding systems and performance appraisal systems, and through showing commitment and providing the required resources for implementing and using the KMS.

Support from the management of an organisation is imperative for successful management of knowledge. An important issue before implementing a desired level of KMS is to convince senior managers about its importance and usefulness to the organisation. If managers encourage and support the implementation of KM initiatives, this will motivate developing new KMSs or improving the existing ones.

KM also requires the use and consumption of organisational resources. Money, time and effort are required in developing and using KMSs as well as in building the required IT infrastructure. On the other hand, the outcomes of KM not only include learning new technologies and skills but also include economical outcomes such as profitability and sales growth (Amo, 2006). The more the KMS is financially feasible, the more it inspires organisations to join the KM field.

Finally, regulation factors such as knowledge security and privacy should be regarded when implementing and using knowledge systems. Egbu (2004) encouraged companies to strike a balance between openness and protection of their knowledge systems. Too much openness may threaten the organisation competitive advantage, while too much protection may negatively affect the innovation process and encourage bureaucracy and hierarchy in the organisation.

5.2.3 Phase 3: KM Activities

The proposed model presents main KM activities in which each main activity can be further broken down into sub-activities that may vary according to the requirements and special characteristics of organisations. The main activities are categorised according to the types of KM resources proposed in the first stage of the KM model shown in Figure 5.2.

The KM activities proposed in this section aim at managing and processing the proposed different types of KM resources in order to successfully implement and apply KMSs in construction projects. This will help to build and develop successful KMSs and to successfully apply KMSs to capture and share available and useful knowledge to enhance organisational and individual learning and to transform knowledge into a more useful and important format. It is important in this context to provide an adequate level of detail to help construction organisations to identify required processes and procedures without negatively affecting their way of carrying out works or the special characteristics that differentiate each company from others. Activities of KM implementation and application are discussed in the following sections.

5.2.3.1 KM Implementation Activities

KM implementation activities are the activities required to build a new KMS, add new components to an existing system or to enhance existing services of a KMS. Four stages were proposed to represent KM implementation. The stages are analysis, design, implementation and evaluation of the KMS as shown in Figure 5.4.

KM implementation is a cyclic process where the first iteration represents the implementation of a prototype to test a new tool or service before making it available to all targeted end-users. The second iteration refers to a wide range implementation of the KMS to make it available to all people who have been chosen by the organization to receive KM services or required to apply KM activities. Finally, the third iteration represents a continuous process of maintenance and enhancement of the existing KMS. This may include solving system problems and drawbacks, enhancing quality and performance of an existing system, or implementing new services, activities and procedures required for or missing from an existing KMS. The three iterations of KM implementation were represented by a spiral to show the continuation of the process, the transfer from one stage to another and the increase in the range of KM implementation as shown in Figure 5.4.

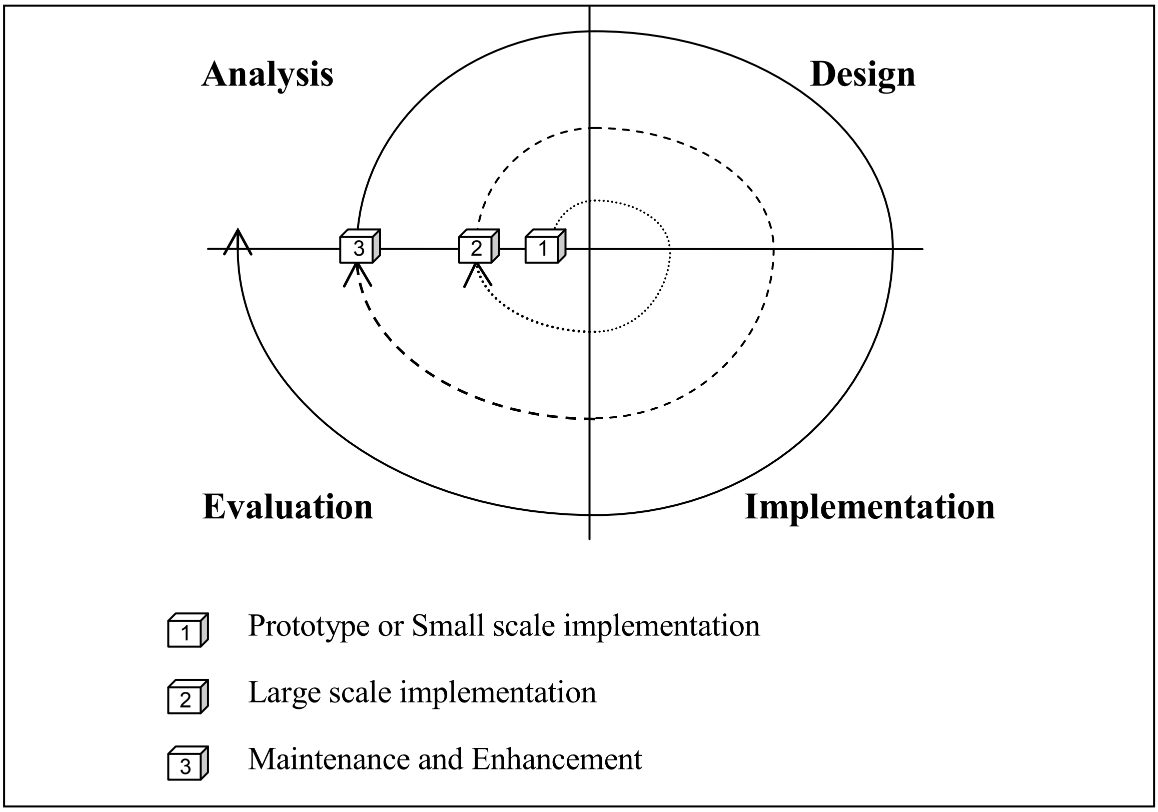

Figure 5.4: The Cyclic Process of KM Implementation (Based on Pressman (2005))

Implementation of KM within an organisation starts with collecting knowledge from potential end-users by using methods such as interviews, questionnaires or by reviewing previous project documents, regulations and related literature. The objectives of the analysis phase are to understand the real status of the organisation and identify the desirable and feasible options for improving work processes and performance. The aim is to identify vision and strategy of the organisation top management, roles and culture of the employees, and existing business processes and operations that should be understood and considered when designing the KMS. Identification of the options available for improvement of KMS includes understanding the types and forms of knowledge available and necessary for the organisation to be collected and shared.

An effective way to perform the analysis phase is to establish a KM team dedicated to this purpose to examine challenges and potential problems that the organisation may face in planning, building, maintaining and evaluating the KMS. The questionnaire survey conducted for the purpose of this research showed that conducting a detailed analysis is one of the most important activities among other KM implementation activities. The greater the effort spent during the analysis phase, the better the design alignment with business strategy and organisational objectives. It is important to perform a high quality analysis at the early stages of KMS development to reduce the cost and effort of rework and correcting errors. Preparation of detailed and proper analysis is the most effective way to implement KM so that the full potential of the KMS can be exploited.

In the design phase, the set of needs and requirements established as an output of the analysis phase are converted into an appropriate design of the KMS. The design phase requires transferring the organisation's needs and requirements into technical specifications. Effective methods and tools to capture, create, categorise, disseminate, search and share knowledge should be determined. An effective action plan and a set of guidelines should be prepared to provide a step by step approach and details for KM implementation and evaluation, and to show the relationships among KM initiatives.

The system specifications, the components of the architecture, the KM services and the interface details also need to be determined in the design phase. This will provide an appropriate platform to deal with the organisation's requirements. The design phase helps organisations that intend to implement KMSs to avoid implementation errors and save time, cost and effort by providing directions on the KM procedures and specific details on how those procedures should be accomplished.

In the implementation phase, the design is transformed into the form that will be used by end-users. This phase is the actual application of the plans that are made in the previous phases. Installing the technical parts of a KMS is not enough to ensure that the system will be used effectively and efficiently, but employees should be motivated and encouraged to use and add to the KMS. Roles and activities of applying KM should be identified and embedded in the work procedures of employees (Ahmad *et al*., 2008). Providing KM roles and appointing KM teams and/or knowledge workers are effective ways to ensure enhancing and encouraging knowledge capturing and providing support and training for employees.

In the evaluation phase, the performance of the KMS and the effect of the KMS on the performance of the employees and the organisation need to be monitored and assessed. Evaluation results may encourage organisations to apply new tools and procedures, or to modify and enhance existing ones in order to improve performance of existing KMS and encourage end-users to add new knowledge into the KMS. The KMS should also be checked in terms of the alignment of the implemented KMS to design requirements and specifications and/or the alignment of the KMS to the objectives and strategies of the organisation.

The questionnaire survey of this research showed that adopting effective evaluation methods of KM efforts is the most important activity among other KM implementation activities. KM evaluation methods developed and used in the literature were discussed in chapter 1 of this thesis.

As will be discussed later in this chapter, an evaluation method dependent on a feedback collection mechanism is proposed in this research to overcome existing shortcomings, identify new knowledge types for managing and identify opportunities for improvements in the performance and services of the KMS. One of the methods used in organisations to evaluate KM adoption is by using KM models to evaluate the existing components and identify changes and new components that may be required.

The process of KMS analysis, design, implementation and evaluation needs to be a continuous process, as shown in Figure 5.4. The first iteration refers to the implementation of a prototype or a small scale implementation of the KMS. Feedback collected from the evaluation of the prototype provides valuable knowledge for modifying the design of the system and beginning a wide range implementation of the KMS. Furthermore, feedback collected during the application and use of the implemented KMS provides knowledge for continuous enhancement and maintenance of the existing KMS.

Although many construction organisations may use specialised companies to develop and install a KMS, organisations needs to be involved in KM implementation in order to participate in some implementation activities, monitor and supervise the implementation process and evaluate outputs of each implementation stage. In the analysis stage, for example, organisations needs to appoint their own KM team, as this will have more ability than teams from outside the organisation to investigate internal aspects of the organisation, such as strategies and objectives, work processes and procedures, and employees' roles and cultures. In the design stage, the organisation needs to carefully study and evaluate the developed designs and plans to ensure building a KMS that is reliable and effective. In the implementation stage, the KMS's potential users need to test the implemented components of the KMS to ensure its alignment to design specifications and organisational objectives. Finally, end-users are required to provide feedback and evaluation about the use of the KMS in order to identify opportunities for improvement and overcome shortcomings and bottlenecks.

5.2.3.2 KM Application Activities

The results of the questionnaire survey conducted in this research showed that the most important group among the KM implementation activities, application activities, environmental factors and technological tools is the KM application activities. However, the results showed a need to enhance the adoption of KM application activities in the construction organisations through applying procedures such as enhancing awareness of employees and organisations about their importance, providing more structured processes and activities, and embedding the KM application activities into the employees' daily work activities.

5.3.3.2. (A) Processing Data and Information into Knowledge

The main aim for establishing a database in construction organisations is to capture the important operational data that is created through the life cycle of construction projects. Databases are normally designed to collect facts that are easy to capture in table format but this may have little meaning.

Research conducted by Rujirayanyong and Shi (2006) presented a design of a project-oriented database that consists of 26 tables that are connected to each other through primary and secondary keys. Using data processing tools such as data mining, analysis and reporting will help to add meaning to data and transform them into knowledge that is more useful in problem solving and decision making. This will increase its value to other users. The process of capturing data and information, and transforming them into knowledge is described in Figure 5.5.

The results of the questionnaire survey showed the importance of adopting procedures to transform data and information into knowledge. However, the results showed a need to enhance the awareness of the construction organisation about the importance and usefulness of using databases to create new knowledge and to support and approve other existing knowledge contents.

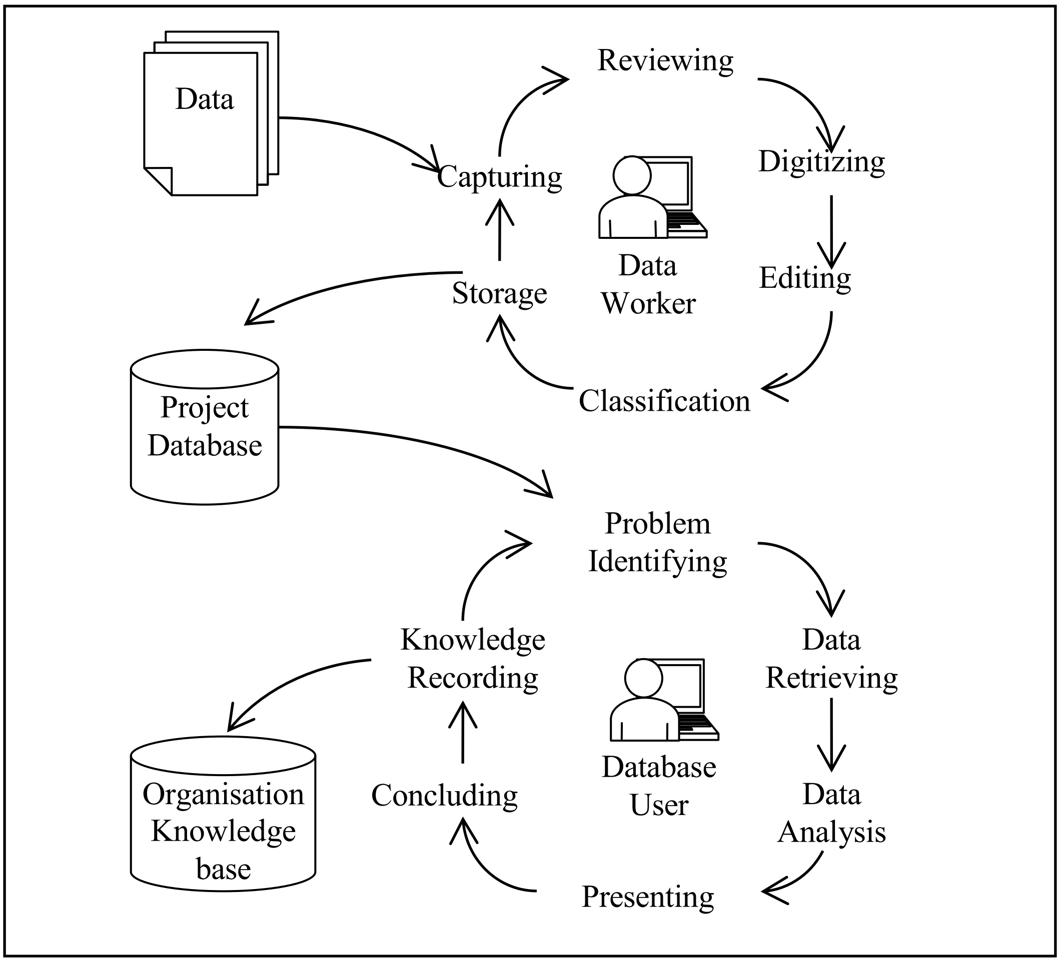

Figure 5.5: Processing Data and Information into Knowledge

5.3.3.2. (B) Processing of Capturing and Sharing Knowledge

In this stage the organisation needs to decide which activities are required to process and manage the different types of knowledge to arrive to a successful and useful application of the KMS. The results of the questionnaire survey showed that the activities of reusing and sharing knowledge are of high importance to the KMS. The results from the conducted interviews of the research showed the need to provide procedures and activities to better deal with tacit knowledge. For this reason a method that categorises knowledge resources into more types to distinguish types of knowledge that require different processing activities and methods was proposed in the KM model. These activities can be categorized into four levels according to the knowledge types that need to be captured and/or shared by the KMS as shown in Figure 5.2.

A processing procedure, shown in Figure 5.6, is proposed in the research to represent the four levels of activities required to effectively manage and deal with the knowledge resources which are required to be captured and shared in the KMS.

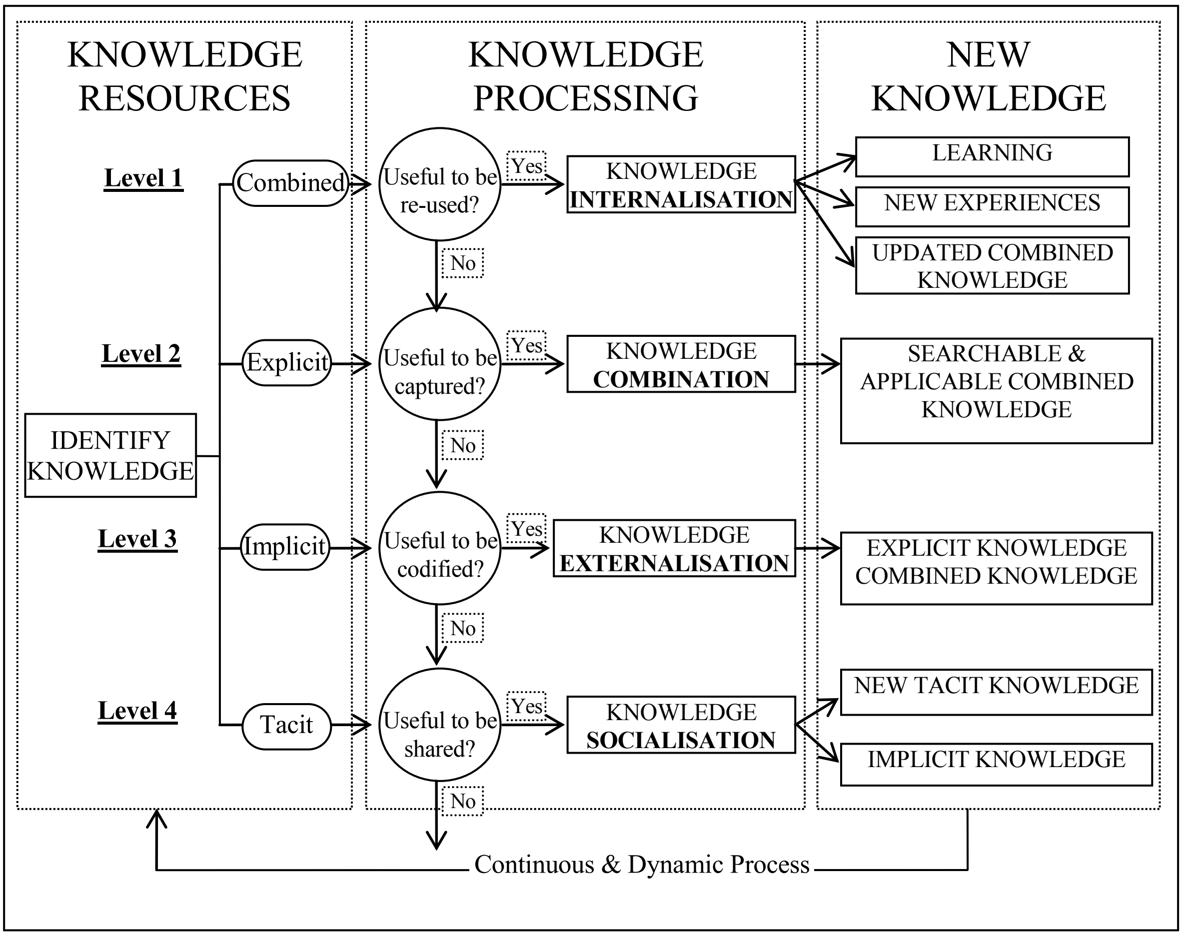

Figure 5.6: Processing of Capturing and Sharing Knowledge Resources

Level 1:

Knowledge internalisation includes all activities that the organisation needs to deal with combined knowledge. Using the KMS technological tools to retrieve, reuse, evaluate and update knowledge that was previously saved in repositories of the KMS are all examples of activities that can be applied to process combined knowledge in this processing level.

The KMS should address the knowledge requirements of end-users and support their existing practices while guaranteeing security and confidentiality. A successful KMS should provide the ability to easily find desired knowledge and contact details of the required people. Therefore, a KMS has to be designed to be available for people within or outside the organisation with a keyword access process that defines the authority level for each user. Users from outside the organisation are allowed to access and use the KMS in order to support the organisational relationships with customers, suppliers and partners.

In accordance with the authority levels defined for end-users, they can update knowledge in the knowledge base by adding details, comments, relevant experiences, and providing recommendations to remove invalid and unnecessary knowledge from the KMS.

Figure 5.7 shows the procedures of adding and updating knowledge. As can be noticed from the figure, knowledge that comes from combining knowledge of explicit origin such as specifications, manuals, procedures, etc, can be easily updated simply by replacing the old contents with new versions. On the other hand, updating combined knowledge of tacit or implicit origin such as problem solutions, know-how, experience notes, innovations, etc., needs more attention to be paid, because updating such knowledge requires reusing old knowledge and creating new experiences.

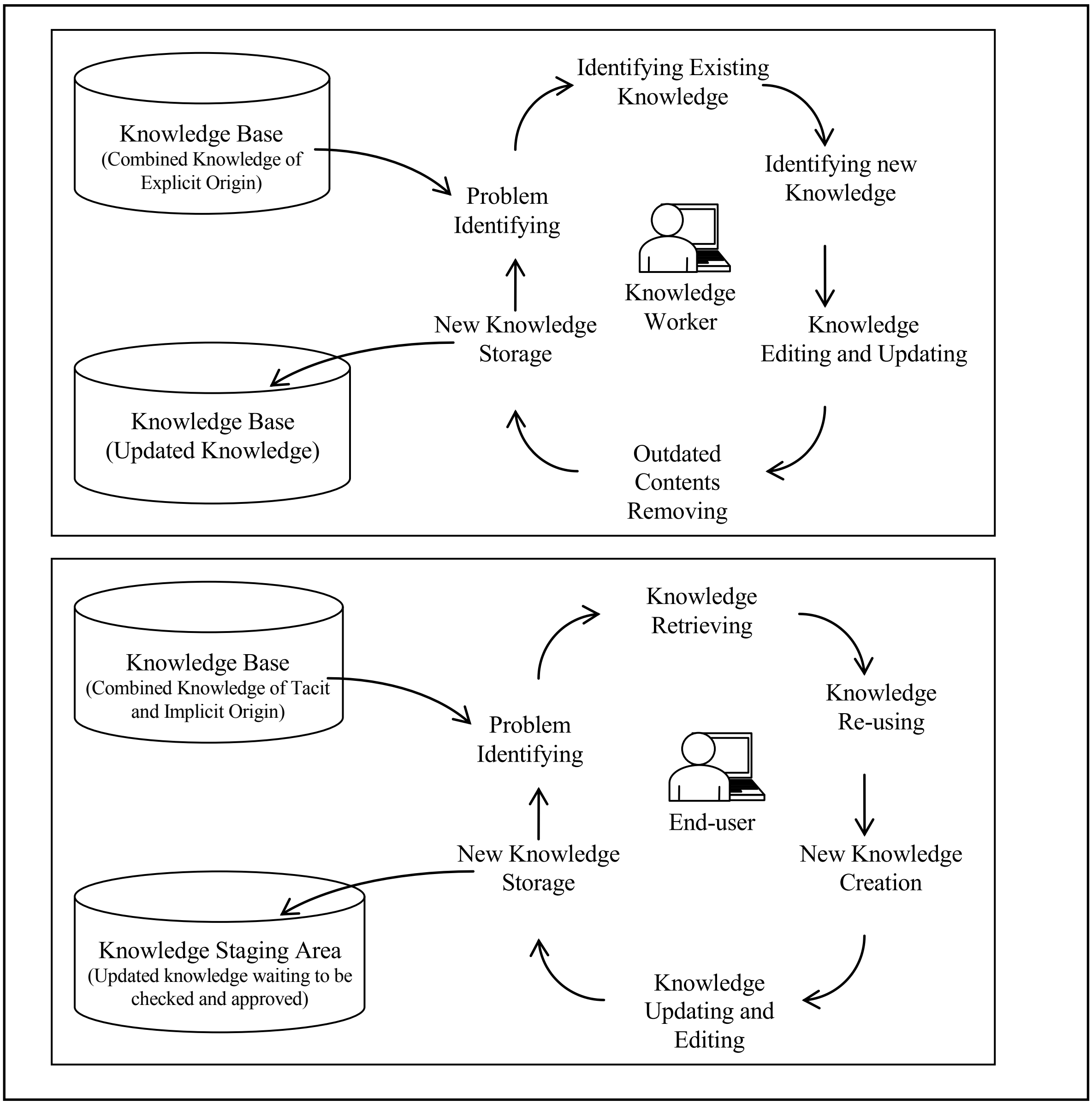

Figure 5.7: Process of Knowledge Updating

<u>Level 2:</u>

Knowledge combination is about managing explicit knowledge by capturing documents, combining related contents, putting contents into proper formats and, finally, making them available to be searched and re-used by end-users of the KMS. This level of knowledge processing may include activities such as digitizing (e.g. scanning) paper-based documents, reviewing, editing, attaching files, photos and videos, referring to related people, resources and links, categorizing and, lastly, approving knowledge to be available for end-users of the KMS.

Explicit knowledge may include internal knowledge within the organisation, which is specific for certain departments or projects, and external knowledge from outside the organisation, which is general and can be used by different projects and departments. By appointing a KM team to manage knowledge, explicit knowledge can be easily captured and communicated among employees. The process of capturing internal and external explicit knowledge is illustrated in Figures 5.8.

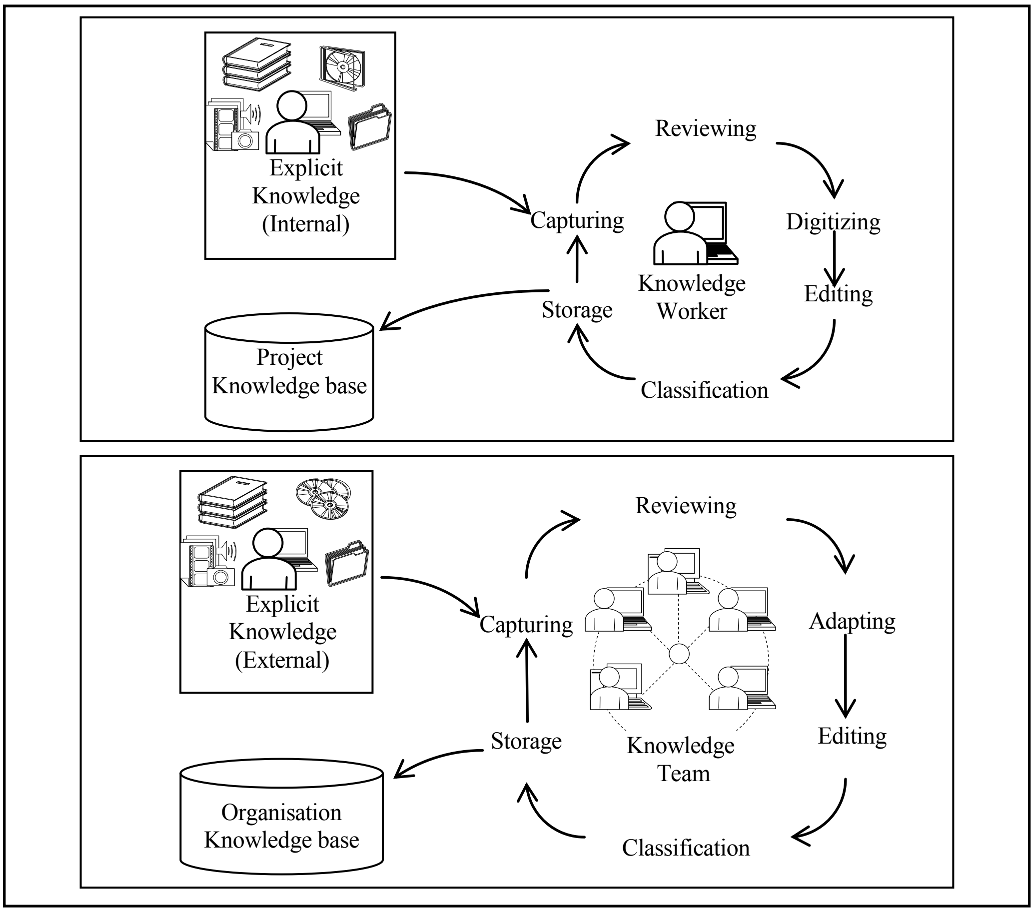

Figure 5.8: Capturing and Processing Explicit Knowledge (Knowledge Combination)

Level 3:

Knowledge externalisation includes activities required to capture implicit knowledge and transform it into explicit and combined knowledge. This level of knowledge processing requires people to codify their work experiences, perceptions, know-how and best practices. That may require people within the organisation to prepare reports of problems, solutions, meetings, discussions, innovations and useful ideas in the projects, and articulate them into explicit formats that can be captured easily in the repositories of the KMS.

During the life cycle of construction projects a large volume of tacit and implicit knowledge is generated. The need for tacit and implicit knowledge becomes very important, but, unfortunately, most construction organisations have not always been successful in collecting and sharing them (Carrillo *et al*., 2004; Woo *et al*., 2004).

An effective way to collect implicit knowledge is by converting it to explicit and combined knowledge that can be available for retrieving and reuse. Figure 5.9 shows the procedures in the proposed KM model for collecting implicit knowledge and converting it into explicit and combined knowledge. It is essential for the KMS to allow its end-users to identify and capture their knowledge into different file formats such as text, image, video, drawing, etc., and then send them to be adapted, stored and combined with other knowledge by knowledge workers to make them available for other end-users.

As can be noted from Figure 5.9, the processing procedure of implicit knowledge requires more effort than the processing of explicit knowledge described in Figure 5.8 because implicit knowledge needs more activities to be transformed into explicit and to check the reliability, applicability and usefulness of the captured experiences, know-how, best practices and problem solutions before making them available for other users of the KMS.

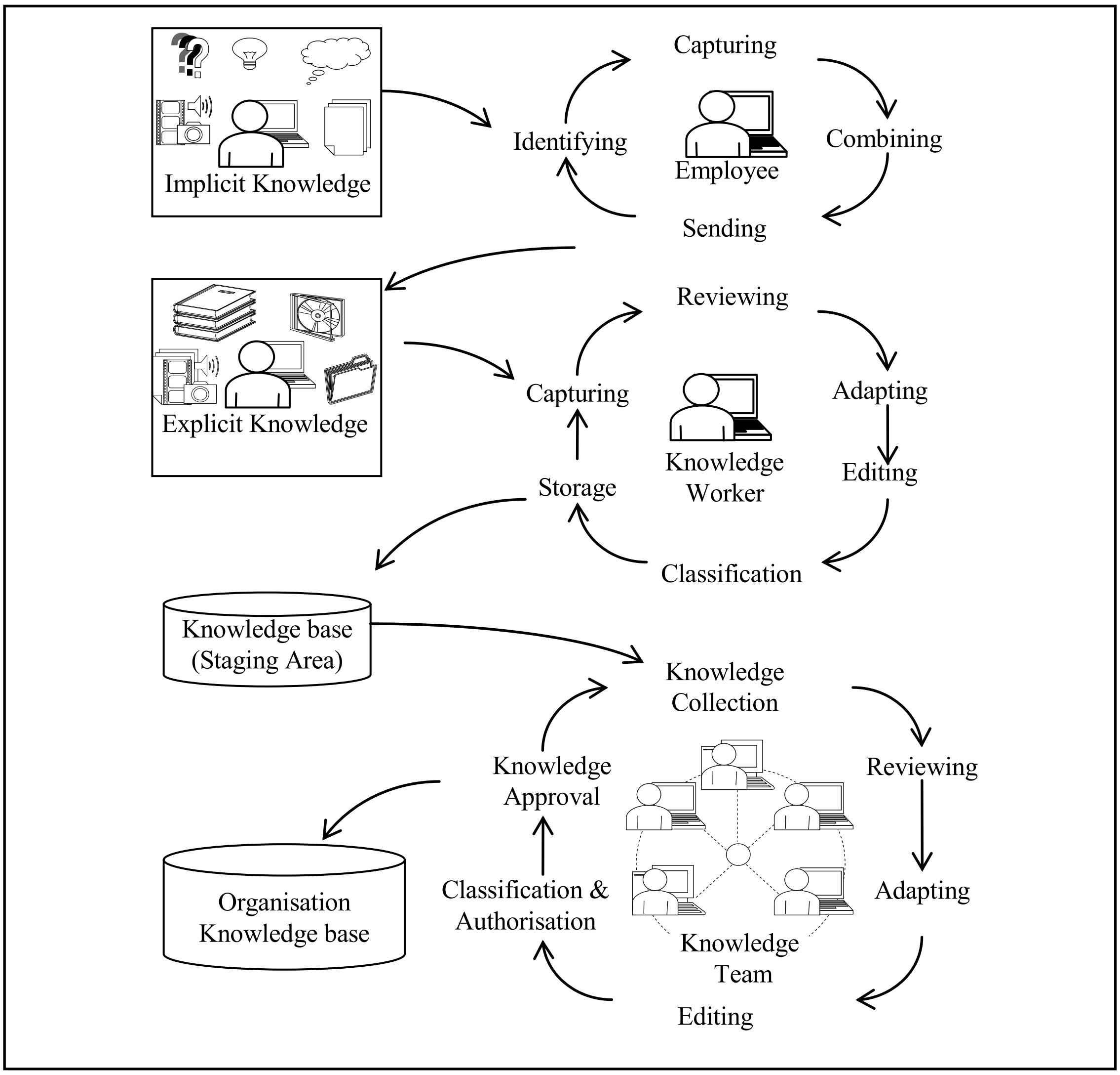

Figure 5.9: Capturing and Processing Implicit Knowledge (Knowledge Externalisation)

<u>Level 4:</u>

Knowledge socialisation level includes all knowledge processing activities required to deal with the rest of tacit knowledge of the employees that cannot be captured and stored explicitly in the KMS repositories. This knowledge cannot be captured because of many reasons, such as that recording it may fail to show its meaning and context, contradict with privacy and confidentiality regulations, oppose organisational strategies and objectives, and overload the KMS's repositories with less important knowledge (Ahmad *et al.*, 2009). This tacit knowledge can be more useful for an organisation if successfully shared among its people through technological and non-technological components of the KMS in use.

It can be essential for the KMS to capture and store knowledge in repositories, but since tacit knowledge is hard to formalise, it is very important to share tacit knowledge by connecting people through collaborative tools such as e-mail systems and Groupware. These tools aim to facilitate the exchange of tacit knowledge rather than storing it into repositories. Figure 5.10 shows how the collaborative tools in a KMS support sharing tacit knowledge among different players.

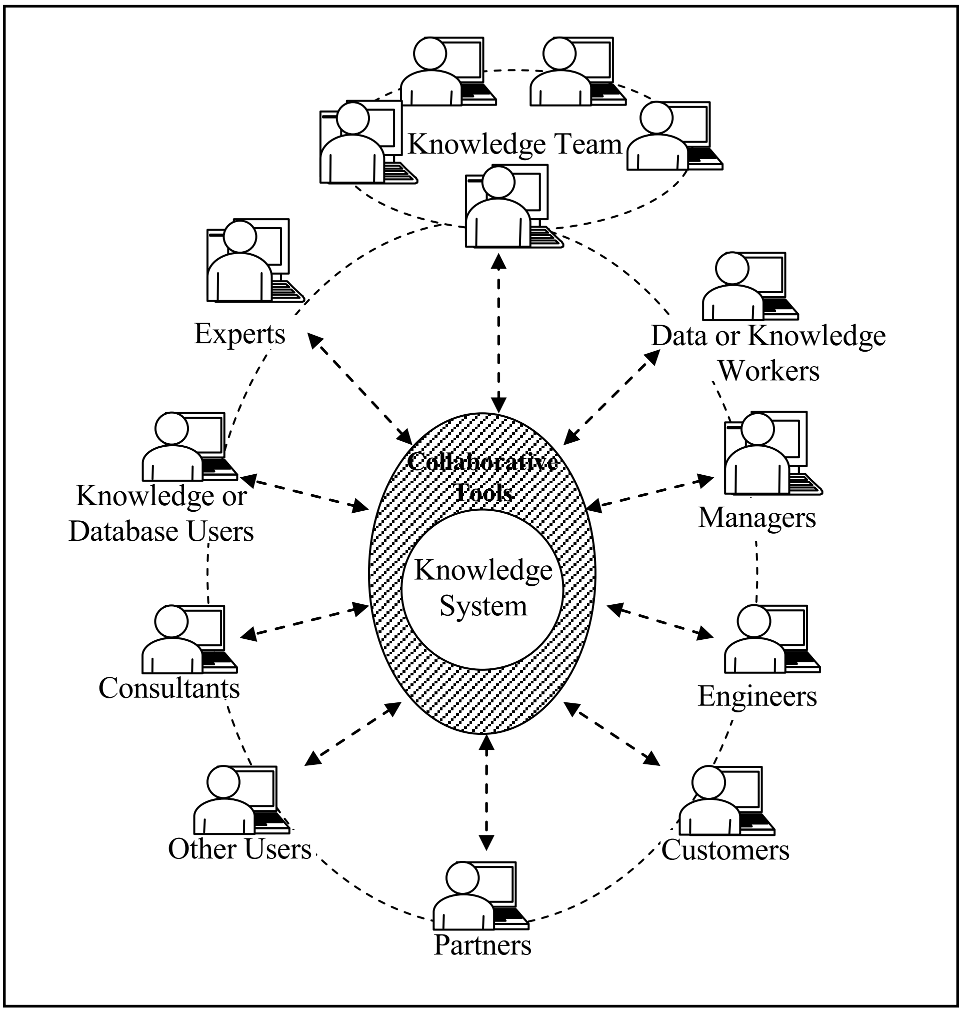

Figure 5.10: The Role of Collaborative Tools in Sharing Tacit Knowledge

Using Alternative Levels:

The proposed procedure, represented in Figure 5.6, shows how organisations can process combined knowledge by using lower processing levels, i.e. knowledge combination, knowledge externalisation and knowledge socialisation levels. This can be useful if the combined knowledge is not in itself useful enough, is outdated or has insufficient details. Thus the KMS can help end-users to edit, combine and capture new contents to add more meaning and value to the old knowledge stored in the repositories of the KMS.

Furthermore, the organisation has to decide which types of explicit knowledge are required and important to be captured into the KMS repositories. Capturing too much knowledge in the KMS repositories can waste the organisation's money, time and efforts to manage knowledge that is not very useful to the organisation. Organisations may make a decision to delay or cancel capturing some shapes of explicit knowledge. However, this knowledge can be made available to people to use and learn from outside the KMSs such as in books, manuals and specifications.

Organisations may also decide to delay capturing some types of implicit knowledge but it is still can be shared among the organisation's people through socialisation processing activities. Some other types of tacit and implicit knowledge may exist in the organisation but have not yet been identified. Through a continuous process of knowledge identification and processing, new types of useful knowledge can be identified that require the organisation to apply new methods, tools and activities to capture, share and use them through the KMS as will be discussed in the following sections.

Approving knowledge

Activities of knowledge reviewing and approving have received the highest importance level in the conducted questionnaire survey among other KM application activities. However, the results showed a need to enhance the adoption of knowledge approving procedures by, for example, developing and following a structured effective process of knowledge approval and appointing roles and responsibilities for qualified people to review and evaluate captured knowledge. Knowledge collected by employees of the organisation needs to be reviewed and edited. Knowledge added to the KMS by employees needs to be adapted in the formats that are acceptable by the system. The knowledge also needs to be classified in order to facilitate knowledge searching and reusing functions. Descriptions, details, photos and videos can be attached to the contents to improve knowledge understanding and reusing, and increase the knowledge value. Referring and providing links to the knowledge sources and other related knowledge resources is an effective technique that facilitates a comprehensive understanding of the knowledge and enables end-users to find more important knowledge.

Knowledge approval is about all the activities involved in transforming knowledge content from non-approved, invalid knowledge into knowledge contents that is valid and available for authorised end-users of the KMS. Knowledge approval is a continuous process, involving checking and testing the knowledge contents in order to remove outdated contents from the system repositories and add new valid contents to the KMS. The continuous activities of knowledge approval can help to identify new shapes and formats of important knowledge that the existing system does not deal with.

Identifying new important shapes of knowledge, collecting feedback from end-users about the system use, and evaluating the system's usefulness, effectiveness, reliability can motivate the organisation to implement new improvements and enhancements for the existing system.

The process of knowledge approving, its role in identifying new important formats of knowledge and how it motivates the organisation to enhance the existing KMS is illustrated in Figure 5.11.

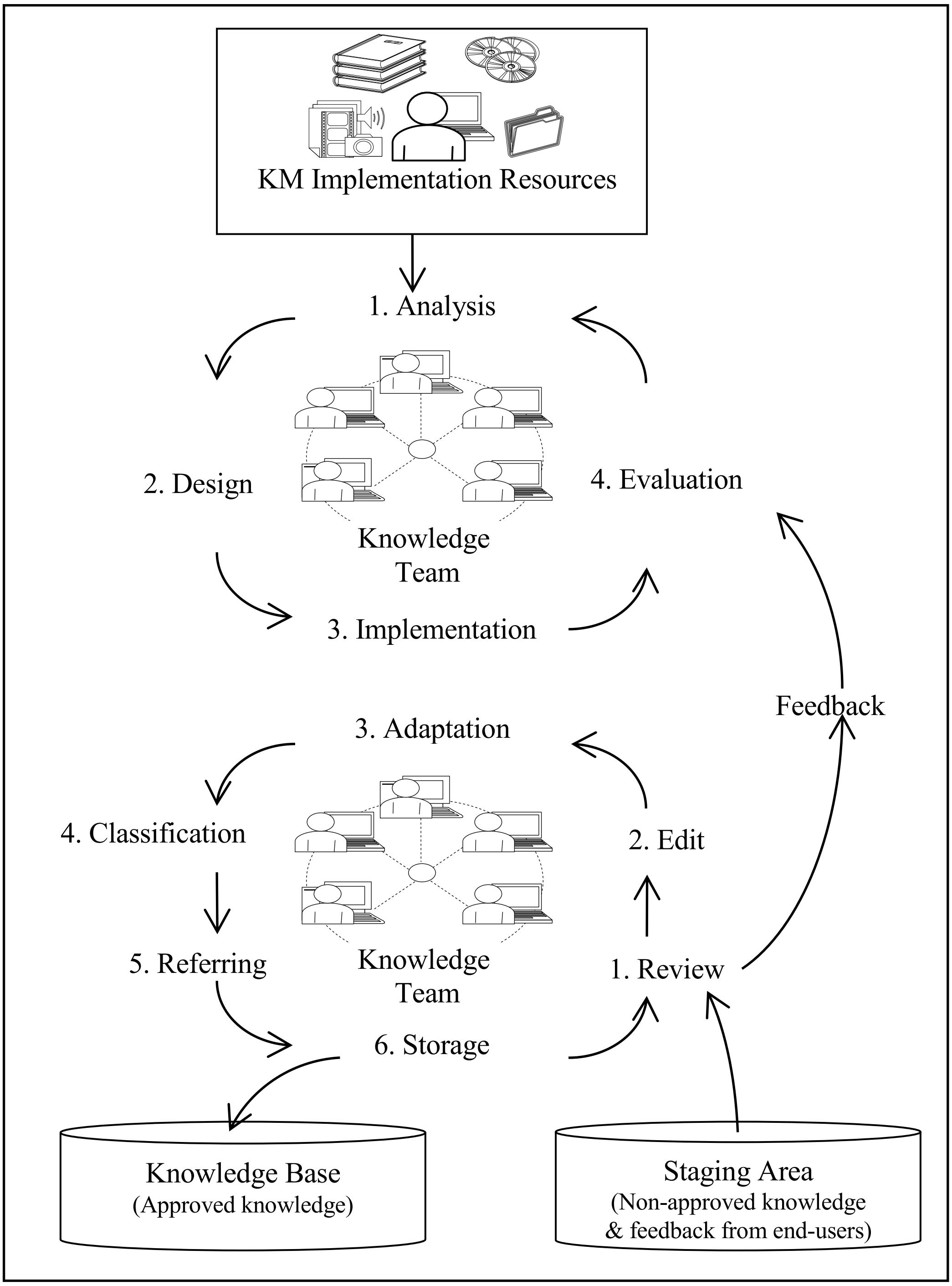

Figure 5.11: Knowledge Approval and Providing Feedback for the System Enhancement

The Relationships among KM Implementation and Application Resources

Figure 5.12 shows a representation of the relationships and the knowledge flows among KM resources, KM activities, KM roles and system repositories to simplify understanding and adoption. The flow chart shows the flow of knowledge from KM resources to the KMS repositories and to other end-user. The representation shows how the process of identifying new important knowledge from the knowledge staging area and collecting feedback of end-users can help to enhance the existing KMS. Also, it shows the roles, processes and the system repositories required to manage the different resources of KM implementation and application. The questionnaire survey results have shown that the role of KM teams, workers and end-users are highly important and that appointing roles for them is highly important in the specifications of successful KMSs.

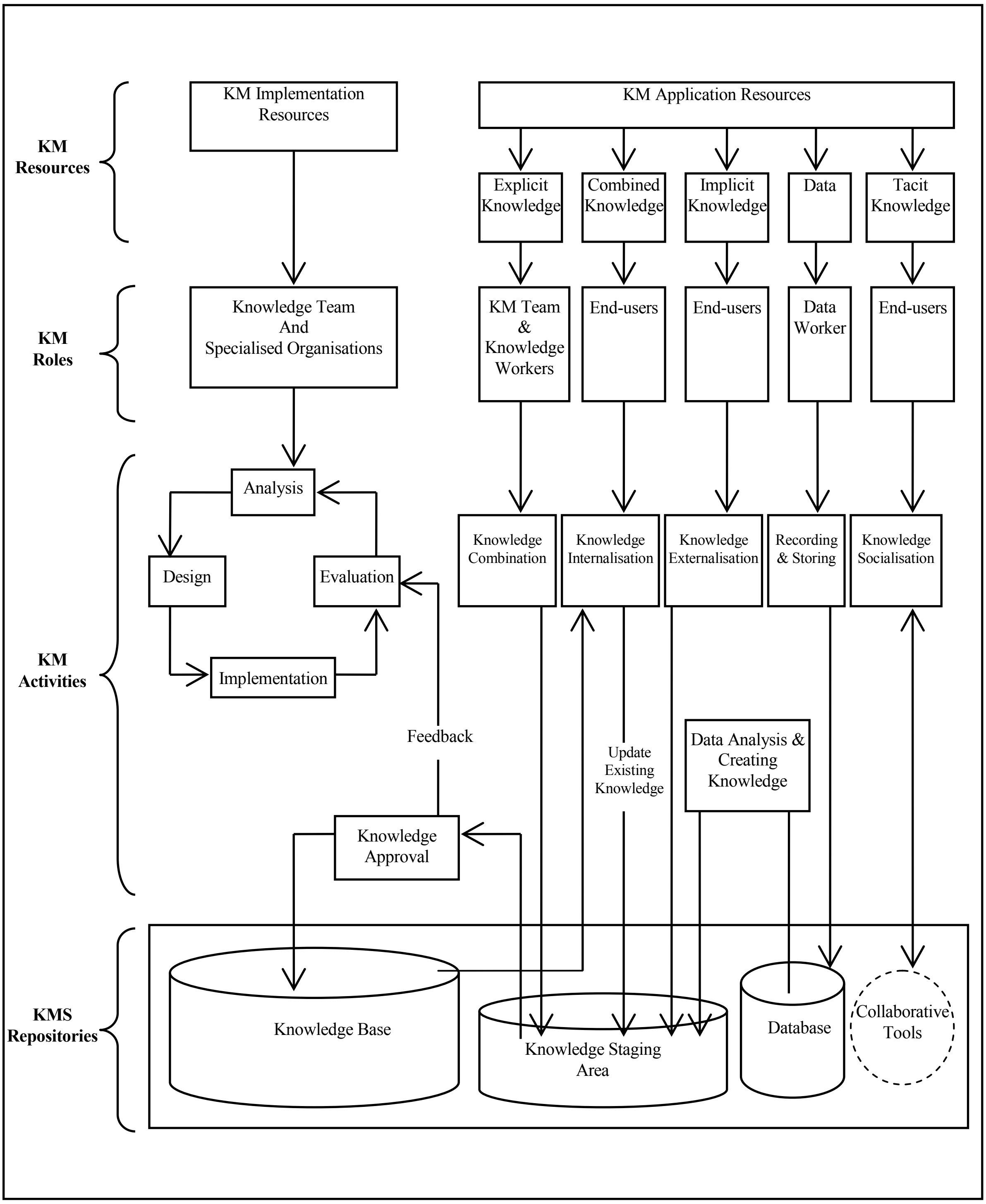

Figure 5.12: Flow, Roles and Relationships of KM Implementation and Application Resources

5.2.4 Phase 4: KMS Technological Architecture

The technological components of the proposed KMS are divided into five major layers, comprising: interface layer, access and authority layer, application layer, repositories layer and infrastructure layer, as shown in Figure 5.13. Each layer includes a number of sub-layers and components that aims to perform the functions of the main layers.

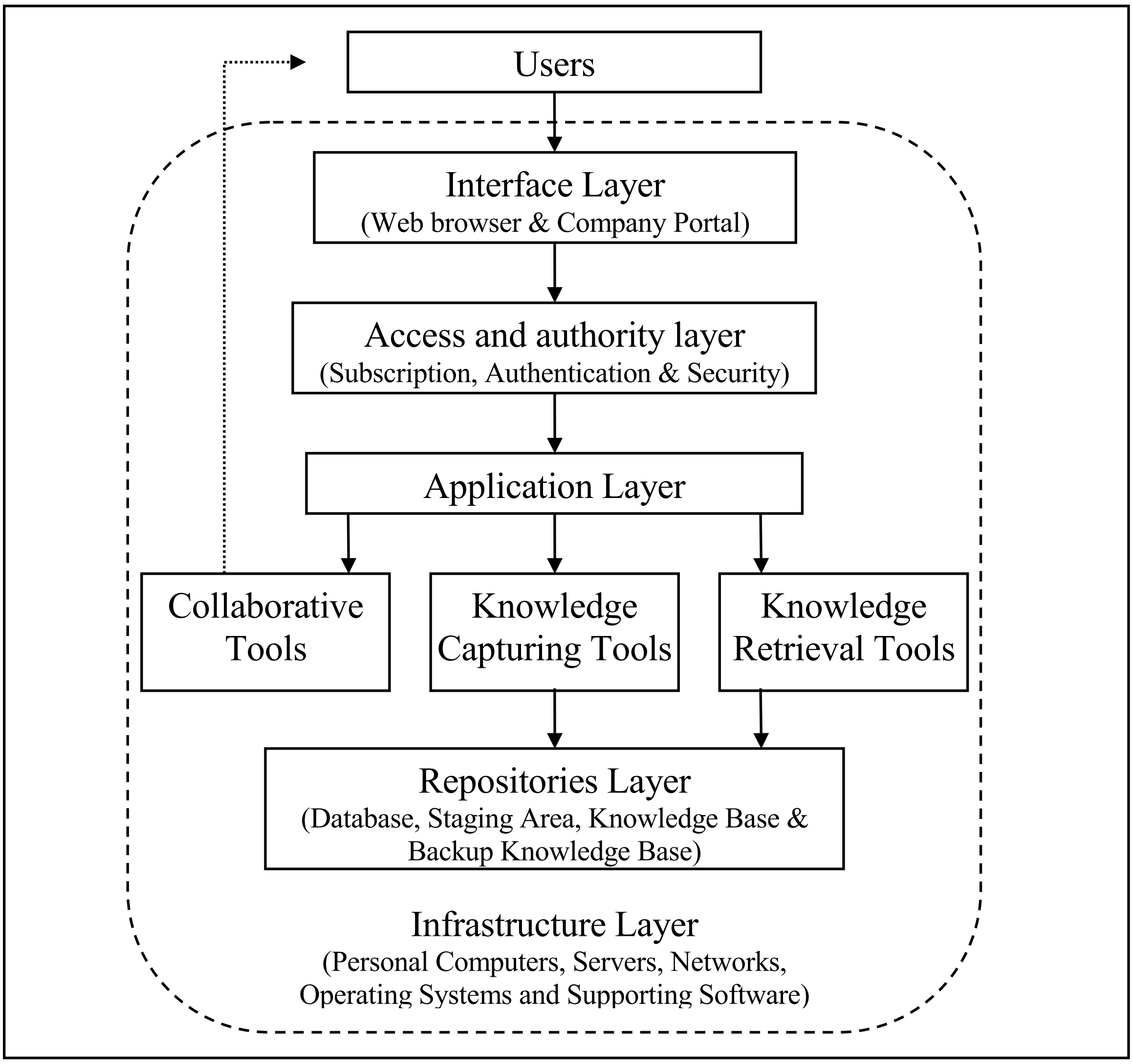

Figure 5.13: KMS Technological Architecture

The interface layer is the users' start point where end-users interact with other layers of the system. It provides the users with the ability to use services and tools that allow users to access and benefit from the knowledge contents of system repositories. The access and authority layer is the first layer accessed by the interface layer that defines, through a user name and password system, the level of authority of end-users and maintains the security and privacy issues of the KMS.

The application layer provides users with the ability to access services and tools that are available and allowed in the KMS. These tools are classified into three types according to their functionality. Knowledge capturing tools allow users to store, classify, edit and approve knowledge, while retrieval tools allow users to access knowledge repositories to search, retrieve and analyse knowledge. Collaborative tools help users to search and contact other users and experts to benefit from their experiences and perceptions.

Examples and descriptions of tools from the three categories are provided in Table 5.2 and ranked according to the average importance rates provided by the results of the conducted questionnaire survey. Those results have shown highest importance levels for knowledge capturing tools such as documents, photos, videos and drawing management tools, followed by knowledge retrieval tools such as manuals, training and searching tools and, finally, those with the least received importance are the collaborative tools such as e-meeting, e-messaging and e-discussion tools. The results have also shown a high need to enhance the awareness of people and organisations about the usefulness and importance of knowledge maps and yellow pages.

The repositories layer includes repositories for storing data, non-approved knowledge, approved knowledge and backup copies of the knowledge. Finally, the infrastructure layer should provide compatible components to guarantee that all the KM architecture components discussed previously can work effectively and efficiently in the present time and in the future.

Table 5.2: Description of services provided by KMS

Functions	Tools	Descriptions
Knowledge Capturing Tools	Documents Management	Facilitate saving and recording the contents of documents and reports of projects in digital forms.
	Videos, Photos & Drawings Management	Facilitate saving videos, photos and drawings, and also facilitate attaching them to digital records to simplify understanding of contents.
	Knowledge Publishing	Provide the ability for the KM team to publish knowledge to be shared by users.
	Knowledge Classification	Provide the ability for the knowledge team/workers to categorise knowledge in order to facilitate future retrieve.
	Knowledge Editing & Approving	Provide the ability for the KM team to review and modify the contents of knowledge packages and approve them to be available for other users.
	Knowledge Recording & Storing	Provide knowledge team, workers and other users with the ability to record and save new knowledge of problem solving and innovations in digital format.
Knowledge Retrieval Tools	Knowledge Searching	Provide the ability to search for knowledge by using one or a combination of keywords, expert name, knowledge domain, activity name, project name etc.
	Knowledge Linking	Provide links to connect knowledge users to more details, drawings, photos, videos or other related knowledge resources.
	Data Mining and Analysis	Provide a way to retrieve data and analyse it.
	Business Training & Support	Provide guidelines and e-learning to the construction activities.
Collaborative Tools	E-Meeting & Message	Connect people through video conferencing, e-mails, e-chatting and discussion groups, which also provide the ability to record and save contents in the KMS.
	Yellow Pages & Contact Details	Provide contact information of experts and employees with details of their professions and experiences.
	Knowledge Referring	Provide the ability for KM team/workers to refer and connect knowledge package with related experts.
General Purpose Tools	Knowledge Maps	Provide a way for knowledge searching and an overview of available and missing knowledge in the KMS.
	User Manuals and Help Desk	Provide guidelines and training to enhance KMS using.
	Subscribing	Subscribe new users and determine their authority level.

The proposed KMS suggests different authority levels according to end-users' positions and roles within the organisation. Two types of authority levels were provided to knowledge users in the KMS and to people who have roles in processing and capturing knowledge. Table 5.3 shows the levels of authority provided for using knowledge by end-users of the proposed KMS. The system also provides authority levels for knowledge actors who are responsible for knowledge capturing and processing with predefined levels of authority as shown in Table 5.4.

Table 5.3: Authority levels for knowledge retrieving and using in the proposed KMS

Authority Level	Description
General Level	Knowledge is available to all people and companies. It can include general information about the company and its projects as well as the services and contact details. The aim of this level is to maintain good relations with current customers and seek for new customers by providing marketing information, collecting feedback and delivering requests.
Organisational Level	This level includes general knowledge and services that made to be available for all the employees of the company such as the organisation announcements, regulations, news etc.
Departmental Level	This level includes many layers. Each layer can be available or unavailable for users regarding the employee jobs and positions. These layers are company specific and compose the intellectual capital of the organisation. It includes knowledge and experience of the employees in the organisations' projects and departments. Some of knowledge is specific for employees in a certain department or a specific management positions in the organisation. The most important part of this level is that includes experiences, know-how, best practices and problem solutions of projects that are made available for use by the entire organisation projects. This authority level also includes a knowledge layer that is available for loyal customers, suppliers or partners in order to maintain a good coordination and long term relationship.
Project Level	Knowledge in this level is specific and available for the employees in a certain project. It includes data and information about the project such as quantities, bills and performance, and the project knowledge and documents such as specifications, tenders, reports, records, problems and solutions. This knowledge only available for the project employees, and forms an important source of knowledge that if successfully managed and learned from can by useful and available for other projects in the organisation.

Table 5.4: Authority levels for knowledge capturing and processing in the proposed KMS

Authority Level	Description
Data Entry Level	Include tools and services that is available for certain employees to collect, review and edit data in the tables that form the organisation database.
Data Analysis Level	Include tools and services that allow users to retrieve, analyze and conclude from the data stored in the organisation database, and capture and store analysis results i.e. information in the system repositories.
Knowledge Entry Level	Provide users with the ability to add knowledge from documents, files, databases or experiences to the knowledge base with the ability to attach related files, photos or videos.
Knowledge editing Level	Allow users to review and edit non-approved knowledge and make this knowledge available to other users, e.g. classifying knowledge, referring to knowledge sources, and adapting knowledge (putting knowledge in a format that is acceptable by the system and the users).

5.2.5 Phase 5: New KM Resources

Processing KM resources through KM activities and technological tools helps to transform them into more useful forms of resources. These new resources can be reused to update knowledge contents in the KMS repositories, form new resources for the creation, capturing and sharing of knowledge, or can be used to enhance the existing KMS. This stage requires the organisation to identify new types and forms of KM resources that are produced from the processing of older resources, and to adopt plans for further reuse and enhancement.

Organisations applying KMSs need to monitor the usefulness and importance of the newly produced KM resources. These resources can provide a useful feedback that may help an organisation to identify opportunities to improve methods, tools and activities of the existing KMS. A continuous process of identifying and processing different types of KM resources is important to update, re-validate and add value to old contents in the KMS repositories and to maintain and enhance both the technological and non-technological components of the KMS.

Figure 5.6 shows the new knowledge resources produced from processing capturing and sharing knowledge in its four different types. Internalisation activities aim to help people in re-using combined knowledge to produce new knowledge with more value to the organisation and people. Knowledge internalisation can help end-users to learn new methods, procedures and experiences of other users by using knowledge searching and retrieval tools. KMSs can help junior engineers to learn faster, rather than the need to spend more time and efforts learning through the long duration of projects' life cycles. Moreover, re-using combined knowledge of past experiences and best practices can help in processes such as problem solving and decision making, which can help end-users to make better decisions and generate new experiences. The new experiences and methods can be used to modify, update and re-validate the old contents in the repositories of the KMS.

Knowledge combination includes activities such as knowledge capturing, digitizing, reviewing, combining, categorizing and approving knowledge from inside and outside the organisation, which can help the organisation to transform explicit knowledge into more valuable, searchable and applicable new combined knowledge. Implicit knowledge can be processed through knowledge externalisation activities to produce new explicit knowledge that can be easily captured, reviewed, categorized, approved and stored in the repositories to be available for end-users of the KMS.

Finally, the organisation needs to deal with the rest of knowledge, i.e. tacit knowledge that cannot be stored in the KMS repositories. Knowledge socialisation tools and activities help people to share tacit knowledge to produce new experiences and knowledge. End-users can find solutions for the project's problems by using the KMS tools to search and contact people with the required experiences related to the problems, rather than searching for the solution in the KMS repositories. In many circumstances this can provide better problem solutions. People interactions and discussions may help to find solutions that better align to the special characteristics and contexts of a project than the solutions provided in the repositories of the KMS.

Organisations can benefit from the dynamic nature of knowledge by planning for a continuous process for re-identifying and re-processing the produced new knowledge as shown in Figure 5.6. This will help to update, re-validate and enhance knowledge for future use, and ensure the continuous processing of knowledge creation that is highly important in order to provide competitive advantages for the organisation. This process helps to re-validate knowledge contents and remove outdated, incorrect and misleading knowledge from the repositories of the KMS. Identifying new important types of the produced new knowledge will provide feedback to identify required improvements for KM methods, tools, and activities to successfully manage the new types of knowledge.

New KM resources that help enhancing KMSs can be identified from results of KM evaluation methods, feedback captured from KMS end-users, new useful KM methods, procedures and tools investigated in literature, plus new formats of knowledge identified to be important for capturing and sharing. These can encourage the improvement of KMS design and the KM technological and non-technological components, procedures and activities as described in Figure 5.14.

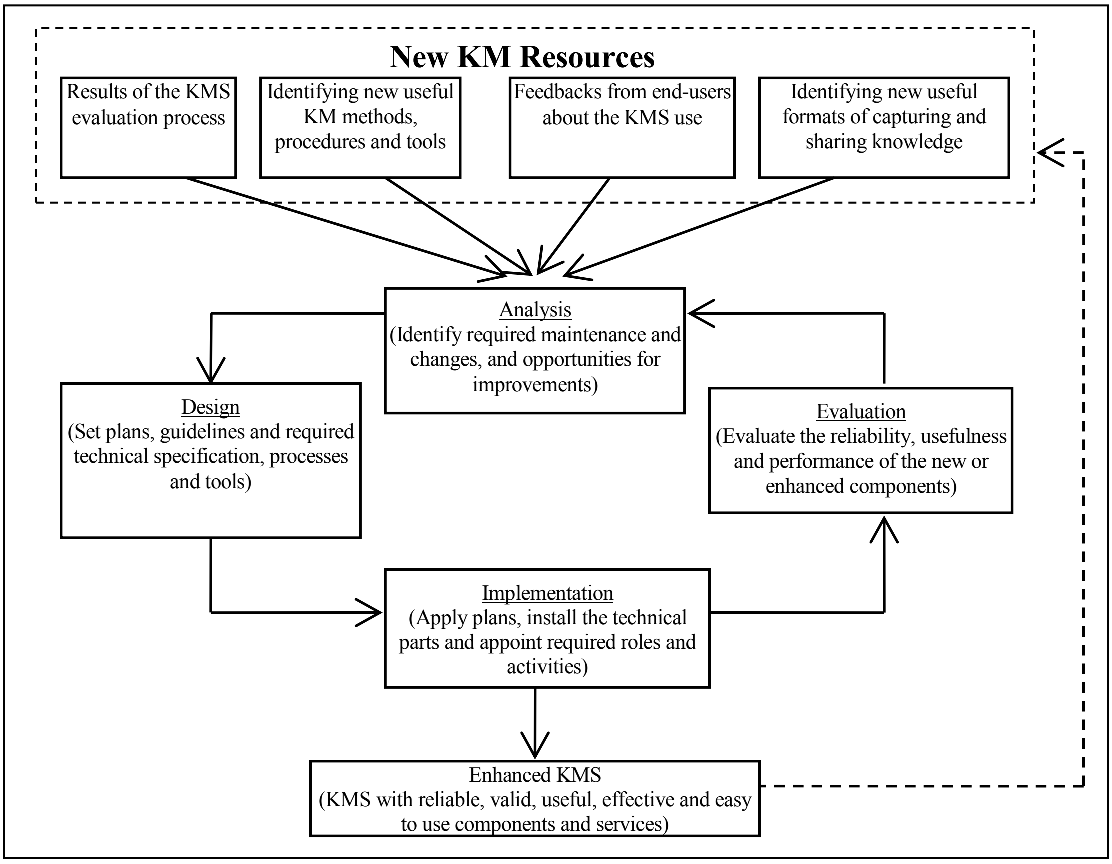

Figure 5.14: Proposed Process for KMS Improvement

5.3 Characteristics and Advantages of the Developed KM Model

The new KM model has been developed to simplify the processes of implementation, use and improvement of KMSs by providing a structured, comprehensive and easy to use method for managing knowledge in construction organisations. This model overcomes and solves problems that exist in other KM models, and emphasises the important roles of the KM team and users. The advantages of the new KM model can be summarized as follows:

- The new KM model represents and classifies all KM content resources that are required in the processes of KM implementation and application. The proposed KM model differentiates among four types of knowledge instead of the traditional classification of two types. This can help to provide better methods and procedure to manage and process the different types of knowledge. The KM model shows how different KM resources require different procedures, processes, roles and tools to be created, captured and shared.

- The proposed KM model provides a clear structured procedure for data collection and transforming it into information and knowledge. Although some few KM researches have discussed the importance of data and information to the process of knowledge creation, the KM literature and the construction KM models lack providing and adopting structured methods to help organisation to adopt this process. The new KM model provides structured procedures to capture data of the construction projects, transform it into information, use data and information to create new knowledge, and use this knowledge to approve, support and add value to other knowledge that exists in the KMS repositories.

- The proposed KM model provides a clear monitoring and evaluating mechanism of the KMSs. The new model proposes a structured feedback collection mechanism to capture end-users comments about the KMS performance, ease of use and usefulness. The KM model provides a continuous monitoring mechanism that help organisations to identify new opportunities for capturing and sharing new KM resources. The new KM model provides a structured procedure for enhancing KMSs by using the outputs of the KM evaluation process, the feedback collected from end-users about the system use, the new KM resources and opportunities identified in the KMS, and the new methods, tools and technological advances identified in the KM research works and literature.

- The proposed KM model combines activities required for designing and implementation of KMSs, activities of applying and using KMSs, technological components required for a successful KMS, and activities required to deal with environmental factors that affects applicability and usefulness of KMSs. Reviewed KM models lack the adoption of many of the important KM components. The new KM model provides a relatively comprehensive method that includes important KM components and proposes clear relationships and knowledge flows within and between the different parts.

- The proposed KM model provides continuous processing procedures with the ability to apply parallel or simultaneous activities. Many of other KM models may provide sequential processes that require completion of an activity before starting another one. The proposed KM method, for example, allows adopters to apply knowledge processing activities while applying other implementation, evaluation and enhancement activities.

- The proposed KM model provides a good level of details that makes implementation and using of the KMSs easier. It has been identified in the KM literature that one of the main challenges of KM adoption in the construction companies is the lack of adoption of structured methods for KM implementation, application and evaluation, which encourages for more research efforts to provide structured methods to provide details and guidelines for important KM processes, methods and tools.

- The proposed KM model shows the importance of appointing and/or providing roles to KM team members, knowledge workers, data workers and end-users in the process of KM. Representing these roles in the KM model can help to provide better understanding of the processes of the KM model, enhance awareness about the KM roles and their importance to encourage KM initiatives, and help to provide a more structured comprehensive method for KM adoption.

- The proposed KM model pinpoints the environmental factors that may affect the implementation and application of the KMSs. These factors can be hinders or motives to KM adoption and use in the construction projects. The KM model shows the importance of monitoring and adapting these factors to be appropriate for KMS adoption, and suggests activities and procedures to avoid and overcome KM challenges and to encourage KM drivers and motivations.

- The proposed KM model provides a more suitable KMS technological architecture and its components. The proposed architecture ensures providing required components to support successful KMSs for the construction projects. The suggested technological components support the aim of the KM model of providing different processing procedures and tools to manage the different types of knowledge resources available and important in the construction project contexts. The proposed architecture helps to enhance KMS performance while taking into consideration the privacy, security, contractual and copyright issues of organisations, people and knowledge. The suggested KMS architecture proposes a more detailed and structured method for defining authority levels by distinguishing between authority levels of knowledge using and retrieving, and authority levels of knowledge capturing and processing in the KMSs.

- The research links, evaluates and prioritises the KM model components according to the results of the conducted questionnaires, interviews and intensive review of KM literature. These results have encouraged the enhancement and addition of new components and details to the previous KM model versions. The results support and add value to the proposed KM model by testing and indicating the importance, usefulness and spread of the different parts of the KM model in the construction industry.

The new proposed KM model aims at comprising all the issues and components that play an important role in the successful implementation and application of KM in construction projects. They were investigated through an extensive review of KM literature, and enhanced through evaluations of the KM model versions by conducting interviews, questionnaires, published papers and detailed study and review of the KM model components and recent KM literature. Furthermore, the developed KM model was designed to overcome drawbacks that can be found in previous KM models.

Although the adoption and application of KM models facilitate and encourage KM initiatives, they cannot guarantee that people in the organisations are willing to share their knowledge with others or to participate in using knowledge and/or creating new knowledge. Hence there is a need for more effort from the organisations' management to enhance the employees' awareness about KM benefits, build trust among employees, and provide more time for employees for sharing knowledge and learning. The management should also provide the required tools and technologies for KM, adopt a performance appraisal method that appreciates and rewards KM activities and apply modifications to the work processes and activities of the employees by embedding KM activities and processes into them. Providing an ultimate comprehensive KMS for the construction projects may be quite complex due to the continuous changes in knowledge and construction domains over time. This study provides a platform for further development and modification of the KM model so that the proposed model can be used in practice more efficiently and effectively.

5.4 Summary

In this chapter, the details of a final version of the KM model developed throughout the research stages are described. The proposed KM model is developed by following methodologies to fill the gaps of existing models and to provide a useful and practical method for KM in construction projects.

The proposed model encompasses five phases, which are: identifying useful and available KM resources; investigating KM environmental factors and assigning required activities to deal with them successfully; appointing KM activities and procedures to process and manage the different types of knowledge resources; identifying the system architecture and specifications required to achieve KM goals and strategies; and finally, identifying the resulting new KM resources and considering them for further improvements and validations.

The proposed KM model considers the types of knowledge resources required for building and developing the KMS (implementation resources) and for processing and using in the KMS (application resources). The differences between data, information and knowledge have been taken into consideration, and the importance of using data and information to create new knowledge and support existing one is highlighted. A method that categorises knowledge into four types is adopted to identify the different formats of knowledge, which require different activities, tools and methods to manage and process.

Environmental factors that may affect KM implementation and application are discussed, and categorised to simplify understanding and managing them. The environmental factors, categorised according to their importance in the results of the questionnaire survey, are: customers, partners and suppliers' factors; technological factors; cultural and individuals' factors; organisational and managerial factors; financial and resources' factors; and regulations' factors. Useful solutions and procedures that may help to deal successfully with the environmental factors are suggested.

KM activities include activities required to manage and process the different types of KM resources discussed previously. These activities are categorised into KM implementation activities and KM application activities. KM implementation activities include the activities for the analysis, design, implementation and evaluation of the KMS. It is a cyclic process where the continuation in its stages refers to enhancing the KMS quality or performance, and widening the range of implementation or application.

KM application activities include activities required to create, capture, update and share knowledge available and useful in construction projects. The questionnaire survey of the research has shown that these activities received the highest average importance rate among other components in the proposed KM model. The KM application activities include activities for processing data and information, so they can be used to validate existing knowledge and create new knowledge.

The KM application activities also include activities for managing and processing knowledge that is categorised into four types, i.e. combined, explicit, implicit and tacit knowledge. Each type of knowledge requires different processing activities, which are defined and detailed in the proposed KM model into four different levels of activities. These levels respectively are: knowledge internalisation, which includes the activities of retrieving, reusing, evaluating and updating the knowledge that is already stored in the KMS; knowledge combination, which refers to activities of capturing knowledge, combining related contents, and making them available and searchable for end-users; knowledge externalisation, which includes activities of capturing experiences, perceptions, know-how and best practices into formats that are easier to be stored, categorised and retrieved; and knowledge socialisation, which includes activities of sharing experiences, ideas and lessons learned through collaborative tools, without the need to store them in the KMS repositories.

A structured continuous process for approving knowledge stored in the KMS repositories is proposed in the KM model. Knowledge requires reviewing, evaluating, editing, adapting, classifying and validating before making it available and searchable for the KMS end-users. Identifying new formats of important knowledge and capturing feedback from end-users help the organisations to identify opportunities for improvements in the existing KMSs.

The KM model shows the relationships and flow of knowledge among the different stages and components. It helps to show how knowledge transforms from one shape to another during the different stages of KM. It also provides different processing stages, different roles and different technological components for each different type of knowledge.

A technological architecture for KMSs is proposed, which satisfies objectives and goes with components and characteristics of the developed KM model. The five layers proposed to represent the KMS technological architecture are: the interface layer, which allows end-users to access and use the technological services and tools of the KMS; the access and authority layer, which defines the authority levels of end-users and maintains the security and privacy of the system; the application layer, which provides services for end-users to make them able to capture, retrieve and share knowledge; the repositories layer, which stores knowledge in its different formats; and the infrastructure layer, which provides the required tools and technologies to maintain effective and efficient performance for the previous layers.

New KM resources are the output of processing KM resources through KM activities and tools. The KM model proposes a method to reuse and update these new KM resources to revalidate them. This also can help to identify new formats of knowledge and thus the existing KMS can be enhanced to successfully manage them. A continuous process of identifying and processing new types of KM resources is important to update, re-validate and add value to the KMS and to the knowledge in its repositories.

The proposed KM model overcomes shortcomings of the existing KM models and provides a structured, comprehensive and easy to use KM method for construction organisations. The advantages of this KM model include characteristics such as differentiating KM resources that require different processing, providing structured processing procedures for knowledge and data, providing clear monitoring and evaluation mechanism for knowledge and KMSs, presenting activities, procedures, tools, architecture, roles and environmental factors for KM implementation and application, providing continuous processing with abilities to apply parallel activities, and representing adequate levels of details and processes.

This chapter is dedicated to discuss the components of the research developed KM model and its advantages compared to other existing KM models. Next chapter will present two case studies from the construction industry to validate the KM model and evaluate it in terms of usability and usefulness.

CHAPTER SIX

CASE STUDIES

6.1 Introduction

This chapter will initially describe the objectives of the conducted case studies. The case studies will cover information and background of the companies, description of the implementation, application, tools, technologies and procedures of their KMSs, and finally analysis and evaluation of their existing KMSs. This will be followed by an evaluation of the proposed KM model of the research by collecting feedback from selected users of the KMSs in the two organisations. Finally, analysis and discussion will be carried out and final findings and results will be concluded for the case studies.

6.2 Objectives

This chapter presents two case studies conducted in the construction industry. The case studies aim at investigating KM application in construction organisations and evaluating the proposed KM model in terms of its suitability, usefulness and applicability in construction projects. Furthermore, the case studies aim to demonstrate how the proposed KM model can be used to improve performance of KM processes in the construction industry. The case studies include two international companies: a consulting company and a full-service construction organisation. More details about these two companies are described in sections 6.3 and 6.4.

A case study protocol has been used as a general guide for the interviews of the case studies. This provides an opportunity for more discussions and details as shown in Appendix 3. The case study protocol starts with gathering background information of the participant companies and respondent employees. Then general questions are asked to investigate the existing KMSs in the participating companies in terms of KM resources, processes, activities, technological architecture, and influential factors. Finally, the participants were asked to evaluate the proposed KM model in terms of provided criteria. A number of interviews were organised and conducted with people from the participating organisations who regularly use the system and/or who have a role in the process of implementing and applying the KMS.

6.3 Case Study 1

Consultancy A

6.3.1 Background

"Consultancy A" is used instead of the company's name due to business confidentiality. With over 4,500 employees across the UK, Europe, Middle East, Asia and Australia, and an annual turnover of approximately £320 million, Consultancy A is a large international advisory and design consultancy specialising mainly in infrastructure, property and environmental solutions.

With rapid growth in employee numbers (about 20% from April 2007 to April 2008) and international operations, the organisation increasingly adopts procedures and activities that encourage knowledge transfer among employees in order to help with individuals' career development. Based on feedback from its employees the organisation prepared brief guides for working practices associated with legislations, local customs and social activities for different projects' types and regions, in order to assist with the employees learning process. The organisation is adopting an ongoing IT network investment strategy to provide more flexibility that enables their people to retrieve important knowledge and implement their jobs from almost anywhere at any time. The organisation has adopted KM solutions to enhance work quality, maintain and improve relationships with customers, suppliers and partners and gain competitive advantages.

A number of interviews have been conducted in the organisation with the KM system employees and end-users. The participants include two senior engineers, two junior engineers, a knowledge manager and a knowledge worker. The case study protocol, as shown in Appendix 3, has been used to direct the interviews in general, while the findings are described in the following sections.

6.3.2 KM in the Organisation

To maintain technical and professional excellence of its employees, Consultancy A has implemented and applied a technological part of its KMS through a computer-based system which is called the 'Hybis knowledge system'. Furthermore, the organisation has developed regional and global Professional Excellence Groups from each business discipline or function who lead the implementation and application of the KMS. This group includes senior management members that form a Community of Practice (CoP) who meet regularly to discuss the latest technologies and innovations to promote professional excellence amongst all employees. Global Communities have been established with assistance of the organisation KM department to enhance the transfer of knowledge through the organisation and enable the organisation to offer the latest international advice to clients wherever they may be located.

The organisation has considered knowledge as one of the most important assets to the company held by its people that if not managed successfully can be easily lost from the organisation due to many reasons, such as when employees leave the organisation or take new positions in the company. KM includes all activities, tools and methods to store this knowledge or help to transfer it among the organisation employees. KM can be looked at as the process of transforming the people's valuable knowledge from a volatile into a more stable form that is more valuable for the organisation. In other words, KM includes all the processes and tools that help the transformation of individual knowledge into organisational knowledge. KMSs provide flexibility for their end-users to retrieve and use the required knowledge any time from almost anywhere to implement work tasks perhaps without having previous knowledge or experience in the field. The effective implementation of KM can help the organisation to improve quality of work while reducing time, cost and effort required for completing projects. So, KM helps the organisation to meet customers' needs and develop competitive advantages.

A successful implementation and application of KMSs requires a KM strategy that fulfils the organisation business strategy. KM strategies should be specified that ensure successful capturing of important knowledge, providing required knowledge when needed, introducing a platform for people to communicate and share knowledge, and finally, promote people to innovate and create new knowledge. The organisation has considered successful KM strategies as the strategies that make required knowledge available for end-users and can be easily accessed at anytime from anywhere to be used for the benefit of the clients and to keep the organisation's people updated with modern techniques in the industry.

6.3.2.1 Knowledge Resources

In the organisation, two types of knowledge have been identified, i.e. explicit and tacit knowledge. Explicit knowledge is the knowledge that can be found in the organisation's documents, so it can be easily captured and stored. Tacit knowledge is the other type of knowledge that is built in the individuals' heads through experience and learning, so it is more difficult to be documented and stored, but it can better be shared through direct and indirect contacts.

The proposed KM model of the research provides more categories of knowledge to differentiate among the different formats that require different process and tools. This can help organisations to better understand the different characteristics of knowledge formats to enhance processing and managing them.

Another useful way to categorise knowledge within an organisation is through differentiating between two types of knowledge i.e. individual knowledge and corporate knowledge. Individual knowledge is the knowledge held by individuals. Corporate knowledge is the one that can be found in the corporate databases, web site, library and/or archives. The successful management of both individual and corporate knowledge may effectively contribute to the creation and application of organisational knowledge to support the organisation in important processes, such as decision making, problem solving, and learning.

The proposed KM model of the research provides two types of individual knowledge regarding the ability to capture it in the system repositories, which include tacit and implicit knowledge. Also, the KM model provides two types of corporate knowledge regarding its availability in the KMS, which include combined and explicit knowledge, and also refer to other knowledge that is available outside the corporate borders. The KM model details processing activities, environmental activities and technological tools required to successfully capture, re-use and share knowledge to transform individual and corporate knowledge into more valuable organisational knowledge. The KM model makes use of the dynamic nature of knowledge to ensure a continuous process of updating and validating contents.

6.3.2.2 Processing Activities and Roles

It has been indicated by the organisation that the aim of the KMS is to create communication links through tools such as e-mails, e-chatting and video-conferencing to help to connect people and share their knowledge. But this is not the only important objective of the KMS, for it also aims to provide the ability to store important knowledge in an explicit format available and accessible to the system's end-users. To build a successful KMS the organisation should find a balance in adopting procedures and tools for applying the two concepts of knowledge sharing and knowledge storing while considering the special characteristics and needs of the organisation.

The proposed KM model provides more detailed KM activities that enable the employees and end-users of the KMS to process and manage the different types of knowledge. The KM model shows procedures for capturing explicit and implicit knowledge, sharing tacit knowledge, re-using and updating combined knowledge, and also processing data and information into knowledge, which simplifies understanding and adopting KM processing activities in the organisations. The KM model provides a good level of details for the KM activities and processes, while enabling the organisations to decide other details that meet the special characteristics and needs of each organisation.

In the design phase of the KMS, the organisation has appointed roles to some of its employees from different departments and professions to provide required details and documents to the design and implementation teams. They have also been asked to provide the required contents to load the implemented system with useful knowledge. Those are also given the role of controlling knowledge that includes processes such as ensuring that the contents stored or to be stored in the system are reliable, useful, consistent and provide the latest revision of a document or drawing.

For a successful adoption of KM processes, the interviewees have referred to the importance and the need to update the existing KMS on a regular basis to reflect the organisational changing context and experiences. The organisation has decided to improve its previous KMS by implementing new, advanced, easy-to-use technological components to promote its people to share and store their valuable knowledge.

The new system has been applied in a staged way, starting with implementing its new technological tools, and then applying procedures and methods for applying and using the new tools, only in some chosen regions or sections of the organisation, ending with full implementation of the system in the entire organisation. Applying small scale implementations or prototypes before the wide implementation of the KMS helps the organisation to evaluate the KMS by collecting feedback from end-users, identify problems and errors of the implemented tools, and make modifications, without wasting money, time and efforts due to large scale implementations.

To encourage and simplify the use of the new services adopted in the KMS, the organisation has implemented other environmental activities such as providing awareness and training programmes. Furthermore, the new enhanced KMS provides links to the tools and services of the old system to allow end-users to use the old services that have not yet been widely implemented and give users enough time to learn the new procedures of the new system without delaying their job tasks that depend on the use of the old system. However, the services and contents that have been tested, widely implemented and successfully used in the new system, have been removed from the old system and are no longer available through the new system links to the old system.

The proposed KM model suggests a detailed structured procedure for the KM implementation activities, which are discussed in the previous paragraphs for the case study, to make their adoption easier and more successful. The KM model suggests four implementation phases, which include the phases of analysis, design, implementation and evaluation. Furthermore, the model shows three phases to represent the continuous stages of the KM life-cycle that starts with an implementation of a prototype, followed by a large scale implementation, and finally, an implementation of enhancements and maintenance to the KMS. The continuation in these stages refers to the need for a continuous procedure for updating and validating the KMS. Also, the KM model stresses the importance of conducting detailed analysis and the importance of appointing roles to KM teams to identify the existing business operations and the available and useful knowledge resources to be considered in the design of the KMS.

An important challenge for the organisation is to make the KMS rich with knowledge of high value and eliminate contents of little or no value. There would be little or no motivation for the organisation's people to use the KMS if the KMS does not provide knowledge that is useful for both the people and the organisation. For this reason, the organisation has assigned a KM team to enhance and support the KMS application. A main objective of the KM team is to study and identify KM resources important and required to meet current and future needs of the people in the different departments and functions of the organisation. The KM team works to make sure that the system includes and maintains important recent knowledge about industry best practices, legislations, health and safety issues, innovations, and different function-related standards, specifications and guidelines. The main tasks and objectives identified by the organisation to be achieved by the KM team can be summarised as follows:

- The KM team is responsible for keeping the KMS up-to-date with modern technological tools and advanced systems and methods. The KM team is responsible for recommending appropriate improvements for the system when possible and promoting better quality techniques for the organisation's benefit and use.

- The KM team decides objectives needed by the KMS and decides the required strategy to achieve them. The KM team should ensure the alignment of the KM strategy with the overall business objectives and processes.

- The KM team is responsible for evaluating knowledge contents in the KMS repositories to ensure its alignment with objectives of the organisation to meet current and future needs of employees and customers. In this case, the KM team needs to ensure that the KMS maintains and disseminates up-to-date important knowledge, such as legislations, best practices, problem solutions, standards, manuals, health and safety aspects, and reports related to the different sections and specialities in the organisation.

- The KM team is required to report on any gaps and performance deficiencies of the KMS. The KM team should set evaluation measures or Key Performance Indicators (KPIs) to evaluate the existing KMS, report results, and suggest solutions if required.

- One of the KM team's tasks is to study cultural factors in the organisation and suggest methods to promote cultures that encourage knowledge sharing and transferring.

- A KM team responsibility is to work with sectors' leaders to identify skills and technical abilities that need to be enhanced for the different sectors' employees. It is then important to identify the training programmes and resources needed in the KMS to enhance the employees' abilities and skills in the different sectors of the organisation and to simplify and promote the use of the existing KMS.

- The KMS also suggests and provides authority levels to the system users that define users' accessibility to the system repositories and services regarding their job positions and experiences. The KM team suggests and registers people of high experience to become approved reviewers for contents that are recently added to the KMS repositories. The KM team is responsible for identifying people to capture knowledge and experience, write technical guidelines, and edit and/or approve knowledge contents.

The proposed KM model stresses the essential roles and responsibilities of KM teams, KM workers and Communities of Practices (CoPs) in the success of KM adoption in the organisations. The KM model shows the role of KM teams and workers in monitoring the use of the KMS and ensuring the validity of the knowledge in its repositories. The KM model proposes procedures for updating knowledge, ensuring its usefulness and deleting old invalid contents. Also, it suggests activities to evaluate the existing KMS and capture feedback of end-users that can be used to update and enhance the existing KMS.

The KM model shows the important role of KM teams in the process of building and enhancing the KMS, through identifying existing knowledge resources, existing business procedures and strategies, existing employees' culture and backgrounds, and opportunities and challenges for KM adoption and improvement. Furthermore, the KM model suggests levels of authorities to help KM teams in deciding and providing the accessing and editing abilities for the KM team members and the KMS end-users.

The KMS in the organisation is used to issue work and provide abilities for clients, contractors, partners and projects' engineers to access required contents and communicate issues back to the organisation's designers and managers. The system is also used by the projects' resident engineers to record site diaries and reports, supported with photographs of the current works and activities in the construction projects, so the managers and designers of the organisation can monitor projects and track progress. Project engineers can use the KMS to post a 'request for information' and also to report problems, enquiries, suggestions and solutions. These reports are normally saved and sent by the KMS after being checked and approved by the projects' managers.

The proposed KM model supports all important formats of knowledge transfer and knowledge sharing inside and across the organisational boundaries. The conducted questionnaire survey and the developed KM model have shown the importance of providing required knowledge and services through the KMS in order to maintain good relationships with customers, partners and suppliers. The KM model also supports knowledge transfer among the different organisational departments and hierarchical levels, and among the different projects.

6.3.2.3 System Architecture and Tools

The success of KMSs in any organisation depends largely on the architecture adopted by that organisation. The KMS technological architecture needs to align with the organisation processes and satisfy the organisational objectives and special characteristics. Every organisation needs to decide the way knowledge is to be transmitted amongst its people based on its knowledge and business requirements.

The organisation of this case study has adopted basically a centralised knowledge hub system to coordinate its various knowledge sources. The KMS provides centralised repositories or storage areas for knowledge where people can find needed documents and critical knowledge in one central location. It provides a singular, integrated platform to manage intranet, extranet and internet applications across the organisation. The KMS provides centralised services that support end-users to create, capture, retrieve and reuse knowledge of the KMS repositories, and prevent knowledge duplication and contradiction.

The ability of the centralised services to effectively diffuse knowledge among the organisational people is essential for the overall success of the KMS. The KMS has been designed to provide critical business knowledge through identical shared interfaces to direct people of the organisation toward required targets and objectives. In spite of this, the KMS is designed to be flexible by allowing a degree of personalisation, so the system end-users can manipulate the structure of the system interfaces according to their desires and needs.

The existing centralised hub also provides services that support the other forms of knowledge transfer, i.e. knowledge webs, knowledge sets and knowledge chains. The KMS provides services that support a web form of knowledge transfer, where the services act as a communication platform to promote collaboration and encourage sharing and transferring of knowledge among employees. The KMS also supports knowledge sets by providing resources and tools to help professionals and experts when they work individually to retrieve and analyse the required knowledge. Furthermore, the KMS supports the chain form of knowledge transfer through simplifying and systemising the flow of knowledge between individuals during the routine chain of work.

The proposed KM model suggests implementing centralised knowledge repositories that support end-users to retrieve and reuse knowledge of other projects, and help to prevent knowledge inconsistency. The model also suggests implementing centralised knowledge services to motivate collaborations and knowledge sharing among people in different divisions, projects and organisations. However, the KM model also supports other forms of knowledge transfer, such as knowledge webs, which enables users to create personal profiles supported by useful knowledge and links that may be useful to other users; knowledge sets, which allow users to work individually to search, retrieve and analyse knowledge to innovate and find best problem solutions; and knowledge chains, which manage the flow of knowledge in the routine work processes and correspondences.

The KM model provides roles for KM teams to investigate and identify work procedures and processes, knowledge flow within these work processes and opportunities to motivate knowledge transfer. The KM model supports embedding KM activities and methods into the existing work processes that may help to enhance performance and quality of these work processes and encourage capturing and sharing important knowledge from the people transactions, communications, correspondences, and work reports.

The organisation knowledge system has been designed to be accessible through internet services to allow end-users to use the system and do their job tasks any time from almost everywhere. The internet connections are provided via telecommunications service providers such as British Telecom (BT), one of the world's leading telecommunications service providers that offers local and international telephone, mobile and internet services, primarily in the United Kingdom and Western Europe. Through the internet connection, end-users can access the organisation main servers and use the applications and services provided by the organisation's knowledge system.

The organisation is applying a firewall system between its servers and the internet to help the organisation to monitor and protect sensitive information, such as private financial, transactional, personnel and projects information, from unwanted intruders. Figure 6.1 shows the role of the internet in connecting end-users to the company KMS, and shows the role of firewalls in protecting the system servers, and the relationships among the company servers, firewall systems and internet. It is important to define authority levels and access limits to help protect organisational sensitive knowledge without limiting the diffusion of useful business-related knowledge to the employees.

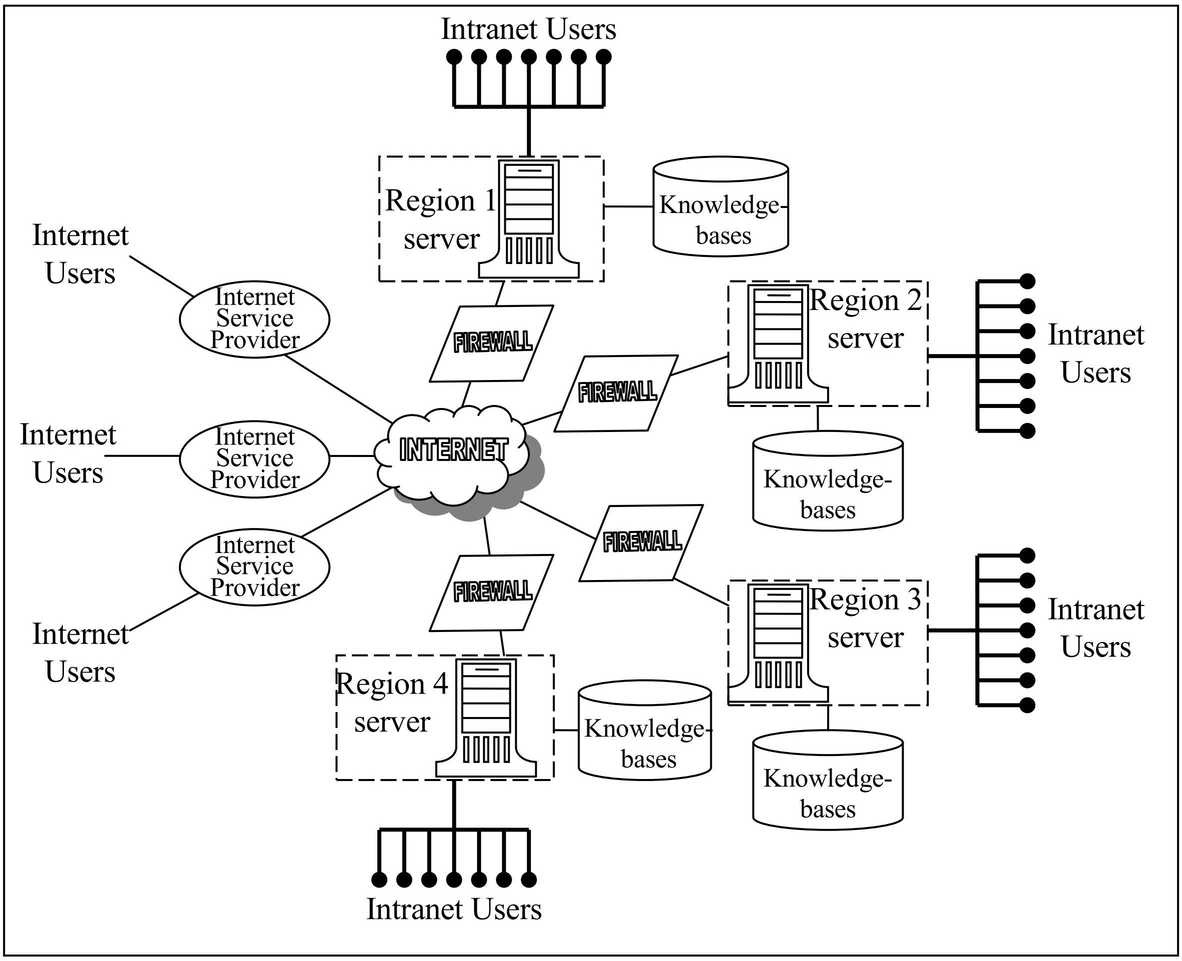

Figure 6.1: Servers, Firewalls, Intranet and Internet Connections in the Organisation

The proposed KM model adopts a technological architecture that enables end-users to access and use the KMS repositories and services from different location inside and outside the organisation through internet connections. However, the KM model defines access authority levels for different end-users to help organisations to provide the required services to the right users and protect private and sensitive contents from unwanted intruders. For example, the KM model suggests authority limits to define the end-users' abilities to capture, retrieve, use and edit knowledge in the KMS repositories.

The KMS provides services such as help desk, online support and training sessions that aim at improving and supporting the effective and efficient use of the KMS and accelerating the spread of the required business processes across the organisational boundaries. These are designed to provide a flexible and accurate way of training and minimise the learning time of the new activities and procedures caused by the implementation of the KMS.

The KMS in use supports only one search function using keyword category. The system needs to be improved by adding more search functions or categories, such as project and expert categories, to help in refining search results and simplify and enhance finding required knowledge from the system repositories.

Using knowledge maps need to be improved in the KMS of the organisation so it can help to simplify retrieving and accessing required knowledge across the system. The yellow pages provided by the KMS is an important tool that presents general details about the people of the organisation to simplify finding and contacting people with the required experience to help in processes such as problem solving and decision making. Detailed information about each employee has been provided by the system that is helpful for managers, for example, when deciding which people have the desirable skills and experience to be appointed for specific tasks and functions in the construction projects.

The KMS services have been made available to the system end-users of the organisation through a portal which also provides a messaging (e-mail) service for the people of the organisation. The portal is the entry point to the company web site and/or internal company intranet. Generally, the portal helps users to locate knowledge from many resources more efficiently The portal is a key element in the organisation KMS and provides through usernames and passwords entry tool different access authorities and logging into different areas of the system repositories and services.

The portal interfaces of the case study organisation supplies up-to-date links to important contents of knowledge, such as the latest internal publications and/or reports, important company news and announcements, and messages and directions from the company's management. Also, links to the different services are provided through the portal interfaces to simplify finding, navigating and using the different tools and contents of the KMS. The interfaces have been designed to present a clear vision that helps end-users to easily know and reach available services and contents of the KMS. Functions or services that are provided by the KMS interfaces can be summarised as follows:

- Details about the company are provided in a '***Web Site'*** separated from the internal technological KMS of the organisation for the purpose of providing marketing contents and customer services. The web site provides news, achievements, projects, services, job opportunities and contact details and forms of the company. Furthermore, the web site provides key financial details to shareholders and potential investors. Subscribing for 'email news alerts' is a useful tool for shareholders and customers to receive news headlines of the organisation linked to more details for keeping interested people up-to-date with the recent company news and new contents on the company's web site.

- The first contact point for end-users is the '***Main Web Page'*** that gives the people of the organisation an access point to the knowledge system and defines authority and accessibility levels to the knowledge and services through a username and password access tool.

- When users log in to the main web page they view the ***'Home'*** page of the knowledge system that includes general details about the organisation and its projects, and shows the organisational vision, values and goals. It provides links to the services and tools available and authorised to end-users through the knowledge system. Using some services requires end-users to reinsert their usernames and passwords to establish if they have permission to use these services.

- The current knowledge system supplies a link to the old previous system that with time will be replaced with the user-friendly formats of the new system.

- A ***'Library'*** service is included in the knowledge system where knowledge resources and documents of the organisation are made available to be searched and viewed by the system end-users. These knowledge resources include reports, manuals, technical guides, standards, published works, best practices, innovations and links to useful web sites.

- The knowledge system includes '***News'*** service that introduces links to recent important company news and announcements, and other related recent industry news. This service also provides a link to archived news that allows end-users to search through previous news.

- The knowledge system allows its users to search for people of the organisation and find details of experiences and skills through the '***People'*** service. This service provides general information to help seekers to find and contact people who can help in processes such as decision making, problem solving and innovations. The managers of the organisation can access and view more details about the people of the organisation to help, for example, to appoint the employees with the required skills and experience for the different projects and operations. This service is integrated with the human resources management system (HRMS) that includes the full people's full CVs supported with searching tools to help find those people with the required characteristics.

- The system provides a list of the approved ***'Suppliers'*** combined with locations, contact details and services provided by them. The user can easily search and find the approved suppliers regarding the location of the project and the services required.

- The ***'Key reports'*** service provided by the knowledge system helps to store, categorise and retrieve all documents reported to or from regions' management head offices.

- The knowledge system provides a '***Project Document Management'*** service that is used in each project to manage the different types of documents used in projects. An '***Administration'*** service is also available to be used in managing documents of the organisation offices and departments.

- The knowledge system includes an '***Archive'*** service that provides links to archived documents and provides the ability to search and retrieve required knowledge.

- '***My Site***' is a service in the knowledge system that end-users can use to create their own profiles, list important links, and store and share files and knowledge with other users. Each user can create links to pages within the knowledge system that they find particularly useful and may be used regularly to simplify accessing and using them. The 'My Site' webpage is personalised to each user and can be adapted and customised by them according to their needs and preferences.

- The service called '***One-way***' supplies the required forms and procedures for the day-to-day business tasks and activities. This service works as a handbook and guideline to the company's processes, systems and management.

- '***Timex***' is the name of the service that provides a timesheet management tool to the organisation. It is the service where issues such as the time for sending bills to clients, employees' leave time and profitability calculations are managed. The service is to be improved to manage most of the company's financial issues.

- The ***'Help'*** service provides manuals to help to improve end-users' ability of using the system and gives end-users a clearer idea about the services available in the system, their importance for the organisation and employees, and how they can be used more effectively and efficiently.

- The ***'Regions'*** service provides links to the portals' home pages of other regions in the organisation. The company has applied separate knowledge systems for each region of the company, such as UK/Europe, Australia, East Asia, Germany and the Middle East regions.

Technological tools of knowledge sharing, capturing and retrieving are provided in the KMS through the system functions discussed previously, such as e-messaging, e-conferencing, e-discussion, file management systems, searching and full text retrieval tools. The system has been designed to be scalable, which means that it can be easily enhanced and extended through installing new tools, increasing size of repositories, and/or enhancing the design and performance of existing tools and services.

The proposed KM model presents KMS architecture that categorises the technological components of the KMS into five layers and shows the relationships among these layers to simplify understanding and adopting them in the construction organisations. This architecture highlights essential specifications of the KMSs and supports providing user-friendly interfaces, required help and support, and online training programmes, to accelerate the process of learning the activities and procedures of the KMS. The interface should be designed to provide a clear view that encourages end-users to know and use the services available in the KMS. The proposed KMS architecture shows how the system interfaces are the starting points that connect end-users to the other technological layers.

The KM model, supported with the questionnaire results, has shown that the KMS should provide knowledge and services to customers, partners and suppliers to help maintain good relationships with them. It proposes methods to simplify defining access levels to the KMS services and authority levels for using and editing knowledge in the KMS repositories.

The KM model also provides lists of KM technological tools, shown in Table 5.2, categorised according to their purposes to help organisations to satisfy the required functions of knowledge capturing, retrieving and sharing. These tools can help organisations to capture important knowledge from the organisational reports, projects' documents and also experiences, ideas and know-how of the organisation's people. They also simplify and encourage knowledge retrieval and use by using multi criterion searching tools, knowledge linking tools and data mining and analysis tools. Moreover, sharing knowledge can be enhanced by applying collaborative tools, such as e-messaging, e-chatting, video-conferencing, and through yellow pages and individuals' profiles. Other tools, such as knowledge maps and help desk, can be effective tools that motivate knowledge capturing, retrieving and sharing in the construction organisations.

6.3.2.4 Influential Factors

Implementing and applying a KMS in an organisation does not guarantee that it will be used effectively. Usually, people are unwilling to learn the new work methods and procedures that come with the application of KMSs. Therefore, the organisation should apply procedures and tools to promote cultural changes and achieve success. Motivations such as obtaining rewards and building reputation are used by the organisation to promote the people communication and collaboration, and to improve people's contribution to the KMS.

Applying motivations and promoting cultural changes within the organisation requires support and encouragement from the organisational management. Therefore, the organisation of the case study has developed what is called 'Professional Excellence Group' that includes a group of senior managers to lead the KMS. This group provides high level decisions related to the KMS, such as implementing new services, applying changes and improvements, and promoting KM activities and methods.

Another method adopted to promote KM practices in the organisation is by encouraging the development of Communities of Practices (CoPs) that helps people who may have similar interests and experiences to work together, to share knowledge and solve problems. The collaboration of the CoP's members is facilitated through KM tools such as discussion lists, web-site forums or other forms of virtual networking.

The proposed KM model motivates the development of KM groups, such as Communities of Practices (CoPs) and KM teams. Development of CoPs is encouraged by the KM model to motivate knowledge sharing, collaboration and trust among employees. Furthermore, the model encourages the creation of formal KM teams to handle activities of KM implementation and application, such as investigating KM resources, identifying opportunities of enhancements, capturing knowledge of external resources and previous projects to enrich the KMS repositories, and checking and approving knowledge contents added by other users. In the proposed KM model, more roles and activities of KM are appointed and identified to individuals such as knowledge workers, data workers and end-users. Examples of activities and responsibilities of each role are presented in the proposed KM model to simplify understanding and adoption of them by the construction companies.

Two major factors are identified in the organisation that may extremely affect the applicability of the KMS. These are the system speed when accessing and processing knowledge, and ease of use of the system services and contents. The amount of time that is required for knowledge retrieval and data analysis may encourage or hinder the use of the KMS. One example of a problem that is experienced by participants of the case study is that logging in to the main knowledge system, accessing the system applications, and using the system tools and services is too slow and that makes using the system more difficult and less productive.

One of the current interests of the IT team is how to minimise the amount of time required to log in and access the required services and tools. The employees have suffered difficulty in accessing the system and using its services from outside the organisation. For example, difficulties are encountered when the system automatically logs the user out if the system stays inactive for a period of time to ensure the security of the system. This security issue is important but should be designed carefully to ensure that users will not lose the knowledge they are viewing or entering when an automatic log out occurs.

Another issue encountered when searching for stored documents and drawings is that the user may retrieve many edited copies of the same document and it is not easy to know which is the latest revision. These problems often result in more time and effort by end-users to find required knowledge, or sometimes they choose to use the low productivity paper-based filing systems instead.

The people of the organisation have also encountered the problem of having to spend a long time uploading documents and drawings into the system repositories due to the low speed of connection and amount of fields required to be filled to categorise the knowledge for future searching and retrieving. Even when a document is updated or edited the same number of fields needs to be refilled. However, it is sometimes not easy to retrieve a document unless the end-user knows where to search, i.e. under which category, due to the inflexibility of using the categorisation fields through the search service.

When designing the information and communication network, the organisation should take into consideration the need to enhance the speed of internet connection due to the expected future increase in internet use and the need to use more complex system tools in the future that require more capabilities. The organisation of the case study have designed and implemented a communication network with capabilities that allow for future expansion in the system use and speed.

The proposed KM model and the results of the conducted survey show that the technological factors are highly affecting the success of KM adoption in the construction organisations.

Methods are suggested in the model to ensure high performance and applicability of the KMS. These methods include procedures such as applying user-friendly interfaces and services, using advanced technologies with high performance, removing outdated invalid knowledge from the system repositories, and providing help, support and training on using the KMS.

The participants were asked if reasons, such as the lack of IT skills, or the reluctance to share knowledge and considering it as a private property and source of power for the person who owns it, may negatively affect the successful use of the KMS. The responses showed that the organisation has dealt with these two issues by conducting IT training programmes and providing incentives and rewards to encourage people to participate in the system and share their knowledge.

The organisation is working on simplifying the use of the KMS by re-designing the system services and interfaces to be similar to software programmes that the people of the organisation are familiar with, such as the operating systems, internet (or web) browsers, spreadsheets, word processing programmes, presentation graphics software, data and documents management software, engineering drawing programmes, and design and planning software programmes. Using formats of interfaces that people of the organisation are familiar with can simplify and promote the use of the KMS and reduce the cost, time and effort required to learn using the KMS services.

6.3.2.5 Assessment of the Organisation's Existing KMS

The existing KMS is relatively easy to use through providing user-friendly and simple interfaces to its users. The existing KMS enhances employees' performance by simplifying business activities such as problem solving and decision making. It spreads business methods and procedures across the organisation to help streamline everyday business tasks and activities.

The KMS provides a central repository for knowledge where people can find the required documents and critical knowledge in one central location. The KMS also provides an easy to use singular communication platform that simplifies internal and external collaboration and enhances relationships with customers and partners whilst providing protection to sensitive knowledge. By using web-based technologies the system provides flexibility for end-users to find required knowledge and do the work tasks when and where they want.

In many circumstances the organisational staff may become familiar with some tools in the KMS while becoming reluctant to try and use other tools. Furthermore, it has been found that a number of employees in the organisation lack experience and knowledge of using computer systems.

The training courses are limited for some KM tools because the KM team members feel they lack enough resources in terms of time and money to provide sufficient effective training for every employee. They also lack a structured method to know and decide what subjects and aims are the most important in the training courses and how to decide which people are to be targeted with those programmes. To deal with the employees' lack of awareness and experience regarding the use of the computer systems, the organisation managers have decided to recruit more people with experiences in computer systems and to motivate the existing staff to become involved in the knowledge system.

The organisation may need to provide more effort to monitor the captured and shared knowledge to ensure and control its alignment to the general and organisational regulations, strategies and objectives. Furthermore, the organisation is recommended to apply rating and feedback systems to collect end-users' evaluations on the value of knowledge stored in the system repositories and on the KMS's performance and usefulness. The organisation also needs to enhance the ability of the KMS to capture, manage, link and attach photos, videos and drawings in order to clarify and add more value to stored knowledge contents.

Knowledge maps can be used more effectively in the organisation to provide a view of existing and missing knowledge before wasting time and effort on capturing knowledge that has already been captured in the organisation. Also, searching tools need to be enhanced by providing more characteristics to refine searching results and to retrieve the most recent revision of a document or drawing with links to older ones. Finally, the organisation lacks the adoption of a structured method for implementing and applying KM.

6.4 Case Study 2

CCC Group (Consolidated Contractors Company)

6.4.1 Background and General Information

CCC was founded in 1952 as one of the first Arab construction companies. To enhance its regional and international status, CCC has always been concerned with the adoption of new technologies to sustain suitable relationships with clients and better communication and coordination among different departments and locations of the Group. The adoption of KM methods and techniques provides the Group with the ability to improve the efficiency of work processes while providing more rapid execution and higher quality performance. Today, CCC Group employs more than 69,000 people, composed of more than 60 nationalities, in almost every country of the Middle East and Africa, with total revenues exceeded $2.1 billion in 2004.

Interviews were conducted at the Morganti Group Inc., a large U.S. construction company that was acquired by CCC Group in 1988. The Morganti Group, which currently completes $200 million of annual construction volume throughout the United States and the Middle East, is a full-service construction organisation that implements construction projects for business and industry, healthcare, education, water, sewage and refuse treatment facilities, all within several contractual arrangements, such as general construction, construction management or design/build contracts. The interviews were conducted with two senior engineers, a knowledge manager and a knowledge worker. The case study protocol, shown in Appendix 3, was used to direct the interviews in general. Findings are discussed in the following sections.

6.4.2 KM in the Organisation

KM is understood by the Group as storing and categorising knowledge of the organisation wherever it resides, such as in documents, specifications, reports, bills, drawings, photos, videos, memos and people's heads, in the KMS knowledge bases to be easily retrieved in the future. Furthermore, KM is about connecting people of the organisation by using tools of knowledge sharing to facilitate discussions, collaborations and coordination.

CCC group has implemented and applied a computer-based KMS called 'Visual Byblos Cyberspace (VBC)'. VBC is a computer-based KMS that provides collaboration tools and a Document Management System. The Document Management System is used to make an inventory of blue prints, memo letters, emails, and transactions that are between the company and the clients or consultants in construction projects. By capturing and managing knowledge into the repositories of the KMS, the organisation can help its people to find required knowledge more easily to improve business activities such as problem solving, decision making and training of employees, especially junior engineers. This may help the organisation to reduce the time and effort required by individuals to learn rather than having to learn throughout the long duration of projects' life-cycles.

6.4.2.1 Knowledge Resources

Every individual in the organisation is considered by the organisation to hold valuable knowledge, and most of this knowledge has not been yet captured in the organisational systems. This knowledge can be lost from the company if it is not managed, shared and stored successfully. Data, information and knowledge of a number of previous projects has been collected and stored to enrich the repositories of the implemented KMS.

The organisation looks at knowledge in two different ways. The first considers knowledge as an object that can be located in documents to be captured and stored in the organisational computer-based systems' repositories to enable the system end-users to retrieve and reuse. The second method considers KM as collaboration and communication process facilitated through Communication Technologies and the creation and motivation of Communities of Practices (CoPs). Technological tools were installed in the organisational KMS to support both methods.

The proposed KM model provides a more useful method by categorising knowledge of the organisational people into implicit knowledge that the organisation has decided to capture, and tacit knowledge that cannot be captured or the organisation has not yet decided to capture, but sometimes it is useful to share it through collaborative tools of the KMS.

Furthermore, the KM model helps to understand and manage other types of knowledge, which include explicit knowledge that is coded and easy to be captured in the KMS, and combined knowledge, which is stored in the KMS repositories and can be reused and updated by the system end-users. The KM model categorises knowledge into types that are important to be managed in successful KMSs. The KM model categorises the technological tools in KMSs according to the functions that the tools are supporting the most, which includes capturing, retrieving and sharing of knowledge, while a fourth category is used to represent tools that may strongly support more than one function.

6.4.2.2 Processing Activities and Roles

KM managers and knowledge workers have been appointed roles to capture, store, categorise, approve, and motivate the creation of new knowledge in the construction projects. The knowledge workers provide support, encouragement and training programmes to the employees, both in the construction projects and in the organisation offices, in order to motivate an effective use of the KMS and sharing of knowledge among employees. Training programmes are conducted to enhance the employees' awareness about the future advantages of capturing and sharing knowledge. Support is provided for the organisational employees on using the KMS tools and services in order to reduce the time and effort required by employees to learn the new procedures.

Furthermore, the organisation has appointed KM teams that consist of experts and senior managers. These teams are responsible for decisions that define KM strategies, plans and improvements. They are also responsible for making visits to the construction projects in order to evaluate the performance, applicability and usefulness of the KMS, make decisions of enhancements and provide support if required on the use of the KMS. Another role of the KM teams is to evaluate the validity of the knowledge contents in the system repositories and to encourage updating knowledge.

The proposed KM model suggests procedural processes that help organisations to identify required roles and activities for successful implementation and application of KMSs. It proposes a useful method of embedding KM roles and tasks, such as capturing and reporting best practices and problem solutions, into the normal routines of business processes. KM roles of knowledge workers are proposed in order to promote storing documents, capturing and sharing experiences, categorising contents, and providing support for end-users. Furthermore, the KM model proposes roles for KM teams in order to monitor and evaluate the use and performance of the KMS; investigate shortcomings and opportunities; decide, plan and implement improvements; decide and provide access authority levels; provide training and support; and approve, edit, combine and update knowledge contents. Finally, other roles of knowledge capturing, retrieving, re-using and suggesting updates are provided to other end-users.

The organisation implemented and applied the KMS according to a continuous procedural process described by the interviewees, and represented in Figure 6.2. One of the methods used by the organisation to evaluate the usefulness of the KMS was by utilising the organisation databases to compare information of a number of projects before and after applying the KMS, such as cost per unit of activities and projects, time delays in projects' completion and quality of finished work. For example, the quality of finished projects can be evaluated by using measures such as the number and significance of the notes in the project submission reports. Engineers and managers have found that many problems associated with projects could be avoided and the best solutions could be found for these problems through applying the KMS.

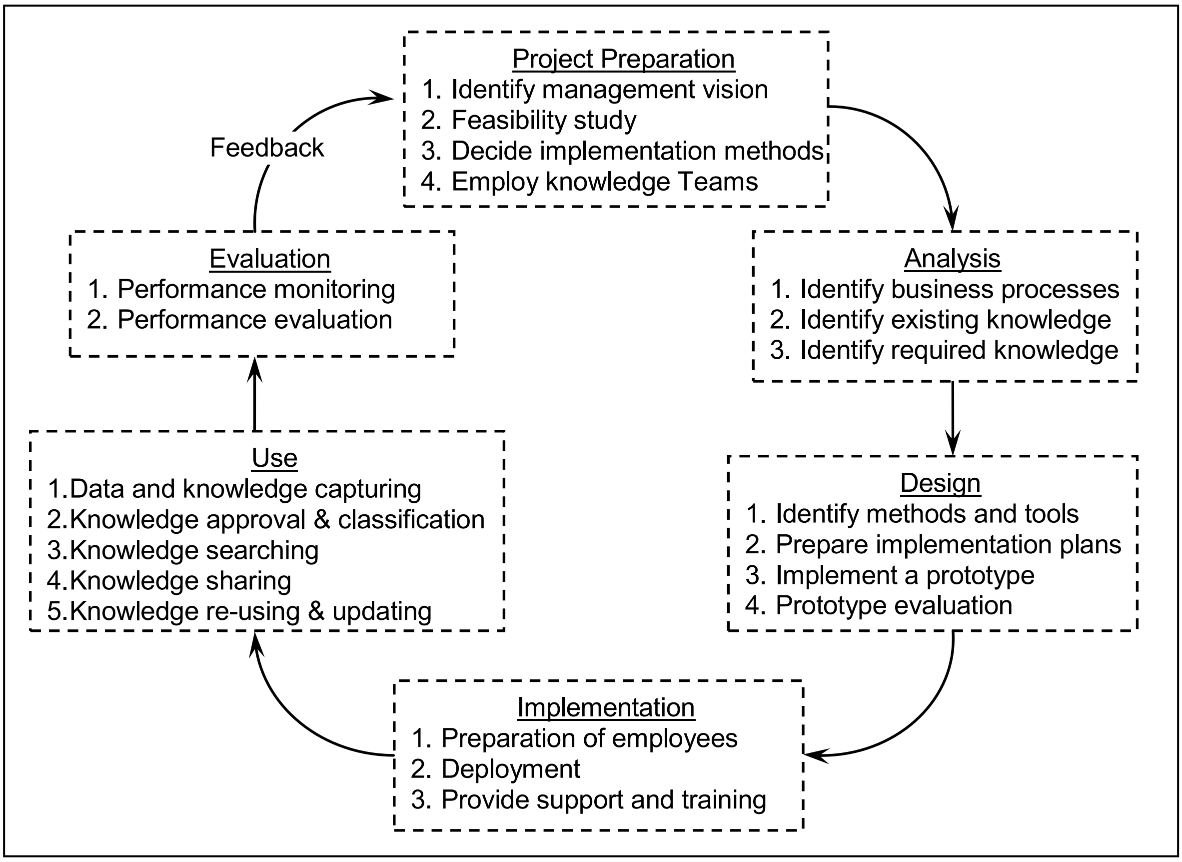

Figure 6.2: Procedural Process for KM Implementation

The existing KMS has been described as an effective tool for decision making. The role of applying the KMS in the process of decision making has been described by the participants and represented in Figure 6.3. It demonstrates how KM tools can help in the process of decision making and lead to creating new knowledge. This newly created knowledge will be stored in the knowledge base and reused in the future to solve similar problems. This reduces time, cost and effort of reinventing solutions that have been created previously in the organisation.

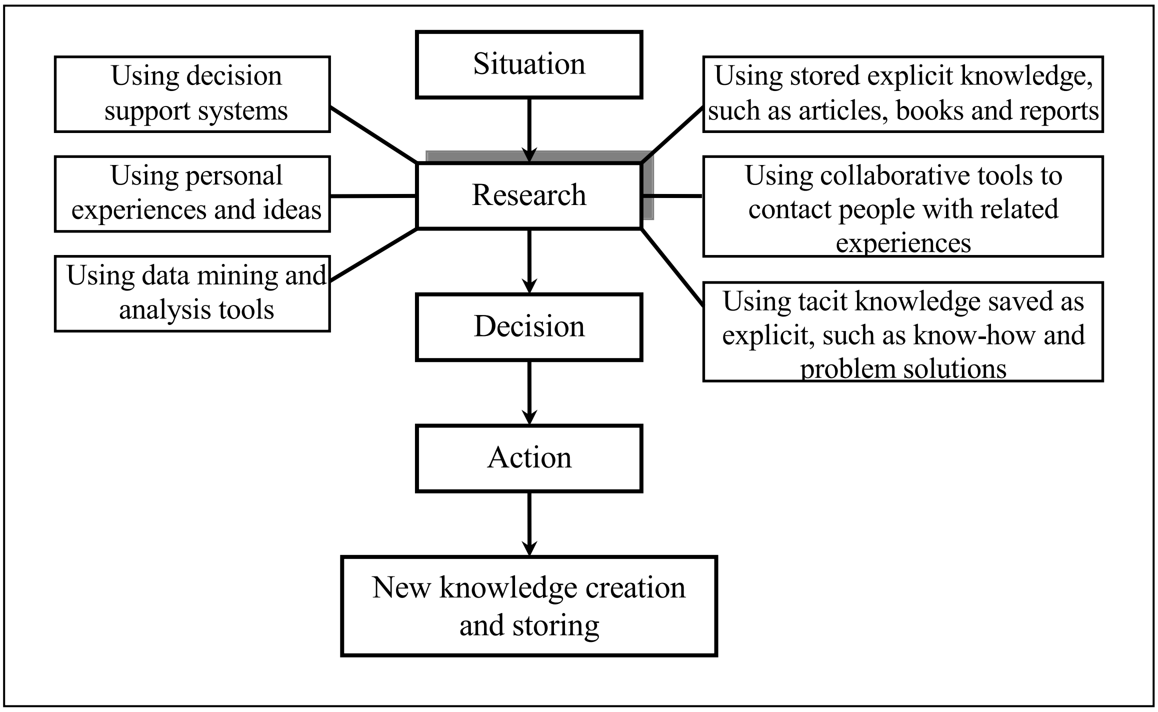

Figure 6.3: The Role of KM in Decision-making

The proposed KM model represents a continuous process of major components. Every component in this process is detailed with sub-components that also provide continuous structured minor processes and activities for KM implementation and application. The KM model suggests monitoring the use and performance of the KMS, and evaluating the KMS by capturing and analysing feedback of end-users and/or defining measures to evaluate KM benefits. Also, the model discusses procedures of processing and transforming knowledge into more valuable formats, and shows how the continuous process of KM can be useful to update and re-validate both the KMS and the knowledge stored in its repositories.

6.4.2.3 System Architecture and Tools

The organisation has adopted a KMS with a user-friendly interface that provides end-users with an overview about the existing services in the KMS. The system is basically designed in formats, which are similar to the formats of other common programmes and that the end-users are familiar with. Figure 6.4 shows the main interface of VBC that provides links to the services provided in the KMS.

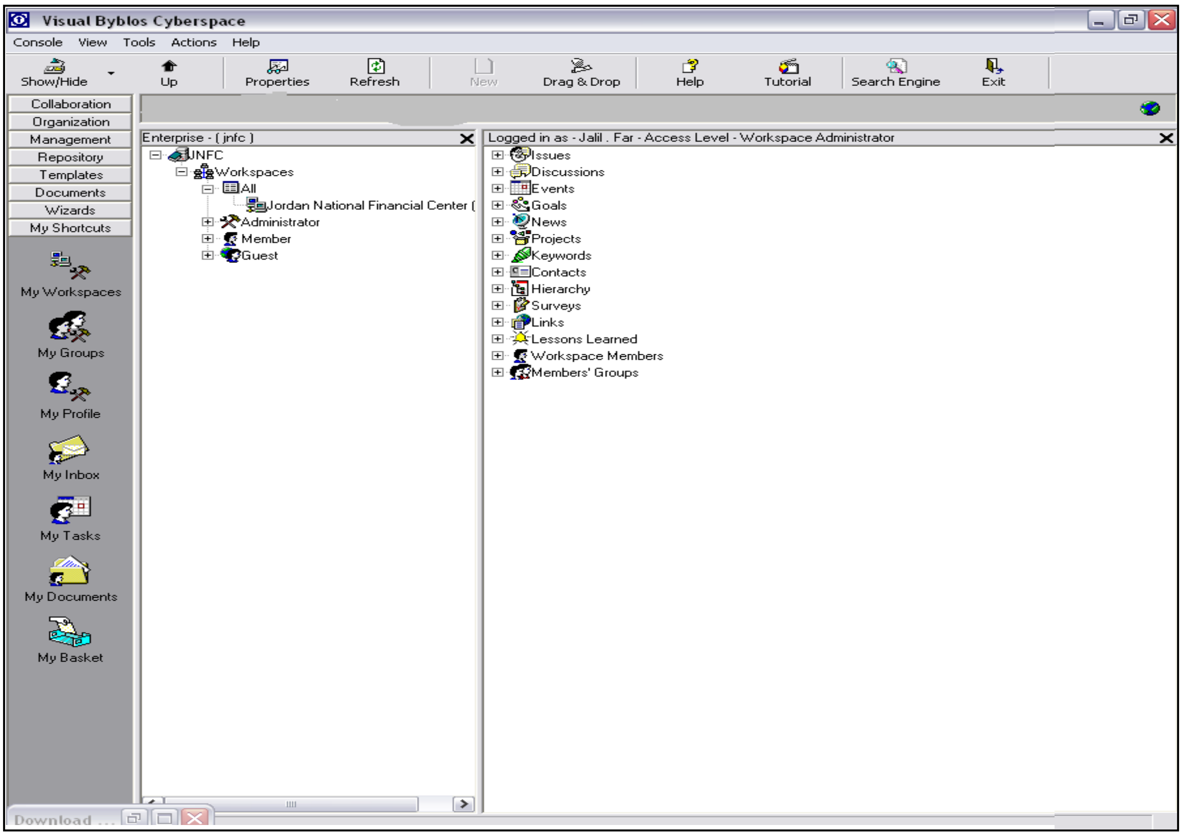

Figure 6.4: Main Interface of the KMS

As described by the interviewees and also can be seen in Figure 6.4, the KMS provides services and tools that can be summarised as follows:

- VBC '***Drag & Drop***' tool provides an easy straightforward way to capture knowledge from the different formats of electronic files available and used in the construction projects. Storing any file in the system repositories requires filling a form that automatically appears to collect characteristics and keywords about the file to simplify future retrieval.

- '***Help***' and '***Tutorial***' services are available to provide guidelines and support for the KMS end-users.

- The '***Search Engine***' service provides the ability for end-users to search keywords rather than the need to use knowledge maps. This method is useful when an end-user finds difficulty in identifying the category in which the knowledge can be found.

- The KMS is supported with two types of '***Maps***' that provide links to other people and services in the system. The first map represents the end-user place and position in the organisation, which are required to define the authority levels of accessing and using knowledge and services of the KMS. The second map provides links to other services of the KMS that help end-users to find the required knowledge and people. The map is designed to provide links to other sub-maps that can help find knowledge and people through different categorisation methods, such as using names, locations or identification numbers of projects or departments; using name or description of activities or materials; using titles, key words, authors' names or file formats of documents or knowledge contents; and using names, positions, locations or experiences to locate people. Also, the map provides links to knowledge in the form of news, projects' documents, experiences and lessons learned.

- Furthermore, the map provides links to collaborative tools such as '***e-messaging***' tools to help end-users to find people with required experience and discuss subjects for problem solving and decision making.

- The KMS enables users to create their own '***profiles***' to show general information about their backgrounds, experience and interests to encourage knowledge sharing and collaboration within the organisation.

- The KMS provides tools that help end-users to manage their job tasks, schedules, files and documents, such as '***my tasks***', '***my documents***' and '***my basket***' tools.

- The system uses a technique that helps knowledge workers to save all the revisions of a document in one place, and shows the latest revision when retrieving the document with links to older revisions if needed.

The proposed KM model categorises KM technological tools and services according to the functions the tools support, such as knowledge capturing, knowledge retrieving and knowledge sharing. The KMS functions proposed in the KM model covers all the tools discussed in the case study. For example, knowledge capturing tools include the 'Drag & Drop' tool; knowledge retrieving tools include the 'Search Engine' tool; knowledge sharing tools include the 'e-messaging' and 'profiles' tools; and other tools serve general functions or more than one of the previous functions. The KM model encourages the application of tools that provide support and training to end-users to accelerate the learning process of the KMS. Also, the model supports providing categorisation characteristics to the knowledge stored in the KMS repositories to simplify retrieving it when required.

Knowledge maps are encouraged in the proposed KM model because they provide a structured method for capturing, categorising and retrieving knowledge. They can also help in providing an overview about the knowledge available and missing in the KMS repositories. Knowledge maps also can be useful tools that provide links to different services of the KMS and can also provide links to search and contact people with required experience and background. Authority levels are proposed in the KM model to simplify defining them for different end-users in the organisation. More details are provided in the KM model to provide an overview of required technological components and specifications and to deal with issues such as system security and applicability.

6.4.2.4 Influencing Factors

The interviews of the case study show important challenges for applying the KMS in construction projects. The resistance of employees to learn new methods of using the KMS, to share their knowledge with others and/or to accept solutions from others are major problems that may negatively affect the KMS. Privacy and copyright issues can sometimes prevent useful knowledge from being captured and shared in the KMS. The tendency of many employees to hoard their mistakes minimises the ability to learn from these mistakes and to avoid them in future projects. Finally, the pressure to finish construction projects during a relatively tight schedule makes the projects' people feel they lack the time to use and add to the KMS.

The proposed KM model discusses the factors that might affect KM adoption in construction organisations. The model categorises the environmental factors to help identify them in the construction organisations. Adequate details are provided in each category to better represent possible environmental problems and solutions in the KMS. These help the organisation to follow procedures and apply activities in order to motivate KM efforts and mitigate the effect of KM barriers.

6.4.2.5 Assessment of the Organisation's Existing KMS

The existing KMS uses interfaces and formats similar to other programmes that end-users are familiar with. 'Help' and 'Tutorial' services are also used to enhance performance and reduce the time required to learn how to apply the KMS more effectively. The existing KMS enhances the processes of knowledge searching and retrieval, and solves the problems of the old paper-based filing systems. The system includes technological tools to manage both tacit and explicit knowledge. Using knowledge maps is very important in the KMS to provide a useful representation of available services, knowledge resources and people experiences and contact details. Using web-based technologies provides end-users with time and place flexibility to find required knowledge and carry out the work tasks.

Although technological tools are available to capture tacit knowledge, the application of this process is still unsuccessful and the tools are not used by the employees in many regions of the organisation. There is still a need for the organisation to provide more time, incentives and awareness programmes to encourage tacit knowledge capturing and sharing among employees. Embedding KM activities into the work procedures may encourage capturing experiences such as best practices, problem solutions and innovations. The organisation also needs to enhance the employees' awareness regarding the importance of using data and information from the organisational databases to create new knowledge. Although the organisation monitors and evaluates the KMS through the KM teams, there is still a need to adopt a structured method for collecting feedback from end-users and to adopt measures for evaluating the KMS's usefulness and performance. The organisation lacks the adoption of a structured method for implementing and applying KM.

6.5 Evaluation of the KM Model

Participants from the case studies were asked to study the research proposed KM model and provide feedback and evaluation in terms of its usefulness and usability. Interviews with two junior engineers, four senior engineers, two knowledge workers and a knowledge manager have been conducted on construction sites and companies' offices to discuss and collect their opinions and to provide evaluation of the proposed KM model.

The interviews use open-ended questions, such as what benefits can be provided by the KM model; what problems in the existing KMS can be solved by applying the proposed KM model; what benefits can be provided by the evaluation and feedback system supported in the proposed KM model; how easily the proposed KM model can be used and applied; how easily different types of knowledge can be managed; how important is applying the proposed KM model in processes such as decision making, problem solving and innovation; how useful are the services and tools in the proposed KM model for end-users of the KMS; and what problems or difficulties can be faced in adopting and using the proposed KM model. Suggestions and recommendations from the interviewees have been provided. Findings are summarized as follows:

- Applying the proposed KM model can provide a great opportunity for KMS end-users to learn from previous projects and avoid repeating mistakes. Its application will result in producing a KMS that assists users in processes, such as decision making and problem solving. The KM model can help companies to gain competitive advantages by reducing cost and time of work completion while maintaining better quality of products and services compared with competitors.

- The proposed KM model describes tools that help to provide KMS with the ability to capture people's experiences, know-how and perceptions. This helps organisations to solve the problem of losing the knowledge and experience of engineers and experts when they leave and helps to keep their knowledge within the organisational knowledge bases. This knowledge can be combined with other types of knowledge and can be used to provide training for junior engineers in a relatively short time, rather than the need to spend a long time during the projects' life cycles. One of the essential KM tools supported by the KM model is the use of knowledge maps, which is a powerful tool for providing an overview of existing and missing knowledge in the system repositories and facilitates finding appropriate knowledge and experts for problem solving and decision-making.

- The proposed KM model promotes collection of feedback from the system end-users to evaluate the KMS in use, and to capture useful suggestions to fix problems and implement improvements to the existing KMS.

- The proposed KM model is relatively easy to understand and use. It is categorised into sections; a way that allows users to find and understand required details without the need to go through all other details in the other sections.

- The proposed KM model helps the organisations to identify different types of knowledge that may require different procedures to process and manage. Identifying and categorising important types of KM resources helps organisations to identify and design the required tools, processes and methods for successful use and management of these resources.

- The KM model is found to be important and useful in the sophisticated environment of construction projects where many interrelated components work together in a complex manner. It supports and promotes activities of knowledge sharing, group discussions and collaboration, which are very useful in processes of problem solving, decision making and innovation.

- The proposed KM model represents the required components, the important relationships among the different components, and the flow of knowledge from one part to another in the KMSs. It also helps to understand and simplify the complexity of the real KMSs.

- The proposed KM model promotes appointing KM teams and knowledge workers to manage and handle KM activities such as knowledge capturing, documents digitising and adapting, and contents monitoring and updating. It represents the different roles required for a successful implementation and application of the KMS.

Evaluation of the proposed KM model has been carried out by obtaining feedback from the participants on its characteristics. The results provide evaluation of the KM model in terms of its usability and usefulness. The model usability includes specification issues relating to the ability of using the KM model, such as ease of use, systemisation, comprehensiveness, reliability, appropriateness, applicability and sufficiency. The model's usefulness includes assessment of benefits that it can supply to readers and users, such as providing guidelines for KM implementation and application; helping to understand KM concepts and its importance; leading to apply KMSs that enhance knowledge sharing, creation, capturing and updating; and helping organisations to decide required tools, processes and methods to enhance their existing KMS.

The evaluation was captured by using questionnaires that use six levels of rating scale, where 1 stands for strongly disagree and 6 stands for strongly agree. The results show that the weighted average score is 5.17 for the KM model usability and 5.11 for the model usefulness, which indicate that the respondents favourably agree that the KM model is applicable and useful. The KM model evaluation results are illustrated in Figure 6.5.

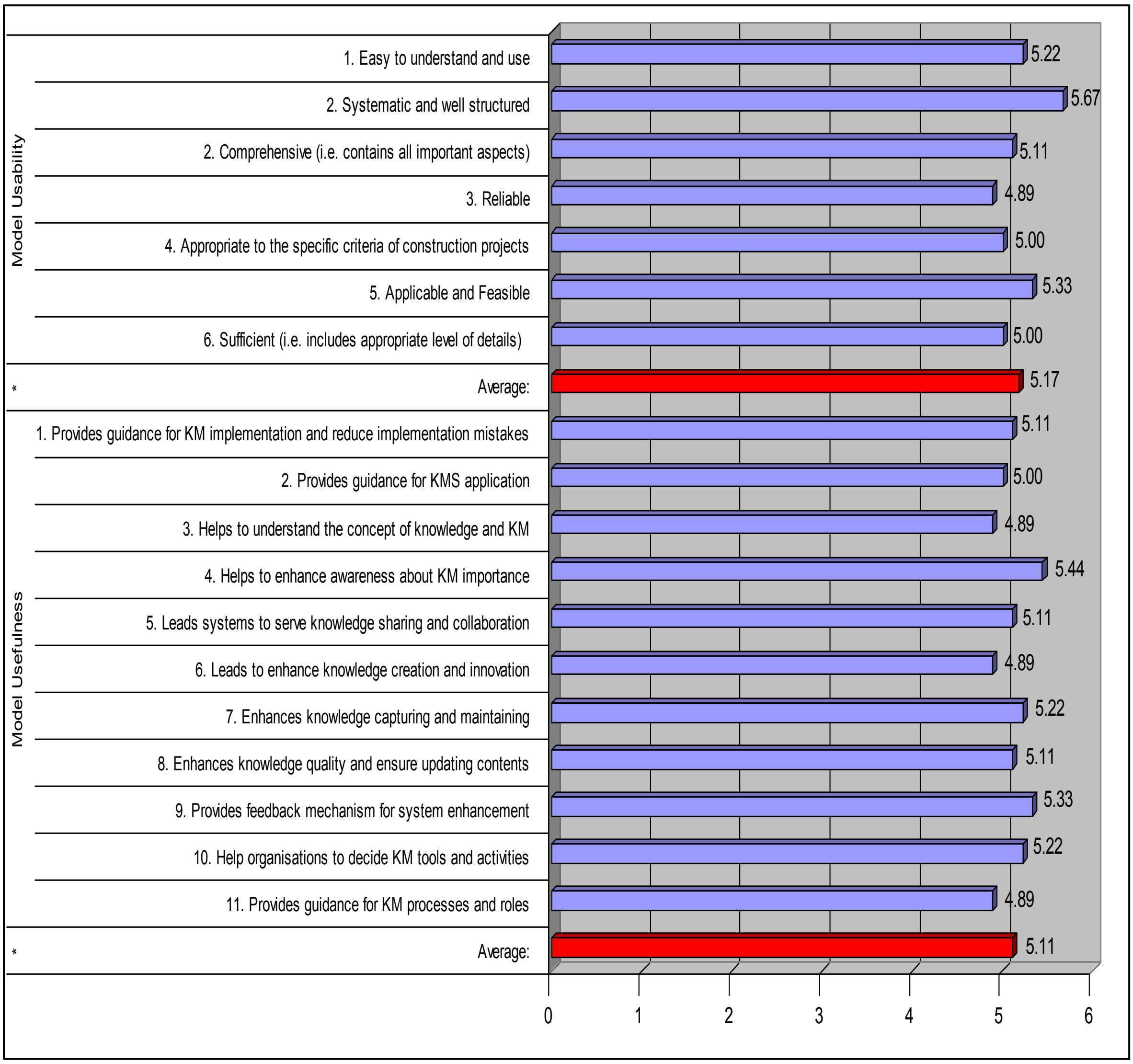

Figure 6.5: KM Model Evaluation Results

In terms of the proposed KM model's usability, the respondents have indicated that it provides a highly systematic and structured method that is adequately applicable and feasible for KM implementation and application in construction projects. The results also show that the KM model provides adequate level of details, which are categorised, organised and well represented in a way that makes it easier to understand and use.

In terms of the proposed KM model's usefulness, the respondents have indicated that it helps to increase the awareness of people and organisations about KM importance, and helps construction organisations to decide required KM tools and processes. The results also show that it provides useful methods and mechanisms that help organisations to collect feedback from end-users for system enhancement, and help to enhance capturing, maintaining and updating knowledge in the KMS repositories.

6.6 Summary

This chapter presents two case studies that aim at investigating and demonstrating the usability and usefulness of the proposed KM model for construction organisations. A case study protocol, shown in Appendix 3, has been used to guide the interviews with ten participants from the two companies. The interview questions aim at capturing background information about the participant companies and individuals; investigating existing KM resources, KM practices, environmental factors and technological tools; and finally, evaluating the proposed KM model in terms of criteria to measure its usability and usefulness.

The KMSs have been investigated in the two participant companies in terms of their adopted methods of categorising and managing knowledge resources, appointed KM processing activities and roles, implemented architecture and tools of the KMS, and applied procedures for dealing with environmental factors. The results showed useful methods, procedures and tools of KM adopted in the two companies. However, comparisons between the existing KMSs of the case studies and the methods, procedures and tools in the proposed KM model show that the application of the KM model can enhance KM adoption in the two companies and also in other construction companies.

The comparison results show that the KM model covers all the KM aspects in the participant companies, while providing more useful characteristics. One of the KM model's characteristics is that it provides more categories for knowledge resources that help organisations to better understand and manage knowledge formats. Another characteristic is that it presents more detailed and structured KM activities and roles that enable organisations to identify required KM processes and people to manage the different types of KM resources in a continuous process. Furthermore, the KM model supports technological architecture that assists organisations in identifying required technological components of the KMS, and enables end-users to easily use the KMS from different locations while protecting private and sensitive knowledge. Finally, the KM model provides a list of environmental factors and suggests environmental activities and procedures to motivate KM efforts and mitigate the effect of KM problems and barriers.

Evaluation of the proposed KM model, by nine participants of the case studies, has been conducted to collect opinion and feedback and to evaluate it in terms of usability and usefulness. The feedback from the participants indicates that the application of the proposed KM model in construction organisations can motivate knowledge capturing, sharing and re-using, and thus enhance and accelerate organisational learning. The participants also have indicated that the KM model provides a useful mechanism for feedback collection to enhance the existing KMS.

The participants have indicated that the KM model provides adequate components and details, while organising the components into main sections to simplify understanding and following. Providing detailed and structured KM processes, roles and tools helps the organisation to identify required procedures and components during the implementation and application stages of the KMS life-cycle. The evaluation results have shown that the users of the KMSs in the participant companies favourably agree that the proposed KM model is highly usable and useful.

This chapter presents the results of two case studies, which are conducted to investigate KM application in construction companies and to evaluate the usability and usefulness of the proposed KM model in construction projects. The next chapter will discuss the final findings and achievements of this study, and provide recommendations for future research.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The research has achieved its main goal of developing an integrated comprehensive KM model by following a process of research methodologies. The research has proved that the proposed KM model can successfully help construction organisations to enhance KM adoption. The achievements of this research can be summarised as follows:

- The objective of providing required background to simplify understanding and developing the KM model of the research and to identify the various areas of KM that may require more research and investigation has been achieved. This has been accomplished through conducting an extensive review of KM literature that highlights KM concepts and discusses technological, cultural and managerial aspects of KM implementation and application in the context of construction projects. The research has started with an investigation of important KM principles, methods, tools and techniques. Then the research has investigated the unique features of construction projects and discussed the associated motivations and challenges affecting KM adoption in the knowledge-intensive environment of construction projects.

- The objective of investigating shortcomings of existing KM models has been accomplished through an extensive review of sufficient number of KM models in the literature. This has helped the researcher to investigate problems of existing KM models and identify opportunities for improvements. The results have shown that, although many KM models have been developed to enhance the adoption of KM in organisations, those models still have many shortcomings that prevent them from being used successfully in construction projects. For example, many of these KM models may lack necessary components and processes of KM or may not consider the special characteristics and situations of the project-oriented construction organisations. Most KM models fail to provide a structured method for KM adoption, while others lack successful methods and procedures for dealing with the different types of knowledge and fail to fulfil the requirements of end-users and organisations in the construction industry.

- A preliminary KM model has been developed on the basis of reviewing and analysing KM literature to identify the main components required in the proposed KM model. The review and analysis of previous KM models has helped to address the key characteristics required in the KM model in order to overcome shortcomings of other models and to provide a useful method for KM in construction projects..

- Further effort has been made to accomplish the aim of transferring the preliminary KM model into a final, refined, improved KM model. Interviews and questionnaires have been conducted with a sufficient number of people who have wide experience with KM implementation and application in construction projects to evaluate the proposed KM model and explore more important components and details. The incorporation of recommendations and findings resulted from the questionnaires, interviews and further review of KM literature has helped to refine and enhance the proposed KM model in terms of ease of use, comprehensiveness, usefulness, reliability, applicability and alignment with the characteristics of construction projects.

- A final enhanced KM model has been developed to fulfil the research objectives of providing a structured and practical method for KM implementation and application in construction projects. It includes all important components with sufficient details required for a successful adoption of KM in the construction organisations. It can solve problems of previous KM models, such as the lack of important KM activities, technological tools or influential factors; the non-alignment with characteristics and requirements of the construction projects; the lack of an appropriate method for knowledge identification and categorisation; the absence of the required roles of KM teams, workers, end-users and Communities of Practices (CoPs); and lack of providing methods for KMS evaluation and feedback collection. The proposed KM model provides a classification of knowledge resources that shows more types of knowledge resources and provides clearer process for managing them. The KM model provides a clearer map and useful guideline for appropriate KM processes and tools in construction projects.

- In order to fulfil the aim of the research to evaluate and validate the developed KM model in terms of its usability and usefulness, an extensive investigation of KMSs through two case studies has been conducted in the construction industry. Evaluation results obtained from an adequate number of KM practitioners and experts in the case studies have shown that the KM model is favourably recommended for its applicability and usefulness in construction projects. The case studies have provided useful understanding and clarification of KM practices, and have shown how the proposed KM model can be used to enhance existing KMSs.

The conducted research, the developed KM model and the achieved results and findings have received high interest from researchers and experts in the KM and construction domains, especially throughout the presentation of the study in a number of subject-related journals and conferences. It was stated by many reviewers and participants that by applying the methods, procedures and tools of the proposed KM model, knowledge can be managed more effectively and efficiently in the construction projects.

7.2 Recommendations for Future Research

The proposed KM model of the research is designed to provide a useful structured method that solves problems of other models, and facilitates and encourages KM initiatives to help to successfully adopt KM in the construction projects. However, as with any other research, recommendations and suggestion for further investigation, improvement and refinement of the proposed KM model are provided in order to improve the implementation and application of KM in the construction organisations.

This study provides a platform for further development and modification of the KM model so that the proposed KM model can be used in practice more efficiently and effectively. More efforts can also be conducted to enhance the awareness of SMEs in the construction industry about the importance of KM to encourage more implementation and application of KMSs in this sector.

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APPENDICES

Appendix 1.
Interviews Form

Evaluation of a Knowledge Management (KM) Model for Construction Projects

A. Background and General Information

Name:
Address:
Date of Interview:
Position:
Experiences in KM:

B. Knowledge Management

1. What do you understand by the term KM?
2. What is the stimulus/reason for practicing KM?
3. What activities are important in KM?
4. What are the results and outcomes required from the implementation of KM?
5. Are there any other issues that you would like to mention regarding KM?

C. Model Evaluation

I would be grateful for your comments on the following KM model with regards to criteria such as ease of understanding and use, comprehensiveness, applicability, feasibility, structure, etc.

This model is designed to help firms taking the first step into KM or those trying to improve their existing system, by providing a general guide for construction organisations to identify what knowledge is available and important to their organisations and where it is found, what stages and activities can be followed to develop and apply a successful KMS, what tools and services can be provided by an effective and efficient KMS, how users can benefit from the KMS, and what challenges and factors can be faced throughout the implementation and application of a KMS. This model can be considered as a general guide for construction organisations, while more specific details will be left to be decided by the organisations to support their special characteristics.

The main components of the KM model developed in the research are shown in Figure 1, where more details and descriptions of the components will be provided in the following sections.

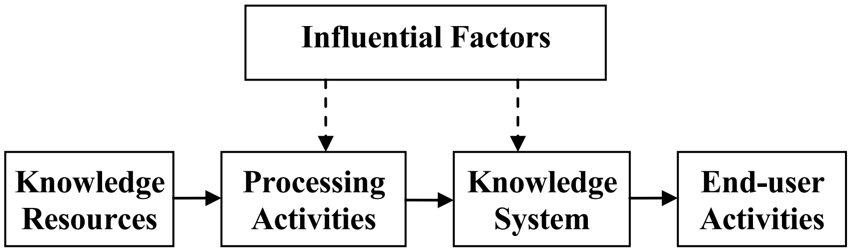


Figure 1 *Components of the proposed KM model for construction projects*

1. Knowledge Resources

Many different types of knowledge are available inside and outside the organisation to design and implement the KMS and to be captured and shared by the implemented system. The success of a KMS depends largely on the way in which an organisation identifies the important knowledge resources available.

(The details and descriptions of the KM model depend on the updated version that was developed at the stage of sending the letters to the participants).

Appendix 2.
Questionnaire Survey

Appendix 2.1 Questionnaire web-page

Was Available online before 26 October 2009

SURVEY ON KNOWLEDGE MANAGEMENT (KM) IN CONSTRUCTION COMPANIES

INTRODUCTION

Knowledge Management (KM) is a process that helps organisations to create, organise, store, use and share information and expertise necessary for activities such as problem solving, dynamic learning, strategic planning and decision making. **Knowledge management systems** refer to a type of IT-based information systems developed to include information, documents, knowledge, experiences and perceptions of employees and to facilitate collaboration of employees through e-messaging, e-chatting and other tools. The aim of this survey is to capture the initiatives for KM and investigate the critical success factors for implementing knowledge management in the construction industry. You are kindly requested to participate in the survey. This will not take you more than 15 minutes to complete.
This survey is not aiming to capture any commercially sensitive information. Nevertheless, all information will be treated as strictly confidential with full anonymity to participating organisations.

INSTRUCTIONS

This questionnaire ask for your opinion about KM in general and also KM system in your organisation. The answers will depend on your own judgement that comes from your experiences in this domain.

Note: If you do not know or are unsure of how to respond, please leave boxes blank.

Note: If your company does not practice knowledge management system please go to Section 4.

SECTION 1: GENERAL INFORMATION

This section seeks general information about you and your company. This information is used only to analyze the results of the submitted questionnaires. It will be treated as strictly confidential.

1. Company Name:
2. Your Name (Optional):
3. Job Title:
4. Your Location:
5. The number of employees: (Please choose from the list)
6. How do you best categories your company? (Please choose from the list)
   If other, please specify:
7. When did your company start to implement knowledge management? Year

SECTION 2: KM ACTIVITIES, TOOLS AND PROCEDURES

This section seeks activities, procedures and tools of KM in your company

8. Which of the following KM activities and methods has implemented or used in your company, and please indicate the level of importance for each activity or method for successful KM implementation.

IMPLEMENTATION		
1	2	3
Not implemented	Prototype or Small scale implementation	Large scale implementation

IMPORTANCE					
1	2	3	4	5	6
Not important at all	Slightly important	Moderately important	Important	Very important	Extremely important

ACTIVITIES & METHODS	IMPLEMENTATION 1	2	3	IMPORTANCE 1	2	3	4	5	6
A1. System Analysis									
1. Conducting questionnaires and/or interviews with employees	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Identifying business processes and procedures	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Identifying data & knowledge available and important for the organisation	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Identifying what tools appropriate for KM system	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Other (please specify)									

A2. System Design

1. Defining aims and objectives for KM
2. Using KM models to represent KM activities, methods, and components
3. Preparing an action plan and guidelines for KM implementation
4. Other (please specify)

A3. System Implementation

1. Implementation of a Prototype before applying wide range KM system
2. Appointing KM offices to provide training and support to employees
3. Embeding KM activities into employees' work processes and activities
4. Other (please specify)

A4. System Maintaining and Monitoring

1. Collecting feedbacks from end users regarding improvement requirements
2. Observing the differences in operations after implementing KM
3. Monitoring the system performance and showing bottle necks
4. Monitoring the environmental factors such as management strategy, employees culture and technological factors
5. Other (please specify)

A5. System Evaluation

1. Investigating business process improvements
2. Evaluating the system correctness and Alignment with design specifications
3. Evaluating the system usefulness, ease of use, and applicability
4. Other (please specify)

A6. Knowledge Capturing and Storing

1. Recording problem solutions & experiences in electronic repository
2. Referring knowledge to its sources (experts, books, articles or websites)
3. Recording new ideas and perceptions of experts and engineers
4. Attaching pictures, videos, and text files to clarify knowledge contents
5. Other (please specify)

A7. Knowledge Reusing and Sharing

1. Using the intranet to share and transfer knowledge
2. Using searching tools to find required knowledge
3. Showing contact details and experiences of the employees
4. Other (please specify)

A8. Knowledge Reviewing and Approving

1. Using the intranet to publish and edit knowledge
2. Reviewing knowledge contents by experts or a knowledge team
3. Classifying knowledge to facilitate knowledge searching functions
4. Other (please specify)

A9. Using Databases to create Knowledge

1. Capturing data and information of projects in electronic repository
2. Using Data Mining, Data Analysis, and Reporting tools
3. Recording knowledge and information concluded by using previous tools
4. Other (please specify)

A10. System Tools	1	2	3	1	2	3	4	5	6
1. User manuals and help desk	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Data Mining, Analysis and Reporting	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Document Management	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Photos and/or Videos Management	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Training and Support (E-learning)	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Knowledge Searching	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Knowledge Map (graphical presentation provides overview and sometimes links to existing knowledge and domain experts)	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Yellow Pages and/or Contact Details	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Subscribing and/or Password Interring to define authority level	☐	☐	☐	☐	☐	☐	☐	☐	☐
10. E-Meeting, Messaging, Chatting and Discussion board/forum	☐	☐	☐	☐	☐	☐	☐	☐	☐
11. Decision support systems and/or Intelligent agents	☐	☐	☐	☐	☐	☐	☐	☐	☐
12. Other (please specify)									

SECTION 3: CRITICAL SUCCESS FACTORS

This section seeks your perception on the importance of factors for successful KM in your company.

9. Which of the following statements can be used to describe the KM system in your company? Decide the level of importance for each statement for successful KM system in general? Please use this scale:

Describe your company' knowledge system			IMPORTANCE					
1	2	3	1	2	3	4	5	6
Not describing at all	Moderately describing	Extremely describing	Not important at all	Slightly important	Moderately important	Important	Very important	Extremely important

FACTORS	Describing knowledge system in your company			IMPORTANCE					
	1	2	3	1	2	3	4	5	6
F1. Culture									
1. A culture that values knowledge seeking and problem solving	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Providing time to employees to perform knowledge related activities	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Encouraging collaboration and teamwork among employees	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Updating employees and other users about the changes in KM system	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Building up awareness and providing training on use of the KM system	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Other (please specify)									

F2. Management leadership and support

1. Management establishes the necessary conditions for KM
2. Leaders encourage and support knowledge creation, sharing and use
3. Knowledge managers constantly search for new approaches to KM
4. Development of a KM strategy with clear objectives and goals
5. Sufficient financial resources for building up a technological system
6. Other (please specify)

F3. Information technology

1. Matching the KM system with KM objectives and user's needs
2. Utilisation of the intranet and internet
3. Ease of use of the technology
4. Protecting knowledge from unauthorised exposure or being stolen
5. Ability of the system to capture and store tacit knowledge
6. Appropriate categorization and updating of knowledge
7. Application of technological tools (collaborative tools, searching tools, indexing, document management etc)
8. Other (please specify)

F4. Measurement

1. Measuring benefits per unit of investment
2. Monitoring the system performance and showing bottle necks
3. Developing indicators for measurement of KM
4. Other (please specify)

F5. Organisational infrastructure

1. Appointing of a knowledge leader and/or knowledge team or workers
2. Ensure of sufficient human resources to support KM initiatives
3. Specifying activities, tasks and processes for performing KM
4. Specifying roles and responsibilities for performing KM tasks
5. Recruiting and hiring of employees to fill knowledge gaps
6. Other (please specify)

F6. Drivers for KM

1. Building up and maintaining employees' expertise and skills
2. Sharing employees' expertise and perceptions
3. Identifying internal and/or external best practices
4. Reducing cost and/or time to solve problems in projects
5. Enhancing work quality of projects
6. Providing competitive advantages to the company
7. Helping senior engineers and managers to avoid many problems' causes
8. Presenting accurate and timely knowledge to facilitate decision making
9. Providing an effective tool to train junior engineers
10. Enhancing relation and coordination with customers, partners and suppliers
11. Encouraging continuous improvement and/or new products and services
12. Reducing rework and save time of solving repeated problems
13. Other (please specify)

F7. Specification of the KM system

1. The knowledge system is easy to use
2. It is easy for users to find useful information for problem solving
3. The system Collects knowledge that is important for the organisation
4. The system Ignores knowledge that is not important for the organisation
5. The system facilitates knowledge sharing between company's employees
6. The system maintains good relationships with customers and other partners
7. The role of knowledge team and knowledge workers is very important
8. Other (please specify)

F8. KM Barriers and Challenges

1. The nature of construction projects (e.g. non-repetitive work, no standard procedure for activities, pressure to complete on schedule, changing employees in different phases, etc.)
2. Lack of organisational culture for knowledge creation and sharing (e.g. build trust among employees, establish times and places for knowledge transfer, provide incentives, accept and reward creative errors, etc.)
3. Lack of structured procedures and processes to implement KM
4. Lack the adoption of well formulated KM strategies and implementation plans
5. Lack of knowledge manager or a team to implement KM strategy
6. Lack of awareness of the importance of KM in construction organisations
7. Lack of training and support
8. Lack of technology and techniques for knowledge capture and sharing
9. Lack of leadership support
10. Lack of resources in term of a budget, staff, and IT infrastructure
11. Employee resistance to share their knowledge
12. Lack of post-project reviews and project documentation
13. Other (please specify)

10. To what extent do you consider your company's knowledge management effort to be successful?

11. To what extent do you consider the KM activities and critical success factors presented earlier to be successful in describing those which are crucial for knowledge management adoption in the construction industry?

Please go to Feedback Section

SECTION 4: FOR NON KNOWLEDGE MANAGEMENT ADOPTERS

12. Why do you not practise knowledge management in your company? (You may tick more than one answer)

- ☐ Lack of time
- ☐ Lack of financial resources
- ☐ Lack of human resources
- ☐ Top management does not support
- ☐ Not needed
- ☐ Other (please specify)
- ☐ Have never heard
- ☐ Do not understand
- ☐ Unsure of its potential benefits
- ☐ Not interested

13. Do you plan to implement KM in the future?

FEEDBACK

14. If you are interested to be contacted for a follow up short interview, please tick this box. ☐

15. If your company is interested in participating in the research case study, please tick this box. ☐

16. If you require a summary of the finding of this survey, please tick this box. ☐

17. If you ticked any of the feedback questions, please enter your e-mail address and/or contact details:

<u>Other comments</u>

(Please use the space provided to reflect on how to improve KM in the construction industry)

THANK YOU VERY MUCH FOR YOUR VALUABLE TIME AND CONTRIBUTION TO THIS SURVEY.
ALL RESPONSES WILL BE TREATED ANONYMOUSLY.

Submit Reset

Appendix 2.2   Example of UK Construction Companies' Population Lists

<u>Not available in the digital version of this thesis.</u>

Appendix 2.3   Part of the UK Construction Companies Sample

Not available in the digital version of this thesis.

Appendix 2.4 Sample of Invitation Message

Survey on Knowledge Management (KM)

Dear Sir/Madam

I am a PhD student at the University of Birmingham, School of Engineering. My work is centred on investigating Knowledge Management (KM) application in Construction Companies. The following survey is a very important part of my PhD research project.

It will be greatly appreciated if you help to forward the following message to at least one of the employees in your company who may have interests in databases, information systems, computer networks and/or research and development projects so as to participate in this survey.

Thank you very much for your support.

Dear Sir/Madam,

Re: Survey on Knowledge Management (KM) in Construction Companies.

I am conducting a research about Knowledge Management (KM) practices in construction. KMSs refer to a type of IT-based information systems developed to include information, documents, procedures, experiences and knowledge of employees, and to facilitate collaboration of employees through tools such as e-messaging, e-chatting and e-meeting.

I am seeking the opinion of a group of experts in computer systems, such as you, to assess the importance of a set of factors which are provided in the questionnaire. You do not need to have a formal knowledge management programme in your organisation to answer these questions - many of the practices listed in the survey may be parts of other programmes and systems you have, for example, database, information system, etc.

I would appreciate your participation to complete the questionnaire which will not take more than 15 minutes from your time. Your response is very important for the success of the research, which in turn could be helpful to many construction companies which are trying to apply KM.

All survey responses will be treated confidentially and used only for research purposes. Your information will be coded and will remain confidential. If you have questions at any time about the survey, you may contact me by email at the email address specified below.

Thank you very much for your time and support. Please start with the survey now using the link below (if the link does not work cut and paste into your browser):

http://www.geocities.com/hisham1975a/Survey.html

Yours sincerely,

Hesham S. Ahmad

Appendix 2.5 Sample of Follow-up Invitation Message

Dear Sir/Madam

I have sent you before a message to participate in a questionnaire investigating your opinion about the importance of KM practices, methods and tools. To date, the response to my survey is inadequate. It will be greatly appreciated if you participate in the questionnaire provided in the link below and/or help to forward the below message to some employees in construction companies whose jobs are related to or may require them to use information and computer systems, so as to participate in this survey. Your participation is very important to my research.

If the link does not work please cut and paste into your browser:

http://www.geocities.com/hisham1975a/Survey.html

Thank you very much for your support.

Survey on Knowledge Management (KM)

Dear Sir/Madam,

Re: Survey on Knowledge Management (KM) in Construction Companies.

I am a PhD student at the University of Birmingham. I am conducting a research about Knowledge Management (KM) practices in construction. KMSs refer to a type of **information systems** developed to include information, documents, procedures, experiences and knowledge of employees.

I am seeking the opinion of a group of experts in **computer systems**, such as you, whose jobs are related to or may require them to use information and computer systems, to assess the importance of a set of factors which are provided in the questionnaire. Please start with the survey now using the link below (if the link does not work please cut and paste into your browser):

http://www.geocities.com/hisham1975a/Survey.html

I would appreciate your participation to complete the questionnaire which will not take more than 15 minutes from your time. All survey responses will be treated confidentially and used only for research purposes.

Thank you very much for your time and support.

Yours sincerely,

Hesham S. Ahmad

Appendix 2.6 Samples of Reliability Results by Using SPSS Programme

Scale: A1

Case Processing Summary

		N	%
Cases	Valid	24	88.9
	Excluded	3	11.1
	Total	27	100.0

Reliability Statistics

Cronbach's Alpha	N of Items
.834	4

Item Statistics

	Mean	Std. Deviation	N
A1.1	4.5417	.77903	24
A1.2	5.1667	.91683	24
A1.3	5.2917	.62409	24
A1.4	4.0417	1.08264	24

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
A1.1	14.5000	4.870	.746	.760
A1.2	13.8750	4.723	.622	.811
A1.3	13.7500	5.935	.565	.838
A1.4	15.0000	3.565	.808	.727

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
19.0417	8.042	2.83578	4

Scale: A2

Case Processing Summary

		N	%
Cases	Valid	25	92.6
	Excluded[a]	2	7.4
	Total	27	100.0

Reliability Statistics

Cronbach's Alpha	N of Items
.865	3

Item Statistics

	Mean	Std. Deviation	N
A2.1	4.0000	1.35401	25
A2.2	4.4400	1.44568	25
A2.3	3.9600	1.51327	25

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
A2.1	8.4000	8.500	.549	.969
A2.2	7.9600	6.123	.902	.653
A2.3	8.4400	6.257	.808	.746

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
12.4000	14.667	3.82971	3

Scale: F1

Case Processing Summary

		N	%
Cases	Valid	27	100.0
	Excluded[a]	0	.0
	Total	27	100.0

Reliability Statistics

Cronbach's Alpha	N of Items
.776	5

Item Statistics

	Mean	Std. Deviation	N
F1.1	4.5185	1.12217	27
F1.2	4.7407	.76423	27
F1.3	4.7407	.81300	27
F1.4	4.5556	.84732	27
F1.5	4.8519	.94883	27

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
F1.1	18.8889	7.103	.419	.796
F1.2	18.6667	8.308	.448	.765
F1.3	18.6667	6.538	.882	.627
F1.4	18.8519	7.208	.646	.704
F1.5	18.5556	7.564	.460	.765

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
23.4074	10.866	3.29638	5

Scale: F2

Case Processing Summary

		N	%
Cases	Valid	24	88.9
	Excluded[a]	3	11.1
	Total	27	100.0

Reliability Statistics

Cronbach's Alpha	N of Items
.941	5

Item Statistics

	Mean	Std. Deviation	N
F2.1	4.5833	1.38051	24
F2.2	4.3750	1.17260	24
F2.3	4.1250	1.26190	24
F2.4	5.2083	1.38247	24
F2.5	5.1667	1.46456	24

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
F2.1	18.8750	22.984	.852	.926
F2.2	19.0833	24.688	.867	.925
F2.3	19.3333	24.319	.824	.931
F2.4	18.2500	23.065	.843	.928
F2.5	18.2917	22.389	.840	.929

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
23.4583	36.172	6.01432	5

Appendix 2.7 Validity Results by Using SPSS Programme

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	F7, A4, A3, A8, A5, A1, F4, A7, F1, A6	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.942[a]	.886	.783	.40471

a. Predictors: (Constant), F7, A4, A3, A8, A5, A1, F4, A7, F1, A6

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.062	10	1.406	8.585	.001[a]
	Residual	1.802	11	.164		
	Total	15.864	21			

a. Predictors: (Constant), F7, A4, A3, A8, A5, A1, F4, A7, F1, A6

b. Dependent Variable: Evaluation of Success

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.032	2.326		1.733	.111
	A1	.243	.142	.215	1.713	.115
	A3	.181	.086	.275	2.100	.060
	A4	-.190	.128	-.200	-1.482	.166
	A5	-.041	.235	-.031	-.174	.865
	A6	-.697	.418	-.679	-1.669	.123
	A7	.882	.310	.760	2.848	.016
	A8	-1.156	.547	-.529	-2.112	.058
	F1	-.927	.404	-.665	-2.297	.042
	F4	.364	.217	.439	1.678	.121
	F7	1.358	.349	1.266	3.893	.003

a. Dependent Variable: Evaluation of Success

Appendix 3.
Case Study Protocol

CASE STUDY PROTOCOL
Investigation of Knowledge Management (KM) application in construction organisations and Evaluation of a KM model

I. Background and General Information

A. Company
Name of company:
Total number of employees:
Address:
Business activity:

B. Respondent
Name of respondent:
Contact details of respondent:
Position in company:
Background:
Time in company:
Time on current position:
Date of Interview:
Experiences in KM:

II. Knowledge Management

A. General questions

6. What do you understand by the terms Knowledge and Knowledge Management?
7. How is knowledge managed within the company?
8. What is the stimulus/reason for practicing KM?
9. Does your company have a strategy for implementing KM? If so, what does it include and what are its objectives?
10. What are the results and outcomes that your company required from the implementation of KM?
11. What are the barriers for implementing KM in your company?

B. Knowledge Resources

1. What are the different types of knowledge captured and shared by the KMS?
   (e.g. Data, information, know-how, procedures, problem solutions, ideas, innovations, best practices articles, reports, news, manuals, policies, project and organisation descriptions, contact details and experiences of employees etc.)
2. Does the system have different processing procedures for the different types of knowledge? Give examples?

C. Processing Activities and Roles

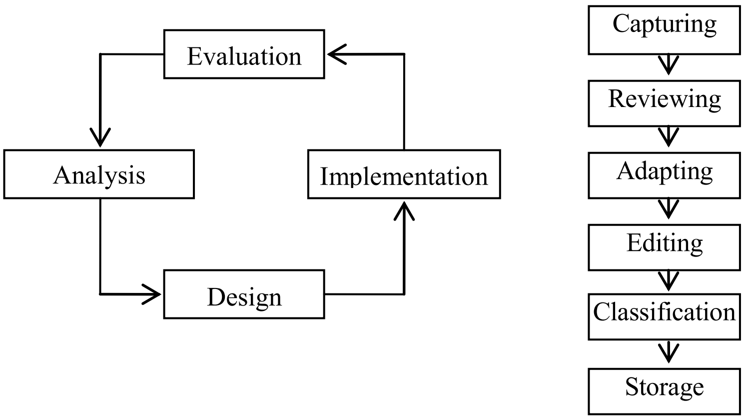
1. What is the focus of the KM activities in your company? (e.g. sharing knowledge, creating new knowledge, capturing knowledge into repositories etc.)
2. Does your company appoint roles/positions for KM implementation and coordination?
   (e.g. knowledge manager, knowledge team, knowledge workers, data workers, communities of practice etc.), Describe their roles and tasks?
3. Does your company use models or frameworks for implementing or using the KMS? If so please describe it?

4. Describe the stages and activities were conducted to build the KMS? (e.g. Forming a KM team, collecting and analysing data, developing design and implementation plans, implementing a pilot or a prototype, evaluating prototype, large scale implementation, evaluating and monitoring the KMS, maintenance and enhancement, and evaluating effects on business performance)

5. What activities are conducted when using the KMS? (e.g. Capturing, adapting, reviewing, approving, classifying, re-using, editing, updating and sharing knowledge)

6. Based on questions 4 and 5, please represent the activities in a flow diagram to show their relationships.

E.g.



7. How does your company evaluate and monitor the KMS?

8. How does your company motivate its employees to use and add to the KMS?

D. System Architecture and tools

1. Does your company use a formal KMS? (What is its name, start date, its technological platform etc.)

2. Describe the contents of the KMS?

3. Which of the following services are provided by the KMS? Please add the services which are not available in the table below.

Collaborative Tools	Knowledge Capturing Tools	Knowledge Retrieval Tools
E-messaging, e-chatting and e-meeting	Knowledge recording and storing	Knowledge searching
Yellow pages, contact details, and details of professions and experiences	Knowledge publishing, editing and updating	Data mining, analyzing and reporting
Knowledge Referring	Knowledge classification	Manuals, training and support
	Video and photos management	Knowledge maps
	Document management	Decision support and expert systems

4. Describe the levels of authority provided by the KMS to knowledge employees and end-users?

E. Influential Factors

1. What factors motivates the success of the KMS in your company?

2. What factors work as a barrier for implementing and using the KMS in your company?

(e.g. top management support and awareness, employees experience and culture, training and support, increasing competition and customer demands, cost of implementation and use, current business processes and operations etc.)

Are there any other issues that you would like to mention regarding KM?

III. Model Evaluation

This section provides a description of the KM model developed in the research. Please give your comments and suggestions on the model, and evaluate the model in terms of the following criteria:

Criteria	Strongly Disagree (1)	Moderately Disagre (2)	Slightly Disagre (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
Model Usability:						
1. Easy to understand and use						
2. Systematic and well structured						
2. Comprehensive (i.e. contains all important aspects)						
3. Reliable						
4. Appropriate to the specific criteria of construction projects						
5. Applicable and Feasible						
6. Sufficient (i.e. includes appropriate level of details)						
Model Usefulness:						
1. Provides guidance for KM implementation and reduce implementation mistakes						
2. Provides guidance for KMS application						
3. Helps to understand the concept of knowledge and KM						
4. Helps to enhance awareness about KM importance						
5. Leads systems to serve knowledge sharing and collaboration						
6. Leads to enhance knowledge creation and innovation						
7. Enhances knowledge capturing and maintaining						
8. Enhances knowledge quality and ensure updating contents						

9. Provides feedback mechanism for system enhancement						
10. Help organisations to decide KM tools and activities						
11. Provides guidance for KM processes and roles						

The main components of the KM model developed in the research are shown in Figure 1.

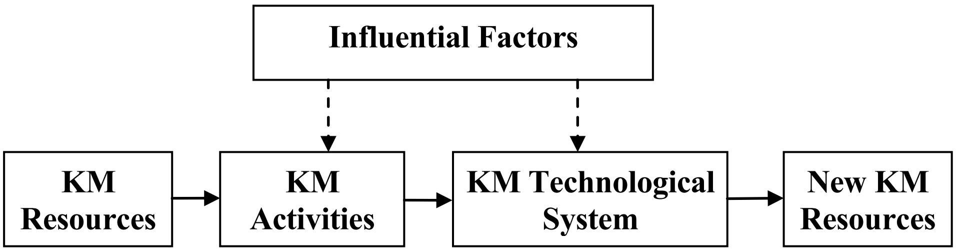


Figure 1 *Components of the proposed KM model for construction projects*

A brief description of the KM model is attached

Appendix 4.
Publications

Not available in the digital version of this thesis.