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**IMPROVING CONSTRUCTION SITE MANAGEMENT
PRACTICES THROUGH KNOWLEDGE MANAGEMENT**

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of Loughborough University
for the degree of Doctor of Philosophy

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ABSTRACT

There are several challenging engineering and management problems that occur on construction sites. Failure in managing construction site problems results in a high proportion of rework, defects, delays, disputes and cost overruns on construction projects. In site management, knowledge is often embedded not only in documents and repositories but also in organisational routines, processes, practices and norms. However, site management teams still do not have a systematic approach to managing knowledge. Knowledge management (KM) processes can effectively be used to enable construction site managers deal with on-site problems and risks in a systematic and efficient way. With regard to these problems, the aim of this research was to investigate the improvement of construction site management practices through the integration of knowledge management processes.

The research methodology adopted consisted of several methods. A literature review on site management practices and knowledge management was first undertaken. This was followed by case studies involving five construction sites which sought to investigate the key problems of site management practices and to examine existing knowledge management practices on the construction site. They also explored how KM processes could improve current site management practices. The case study findings underpinned by literature results were used to develop a conceptual framework to managing construction knowledge that is entrenched in site management processes. The integrated KM framework (incorporating both proactive and reactive approaches) was intended to enable site managers to adopt a knowledge management approach to addressing site management problems. The framework was encapsulated in a computer-based prototype system (developed using Microsoft Visual Basic) to simplify the use of the integrated KM framework and provide construction organisations with a practical tool. Evaluation of the prototype system was carried out by industry practitioners and construction researchers to assess its appropriateness and functionality. It was established that the prototype system was highly effective in enabling site managers to address site management problems from a knowledge management perspective. Several benefits of the system were also identified.

It is concluded that construction site management practices can be improved if the knowledge dimensions of the problems are well understood and appropriately managed. This research has developed an integrated KM framework that provides a structured approach to achieving this. The framework is simple to use, requires a relatively short time to implement, is scalable to any type of project and can easily be deployed on any construction site. Knowledge gains economic value when it is used to solve problems, explore opportunities and make decisions. The developed prototype system is expected to increase the ability of the site manager to learn from previous experience and to better address any site management problems that may occur. It also enables the site manager to be proactive in minimising the number of problems that occur on the construction site and to reduce the impact of those that do occur.

DEDICATION

*'When a man dies, all his deeds come to an end
except for three: an ongoing charity, beneficial
knowledge or righteous son who will pray for him'*

(Narrated by Muslim, 1631)

*To my lovely mother (Fatimah) who taught me love
and kindness*

My father (Mohamed) who taught me to be a man

*My wife (Siti Hamidah) who gave support even
though she needed it more*

*Our lovely son (Munif Afifi) for his welcome arrival
during the research period*

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LIST OF ABBREVIATIONS

AI	- Artificial Intelligence
BASIC	- Beginners All-Purpose Symbolic Instruction Code
BDMS	- Building Division Management System
BMS	- Business Management System
BIW	- Building Information Warehouse
BPR	- Business Process Re-engineering Approach
CAD	- Computer-Aided Design
CLEVER	- Cross-sectoral Learning in the Virtual Enterprise
CoP	- Communities of Practice
CDM	- Construction (Design and Management) Regulation
CFI	- Confirmation for Information
COBOL	- Common Business Oriented Language
CRM	- Customer Relationship Management
COSHH	- Control of Substances Hazardous to Health Regulations
DTI	- Department of Trade and Industry
EXE	- Executable Files Extension
FORTRAN	- Formula Translator
HRM	- Human Resource Management
ICT	- Information and Communication Technology
IDEF	- Integrated Definition Function Modelling
IT	- Information Technology
JIT	- Just-In-Time Approach
KE	- Knowledge Engineering
KM	- Knowledge Management
KMS	- Knowledge Management System
PC	- Personal Computer
QA	- Quality Assurances
RFI	- Request for Information
RIQ	- Request Information Queries
SELEKT	- Searching and Locating Effective Knowledge Tools
SM	- Site Management
SMAZ	- Sustainability Management Activity Zone
SSM	- Soft System Methodology
TQM	- Total Quality Management
UML	- Unified Modelling Language

CHAPTER ONE

Introduction

1.1 General Introduction

This chapter introduces the context for this research. It starts with a brief over view of the background to the research and the justification for the research. This is followed by the aim and objectives of the study and a brief summary of the methodology adopted. The structure of the thesis is also presented.

1.2 Background

An increasing number of construction organisations are applying project improvement initiatives to improve their performance (Carrillo and Chinowsky, 2006; Liao, 2002). The fundamental objectives are to deliver construction projects of the required quality more quickly (CIRIA, 2001), prevent the 're-invention of the wheel' (Holroyd, 1999), and improve project performance (Wong and Aspinwall, 2006). However, practice is not that simple as construction work has become more complex technically and administratively (Gray, 1992). There is a need to look deeply at the underlying causes and rethink the management strategy so as to utilise and maximise the knowledge of an organisation (Mohamed and Anumba, 2005).

Unfortunately, construction organisations still do not have any well defined and systematic methods for the creation, capture, storage, sharing and reuse of a professional's domain knowledge of products, people and processes (Robinson *et al.*, 2004). More specifically, there is much scope for making site management practices more effective through better knowledge management. An improvement in the management of construction sites can be achieved by implementing management forms,

which emphasise co-operation, delegation, continuous learning and the use of information technology. Knowledge management (KM) is central to this as it facilitates continuous improvement through project learning and innovation (Robinson *et al.*, 2001). According to Al-Ghassani *et al.* (2006), knowledge generated on a construction site is rarely shared and this can result in loss of this knowledge. In addition, there is insufficient effort and no structured approach to managing construction knowledge at the construction site level (Mohamed and Anumba, 2005). Therefore, this research seeks to investigate the potential of KM approaches in the improvement of site management practices. There are four main benefits identified by the UK Department of Trade and Industry's (DTI) Intelligent System in Business Programme for a range of industrial sectors resulting from the application of knowledge management and knowledge based techniques (Anumba *et al.*, 1998):

- *Organisational memory*: Preservation of knowledge when staff move;
- *Decision support*: Assisting experts by evaluating and suggesting possible options, enabling a wider range of design solutions etc to be considered;
- *Routine decision automation*: Relieving key staff from trivial but time-consuming tasks; and
- *Product improvement*: Enabling increased differentiation from competitors' products through the addition of smart features.

Knowledge management is not simply about extracting the knowledge held in an individual's mind and converting it to an accessible electronic format, or disseminating and making available an organisation's knowledge. It is about providing knowledge to facilitate collaboration between individuals, teams and communities of specialists, thereby providing access to knowledge assets: individual experiences, lessons learnt, and best practices (Williams, 2004; Kasvi *et al.*, 2003; Weber *et al.*, 2001; and Belle, 2000). The role of knowledge management and learning as a source of potential advantage for construction organisations was addressed by Carrillo *et al.* (2000). In addition, it is acknowledged that KM in construction includes locating, accessing, sharing, and using the required knowledge so that optimisation can be achieved in terms of execution, quality, cost and maintenance (Al-Ghassani *et al.*, 2002). So far, however,

there has been little or no work on KM deployment at site management level, which is the focus of this research project.

1.3 Justification for the Research

An awareness of the importance of quality site management has been growing in the construction industry over the last few decades. In order to achieve the quality of construction that is needed, site management must concentrate on understanding the whole system of construction and ensuring that it is focused on the production aims of the site operations (Gray, 1992). The main function of a site management team is to organise, inform, coordinate, order, instruct and motivate others to undertake site activities (Ashworth, 2001). However, there are several challenging engineering and management problems that occur on the construction site. For instance, Barber *et al.* (1999) identified five major problems that inhibit a contractor's performance; poor communication, poor information, inaccurate/inadequate planning, training and education issues, and motivation issues. The majority of the problems were due to the attitudes that members of the work force were adopting. Mackenzie *et al.* (2000) and Agapiou *et al.* (1995) examined the manpower problems in the industry and found that the shortage of skilled workers is affected by the cyclical nature of the UK construction industry. Ogunlana and Olomolaiye (1999) concerned themselves with productivity in the industry. The study found that lack of materials, repeat work, lack of proper tools, supervision delays and absenteeism were major problems affecting craftsmen's productivity. These identified problems would affect the time, budget and plans, and specifications (Trauner 1993) and often resulted in defects, disputes and delays (Clarke, 1988).

According to Forster (1989), there are two current approaches practised by the construction site managers to tackle site management problems; previous experience and reference to site documents (e.g. project procedures, specifications, bill of quantities, drawings etc.). First, the site manager intuitively knows how to deal with site management problems or is able to solve them through previous experience. Second, the site manager refers to the site documents which cover the problem encountered on-

site. However, it was observed that site managers repeat the same mistakes and current practices are ineffective in avoiding the occurrence of a problem (Holroyd, 1999). There is a vital need to look in depth at a management strategy which would minimise the number of repeatable problems that occur on the construction site and reduce the negative impact of unpredictable problems.

From the perspective of knowledge management, these experiences and this know-how of site managers are the most valuable assets because they will enable site managers to resolve site problems and will result in prompt decision-making processes. Currently, there is insufficient effort and no structured approach to managing construction knowledge at the construction site level; there appears to be a gap with respect to the exploitation of KM strategy for site management practices. Therefore, this research seeks to investigate how to improve site management practices through an integration of applicable KM processes.

Site management practices can benefit from knowledge management by implementing initiatives that enable the site management team to avoid repeating past errors. By capturing best practices, lessons learnt, and especially the solutions to problems that arise on site, similar situations in the future can be dealt with efficiently and effectively. Moreover, there has been significant growth in the adoption of knowledge management (KM) in construction organisations in the last five years. This is because KM techniques are seen as a means of identifying and exploiting knowledge assets: individual experiences (Tserng and Lin, 2004; and Snider and Nissen, 2003), lessons learnt (Carrillo, 2004; and Liebowitz, 2001) and best practices (Gratton and Ghoshal, 2005).

Recently, the competitive business environment has prompted construction organisations to rethink the nature of the resources and capabilities that generate advantage. One of the drivers is the fact that clients are becoming more sophisticated, insisting on better value for money and demanding more units of construction for less units of expenditure (Kamara *et al.*, 2000). It is now widely recognised that knowledge of construction practices and construction processes is an important component of constructors' core competence. It is also now being recognised that some of the intellectual assets (knowledge) of construction organisations or contractors are

entrenched deep into site management practices. This needs to be managed if construction businesses are to be more responsive to clients' needs and to improve the quality of construction performance, while reducing construction costs (Mohamed, 1996; and Rwelamila and Hall, 1995).

In the site management context, problems often arise on site and may lead to costly defects and delays if not resolved quickly and effectively (Kaming *et al.*, 1998). The greatest challenge facing construction managers are: to find the most efficient way of managing the construction site, to select the best method to resolve problems, and to make decisions in real time. An integration of KM into site management practices can act as a vehicle for connecting knowledge and performance as knowledge gains economic value when it is used to solve problems, explore opportunities and make decisions that improve production performance. Tserng and Lin (2004) argued that reducing problems on the construction site will reduce the cost of problem solving and will decrease the probability of repeat problems.

In the construction site environment, KM can incorporate any or all of the following four components:

- *Business processes*: In written documents such as drawings, minutes of meetings, specifications or embedded in the construction methodology or setting-out procedures;
- *Information technologies*: IT tools used by site staff such as specialist management applications, word processing and CAD workstations;
- *Knowledge repositories*: Structured collections of documents, often written documents by internal company experts. These documents attempt to capture their author's expertise and insight on a subject; and
- *Individual Behaviours*: Construction knowledge in the mind of knowledge workers and trade workers, artisans and operatives.

An effective KM system is a complex combination of a series of organisational routines, themselves multi-faceted (and not necessarily IT-based). Dent and Montague

(2004) argued that the components of KM systems in the construction organisation typically comprise:

- Standard procedures;
- Post-project reviews;
- Expert lists;
- Knowledge databases – e.g. best practice, lessons learned, customer relationship management (CRM);
- Intranets, including corporate portals;
- Knowledge networks and knowledge centres, both formal and informal (i.e. Communities of Practice);
- Collaborative technologies; and
- E-learning systems.

Figure 1.1 illustrates the typical components of KM systems in construction organisations. The corporate portal is an application that enables organisations to provide users with a single gateway to internal and external sources of information while the main function of the intranet is to store explicit and tacit knowledge (Dent and Montague, 2004). It is particularly important, in seeking to implement KM at site management level, to examine failed knowledge management initiatives in other organisations. Storey and Barnett (2000) have identified three main causes for the failure of knowledge management initiatives in an organisation. These are:

- Top management is ‘committed’ only up to a point;
- The KM initiative was undermined by divisions and differences in perspectives between diverse functional ‘camps’; and
- A pilot for the KM initiative had been tried in one part of the company rather than planning for a total company-wide launch.

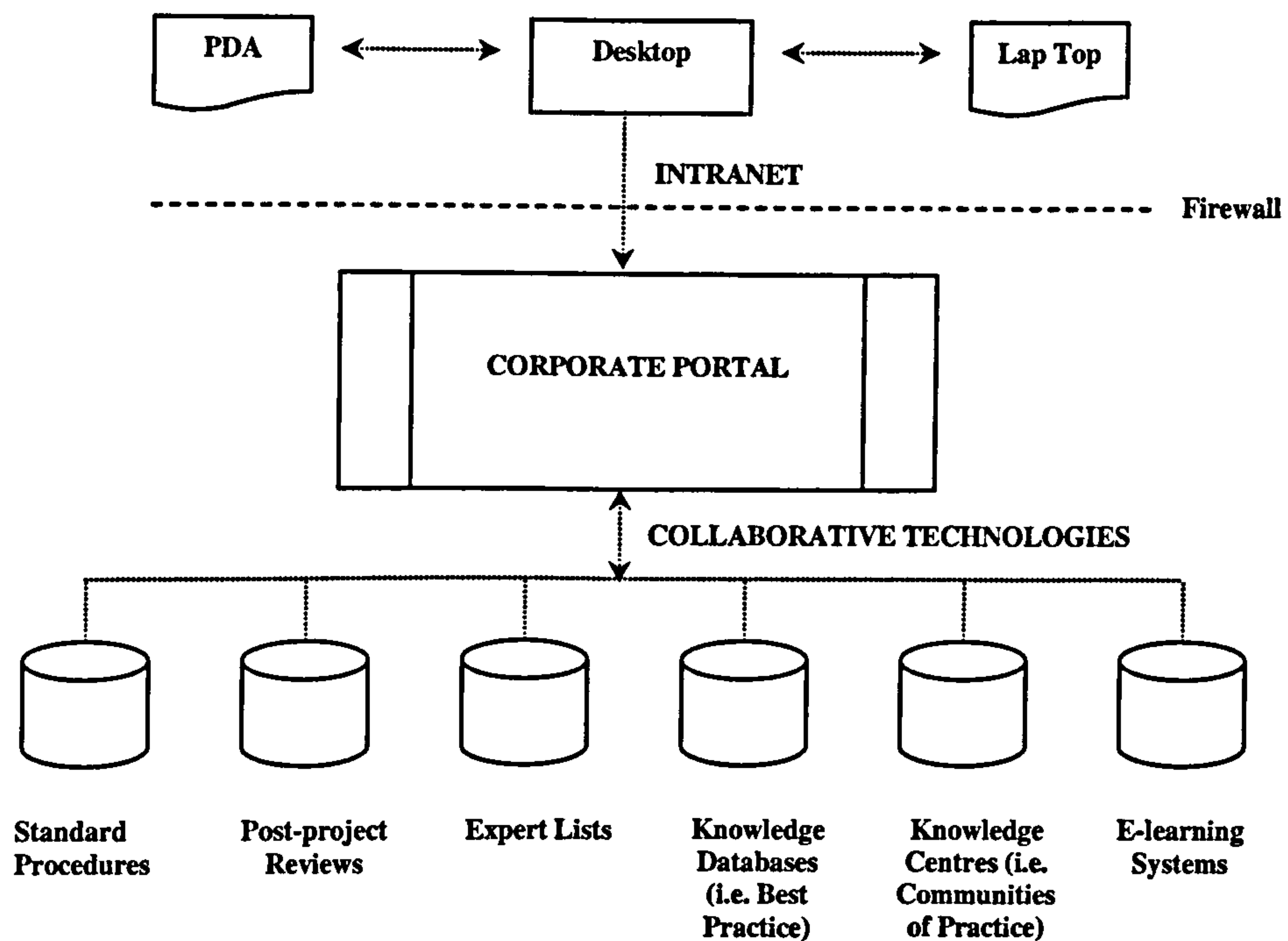


Figure 1.1: The Typical Components of KM Systems in the Construction Organisations (adapted from Dent and Montague, 2004).

Site managers can no longer depend totally on their past experience and intuition to find prompt solutions to technical and complex problems on the construction site because the nature of construction projects has become more complex during the past few years. Recent evidence has revealed that construction knowledge is more tacit than explicit (Egbu and Robinson, 2005). Tacit knowledge is difficult to communicate externally or to share while explicit knowledge can readily be captured and stored in project manuals, and procedures, and is, therefore, easily communicated and shared with others. The distinction between tacit and explicit knowledge is relevant because each must be managed differently. A workable and detailed framework that reflects the specific context of site management practices, and which makes provision for both explicit and tacit knowledge is therefore required. It is this need that this research has sought to address.

1.4 Research Aim and Objectives

The aim of this research project is to investigate the improvement of construction site management practices through an integration of knowledge management processes. The specific objectives of the project include:

- a. To review current site management practices, focusing on the key processes, actors involved and existing management procedures with a view to identifying current problems, and opportunities for improvement.
- b. To investigate knowledge management processes with a view to identifying those which are applicable at the construction site level.
- c. To develop a framework for improving site management practices based on an integration of KM processes.
- d. To encapsulate the framework in a computer-based prototype system.
- e. To evaluate the prototype system and underlying model using industry practitioners and researchers.

1.5 Research Methodology

To achieve the research objectives, a combination of research methods were adopted. These included literature review, case studies, rapid prototyping, and evaluation. Table 1.1 illustrates the relationship between the research objectives and the research methods adopted to achieve them.

Table 1.1: Relationship between Research Objectives and Research Methods.

Objectives	Research Methods			
	Literature Review	Case Studies	Rapid Prototyping	Evaluation
To review current SM practices, focusing on the key processes, actors involved and existing management procedures, with a view to identifying current problems, and opportunities for improvement	✓	✓		
To investigate KM processes with a view to identifying those which are applicable at the construction site level	✓	✓		
To develop a framework for improving SM practices based on an integration of KM processes	✓	✓		
To encapsulate the framework in a computer-based prototype system		✓	✓	✓
To evaluate the prototype system and underlying model using industry practitioners and researchers.		✓		✓

The following sections briefly summarise the research methods used. Chapter 2 provides full details of the research methods adopted, including a justification for their use.

Literature Review: The research started with an extensive literature review which focused on two major subjects. Firstly, a structured review was undertaken in the areas of construction site management, problems on the construction site, management approaches to improve construction site management and knowledge-based system for construction site management. Secondly, a review of knowledge management, knowledge management processes and knowledge management tools was carried out. Relevant sources were identified such as refereed journals, books, the Internet, government reports, workshop and seminar proceedings, doctoral dissertations, KM websites, and conference proceedings. The literature review was aimed at identifying the problems and aspects of site management practices that can be improved and to examine the applicability of key knowledge management processes. The literature

review was an ongoing process, carried out simultaneously with all stages in the research project.

Case Studies: Case study research excels at bringing researchers to an understanding of a complex issue or subject and can extend experience or add strength to what is already known from previous research. Five construction sites suggested by organisations involved in previous KM studies at Loughborough were used for the case studies. The case study was aimed at understanding the key problems of site management practices and to observe existing practices in managing knowledge on the construction site. They also sought to identify how KM processes could improve current site management practices. The case study findings were used as a basis for developing a conceptual framework for integrating KM into site management practices. The case study protocol was designed to be systematic approach so as to ensure the reliability of the results. The procedure adopted for the five case studies undertaken is described below. The last step was essential to eliminate bias:

- *Company identification:* The focus here was on selecting construction organisations that have attempted to implement knowledge management;
- *Identify and select construction site:* This involved choosing a construction site that will provide adequate scope for exploring the integration of KM processes into site management practices. The selection of these construction sites was based on the willingness of individuals within these organisations to participate, share their experience in managing construction sites, and make information available for the research project;
- *Data collection:* This involved semi-structured interviews (recorded on tape) and sought to identify site management problems, procedures used, actors involved and KM practices within site management practices. The questions were divided into three main sections: context of the construction site; site management practices (e.g. problems, procedures and actors involved); and KM processes within the site management practices;
- *Data analysis:* This was concerned with an assessment of the appropriateness of the KM approaches adopted by the case study organisations in resolving site

management problems. The results were used to support the development of the framework for KM integration into site management practices; and

- *Case study review and confirmation:* The aim was to clarify any unclear factual information with the interviewees and to confirm the contents of the case study report.

Rapid Prototyping: Prototyping is a process of building an experimental system quickly and inexpensively for demonstration and evaluation so that users can better determine information requirements (Laudon and Laudon, 2002). The prototype was developed on a personal computer (PC) and the implementation environment was Microsoft Visual Basic, Version 6. There were four main steps in developing the prototype:

- *Identify the user's basic requirements:* The case study results and literature review findings were used to establish the basic requirements for improving construction site management practices;
- *Develop an initial prototype:* Working prototypes were created quickly, using Microsoft Visual Basic programming language;
- *Use the prototype:* The prototype system was demonstrated so that site managers and others (e.g. researchers) could evaluate its performance and ensure that it meets an acceptable level of accuracy and efficiency; and
- *Revise and enhance the prototype:* The suggestions made by the site managers and researchers were used to refine the prototype.

Evaluation: The focus group approach was adopted to evaluate the prototype system, which involved four site managers and 10 university-based researchers. The evaluation workshops were undertaken consists of three main elements: presentation on the background to the prototype system, demonstration, completed an evaluation questionnaire and discussed key issues relating to the system. The relevant comments and suggestions were used to refine and improve the prototype system.

1.6 Thesis Structure and Contents

Figure 1.2 shows the overall research process carried out to achieve the specific objectives of the research. The thesis is structured into nine chapters and a brief description of each chapter is given below:

Chapter One: Introduction

This chapter provides an introduction to the research project undertaken and briefly describes its background. It justifies the need for the research and outlines the associated aim, objectives and methodology.

Chapter Two: Research Methodology

This chapter reviews research methods, discusses the methodological considerations for this study, and justifies the adopted research methodology.

Chapter Three: Site Management Practices

The literature review on construction site management practices and processes is the focus in Chapter 3. It also discusses the common problems that occur on the construction site, followed by a discussion of approaches to improving construction site management. The chapter also reviews the importance of managing knowledge on the construction site.

Chapter Four: Knowledge Management in Construction

This chapter reviews the key concepts and characteristics of knowledge, different perspectives on a knowledge model, taxonomies of knowledge, and knowledge management processes and tools. It also reviews the characteristics of knowledge management systems for the construction site. It concludes with identifying aspects of the site management practices that are best supported by the viable KM processes and tools identified for use in this research project.

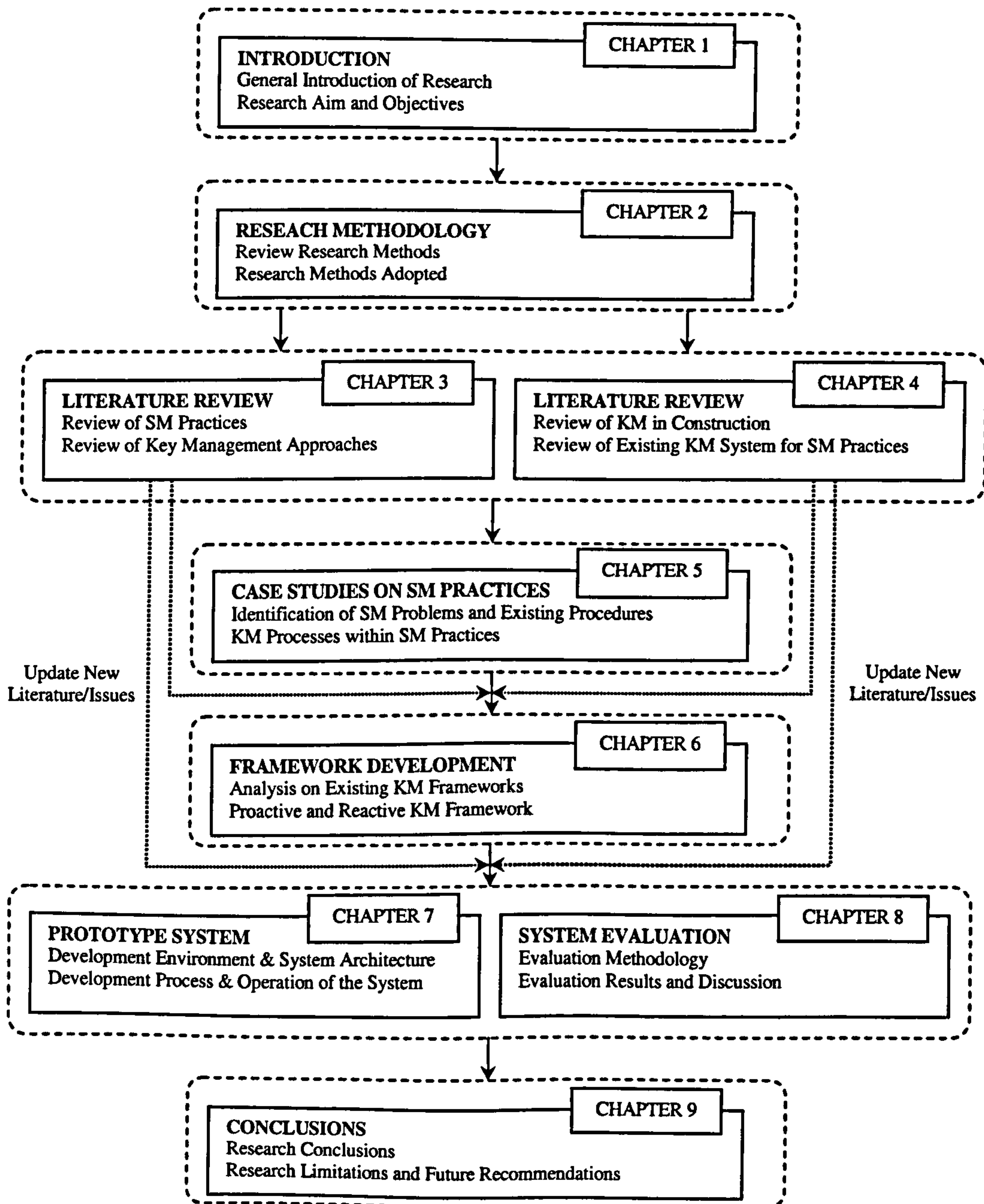


Figure 1.2: The Research Process.

Chapter Five: Case Studies on Site Management Practices

The findings obtained from the five case studies are presented in this chapter. The findings were used to demonstrate the 'real' problems, procedures and actors involved on the construction site. An analysis of KM processes within site management practices

is also presented. The chapter concludes with suggestions on a practical framework for integrating site management practices with KM processes.

Chapter Six: Framework Development for KM Integration

This chapter analyses the existing KM frameworks and related models for construction organisations. It then presents the CLEVER (Cross-sectoral Learning in the Virtual Enterprise) framework and SELEKT framework that adopted apart in the developed framework and justifies this. It is also presents an integrated KM framework that reflects the specific context of site management practices, and which makes provision for both explicit and tacit knowledge. The objectives, features, development process and potential benefits of the integrated KM framework are also discussed.

Chapter Seven: Prototype System Development

This chapter presents the choice of a development environment and system architecture for the prototype system. It then describes in detail the development process of the prototype system. It also demonstrates the operation of the system and system testing with a 'real' construction site management problem.

Chapter Eight: System Evaluation

This chapter describes the system evaluation process. It starts with an introduction to the evaluation aim and objectives. This is followed by a description of the evaluation methodology. The evaluation results were used to improve the developed prototype system. The benefits and limitations of the system are also presented. The chapter than concludes with discussion on the improved prototype system and appropriateness of the evaluation approach.

Chapter Nine: Conclusions and Recommendations

This chapter presents the summary and conclusions of the thesis. It covers the major findings, the conclusions of the study, and the limitations, and provides recommendations for both industry practitioners and future researchers.

CHAPTER TWO

Research Methodology

2.1 Introduction

This chapter describes the research methodology framework for this study. It reviews the basic concepts and principles relating to the research methodology and then justifies the adopted methods.

2.2 Research Strategy and Methodology

2.2.1 Overview

Research can be described as a systematic and organised effort to investigate a specific problem that needs solution (Neuman, 2006; Walker 1997; and Sekaran, 1984). The Concise Oxford Dictionary (1999) defines research as ‘the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions’. Greenfield (1996) views research as an art aided by skills of inquiry, experimental design, data collection, measurement and analysis, interpretation, and presentation. A further skill, which can be acquired and developed, is creativity and invention.

Research generally starts with the researcher being interested in solving a particular problem through being better acquainted with the facts surrounding the problem. According to Love *et al.* (2002), two research philosophies appear to dominate the study of construction management; the interpretivist (otherwise known as phenomenological) approach and the positivist approach. Interpretivists argue that knowledge is developed and theory built through developing ideas inducted from the

observed and interpreted social constructions (qualitative approach). Blumberg *et al.* (2005) promote the positivist view that knowledge is developed by investigating the social reality through observing objective facts (quantitative approach). There are four important concepts that establish the basis on which researchers should regard a piece of research as knowledge that can be assimilated into the knowledge base of a field of study. These are: bias, validity, reliability and generalisability.

Bias is any influence, condition, or set of conditions that singly or together distort the data (Leedy and Ormrod, 2001). According to Neuman (2006), bias is influenced by personal prejudice or cultural values. Bias can creep into a research project in a variety of subtle and undetected ways. It may be introduced in the data collection, analyses and inference (Fellows and Liu, 2003). Bias can be easily overlooked by even the most sensitive and careful researcher. It is important to identify the source of bias and reduce it as much as possible. Also researchers need to take into account the possible impact of any bias that cannot be eliminated (Al-Ghassani, 2003).

Validity concerns how well a measure does measure the concept it is supposed to measure (Fellows and Liu, 2003). In research methodology literature, there are three validity tests that have been widely used to establish the quality of empirical social research (Rowley, 2002): construct validity, internal validity and external validity. The construct validity refers to the process of establishing correct operational measures for the concepts being studied. According to Yin (2003), to meet the test of construct validity, a researcher must be sure to cover two steps; select the specific types of changes that are to be studied (e.g. site management practices and relate them to the original objectives of the study); and demonstrate that the selected measures of these changes do indeed reflect the specific type of change that have been selected. The internal validity of a research study is the extent to which its design and the data that it yields allow the researcher to draw accurate conclusions about cause-and-effect and other relationships within the data (Leedy and Ormrod, 2001). External validity refers to the ability to generalise findings from a specific setting and small group to a range of settings and people (Neuman, 2006). Validity increases as researchers search continuously in diverse data and consider connections between them.

Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (Yin, 2003). The term reliability means that measurements are made consistent: if the same experiment is performed under the same conditions, the same measurement will be obtained (Melville and Goddard, 1996). With reliable instruments, the research can be undertaken with confidence that transient and situational factors are not interfering.

Generalisability is concerned with whether or not the resulting conclusions are applicable to a population. This puts pressure on the sample to be representative for the whole population being researched (Stenbacka, 2001). There are different bases on which qualitative and quantitative research approach to research to seek to establish generalisations. The basis for generalisation in a quantitative study is statistical generalisation (Hyde, 2000). The basis for generalisation in a qualitative study is analytical generalisations (Yin, 2003). The results in a qualitative study are intended to be general with respect to the theory, not to a population. This is made possible by strategic choice of informants relevant to the study and not by statically drawn samples.

2.2.2 Types of Research Methods

In general, there are three types of research methodology; quantitative, qualitative and a combination of both methods called triangulation or mixed method (Neuman, 2006; Fellows and Liu, 2003; and Punch, 1999). Research methodology refers to the principles and procedures of logical thought processes which are applied to a scientific investigation (Fellows and Liu, 2003; and Klien and Myers, 1999). Kagioglou *et al.* (1998) introduce a nested approach to describe a hierarchical model of research methods that is divided into three main interrelated themes: research philosophy; research approach and research techniques, as shown in Figure 2.1. The research philosophy found at the outer ring guides and energizes the inner research approach and research techniques. The research approach consists of dominant theory generation and testing methods. Research techniques comprise data collection tools. A research technique is simply a method of collecting data. It involves instruments, such as self completion questionnaire or a structured interview schedule, or participant observation (whereby the researcher listens to and watches others) (Bryman, 2004).

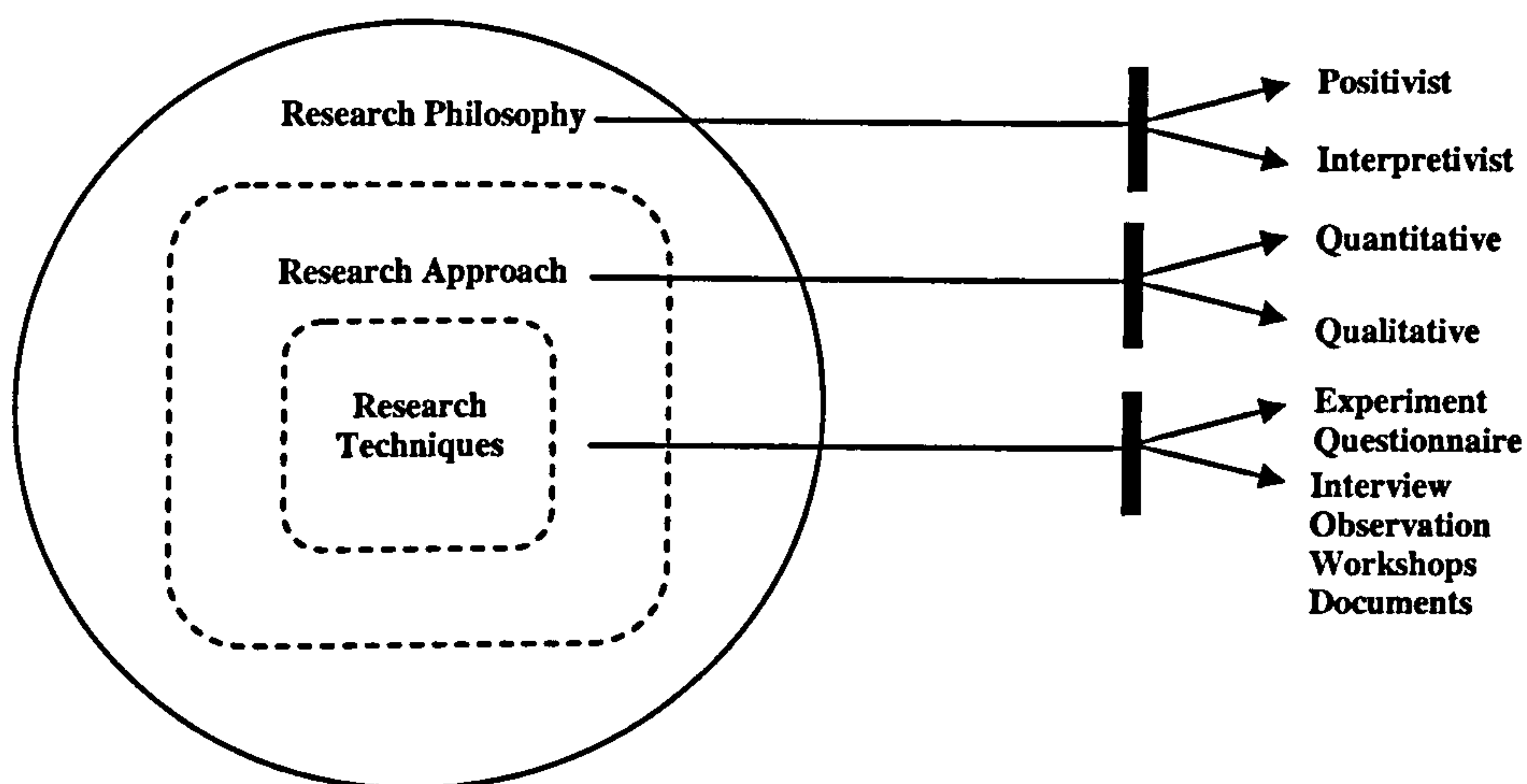


Figure 2.1: Nested Approach of Research Methodology (adapted from Kagioglou *et al.* 1998).

Many research projects use methods from more than one class. The reasons for combining methods are to capitalise on the strength of the two approaches, and to compensate for the weakness of each approach. Before discussing the adopted research methods, the following sections review the characteristics of these research methods including their advantages and limitations.

2.2.3 Quantitative Research

Fellows and Liu (2003) defined quantitative research as an investigation that is related to positivism and seeks to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and findings of any research executed previously. According to Leedy and Ormrod (2001), this method is used to answer questions about the relationship between the measured variables with the purpose of explaining, predicting and controlling phenomena. Analysis of quantitative measures can be categorised into two different types (Emmit and Gorse, 2003):

- *Statistical analysis:* When quantitative information is collected it is normally analysed with the aid of either descriptive or inferential statistics. Descriptive statistics simply segregate and aggregate the data and use various methods to present the data graphically (e.g. histograms, pie charts, etc). Inferential

statistics use various formulae to determine the probability of something occurring, or to identify the strength of the relationship between two or more variables.

- *Content analysis*: This form of analysis usually seeks to classify communication acts into categories that have common features. This analysis provides the researcher with a qualitative picture of the respondents' concerns, ideas, attitudes and feelings.

Quantitative researchers tend to rely more heavily on deductive reasoning, beginning with certain premises (e.g., hypotheses, theories) and then drawing logical conclusions from them. A quantitative researcher uses a variety of research methods to provide objective description and/or causal explanation about social phenomena or processes (Abdullah, 2003). The following are the two most commonly used quantitative research methods:

a. Experimental Research

Fellows and Liu (2003) defined an experiment as an activity or process, a combination of activities, which produces events and possible outcomes. Usually, in scientific contexts, experiments are devised and conducted as tests to investigate any relationships between activities carried out and the resultant outcomes. It is the research method that measures the effect of manipulating one variable on another variable for finding causal relationships between variables (Keppel 1991). The experimental method can be thought of as systematic trial and observation; trial because the answer is not known beforehand, observation because the result must be carefully recorded and systematic because all good research is planned and purposeful (Melville and Goddard 1996). The main idea of the experiment methods, and at once its main problem, is that all external factors are bracketed out; every effort must be made to control for those factors. According to Fellows and Liu (2005), there are two approaches to experimental research: laboratories experiments and field experiments. Field experiments are not conducted in specially built laboratories but in dynamic social, industrial, economic and political arena. The key strength of experimental research is its control and logical rigor in establishing evidence for causality. In general, experiments tend to be easier to

replicate, less expensive and less time consuming than the other techniques (Neuman, 2006 and Blumberg *et al.*, 2005). The key disadvantage of this method is that it is extremely difficult in a study involving human individuals (Alasuutari, 1999). Another limitation of this method is that some questions cannot be addressed using experimental methods because control and experimental manipulation are impossible (Neuman, 2006).

b. Surveys

This is a research methodology in which the researcher systematically asks a large number of people the same questions and then records their answers (Neuman, 2006). This method produces observations that are constructed in a specific manner. Knowledge of the presumptions that are typical of this construction will help both to draw conclusions about the applicability of the method to a particular study and to recognise the limits of the methods. The disadvantages of this method are that it is quite difficult to develop fresh perspectives or to come up with new ways of interpreting the researched phenomena. This is because of the inherent requirements of the method. The researchers must have a reasonably clear idea of the hypotheses they want to test and the preset responses they will set out before the interviews are even started (Alasuutari 1999).

There are two main type of data collection method in survey research, which includes: face-to-face or telephone interviews and questionnaires survey. The choice of data collection method is significant because it affects the quality and cost of the data collected (Abdullah, 2003). Neuman (2006) asserts that questionnaire offer anonymity and avoid interviewer bias, but a researcher can not control the conditions under which a questionnaire is completed. Although the questionnaire survey is cheaper compared to interview survey, in terms of quality, interview survey is more capable of obtaining quality data.

2.2.4 Qualitative Research

Creswell (1998) defined qualitative research as an inquiry process of understanding based on distinct methodological traditions of inquiry that explores a social or human experience. Qualitative researchers operate under the assumption that reality is not easily divided into discrete, measurable variables. Qualitative data, with its emphasis on peoples' 'lived experience', are fundamentally well suited for locating the meanings people place on the events, processes and structure of their lives: their 'perceptions, assumptions, prejudgements, presuppositions' (Amaratunga *et al.*, 2003). Qualitative data does not seek to turn data into quantities, rather it helps to analyse interaction, statements, and transcripts with the intention of identifying patterns, links, beliefs and trends. Emmit and Gorse (2003) assert that there are three main categories of qualitative research methods of analysis:

- *Conversation analysis*: This is concerned with the contextual sensitivity of language with a focus on interaction and social action. Investigations using conversation analysis can only be pursued through intensive qualitative analysis of interaction events. Transcripts or audio recordings of interaction are required to provide the detailed data necessary for conversation analysis. The analysis attempts to understand the relationship between different events.
- *Discourse analysis*: This is a slightly broader term than conversation analysis. It involves the scrutiny of transcripts of discussions and statements. The content and the linguistic context are considered when establishing meaning and intention of the interaction
- *Semiological analysis*: This form of qualitative analysis assumes that there is a relationship between the appearance and structure of the text and interaction and the meanings that it produces within a specific culture or context.

According to Neuman (2006), qualitative research makes considerable use of inductive reasoning. They make many specific observations and then draw inferences about larger and more general phenomena. Discussions of qualitative research approaches are as follows:

a. Ethnographic Research

Ethnographic research is a description and interpretation of a cultural or social group or system (Creswell, 1998). Alasuutari (1999) asserts that an ethnography research is used to study an intact cultural group over a prolonged period of time by collecting primarily observational data. The researcher studies the group in its natural setting for a lengthy period of time and data collection methods are site-based fieldwork and participant observation. The focus of investigation is on the everyday behaviours (e.g. interactions, language, rituals) of the people in the group, with an intent to identify cultural norms, belief, social structures, and other cultural patterns (Leedy and Ormrod, 2001). This method has a different level of abstraction and the meaning of the distinctions compare to others statistical social research. Generally, all ethnographic research shares the same objective of lying bare, from within, the logic that informs and organise the collectivity's life and way of thinking. The key strength of this method is it gives detail view of the entire cultural scene by pulling together all aspects learned about the group and showing its complexity. The disadvantages of an ethnography research is that it may have limited generalisability to other topics or domains and it takes a lot longer than most other kinds of research.

b. Grounded Theory

Grounded theory is a research method that attempts to construct a theoretical model by using multiple stages of data collection and the refinement of information (Leedy and Ormrod, 2001). This method has become popular in social research, partly because it enables processes to be explored systematically and it does not require large sample sizes (McKenzie *et al.*, 1998). The key data collection methods for grounded theory are: interviews, observations, documents, historical records, videotapes, and anything else of potential relevance to the research question. But, grounded theory analysis appears to be used as a type of poorly controlled content analysis. As a result, this has given rise to a large number of poor quality studies, with inadequate sample sizes to ensure adequate saturation of categories and failure to develop conceptually an analytical version of the theory.

c. Phenomenological Study

Leedy and Ormrod (2001) defined phenomenological study is a study that attempt to understand people's perceptions, perspectives, and understanding of a particular situations. It is a research methods in which human experiences are examined through the detailed descriptions of the people being studied (Creswell, 1998). The main focus of this method is an investigation of a particular phenomenon as it is typically lived and perceived by human beings. The key data collection method is in-depth unstructured interviews and typical purposeful sampling of 5 to 25 individuals. Phenomenological analysis gives priority to people's accounts of intentionality and subjective meanings. This is the phenomenological researcher's first and only point of reference. Those who dispute the adequacy of this seek to go beyond subjective meanings and argue that there is an important difference between 'things seeming to be the case to the actor and things being the case'. In other words, the phenomenological researcher may fail to come to terms with the social structures that underpin and position actors' intentional behaviours (McKenzie *et al.*, 1998).

d. Action Research

Action research was originally concerned to apply social science knowledge to solve social problems such as conflict between groups and the need to change eating habits in wartime. Its main aim is to contribute both to the practical concerns of people in immediate problematic situations and to the goals of social science by joint collaboration within a mutually acceptable ethical framework (Gill and Johnson, 2002). Action researchers intend not only to contribute to existing knowledge but also to help resolve some of the practical concerns of the people, or clients, who are trying to deal with a problematic situation. Blumberg *et al.* (2005) notes that there are four main characteristics of action research:

- Addresses real-life problems and is bounded by the context;
- Involves collaborative venture between researchers, participants and practitioners;

- Continuing reflecting process of research and action; and
- The credibility and validity of action research are measured on whether the actions solve the problems and realise the desired change.

The key advantages in using action research include: It provides an experience for researchers who want to work closely with the practitioner community; it can be used in many research modes; and it can be combined with other research methods for diversifying a research program (Abdullah, 2003). The key weakness of this method is that it cares less about general principles, although those can be the outcome of the project (Blumberg *et al.*, 2005). Baskerville and Harper (1996) view that action research is context-bound, and not context-free. Therefore it is difficult to determine the causes of a particular effect that could be due to the environment, researcher or methodology. This means that the action research produce narrow learning in its context because each situation is unique and cannot be repeated.

e. Case Studies

Yin (2003) defined the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. Case study refers to the investigation of a single entity (the case) or multiple cases by using a variety of data collection methods during a sustained period of time. According to Johnston *et al.* (1999), good and effective case study research should have the following elements:

- The research must begin with hypotheses developed by theory;
- The research design must be logical and systematic; and
- The findings must be independently evaluated.

The key feature of the case study approach is not method or data but the emphasis on understanding processes as they occur in their context (Amaratunga *et al.*, 2002). The data collection methods include interviews, observations, documents, past records and

audiovisual materials. In many instances, the researcher may spend an extended period of time on-site and interact regularly with people who are being studied (Leedy and Ormrod, 2001). The researcher interviews individuals or studies life history documents to gain an insight into behaviour and attempts to discover unique features and common traits shared by all persons in a given classification.

Yin (2003) asserts that case studies are the preferred strategy when 'how' and 'why' questions are being posed, when the investigator has little control over events, and when is on a contemporary phenomenon within some real-life context. According to Leedy and Ormrod (2001), the key strength of case study research is because it is suitable for learning more about a little known or poorly understood situation. It may also be useful for investigating how an individual or program changes over time, perhaps as the result of certain circumstances or interventions. Critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generality of findings. Some researchers feel that the intense exposure to the study of the case biases the findings. However, Johnston *et al.* (1999) are of the view that case studies have become theory-based, rigorous and more objective, if the case study design considers three important elements of case studies: must define unit of analysis; select the appropriate cases to study, and decide on what data to collect and how to collect it. Yet researchers continue to use the case study research method with success in carefully planned and crafted studies of real-life situations, issues, and problems. Its major weakness is that, especially when only a single case is studied, it provides a limited basis for the traditional 'scientific generalisation' (Yin, 2003). However, Amaratunga *et al.* (2002) argued that like all experimental observations, case study results can be generalised to theoretical propositions (analytical generalisation) not to populations or universes (statistical generalisation). Meredith (1998) point out that some of the difficulties of doing case study research include: the requirements of direct observation in the actual contemporary situations (cost, time, access hurdles); the need for multiple methods, tools, and entities for triangulation; the lack of controls; and the complications of context and temporal dynamics.

2.2.5 Triangulation

Triangulation is the combination of methodologies in the study of the same phenomenon (Amaratunga *et al.*, 2002). Furthermore, Love *et al.* (2002) argue that triangulation is a means of representation based on the logic that we can move closer to obtain a truer picture if we can make multiple measurements, using multiple methods, or at multiple levels of analysis. Typically, the triangulation process involves corroborating evidence from different sources to shed light on a theme or perspectives (Creswell, 1998). As triangulated studies employ two or more research techniques, qualitative and quantitative approaches may be employed to reduce and eliminate the disadvantages of each individual approach whilst gaining the advantages of each, and of the combination, as illustrated in Figure 2.2 (Fellows and Liu, 2003). Amaratunga *et al.* (2002) analysed that quantitative data can help with the qualitative side of a study during design by finding a representative sample and locating deviant samples, while qualitative data can help the quantitative side of the study during design by aiding with conceptual development and instrumentation.

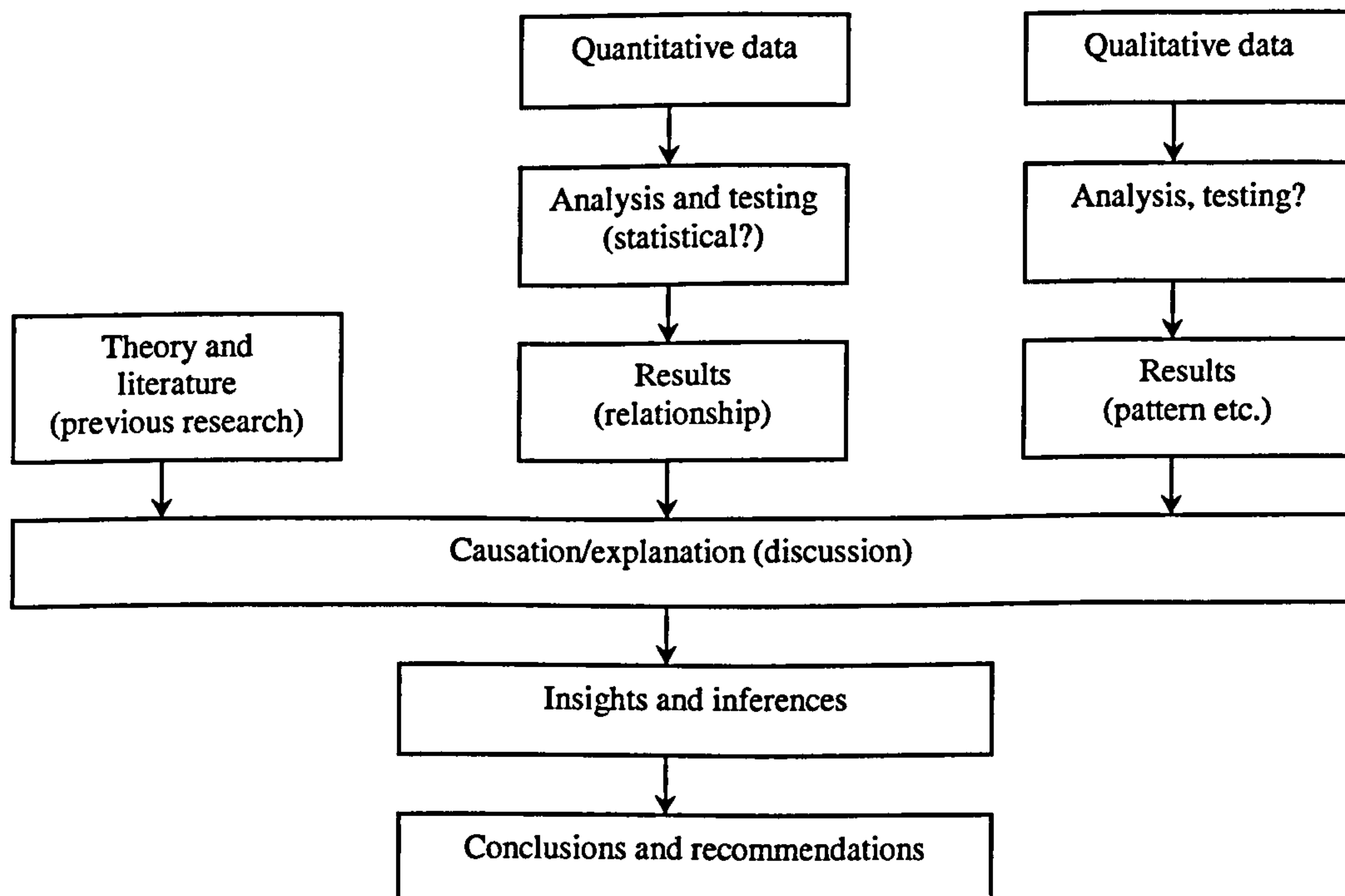


Figure 2.2: Triangulation of Quantitative and Qualitative Data (Fellows and Liu, 2003).

According to Easterby-Smith *et al.* (2002), there are four distinct categories of triangulation involving the theoretical, data, investigator and methodological triangulation:

- *Theoretical triangulation* involves borrowing models from one discipline and using them to explain situations in another discipline;
- *Data triangulation* refers to the research where data is collected over different time from or from different sources;
- *Investigator triangulation* is where different people collect data on the same situation and data, and the results are then compared; and
- *Methodological triangulation* using both quantitative as well as qualitative methods of data collection. These were extremely diverse and included questionnaire, interviews, telephone survey, and field study.

Love *et al.*, (1998) assert that there are two main advantages of combining qualitative and quantitative research methods. Firstly, combining these methods increases the capability to transmit the knowledge in a tangible form. Secondly, convergent findings can allow greater researcher confidence in the reliability and/or validity of results, whereas divergence can lead to greater definition and theoretical elaboration as the researcher attempt to piece together many pieces of a complex puzzle into a coherent picture. Moreover, triangulation methods may lead to a better understanding of the phenomena under investigation, when additional information may be revealed that would otherwise remain undiscovered via a single methodological approach (Abdullah, 2003). For example, using a quantitative method such as questionnaire survey can provide a broad idea on the subject studied and combining it with qualitative methods such as semi-structured interviews or/and case studies provide a better understanding of the same study. Yin (2003) asserts that there may be problems in implementing triangulation methods in any research. First, the collection of data from multiple sources is more expensive than if data were collected only from a single source. Second, each investigator needs to know how to carry out the full variety of data collection techniques. If any research technique is used improperly, the opportunity to address a broader array of issues or to establish converging lines of inquiry may be lost. Table 2.1

shows a summary of distinguishing characteristics of quantitative and qualitative research methods including their main strengths and weaknesses.

Table 2.1: Distinguishing Characteristics of Quantitative and Qualitative Methods (adapted from Neuman, 2006; Abdullah, 2003; Amaratunga *et al.*, 2002; and Leedy and Ormrod, 2001).

Characteristics	Quantitative research	Qualitative research
Purpose	<ul style="list-style-type: none"> • To explain and predict • To confirm and validate • To test theory 	<ul style="list-style-type: none"> • To describe and explain • To explore and interpret • To build theory
Process	<ul style="list-style-type: none"> • Focused • Known variables • Established guidelines • Statistic design • Context free • Detached view 	<ul style="list-style-type: none"> • Holistic • Unknown variables • Flexible guidelines • Emergent design • Context-bound • Personal view
Research Procedures	<ul style="list-style-type: none"> • Procedures are standard, and replication is frequent 	<ul style="list-style-type: none"> • Research procedures are particular, and replication is very rare
Data Collection	<ul style="list-style-type: none"> • Representative, large sample • Standardized instruments 	<ul style="list-style-type: none"> • Informative, small sample • Observations, interviews
Theory	<ul style="list-style-type: none"> • Theory is largely causal and is Deductive 	<ul style="list-style-type: none"> • Theory can be causal or noncausal and is often inductive
Data Analysis	<ul style="list-style-type: none"> • Analysis proceeds by using statistics, tables, or charts and discussing how they show relates to hypothesis 	<ul style="list-style-type: none"> • Analysis proceeds by extracting themes or generalisations from evidence and organising data to present a coherent, consistent picture.
Reporting Findings	<ul style="list-style-type: none"> • Numbers • Statistics, aggregated data • Formal voice, scientific style 	<ul style="list-style-type: none"> • Words • Narratives, individual quotes • Personal voices, literary style
Strengths	<ul style="list-style-type: none"> • Provide wide coverage of the range of situations • Fast and economical • Where statistics are aggregated from large samples, they may be considerable relevance to policy decisions 	<ul style="list-style-type: none"> • Data gathering methods seen as natural than artificial • Ability to look at change process over time • Ability to understand people's meaning • Contribute to theory generation
Weaknesses	<ul style="list-style-type: none"> • Tend to be rather inflexible and artificial • Not very effective in understanding process • Not very helpful in generating theories 	<ul style="list-style-type: none"> • Data collection can be tedious and require more resources • Analysis and interpretation of data may be more difficult • Harder to control the pace, progress and end-points of research process

2.2.6 Interview as Method of Collecting Data

An interview is a secondary social interaction between two strangers with the explicit purpose of one person obtaining specific information from the other. The social roles are those of the interviewer and the interviewee or respondent (Neuman, 2006). Leedy and Ormrod (1999) view that the key limitation of the interview is when a researcher asks about past events and behaviours, the interviewees must rely on their memories, and human memory is notoriously inaccurate. Interviews can be divided into two approaches: face-to-face interviews and telephone interviews.

A face-to-face interview is a two-way conversation initiated by an interviewer to obtain information from a participant. The main strength of this approach is the interviewer can pre-screen respondents to ensure he/she fits the populations profile (Blumberg *et al.*, 2005). The interviewer can also do more things to improve the quality of the information received than other methods (i.e. responses can be entered into a portable tape recorder to reduce error). The key weakness of this method is because it is costly, in terms of both money and time. Cost is particularly high if the study covers a wide geographic area or has stringent sampling requirements. While, telephone interview can be helpful in arranging personal interviews and screening large populations for unusual types of participants (Blumberg *et al.*, 2005). The main advantages of this method is because telephone interviews are less consuming and less expensive, and the researcher has ready access to virtually anyone in the different geographical area who has telephone. However, the response rate in telephone interviews is lower than for comparable face-to-face interviews.

Neuman, (2006) asserts that there are three categories of interviews: structured interview, semi structured interview and unstructured interview. According to Fellows and Liu (2003), the major differences between these categories lie in the constraints placed on the respondent and interviewer. In a structured interview, the interviewer administers a questionnaire, perhaps by asking the questions and recording the responses, with little scope for probing those responses by asking supplementary questions to obtain more details and to pursue new and interesting aspects. In unstructured interviews, the interviewer introduces the topic briefly and the records the replies of the respondent. This is to ensure completion of the statements; clearly the

respondent can say what and as much as he/she desires. In a semi-structured interview, the research may follow the standard questions with one or more individually tailored questions to get clarifications or probe a person reasoning (Leedy and Ormrod, 1999). Table 2.2 summarises the main differences between, structured, semi-structured and unstructured interviews.

Table 2.2: Comparison of Interview Techniques (Wright and Ayton, 1987).

Category	Process	Advantages	Disadvantages
Structured Interview	<ul style="list-style-type: none"> • Questions are set in advance • Each interview is conducted in exactly the same way • The question and their order are the same for all respondents • The range of possible responses is determined by the researcher 	<ul style="list-style-type: none"> • Quick and easy to answer • Answers are easy to code and analyse • The direction of the inquiry is clear • High degree of reliability – straightforward ‘factual’ information. • Produces ‘comparable’ data • Reduced possibility of interviewer bias 	<ul style="list-style-type: none"> • Inflexible • Participants may be forced into giving responses which do not reflect their true feelings about an issue • Gathers a limited amount of information: lack the richness obtained by more open-ended interviews
Semi-structured Interview	<ul style="list-style-type: none"> • Very much like questionnaire • Open-ended questions • Permissible to stray from the subject area and ask supplementary questions two-way communication • They can be used both to give and receive information 	<ul style="list-style-type: none"> • Less intrusive to those being interviewed as the semi-structured interview encourages two-way communication • Confirms what is already known but also provides the opportunity to learning • Gives the freedom to explore general views or opinions in more detail 	<ul style="list-style-type: none"> • Requires interviewing skill • Need to meet sufficient people in order to make general comparisons • Time consuming and resource intensive • Preparation must be carefully planned so as not to make the questions prescriptive or leading
Unstructured Interview	<ul style="list-style-type: none"> • Exploratory approach • No prepared list of questions • Open-ended questions 	<ul style="list-style-type: none"> • Allows flexibility • Respondents can answer in their own words • The nature of the response is not limited • The result of this more open-ended approach is a richness of data • More complex and sensitive questions possible 	<ul style="list-style-type: none"> • Requires interviewing skills • lack of standardization • The answers are difficult to analyse • Depends on the ability of respondents to express themselves • Time consuming • Largest potential for interviewer bias.

Blumberg *et al.* (2005) point out that the main differences between interview methods are partly connected to the underlying research philosophy (positivism versus interpretivism, the data collection strategy (quantitative versus qualitative), and the sampling strategy (sample versus case study). Smith *et al.* (2002) suggest that interviews, both semi-structured and unstructured, are therefore appropriate method when:

- It is necessary to understand the constructs that the interviewee uses as a basis for his/her opinions and beliefs about a particular matter or situation; and
- One aim of the interview is to develop an understanding of the respondent's 'world' so that the researcher might influence it, either independently, or collaboratively as in the case with action research.

2.3 Choice of Research Strategy

From the previous discussion, it is apparent that research that involves the integration of quantitative and qualitative has become increasingly common in construction management research in recent years. However, Walker (1997) argued that many researchers struggle with the difficult question of how to choose an appropriate methodology for the research problem they are attempting to investigate. According to Yin (2003), research strategy should be chosen as a function of the research situation. Each research strategy has its own specific approach to collect and analyse empirical data, and therefore each strategy has its own advantages and disadvantages. However its depend on three conditions: the type of research questions; the control an investigator has over actual behavioural events; and the focus on contemporary as opposed to historical phenomena. Table 2.3 shows these three conditions and show how each is related to the five most common research strategy: experiments, surveys, archival analyses, histories and case studies.

Table 2.3: Research Strategies versus Characteristics (Yin, 2003).

Strategy	Form of Research Question	Requires Control of Behavioural Events	Focuses on Contemporary Events?
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How Many, How Much	No	Yes
Archival Analysis	Who, What, Where, How Many, How Much?	No	Yes/No
History	How, Why	No	No
Case Study	How, Why	No	Yes

Creswell (1994) asserts that the guiding principle for developing any research methodology is that it must completely address the research questions. To meet these objectives, a research study should have a detailed research design that can be used as a blue print for collecting observations and data that are connected to the research objectives. Fellows and Liu (2003) suggest that the choice of research strategy affected by consideration of the scope and depth required. The choice is between a broad but shallow study at one extreme and a narrow and deep study at the other, or an intermediate position, as shown in Figure 2.3.

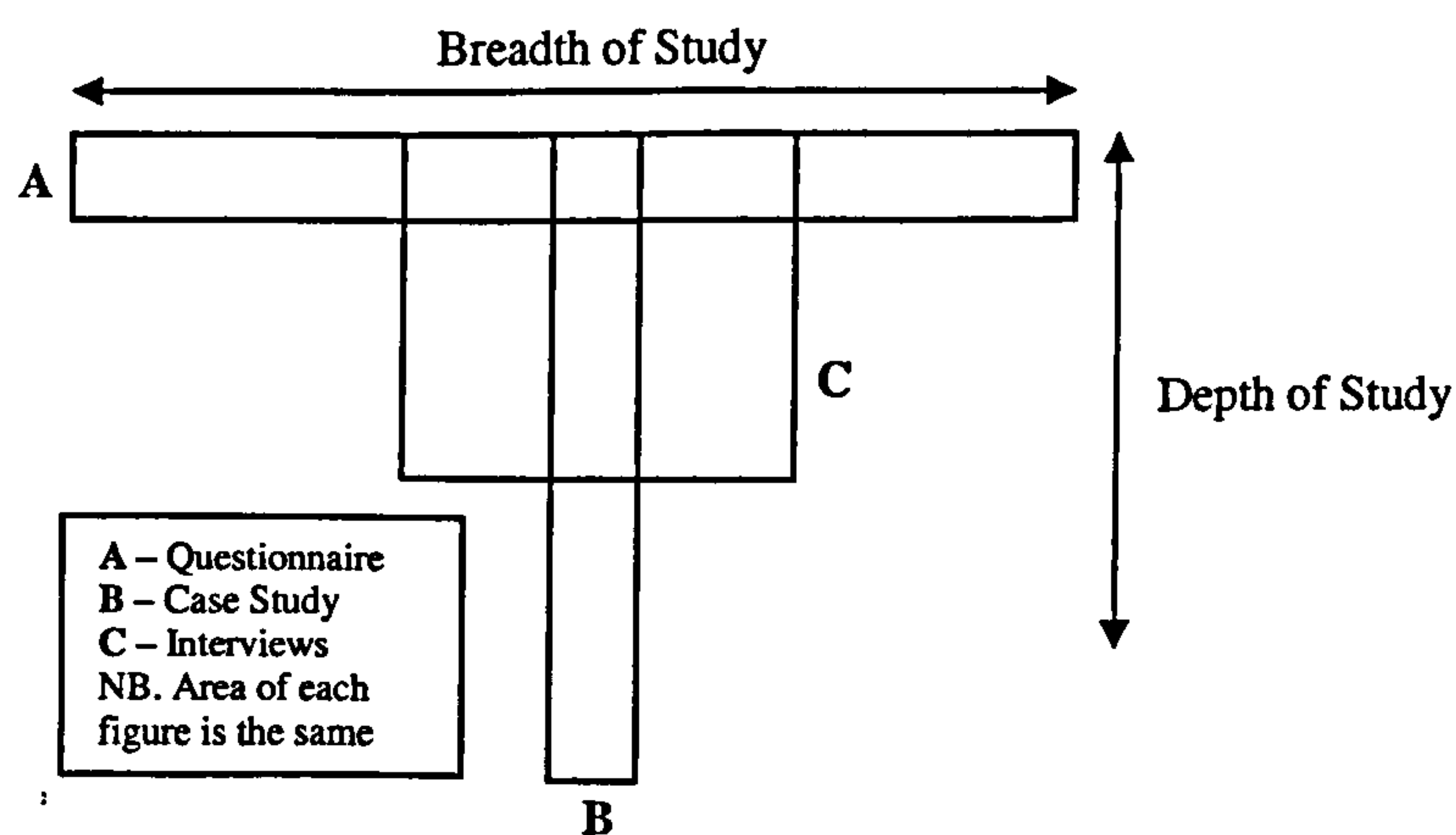


Figure 2.3: Breadth and Depth in 'Question-Based' Studies (Fellows and Liu, 2003).

In planning research strategy, therefore, it is extremely important for the researcher not only to choose a viable research but also to consider the kinds of data an investigation of the problem will require and feasible means of collecting those data (Leedy and Ormrod, 2001). Galliers (1992) provides a list of research approaches that can be chosen based on the quantitative and qualitative research approach. Table 2.4 summarises the most common research approaches that can be chosen based on the quantitative and qualitative research approach. It is important to note that most research approaches listed in the table can be used at least to some extent, as either quantitative or qualitative approaches.

Table 2.4: Research Approaches and Philosophical Bases (adapted from Galliers, 1992).

Research Approaches	Positivism (Quantitative)	Interpretism (Qualitative)
Action Research		✓✓✓
Case Studies	✓✓	✓✓
Ethnographic		✓✓✓
In-depth Survey		✓✓✓
Large Scale Survey	✓✓	✓
Laboratory Experiments	✓✓	✓
Field Experiments	✓✓	✓✓
Simulation & Modelling	✓✓	✓

Legend:

- ✓✓✓ *Strictly quantitative/qualitative*
- ✓✓ *Have scope to be neither*
- ✓ *With some room for quantitative/qualitative*

2.4 The Methodologies Adopted for the Research

The main aim of the research is to develop a systematic approach for the improvement of construction site management practices through an integration of applicable knowledge management processes. This study focuses on the development of a viable framework that reflects the specific context of site management practices, and which makes provision for both explicit and tacit knowledge. In order to achieve its main aim and specific objectives, both quantitative and qualitative research approaches were adopted. Brief descriptions of the research methods adopted were provided in Section 1.5. The next section provides further details of these methods.

2.4.1 Literature Review

The essential part of every research project is the review of the current literature (Blumberg *et al.*, 2005). Literature review is the documentation of a comprehensive review of the published work from secondary sources of data in the areas of specific interest to the researcher. The purpose of the literature review is to ensure that no important variable is ignored that has in the past been found repeatedly to have had an effect on the problems (Sekaran, 1984). According to Fellows and Liu (2003), literature should not merely be found and reviewed; the body of relevant literature from previous research must be reviewed critically. The literature must be considered in the context of theory and other literature; the methodologies, data, analytic techniques, sampling, etc. Gill and Johnson (2002) assert that there are several important outcomes of a well conducted literature review:

- It helps describe a topic of interest and refine either research questions or directions in which to look;
- It presents a clear description and evaluation of the theories and concepts that have informed research into the topic of interest;
- It clarifies the relationship to previous research and highlights where new research may contribute by identifying research possibilities which have been overlooked so far in the literature;
- It provides insight into the topic of interest that are both methodological and substantive;
- It demonstrates powers of critical analysis by, for instance, exposing taken for granted assumptions underpinning previous research and identifying the possibilities of replacing them with alternative assumptions; and
- It justifies any new research through a coherent critique of what has gone before and demonstrates why new research is both timely and important.

Literature can be found in both primary and secondary sources. Primary sources are full-text publications of theoretical and empirical studies and represent the original work. Secondary sources are compilations of information, either in printed and digital form. In general, the systematic literature search has five main processes (Neuman,

2006): define and refine the search; design a search; locate research reports; evaluating research articles; and taking notes. Before locating research reports, it is essential to plan a search strategy. The researchers need to decide on the type of review, its extensiveness, and the types of materials to include. In this research, the main role of literature review is to find a gap in the theory emerged, providing some potential research areas. In general, researchers and practitioners in the KM field have not investigated the implementation of KM processes at the operational level in the construction industry context. It is therefore, the journals and reports related to knowledge management and site management, were valuable for this effort. Most construction management research is published in refereed academics journals, professional journals, text books, conference proceeding, government reports and theses. In this research, most of the books and journal articles have been obtained through libraries. The task of searching the published literature is made easier through the existence of computer databases, electronic resources portal (i.e. Metalib), electronic journal, computerised catalogues, searches on the Internet (i.e. Google scholar).

In order to achieve the first and second objective of the research, two main topics were selected to be reviewed as illustrated in Figure 2.4:

- Current site management practices with a view to identifying current problems and which aspects of the site management practices could be improved; and
- Knowledge management processes, taxonomies of knowledge and knowledge management tools and techniques. A well structured synthesis will be carried out, with a focus on establishing the most viable processes for use in construction site management practices.

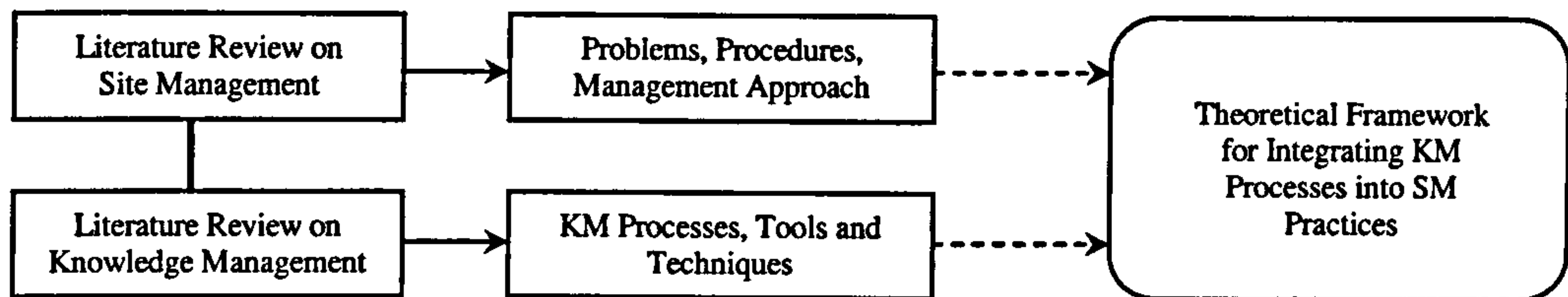


Figure 2.4: Literature Review Search.

Literature reviewed on these two topics provides a theoretical framework for integrating knowledge management processes into site management practices. The literature review is a continuous process, which will be carried out simultaneously along with a case study stage and framework development stage to capture new issues and gaps in literature. Other topics related to the research such as research methodology and prototype system development process were also reviewed.

2.4.2 Case Studies

The case study approach consists of a detailed investigation that attempts to provide an analysis of the context and processes involved in the phenomenon under study (Johnston *et al.*, 1999). Blumberg *et al.*, (2005) classified case study research into two main types: single and multiple case studies. The former relies on one single case, while the latter calls for the investigation of several cases. According to Naoum (1998), there are three types of case study designs:

- *The descriptive case study*, which is similar to the concept of the descriptive survey (i.e. counting), except it is applied to detailed case(s);
- *The analytical case study*, which is similar to the concept of the analytical survey (i.e. counting, association and relationship), except it is applied to detailed case(s); and

- *The explanatory case study*, which is the theoretical approach to the problem. It explains causality and tries to show linkages among the objects of the study. It asks why things happen the way they do. In other words, the researcher collects facts and studies the relationship between them.

Basically, one of the problems with case research is its inherent “looseness”. Yin (2003) suggests that one way to combat this looseness is to establish a protocol that outlines the procedures and general rules that will be used during data collection. The steps of procedures should provide an overview of the project, definitive data collection procedures, and the instruments that will be used for data collection. A case study protocol establishes a framework for collecting and analysing data. The protocol is a major tactic in increasing the reliability of case study research and is intended to guide the investigator in carrying out the case study. Well-designed steps of protocols ensure that the operations of the study can be repeated with the same results. According to Johnston *et al.*, (1999), when developing a case study protocol, there are four important considerations:

- *Defining the unit of analysis*: One of the major problems in designing a case study is defining the units of analysis to be used during the research. Choosing the unit analysis pushes the researcher to articulate the conceptual frame of reference and encourages proposition development. McClintock *et al.* (1997) write; “Although the units of analysis are typically defined as individuals, groups, or organisations, they could almost be any activity, process, feature, or dimension of organisational behaviour”.
- *Case selection*: Whilst a single-case study needs only to focus on one case, in multiple-case studies, cases should be selected so that they are replicating each other; either direct replications or predictably systematic replications. Using single-case design, the investigator should be prepared to make an extremely strong argument in justifying the choice for the case. In contrast, analytic conclusions independently arising from multiple-case study will be more powerful than those coming from a single case alone.
- *Data collection*: A systematic plan must be developed that stipulates what information is to be sought to fully investigate the research hypotheses and how

it is to be obtained. Yin (2003) asserts the use of a 'study protocol' which systematically documents all decisions pertaining to the research design, and includes the set of substantive questions reflecting the actual inquiry.

- *Data analysis*: The analysis of case study research represents assessing whether or not the evidence within each case is internally valid, supportive of the pre-specified hypotheses across the multiple cases, and conclusive. The preferred strategy for data analysis is to use the propositions that encapsulate the objectives of the study, and which have shaped the data collection.

a. Multiple-Case Studies

To fulfil the first, second and third research objectives (explained in Chapter 1, section 1.4) proposed by this study, multiple-case studies were undertaken. A case study uses a variety of data collection methods during a specific period in effort to study a single research case. Case studies are used widely in social science as well as the practice oriented fields in construction engineering, management science and education. According to Yin (2003), case studies are the preferred strategy when "how" and "why" questions being posed, when there is little control over events, and when the focus is on contemporary phenomenon within real life context. The advantage is that the researcher can better understand phenomena that influence organisational and project performance in construction (Love *et al.*, 2002). Moreover, Johnston *et al.*, (1999) assert that case study research can also make extensive use of other sources of data within the organisation. In order to conduct a systematic case study approach, Yin (2003) develops a three stages process to help guide case research. These processes include define and design stage; prepare, collect and analyse stage; and analyse and conclude stage. By progressing through these stages, the initial step in designing the study must consist of theory development and then shows that case selection and the definition of specific measures are important steps in the design and data collection process.

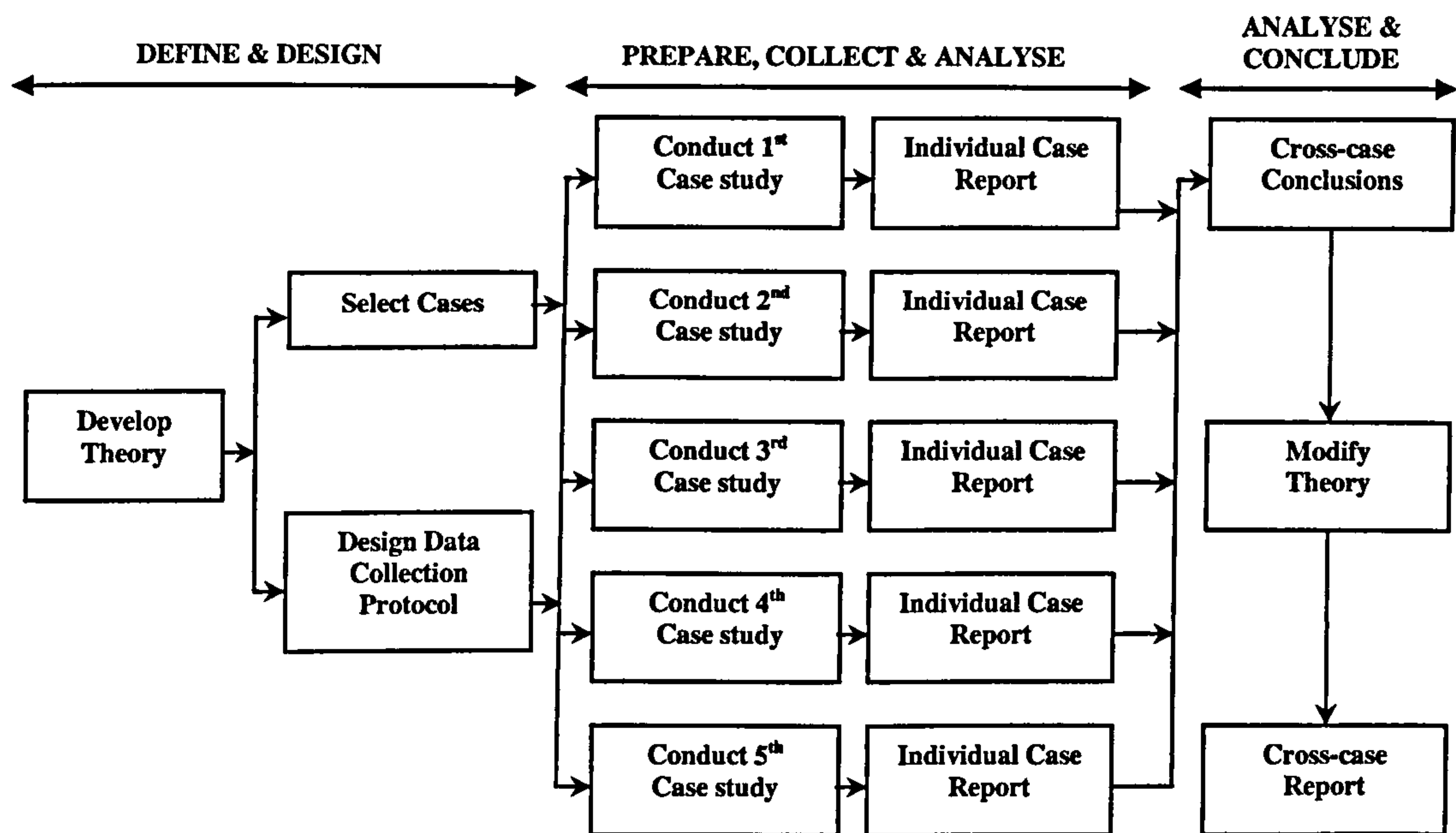


Figure 2.5: Multiple-Case Studies Approach Used (adapted from Yin, 2003).

This study used a multiple-case studies approach that incorporates qualitative comparators with observations made within five construction site, as shown in Figure 2.5. The qualitative methods will include comparison characteristics of site management practices. To help add depth to the study, qualitative data will be collected during each of the case study interviews. In turn, this qualitative data will be used to explicate site management problems with regard to knowledge management dimensions. This multiple-case studies approach will help support the construct validity of the research design. Perry (1998) suggests that the ideal number of multiple-case studies is between four and ten cases. With fewer than four cases, it is often difficult to generate theory with much complexity, and its empirical grounding is likely to be unconvincing. The main advantage of case studies compared to other approaches is that they permit the combination of different sources. In this research, there are three main sources of evidence for data collection: semi-structured interviews, documents and archives and observation. This research seeks to answer specific questions of how to integrate applicable KM processes into site management practices. Given the “how” nature of this study’s research aim, a case study approach provides a useful research

method for answering them. The case study protocols used in this research are described as follows:

Defining the unit of analysis: The selection of the ‘units of analysis’ is geared towards achieving the study objective, which is to investigate the potential for improving site management practices through knowledge management implementation. The “units of analysis” adopted are as follows:

- *Approaches to problem solving:* This explores the most significant problems that occur on the construction site and approaches and strategies used by site managers to solve these problems.
- *Approach taken when a mistake is made:* This seeks to identify current methods used by site managers to capture mistakes and lessons learned.
- *Knowledge sharing mechanisms:* This aims to identify the tools and techniques used by site managers to share knowledge on the construction site.
- *IT tools and software used:* This investigates the IT tools and software used in managing the construction site.
- *Roles of intranet:* This explores the potential of the intranet as a vehicle for disseminating and sharing knowledge.

Case selection: At the broadest level of study, a “case” is defined by the setting of the project, the people who manage the project, the events that occur, and the processes that develop over the course of the project (Creswell, 1994). Because this research is focused on the integrating KM processes into site management practices, the “case” acted as a single construction site that had implemented knowledge management strategy in their organisations. The focus here was on selecting construction organisation having attempted to implement knowledge management. Related research in knowledge management such as “ConABKM Project” (Tserng and Lin, 2004), “CLEVER Project” (Anumba *et al.*, 2005) and “IMPAKT Project” (Robinson *et al.*, 2004) were helpful in this regards. The five construction sites were selected based on a willingness of individuals within these organisations to collaborate and share their

experience on managing construction sites and make information available to the research project.

Data collection: This involved semi-structured interviews (recorded on tape) and sought to identify site management problems, procedures used, actors involved and KM practices within site management practices. The questions were divided into three main sections: context of the construction site; site management; problems, procedures and actors involved; and KM processes within the site management practices.

Data analysis: This was concerned with an assessment of the appropriateness of the KM approaches adopted in resolving site management problems. The results will be used to support the development of KM framework to be integrated into site management practices.

Case study report and confirmation: The researcher provides a case study report to the interviewee for approval after the document was transcribed in detail. The aim is to clarify any unclear factual information with the interviewees and confirm the contents of the case study report.

b. Semi-Structured Interview

The case studies were based principally on semi-structured interviews with one site-based project manager in each of the companies. Semi-structured interviews were conducted using a set of questions designed to get opinions and responses from project manager or site managers about current problems and which aspects need to be improved on the construction site. Interviews lasted from 2 hours to 5 hours; which included an interview session, site visit and demonstration of current management system on the construction site. Semi-structured interviews were selected as they allow the interviewer more freedom to explore the expert's views or opinions while maintaining a level of comparability between interviewees.

The semi-structured interviews contained three parts: The first part was aimed at capturing general information about the site managers such as roles of site manager,

type of project involved in, type of procurement, and experience involved in construction site management. The second part was aimed at finding current problems, procedures and actors involved in the construction site and the last part was intended to investigate knowledge management processes within site management practices. From this finding, it is essential to make a judgement of the problems and aspects of site management practices that can be improved. Additionally, from this finding also, this study attempts to find the approach used by site managers to solve site management problems. Chapter 5 describes in detail the findings from each interview.

2.4.3 Framework Development

The third objective, development of a framework for improving site management practices based on an integration of KM processes, was achieved through case study findings and supported by extensive literature review on knowledge management and site management practices. The case studies have helped to identify aspects of KM at the construction site level. The organisations have a variety of mechanisms for managing their knowledge, although the label of KM is often not used. Nonetheless, the site management team have difficulties with regard to resolving site management problems. The key findings from the case studies are as follows:

- Site managers often wait until late in the project, when many problems start occurring, before tackling such problems and related issues; and
- Site organisations do not have any systematic methods and processes to locate/access and share knowledge from experts and senior people in the organisation.

The integrated framework consists of two main approaches:

- *Proactive approach*: Five stage KM approach which involves taking measures to prevent the most common site management problems from occurring; and
- *Reactive approach*: Nine stage KM approach to identifying the knowledge gap that has led to specific problems and recommending measures to tackle the problem.

The framework provides a structured approach to managing construction knowledge that is entrenched in site management processes. Figure 2.6 shows the linkage between literature review stage and case studies stage with framework development stage. The integrated framework includes the approach to be taken to tackle a specific problem (reactive approach) and the approach to be followed to avoid potential problems (proactive approach). Chapter 6 provides detail discussion on framework development process for this research project.

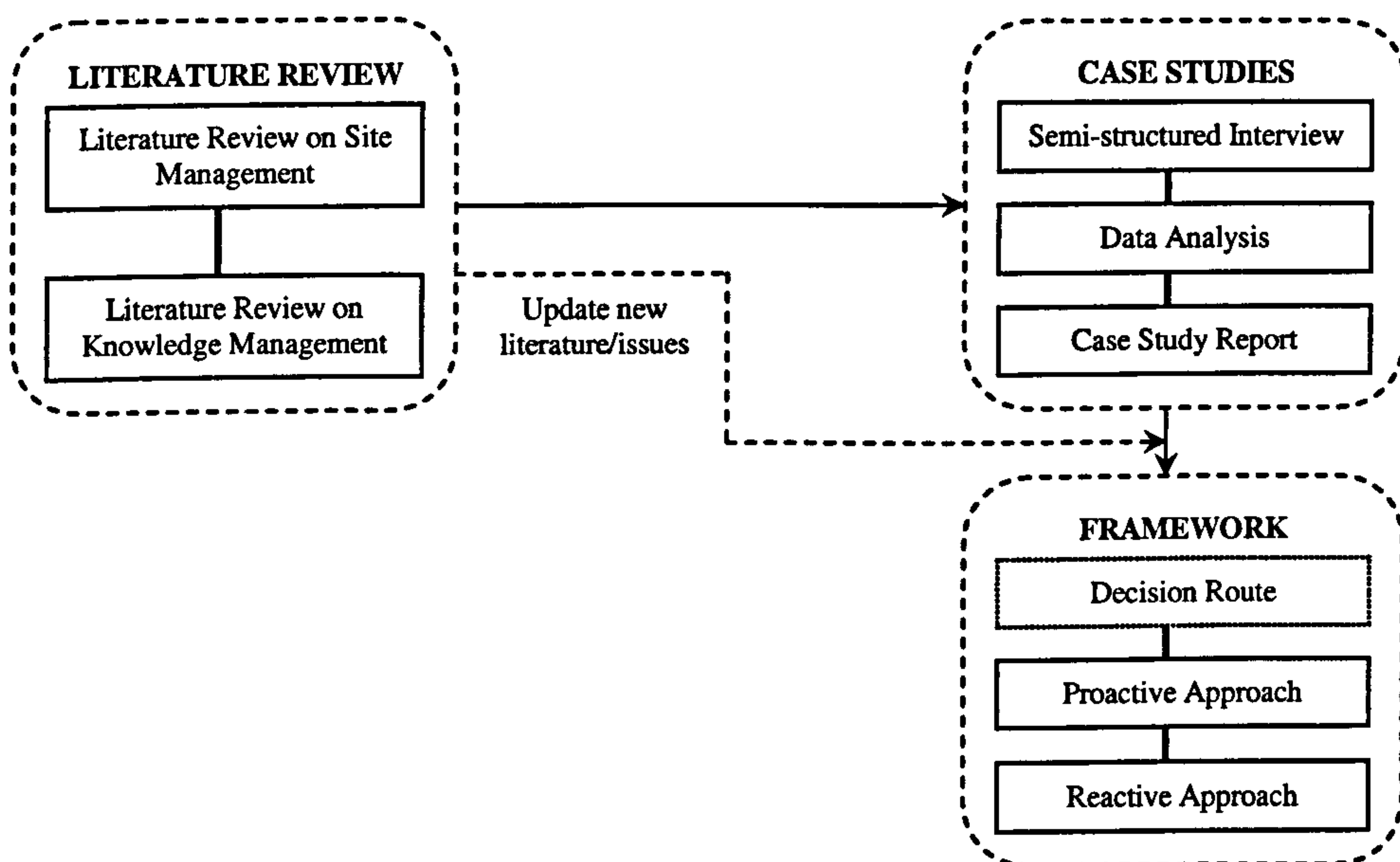


Figure 2.6: The Linkage between Literature Review Stage and Case Studies Stage with Framework Development Stage.

2.4.4 Encapsulate the Framework into Computer-Based Prototype System

An important element of the methodology used which relates to the fourth objective of the project was the automation and implementation of the framework (refer to Chapter 1, Figure 1.2). More specifically, the intention was to encapsulate the developed integrated KM framework into a prototype system. The aim of developing a prototype is to simplify the format and use of the integrated KM framework. The prototype system development used a methodology known as Rapid Prototyping. Laudon and

Laudon (2002) defined prototyping as a process of building an experimental system quickly and inexpensively for demonstration and evaluation so that users can better determine information requirements. Because a prototype can be developed quickly and inexpensively, the researcher can go through several iterations, to refine and enhance the prototype before arriving at the final operational one. The key strength of the prototyping include: short development time; short user reaction time (feedback from user); improved user understanding of the system, its information needs, and its capabilities; and low cost (Turban and Aronson, 1998). However, Laudon and Laudon (2002) stress that prototyping can gloss over essential steps in systems development. If the completed prototype works reasonably well, management may not believe there is a need for reprogramming, redesign, or full documentation and testing to build a polished production system. The process of rapid prototyping is shown in Figure 2.7 (Turban and Aronson, 1998)

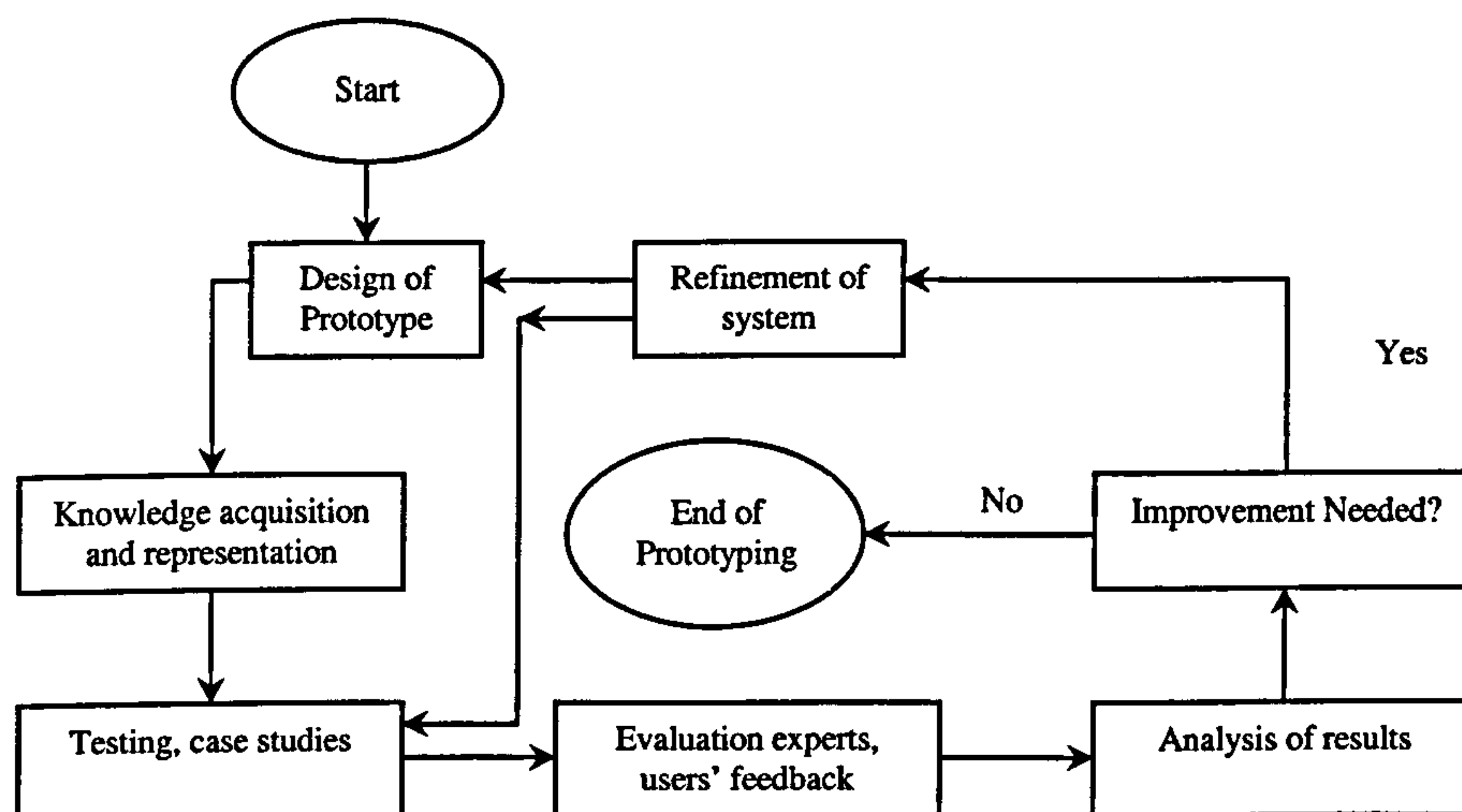


Figure 2.7: Rapid Prototyping Process (Turban and Aronson, 1998).

The process starts with the selection of the development environment, designing the system architecture, and identifying the system's operational framework. Then the knowledge is captured through case studies findings and represented in the prototype. Next, several tests were carried out based-on the numerous problems that occur on the construction site. Afterwards, the site managers and researchers were invited to participate in the evaluation workshop in order to evaluate how well the prototype

meets their needs and to assess the effectiveness of the software. The results of the evaluation workshop were analysed, and suggestions for improvement were used as a guide to improve the prototype system. The overall development process of the prototype system is discussed in Chapter 7.

2.4.5 Evaluation of the Prototype System

Neuman (2006) identifies two types of evaluation: formative and summative. Formative evaluation is built-in monitoring or continuous feedback on a program used for program management and takes place during development of the system. Summative evaluation looks at final program outcomes and takes place after development of the system. Table 2.5 shows the comparison between summative evaluation and formative evaluation. Both are usually necessary to determine how well a program is working or reaching its goals and objectives.

Table 2.5: Comparison between Summative Evaluation and Formative Evaluation (Patton, 2002).

Criteria	Summative Evaluation	Formative Evaluation
Purpose	<ul style="list-style-type: none"> • Determine effectiveness of human interventions and actions 	<ul style="list-style-type: none"> • Improve an intervention
Focus	<ul style="list-style-type: none"> • Goals of the interventions 	<ul style="list-style-type: none"> • Strength and weakness of the specific program.
Desired Results	<ul style="list-style-type: none"> • Judgements and generalisations about effectiveness types of interventions and the conditions under which those efforts are effective 	<ul style="list-style-type: none"> • Recommendations for improvements
Level of Generalisation	<ul style="list-style-type: none"> • All interventions with similar Goals 	<ul style="list-style-type: none"> • Limited to specific setting studied

To determine the appropriateness and functionality of the developed prototype system in improving construction site management practices, an evaluation workshop was conducted. The evaluation workshops were undertaken by four of the construction organisations involved in the case studies and selection of ten researchers who were willing to participate in the evaluation workshop. The evaluation workshop consisted of

three parts. First, there was a short presentation on the background to the framework and prototype system. Then, a demonstration of the prototype system was carried out. Its aim was to give a clear understanding to participants in order to assess the capability of the prototype for addressing all stages of the framework. This was followed by open discussion to get further feedback and suggestion from the participants after which participants were asked to complete a questionnaire. Figure 2.8 summarises the research methodology adopted in this research project including the evaluation of the prototype system.

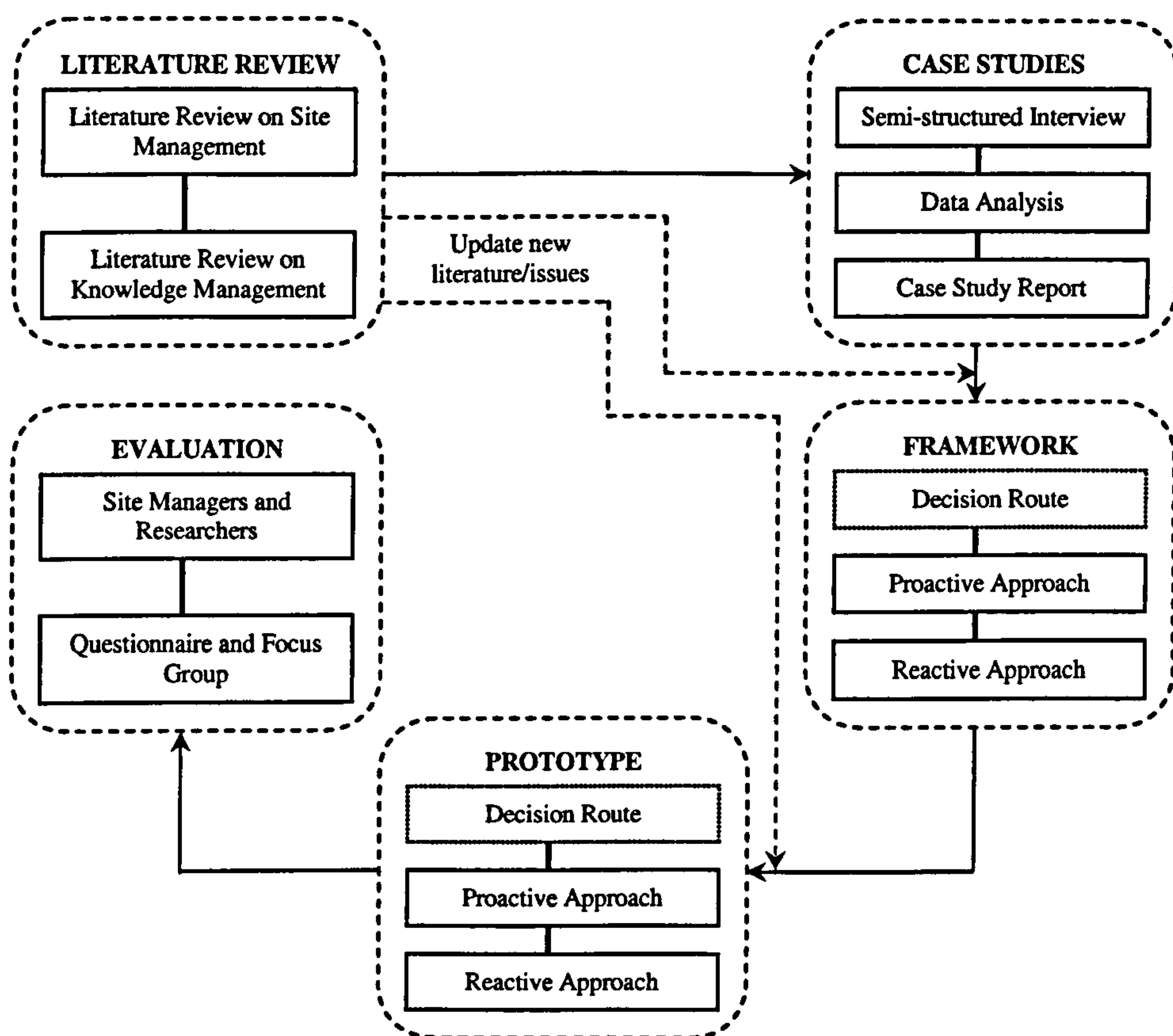


Figure 2.8: Research Methodology Adopted.

The prototype system was evaluated using questionnaire survey techniques. There are two types of questions have been used in the questionnaire survey: closed questions and open-ended questions. Close questions limit respondents' answers to the survey. The respondents are allowed to choose either a pre-existing set of answers (i.e. yes/no,

true/false), or multiple choice with an option for 'other', or rating scale response action (i.e. 1 – good, 2- fair, 3 – poor). Open ended questions do not give respondents answers to choose from, but rather are phrased so that the respondents are encouraged to explain their answer and reactions to the question with a sentence, a paragraph, or even a page or more, depending on the survey. The main limitations of the close ended questionnaire techniques is the researcher cannot visually observe the respondents' reactions to questions, physical characteristics, or the setting (Neuman, 2006). Fellows and Liu (2003) consider open-ended questions appropriate to enable respondents to answer to whatever extent the respondent wishes.

2.5 Summary

This chapter has described the basic concepts and principles relating to research methodologies. Specifically, this chapter described the research methodology that was adopted and 'triangulates' research strategies as a means for achieving the main aim and specific objectives of the research. The research methodology adopted well-established research approaches and is divided into five main sections: literature review; case studies; framework development; automation and implementation of the framework; and evaluation of the prototype system. The next chapter focuses on current site management practices including identifying current site management, existing management procedures and management approaches to improve construction site management.

CHAPTER THREE

Site Management Practices – A Review

3.1 Introduction

This chapter starts by reviewing the relevant literature on current site management practices, including construction site management processes and common problems that occur on the construction site. It then reviews current approaches to improving construction site management, analysing the strengths and challenges in implementing each approach in construction project management. The management of knowledge on the construction sites and the benefits of KM application are also discussed.

3.2 Site Management Practices

3.2.1 Definition

Santos *et al.* (2002) defined site management practice as a fundamental integrating process used to achieve organised and purposeful results in the area where building or construction work is being carried out, whether it is within, adjacent to, or separate from an existing occupied building. In this context, Illingworth (1998) categorised the construction sites into three basic types. These include:

- *Open field site*: What has to be built occupies only a portion of the site. Ample access is available and there is plenty of space for materials storage and accommodation. Examples are housing estates, factory developments, and many civil engineering projects;

- *Long and thin site*: Very restricted in width, considerable length. Access at few locations. Examples are railway work, motorways and gas and fuel pipelines; and
- *Restricted site*: New construction occupies the whole or a very high percentage of the site. Access is restricted. Examples are city centre developments, industrial improvement or additions and some railway or motorway work.

Construct I.T. (1996) views site management practices as a combination of activities which turn basic resources into a finished product. This can range from organisation of the materials, labour and other resources on the site to which control the flows of information and finance. According to Griffith and Watson (2004) site management is a combination of four groups of inter-related components: preliminary works, site organisation, and site layout and welfare provision. Efficient site management practices provide the foundation for a successful project by configuring, structuring and organising those temporary facilities needed to support the works on site.

3.2.2 Site Management Team and Organisational Arrangements

The main function of a site management team is to organise, inform, coordinate, order, instruct and motivate others to undertake site activities (Ashworth, 2001). Generally the site management team has responsibility for:

- Production management in respect of the work undertaken by the main contractor and carried out directly on site (Santos *et al.*, 2002);
- Control of sub-contractors and specialists on site (Holroyd, 1999); and
- General control of all activities on the site (Newcombe *et al.*, 1993).

According to Walker (2002) there are three most important factors considered by a site management teams to be 'critical success factors' in measuring their performance. These include: completion on time; completion within budget; and attaining the specified quality level. When designing a formal system for site management, the ranking of the functions and the critical success factors should be addressed. This is

necessary if high quality site management is to be attained. Griffith and Watson (2004) provide a systematic diagram of organisational arrangements on the construction site, as illustrated in Figure 3.1. However the precise project arrangements will vary depending upon the degree of the contractor's involvement in actual construction. While in other types of contracting, such as management contracts, the site labour force's responsibilities are largely eliminated. Conversely, there would be a need for strengthened design, planning and cost management teams to work closely with the client's advisors as design tends to continue alongside construction and works/subcontractors have to be carefully co-ordinated (Harris and McCaffer, 2001)

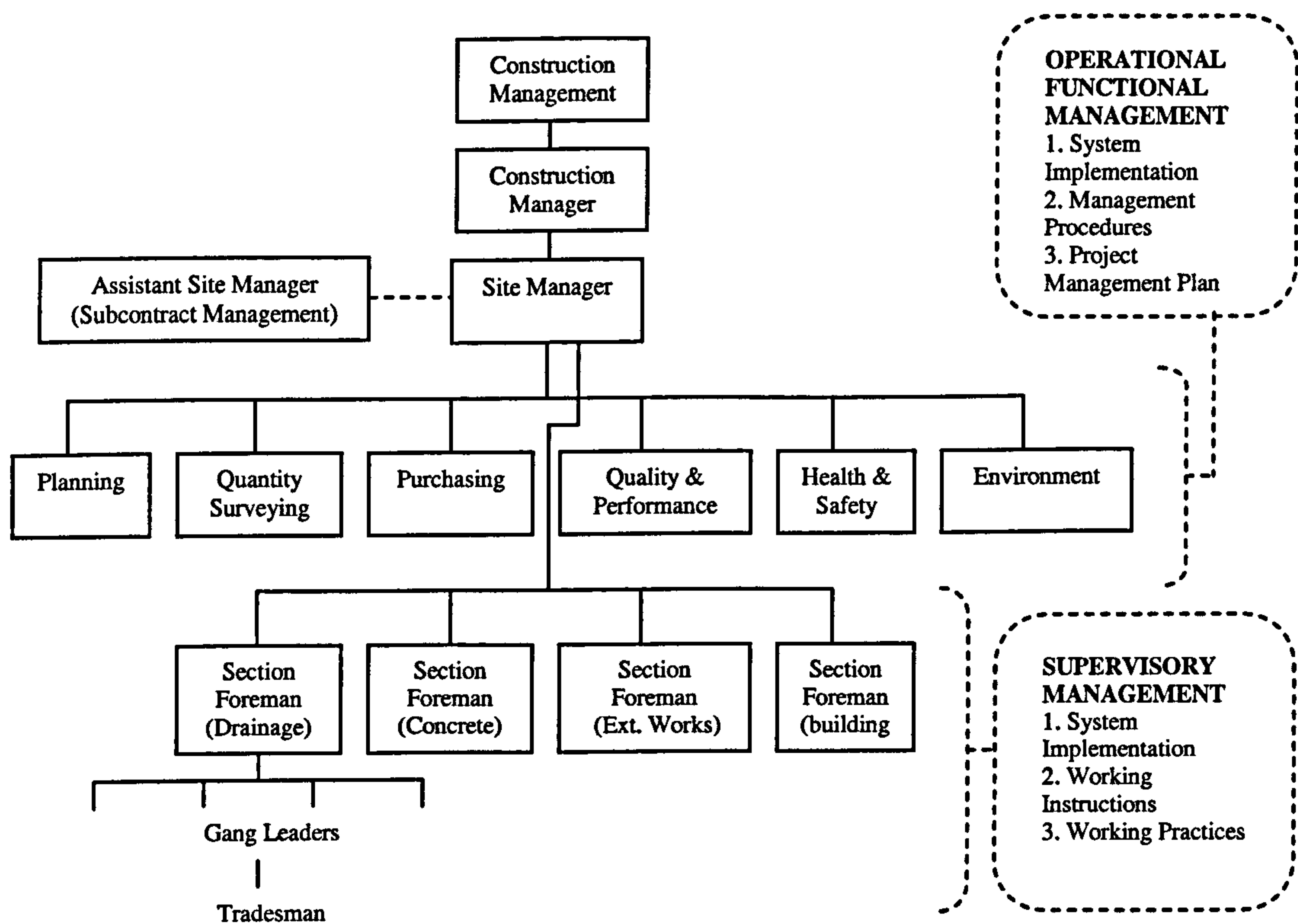


Figure 3.1: Project or Site Structure for a Medium-Sized Contracting Organisation (Griffith and Watson, 2004).

The site management team is also responsible for maintaining accurate records of the important happenings on site. The information should be properly recorded, so that

whenever necessary it can be quickly retrieved for future use. The important site records that are normally kept include (Ashworth, 2001):

- *Reports*: An analysis by site manager on daily weather conditions, daily work, activities and material deliveries to the site;
- *Site diaries*: To record daily events and be retained on site for future reference;
- *Materials received sheets*: To record all materials arriving on site;
- *Drawing registers*: Design drawings (signed and sealed) by the architect, structural engineer and mechanical engineer, and other consultant.; and
- *Confirmation of verbal instructions*: A standard form to record verbal instructions from the architect. The architect should then issue an official written variation order when he/she has receives this standard form.

3.2.3 The Role and Responsibilities of Construction Site Managers

The main responsibility of construction site managers is to put together an effective team, as well as dealing with outside influences such as the local labour market, competitors, local authorities and suppliers (Newcombe *et al.*, 1993). Griffith and Watson (2004) see the main roles of construction site managers as: forecasting, planning, organising, controlling, motivating, co-ordinating and communicating. Furthermore, Styhre and Josephson (2006) take the view the site manager as a project leader who is responsible for a number of different activities and processes including production planning, procurement, administration, staff management activities, leadership works, and meeting with stakeholders such as clients, end users and customers. In terms of responsibility, Djerbarni (1996) found that construction site managers carry out one of the toughest and hardest jobs in the construction industry. Site management is characterised by a high work overload, long working hours, and many conflicting parties to deal with, including (amongst others) management, sub-contractors, subordinates, and the client. Moreover, Mustapha and Naoum (1998) argue that the site manager stands at the heart of the success or failure of a project. In the project context, the site managers are assigned an intermediary role between the ‘thinking’ (top management) and the ‘doing’ (subordinate workers). Styhre and

Josephson (2006) suggested that the experience of being stuck in between project objectives and day-to-day administrative routines has imposed an additional workload on site managers and caused some concerns. The site manager is responsible for directing and controlling all on-site activities within the limits of the organisational hierarchy. Therefore, how they spend their time is of critical importance. Griffith and Watson (2004) revealed that 25% of the site managers' time was being spent on administrative duties, instead of concentrating on managing the site more effectively. Figure 3.2 demonstrates the position of the construction site manager within construction organisation. It clearly shows that site managers play the role either of knowledge broker or of technical experts capable of dealing with practical problem-solving between head office and operational workers (e.g. sub-contractors, foremen, and tradesmen).

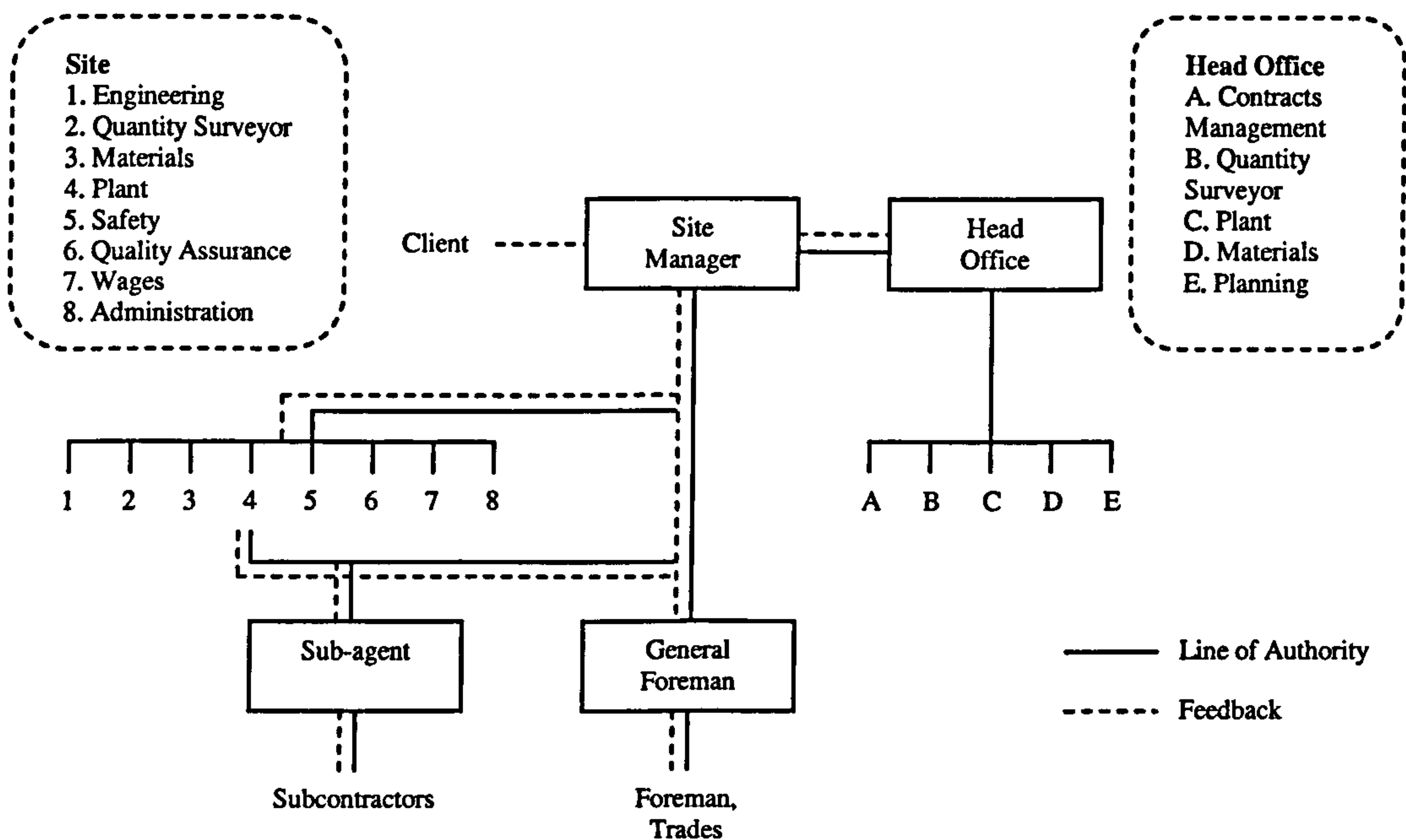


Figure 3.2: Position of the Construction Site Manager within a Construction Organisation (Griffith and Sidwell, 1995).

Construction site managers must have certain skills such as managerial skills and the competencies to overcome daily problems and constraints on the construction site.

According to Newcombe *et al.* (1993), an effective site manager needs five skills as essential ingredients for managing the construction site:

- *Negotiation skills:* The site manager must have the ability to negotiate with other people to solve particular problems on site;
- *Skills associated with engineering change:* Here the capacity for the site manager to align other organisations to the needs of the site;
- *Match-making skills:* Matching the people who want information with those who have the required information;
- *Team building skills:* To build the necessary team to undertake the work of the production sub-system; and
- *Skills of bending rules:* On occasion the site manager must bend rules to overcome problems which no one party sees as their responsibility.

3.2.4 Components of Site Management Procedures

Effective site management procedures provide the foundation for a successful construction project. The key components of site management procedures contributing to the success of a project are (Newcombe *et al.*, 1993): The site organisation; site policies and procedures; planning; supervision; and meetings and reports.

The site organisation: The structure of the site organisation will reflect the characteristics of the construction project; its size, the type of projects in terms of technical complexity, the procurement method being used and the type of staff available to manage the project. According to Griffith and Watson (2004) there must be a clear line of authority from the site manager to all functional managers and first line supervisors. Everyone on site needs to be clear and understand the duties for which they are responsible and to whom they are accountable.

Site policies and procedures: The site manager implements the company's general policy in numerous areas: personnel, production, health, public relations, quality control, communication, purchasing, etc. The general policies and procedures embrace

the total site organisation and its activities, and detail the strategy by which a site management team should achieve its objectives (Forster, 1989). They need to be relevant to the particular site and monitored to ensure that the policies and procedures are assisting the work being undertaken on site rather than hampering it.

Planning: Site planning is the process of determining, analysing, devising and organising all resources necessary to undertake a project. The main aim is to obtain and maintain the necessary volume and speed of output, and ensure quality. Site planning is concerned with two fundamental aspects. First, programming the works: this involves the planning of the works over the anticipated duration of the project in relation to its requirements with full knowledge of resource needs and availability. Second, progress monitoring and controlling of the works: this follows on from the programming of the works and compares the work undertaken against the programme (Griffith and Watson, 2004).

Supervision: This is a mechanism for ensuring that the work being carried out is in accordance with the programme. Its aim is to control operations and the operatives who carry out the work. Progress controls cover a number of management tasks by ensuring that: operations start when intended; resources are deployed as required; materials are delivered when needed; and plant is fully utilised as possible, and information has been received as required from the client's representative.

Meetings and reports: The main function of a meeting is to exchange information, discuss difficulties and explore alternative solutions. The site management team uses meetings to undertake the following activities: information gathering and sharing; monitoring and control; co-ordination; and problem solving. Meanwhile, reports are very important instruments for monitoring events on the construction site. Reports are frequently used to give feedback on progress, cost performance, environmental effects, and health and safety.

3.3 Construction Site Management Processes

Construction site management process is a combination of two fundamental activities (Illingworth, 2000): handling of materials and equipment; and the skill of the workforce in the positioning of the materials and equipment (assembly) to produce the desired completed whole as shown in Figure 3.3. To accomplish these two fundamental activities, Construct IT (1996) has divided construction site processes into six sub-processes:

- Management, supervision and administration of sites;
- Commercial management;
- Health and safety management;
- Planning, monitoring and control;
- Delivery and materials' handling; and
- Production on-site and off-site.

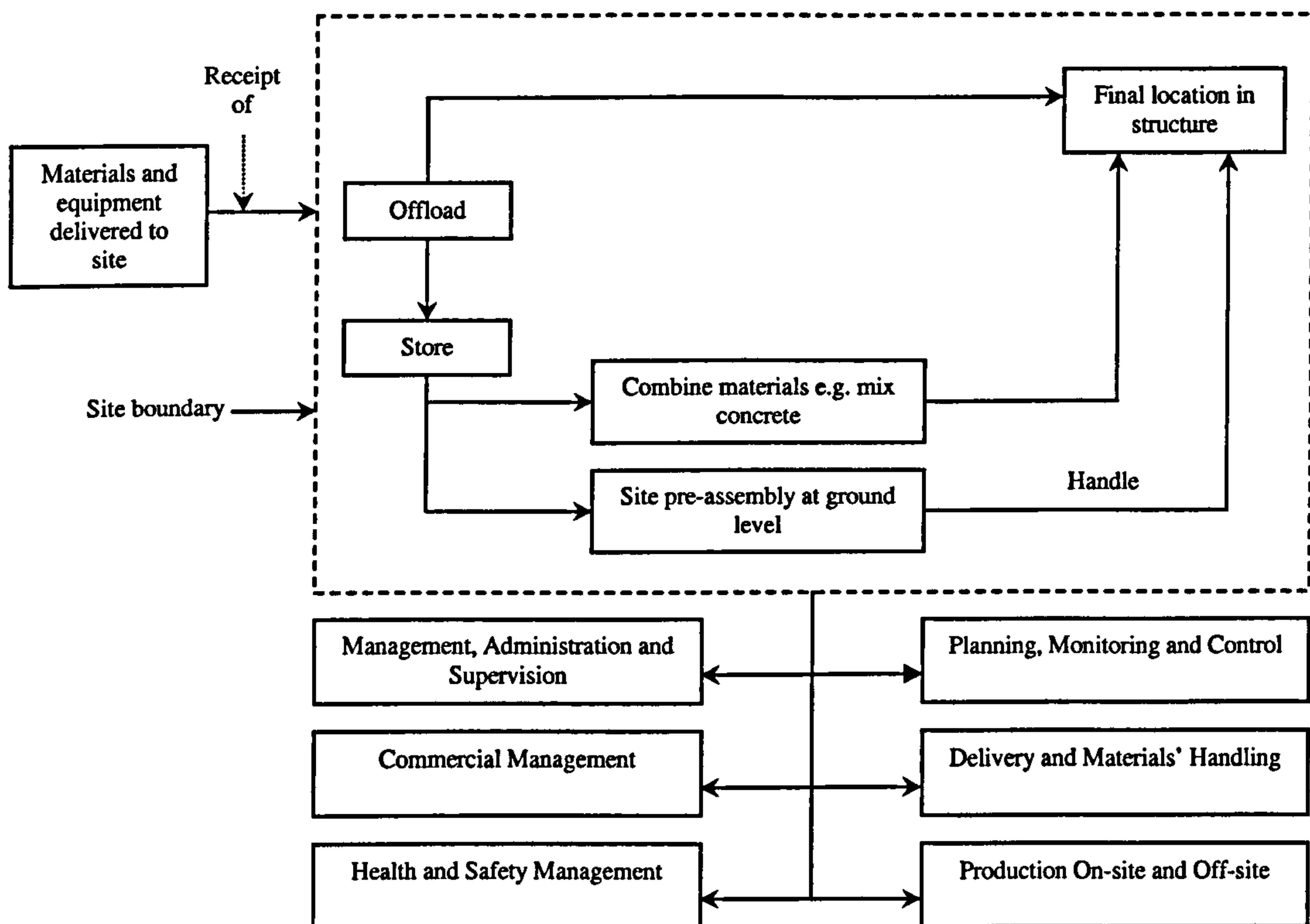


Figure 3.3: Representation of Construction Processes (adapted from Illingworth, 2000).

3.3.1 Management, Supervision and Administration of Sites

For any construction project it is fundamental need to have appropriate management of the site. Basically, all the information collected on site needs to be referred back to the Head Office. It must be submitted on time so that the department receiving it can process the information. The site management team will have required timings and calculations for such items as the following: wages, plant, materials received on a weekly basis; valuations, sub-contract details on a monthly basis, and correspondence and general information as necessary. Although the site management team will receive information on costs on a monthly basis, wages arrive weekly, and general data also arrives weekly. For the purposes of communication it is customary for site managers to design suitable standard forms to be used in as many situations as necessary and which everyone finds easy to understand (Forster, 1989). Important information includes correspondence, minutes, RFIs, labour allocations, payroll, progress reporting, notices or claims, instruction, drawing register and technical information.

3.3.2 Commercial Management

It is important for construction site managers to fully appreciate that commercial management is essentially a management technique, not a quantity surveying technique. A cost control system should be designed so that it enables the site management team to satisfactorily collect and produce information from which the monitoring of actual costs can be compared to estimated costs. This covers estimating, valuations, interim payment, variations, dayworks, cost-value reconciliation, final accounts and cash flow. To get maximum benefits from the system that the site management team employs, crucial actions are required (Griffith and Sidwell, 1995):

- The budgets for costs and earnings must be realistic, being based on an achievable programme and a correct appreciation of the required resources based on practical experience;
- The system must give the organisation early warning of problems so that the site manager can take remedial action quickly. Site monitoring on a weekly basis is ideal;

- The site manager needs to check that costs are correct and ensure that values are not optimistic; and
- Work as a team on the identification of cost savings or earnings increases.

3.3.3 Health and Safety Management

Effective health and safety management is founded on the provision of a safe and healthy working environment with safe systems of work at its core. The key to success is to ensure that health and safety aspects are carefully considered and the risk of danger and hazard to persons, as a result of site activities, is systematically safeguarded. According to Mohamed (2002), the major causes of accidents on site have been identified and can be directly attributed to unsafe design and site. Health and safety management on the construction site should include the following: safety policy; COSHH and CDM regulations, insurance, building regulations, British Standards, and Codes of Practice. The achievement of the health and safety management implemented is evidenced in the effectiveness of information gathering through monitoring and the methods by which it is recorded. Different organisations will have their own procedures for documenting health and safety activities on site. Typical approaches include the use of a set of forms which are completed by supervisors and operatives as elements of the health and safety plan are implemented (Griffith and Watson, 2004).

3.3.4 Planning, Monitoring and Control

Planning is the process of determining, analysing, devising and organising all resources necessary to undertake the project. The core element of planning is the establishment of a programme which reflects the planning process in relation to real time (Griffith and Watson, 2004). In practical terms; construction planning is the total process of determining the method, sequence, labour, plant, and equipment required to undertake a building project. It is also to obtain the necessary volume and speed of output, and ensure quality. Harris and McCaffer (2001) argued that construction planning involved two main elements: method study and work measurement. The method study is to record work procedures, provide systems of analysis and develop improvement. It gives

improved planning and control and better use of material, plant and manpower. The work measurement is the measurement of the time required to perform a task so that an output standard of production for a worker and machine may be established. The main aim is to assess human effectiveness to production planning, estimating and incentive scheme on site. This covers all activities associated with project planning and scheduling, typically the production of a Gantt-chart, network analyses, method statements, resource levelling, progress reports and exception reports.

3.3.5 Delivery and Materials' Handling

This process is to bring to the project the appropriate materials at the right time, quantity and price to enable the construction work to proceed according to programme and to the necessary quality standards (Newcombe *et al.*, 1993). There are four types of information considered useful for the delivery and materials' handling process: the Specification, the Contract Drawings, the Bill of Quantities, and Architect's instruction issued during the construction. The activities associated with the management of deliveries and the subsequent handlings of materials on site are covered including requisitions, purchase orders, material call off, and plant returns. Clearly a site manager or his/her sub-ordinate has to carry out a crucial task to monitor the performance of materials on-site including quality and quantity checks on arrival. The quality checks include: visual checks on all materials; examination of ready-mixed concrete by hand for texture and check using slump tests; and carry out visual and handling checks on bricks and the like for broken edges. The quantity checks can be by: a site or public weighbridge; counting; and volume checks. The site control measures that the site manager needs to implement include the following (Holroyd, 1999):

- Keep a firm control on materials received on site and materials issued from store;
- Checks materials acceptability before unloading;
- Minimise double handling;
- Ensure one batch of material is fully used before starting another;
- Minimise the quantities stored on site; and
- Ensure materials store cabins are fully weatherproof.

3.3.6 Production On-site and Off-site

Applying quality procedures to production on-site and off-site will enhance quality levels by reducing defects. Examples of activities supporting production include QA plans and report, contract terms, drawings, specifications, setting-out and measurements. The QA plan is important for the site management team to have as a benchmark against which to control quality on site. Quality assurance focuses upon consumer protection and offers clients an assurance that the building has been built properly under satisfactory conditions of quality controls and that the building has been judged suitable for its intended use. The essential measures for controlling quality include the following:

- Proper checking systems and recording procedures. The systems allow the site management team to share good practice;
- Delegation of responsibilities for quality must be clear and cover all aspects of the requirements;
- Materials' checks should be an ongoing routine;
- Plant maintenance must be regular; and
- Keep constant check on materials' utilisation. Minimise waste, not just for permanent materials, but of temporary provisions, e.g. plywood and timber and hardcore.

3.4 Problems on the Construction Site

There are several challenging engineering and management problems that occur on construction sites. These problems affect the time, budget and plans, and specifications (Trauner, 1993) and often cause defects, disputes and delays (Clarke, 1988). According to Holroyd (1999) many construction site procedures and methods have not changed over the years and the same mistakes are being repeated. The main reason are because the site management is characterised by high work overload, long working hours and many conflicting parties to deal with, including the management of the sub-contractors and liaison with the clients (Griffith and Watson, 2004). For instance, the problems identified within site management practices can be categorised into three main

categories: management and administration problems; technical and engineering problems; and site communication problems.

3.4.1 Management and Administration Problems

Most site organisations have policies which lay down procedures for the site manager to observe regarding management and administration problems. These problems have to be addressed in order to ensure that project objectives are achieved. Additionally, there are a wide range of constraints which could occur on-site and for each the site managers should be prepared to deal with them in a systematic and efficient way. This can only normally be possible if the project managers or site managers have been forewarned, trained or educated on how to deal with the unexpected (Forster, 1989). The most common problems were:

- *Poor information:* The information passed on was often wrong or inaccurate (Barber *et al.*, 1999);
- *Inaccurate/Inadequate planning:* Wrong assumptions were made as to where the project was in terms of completion, low technological input, unfavourable clients' attitudes towards projects and lack support from top management (Barber *et al.*, 1999);
- *Training and education issues:* The majority of personnel on site are skilled in one very narrow area and the teams had not become truly multi-functional (Barber *et al.*, 1999);
- *Motivation issues:* The bonuses paid were still based on old efficiency-based performance measures rather than team performance (Barber *et al.*, 1999; Ling 1991; and Ogunlana and Olomolaiye, 1989); and
- *Shortage of skilled workers:* Affected, by the cyclical nature of the UK construction industry (Mackenzie *et al.*, 2000; and Agapiou *et al.*, 1995).

3.4.2 Technical Problems

- *Plant problems:* Maintenance of construction plant and plant management (Ogunlana and Olomolaiye, 1989). Many construction organisations tried to avoid these costs by providing the minimum of maintenance, which has often resulted in unexpected breakdowns, lost production and inefficient machinery (Harris and McCaffer, 2001);
- *Piling construction:* Methods used for recording the pile information may duplicate effort and potentially places the integrity of the pile at risk. Data transfer errors made from the schedule and miscalculation during pile construction can result in nonconforming piles being constructed, leading to additional costs, delays, and client dissatisfaction (Ward *et al.*, 2003); and
- *Existing services:* The utility services such as existing sewers, water distribution pipes, electricity cables, gas mains and telecommunications cables can disrupt construction works (Illingworth, 2000). Site managers should take necessary actions to prevent damages occurring during the construction works and to avoid unnecessary costs of rectifying the damaged existing services (Forster, 1989).

3.4.3 Communication Problems

The nature of the relationships was the main factor behind the poor communication; as a result of the historical development and fragmentation of trades, professions and responsibilities. In fact, top management often did not know what was happening on site (Tah and Carr, 2001; and Barber *et al.*, 1999). Communication difficulties often occur during the construction stage because it is here that the level of information available to all parties reaches its peaks. However Emmitt and Gorse (2003) suggest that as information is received from structural engineers, architect, mechanical engineers, and other consultants, discrepancies between drawings should be expected, and checks should be made to find where instructions are incompatible. Any problems must be reported to the contract administrator and meetings should be held with the aim of quickly resolving any differences. In addition, developments in information technology and communication have changed organisational communication. Information is now

available to site managers and other employees faster, more reliably and in larger quantities than ever before. Information now has to be systematically managed and information networks carefully designed and monitored (Fryer, 2004)

3.5 Management Approaches to Improving Construction Site Management

Currently construction firms are faced with the problem of securing sufficient work to remain viable in an industry that contains many companies capable or at least willing to undertake almost any type of work for clients. (Harris and McCaffer, 2001). According to Griffith and Watson (2004), successful organisations are those that have drastically changed or re-engineered their business processes. Consequently, other industrial sectors such as manufacturing and petrochemical industries are commonly able to benefit from better prospects in attracting skilled workers, either by providing superior working conditions or in being able to pay higher levels of remuneration. Improvement of the construction site management processes has focused on attempts to change practices to be more responsive to customers and to improve performance in quality, time, speed and reliability, while reducing production costs. There are several management approaches implemented to improve construction site management. These approaches include Total Quality Management, Just-in-Time, Business Process Re-Engineering, Concurrent Engineering and Knowledge Management.

3.5.1 Total Quality Management Approach

Total quality management is a management system that is based on the application of quality principles to all aspects of the business (Griffith and Watson, 2004). Its main aim is to reduce or eliminate defects. A wide range of quality tools and techniques are available to organisations, which provide a common language, and a consistency of approach to continuous quality improvement. These tools range from simple techniques such as brainstorming to more sophisticated options including statistical process control techniques (i.e. matrix analysis, pareto analysis, cause and effect diagrams, failure prevention analysis). The benefits of TQM implementation are as follows:

- Increased customer satisfaction and hence additional sales;
- The attainment of a competitive advantage;
- The minimisation of waste; and
- Focusing attention on a continuous improvement processes.

The implementation of TQM on the construction site could be harmful if there is a lack of total support from the organisation. This total support must come from not only top management but also from the operative workers including from the people who are involved at the construction stage. The major obstacles to implementing TQM are poor coordination and communication between parties in solving the problems arising from what they see as endemic on the work site (Toma *et al.*, 1998).

3.5.2 Just-in-Time Approach

Just-in-Time approach is a philosophy developed in Japan for efficient and quality production (Akintoye, 1995). The main objective of JIT is the achievement of zero inventories, not just within the confines of a single organisation but ultimately throughout the entire supply chain. It requires far-reaching changes of production systems and techniques and an integrated system between suppliers, customers and the host organisation. The benefits of JIT concepts for construction site management can be summarised as follows (Pheng and Hui, 1999):

- *Construction site processes*: The contractor's programme can be used as a powerful tool to predict the sequence and timing of each activity undertaken by both the main and subcontractors;
- *Better materials management*: Materials should be ordered according to actual consumption on site and scheduled to arrive just in time before work begins;
- *Better plant management*: Plant and equipment usage is planned with respect to the contractor's programme and is available just in time for use; and

- *Proper site layout:* Site is planned properly and neatly to minimise unnecessary movements, handling of materials, plant and equipment and to ensure smooth work flow.

The main obstacles to implementing JIT for construction site management are trust and discipline on the part of the contractor and its suppliers. This requires the contractor to redefine its relationships with its suppliers; for example, by developing long-term relationships and being prepared to share information with them (Akintoye, 1995).

3.5.3 Business Process Re-Engineering Approach

Business Process Re-Engineering is a systematic methodology developed to help an organisation make significant advances in the way in which its business processes operate (Harrington, 1991). It is a fundamental rethinking and radical redesign of the business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed (Ulrich, 2006; Betts and Harper, 1994). Basically, BPR has been used to restructure the production process of the construction project with an emphasis on the business process to ensure that each and every task is a value-adding activity (Griffith and Watson, 2004). Anumba and Evbuomwan (1996) reported that business process re-engineering may significantly improve the performance of organisations if they adopt a strategy that focuses on the use of integrated design and construct models of procurement and multidisciplinary design practices. According to Hammer and Champy (1993) modern IT has an important role in the re-engineering process that is difficult to overstate. But organisations need to beware of thinking that technology is the only essential element in re-engineering.

An example of BPR in the construction industry is a UK brick supplier re-engineering its links with architectural buyers through their innovative use of IT, which shows that such a concept is applicable to construction site management. The main tools for BPR in construction include: process modelling and mapping approach; information technology; and best practice benchmarking. The BPR approach can provide the methodological deployment model for attaining a sustainable competitive advantage

and eliminating non-value adding activities. The main obstacles to BPR are lack of top management support and lack of cooperation from business units involved during the implementation process. To achieve this radical change the organisation has to be prepared to work cross-functionally, cutting through functional boundaries and departmental walls.

3.5.4 Concurrent Engineering Approach

Concurrent Engineering attempts to optimise the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by integration of design, fabrication, construction and erection activities and by maximising concurrency and collaboration in working practices (Evbuomwan and Anumba, 1998). By applying these principles it is envisaged that clients and project participants may share several benefits. These may include (Love *et al.*, 1998):

- Improved understanding and implementation of client and end-user requirements;
- Improved communication and cooperation between project participants;
- Improved team and project effectiveness;
- Reductions in rework (e.g. redesigns, non-conformances etc.) and in variations; and
- Reduction of project time and cost.

However, simply superimposing concurrent engineering principles within an existing procurement structure where culture and attitude have not changed will not yield the expected performance improvements sought by practitioners.

3.5.5 Knowledge Management Approach

Knowledge management (KM) is “the identification, optimisation and active management of intellectual assets to create value, increase productivity, and gain and

sustain competitive advantage” (Webb,1998). KM allows an organisation to learn, reflect, unlearn and relearn, to build, maintain, and replenish its core-competencies. Therefore, the primary goal of knowledge management in a business context is to facilitate opportunistic application of fragmented knowledge through integration (Tiwana, 2002). Laudon and Laudon (2002) argue that information and communication technology plays an important role in knowledge management as an enabler of the business processes aimed at creating, storing, maintaining, and disseminating knowledge. The major potential benefits of adopting KM can be summarised as follows (Wong and Aspinwall, 2006):

- Enhance decision making through just-in-time intelligence;
- Improve work efficiency and productivity;
- Increase innovation in products, services and operations;
- Improve competency and competitiveness;
- Enable rapid generation of technical solutions to clients’ problems; and
- Increase responsiveness to customers.

Nevertheless, knowledge in the construction organisations is by no means always easily captured or effectively shared amongst industry players (Bresnen and Marshall, 2001). It is generally recognised that there is much “knowledge wastage” and often considerable difficulty in accessing important information. An analysis by Al-Ghassani (2003) found that knowledge status (whether tacit or explicit), knowledge domains and organisational culture are considered as the main barriers in implementing knowledge management in construction organisations. There is therefore a need to proactively tackle organisational culture and associated barriers such as people’s fears, attitude or resistance to knowledge sharing.

3.6 Management of Knowledge on Construction Sites

Principally, some form of knowledge management is being practised within the construction industry, either in the documentation of best practices (e.g. codes of practice for certain operations), or the use of information technology applications

(Kamara *et al.*, 2000). Construction knowledge is both explicit (i.e. captured in drawings, specifications, etc.), and tacit (held in people's heads) (Whetherill *et al.*, 2002; Robinson *et al.*, 2001; and UMIST-Klicon, 1999). Tacit knowledge is stored in the minds of individuals and is difficult to communicate externally and share. Explicit knowledge is captured or stored in an organisation's manuals, procedures, information systems, and is easily communicated or shared with other people or parts of an organisation (Nonaka and Takeuchi, 1995).

3.6.1 Role of Knowledge on Construction Site

The Project Management Institute (PMI, 2004) defines knowledge as 'knowing something with the familiarity gained through experience, education, observation, or investigation: it is understanding a process, practice, or technique, or how to use a tool'. In construction organisations, knowledge often becomes embedded not only in documents and repositories but also in organisational routines, processes, practices and norms. Knowledge can be considered as a production resource with a specific economic value and it needs to be managed in a professional manner (Nonaka and Takeuchi, 1995; Schaefer, 1993). It is recognised that an accumulation of experience and knowledge on the nature of projects assists the site manager to clearly understand site management problems and related issues.

In the site management context, site managers or project managers solve technical and complex problems by using their experience and intuition to find prompt solutions. These complex problem-solving events are mainly involved with tacit knowledge that is mainly people-bound and difficult to formalise and therefore difficult to transfer or spread (Egbu *et al.*, 2005). According to Styhre and Josephon (2006), site managers are the best personnel to optimise KM initiatives in site organisations. This is attributable to the fact that they play the role either of knowledge broker or of technical experts capable of dealing with practical problem solving. The expertise and experiences, both administrative and technical, can certainly be utilised for managing knowledge on the construction site.

3.6.2 Knowledge Production

Knowledge management in construction includes locating, accessing, sharing, and using the required knowledge so that optimisation can be achieved in terms of execution, quality, cost and maintenance (Al-Ghassani *et al.*, 2002). Knowledge management is not simply about extracting the knowledge held in an individual's mind and converting it to an accessible electronic format, or disseminating and making available an organisation's knowledge. It is about providing knowledge to facilitate communication between individuals, teams and communities of specialists and thereby providing access to knowledge assets: individual experiences, lessons learnt, and best practices (Williams, 2004; Kasvi *et al.*, 2003; Weber *et al.*; 2001 and Belle, 2000).

Knowledge of managing construction sites, procedures for dealing with particular problems and the management of particular site conditions help the site manager to be effective. During the construction phase of projects, an effective means of improving site management practices is to share experiences amongst construction site workers, which helps to prevent mistakes that have already been encountered in previous projects. In solving site management problems, a great deal of the site manager's effort is directed at understanding the problems in order to establish similarities (if any) with previously solved problems. Drawing on experience avoids the need to solve problems from scratch: problems that have already been solved do not need to be solved again. Egbu *et al.*, (2005) identified there are three aspects of knowledge to manage in the construction context:

- *Product knowledge*: Relates to the characteristics of the services or goods to be produced, whether standardised, traditional or innovative;
- *Process knowledge*: Relates to the technical and management systems required for the delivery of products; and
- *People knowledge*: Relates to the skills, problem-solving abilities and the characteristics of teams.

Hansen *et al.* (1999) noted that there are two distinct strategies for managing knowledge in an organisation: codification strategy and personalisation strategy. Personalisation

strategy revolves around tacit knowledge using non-IT tools or human interactive systems such as knowledge sharing networks, communities of practice, brainstorming and post-project reviews (Dent and Montague, 2004). The codification strategy is based on IT tools and can be used to make intelligent decisions. Al-Ghassani *et al.* (2005) assert that the most widely used IT tools for knowledge management include: intranets; document management systems (e.g. Documentum and Saga Desk); groupware (e.g. Lotus Notes, Lotus Quick Place and e Room) and taxonomy tools (e.g. Autonomy).

3.6.3 Knowledge Sharing and Communicating

Knowledge sharing and communicating are essential components of knowledge management implementation. Recent research evidence revealed that most of the construction knowledge is tacit rather than explicit (Egbu and Robinson, 2005). Tacit knowledge is difficult to communicate externally or to share while explicit knowledge is captured and stored in project manuals, procedures, and is therefore easily communicated and shared with other people. The distinction between tacit and explicit knowledge is relevant because each must be managed differently. The availability of knowledge in user-friendly formats to employees, particularly to virtual and remote teams, enables:

- Routine tasks to be undertaken efficiently;
- The collation of formerly disconnected information;
- The securing of valuable intellectual assets if expertise leaves the company;

The backbone of almost all KM initiatives and knowledge sharing, particularly at present for construction organisations, are likely to be an intranet. Intranets provide the platform for knowledge sharing particularly in large construction organisations that are often geographically dispersed with diverse knowledge to share (Al-Ghassani *et al.*, 2005). However, Dent and Montague (2004) find informal networking systems are better able to create and transfer tacit knowledge because human relationships are necessary to share knowledge that is unclear and difficult to document.

3.6.4 The Benefits of KM Application

The adoption of applicable knowledge management processes can increase the ability of the site manager to learn from his/her environment and to incorporate knowledge into site management practices. It is evident that KM has the potential to support the way knowledge is used and can provide several benefits to site management practices such as:

- *Leveraging lessons learned from past solutions and experiences:* Using experiences gathered in site management practices will enable teams to resolve site problems and will result in positive construction performance;
- *Capturing and reuse of tacit knowledge:* As construction workers are required to record their knowledge in a reusable format, it could be used for future projects even if the person no longer works for the organisation;
- *The sharing of best practices and the building of consistent processes:* Sharing of best practices reduces costs and saves time. Also there is scope for all the site management activities to be consistent;
- *Networking of organisational structures involving many parties with differing areas of expertise and skills:* Knowledge such as productivity rates, cost and timelines, and client details can be used when preparing tender bids for new projects.

3.7 Summary

The literature review on site management practices was followed by a review of construction site management processes. It has been observed that managing the construction sites offer a wide range of interesting management, technical and communication problems. Consequently, understanding the underlying cause of problems is a prerequisite to incorporating any management approach into site management practices. This chapter has analysed several management approaches to improving construction site management with a view to identifying its focus and benefits of implementation. The chapter then discussed the management of knowledge on construction sites and concluded with a discussion of the benefits of KM application in construction site management practices.

CHAPTER FOUR

Knowledge Management in Construction

4.1 Introduction

This chapter examines the current literature on knowledge management practices in construction organisations. It starts with the key concepts and characteristics of knowledge in construction. The characterisation of knowledge flows, key knowledge models and taxonomies of knowledge are also discussed. The chapter then reviews knowledge management processes and knowledge management tools with a view to identifying applicable KM process and relevant KM tools to be integrated into site management practices. It concludes with a discussion of the application of knowledge management systems to construction site management practices.

4.2 Knowledge: Key Concepts and Characteristics

Knowledge management has become an important strategy for improving organisational competitiveness and performance (Wong and Aspinwall, 2006; Liao, 2003; and Gray, 2001). Over the last five years there has been significant growth in the adoption of knowledge management (KM) in construction organisations. Knowledge management could be defined as the identification, optimisation and active management of intellectual assets to create value (Nemati *et al.*, 2002 and Liebowitz, 2001), increase productivity (Webb, 1998) and gain and sustain competitive advantage (Hicks *et al.*, 2002). Furthermore, KPMG (1998) describes knowledge management as a systematic and organised attempt to use knowledge within an organisation to transform its ability to store and use knowledge to improve performance.

From an integrated perspective, knowledge management can be defined as:

A systematic method for managing individual, group and organisational knowledge using the appropriate means and technology. At its roots it is to do with managing people, what they know, their social interactions in performing tasks, their decision making, the way information flows and the enterprise's work culture.

(Sallis and Jones, 2002)

Before implementing KM in construction organisations, it is important to examine the variety of definitions of knowledge which come from a number of different perspectives (e.g. information systems, human resources, management and construction). Davenport and Prusak (1998), from an integrated perspective (information systems and human resources), define knowledge as a fluid mix of framed experiences, values, contextual information, expert insight and grounded intuition that provides an environment and framework for evaluating and incorporating new experiences and information. In organisations, knowledge becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms. A definition to illustrate the importance of knowledge to the organisation is presented by Drucker (1993):

Knowledge is not impersonal, like money. Knowledge does not reside in a book, a databank, a software program – these contain only information. Knowledge is always embodied in a person; carried by a person; created, augmented, or improved by a person, applied by a person; taught and passed on by a person, used or misused by a person.

(Drucker, 1993)

Furthermore, Turban and Aronson (1998), from a knowledge engineering (KE) perspective, view knowledge as a productive application of data and information to make decisions and which is sometimes used interchangeably with the term decision support system:

Knowledge consists of data items that are organised and processed to convey understanding, experience, accumulated learning and expertise as they apply to a current problem or activity. A set of data items processed to extract critical implications and to reflect past experience and expertise provides the recipient with organisational knowledge and has very high potential value.

(Turban and Aronson, 1998)

In addition, Liebowitz (2005) asserts that there are several environment factors affecting the knowledge cycle in project organisations as shown in Figure 4.1. These include:

- *Domain context*: It is crucial to determine the criticality of the knowledge and what should be done to resolve problems in organisations;
- *Organisational culture*: Lack of knowledge sharing affects the creation and exchange of knowledge in organisations and may be at risk of not being codified and transferred to others in project organisations;
- *Management initiatives* : These could influence how the knowledge is shared throughout an organisation; and
- *Benchmarking/standards*: These could affect the creation of knowledge in the organisation.

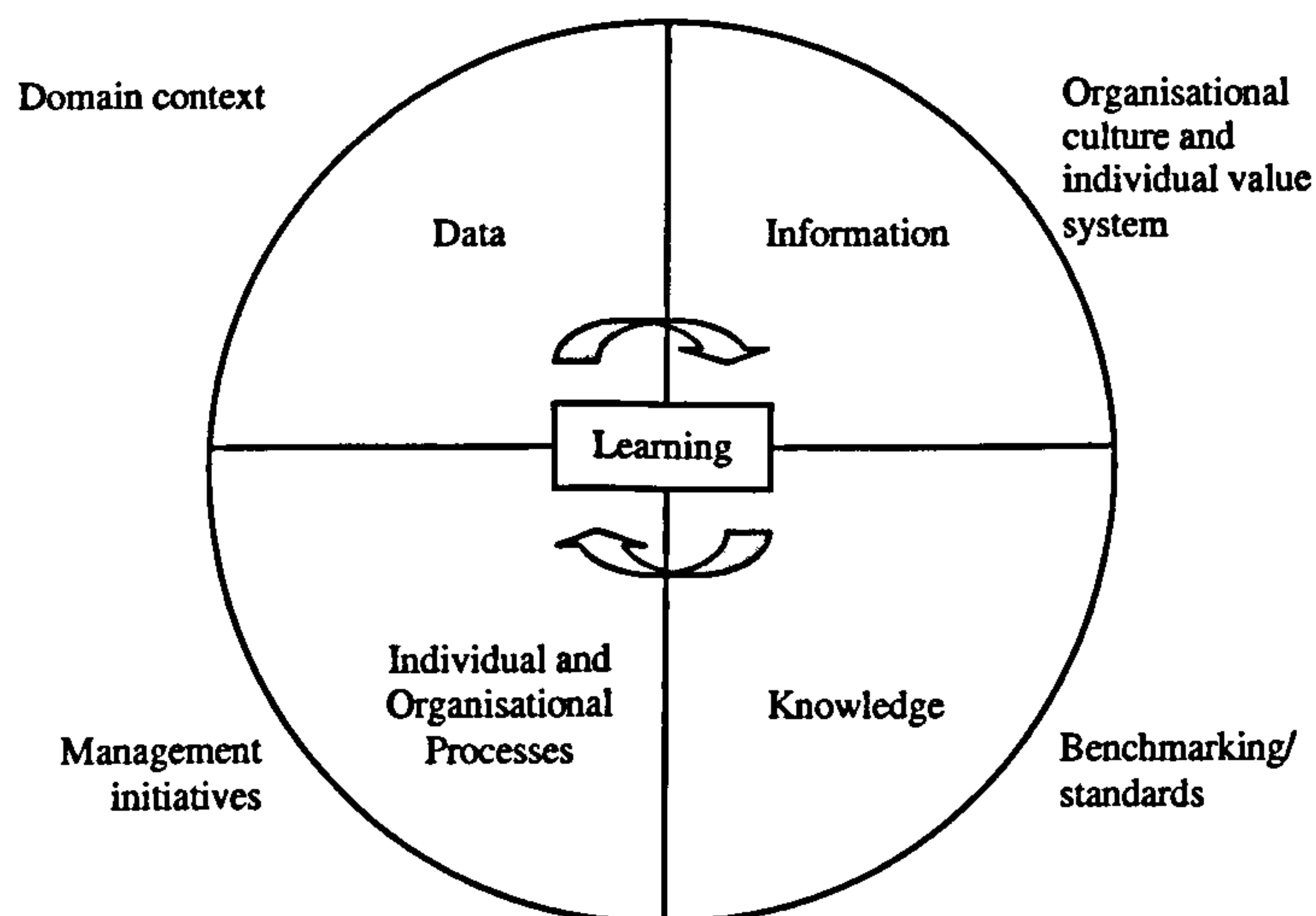


Figure 4.1: Conceptual View of the Knowledge Framework (Liebowitz, 2005).

Managing knowledge is a challenging task because it is hard to identify and even more difficult to deploy to give the organisation a competitive edge in the market. In the construction industry context, Egbu and Robinson (2005) state that much knowledge in the construction industry is experience-based and a mixture of tacit and explicit knowledge. Tacit knowledge is a product of experiences, insight and intuition which could be technical (i.e. know-how or expert) or cognitive (i.e. based on values, beliefs and perceptions). Explicit knowledge is stored in written documents or procedures. Examples of explicit knowledge in construction include design codes of practice, specifications, drawings, 3-D models, etc. These definitions provide an initial idea of construction knowledge. Further discussions on characterisations of knowledge flows provide a useful perspective on knowledge management in construction site management practices.

4.2.1 Characterisations of Knowledge Flows

According to Snider and Nissen (2003), there are three perspectives of knowledge flows and a key aspect of each is that such flow is a critical factor in an organisation's success. These three perspectives were considered essential to describe a workable framework of knowledge management in construction site management. In the site management context, knowledge of managing construction sites, procedures for dealing with particular problems, and management of particular site conditions help the site manager to be effective. Integrating a knowledge management approach into site management practices therefore requires an understanding of the knowledge flows and their characteristics.

a. Knowledge as Solution

The '*knowledge-as-solution*' perspective emphasises the often real-time transfer of knowledge among practitioners seeking to solve problems or enhance operations. KM efforts focus on technologies and processes such as 'groupware' systems (e.g., electronic bulletin boards and Lotus Notes), which enable linkages and facilitate communications among members of the organisation. Arup Consulting adopted Web-based knowledge sharing tools to allow them to locate experts from among the 7000

staff in different geographical areas and business structures. This enabled the organisation to '*know who knew*' the answer to a particular problem (Sheehan, 2005). A recent study by Carrillo (2004) revealed that organisations used IT tools and non-IT tools for creating and sharing knowledge. In this context, construction companies believed that IT tools provide sufficient functionality but the main problem is the lack of time to learn how to use the tools. Key managerial issues from this perspective include selecting an appropriate technology; and motivating organisational members to use the system.

b. Knowledge as Experience

From this perspective, knowledge is recorded and stored for future use. That is, the principal flow of knowledge is across time, rather than across organisational or geographical space in the '*solution*' perspective. The emphasis is on capturing practitioner experiences so that others may have access to and potentially learn from them, in the sense of 'learning from the mistakes of the past' and avoiding 'reinventing the wheel'. According to Tserng and Lin (2004), capturing tacit knowledge such as project related problems, solutions, experiences and know-how and making it available as explicit knowledge are important to KM in the construction phase; the reuse of knowledge in other projects and the preservation of such knowledge as a corporate asset. Such KM efforts typically require organisational processes and technology to perform the functions of recording, storing and dissemination (Zack, 1999).

c. Knowledge as Socially Created

The two previous perspectives portray knowledge as a commodity that may be transferred to others. Against this 'commodity' view of knowledge is the idea of knowledge as a social process between individuals (Nonaka and Takeuchi, 1995), or as the product of interpersonal relationships. Kazi *et al.* (2005) take the view the most valuable form of knowledge is tacit, based on the experience of individuals, and articulated through social interaction. Knowledge emerges from social interactions around a problematic situation (e.g. lack of quality control of work, materials damaged

and defects, services obstruction, etc.). This perspective thus emphasises social processes that lead to knowledge creation and sharing. Managerial issues associated with this perspective are substantially different from those of the other two perspectives. Here the major issue is organisational design to enhance development of interpersonal relationships. Members must engage in informal, unstructured communications and processes of sense making; discussion, negotiation, and argument are central to the learning process. This suggests the necessity for informal interactions between individuals for knowledge to be created.

4.2.2 Knowledge Model

Knowledge management is a continuous and integrated process. Knowledge must be identified, captured, stored, disseminated, and used effectively to provide the best possible benefits for organisations (Egbu *et al.*, 2005). More specifically, knowledge is never static, it is continuously changing and evolving and this allows it to be employed to enable action and solve problems (Snider and Nissen, 2003). There have been several types of knowledge models developed in previous research. It is important to examine different knowledge models in order to understand how they might be used in a different context, as well as helping organisations to shape their KM approach in the future. The most relevant models of knowledge management include: SECI (Socialisation, Externalisation, Combination and Internalisation) Knowledge Model, Integrated Knowledge Model and Tiwana Knowledge Model.

a. The SECI Knowledge Model

Based on the distinction between tacit-explicit, individual-collective knowledge, Nonaka and Takeuchi (1995) formalised a generic model of organisational knowledge creation; the so-called SECI (Socialisation, Externalisation, Combination and Internalisation) model. This suggests that new knowledge is the outcome of the continual interplay between tacit and explicit dimensions of knowledge. The SECI model consists of four modes as illustrated in Figure 4.2, through which explicit and tacit knowledge are exchanged and transformed:

- *Socialisation*: This enables tacit knowledge to be shared between individuals. In this process, knowledge is transferred through learning by doing;
- *Externalisation*: This converts tacit knowledge into explicit knowledge in the form of models, concepts and metaphors;

	Tacit	Explicit
Tacit	Socialisation	Externalisation
Explicit	Internalisation	Combination

Figure 4.2: SECI Knowledge Model (Nonaka and Takeuchi, 1995).

- *Combination*: This allows the existing explicit knowledge to be restructured, systemised and combined into new forms of knowledge; and
- *Internalisation*: This enables individuals to absorb explicit knowledge, thus allowing them to broaden their tacit knowledge base so that new knowledge and skills can be developed.

The central theme in these processes is to transform an individual's tacit knowledge into explicit knowledge and make it available to the organisation as a whole (Handzic and Zhou, 2005). This will then ignite new knowledge and innovative activities (Nonaka and Takeuchi, 1995).

b. Integrated Knowledge Model

The integrated and strategic perspective of knowledge is investigated by Jashapara (2004). From an interdisciplinary perspective, knowledge management can be defined as:

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 organisation's intellectual capital and performance.

(Jashapara, 2004)

In this model, the past experience of human actors shapes the broad social, economic and political networks within an organisation. If a person is confronted with a totally new situation, it is likely that the person will predominantly have recourse to their past experience and intuition to determine how to manage in a given environment. Figure 4.3 demonstrates the multifaceted dimension of knowledge management. According to Carrillo (2006), regardless of the strategy selected, a number of interdisciplinary factors such as organisational culture, the approach to learning, and the systems and technology available, have an impact upon knowledge management in an organisation.

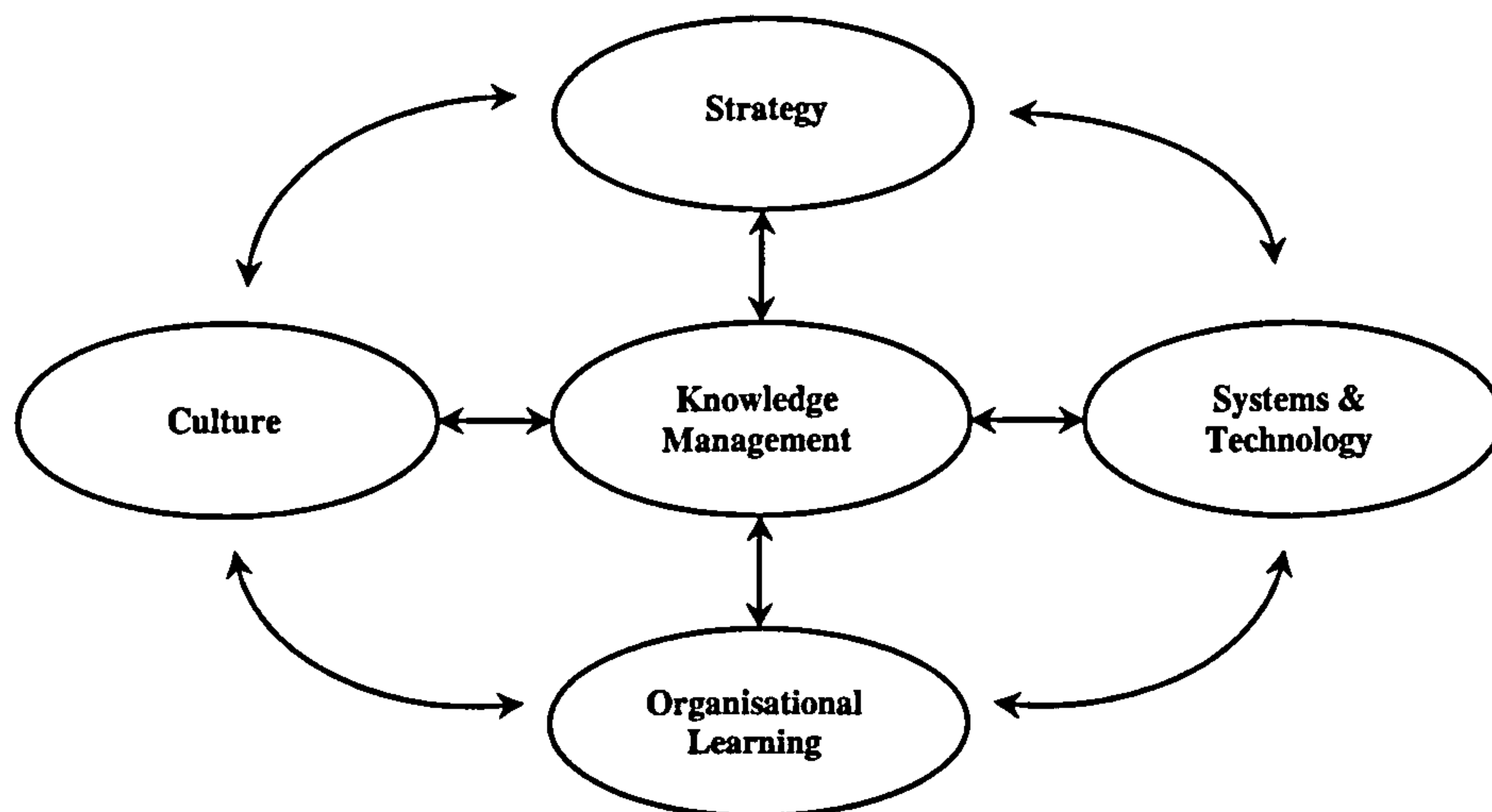


Figure 4.3: Dimensions of Knowledge Management (Jashapara, 2004).

The knowledge management cycle proposed in this model consists of five major stages. These include:

- *Discovering knowledge*: Involves discovering the interrelationships between data, information and knowledge. Individuals and organisations have different approaches to learning;
- *Generating knowledge*: Involves the processes of knowledge acquisition, information distribution, information interpretation and organisational memory. Several KM tools and technologies can be used to generate knowledge (e.g. taxonomies, cognitive mapping tools, search engines, information retrieval tools, video conferencing, expertise, yellow pages, intranets);
- *Evaluating knowledge*: Involves the process of KM system development in an organisation. Several KM systems can be used such as document management systems, decision support systems, and workflow management systems;
- *Sharing knowledge*: There have been two main concepts of knowledge sharing in organisations; organisational climate and organisational culture. 'Communities of practice' is the main approach to cultivating tacit knowledge that moves beyond organisational artefacts; and
- *Leveraging knowledge*: This entails utilising knowledge to solve existing problems and to improve continuously in the face of changing conditions. There are two main methods to measuring knowledge; human resource accounting and scorecards.

c. Tiwana Knowledge Model

The concept of a knowledge management platform was investigated by Tiwana (2002). The KM platform includes the KM systems infrastructure, KM strategy, cultural facets of knowledge works, design of incentive schemes, and measurement and evaluation mechanisms in place as shown in Figure 4.4. A KM system is therefore a subset of the KM platform. The main role of knowledge management is to enable the creation, distribution, and exploitation of knowledge to create and retain greater value from core business competence. Three basic processes of knowledge management are:

- *Knowledge acquisition*: The process of development and creation of insights, skills and relationships. The key to successful knowledge management lies in

leveraging the existing infrastructure, primarily communications and storage capabilities, that is already in place. Data capture tools with filtering abilities, intelligent databases, keyboard scanners, note-capture tools, and electronic whiteboards are examples of information technology components that can support knowledge acquisition.

- *Knowledge sharing*: This process involves disseminating and making available what is already known. The critical aspect in knowledge sharing is determining the best mix of available tools and integrating them into a coherent architecture. Firstly, an organisation needs to choose information technology components to find, create and share both within and outside the organisation. The optimal choice of components must let the organisation integrate and apply fragmented tacit and explicit knowledge in cost effective and timely manner. Artificial intelligence, data warehouses, genetic algorithms, neural networks, expert reasoning systems, rule bases, and case-based reasoning are technologies that provide intelligence to the knowledge management system.

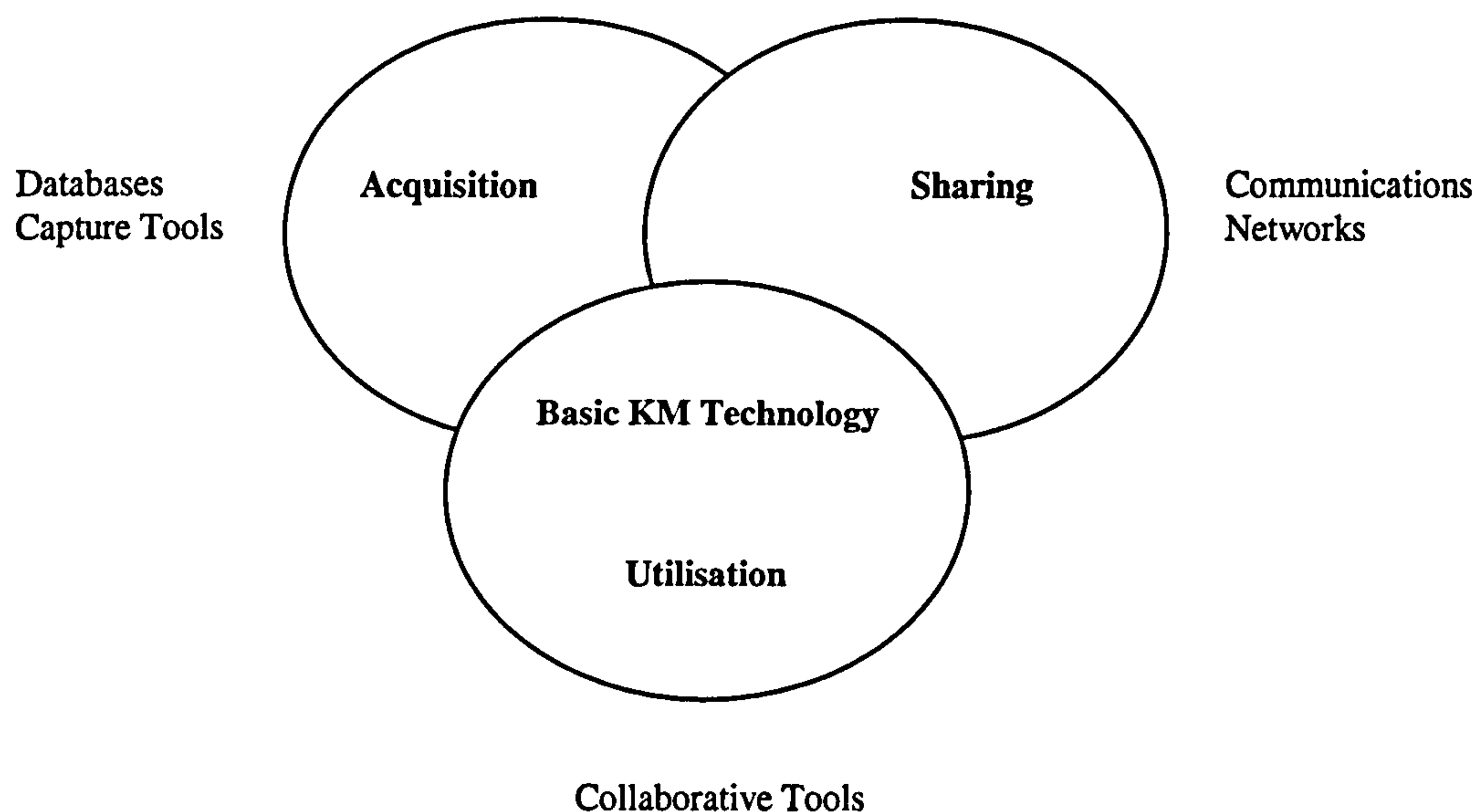


Figure 4.4: The Basic Elements of KM and Typical Technology Tools (Tiwana, 2002).

- *Knowledge utilisation*: This process involves integrating learning into the organisation. Knowledge that is broadly available throughout the company can

be generalised and applied, at least in part, to new situations. The first step that needs to be undertaken is to select a pilot project that is representative and that will help identify and isolate failure points and must consider two aspects: high visibility and tangible outcomes. Secondly, the organisation needs to develop a clear communication process that explains the expectations and reasoning behind the introduction and integration of the knowledge management system with the business process. A healthy knowledge management system needs iterative improvements as the business environment and accompanying processes evolve over time.

There are four main phases of knowledge management implementation (Tiwana, 2002):

- *Infrastructural evaluation*: This involves analysing the existing infrastructure and aligning knowledge management with the business strategy;
- *KM system analysis, design and development*: This involves designing the KM infrastructure, auditing existing knowledge assets and systems, designing the KM team, creating the KM blueprint, and developing the KM system
- *Deployment*: This involves deploying KM using the results-driven incremental methodology; and
- *Evaluation*: This involves evaluating performance, measuring return on investment (ROI), and incrementally refining the knowledge management system.

4.2.3 Taxonomies of Knowledge

Knowledge can be generally classified as either explicit or tacit (Nonaka and Takeuchi, 1995). Explicit knowledge refers to the knowledge that is transmittable in a formal, systematic language. It is rooted in the form of hard data, scientific formulae, manuals, computer files, documents, patents, and standardised procedures that can easily be transferred or shared. Tacit knowledge, on the other hand, is mainly personal, context-specific, and therefore hard to formalise and communicate. It is mainly located in people's minds thus there should be ways of recording who has what experience, on

past projects for example, and ways of getting these people together with others who need that knowledge (Sun and Howard, 2004). Tacit knowledge can be segmented into two dimensions (Nonaka and Takeuchi, 1995):

- *Technical dimension*: Encompasses the kind of informal and ‘hard to pin down’ skills or crafts captured in the term ‘know-how’. A master craftsman, for example, develops a wealth of expertise ‘at his fingertips’ after years of experience. But he is often unable to articulate the scientific or technical principles behind what he knows; and
- *Cognitive dimension*: Consists of schemata, mental models, beliefs and perceptions so ingrained that we take them for granted. The cognitive dimension of tacit knowledge reflects our image of reality (what is) and our vision for the future (what ought to be).

Before exploring the development of the framework to integrate KM processes into site management practices, it is pertinent first to discuss the different taxonomies of knowledge and attempt to explicate those that are of particular relevance in a site management context. This will include a review of well known knowledge management process frameworks developed by earlier researchers and industrial practitioners including: Nonaka and Takeuchi (1995), Whetherill *et al.* (2002), Robinson *et al.* (2001), KPMG (1998), Ruggles (1997), Heron (1996) and Blacker *et al.* (1993). The classification of knowledge can be viewed from three main perspectives:

a. Management Science Perspective

According to Nonaka and Takeuchi (1995) there are four modes of knowledge conversion:

- *Sympathized knowledge*: The socialisation process and process of sharing information with others. This means more than just talking, and involves sharing

internal knowledge and insights in a structured manner. This is related to how the apprentice learns from the master craftsman;

- *Operational knowledge*: The internalisation process through learning by doing and creating tacit knowledge from specific knowledge;
- *Conceptual knowledge*: The externalisation process through the ability to look outside and envisage something better and different, the basis of innovation; and
- *Systematic knowledge*: A combination process of systemising concepts into a knowledge system. This conversion involves combining different bodies of explicit knowledge.

Heron (1996) asserts that practical knowledge is the highest form of knowledge, as it remains open to the lenses offered by new experience. His classification of knowledge types is as follows:

- *Propositional knowledge*: Theoretical ideas about things;
- *Practical knowledge*: Action related know-how;
- *Experiential knowledge*: Things as actually experienced;
- *Presentational knowledge*: A feedback loop from experiential to propositional knowing in a form of creative output; and
- *Taxonomic knowledge*: Knowledge that makes the distinction between explicit and tacit knowledge.

In contrast, Blackler *et al.* (1993) argued that all knowledge is either tacit or rooted in tacit knowledge and their classifications of knowledge can be summarised as follows:

- *Embrained knowledge*: Conceptual skills and abilities. These are sentient, action dependent and context dependent or on the skills of 'acting with' (which involve sharing, communication and problem solving);
- *Embodied knowledge*: Acquired by doing;
- *Encultured knowledge*: Acquired through socialisation;
- *Embedded knowledge*: Can be embedded in tacit skills, established team working, organisational routines, broader professional and affiliate networks, and in geographical locations; and

- *Encoded knowledge*: Signs and symbols.

b. Business Perspective

The KPMG Report on knowledge management in 1998 classified knowledge into seven main types. These include customer knowledge, company's own market, company's own products and services, competitors, employee skills, regulatory environments, and methods and processes. Ruggles (1997) classified knowledge into four main categories:

- *Process knowledge*: Process knowledge can be thought of as "recipes for doing things well". Often collected through benchmarking or best practice efforts, this knowledge is useful in optimising operations and increasing efficiency;
- *Factual knowledge*: Basic information about people and things is factual knowledge when it resides in people's heads. Easiest to document, it is relatively low value-added information unless synthesised and contextualised;
- *Catalogue knowledge*: Individuals who possess catalogue knowledge know where things are. These people are like directories of expertise, and while such knowledge can often be codified into a sort of yellow pages, the dynamics within organisations change so quickly that there will always be individuals who are more valuable because they know where to go for the right knowledge; and
- *Cultural knowledge*: Knowing how things actually get done in an organisation, culturally and politically, is an invaluable asset. Often, cultural and catalogue knowledge are the two hardest hit areas when organisations downsize. Without this type of intellectual capital, getting work done becomes much more inefficient as people re-learn the invisible rules and norms.

c. Construction Perspective

In the construction industry context, Whetherill *et al.* (2002) and Robinson *et al.* (2001) discussed different classifications of construction knowledge. Whetherill *et al.* (2002) classified knowledge into three main categories:

- *Domain knowledge:* This forms the overall information context. It includes administrative information (e.g. zoning regulations, planning permission), standards, technical rules, product databases, etc. This information is, in principle, available to all companies, and is partly stored in electronic databases.
- *Organisational:* This is company-specific, and is the intellectual capital of the firm. It resides both formally in company records and informally through the process knowledge of the firm. It also comprises knowledge about the personal skills, project experience of the employees and cross-organisational knowledge.
- *Project knowledge:* This is the potential for usable knowledge and is at the source of much of the knowledge identified above. It is both knowledge each company has about the project and the knowledge that is created by the interaction between firms. It is not held in a form that promotes re-use (e.g. solutions to technical problems or in avoiding repeated mistakes).

Robinson *et al.* (2001) assert that knowledge in a project environment can be found in people, processes and products. The classification of knowledge is as follows:

- *Product knowledge:* Construction organisations produce a range of end products from a small and simple building to large and sophisticated structures (e.g. bridges and dams). Bennett (1991) classified construction end products into three distinct types: standard construction; traditional construction; and innovative construction. The nature of these end products determines what processes and knowledge are required, and the way they are managed;
- *Process knowledge:* Construction projects are characterised by a certain process-project organisational structure, procurement system, and site management system. The 'end products' required by the clients are often different as are the (technical and management) processes used in the delivery of construction projects; and
- *People knowledge:* Relates to the characteristics of the individuals and teams in terms of their skills, problem-solving and learning styles.

Table 4.1 shows the variety of classifications of knowledge and the mapping between them. Based on the preliminary synthesis undertaken, several knowledge types are

relevant for integration into site management practices. In general, knowledge on site practices can be found in people, processes and products.

Table 4.1: Taxonomies of Knowledge.

	Whetherill <i>et al.</i> (2002)	Robinson <i>et al.</i> (2001)	KPMG (1998)	Ruggles (1997)	Heron (1996)	Nonaka and Takeuchi (1995)	Blackler <i>et al.</i> (1993)
Project		Process	Methods and processes	Process knowledge	Practical knowledge	Sympathized knowledge	Embedded knowledge
	Domain	Product	Customers Company's own markets Competitors Company's own products and services Regulatory environments	Factual knowledge	Propositional knowledge Presentational knowledge	Operational knowledge	Encoded knowledge Embodied knowledge
	Organisational			Cultural knowledge			Encultured knowledge
		People	Employee skills	Catalogue knowledge	Experiential knowledge Taxonomic knowledge	Systematic knowledge Conceptual knowledge	Embrained knowledge

However, the cognitive (in the form of heuristics and intuitions) and the support processes (such as experiential, cultural and catalogue) are the two most important constructs associated with knowledge management (KPMG, 1998; Ruggles, 1997; Heron, 1996; Nonaka and Takeuchi, 1995; and Blackler *et al.*, 1993). Consequently, an effective knowledge management framework should have the ability to manage intellectual assets by leveraging both the cognitive and support processes in construction site management practices.

4.2.4 Knowledge Types Relevant to Construction Site Management

Based on the preliminary synthesis undertaken, several knowledge types are relevant for integration into site management practices. The knowledge types relevant to site management practices are summarised in Table 4.2:

Table 4.2: Knowledge Types Relevant to Construction Site Management.

Knowledge Type And Sub-Type	Relevance to Construction Site	
Process Knowledge	<p>Collected through best practices and bench marking efforts. Knowledge of construction methods, site lay out, use and maintenance of equipment and plant, concrete technology, estimating and site cost control.</p> <p><i>Impact: Optimising operations and increase efficiency</i></p>	
	Organisational	<p>This knowledge resides both formally in company records and skilled processes of the organisation. It also comprises knowledge about the personal skills, project experience and cross-organisational knowledge. In the site environment, it comprises knowledge of trade workers.</p> <p><i>Impact: Improved quality of workmanship and avoiding repeated mistakes.</i></p>
	Regulatory	<p>This knowledge is crucial to protect the natural environment and create a healthy and non-toxic environment. It is encapsulated in the site planning and organisation, material selection and waste management processes (Khalfan <i>et al.</i>, 2002).</p> <p><i>Impact: Changes of construction process and improve quality of product</i></p>
Product Knowledge	<p>Collected throughout the life cycle of construction; planning, design, construction and maintenance. Embedded in the procurement process, estimating and tendering process, material management process and construction method process.</p> <p><i>Impact: Creative problem solving and suitable to be used for long-term partnering project arrangements.</i></p>	
	Domain	<p>This knowledge is in principle, available in the company and partly stored in electronic databases. The overall information context which includes administrative information (e.g. zoning regulations, planning permissions), standards, technical rules, product databases etc. (Whetherill <i>et al.</i>, 2002).</p> <p><i>Impact: Information portal sites that constitute a storefront to the actors (e.g. clients, consultants, suppliers and contractors) in managing site activities.</i></p>
	Operational	<p>This knowledge resides in the project management, production process, and new product usage and policy implementation of construction site. It is crucial for on-site issues such as labour, material, subcontractors and health and safety management.</p> <p><i>Impact: Produce high quality products and increase site management efficiency (time, cost and quality).</i></p>
People and Employee Skills	<p>Knowledge of mental model and technical tacit skills of workers (Nonaka and Takeuchi, 1995). On the construction site, it resides both formally in knowledge workers (engineer, architect and site manager) and trade workers (plasterers, bricklayers, roofers, carpenters, etc.).</p> <p><i>Impact: Tracks the people who where involved in a previous project, in recorded decisions with those who understand the context of the making of the decision and its implementation.</i></p>	
	Project	<p>Created by the interaction between firms. Knowledge for project records (Logs and submittal documents), design documents and schedule. Also unrecorded such as memory of processes, problems and solutions</p> <p><i>Impact: Solutions to technical problems and avoiding repeated mistakes.</i></p>
	Cultural	<p>Individuals who possess catalogue knowledge know where things are. These people are like directories of expertise, and while such knowledge can often be codified into a sort of Yellow Pages.</p> <p><i>Impact: Assist decision making process when problem arise because the individuals who have valuable knowledge know where to go for the right knowledge.</i></p>
	Catalogue	<p>Knowing how things actually get done in an organisation, culturally and politically, is an invaluable asset.</p> <p><i>Impact: Preservation of knowledge when staff move and reduces learning times of new staff to relearn the invisible rules and norms.</i></p>

It is crucial to assess the knowledge embedded in construction site management practices in a structured and systematic manner. However, the nature and problems of construction site management also present challenges for the integration of knowledge management within the site management context. These problems can be addressed by the development of an effective framework for integrating applicable knowledge management processes into site management practices. It is equally important to recognise that the integration of KM processes may not completely resolve current site management problems, but it should minimise the number of problems on site. Before integrating KM processes into site management practices, it is important to synthesise KM processes with a focus on establishing the most viable processes for use in construction site management practice. However from the above discussion, it is clear that construction knowledge is made up of tacit and explicit knowledge. The type of knowledge determines which knowledge management processes will be mapped onto the various aspects of site management practices.

4.3 Knowledge Management Processes

The main objective of knowledge management implementation in an organisation is to create an environment in which information is accessible to individuals and in which individuals acquire, share and use that information to develop their own knowledge and are encouraged and allowed to apply their knowledge for the benefit of the organisation (Wong and Aspinwall, 2006; Robinson *et al.*, 2005; Hadikusomo and Rowlinson, 2004; Tserng and Lin, 2004). Several authors have described knowledge management processes. Table 4.3 shows the comparison between authors with different perspectives of knowledge management processes. Depending on their original focus, each perspective of knowledge management processes has its strengths and weaknesses.

Table 4.3: Different Perspectives of Knowledge Management Processes.

Author(s)	KM Processes	Perspective
Robinson <i>et. al</i> (2001)	KM consists of five distinct but interrelated processes: <ul style="list-style-type: none"> • Discovery and capturing • Organisation and storage • Distribution and sharing • Creation and leverage • Archiving and retirement 	Construction industry
Davenport and Prusak (1998)	KM systems which involve the following processes: <ul style="list-style-type: none"> • Generation • Codification and coordination • Transfer 	Management science
Bhatt (2001)	Divided KM processes into five main areas: <ul style="list-style-type: none"> • Creation • Validation • Presentation • Distribution • Application 	Business management
Tiwana (2002)	Three basic processes of KM are: <ul style="list-style-type: none"> • Acquisition • Sharing • Utilisation 	Business and information management
Vorbeck and Fenke (2001)	Divided KM process into 4 main areas: <ul style="list-style-type: none"> • Creation • Store • Distribution • Utilisation 	Organisation management

The next section discusses the characteristics for KM processes suggested by Robinson *et al.* (2001), which consists of five distinct but interrelated processes; discovering and capturing, organisation and storage, distribution and sharing, creation and leverage, and retirement and archiving. These five processes in knowledge management allow an organisation to learn, reflect and re-learn, usually considered essential for building, maintaining and replenishing core competencies as shown in Figure 4.5.

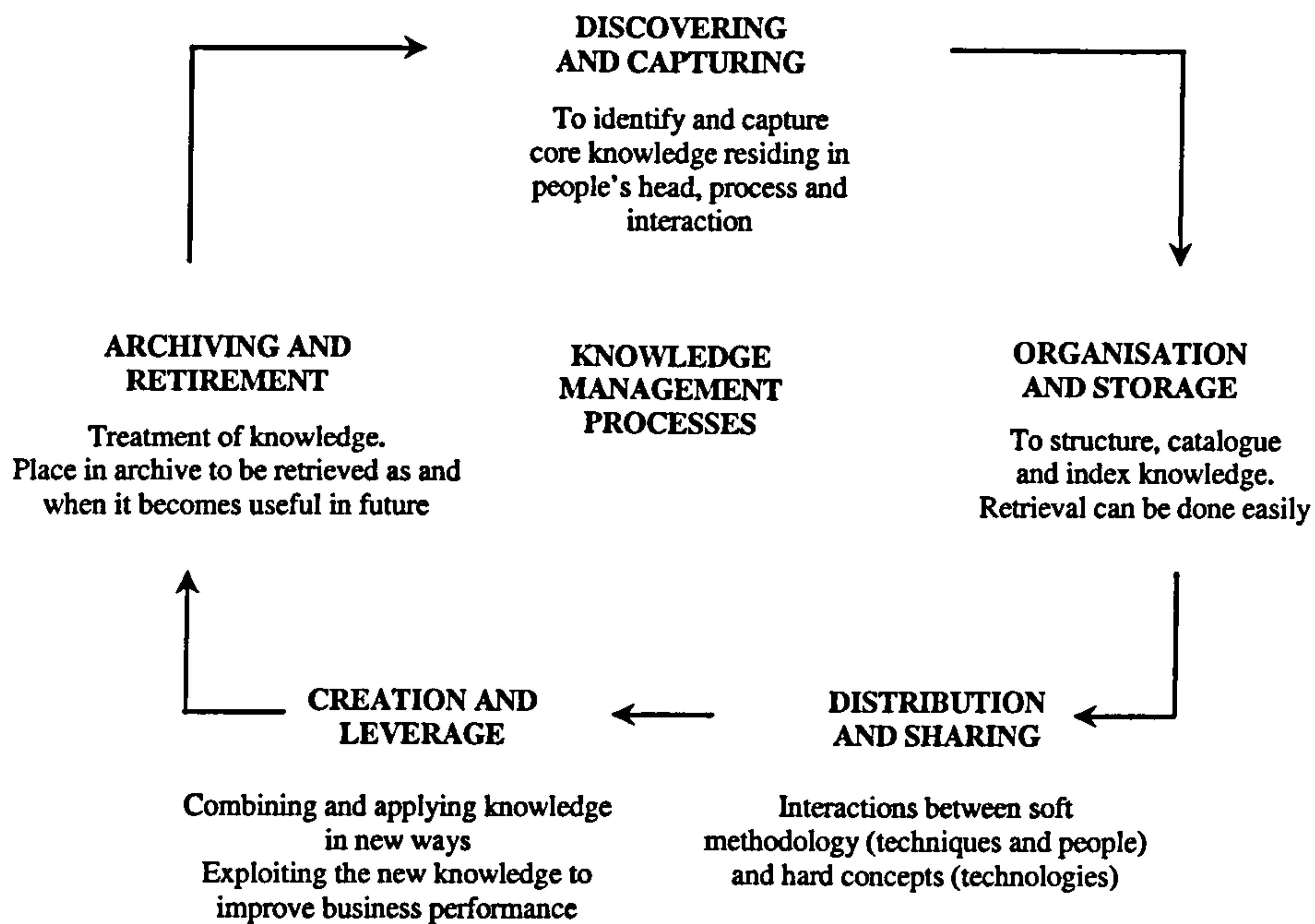


Figure 4.5: Knowledge Management Processes (adapted from Robinson *et al.*, 2001).

4.3.1 Knowledge Discovery and Capture

This process is aimed at finding out where knowledge resides, whether in peoples' heads, processes or products. According to Kululanga and McCaffer (2001) knowledge can be captured from both the internal and external business environment. For example, a construction organisation can acquire knowledge internally by:

- Tapping knowledge from its staff;
- Conducting internal benchmarking studies; and
- Learning from experience.

Knowledge can also be externally acquired, for no single construction organisation can ever dominate all the valuable knowledge and innovative ideas. Construction organisations can capture knowledge from their external business environment, for example, by:

- Attracting staff from innovative organisations;
- Use of experienced practitioners to address their knowledge requirements;
- Conducting external benchmarking;
- Collaborating with other organisations;
- Reviewing innovations in the business environment; and
- Attending conferences on new developments.

In the construction management context, mechanisms for knowledge capture include formal meetings, where meetings are minuted and circulated, and a central database for capturing project reviews (Egbu *et al.*, 2005). The combination of both ‘soft’ (i.e. organisational, cultural, and people issues) and ‘hard’ (i.e. information and communication technologies, ICTs) concepts and tools will deliver a more complete solution and allow the reaping of benefits derived from the use of ICT (Kamara *et al.*, 2005).

4.3.2 Knowledge Organisation and Storage

This process deals with structuring, cataloguing and indexing knowledge so that retrieval can be done easily. The storage of knowledge should promote both informal (i.e. process-oriented) and formal (i.e. codified). Such repositories should be structured around functions, locations, business-process objectives and the learning needs of construction organisations. The ability to store knowledge effectively allows (Vorbeck and Fenke, 2001):

- A quick search for information;
- Access to information for other employees;
- The directing of colleagues to specific information; and
- The effective sharing of knowledge as it is easily stored for everyone’s use.

With regard to the documentation of experiences, the storage of the relevant inherent statements does not only require ability to abstract, but also a capability to focus on the substantial and to word briefly and succinctly. According to Woo *et al.* (2004) some

construction organisations have been successful at collecting and storing explicit knowledge in organisational databases, but are not always good at tracking and sharing tacit knowledge. Egbu *et al.* (2005) argued that it is important to record valuable experience (tacit knowledge) in electronic form (documents, databases, Web pages, and knowledge-based systems) in order to help prevent the repetition of mistakes and to encourage the reuse of best practice, while reducing costs and improving consistency.

4.3.3 Knowledge Distribution and Sharing

This process is aimed at disseminating and making knowledge available within and across organisations. It involves interactions between soft methodology (techniques, culture and people) and hard concepts (information and communication technologies). It also requires awareness of the relevant knowledge or best practice. Egbu *et al.* (2005) revealed that lack of time, lack of communication skills and rapid change in Information and Communication Technologies (ICT) are highlighted as the main barriers to knowledge sharing in construction organisations. According to Handzic and Zhou (2005) there are four modes of knowledge sharing: informal, formal, personal and impersonal. Each sharing mode has its strengths and weaknesses, as shown in Table 4.4.

Table 4.4: Comparison between Four Modes of Knowledge Sharing (Handzic and Zhou, 2005).

Type of Channel	Example	Strengths	Weaknesses
Informal transfer	Informal meetings, coffee break conversations	<ul style="list-style-type: none"> • Encourage socialisation • Effective in small organisations 	<ul style="list-style-type: none"> • May inhibit greater diffusion
Formal transfer	Training, workshops, education programs	<ul style="list-style-type: none"> • Effective in wide distribution 	<ul style="list-style-type: none"> • May hinder creativity
Personal transfer	Apprenticeships, mentoring programs	<ul style="list-style-type: none"> • Effective in transferring highly context-specific and situated knowledge 	<ul style="list-style-type: none"> • May be constrained by time and resource
Impersonal transfer	Knowledge repositories	<ul style="list-style-type: none"> • Easy access to knowledge that is readily generalised to other contexts 	<ul style="list-style-type: none"> • May discourage people from reusing due to the vast amount of knowledge in the repositories

The most effective transfer mechanism depends upon the type of knowledge being shared. For tacit knowledge, the most effective sharing techniques to be used are brainstorming, face-to-face interactions, and training (Al-Ghassani *et al.*, 2005). While, for easily articulated explicit knowledge, the most effective media include minutes of meetings, job instructions, and drawings.

Bhatt (2001) is of the view that knowledge distribution through supervision and a predetermined channel will minimise interactions and consequently reduce the opportunity to question the validity of the transferred knowledge. On the other hand, a horizontal organisational structure, empowerment, and an open-door policy speed up knowledge flow between different participants and departments. The use of e-mail, intranet, bulletin board, and newsgroups can support the distribution of knowledge throughout an organisation and allows organisational members to debate, discuss, and interpret information through multiple perspectives. However, Vorbeck and Fenke (2001) stressed that the readiness to share knowledge is a prerequisite for the ability to make knowledge available to others. Therefore, an organisation must find ways to motivate employees to share what they know and to apply the knowledge of others, contributing to a knowledge sharing culture (Egbu *et al.*, 2005).

4.3.4 Knowledge Creation and Leverage

This process involves combining or applying knowledge in new ways to extend the overall knowledge of the business, and to exploit the new knowledge to improve business performance. Vorbeck and Fenke (2001) are of the view that the creation of new knowledge can occur at different levels: in reproduction, through achievement, by solving problems and completing tasks. Existing knowledge and experience are used in these processes which always include a learning process. The creation of new knowledge should not only be the domain of the research department, but also involve all employees, units and functions of a construction organisation (Kululanga and McCaffer (2001). There are a number of processes that any organisation can undertake to create knowledge as identified by Nonaka and Takeuchi (1995):

- *Tacit to tacit*: Involves knowledge embedded in an individual that diffuses to another individual within a company, for example, through socialisation. The drawback of tacit to tacit creation is that the knowledge is locked within the minds of individuals. As a result, a construction organisation cannot easily leverage it throughout its establishment;
- *Explicit to explicit*: Involves combining discrete pieces of knowledge within an organisation into new knowledge. If new knowledge is created, then the company knowledge base will be extended;
- *Tacit to explicit*: Involves someone with tacit knowledge committing it to an explicit form (e.g. a manual) so that others can learn from it; and
- *Explicit to tacit*: Involves people learning new things from explicit forms of knowledge (e.g. reading a book or a manual).

In the context of knowledge management, it is important to share information, to create connections between ideas, and to build cross-connections to other knowledge areas in a construction organisation. Leadership commitment from top management is important to create an environment within which people are able to share knowledge and are allowed to assimilate it, as well as practise the knowledge gained (Egbu *et al.*, 2005).

4.3.5 Knowledge Archiving and Retirement

This process deals with the treatment of knowledge that has already been used but not updated or knowledge that has not been used or is no longer valid. Bhatt (2001) takes the view knowledge archiving as a careful process of continually monitoring, testing, and refining the knowledge base to suit the existing or potential realities. As the realities change, so does the need arise to convert the parts of 'knowledge' into 'information', and 'data', which may finally be discarded. It is because the developments in a discipline may often constitute new information, rules and theories, and a part of the old rules and theories become updated.

Although there are challenges with archiving existing knowledge, IT can enhance the knowledge archiving and retirement process (Alavi and Leidner, 2001). For example, many construction organisations are enhancing the ease of access and update of their

archives (structural drawings, method statements, specifications, health and safety plan, work procedures) by making them available on corporate intranets. This can increase the speed with which changes or updates can be applied. IT can also allow organisational units to follow a faster learning curve by accessing the knowledge of other units that have gone through similar experiences. Therefore, for any organisation it becomes important to continually review, test, and validate their knowledge base to keep up to date with the latest knowledge in the discipline and discard the outdated knowledge.

4.3.6 Relevant KM Processes for Construction Site Management

To summarise, this section has examined core KM processes with a view to adapting applicable KM processes in line with the requirements of current construction site management practices. However, Alavi and Leidner (2001) are of the view that the main implication of adapting KM processes is that knowledge management consists of a dynamic and continuous set of processes and practices embedded in individuals, as well as in groups and physical structures. Table 4.5 shows the relationships between site management problems, knowledge types, relevant KM processes, and the potential applications.

Table 4.5: The Relationships between Site Management Problems, Knowledge Types, Relevant KM Processes, and the Potential Applications.

Site Problems	Knowledge Types	Relevant KM Processes	Application
Poor communication	<ul style="list-style-type: none"> • Process 	<ul style="list-style-type: none"> • Knowledge storage • Knowledge sharing • Knowledge leverage 	<ul style="list-style-type: none"> • Knowledge forum • Company Yellow Pages
Poor quality	<ul style="list-style-type: none"> • Product 	<ul style="list-style-type: none"> • Knowledge storage • Knowledge leverage 	<ul style="list-style-type: none"> • ISO implementation • Document management system
Labour shortage	<ul style="list-style-type: none"> • People 	<ul style="list-style-type: none"> • Knowledge capture • Knowledge sharing 	<ul style="list-style-type: none"> • Apprenticeships • Mentoring • Special interest group
Existing services	<ul style="list-style-type: none"> • Process 	<ul style="list-style-type: none"> • Knowledge sharing 	<ul style="list-style-type: none"> • Communities of practice • Brainstorming • Intranet
Lack of coordination	<ul style="list-style-type: none"> • Process 	<ul style="list-style-type: none"> • Knowledge leverage • Knowledge capture 	<ul style="list-style-type: none"> • Brainstorming • Use recording devices

There are several aspects to be considered in the integration of KM processes into site management practices. It is important to identify the most significant site management problems, the KM issues associated with the problem, and to develop appropriate KM initiatives, and then establish an action plan for implementation. For example, for monitoring and controlling site progress and workmanship of trade workers, the construction organisation can use a recording device that enables the site managers to specify the day-by-day progress achieved in construction activities, allowing the program to link the playback film with the progress observed on the construction site (Dawood *et al.*, 2002). However, it must be remembered that KM initiatives should be problem-oriented rather than in the technology-oriented. Therefore, it is important to develop a problem-based framework to facilitate the improvement of construction site management practices. In addition, there are suggested developments of strategy which construction organisations can undertake to realise the benefits of a knowledge management (Carrillo *et al.*, 2000):

- Develop a strategic statement and a clear goal of knowledge management intent;
- Map the organisation's business processes to identify one small area that could bring tremendous benefit;
- Establish systematic procedures to capture and transform knowledge components into useful knowledge;
- Allow the sharing and communication of knowledge between individuals within and outside the organisation;
- Implement a process and infrastructure to leverage knowledge, experience and lessons learned to enhance the delivery of strategic planning engagements;
- Implement tools and approaches to leverage and enhance social capital, knowledge content and infrastructure; and
- Implement a system for continuous review and improvement of offerings and services.

4.4 Knowledge Management Tools

Egbu and Botterill (2002) argue that it is difficult to define the concept of knowledge management techniques and technologies in construction. Handzic and Zhou (2005) suggest that knowledge management tools can be viewed from an integrated perspective which considers KM as a social and technological phenomenon. The first perspective is the organisational environment including the organisational culture, organisational structure, leadership and measurement. The second perspective is the technological infrastructure including a wide range of information and communication technologies such as knowledge repositories, electronic forums, intranet, video conferencing, etc. Gray (2001) revealed that there are five common knowledge management tools currently used in any business organisation:

- *Formal training*: Employees attend structured training sessions where they are provided with instructional materials designed to educate them about a particular subject;
- *Knowledge repositories*: Knowledge repositories are structured collections of documents, often written documents by internal company experts. These documents attempt to capture their author's expertise and insight on a subject;
- *Knowledge fairs*: Knowledge fairs are like internal trade shows that are produced by employees for employees. They are relatively unstructured gatherings where employees staff booths, mount displays and talk about their firm's successful practices and products;
- *Communities of practice*: Communities of practice emerge naturally both within and across organisations. Employees who have a common base of expertise, who deal with a common organisational process, or who have an interest in solving similar types of problems naturally group together to share ideas; and
- *Talk rooms*: Talk rooms are social spaces which employees are expected to visit for 20 minutes or so as a normal part of their work day.

While it is now recognised that good knowledge management does not result from the implementation of information systems alone, the role of IT as a key enabler remains undiminished (Anumba *et al.*, 1998). There is a preponderance of IT systems available

to support knowledge management. Most of these systems provide support for only one or more of the four areas illustrated in Figure 4.6 and so cannot realistically be labelled as “knowledge management systems” as most vendors do. While the classification in Figure 4.6 is debatable, it represents a useful framework for discussing IT support for knowledge management. These information technology (IT) systems for knowledge management process are discussed below:

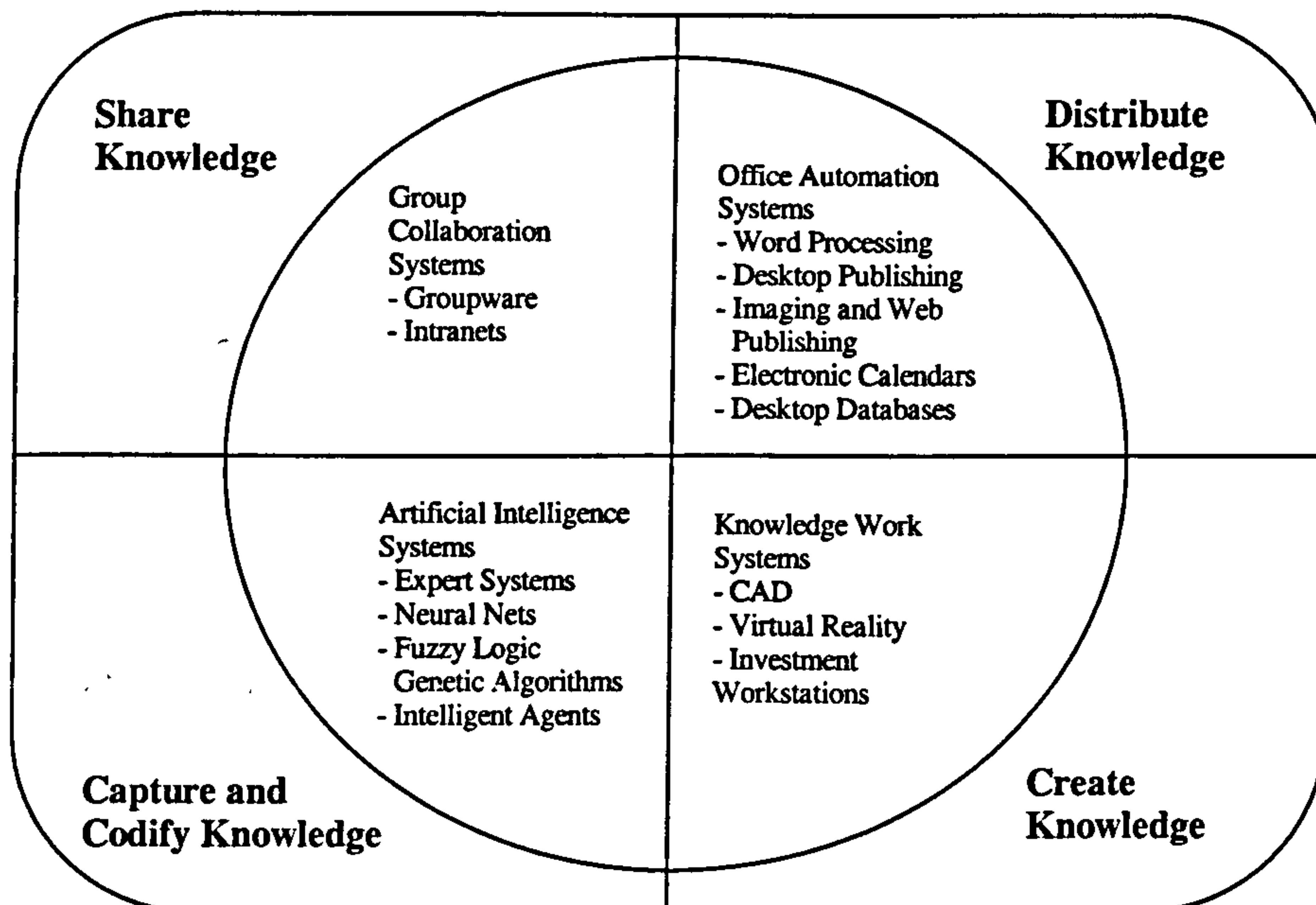


Figure 4.6: IT Support for Knowledge Management (Laudon and Laudon, 2002).

- *Systems for knowledge creation:* Within the construction industry, there are now a variety of systems that facilitate the knowledge creation process. These are usually discipline-specific and include CAD systems, analysis systems, estimating systems, etc. Increasingly, these systems are being integrated both within and across disciplines, thereby facilitating the flow of information.
- *Systems for knowledge processing:* These systems are also known as “office automation systems”. They enable the processing (manipulation, storage, codification, etc.) of knowledge in organisations and include, amongst others, word processors, spreadsheets, desktop publishing systems and databases. These

systems are now routinely used within construction organisations to ensure the smooth running of businesses.

- *Systems for knowledge sharing:* Knowledge sharing systems are utilised to support groups working together such that members of the group can share data, information and knowledge within a given context. Examples of these systems are intranets and other groupware systems such as video-conferencing, document management systems, bulletin boards, shared databases, and electronic mail systems. The use of these systems is growing in the construction industry but, so far, the emphasis has been more on supporting intra-organisation groups rather than virtual project teams that have members drawn from several organisations.
- *Systems for knowledge capture and codification:* Systems that are able to encapsulate knowledge and expertise in coded or symbolic form are vital for knowledge management in an organisation. They enable the setting up and maintenance of knowledge bases that preserve knowledge or expertise that might otherwise be lost when a key member of staff is no longer available. These systems are generally based on the concept of artificial intelligence (AI) and are effective decision support systems. The uptake of artificial intelligence systems in construction has been disappointing and is partly attributed to the hype associated with 'expert systems' in the eighties. However, there is renewed interest and artificial intelligence systems are increasingly embedded as components of larger information technology (IT) systems (Carrillo *et al.*, 2000).

In the construction industry context, Al Ghassani *et al.* (2005) provide a structured categorisation of knowledge management tools. Knowledge management tools can be divided into two main categories: techniques and technologies. KM techniques (non-IT tools) are tools that do not require technology to support them and exist in several forms. KM technologies depend heavily on IT as the main platform for implementation. Table 4.6 shows the comparison between KM techniques and technologies including example of tools. Detailed discussions for each category are provided in the next section.

Table 4.6: A Comparison between KM Techniques and Technologies (Al-Ghassani *et al.*, 2005).

KM Tools	
KM Techniques	KM Technologies
<ul style="list-style-type: none"> • Require strategies for learning • More involvement of people • Affordable to most organisations • Easy to implement and maintain • More focus on tacit knowledge • Examples of tools: <ul style="list-style-type: none"> ○ Brainstorming ○ Communities of practice ○ Face-to-face interactions ○ Recruitment ○ Training 	<ul style="list-style-type: none"> • Require strategies for learning • Require IT skills • Expensive to acquire/maintain • Sophisticated implementation/maintenance • More focus on explicit knowledge • Examples of tools: <ul style="list-style-type: none"> ○ Data and text mining ○ Groupware ○ Intranet/Extranet ○ Knowledge bases ○ Taxonomies/ontologies

4.4.1 KM Techniques to Support Construction Site Management

Knowledge management techniques (non IT tools) are not new because organisations have been implementing them for decades under the umbrella of several management approaches (Al-Ghassani *et al.*, 2005). Egbu *et al.* (2005) argue that some elements of knowledge management are practiced but carried out in an ad-hoc manner. For example, face-to-face social interaction is the most effective KM technique used in knowledge sharing within construction site management practices. It is considered very useful for solving site management problems. Due to the complex structure of construction site organisations, most of the KM techniques adopted are informal (e.g. informal meetings and face-to-face interactions) rather than formal (e.g. site meetings, health and safety training and seminars). It is important to use KM techniques to enable tacit knowledge to be made explicit in an easy and effective manner on the construction site. The main reason is because the KM techniques are (Al-Ghassani *et al.*, 2005):

- *Affordable to most organisations*: No sophisticated infrastructure is required (although some techniques require more resources than others e.g. training requires more resources than face-to-face interactions);
- *Easy to implement and maintain*: KM techniques are easy to implement and maintain as they incorporate features that are relatively simple and straightforward to understand; and

- *Focusing on tacit knowledge:* KM techniques focused on retaining and sharing organisational tacit knowledge, which is a key asset to organisations to improve business performance.

Construction site organisations need to find the most appropriate KM technique for a given site problem. Examples of KM techniques to support construction site management are presented below:

Brainstorming: This is a process involving a group of people, who intentionally proposing as many deliberately unusual solutions as possible in order to push the ideas as far as possible (Al-Ghassani *et al.*, 2005). According to Nonaka and Takeuchi (1995) a brainstorming session is an informal meeting for detailed discussions to solve difficult problems in development projects. The participants propose ideas as they occur to them and then build on the ideas raised by others. All the ideas are noted down and are not criticised. Such a brainstorming session is not only a forum for creative dialogue but also a medium for sharing experience and enhancing mutual trust among participants.

Communities of practice (CoPs): These are groups of people formed to share what they know, learn from each other regarding some aspects of a problem, topic, or task and provide a shared context for these interactions. Usually there are many CoPs within a single company and most people normally belong to more than one (Al-Ghassani *et al.*, 2005). CoPs are seen as practical mechanisms to manage knowledge as an asset, utilising the inherently context-dependent nature of 'know-how' and experience required for collaborative problem solving and innovation in project-based organisations (Dent and Montague, 2004).

Face-to-face interactions: This technique is a traditional approach for sharing tacit knowledge (socialisation) owned by an organisation's employees. It usually takes an informal approach and is very powerful. According to Emmitt and Gorse (2003), face-to-face interpersonal communications tend to be spontaneous and with maximum feedback, with most of the message sent verbally. Face-to-face interactions, when managed correctly, help to develop relationships and overcome the problems posed by organisational boundaries. They also provide an environment within an organisation

where participants see the firm as a human community capable of providing diverse meaning to an organisation's knowledge (Al-Ghassani *et al.*, 2005).

Apprenticeships: This is a form of training in a particular trade carried out mainly by practical experience or 'learning by doing' (not through formal instruction). An individual can acquire tacit knowledge directly from others without using language (Al-Ghassani *et al.*, 2005). According to Nonaka and Takeuchi (1995), apprentices often work with their masters and learn craftsmanship through observation, imitation and practice. In the business setting, on-the-job training uses basically the same principle.

Mentoring: This involves a process where a trainee or a junior member of staff is attached or assigned to a senior member of an organisation for advice related to career development. The mentor provides a coaching role to facilitate the development of the trainee by identifying training needs and other development aspirations. According to Jashapara (2004), a mentor encourages the learner to solve problems and will act as a sounding board. Dent and Montague (2004) take the view that such systems regulate the load across senior managers, allow mentors to help junior staff to identify development directions, and steer individuals to company roles and projects that best support such improvement.

Training: This helps to improve staff skills and therefore increase knowledge. According to Jashapara (2004), there are two types of training and development in organisations: formalised approach and focused approach. The formalised approach links the planned training and development programme with performance appraisals and career planning processes. The focused approach links training and development activities to organisational goals and continuous learning. Gray (2001) states that training usually takes a formal format: employees attend a structured session where they are provided with instructional material designed to educate them about a particular subject. It can be internal, where senior staff train junior employees within the organisation, or external, where employees attend courses managed by professional organisations (Al-Ghassani *et al.*, 2005).

4.4.2 KM Technologies to Support Construction Site Management

Dent and Montague (2004) are of the view that the primary role of KM technologies within a KM strategy is not as a driver, but as an enabler. The KM technologies implemented should be led from the perspective of technology enabling knowledge sharing rather than on the basis of technical compatibility. Handzic and Zhou (2005) provide seven typologies of KM technologies, based on the distinction of knowledge management processes, as shown in Table 4.7.

Table 4.7: Typology of KM Technologies (Handzic and Zhou, 2005).

Category	KM Process	Purpose	Examples
Knowledge storage technologies	Knowledge storage	To store organisational knowledge and enhance organisational memory	Knowledge repositories, databases, text-bases, data warehouse, data mart
Knowledge access technologies	Knowledge storage	To improve access to knowledge and/or facilitate knowledge transfer among individuals	Knowledge maps, knowledge directories, yellow pages
Knowledge search/retrieval technologies	Knowledge retrieval	To locate internal/external knowledge and to improve access to knowledge resources	Search engines, intelligent agents
Knowledge delivery/sharing technologies	Knowledge transfer	To disseminate and make available organisational knowledge.	E-mail systems, electronic bulletin boards, white boards, electronic forums, videoconferencing, voice mail, groupware
Knowledge discovering/visualisation technologies	Knowledge creation	To uncover hidden patterns and extract new knowledge	Data mining, statistical tools, graphical representation, simulation technologies
Knowledge utilisation technologies	Knowledge application	To facilitate knowledge integration and application	KM systems, workflow systems, expert systems, rule induction, decision trees
Platform technologies	All	Multiple purposes: can be used to support any or all of the above processes	Internet, intranet, extranet, portals

In general, KM technologies can support the storing and distribution of information and facilitate the sharing of knowledge. However, it must be remembered that a complete knowledge management solution should also be considered in bringing people together to share and leverage the knowledge. There are several KM technologies for supporting knowledge management in construction. However, most software cannot provide a

complete solution to KM. These software systems often integrate a variety of off-the-shelf products - electronic mail, groupware, document management systems, relational databases, search engines and workflow. Some of the available KM technologies are described below:

Case-based reasoning systems: Some organisations have collective knowledge and expertise built up over a long period of time. This can be effectively captured and stored using a case-based reasoning system (Laudon and Laudon, 2002). These systems use artificial intelligence technology to represent knowledge as a database of “cases”. A “case” describes the experience of human specialists in a particular situation. When a user enters a new case, the system searches for stored cases with similar parameters. The system can infer a number of solutions from a mass of experience, as well as the probability of success of each solution (Turban and Aronson, 1998). The stored case with the best fit to the new case provides a solution based on past experience. Case-based reasoning is an excellent tool for customer service knowledge management.

Databases and data warehouses: Group and corporate memory is a valuable resource. Whether centralised or distributed, stored in databases or a data warehouse, all knowledge management systems should offer access to it where required. A database is simply a collection of structured data that may be used by one or more applications. Depending on the size and function of an organisation, they will probably store data in multiple databases (Turban and Aronson, 1998). In some organisations, it is necessary to integrate key data and store them in a consistent form that facilitates easy analysis and reporting. The data are standardised and consolidated before being made available across the organisation. As the warehouse contains both current and historical data, the contents may not be altered. Data warehouses come with a set of query and analytical tools with which to “mine” the data and allow them to be modelled and remodelled at will. Final results are often presented through a graphical reporting facility for easy assimilation (Handzic and Zhou, 2005).

Data mining: Data mining is a technology for knowledge discovery in databases (Liao, 2003). It provides different methodologies for decision-making, problem solving, analysis, planning, diagnosis, detection, prevention, learning and innovation. Data mining is a process of analysis, undertaken by special software tools, to uncover

patterns in pools of data. Data stored in warehouses, databases, and on the Web, can be mined to produce insights which are then used to guide decision making. Common applications of data mining include direct marketing, trend analysis, new product development, market segmentation and customer retention analysis (Jashapara, 2004).

Document management systems: Document management systems are used to store a wide range of documents, files and images, including computer generated reports, word processed documents and spreadsheets, records of business transactions, customer statements, credit card transactions, photographs and even audio recordings (Jashapara, 2004). Indexes are used to identify and retrieve the required documents. Index data are recorded when the document is input in the system so that it may be retrieved in a variety of ways. Indexing allows documents to be cross-referenced and grouped according to relevance (Laudon and Laudon, 2002). An “industrial strength” document warehouse can store billions of documents which are instantly available to authorised users internally and, via the Internet, externally to customers and suppliers. These systems can generate sufficient savings on paper, microfiche and processing time that implementation can be easily cost-justified in most medium to large organisations.

Expert systems: An artificial intelligence method for capturing knowledge, these are knowledge-intensive computer programs that capture human expertise in a limited domain of knowledge (Laudon and Laudon, 2002). According to Liao (2002) the basic principle of an expert system is that human knowledge must be modelled and presented in a way that computers can process. Knowledge is stored in a knowledge base along with a set of rules for manipulating that knowledge. Expert systems can enable the problem solving and decision making process in a very limited domain by asking relevant questions and offering explanations for a particular course of action.

Intranet and Extranet: An intranet is a private Web that exists within an organisation and uses the same technology as the internet. It is protected from third parties by a firewall; this is a security system with specialised software to prevent outsiders from invading private networks (Laudon and Laudon, 2002). Dent and Montague (2004) state that the intranet is regarded as the primary IT platform for KM as it provides for an integration of business critical applications and tools, and basic facilities such as a standardised resource to assist operational practices and tasks. An extranet is a private

internet to which selected outsiders have access. Access is also controlled by a “firewall” which ensures that internal data remains secure and that external users can only access certain areas of the network.

Groupware: Groupware, along with Web-based tools, promotes information sharing by allowing groups of users to work together. This collaborative working could take many forms; sharing documents or applications, scheduling meetings, building virtual communities, participating in virtual teams, developing shared databases, managing projects and routing electronic forms (Al-Ghassani *et al.*, 2005). According to Jashapara (2004), groupware products combine tools that support knowledge sharing through threaded discussion databases, document repositories, shared calendars and applications, built-in email and a customisable Web interface.

Videoconferencing: “Cybermeetings” are an effective way of encouraging and enabling people to share tacit knowledge. These forms of electronic conferencing are growing in popularity because they save travel time and cost (Laudon and Laudon, 2002). Although the picture quality is still not brilliant, the current desktop systems are well situated to individuals and small groups. Software products such as Microsoft NetMeeting and Netscape Communicator’s Conference provide low cost KM technologies for desktop video conferencing over the Internet.

Workflow management systems: Workflow software controls the movement of documents, information and tasks around an organisation via approved routes (Turban and Aronson, 1998). It also sets rules for who can see what information and who needs to authorise certain procedures. Workflow software is often used in conjunction with document management systems to streamline paper-based business process. According to Kamara *et al.*, (2005) a workflow management system should also have filtering capabilities to ensure that only relevant learning is captured to prevent knowledge/information overload. Examples of workflow management systems include customer orders, insurance claims, university applications and tax returns (Jashapara, 2004).

4.4.3 The Application of KM Tools on Construction Site Management Practices

Construction organisations have a variety of mechanisms for managing their tacit and explicit knowledge (Mohamed and Anumba, 2006). Although the label of KM is often not used, knowledge is being managed through content management (e.g. central project file and business management system), experience management (e.g. quality register, communities of practice, and seminars) and process map and project procedure. According to Robinson *et al.* (2005) an intranet is the backbone of the IT infrastructure to support the above knowledge management activities in construction organisations. The intranet is a useful tool for collaborative work, facilitating knowledge sharing within project teams and the entire construction supply chain. The KM techniques and technologies described in the previous section provide valuable support for knowledge management. However, the dynamic nature and continual evolution of software systems create problems for selecting the most appropriate tools to be implemented in construction organisations. The KM tools can be effectively used on the construction site to enable knowledge to be captured and reused in the future. Tserng and Lin (2004), in a survey of construction organisations, identified several key benefits for construction organisations of implementing knowledge management:

- Increased innovation ability (23%);
- Decreasing the probability to repeat problems (23%);
- Improved training effectiveness (17%);
- Experience reused (13%);
- Improved job effectiveness (13%); and
- Increased knowledge asset (12%).

The benefits of knowledge management can be appreciated only if construction site organisations employ systematic and effective KM strategy on the construction site. Construction site organisations can take advantage of KM tools for its implementation as site management practices involves several knowledge-intensive activities. These activities (e.g. site investigation, site planning and layout, material handling, planning and managing the construction) are influenced by factors that are linked to human intelligence and knowledge, such as experience and engineering judgments (Al-

Ghassani *et al.*, 2006). For example, the implementation of an intranet system in construction site management facilitates knowledge sharing and helps site managers to find the right solution for specific problems based on the response from experts in different geographical areas (Mohamed and Anumba, 2005). Therefore, it is important to identify the techniques (non-IT tools) and technologies (IT tools) needed, including their appropriateness in a specific problem-context within construction site management practices. The next section examines the potential for implementing a knowledge management system on the construction site, including its potential benefits for construction site management practices.

4.5 Knowledge Management System on the Construction Site

In the construction site management context, very little research has been undertaken on managing knowledge in a systematic manner, which includes exploiting the potential benefits of KM techniques (non IT tools) and KM technologies (IT tools). The need for an effective knowledge management system on the construction site was indirectly addressed by Boyd *et al.* (2004). They developed a KM initiative called ‘Audio Diary and Debriefing’ which aimed to capture, store and disseminate knowledge on the construction site using a Dictaphone. This approach involves two operations: recording and debriefing. The first is based on recording events (i.e. audio diary) and the second is based on personal reflection and abstract conceptualisation of the events (i.e. debriefing). In addition, Egbu *et al.* (2005) used story telling and graphical representation as mechanisms for managing the tacit knowledge of experienced site managers. In this research, story telling was observed to be a useful tool for capturing tacit knowledge and graphical representation of the information assisted the sharing of tacit knowledge. Unfortunately, this does not adequately fulfill the KM needs of construction site management practices.

From a site management context, there is the need for a robust KM system that will enable the site manager to capture, store, share, and reuse the different types of knowledge, whether tacit or explicit. According to Mohamed and Anumba (2006) there

are several important needs to be considered in the development of a KM system on the construction site. These are:

- To identify what knowledge is to be managed;
- To identify the characteristics of the knowledge; and
- To develop detailed strategies of how their KM initiatives would be implemented.

These findings were supported by the work of Kamara *et al.* (2005) which revealed that the management of knowledge in construction organisations should include the following two elements. These are:

- The use of formal and informal feedback between providers and users of knowledge as a means to transfer learning and best practice; and
- A strong reliance on informal networks and collaboration, and 'know-who' to locate knowledge' to better focus on the exploitation of the knowledge management approach by construction site organisations.

The main reason is that informal networking systems are better able to create and transfer tacit knowledge, know-how and innovation because human relationships are necessary to share knowledge that is unclear and difficult to document (Dent and Montague, 2004). A clear identification of 'source' and 'destination' of knowledge is also crucial to determine the best mechanism for knowledge sharing, whether it is from people-to-people, people-to-paper, etc. However, Egbu *et al.* (2005) stressed that the implementation of any technological infrastructure to support KM on the construction site must be adapted to the organisation's needs and not the other way round. It is particularly important, in developing a KM system at site management level, to recognise two major misconceptions of knowledge management systems in any construction organisations (Carrillo and Chinowsky, 2006)

- *Lesson learned as KM system:* Many construction organisations claim to undertake 'lessons learned' sessions at project closeout. While these contribute to knowledge sharing, lessons learned are only one specific mechanism to share

knowledge. The lessons learned are also not conducted in a systematic manner, many of the relevant stakeholders are absent and there is ad hoc dissemination of findings; and

- *Intranet or extranet as KM system:* Intranet is crucial KM tools for both communication and access to data. They are classified as information systems rather than knowledge management systems.

4.6 Summary

In this chapter, the key concepts of knowledge, the main characteristics of knowledge and established knowledge models have been reviewed. This chapter has argued for a structured approach involving the development of knowledge taxonomies with a view to identifying the most relevant knowledge types that needed for construction site. The relationships between site management problems, knowledge types, relevant KM processes and the potential IT applications are also reviewed as the basis for developing an effective framework to support the integration of knowledge management processes into site management practices. The need to synthesize knowledge management processes was identified and resulted in the identification of relevant knowledge management processes for construction site management. It is observed that knowledge capture, knowledge sharing, and knowledge creation provide an interesting opportunity for KM to be integrated into site management practices. The variety of knowledge management techniques and technologies have also been discussed. It is important for construction site management practices to carefully select and implement KM techniques and technologies to support knowledge management processes. The needs of KM for any business organisations, the major misconceptions of knowledge management systems and the KM needs of construction site management practices need to be considered and evaluated before developing KM systems for construction site management. The next chapter presents case studies on the construction sites of organisations that have implemented KM. Details of the procedures used to manage the site and aspects of KM in the organisations are presented and analysed.

CHAPTER FIVE

Case Studies on Site Management Practices

5.1 Introduction

This chapter outlines case studies of site management practice on the five construction sites and intends to investigate the possibilities of deploying KM initiatives at the construction site level. Semi-structured interviews were conducted with construction site managers to identify aspects of site management practices that can be improved through the integration of knowledge management processes. The cases are presented individually and then similarities and differences between them are discussed. The key problems on the construction site, procedures used and aspects of knowledge management within site management practices are presented and analysed. The chapter concludes with the discussion of the importance of KM for site management practices and how the KM approach can be deployed to address site management problems. The outline features of a framework to support the integration of KM processes into site management practices are also discussed.

5.2 Case Studies

To obtain more insight into the applicability of KM processes for improving existing site management practices, a five-step descriptive case studies approach (that incorporates qualitative comparators with observations made within five construction sites) was adopted. The main aim of the case studies was to investigate the key problems of site management practices and to observe existing practice in managing knowledge on the construction site. Indeed, the case studies attempt to identify how existing site management practices could be improved through knowledge management. The case studies were based principally on semi-structured interviews with one site-

based project manager in each of the companies. Interviews lasted from two to five hours. Background information about the construction sites investigated and the project personnel interviewed are presented in Table 5.1.

Table 5.1: Details of Site Organisations Involved in Case Studies.

Case	Type of Site	Person Interviewed	Construction Experience	Cost (£)	Procurement Method
A	Pharmaceutical building	Project Manager	35 years	16 million	Design and Build
B	Hospital (PFI)	Design Manager	16 years	82 million	PFI
C	Water works	Design Manager	17 years	6 million	Fast Track
D	Swimming pool and fitness centre	Site Manager	40 years	7 million	Traditional
E	Retail store and service apartment	Project Manager	27 years	22 million	Design and Build

The interviewees under study were all experienced construction professionals with a range of 16 to 40 years experience in managing construction sites. The interviews were recorded, transcribed and returned to the construction organisation in order to ensure the validity of the transcript and also, in some cases, to gain additional information. Additional company information, such as internal KM reports and construction site organisation structure, was used for supplementary information. This study was designed to seek variations in construction size and procurement method, which both play an important role in industry rivalry and profitability (Harris and McCaffer, 2001). These differences provide the opportunity for exploring variations in knowledge resources within and across construction site management contexts.

Based on the results of case studies, this study attempts to develop an appropriate framework to integrate knowledge management processes with construction site management practices. The case study protocol is designed to be a systematic approach to increasing the reliability of case study research and is intended to guide the researcher in carrying out the case study. Well-designed steps within protocols ensure that the operations of the study can be repeated with the same results. The case study protocols were discussed earlier in the Chapter 2.

One of the major problems in designing a case study is defining the units of analysis to be used during the research. McClintock *et al.* (1979) assert “Although the units of analysis are typically defined as individuals, groups, or organisations, they could almost be any activity, process, feature, or dimension of organisational behaviour”. Basically, within the case, there are several ‘units of analysis’, used by researchers. The selection of the ‘units of analysis’ is geared towards achieving the study objective, which is to investigate the potential for improving site management practices through knowledge management implementation. The interviewees were therefore questioned under five main ‘units of analysis’ as follows:

- *Problems on the construction:* This explores the most significant problems that occur on the construction site;
- *Approach to problem solving:* This aims to identify strategies used by site managers to solve site management problems;
- *Approach taken when a mistake is made:* This seeks to identify current methods used by site managers to capture mistakes and lessons learned;
- *Knowledge sharing mechanisms:* This aims to identify the tools and techniques used by site managers to share knowledge on the construction site; and
- *IT tools, software used and roles of intranet:* This investigates the IT tools and software used in managing the construction site and explores the potential of the intranet as a vehicle for disseminating and sharing knowledge.

The data analysis was designed to involve both single case analysis and cross-case analysis as shown in Figure 5.1:

- *Single case analysis:* The aim is to become closely familiar with each construction site case as a stand-alone entity. This process allows the unique patterns of each case to emerge before pushing towards generalised patterns across cases (Amaratunga and Baldry, 2001); and
- *Cross case analysis:* The cross case analysis uses the replication logic process or pattern matching, similar to that used in multiple experiments. The key to good cross case comparison is the avoidance of information-processing biases. The findings are likely to be more robust and this will strengthen the findings even

further. An important challenge in conducting cross case analysis is that the examination of the key findings for cross case patterns will rely on strongly argumentative interpretation, not numeric tallies (Yin, 2003).

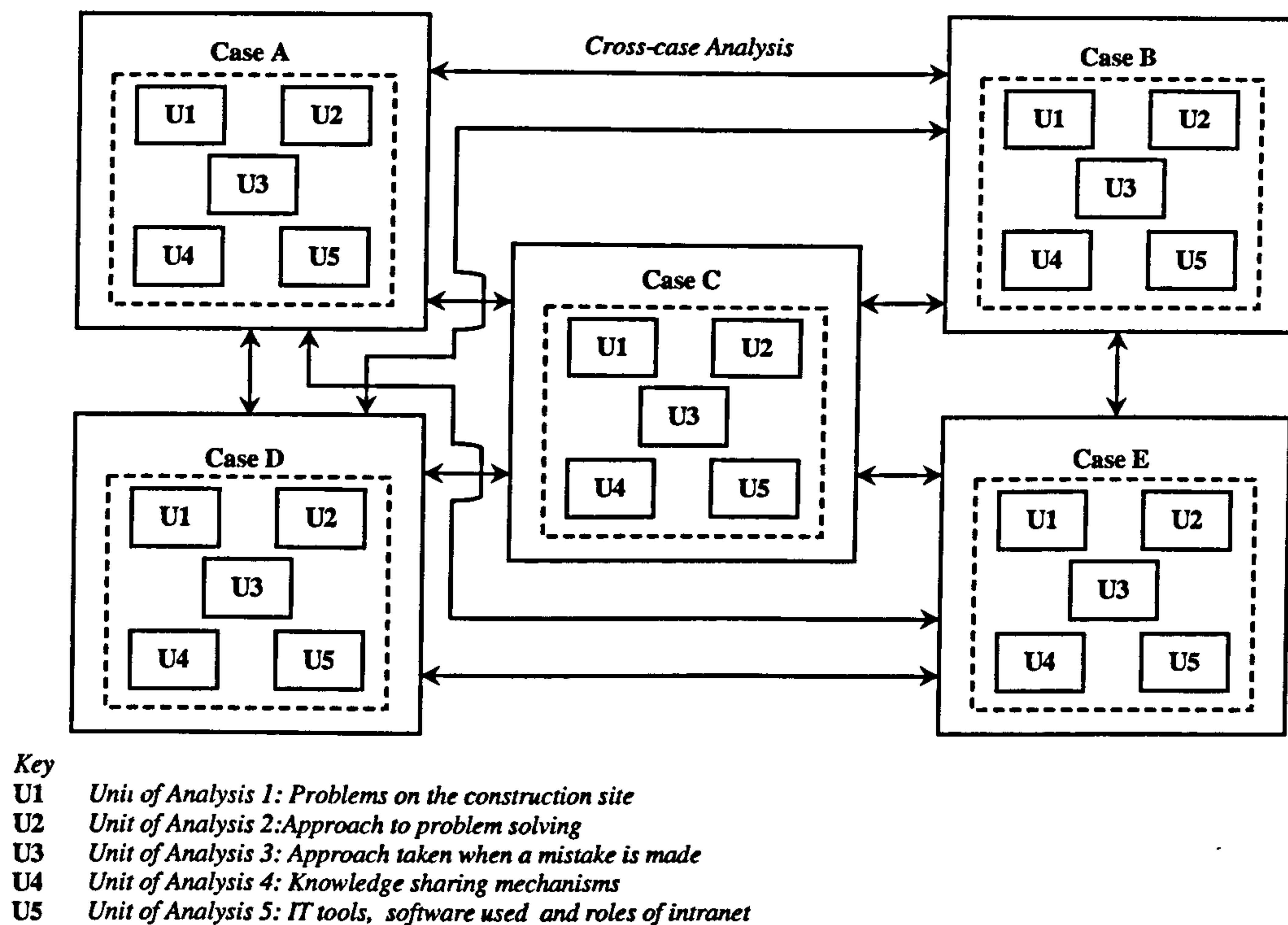


Figure 5.1: Single Case and Cross Case Analysis (adapted form Yin, 2003).

The following section describes a summary of the key findings grouped according to five main 'unit of analysis' respectively and discussed individually.

5.2.1 Case A: Pharmaceutical Building Site

a. *Background and Problems on the Construction Site*

Organisation 'A' is the main contractor for the development and construction of a three storey research laboratory building for a pharmaceutical client in the East Midlands, UK. The main responsibilities of the project manager are to control and monitor the

construction, with assistance from the construction manager, the services manager, the finishes manager and the structure manager. Information and knowledge is relayed to sub-contractors and team leaders via daily meetings and weekly meetings. The purpose of the weekly meetings is to monitor the progress of works, risk assessment and planning of the programme of work. Safety issues, access problems, delivery schedules, problems with construction and cooperation issues are discussed in the daily meeting. Meanwhile, drawings and specifications are provided to the work package sub-contractors. Any technical queries from sub-contractors can be submitted to the engineer and the appropriate construction managers.

There are several problems faced by the project managers and the site management team on this construction site. These are as follows:

- *Lack of co-operation and motivation:* People are not prepared to work together and there is non-existent building of team spirit and co-operation among people such as the site management team, sub-contractors and general workers on the construction site;
- *Poor site communication:* People do not try to communicate and liaise with other individuals in the site organisation team. General workers (bricklayers, plasterers, carpenters, etc.) also do not communicate with each other;
- *Difficulty in monitoring the Health and Safety Plan:* Difficult to make sure everyone on the site is aware of the Health and Safety Plan. There are no monitoring systems for checking that the Health and Safety Plan is being followed. This plan also needs to be extended, reviewed and updated as the work proceeds;
- *Cost cutting and control:* The subcontractors do try to save money in order to maximise the profit. They normally price the job too low and below the profit margin. This might affect the quality of production on the site; and
- *Labour shortage:* Problem of lack of skilled workers in many areas of craftsmanship, especially the 'art work' (brickwork, plastering, tiling and finishing). Currently, most of the construction labourers have little training and knowledge of construction work. These problems affect the quality of the building and increase the construction costs.

b. Approach to Problem Solving

In order to solve these problems, several strategies are applied on this construction site. Firstly, an informal discussion is undertaken with workers or sub-contractors. Then a discussion is carried out to give explanations and solutions, and to get them to realise the rationale for each solution. Secondly, discussion and open-mindedness is encouraged at site meetings. Construction workers are given a chance to sort out problems and the solutions shared among the site management team. The concept of autonomy has been introduced to every scope of works but they also need to be responsible to other units' tasks or work packages.

c. Approach Taken When a Mistake is Made

The Project Manager observed that 95% of knowledge is embedded in the minds of the people involved and 5% of the knowledge is from written documents such as drawings, specifications and method of statements. This was simply based on his personal perception rather than an empirical study. Construction workers always refer to the drawings and specifications to check the size and location of the buildings. However, people also use knowledge from previous experience embedded in their minds to construct the job and ensure the quality of the job. Furthermore, if a mistake occurs, the Project Manager holds a meeting to clarify the error and share the lessons learnt on the construction site. The mistake and the resulting measures are documented and disseminated for the organisation's learning purposes and for the use of the site management team.

d. Knowledge Sharing Mechanisms

The construction knowledge, especially knowledge from experience and training, is shared amongst the people in the company via documentation of the project's procedures and minutes of the site meetings. The site management team has a pre-planned project procedure and guidelines on how to run construction site jobs as well as the Health and Safety Plan. This standard procedure is a customised document and has

been used in all projects carried out by contractors, but it is not necessary to use all the aspects of the procedure. It can be adapted to suit the individual projects and specific sites. Besides that, construction knowledge can also be disseminated via site meetings and can be discussed with the site management team. The site manager produced a 'project learning report' to capture mistakes and lessons learnt on the construction site. The report would contain an 'exception' report based on an analysis of the causes of the mistake.

e. IT Tools, Software Used and Roles of Intranet

The implementation of knowledge management strategies is supported by various kinds of Information Technology (IT) tools. These IT tools can be divided into several categories.

- *An e-mail system:* For disseminating and sharing knowledge;
- *The central project file:* For managing project information internally and sharing project knowledge via the company's intranet and,
- *Intranet:* To share project knowledge between the various departments in the organisation.

Using the intranet, employees can access industry information, best practices, company capabilities, country profiles, archived news and much more. They can also identify specialists across the business and tap into their knowledge. Nowadays, 95% of the communication between parties involved is via email and the central project file.

5.2.2 Case B: Hospital (PFI) Site

a. Background and Problems on Construction Site

Organisation 'B', through its participation in a Private Finance consortium, developed and constructed a large PFI Hospital Project with a total cost of around £82 million. For this site management team, the main responsibilities of the project manager were to

manage and control the whole of the construction process for the three years duration and life cycle maintenance of the hospital's plant. The project manager was assisted by a series of package managers and area construction managers. Area construction managers are responsible for the management of the construction works and communicate with the package manager to make sure that the trade contractors, materials and plant are available for every construction area. Besides this, the construction site was divided into five main areas (Head Block, Body Block 1, Body Block 2, Ward Block 1 and Ward Block 2) and supervised by area construction managers. There are two types of meeting held for this project. Basically, a formal meeting is conducted every two weeks and an informal meeting two or three times each week. The formal meetings discuss the progress of works for each package, design information and amendments, the quality of works, technical problems and commercial management. The informal meetings involve discussions on the work area, resources levelling and planning, deliveries of material and planning for the next jobs. The most important step in communicating information from engineers and architects to trade workers is to check ambiguities, especially in drawings and schedules, before passing the drawings or information to the trade subcontractors. RIQ (request information queries) are prepared if some ambiguities on drawings and specification arise. During the construction works, the biggest problems that occurred on this site were:

- *Poor design management and information:* Incomplete design, lack of details and sequences showing details of how to actually fix building elements together;
- *Unsuitable specified materials:* The need for samples to test the reliability of materials and to meet the supplier's specification;
- *Shortage of labour resources:* Unskilled workers affect productivity and also degrade the quality;
- *Lack of control over the quality of work:* Need proper checking systems and recording procedures on site. Currently, quality control is ensured by subcontractors appointed by the main contractor to check and physically inspect the construction works;

- *Material damaged or defective:* damage occurs on the construction site and affects other works; for example tiling works and other sensitive subcontract works are often unprotected.

b. Approach to Problem Solving

There was a vital need to have a strategy to handle these problems. The first method of addressing the above problems was to take a more practical approach to quality control. The work needed to be regularly checked and also samples of selected materials had to be submitted. This approach will help the main contractor to identify elementary building problems at an early stage of the project. Secondly, the project manager contacted senior people if the problems cannot be resolved at the site level.

c. Approach Taken When a Mistake is Made

In general, construction expertise is in the form of written documents (explicit knowledge) and in people's heads (tacit knowledge). For a complex project, the proportion between explicit knowledge and tacit knowledge is about 50:50. For example, though tradesmen have (say) 20 years experience or tacit knowledge of construction, they also need to refer to explicit knowledge (designs, drawings and specifications) because different projects have different characteristics; especially healthcare and hospital projects. Healthcare 'Communities of Practice' are used to capture certain learning events and share ideas and solutions. They also include a mixture of the main contractor's construction personnel, facilities management personnel, a design team and procurement personnel. Basically, if a mistake is made, the causes of the problem are identified and solutions and 'best practice' guides produced. The company's internal website also has records of problem-solving work from previous jobs.

d. Knowledge Sharing Mechanisms

Currently, this site has two ways of sharing construction knowledge: Healthcare 'Communities of Practice' and an e-mail system called i-Konnect. Healthcare 'Communities of Practice' are used to capture certain learning events and share ideas and solutions while i-Konnect facilitates knowledge sharing by connecting employees who need advice with people who have relevant skills, knowledge and experience. i-Konnect has handled questions from workers on a variety of topics. The employee sends a question or outlines a problem to the Central Administrator. The Central Administrator sends it out to different people throughout the world. There are 3 main administrators, from Europe, the US and the Pacific region. They relay the questions to experts in different fields (healthcare, mechanical, environmental, higher education, safety fields etc.) and the experts send a response back to the Central Administrator. Facilitators then check the validity of the advice and put the solution on the central database.

e. IT tools, Software Used and Roles of Intranet

There were several IT tools used on this construction site. These are as follows:

- i-Konnect – an e-mail system for knowledge sharing;
- Document management system (Hummingbird);
- Project collaboration from Building Information Warehouse (BIW);
- On-line project management system (e.g. Primavera); and
- On-line procurement system.

The site management team has an intranet system to help manage the organisation's base of expertise. The main role of the intranet system is for storing information and helping people access the company's policies and procedures. Updates are announced to various people in different regions using the Intranet system. Clients can log in automatically to the intranet to access relevant information about the project and contractor.

5.2.3 Case C: Water Works Site

a. *Background and Problems on Construction Site*

Organisation 'C' has carried out, through its infrastructure group, the design and construction of flood defences for the Environment Agency and construction of a programme of small sewage works for Severn Trent, a water utility company. The Project Manager leads the site management team and is assisted by the Quantity Surveyor, the Site Engineer and the Project Engineer. Works Managers (i.e. senior foremen) supervise the sub-contractors and general operatives. This organisation carries out daily meetings and weekly meetings with sub-contractors and team leaders. Daily meetings are informal and the progress of work is discussed with sub-contractors. Also discussed are risk assessment and works regulations. The weekly meeting is a formal meeting and the agenda of the meeting normally starts with health and safety, progress of work, forward planning, resources planning, risk assessment and other matters arising. Dissemination of client information (drawings, specifications and instructions) is based on hard copies given to sub-contractors' organisations. Besides that, this organisation conducts formal pre-commencement meetings to discuss quality control procedures. Normally, photographs are used to demonstrate to sub-contractors the bad and good quality works on the construction site.

However, there were several challenges on the construction site. The most significant are as follows:

- *Services obstruction:* Existing underground services can disrupt the progress of construction works and bring uncertainty to the planning and commissioning of the construction project;
- *Inability to accurately resource, plan and schedule:* The wrong information about selecting resources, especially the labour for the construction works. Proper planning and adequate information on resources will enhance the efficiency of the projects and could save money and improve safety on the construction site;

- *Poor site communication:* The problems of knowing how much information needs to be communicated to the sub-contractors and to find the most efficient methods of communicating this type of information to the sub-contractors;
- *Unpredictable final cost and hand over:* The problem of closing out the works and some of the works not being completed properly; and
- *Poor planning of works:* For targets to be determined and met, a proper plan is needed when beginning the works at the job site. It is vital to align the planning of the programme of works with procurement planning.

b. Approach to Problem Solving

The types of problems that occur on the construction site were familiar to the site management team because of the organisation's strategy of working with the same clients and on similar types of works. In this context, the organisation's strategy was to keep people and teams together to allow them to develop knowledge and experiences from previous projects. In parallel to this, ad-hoc meetings were held with the experts if the site management team were faced with particularly complex technical problems (e.g. construction of retaining walls).

c. Approach Taken When a Mistake is Made

The site manager has observed that construction knowledge such as quality of work, construction site planning and quality management systems are within the worker's experience. This organisation did not have any systematic methods or processes to build a knowledge base from experts and senior people in the organisation. However, being structured in client-facing business units, and keeping staff together mitigated the potential short-comings.

d. Knowledge Sharing Mechanisms

This organisation shared safety and environmental knowledge via a very rigorous system that requires the organisation's staff to document the safety bulletins of the company. In terms of construction techniques, an annual best construction practice and innovation event is held at which people (including the client) are encouraged to present their experiences in managing construction sites. Rewards are given in recognition of best practices and knowledge shared within the organisation.

e. IT Tools, Software Used and Roles of Intranet

There are several IT tools used for site management practices. The main IT applications are as follows:

- Business management system called IMSOL - The structure is based on a 'process map' approach for every type of site management process (i.e. tenders, interim payments and evaluation);
- Primavera software – for planning and project monitoring; and
- MENTOR software – a costing and cost management system.

The main role of the intranet is to support people in managing the construction site. The main contents of the intranet include staff location, contract details, IMSOL system, MENTOR software, vendor information and payroll system.

5.2.4 Case D: Swimming Pool and Fitness Centre Site

a. Background and Problems on Construction Site

Organisation 'D' is developing and constructing a new swimming pool and fitness centre in London. This re-development project was to replace an existing building and

demolition works of an existing building are intended to be carried out soon. The site manager's functions are primarily to be responsible for health and safety, to manage the whole site, to control the sub-contractors, to manage all the packages, and to make sure that the jobs are in accordance with the right specifications. In this company, the site manager is not involved in determining and monitoring the cost and budgeting for this project. The estimation of project costs is the responsibility of the procurement division of the company. The organisation conducts weekly informal meetings with sub-contractors and team leaders. The function of the weekly meetings is to discuss the progress of work and planning for the next stages. This organisation also conducts monthly informal meetings to discuss procurement issues and health and safety issues. Project information, such as drawings and specifications, is issued to the sub-contractors immediately on request. However, unnecessary and irrelevant information is not provided to the sub-contractor. This organisation uses RFI (Request for Information) and CFI (Confirmation for Information) as tools to supply the necessary information for the particular sub-contract packages.

In managing the construction site, the main problems faced by the site management team are:

- *Lack of information on sub-contractors:* Information on sub-contractors is not comprehensive and complete;
- *Low awareness of the Health and Safety Plan:* Many sub-contractors do not take action on safety issues seriously;
- *Inaccurate planning of work commencement:* Weather will affect the commencement of work, especially ground works and the installation of a steel roof structure. Planning and programming of the works need to be framed properly to avoid difficulty in starting up;
- *Labour shortage:* Low skill of trade workers especially for brick works. There is also a lack of supervision from the leader of the trade workers; and
- *Poor quality of materials:* Standard of materials such as brick works does not always conform to the British Standards. The procurement division needs to include the B.S. specifications in order to inform suppliers fully about what exactly is required.

b. Approach to Problem Solving

There are two methods used to address site management problems. Firstly, discussion with sub-contractors to give explanations on how to solve particular problems and to improve quality in all aspects of the work being carried out. Secondly, discussions are held amongst colleagues both on-site and off-site, as a means of resolving the problems or issues. For very technical problems (e.g. mechanical, electrical problems), the site manager's approach is to rely on specific people in the company who have expertise in that area.

c. Approach Taken When a Mistake is Made

Most of the construction knowledge is embedded in the specifications and drawings (explicit knowledge) but knowledge of construction also comes from the site management team. When the people working on the construction make errors, the mistakes are registered as 'non-compliance'. However, for technical mistakes, the sub-contractors are informed of the causes of the non-compliance and all the non-compliances are documented and filed on the organisation's records.

d. Knowledge Sharing Mechanisms

Most of the construction knowledge is shared and discussed amongst the site management team in the informal meetings held to discuss specific issues or problems. The site manager produces a 'non compliance' report which is shared in the organisation using a business management system called BDMS (Building division management system).

e. IT Tools, Software Used and Roles of Intranet

There are several IT tools used in the organisation in managing the construction site:

- An e-mail system;

- Business management system called BDMS (Building division management system), and
- Intranet system.

The company has an intranet system to help in managing the organisation knowledge. The main role of the intranet system is to serve as platform for accessing information. The main contents are news and events, work procedures and policies, quality register, business management system and staff contact information.

5.2.5 Case E: Retail Store and Service Apartment Site

a. Background and Problems on Construction Site

Organisation 'E' is the main contractor for the development and construction of a 25,000 square foot retail store and 104 service apartments including a basement car park and infrastructure works. The project manager is responsible for planning and monitoring the programme of works, cost planning and estimation, and health and safety issues on the construction site. In managing the construction site, the project manager is assisted by a deputy project manager, a construction manager, a design manager and a commercial manager. Weekly meetings are conducted between the site management team and sub-contractors. There are also co-ordination meetings between the site management team and sub-contractors on a weekly basis. Several issues are discussed such as safety quality in progress, work co-ordination, planning the works and predicting the programme for the next weeks and months.

The site management team identified several problems that occur on the construction site:

- *Local residents:* There is a need to implement precautionary plans to make sure the construction site is safe and does not cause accidents to local residents under any circumstances;

- *Complexity of design regulations:* There is a problem in saving the conservation area and constructing in line with conservation guidelines and regulations produced by local authorities;
- *Misunderstanding of design and specifications:* The client agent (architects or engineer) who is not part of the client's organisation does not fully understand the client's design requirements;
- *Unpredictable on-site conditions:* The sequence of stages needs to be resolved for any construction project. Construction programmes, especially for retail stores, create pressure for the site management team and there is a need to monitor critical activities such as demolition activities and bulk excavations to ensure that the programme of works is not delayed;
- *Labour shortage:* Particularly in the London area, it tends to be more difficult to find skilled labour to work in the London area. Most of the skilled labour is from Eastern Europe and communication is difficult.
- *Poor site communication and information:* Communication and dissemination of information to the site levels has become a problem. Any decisions or instructions arising from technical meetings need to be distributed to the sub-contractors and trade workers.

b. Approach to Problem Solving

The site management team used several approaches to deal with particular problems. Firstly, the project manager draws on his previous experience to deal with problems, while technical and uncertainty problems are discussed and examined with the site management team. However, if no resolution is achieved, the site management team refers the problems to the company's Engineering Division.

c. Approach Taken When a Mistake is Made

Principally, this organisation relies on the specifications and drawings (explicit) and also on skilled labour to construct the works. However, there are differing proportions

of knowledge and they depend on the types of elements. For the brickworks, there is 100% reliance on the tradesmen's knowledge and skills. However, for the curtain walling installation, the trade workers refer to the specifications produced by the manufacturer and the proportions are about 80% use of knowledge from specifications (explicit) and 20% use of worker's knowledge (tacit). For instance, the mistakes that occur on the construction site are used as an educational tool and immediately relayed to the design team. The organisation aims to simplify the design by positive input from the site management team and also to benefit from the experiences of people from various departments in the company's site management team.

d. Knowledge Sharing Mechanisms

Knowledge is shared in various ways. Firstly, knowledge is shared in design meetings conducted every two weeks. Secondly, knowledge is shared in the construction forums between the project teams. After these forums, the project management team assesses the best issues or problems that can be documented for use in the next project. Thirdly, knowledge is shared in the site organisation meetings every week. Lastly, knowledge is shared in the 'crash' meetings which discuss site management problems such as scaffolding installation, brickwork deliveries and bulk excavation methods and procedures.

e. IT Tools, Software Used and Roles of Intranet

The organisation uses Web-based applications in managing information on the construction site. Drawings and specifications are placed on the project server and Web site. An information required schedule, drawing schedules and communication tools are also included on the database server. Sub-contractors are able to access the internal project Web site at specified levels of navigation to use project information. Sub-contractors are able to submit interim payments electronically via the project Web site using a standard payment method called SITEMAN. The Intranet system allows people

in different site locations to communicate information and ideas. In addition, for knowledge sharing and dissemination of lessons learned, the organisation has established an on-line knowledge management system called 'Top Tips'. The main objective of the system is to capture organisation knowledge on key construction areas (e.g. risk assessment, value management, method of statement, etc.).

5.3 Key Findings from Case Studies

It is vital to examine the knowledge that resides in the construction site processes for the efficient execution of the site management functions. The six key construction site management processes considered were outlined earlier in the Chapter 3, section 3.3. Its basic purpose is to provide a framework for carrying out work on any construction site. Table 5.2 illustrates aspects of KM in the case study organisations, these are discussed thereafter in order to investigate KM processes within site management practices. The next discussion concerns cross-case analysis between five main investigated 'units of analysis' in five construction sites and therefore is structured as follows:

- Problems on construction site;
- Approaches to problem solving;
- Approach taken when a mistake is made;
- Knowledge sharing mechanisms; and
- IT tools, software used and roles of intranet.

Table 5.2: Aspects of Knowledge Management in Case Study Organisations.

Unit of Analysis	Case A	Case B	Case C	Case D	Case E
Construction knowledge *	<ul style="list-style-type: none"> • 95% tacit • 5% explicit 	<ul style="list-style-type: none"> • 50% tacit • 50% explicit 	<ul style="list-style-type: none"> • 100% tacit 	<ul style="list-style-type: none"> • 70% tacit • 30% explicit 	<ul style="list-style-type: none"> • Depend on type of element
Approach to problem solving	<ul style="list-style-type: none"> • Informal discussion • Site meeting (open-mindedness and no blame approach) • Autonomous work package 	<ul style="list-style-type: none"> • Quality control procedure • Refer to senior people and expert 	<ul style="list-style-type: none"> • Previous team experience • Informal meeting with expert 	<ul style="list-style-type: none"> • Discussion with sub-contractors • Consulting colleagues on-site and off-site • Refer to expert 	<ul style="list-style-type: none"> • Draw from experience • Discussion with site management team • Refer to Technical division/expert
Approach taken when a mistake is made	<ul style="list-style-type: none"> • Meeting • Produce report (cause analysis) • Disseminate via intranet 	<ul style="list-style-type: none"> • Problem identification • Lesson learned documented • Share via intranet 	<ul style="list-style-type: none"> • Discussion internally • Circulate bulletin via intranet 	<ul style="list-style-type: none"> • Register as non-compliance job • Document and record in project file 	<ul style="list-style-type: none"> • Produce report (input for design team) • Share via KM system 'Top Tips'
Knowledge sharing mechanisms	<ul style="list-style-type: none"> • Site meeting • Intranet 	<ul style="list-style-type: none"> • Communities of practice • Intranet 	<ul style="list-style-type: none"> • Monthly briefing talk • Seminar 	<ul style="list-style-type: none"> • Informal meeting • Demonstrate example of the job 	<ul style="list-style-type: none"> • Design meeting • Forum • Site meeting
IT tools and software used	<ul style="list-style-type: none"> • E-mail system • Central project file • Intranet system 	<ul style="list-style-type: none"> • E-mail system • Intranet • BMS • Online PM system 	<ul style="list-style-type: none"> • BMS • Online PM system • Intranet system • E-mail system 	<ul style="list-style-type: none"> • E-mail system • BDMS • Intranet system 	<ul style="list-style-type: none"> • E-mail system • Data store project file • online PM system • Intranet system
Role of Intranet	<ul style="list-style-type: none"> • Access information • Access project directory 	<ul style="list-style-type: none"> • Managing construction knowledge • Access to company's BMS 	<ul style="list-style-type: none"> • To support people • Access to BMS and company's information 	<ul style="list-style-type: none"> • Access to process map • Access to BDMS and its content 	<ul style="list-style-type: none"> • Communicate people • On-line training • Expertise information • KM system 'Top Tips'

*Respondent's personal perception rather than empirical study

Key
 BMS Business Management System
 BDMS Building Division Management System

5.3.1 Problems on Construction Site

An understanding of site management problems, including current approaches to problem solving, is important to manage knowledge successfully. Table 5.3 summarises the problems identified from the case studies particularly with respect to the six main categories of construction site management processes.

Table 5.3: Summary of Case Study Findings

Case problems/ Construction site processes		Management, supervision and administration	Commercial management	Health and safety management	Planning, monitoring and control	Delivery and materials' handling	Production on-site and off- site
Case A							
a	Lack of co-operation and motivation	O					X
b	Poor site communication	O			X		X
c	Difficulty in monitoring Health and Safety Plan			O			
d	Cost cutting and control		O				X
e	Labour shortage	O					X
Case B							
a	Poor design management and information	O	X				
b	Unsuitable specified materials				X	O	X
c	Shortage of labour resources	O					X
d	Lack of control the quality of work				X		O
e	Materials damage and defective	X	X			O	X
Case C							
a	Services obstruction	O		X	X	X	X
b	Inability to accurately resource plan & schedule		X		O		
c	Poor site communication	O			X		X
d	Unpredictable final cost and hand over		O		X		
e	Poor planning of works	X	X		O		
Case D							
a	Lack of information on subcontractor	O			X		
b	Low awareness of Health and Safety Plan			O			
c	Inaccurate planning of work commencement				O		X
d	Labour shortage	O			X		X
e	Poor quality of materials		X			O	
Case E							
a	Local residents	O		X	X	X	
b	Complexity of design regulations	O		X			
c	Misunderstanding of design and specifications	O			X		O
d	Unpredictable on-site conditions				O		X
e	Labour shortage	O					X
f	Poor site communication and information	O			X		X

Key

- O Origin of problem
X Sub-processes affected

For example, lack of cooperation and motivation, poor design management, services obstruction, lack information on sub-contractors and local residents were usually associated with 'management, supervision and administration' construction site management processes. These factors were judged to be the most damaging to the more effective management of construction site processes. The implementation of KM processes should not completely restructure current site management practices, but should become an integral part of site management practices. It is therefore important to identify which KM processes and which aspects of site management practices can be integrated.

5.3.2 Approaches to Problem Solving

The approach towards addressing the site management problems differed from one case to another. Organisations (A), (C), (D) and (E) followed informal approaches, which rely heavily on previous experience, informal meetings and experts to solving problems. Organisation (B) followed a quality control procedure, which is a more structured approach. It can, therefore, be concluded that the site management uses two methods to address site management problems. These are:

- *Structured methods*: These include quality control procedures and health and safety procedures; and
- *Informal methods*: These include previous experience, discussion or informal meetings and reference to experts.

It is essential that whatever management strategy is adopted, it can minimise the number of problems that occur on the construction site and reduce their impact.

5.3.3 Approach Taken When a Mistake is Made

Analysis of the site management practices indicates that the main characteristic of site management problems is its reliance on experiential (tacit) knowledge. Experiential

knowledge is not codified in books or written documents and is organised in people's heads (Li and Love, 1998). Of the five organisations investigated, all rely on tacit knowledge in managing the construction site. Moreover, when problems arose that required advice from an expert, all the site managers do not seem to attempt to make contact with quite the same speed. They prefer to conduct a formal meeting or informal meeting with sub-contractors and site management team as a primary approach to solve site management problems. One reason for this could be that sub-contractors are present on site more often, thus they become more familiar with one another and thus more approachable. Another reason may be that the sub-contractors are in a subservient relationship to the contractor (Emmitt and Gorse, 2003).

Although the interviewees gave different figures for the percentages of tacit and explicit knowledge involved in construction work, these figures indicate that most of the construction knowledge is embedded in the minds of professional workers (e.g. engineers, architects, quantity surveyors, estimators, etc.) and operative workers (e.g. plasterers, plumbers, bricklayers, roofers, carpenters, etc.). Therefore, it is important to adopt appropriate mechanisms for capturing tacit knowledge on the construction site. The majority of the site management teams use traditional management methods for capturing mistakes and lessons learned. There are usually two stages: discussion and informal meetings followed by documentation and registration on the project file. Organisations (A), (B), (C) and (D) use an intranet system to disseminate the report to the people on-site and off-site. However, organisation (E) disseminated the report via a knowledge management system based on the company's intranet system.

Basically, workers make the same mistakes and repeat the same errors while carrying out construction work. It was evident during the observations that organisations adopt different strategies for capturing mistakes and lessons learnt. Four of the five case study organisations adopted an information technology (IT) centric codification strategy facilitated by substantial IT support. Only Organisation (C) adopted a human resource management (HRM) centric strategy. The human resource management (HRM)-centric strategy focuses on the establishment of means to motivate and facilitate knowledge workers to develop, enhance, and use their knowledge in order to achieve organisational goals (Carrillo and Chinowsky, 2006). Meetings and actual observation were good approaches upon which to resolve site management problems. Effective application of

these approaches is necessary but no longer sufficient. The potential for improving site management practices depends heavily on the right combination of knowledge and experiences; therefore deployment of applicable KM initiatives is important. However, it is difficult to select the most appropriate initiatives for a specific problem.

The selection of KM initiatives requires clear identification of site management problems and at the same time requires an explanation of the KM dimension for each problem. Al-Ghassani *et al.* (2005) present a useful framework for classifying KM tools and techniques to support knowledge management. While the classification is debatable, it represents a useful framework for discussing IT and non-IT support for knowledge management. KM tools and techniques for supporting site management problem vary from one problem to another problem. For example, the Design Manager of Organisation (C) stated that the lack of information on the subcontractor is the most important problem faced by the site management team. This problem can be avoided if the site management team captures knowledge of the sub-contractors they know and have used before and that they can trust; this can be then be shared through the organisation's intranet. It will help the site management team to make an evaluation of new sub contractors and check their track record on similar types of work and similar types of job.

5.3.4 Knowledge Sharing Mechanisms

Meetings are the most effective mechanisms for sharing knowledge on the construction site. There are many types of meeting: some are relatively informal and organised on an ad hoc basis, while others are formal and scheduled in accordance with contractual demands. Organisations (A), (D) and (E) used meetings as a method to share knowledge. Organisations (C) and (E) used construction forums and best practice seminars to share knowledge amongst people in the organisation. Organisations (C) and (E) had a structured approach and were more serious about sharing best practices and lessons learned. In contrast, informal meetings have also been used for sharing construction knowledge. For example, Organisations (A) and (C) conducted ad hoc meetings (informal meetings), which sought to demonstrate a particular job on the construction site to the workers. In terms of information and communication

technologies, the majority of the sites had an e-mail system and were linked via an intranet system. Organisations (A) and (E) implemented a data store project file on the intranet while Organisation (E) had an on-line payment system to sub-contractors via their intranet system. The intranet system in all organisations was used: to store knowledge, to provide a vehicle for people to seek knowledge, as a directory for each member of staff to share particular skills and experience, and to bring together people with common interests.

The case study organisations use an information technology (IT) centric strategy and human resource centric strategy for organising knowledge in the site management environment. The information technology strategy is based on codifying the knowledge and storing it in artefacts and databases where it can be accessed. In the human resource centric strategy, the knowledge is tied to the persons who develop it and it is shared by personal interaction (Kasvi *et al.*, 2003). As the main focus in knowledge management concentrates on ICT tools and explicit knowledge (codification), face-to-face interaction (personalisation) needs to be strengthened. Central to their strategies are the experiences of people, as tacit knowledge is considered valuable for site management practices. In contrast, explicit knowledge is found in the job procedures, minutes of meetings, drawings and specifications. IT support (such as email system, intranet system and on-line project file store) is an important part of the knowledge management process.

5.3.5 IT Tools, Software Used and Roles of Intranet

The KM techniques and technologies used have demonstrated savings in time for the contractors and sub-contractors, helping both to avoid delays and to assist with the smooth flow of work on the site. Organisation (E) has used a web based application in managing knowledge on construction site. Drawings and specifications have been located on the project server and web site. Information required schedule, drawing schedules and communication tools have also been located on the database server. This organisation claims that they can save a lot of construction time when they use KM tools in terms of knowledge sharing. Moreover, Organisation (B) has used an intranet system called 'i-Konnect'. This tool facilitates knowledge sharing and helps site

managers to find the right solution for a specific problem based on the response from experts in different geographical areas. From this evidence, it can be concluded that comprehensive utilisation of relevant KM processes would formalise the construction knowledge in an explicit form, highlight problematic areas and provide recommendations for improving the construction site processes. In knowledge sharing capability, we observed that Organisations (B) (C) and (E) are using a combination of hard (e.g. communities of practice, seminar, etc.) and soft (intranet, groupware, etc.) mechanisms in sharing knowledge. However, each of these mechanisms comes with significant drawbacks. For example, communities of practice and seminar events used by Organisations (B) and (C) are expensive and beyond the reach of many organisations. However, there are various alternatives can be used for sharing tacit knowledge on a smaller scale. For example, Organisation (E) has organised regular construction forums for site managers to encourage sharing of experiences.

The intranet systems in all the cases are used to store knowledge (procedures, quality system, method of statement, best practices etc.), to provide a vehicle for people to request knowledge and as a directory for each member of staff to share particular skills, experiences and areas of interest (e.g. concrete works, brickworks, earthworks and etc.). However, the content and structure of the systems are slightly different. Organisations (A) and (E) have a well-structured intranet system. However, organisation (E) has developed knowledge management system and shares knowledge via the intranet system. However, the knowledge management system developed is complicated to use and too much information is generated by the system. The collaborative and knowledge sharing features of intranet, combined with their low cost, have made them attractive alternatives to proprietary groupware for collaborative work, especially among small and medium sized organisations. For simple tasks, such as sharing documents or document publishing, an intranet is generally less expensive to build and maintain than applications based on commercial groupware products, which require proprietary software and client or server networks.

5.4 Requirement for Construction Site KM Framework

The case studies have helped to identify aspects of KM at the construction site level. The organisations have a variety of mechanisms for managing their knowledge. The existing procedures in managing knowledge can be categorised into three main elements:

- *Content management*: Used by all case study Organisations (e.g. central project file and business management system);
- *Experience management*: Used by Organisations (B), (C) and (E). (e.g., communities of practice, and seminars) ; and
- *Process management*: Used by Organisations (A), (B) and (D) (e.g. process map, quality register and project procedure).

More specifically, the majority of the case study organisations focus on managing best practice, the solutions to problems, lessons learnt, and knowledge of people. The case study findings revealed that case study organisations use conventional approaches (meetings and project procedure) to resolve management and engineering problems on the construction site. Meetings can be divided into two categories, formal and informal, whilst project procedure is a standard procedure used by site management teams to undertake construction site activities (e.g. quality control procedure, health and safety procedure, material delivery procedure, etc.). Both approaches involved two stages: discussion followed by documentation and registration on the project file, as shown in Figure 5.2. Meetings and discussions can facilitate knowledge capture on the construction site, as they are often used to find the best ways to resolve problems or issues that arise on the construction site. In the site management context, site managers or project managers solve technical and complex problems by using their experience and intuition to find prompt solutions.

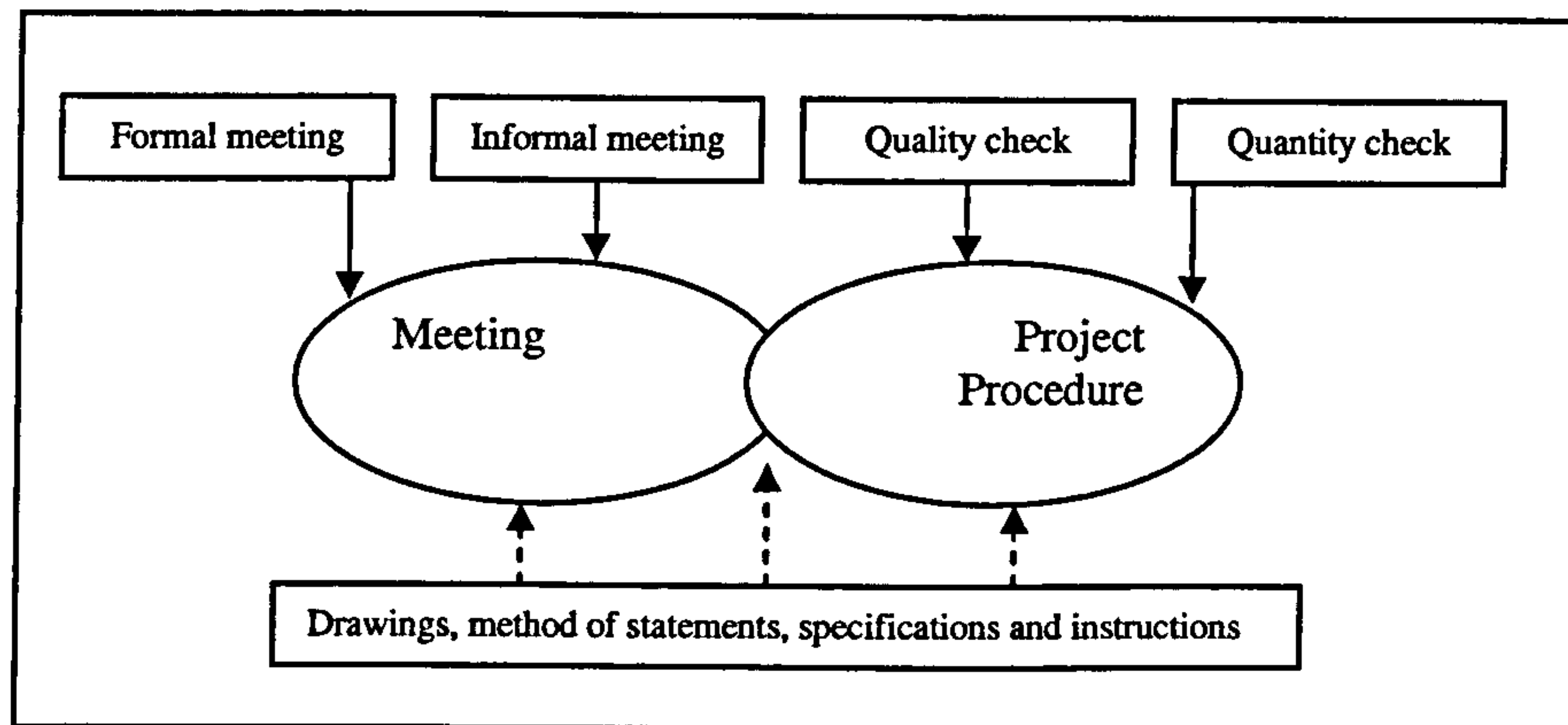


Figure 5.2: Approaches to Problem Solving on the Construction Site.

Understanding the contribution of knowledge management initiatives to solving site management problems may help to improve construction site performance. However, most of the construction knowledge is tacit rather than explicit. Tacit knowledge is difficult to communicate externally or to share while explicit knowledge is captured and stored in project manuals, procedures, and is therefore easily communicated and shared with other people. The distinction between tacit and explicit knowledge is relevant because each must be managed differently. There are several aspects to be considered in the development of a KM framework for construction site management. An integrated framework that reflects the specific context of site management practices, and which makes provision for both explicit and tacit knowledge is therefore required. There are some issues that need to be considered when developing a construction site knowledge management framework as shown in Figure 5.3. This will involve:

Firstly, the construction site manager needs to identify the most significant site management problems which can be attributed to a knowledge gap. There are a variety of site management problems that can occur on construction sites. These problems, for example, could be management problems (e.g. poor site communication, services obstruction, etc.) or technical problems (e.g. unpredictable on-site control). Therefore, it is important to find a systematic method to capture, share and reuse tacit and explicit knowledge based on a KM approach to addressing site management problems. It is also equally important to classify types of construction site management practices that

depend on tacit knowledge (e.g. material management, production on-site, health and safety management, etc.) and explicit knowledge (e.g. structural drawings, specifications, work procedures, etc.).

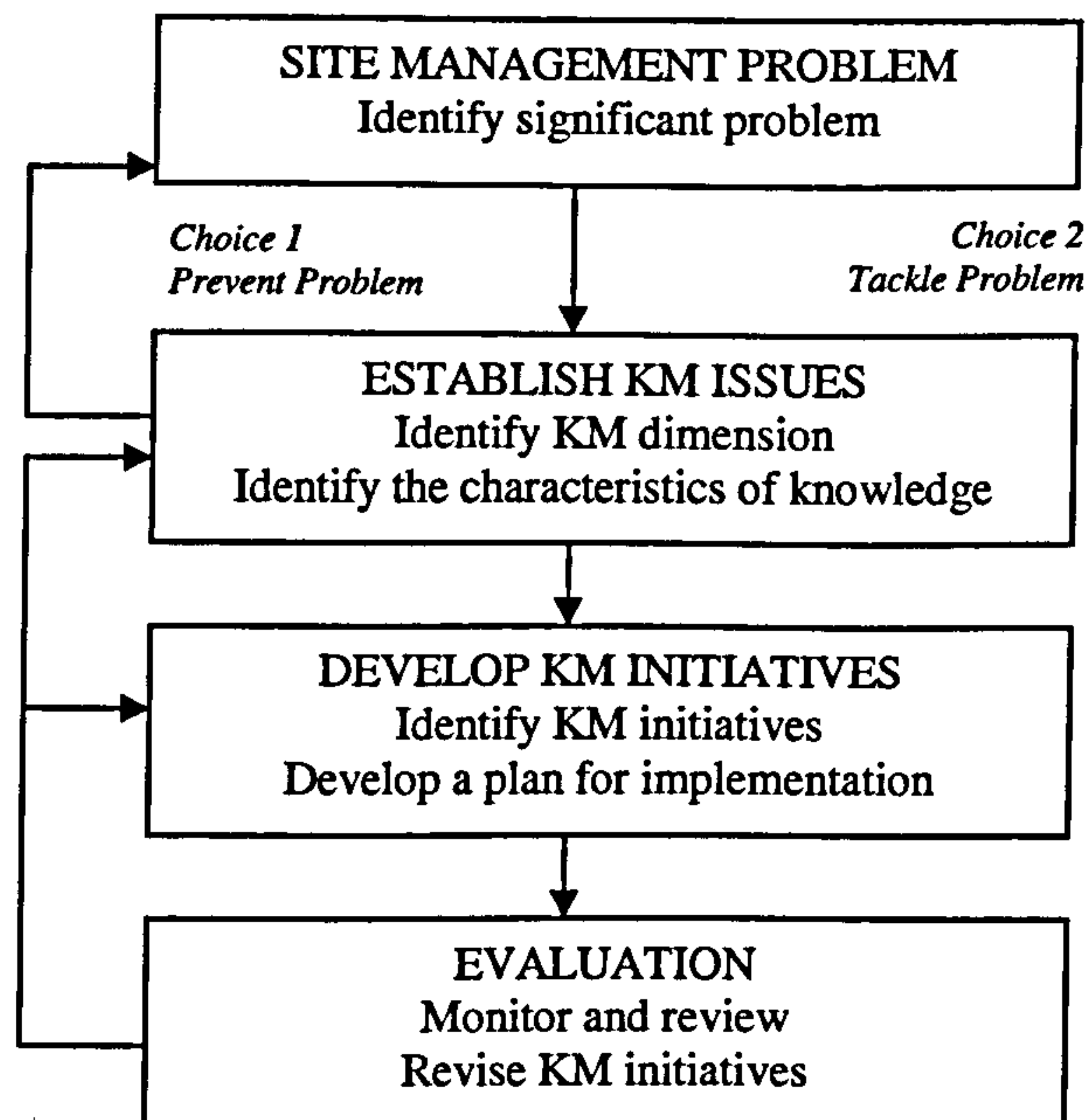


Figure 5.3: Conceptual Framework for Integration of KM into Construction Site Management Practices.

Secondly, the construction site manager should establish KM issues related with the problems. This stage involves putting the site management problems in a strategic KM context in order to understand the KM dimension to the problem and characteristics of knowledge to be deployed to solving the problem. These characteristics, for example, could be tacit or explicit knowledge, internal or external knowledge, and individual or group knowledge.

Thirdly, construction site managers should develop appropriate KM initiatives that will bridge the knowledge gap. This stage involves formulating KM initiatives, which provide a systematic effort for addressing site management problems. The case study findings revealed that all the case organisations require systematic methods for managing the professional's domain knowledge of products, people and processes on

the construction site. The nature of KM initiatives and the tools for implementation are also influenced by the characteristics of knowledge and the need of the site manager to solve the problems. It is equally important to develop a variety of KM initiatives and KM tools for addressing site management problems on the construction site. The main reason is that the nature of the problems is affected by the type of construction site, procurement used and level of experience of the construction site manager.

Fourthly, the construction site manager should develop an action plan for implementation. The implementation plan of KM needs to be assessed in terms of resource required, resource needed, tools required, etc. According to Robinson *et al.* (2004), regardless of the efforts directed towards implementing KM, it may not be successful unless fundamental reform is addressed and monitoring mechanisms put in place. For example, Organisation (E) developed a web-based KM system for sharing knowledge in business organisations, but the Project Manager claimed that the system was complicated to use and too much information was generated by the system. However, the Project manager preferred to use various alternatives for sharing tacit knowledge on a smaller scale, such as regular construction forums for site managers to encourage sharing of experience.

Fifthly, the construction site manager needs to evaluate the implemented KM initiatives. The KM initiatives need to be evaluated in order to measure the effectiveness of implemented KM initiatives. In the construction site management context, ease of use, practical monitoring tools and flexibility are the important factors to be considered when developing tools for monitoring and reviewing KM initiatives. It is crucial to monitor and review the KM initiatives to ensure that they deliver the project business goals.

From the case studies findings, it is important to develop a problem-based knowledge management framework for construction site management practices. The main reason is that a problem-solving KM process is the vehicle for connecting knowledge and performance; knowledge gains economic value when it is used to solve problems, explore opportunities and make decisions that improve production performance. Such a framework should be capable of both proactive and reactive KM support for site management. In the proactive mode, it should support the institution of KM initiatives

that will prevent the most common site management problems from occurring. In the reactive mode, it should be able to identify the knowledge gap that has led to a given site management problem and recommend measures to tackle the problem.

5.5 Summary

The main aim of the case studies was to understand the key problems of site management practices and to observe existing practice in managing knowledge on the construction site. The case studies highlighted the key problem areas as well as the opportunities for using KM to improve site management practices. The case study findings revealed that 'management, supervision and administration' are the areas where problems occur most frequently on the construction site. They also identified services obstruction, poor site communication and information, incomplete design, local residents, and cooperation and motivation issues as major problems inhibiting construction site performance. Therefore, the site management team should be prepared to deal with on-site problems and risks in a systematic and efficient way. Knowledge management processes can be effectively used on the construction site to enable knowledge to be captured and reused in the future. KM can help to prevent the site management team from repeating past errors and, by capturing best practices, lessons learnt, and especially the solutions to problems that arise on site, similar situations in the future can be dealt with efficiently and effectively. Reducing problems on the construction site has the following advantages: (a) The cost of problem solving is reduced and (b) The probability of repeat problems is decreased (Tserng and Lin, 2004). Findings from the case study organisations revealed that site management teams still do not have any systematic methods for the creation, capture, storage, sharing and reuse of a professional's domain knowledge of products, people and processes. The integration of KM into site management practices will address this and result in significant benefits to the construction project delivery process.

CHAPTER SIX

Framework Development for KM Integration

6.1 Introduction

This chapter focuses on the development of a framework to promote the integration of knowledge management within site management practices. The framework promotes a systematic approach to managing knowledge on the construction site. The framework has been developed on the basis of a detailed literature review and industry case studies. This chapter starts with a review of knowledge management frameworks and related models with an analysis of their main features. The chapter then discusses the development of the framework for integrating KM into site management practices, including details of the proactive and reactive knowledge management approaches. The chapter concludes with a discussion of the role of KM in solving site management problems and the potential benefits of the integrated KM framework are presented.

6.2 KM Frameworks and Related Model Functions

Many knowledge management research projects have sought to develop a framework for construction organisations. Some of the recent efforts in developing a KM framework for construction are summarised in Table 6.1. The summaries are based on an analysis of the published information on each of these and correspondence with some of the teams to ensure the accuracy of the information and to gain additional information. Consequently, a comparison of the KM frameworks and related model functions is crucial to achieve two important objectives. Firstly, it facilitates analysis of the main aim and role of these frameworks, with a view to developing an effective KM framework for the construction site context.

Table 6.1: Comparison of KM Frameworks in Construction.

KM Model	General Model Objectives	Framework Development
ConABKM (Tserng and Lin, 2004)	<ul style="list-style-type: none"> Managing tacit and explicit knowledge using Web-based technologies Focusing on sharing knowledge 	<p><i>Main aim of framework</i></p> <ul style="list-style-type: none"> To capture explicit and tacit knowledge during the construction phase and to reuse in similar projects in the future. <p><i>Role of framework</i></p> <ul style="list-style-type: none"> To provide knowledge exchange, to promote the reuse of domain knowledge and experience in future and current projects. <p><i>The end users</i></p> <ul style="list-style-type: none"> Junior engineers, senior engineers, site engineers, experts and KM team members in the organisations.
CLEVER (Anumba <i>et al.</i> , 2005)	<ul style="list-style-type: none"> Supporting the development and implementation of KM strategies in organisation Focusing on the analysis of a knowledge problem in order to select appropriate strategy for KM 	<p><i>Main aim of framework</i></p> <ul style="list-style-type: none"> To explore the characteristics of KM in order to select KM processes tailored to organisation needs <p><i>Role of framework</i></p> <ul style="list-style-type: none"> Facilitate the selection of an appropriate strategy of the KM within an organisation <p><i>The end users</i></p> <ul style="list-style-type: none"> Knowledge Manager, Chief Knowledge Officer, head of business unit, Project Manager, etc.
SELEKT (Al-Ghassani <i>et al.</i> , 2005)	<ul style="list-style-type: none"> Developing framework for selection of appropriate KM tools Focusing on the development of database of KM techniques (non-IT tools) and KM technologies (IT-tools) 	<p><i>Main aim of framework</i></p> <ul style="list-style-type: none"> To identify the critical criteria (KM dimensions) required for the tool selection <p><i>Role of framework</i></p> <ul style="list-style-type: none"> It provides a more informed approach in the selection of appropriate KM tools by incorporating relevant KM dimension and knowledge context. <p><i>The end users</i></p> <ul style="list-style-type: none"> Medium and large construction organisations.
Project Histories (Maqsood <i>et al.</i> , 2004)	<ul style="list-style-type: none"> Managing project histories and conducting project learning Focusing on helping 'pre-tendering' team effectively use project histories 	<p><i>Main aim of framework</i></p> <ul style="list-style-type: none"> To investigate the role of KM in producing innovation and learning in the construction industry <p><i>Role of framework</i></p> <ul style="list-style-type: none"> Facilitate the building and creation of project histories or learning histories <p><i>The end users</i></p> <ul style="list-style-type: none"> Focused on team involved in pre-tendering process but site manager, site engineer and quality engineer could use it in order to prevent re-inventing the wheel.
Audio Diary (Boyd <i>et al.</i> , 2004)	<ul style="list-style-type: none"> Managing valuable experience on the construction site Focusing on developing audio diary problem-solving event by Dictaphone 	<p><i>Main aim of framework</i></p> <ul style="list-style-type: none"> To test a simple but robust way of capturing tacit knowledge by means of an audio diary and debriefing <p><i>Role of framework</i></p> <ul style="list-style-type: none"> Help organisations especially SMEs, to capture, retain and disseminate tacit knowledge. <p><i>The end users</i></p> <ul style="list-style-type: none"> Construction SMEs and site managers
C-Sand (Khalfan <i>et al.</i> , 2002)	<ul style="list-style-type: none"> Capturing and managing the knowledge required to improve sustainability in construction Focusing on creating and sharing knowledge for sustainable construction 	<p><i>Main aim of framework</i></p> <ul style="list-style-type: none"> To enable knowledge creation for sharing and reuse and to promote sustainable development <p><i>Role of framework</i></p> <ul style="list-style-type: none"> As a checklist of sustainability issues within the design and construction phase of a project. <p><i>The end users</i></p> <p>Design team, construction organisations within the design and construction phases</p>

Secondly, it will provide an opportunity to utilise the existing KM frameworks in terms of effectiveness, level of detail and ease of use in the site management context.

6.2.1 Description of General Framework Objectives

a. *ConABKM Framework*

Tserng and Lin (2004) developed an activity based knowledge management framework for construction projects using a web-based portal. The main aim of the framework is to capture explicit and tacit knowledge during the construction phase and to reuse in similar projects in the future. The concept of integrating the IDEF (Integrated DEFinition function modelling) modelling method is used for designing a construction knowledge management framework. This framework was developed within the context of KM framework of five main stages:

- *Knowledge acquisition:* This stage involves the collection of related data and information;
- *Knowledge extraction:* This stage is the process of translating data and information into knowledge;
- *Knowledge storage:* Knowledge has been stored under a centralised and safe environment;
- *Knowledge sharing:* This stage enables the engineer to share the valuable knowledge and information which has been stored in the system by using the internet or intranet; and
- *Knowledge update:* The feedback from various users which has been put back into the knowledge management system and updates the knowledge for reuse.

All project information and knowledge in the KM framework is centralised in a database system. The primary roles of the framework are to provide knowledge exchange and to promote the reuse of domain knowledge and experience in future and current projects. The KM framework facilitates the knowledge sharing process for

junior engineers, senior engineers, site engineers, experts and KM team members in the organisations and improves the performances of the entire construction projects.

b. CLEVER Framework

The CLEVER (Cross-sectoral LEarning in the Virtual entERprise) framework was developed to support the development and implementation of KM strategies in an organisation. Its aim is to explore the characteristics of KM in order to select KM processes tailored to an organisation's needs (Anumba *et al.*, 2005). The framework is focused on the analysis of a knowledge problem in order to select the appropriate strategy for KM as shown in Figure 6.1. The basic strategy adopted was to investigate, through case studies, KM practices in the manufacturing and construction sectors with a view to facilitating cross-sectoral learning to the mutual benefit of both sectors. There are four stages in the framework (Kamara *et al.*, 2002):

Stage 1: Identify KM problem

This stage involves defining the overall KM problem within a business context and it involves a description of the perceived problem and identifying the business drivers underpinning it. It aims to assist users to 'think through' the problem in a 'structured way'. The developed approach requires the user to:

- Describe the 'vague' KM problem;
- State the business driver;
- Characterise knowledge;
- Identify sources and users;
- Identify enablers and resistors;
- Identify current KM sub-processes; and
- Restate/Refine the problem

Stage 2: Identify current and required knowledge dimension

This stage involves identifying the status of a range of knowledge dimensions and highlighting areas of future focus. It is used to confirm the characteristics of the current

(‘as-is’) position and identify the desired (‘to-be’) position in each problem area with regard to organisational strategy and policy. A clear set of concerns are extracted and prioritised, and they are used to identify migration paths for each identified problem. The output of this stage is a set of concerns or specific Km components of the overall problem that the user wishes to focus on.

Stage 3: Identify critical knowledge migration path

This stage focuses on identifying the critical migration path from the current (‘as-is’) situation to the desired (‘to-be’) situation. A set of predefined ‘squares’ that relate to each problem identified in the previous stage are selected. The user then maps out his/her current situation, where he/she wants to be, and the path he/she wants to follow. Each identified problem is considered in turn, and the overall set of migration paths are mapped out for the overall KM problem under consideration.

Stage 4: Select generic KM processes

The main aim of this stage is to help in selecting the appropriate KM processes to develop a strategy for the identified goals and their migration path. Thus for each migration path defined in the previous stage, the relevant KM process is selected from a standard list of processes. Organisation enablers/resistors that may facilitate or inhibit the implementation of the selected process are also identified. This will enable the organisation to develop specific plans (based on enablers/resistors) to implement the selected strategies that relate to its stated KM problem.

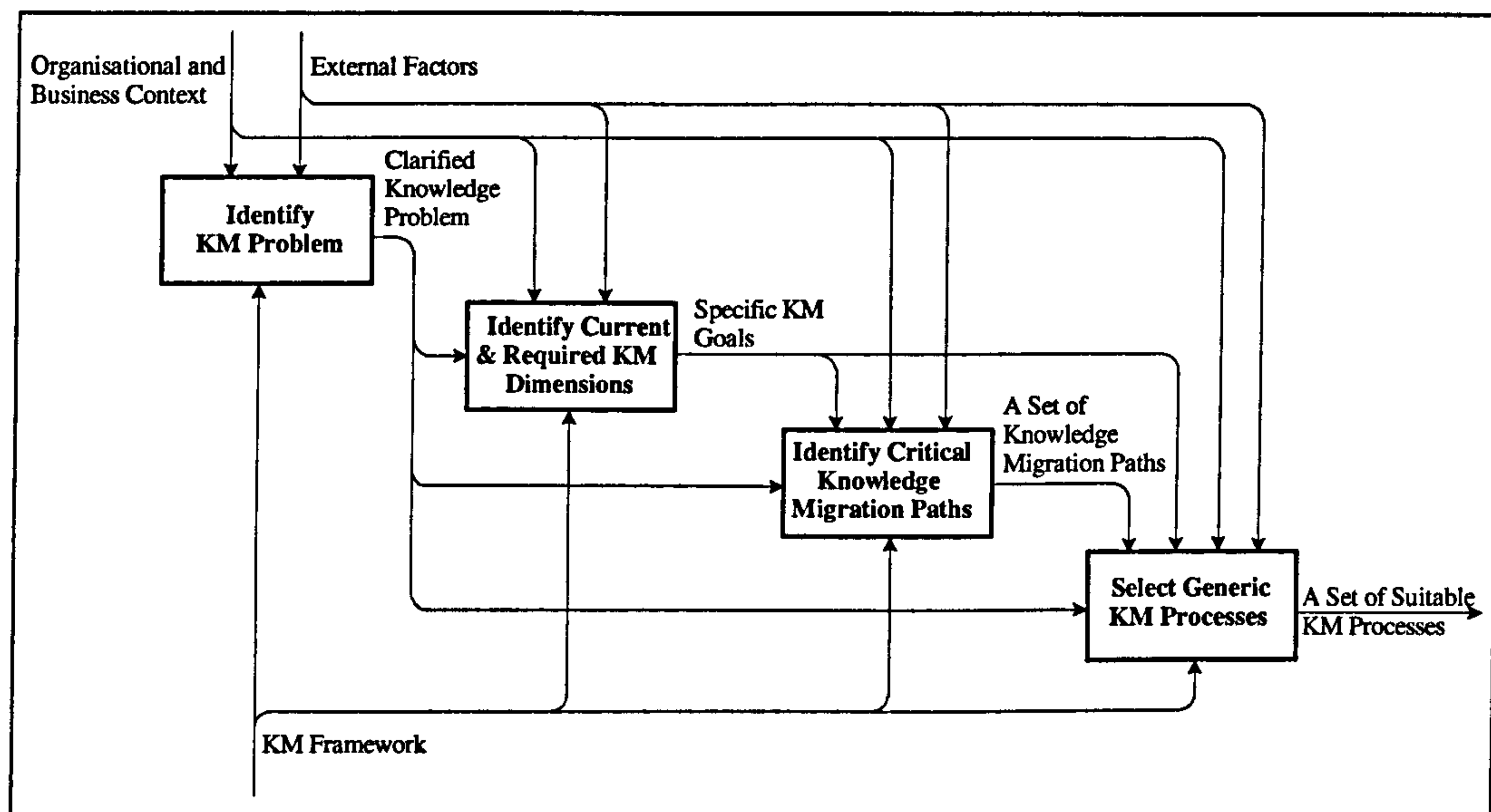


Figure 6.1: The CLEVER Framework for Implementing KM (adapted from Al-Ghassani *et al.*, 2006).

According to Anumba *et al.* (2005), the implementation of each stage of the framework requires the use of various tools. These are the ‘problem definition template (PDT)’ (to identify KM problem), ‘knowledge dimension guide’ (to identify current and required knowledge dimension), ‘migration path tool’ (to identify critical migration path) and ‘generic KM processes model’ (to select appropriate KM processes).

Tool 1: The problem definition template (PDT)

The PDT consists of a structured set of questions which are divided into five sections: ‘type of knowledge’, ‘characteristics of knowledge’, ‘sources and users of knowledge’, ‘current sub-processes for managing knowledge’, and ‘restatement of problem’. After completing the template, the user reviews the knowledge problem that was described at the beginning and refines it on the basis off the understanding gained through using the template.

Tool 2: The knowledge dimension guide

The 'knowledge dimension guide' consists of eight knowledge dimensions where every dimension is described by two contrasting words e.g. tacit versus explicit. Table 6.2 shows eight main elements of the 'knowledge dimension guide'. Also each dimension is complemented by information on the organisational implications of the dimensions. By indicating on a five-point scale the current and required knowledge status it is possible to identify the organisational goal(s) for implementing KM.

Table 6.2: Knowledge Dimension Guide (adapted from Anumba *et al*, 2005).

Left Anchor	Continuum				Right Anchor
Explicit: Automated/Process based Decision Making	F			C	Tacit: Human based decision making by discussion/consensus
	<i>(Approach to Decision Making)</i>				
Auxiliary: Focus on performance, efficiency and costs				FC	Critical: Focus on knowledge as a competitive edge
	<i>(Recognising Core Competence)</i>				
Discipline Based: Emphasis on developing single discipline knowledge domains				FC	Project Based: Focus on developing multi-disciplinary project knowledge
	<i>(Openness to Change/Flexibility)</i>				
Slow change: Competitive edge depends on efficiency of knowledge					Rapid change: Competitive edge depends on ability to innovate
	<i>(Requirement to Innovate)</i>				
External: Emphasis is on managing knowledge which can be bought in as required		FC			Internal: Emphasis is on owning knowledge that is particularly rare or valuable
	<i>(Knowledge Ownership & Availability)</i>				
Individual: Having access to the knowledge is more important than sharing it.	C				Shared: Knowledge is seen as an organisational asset to provide added value
	<i>(Knowledge as an Organisational Asset)</i>				
Problem Specific: Excellent for recurrent problems (runners and repeaters)	C				Generic: Reuse of knowledge is important; allows wider allocation of work.
	<i>(Re-use of Knowledge)</i>				
Learn by Training: Ensure technical/professional competence			CF		Learn by Interaction: Assists transfer of organisational values
	<i>(Propagation of Org. Culture)</i>				

Tool 3: The migration path tool

The 'migration path tool' consists of 56 cells that define the possible migration paths for the knowledge dimensions. Every cell allows selection from 12 possible paths. The cell also includes a description of each path so that users can easily identify the relevant path.

Tool 4: The generic KM process models

The last template in CLEVER is the 'generic KM process model'. For each migration path, a KM process (e.g. knowledge transfer) is selected. The possible factors that could facilitate ('enablers') or hinder ('resistors') the migration to the required status are also identified. For every KM process there is a set of generic models, which assist in developing an appropriate KM strategy that reflects the organisational needs. For example, Figure 6.2 shows the generic process model for the transfer of knowledge. There are four steps in this process: 'identify knowledge to be transferred', 'identify knowledge sources', 'identify knowledge transfer target' and 'select transfer methods'. A clear identification of the 'source' and 'destination' of knowledge to be transferred will determine whether it is people-to-people, people-to-paper transfer, etc. Resistors and enablers that affect each step should be identified.

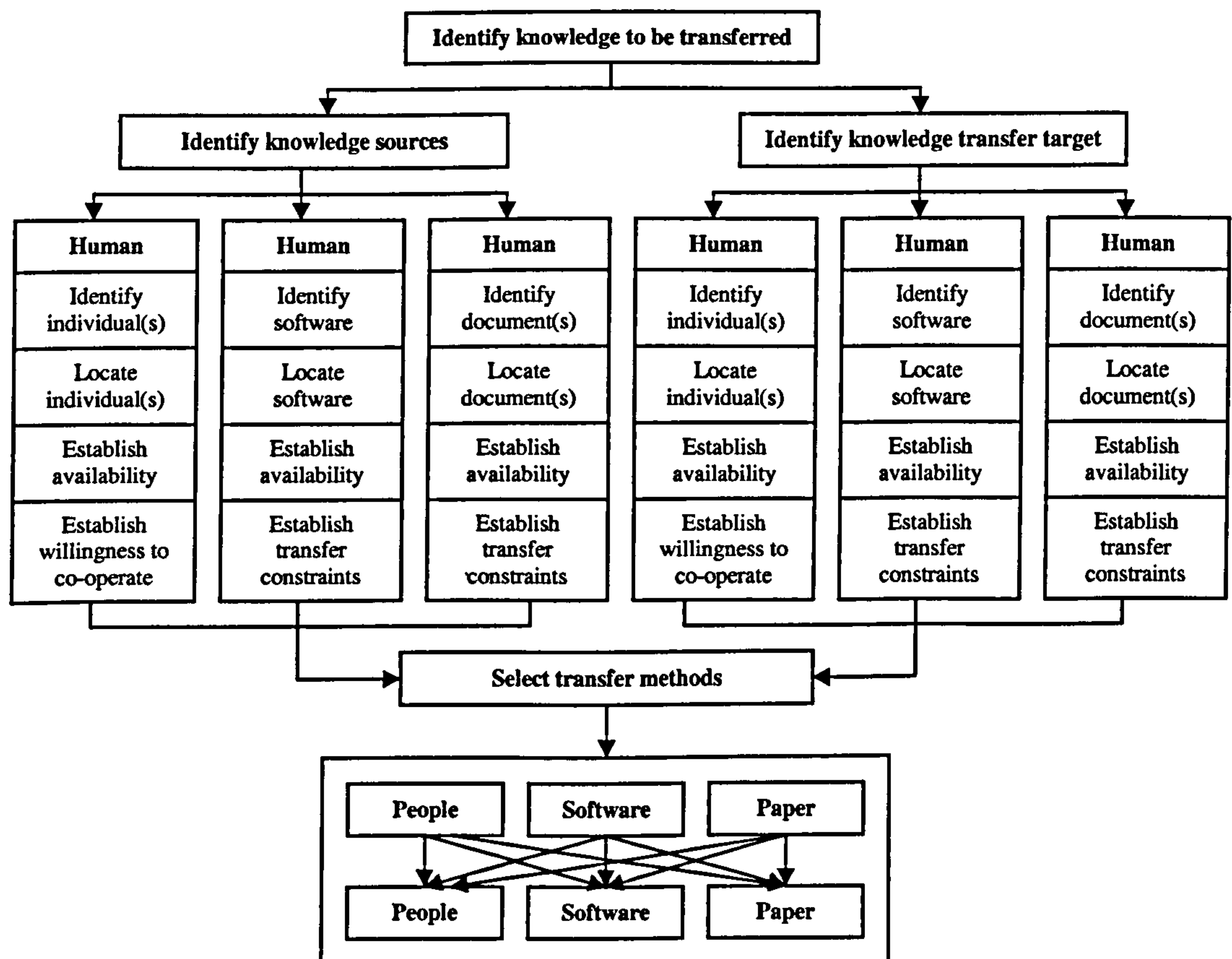


Figure 6.2: Generic Process Model for Knowledge Transfer (adapted from Anumba *et al.*, 2005).

c. *SELEKT Framework*

The SELEKT (Searching and Locating Effective Knowledge Tools) framework was developed to overcome difficulties in identifying the most appropriate tools due to the large number of products in the marketplace and the overlap between what they can do (Al-Ghassani *et al.*, 2005). More specifically, the SELEKT framework relies on specific criteria and integrates the existing methods. The main aim of the framework is to identify the critical criteria (KM dimensions) required for the tool selection as shown in Table 6.3. The framework focuses on the development of a database of KM techniques (non-IT tools) and KM technologies (IT-tools). The SELEKT framework provides a more informed approach in the selection of appropriate KM tools by incorporating relevant KM dimension and knowledge context.

Table 6.3: The SELEKT Approach - KM Dimensions and Their Possible Combinations (adapted from Al-Ghassani *et al.*, 2005).

KM Dimensions				Required Dimension							
Current Dimension	Transfer Domains			Internal				External			
	Ownership Forms	Conversion Types		Individual		Group		Individual		Group	
				Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit
Internal	Individual	Tacit									
		Explicit									
External	Group	Tacit									
		Explicit									
	Individual	Tacit									
		Explicit									
Group	Tacit										
	Explicit										

The supplementary role of the SELEKT framework is to ensure that business needs of an organisation are adequately addressed (Al-Ghassani *et al.*, 2005). There are three main stages in the framework and these stages can be summarised as follows (see Figure 6.3):

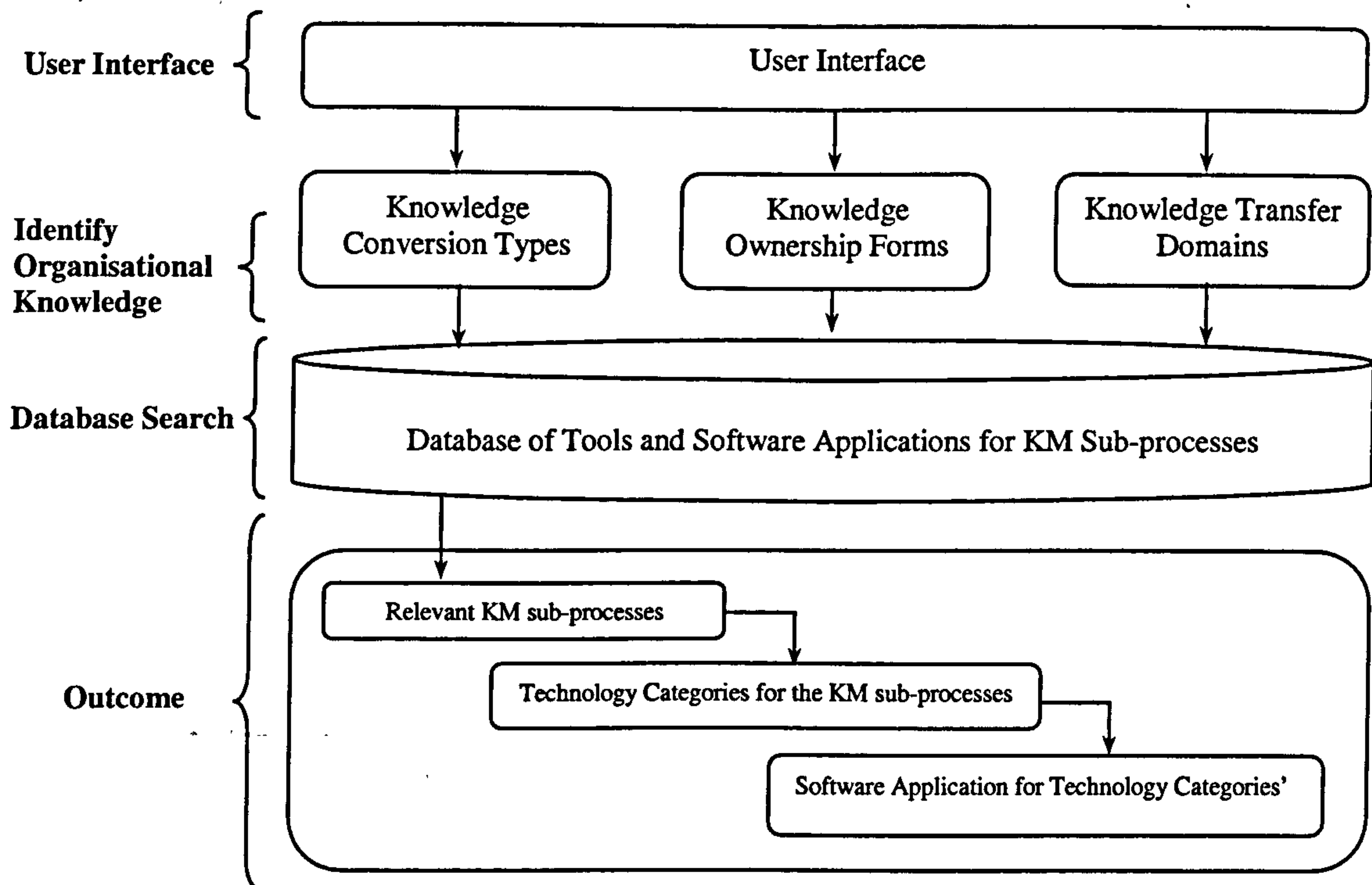


Figure 6.3: The SELEKT Approach for Identifying KM Technologies (adapted from Al-Ghassani, 2003).

- *Identify organisational knowledge:* This stage consists of three KM dimensions required to identify the most appropriate tools. Three dimensions have been identified as critical for the selection of KM tools. These dimensions are: the ‘knowledge transfer domains’ (internal-external), the ‘knowledge ownership forms’ (individual-group) and the ‘knowledge conversion types’ (tacit-explicit). Every dimension should be investigated in terms of current and required status of the knowledge interest;
- *Identify KM sub processes required and link them to the tool categories:* KM is a process consisting of several sub-processes where the sub-processes do not

necessarily follow a linear relationship. The KM sub-processes used in the SELEKT are: locating knowledge and accessing, capturing, representing, sharing, and creating new knowledge; and

- *Identify commercial software applications for the technology categories:* It is necessary to select a suitable software application. The selection of such applications is dependent on several factors, such as the functional capabilities of the individual applications, the existing applications within the organisation and the ability to link them to the selected application, the cost of the selected application, etc.

d. Project Histories Framework

The Project Histories framework was developed by Maqsood and Walker (2004) and aimed to investigate the role of KM in producing innovation and learning in the construction industry. The framework adopted Soft System Methodology (SSM) that uses system thinking in a cycle of action research, learning and reflection to help understand the various perceptions that exist in minds of the different people involved in the situations. The SSM consists of a seven-stage process:

- The problem situation in its unstructured form;
- The problem situation expressed as a rich picture;
- The root definitions of relevant, purposeful activity systems;
- Conceptual models of the systems named in the root definition;
- Comparison of models with real world;
- Identification of the feasible, desirable changes; and
- Action to improve the problem situation.

SSM is useful for analysing any problem or situation, but it is most appropriate as a search for an efficient means for achieving defined ends when the problem cannot be formulated; a problem in which ends, goals, purposes are themselves problematic. The framework is focused on helping 'pre-tendering' teams to effectively use project histories. Furthermore, project histories will help to provide a source of knowledge to

support value analysis in future projects. There are seven main stages of the framework where the fourth earlier stages of the conceptual models are the sources of knowledge for future reuse:

- Acquire details of the client's technical requirement;
- Understand client's expectations for price and value;
- Understand community's expectation for major project;
- Know how to be competitive;
- Set the criteria needed to define what will be a competitive bid;
- Monitor and control the bid; and
- Develop a competitive bid.

e. Audio Diary and Debriefing Framework

Boyd *et al.* (2004) developed an Audio Diary and Debriefing framework and this has allowed the development of a comprehensive, yet simple, tool for knowledge management, which is suitable for small and medium size construction organisations. The main objective of the framework is to test a simple but robust way of capturing tacit knowledge by means of an audio diary and debriefing. The development of the framework consists of two main stages:

- *Audio Diary*: The main tool for capturing oral knowledge in the form of an audio diary is a Dictaphone. Its main focus is to develop an audio diary problem-solving event by Dictaphone. In order to make the diary more structured, a set of important questions is listed to help the participants record their stories. These questions are as follows: What was the context of the event?, What should have happened?, How did people react?, What did you feel?, and What lesson did you learn?; and
- *Debriefing*: Debriefing is a management tool, which can make explicit the tacit learning so that it can be transferred to a wider audience and ultimately to the knowledge base of the industry. In this study, after four or five audio diary recordings, the participants are visited and a debriefing session is conducted.

The debriefing practice helps the participants to start to think about other options to the problems they faced on site and propose alternative solutions.

The implementation of audio diary and debriefing has generated a series of events that cover technical, operational and relationship in the site management practices. The audio diary and debriefing framework is an effective tool for knowledge management for construction SMEs and site managers.

f. C-Sand Framework

The C-Sand (Creating, Sustaining and Disseminating Knowledge for Sustainable Construction: Tools, Methods and Architecture) was developed for capturing and managing the knowledge required to improve sustainability in construction (Khalfan *et al.*, 2002). The framework adopted Soft System Methodology (SSM) for organisational analysis; and incremental and interactive Object Oriented (Unified Modelling Language – UML) modelling for technical components. The main aim of the framework is to bring awareness of sustainability issues in construction processes at the project level. This was achieved by developing SMAZ (Sustainability Management Activity Zone) tool.

According to Shelbourn *et al.* (2006) the SMAZ tool maps activities as a management area on the Process Protocol map. The Process Protocol is a generic process map for design and construction and was mapped into eight sub-processes (Activity Zones); Development, Project, Resource, Design, Production, Facilities, Health and Safety and Statutory and Legal. This could then potentially drive all construction projects towards sustainable construction practices. The main role of the framework is as a checklist of sustainability issues within the design and construction phase of a project. SMAZ was developed in a similar format to the other activity zones within the Process Protocol and it can be used worldwide with the possibility of being adapted into any design and construction process framework. From the discussion, it can conclude that the C-Sand framework is appropriate for use by the design team and construction organisations within the design and construction phases.

6.2.2 Analysis of KM Framework Functions

According to Egbu and Robinson (2005), decisions on what knowledge on construction an organisation needs depends on the context of the business environment, i.e. key knowledge about processes and people for the delivery of its products. There are three aspects of knowledge to be managed in the construction context: Product or project types; processes; and people as shown in Figure 6.4. The discussion about these aspects was presented earlier in the Chapter 4, section 4.2.3.c. Technology supports connectivity as most of the construction knowledge resides in people, not technology. It is also important to have a complete understanding of the organisational element of knowledge in construction site management practices in order to help the site management team to understand the differences and limitations and also the synergistic role of each of these contexts.

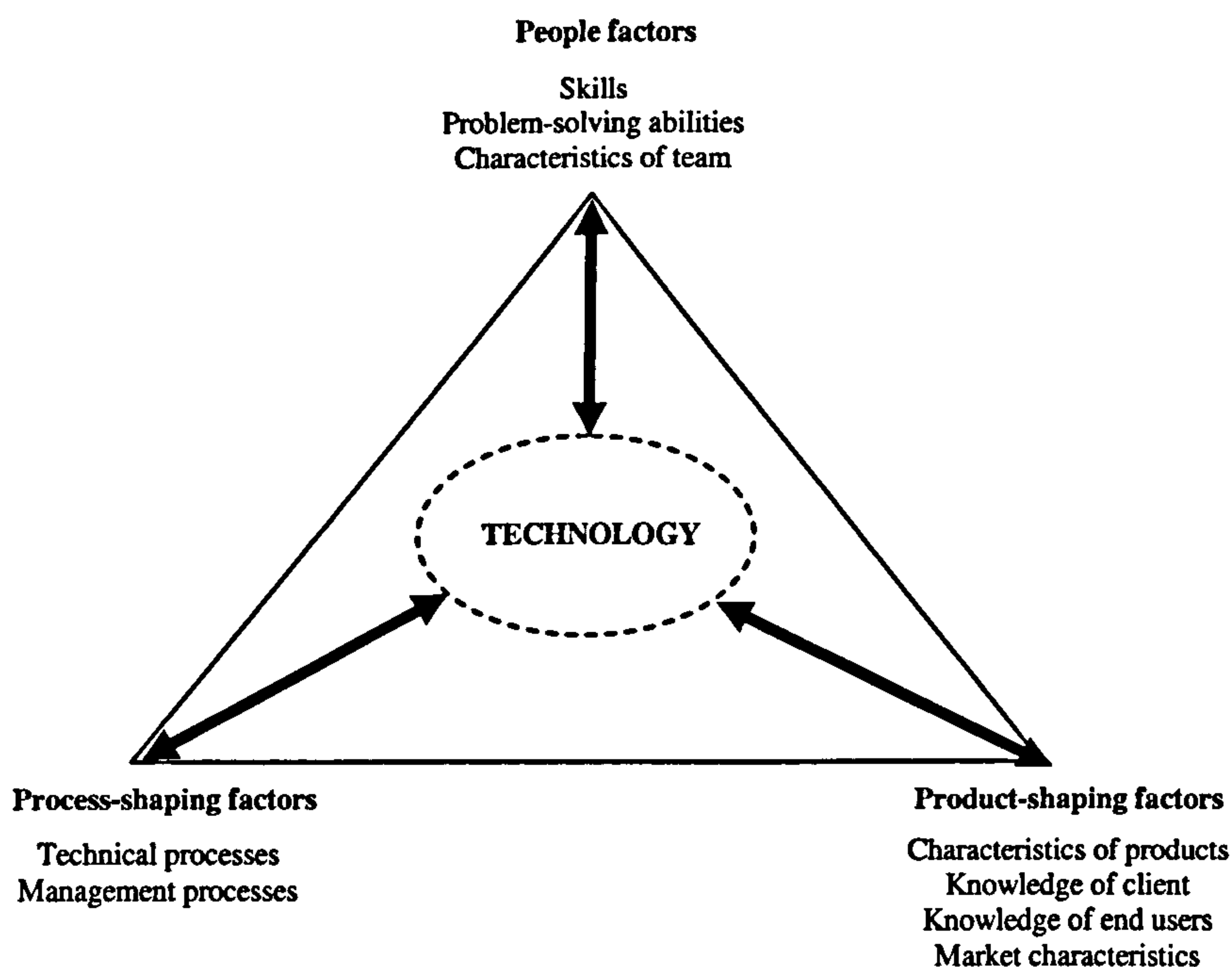


Figure 6.4: Context-Based Factors Influencing a KM Strategy (adapted from Egbu and Robinson, 2005).

Before developing a construction site KM framework, it is important to analyse the limitations of the existing KM frameworks in the construction industry context. An

analysis conducted by Rubenstein-Montano *et al.* (2001) revealed that the key limitations of existing KM frameworks are as follows:

- *Lack of overseeing framework:* The purpose of the framework is to direct work in a disciplined way. The frameworks can be classified as either prescriptive, descriptive, or a combination of the two. Prescriptive frameworks provide direction on the types of knowledge management procedures without providing specific details of how those procedures can be accomplished. In contrast, descriptive frameworks characterise or describe knowledge management. These frameworks identify attributes of knowledge management important for their influence on the success or failure of knowledge management initiatives;
- *Failure to address the entire KM process:* The KM frameworks should address the entire KM process. The KM process includes learning, organisational culture, strategy, tacit versus explicit knowledge, and KM tasks; and
- *Lack of details:* The KM framework must contain sufficient detail to be implemented. It should provide detailed steps of how to carry out KM expected outputs.

According to Bixler (2005), to implement a successful KM framework within an organisation, it is necessary to understand and consider the following concepts:

- KM is increasingly important because of the shift from predictable organisation paradigms to one governed by discontinuous and often unpredictable change. A well constructed KM framework will help solve and improve the problems associated with this unpredictable change;
- KM is not merely collecting information from various domain experts and creating databases supported by organisational intranets. It must be dynamic and problem-solving in nature;
- KM is essential for organisational strategic survival. Problem-solving, knowledge creation, and innovation are core competencies of any successful organisation;

- KM is not a separate function characterised by a separate KM department or a specific and isolated KM process. KM must be embedded into all the organisation's business processes;
- Latest advances in information and communication technology can facilitate processes, such as channelling, gathering, or dissemination. However, the final burden is on the managers and knowledge workers to translate this information into actionable knowledge that enhances performance. This requires creation of a foundational enterprise-wide KM system; and
- Implementing the best leading-edge technologies and information systems does not necessarily ensure the creativity and innovation that is necessary for organisational competence. Effective utilisation of knowledge, information and technology in terms of action and successful implementation is necessary.

Therefore, there is a need to transform the most relevant of the above elements and to derive a more comprehensive KM framework for the improvement of construction site management practices. In the site management context, a well constructed KM framework to solve and improve the problems associated with this unpredictable change (as outlined in the first, second and third of KM framework concept by Bixler, 2005) is essential and required. It is therefore important, in construction site management practices, to develop a KM framework for the construction site level that should be based on detailed KM frameworks, comprehensive (i.e. consistent with system thinking) and contain sufficient details to be useful. However, the developed KM framework should be easy to use by the construction site management team. From the case study findings and from the limitations identified by Rubenstein-Montano *et al.* (2001) a KM framework needs to:

- Address all stages of a KM strategy
- Be easy to use; and
- Contain sufficient details.

Before developing a KM framework for construction site management practices, it is pertinent to analyse the ability of existing KM frameworks in construction with a view to comparing their roles, focus and level of detail. Table 6.4 shows the comparison of

six existing KM frameworks developed in previous KM research in the construction industry. The ratings are based on an analysis of the published information and verified additional information supplied by the principal researcher on each of these.

Table 6.4: Comparison of KM Frameworks for Developing KM Strategies.

Element		ConABKM (2004)	CLEVER (2005)	SELEKT (2005)	Project Histories (2004)	Audio Diary (2004)	C-Sand (2002)
a. Problem based framework	Identify relevant site problem	✓	✓		✓✓	✓	
	Establish KM issues	✓	✓✓✓	✓	✓	✓✓	✓
	Develop KM initiatives	✓✓✓	✓✓	✓✓		✓	✓✓
	Evaluate the KM initiatives	✓					
b. Level of detail		✓✓✓	✓✓✓	✓✓	✓	✓	✓✓
c. Ease of use		✓	✓	✓	✓	✓✓	✓

Key
 ✓ Fairly Good
 ✓✓ Good
 ✓✓✓ Very Good

a. Addressing All Stages of the KM Framework

The discussion of a construction site KM framework and its requirement has been undertaken in Chapter 5, Section 5.4. The comparison of general criteria of KM frameworks including their roles, aim, focus and the end users are presented in Table 6.1. In terms of problem-based framework, it clearly shows that no existing KM framework addresses all of the four main stages of a KM strategy for construction site management practices, although each addresses important parts of the KM processes (e.g. ConABKM (2005) addresses 'develop KM initiatives stage', CLEVER (2005) addresses establish KM issues stage and SELEKT (2005) addresses 'develop the KM initiatives stage'). The CLEVER (2005) framework is the only one explicitly discussed in terms of defines the overall KM problem within a business context. The ConABKM (2004) develops detailed KM initiatives for managing knowledge but does not address

the 'evaluation KM initiatives stage'. Project Histories (2004) framework addresses 'identify relevant site problem' stage while SELEKT (2005) and C-Sand (2002) do not address this stage. The ConABKM (2005) is very good in addressing 'evaluate the KM initiatives' stage, but the evaluation methodologies developed were not appropriate to be used in the construction site management practices. The main reason is that the structure is very complex and difficult to use at the operational level. However, the principles of evaluation provide a good example for the development of evaluation tool at construction site level. The CLEVER (2005) contains built-in templates, which distinguish it from the other frameworks. These templates provide a highly structured way for guiding the user to use the framework and to select the most appropriate options. The combination of CLEVER and SELEKT frameworks might be useful for integrating KM into site management practices based on problem solving KM. While the elements covered in most of KM frameworks are essential, they demonstrate an incomplete coverage of what is needed for KM initiatives at the construction site level. The site management practices require a problem solving KM framework which focuses on capturing best practices, lessons learnt, and especially the solutions to problems that arise on site.

b. Level of Detail

There is a high level of detail in the ConABKM (2004), C-Sand (2002) and CLEVER (2005) frameworks. The ConABKM methodology consists of five main KM processes where a description of how each step can be achieved is provided. The C-Sand framework adopts a detailed Process Protocol map but does not address the entire range of KM processes, particularly 'evaluation KM initiatives' part. The Project Histories (2004) and Audio Diary (2004) only provide superficial guidance on KM: capturing and storing knowledge for example. In contrast, the level of detail in CLEVER (2005) is very well structured. It consists of a group of questions set in different ways (e.g. direct questions, selection from given options, matrices, five point scales, etc.) to clarify and identify the knowledge that needs to be managed. It includes eight knowledge dimensions, which are used to identify an organisation's current and required status in every one of the dimensions. These dimensions are then used to define the organisational goal(s) for implementing KM. CLEVER (2005) also consists of group of

knowledge migration paths (672 paths) based on the identification of which relevant KM sub-processes can be used. Built-in generic KM processes model can then be used for developing a KM strategy.

c. *Ease of use*

None of the existing KM frameworks is easy to use except the Audio Diary (2004) framework, although this issue is crucial in site management practices. The framework developed by Boyd *et al.* (2004) is relatively easy to use and very appropriate for construction site managers. However, the framework does not address the entire range of KM processes, especially for the 'level of detail' aspect which is an essential part of a KM strategy. The ConABKM (2004) has procedures and sub procedures of how to achieve certain outcomes. However, these procedures are difficult to use and need more structured approaches to guide the user to achieve the required outcomes. The Project Histories (2004) and C-Sand (2002) frameworks are more generic and are therefore difficult to use without additional guidance and proper training. In contrast, the CLEVER (2005) framework is rather easier to use when compared to other frameworks because of its built-in-templates. However using this framework requires multiple inputs resulting in input duplication and selection from a large number of built-in models (e.g. 56 migration path cells, 672 migration paths) resulting in the consumption of a considerable amount of time.

It can be concluded that the three criteria outlined by Rubenstein-Montano *et al.* (2001) are considered essential in the development of the KM framework for construction site management practices, underpinned by findings from industry case studies. Before presenting the developed conceptual framework for integration of knowledge management into construction site management, the adaptations of relevant KM frameworks are first justified.

6.2.3 Adaptations of Relevant KM Frameworks

It is evident that research in knowledge management in construction has focused heavily on developing decision strategy, innovative techniques, and information technology tools for construction professionals to formulate and manage construction knowledge. Very little research has been done on understanding problem-based knowledge management as an approach for managing knowledge at the construction site level. The above KM-specific research projects discussed in section 6.2 adopts a broad view of the implementation of KM initiatives to improve project performance and have different levels of focus and maturity. It is observed that these research projects focused initially on the broad project management aspect of the construction process and do not address in adequate depth the underlying construction site processes which are rich with knowledge, best practices and lessons learnt. Nevertheless, some of the approach developed in the CLEVER (2005) framework can be fruitfully utilised for knowledge management at the construction site level. The CLEVER (2005) framework is adopted because it enables the identification of the characteristics of the knowledge required and the key dimensions and transfer issues associated with it. The distinction between tacit and explicit knowledge is made and each is managed differently. For example, for 'lesson learned about project' knowledge, which is generally held as experience, a selection will be put towards the tacit side of the explicit-tacit scale in the Problem Definition Template (PDT). In the construction site context, although the Audio Diary research project concentrates on managing valuable experience on the construction site by developing an audio diary problem-solving event by Dictaphone, the developed framework only addresses the capture and dissemination of tacit knowledge and does not contain sufficient details. Moreover, the adoption of the SELEKT framework will help site managers to explore the critical criteria (KM dimensions) of KM in order to select KM processes tailored to the needs of construction site management practices.

The analysis of existing KM frameworks and model functions, supported by an analysis of the three main criteria, confirms that none of the methodologies addresses all the stages of construction site KM framework as discussed in Chapter 5, section 5.4. The findings show that it is important to develop a workable and efficient KM framework in the site management context and the framework should be capable of addressing all the

stages required for implementing a KM strategy. Sufficient details and ease of use are the factors which also need to be considered when developing the framework. Table 6.5 summarises the suggested features of the framework.

Table 6.5: The Needs of a KM Framework for Construction Site Management.

	Problem Based Framework	Existing Framework	Required Capability
Stage	Identify relevant site problem	Develop a new approach	Aim to prevent and tackle problem
	Establish KM issues	CLEVER Framework	Identify the KM problem Identify the knowledge dimension Identify the characteristics of knowledge
	Develop KM initiatives	CLEVER Framework SELEKT Framework	Identify knowledge migration path Develop generic KM processes Select most appropriate tools for KM processes
	Evaluate the KM initiatives	Develop a new approach	Aim to monitor, review and revise the KM initiatives

The limitations and opportunities identified in existing KM frameworks for construction organisations provide a useful perspective in terms of functionality of the framework and indicate a need for a workable KM framework that contains sufficient details and is easy to use in construction site management practices.

6.3 Conceptual Framework Development

6.3.1 Overview of the framework

The case study findings revealed that the case study organisations have numerous mechanisms for managing their knowledge, although the label of KM is often not used. Nonetheless, the site management team can have difficulties with regard to resolving site management problems. They often wait until late in the project, when many problems start occurring, before tackling such problems and related issues. An integrated framework that reflects the specific context of site management practices, and which makes provision for both explicit and tacit knowledge is therefore proposed. The operation of the integrated framework consists of two main approaches:

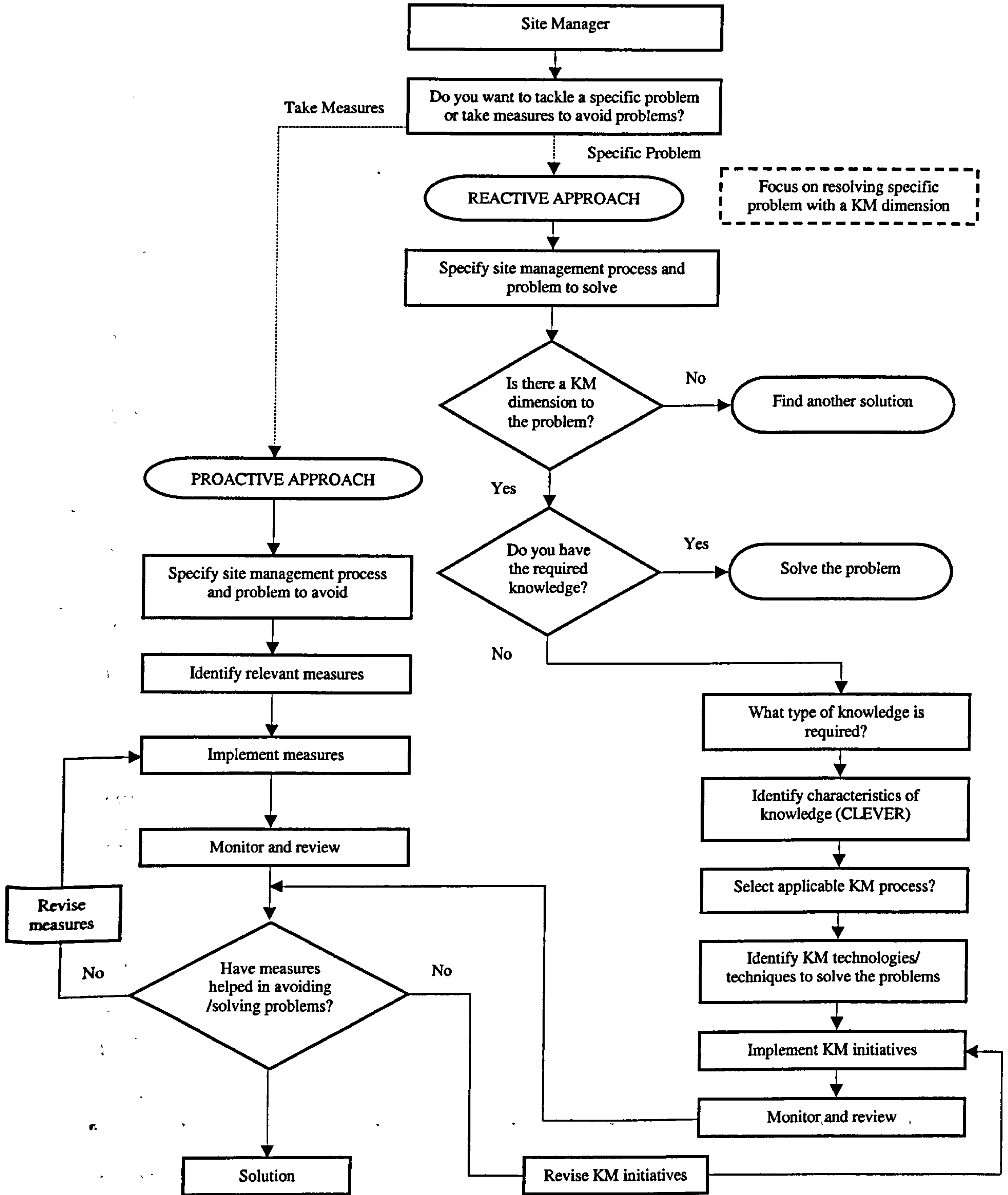


Figure 6.5: Proactive and Reactive Knowledge Management Framework.

- *Proactive approach* – five stage KM approach which involves taking measures to prevent the most common site management problems from occurring; and
- *Reactive approach* – nine stage KM approach to identifying the knowledge gap that has led to specific problems and recommending measures to tackle the problem.

The framework provides a structured approach to managing construction knowledge that is entrenched in site management processes. Figure 6.5 shows the main stages of the knowledge management framework to be implemented on the construction site and indicates the approach to be taken to tackle a specific problem (reactive approach) and the approach to be followed to avoid potential problems (proactive approach).

6.3.2 The Features of the Integrated KM Framework

The integrated KM framework can be used to solve site management problems for any construction site processes (planning, commercial management, material management etc.). Table 6.6 summarises the key stages of the KM framework. The framework can be used as a management tool to minimise the number of problems that occur on the construction site and reduce their impact (Mohamed and Anumba, 2005). The proactive KM approach is intended to support the institution of KM initiatives that will prevent the most common site management problems from occurring and to reduce the impact of those problems which do occur. These objectives form the basis of the five main stages of the proactive KM approach as illustrated in Table 6.6. The main element of this approach is a set of alternative solutions to resolve a specific site management problem. In contrast, the reactive KM approach is a nine-stage framework for identifying the knowledge gap that has led to a given site management problem and recommending measures to tackle the problem. The first decision point (second box in Figure 6.5) involves the site manager deciding on whether to adopt a proactive or reactive approach to site management problems. It may be useful for the site manager to view construction problem-solving as a community activity: problem solvers do not operate within a vacuum but adopt and adapt solutions and methods practised and learned in previous cases (Li and Love, 1998). The framework is appropriate to be a

decision support for the experienced site manager. Alternatively, the framework can also be used collectively in a site management team, with the site manager acting as a facilitator.

Table 6.6: Stages in the Proactive and Reactive KM Framework.

Stage - Proactive Approach	Aim	Outcomes
1. Specify SM process and problem to avoid	To specify construction site management process and potential problem that the site manager wishes to focus on.	Clarification of problem area (site management processes)
2. Identify relevant measures	To identify available measures for avoiding potential problems	Set of alternative measures to avoid problem
3. Implement measures	To take measures to avoid problems and to reduce the impact of problems if they do occur	Measures to avoid problem for each site management problem
4. Monitor and review	To assess the effectiveness of the measures taken	Monitor and review strategy for evaluating the impact of measures on construction site
5. Revise measures	To modify an existing measure so as to improve its effectiveness	Improvement plan with measurable indicators to identify ineffective action plan
Stage - Reactive Approach	Aim	Outcomes
1. Identify KM dimension	To identify whether problem is knowledge based or not	Clarification of the KM dimension in each specific problem
2. Determine if required knowledge is available	To discover if the knowledge to solve a given problem is available	Determination of the site manager's level of knowledge to solve a given problem
3. Identify the type(s) of knowledge required	To identify the type of knowledge required to solve the site management problem	Specific knowledge type(s) for typical site management problems
4. Identify the characteristics of knowledge	To identify the characteristics of the knowledge required. Use 'CLEVER' framework to support this stage (Anumba <i>et al.</i> , 2005)	Set of characteristics of the required knowledge
5. Select applicable KM processes	To facilitate the selection of the applicable KM processes	Appropriate KM processes for addressing a particular problem
6. Identify KM technologies and techniques	To identify KM technologies and techniques for the selected KM processes. Use 'SELEKT' framework to support this stage (Al-Ghassani <i>et al.</i> , 2005)	Set of applicable KM technologies and techniques
7. Implement KM initiatives	To implement KM initiatives to assist the site manager in resolving site management problems	Implemented KM initiatives
8. Monitoring and review	To assess the effect of the KM initiatives in relation to what was meant to be achieved	Report on effectiveness of implemented KM initiatives
9. Revise KM initiatives	To modify existing KM initiatives so as to improve their effectiveness	Revised KM initiatives and action plan

When using a framework, it is crucial to consider one site management problem at a time. This will provide a central focus for all stages in the framework. As such, this framework incorporates a part of the CLEVER (Cross Sectoral Learning in the Virtual Enterprise) framework, and thus has the capability to identify the characteristics of the knowledge required in an organisation. The CLEVER framework is a well-established KM framework developed at Loughborough University, which focuses on the definition and analysis of a knowledge problem in order to facilitate the selection of an appropriate KM strategy within an organisation (Anumba *et al.*, 2005). The framework also adopts a part of the SeLEKT (Searching and Locating Effective Knowledge Tools) framework which facilitates the selection of KM techniques and technologies in any given situation as illustrated in Appendix 4.

6.3.3 Proactive Knowledge Management Approach

The proactive KM approach consists of five inter-related stages. Table 6.7 summarises the stages and key diagnostic questions; these are described below:

Stage 1: Specify site management process

The aim of this stage is to specify which construction site management processes the site manager wishes to focus on. It will assist the site manager to 'think through' the site problem in a 'structured way'. This stage requires the site manager to select one of the six main site management processes: management and administration, commercial management, health and safety management, planning and monitoring, materials management, and production on-site and off-site. He/She also needs to state the potential problem that needs to be avoided on the construction site. The main outcome of this stage is a clarification of the problem area (site management processes) and the specific problem that needs to be avoided on the construction site.

Stage 2: Identify relevant measures

This stage focuses on identifying available solutions for the potential problems identified. The first question at this stage (What measures are available for avoiding potential problems?) asks the site manager to explore measures by using his previous experience. It seeks to discover possible measures to avoid the problem; with a view to decreasing the probability of a similar problem occurring. Depending on the nature of the problem under consideration, more than one measure can be identified, whether for the long term or short term plan. At this stage, the site manager can act as a facilitator in a site management team meeting to find measures for site management problems that they plan to avoid on the construction site. The main outcome of this stage is a set of alternative measures to avoid a specific problem occurring.

Stage 3: Implement measures

This stage involves implementing the identified/chosen measures so as to avoid problems and to reduce their impact if they do occur. The site manager should use this stage to develop an action plan for each problem that he/she has decided to avoid. The main outcome of this stage is implemented measures to avoid potential problems occurring.

Stage 4: Monitor and review

The aim of Stage 4 is to provide a structured approach for evaluating the effectiveness of the measures taken. The site manager has to examine whether the chosen measures have been able to avoid the identified problems. If the site manager is not fully satisfied with the efficiency of the chosen measures, he/she is asked to specify what additional measures need to be taken. The main outcome from this stage is the monitor and review strategy for evaluating the impact of measures on construction site.

Table 6.7: Stages and Key Diagnostic Questions in the Proactive KM Framework.

Stage	Diagnostic Question	Problem	Measures
Stage 1	Specify site management process and problem to avoid		
	Which site management process are you interested in?	a) Management b) Commercial c) Health and safety d) Planning and monitoring e) Material management f) Production	
	Respond to problem proactively		
	What site management problem do you wish to avoid?		
Stage 2	Identify relevant measures		
	What measures are available for avoiding potential problems?		
Stage 3	Implement measures		
	How should chosen measures be implemented?	a) Who is involved? b) List tasks c) List available resources	
Stage 4	Monitor and review		
	Have chosen measures been able to avoid identified problems?	a) No (<i>Revise</i>) b) To some extent (<i>Next question</i>) c) Yes	
	Are you satisfied with current measures in avoiding the identified problem in this project?	a) Revise b) Monitor	
Stage 5	Revise measures		
	Why is the existing measure ineffective?		
	What additional issues need to be addressed?		
	What other measures can address the outstanding issues?		

Stage 5: Revise measures

This involves modifying or replacing existing measures so as to improve their effectiveness. This is usually necessary where the measures are adjudged to be ineffective in addressing a given problem. The first question at this stage (Why is the existing measure ineffective?) asks the site manager to suggest reasons for the failure of the adopted measures. The site manager then has to specify what additional issues need to be addressed and what additional measures are necessary. The main outcome of this stage is an improvement plan with measurable indicators to identify an effective action plan.

6.3.4 Reactive Knowledge Management Approach

The reactive knowledge management approach aims to solve specific SM problems that have a KM dimension. Table 6.8 summarises the stages and key diagnostic questions in the reactive knowledge management approach and involves the following nine stages:

Stage 1: Identify KM dimension

The aim of this stage is to clarify whether or not a given problem is knowledge-based. It involves two main tasks: a clear description of the problem and subjective analysis of the associated KM dimension (if any). If there is no KM dimension for the problem, the site manager needs to identify a possible solution. The main outcome of this stage is a clarification of the KM dimension in each specific problem.

Stage 2: Determine if required knowledge is available

Stage 2 is aimed at determining if the site manager has the required knowledge to solve a given problem. The previous experience and technical dimension of tacit knowledge (Nonaka and Takeuchi, 1995) of the site manager plays an important role in this stage. Basically, a site manager develops a wealth of expertise 'at his fingertips' after years of experience, but he is often unable to articulate the scientific or technical principles behind what he knows. The main question (Do you have required knowledge?) refers to the process of analysing the ability of the site manager to solve a site management problem. It seeks to discover the level of knowledge of the site manager. If the site manager has the required knowledge, he needs to solve the problem. If he/she does not have such knowledge, he/she needs to proceed to the next step in the reactive KM approach. The main outcome of this stage is a determination of whether the site manager has the knowledge to solve a given problem or if further KM initiatives are necessary.

Table 6.8: Stages and Key Diagnostic Questions in the Reactive KM Framework.

Stage	Diagnostic Question	Solutions
Stage 1	Identify problem and its knowledge	
	Which site management process does site management problem fall under?	
	What site management problem are you planning to solve?	
	Is there a KM dimension to the problem?	(a) Yes (b) No (find another solution)
Stage 2	Determine if required knowledge is available	
	Do you have the required knowledge	(a) Yes (solve the problem) (b) No
Stage 3	Type(s) of knowledge	
	What type of knowledge is required?	
Stage 4	Identify the characteristics of knowledge (CLEVER)	
	What are the characteristics of the knowledge?	(a) Explicit – Tacit (b) External - Internal (c) Individual – Shared
	What is the ‘Source’ of knowledge	(a) People (b) Software (c) Paper
	What is the ‘Destination’ of knowledge	(a) People (b) Software (c) Paper
Stage 5	Select applicable KM processes	
	Select generic KM process model	(a) Locating knowledge (b) Sharing knowledge (c) Updating knowledge
Stage 6	Identify KM techniques and technologies	
	Identify KM techniques and technologies to resolve the problem?	(a) Database of KM techniques (b) Database of KM technologies
Stage 7	Implement KM initiatives	
	What is the action plan?	(a) Action plan for locating knowledge (b) Action plan for sharing knowledge (c) Action plan for updating knowledge
Stage 8	Monitoring and evaluation	
	Have KM initiatives been able to solve the problem?	a) No (<i>Revise</i>) b) To some extent (<i>Next question</i>) c) Yes
	Are you satisfied with current KM initiatives in solving the problem?	a) Revise b) Monitor
Stage 9	Revise KM initiatives	
	Why is the existing KM initiative ineffective?	
	What additional issues need to be addressed?	
	What KM initiative can address the outstanding issues?	

Stage 3: Identify type(s) of knowledge

The aim of stage 3 is to identify the type of knowledge required to solve the site management problem. It seeks to help discover the knowledge gap that has led to a given site management problem. For example, if the site manager plans to solve a shortage of labour resources on the construction site, he/she needs to discover the knowledge gap that has led to shortage of labour resources. In resolving this problem, he/she may need to have knowledge of labour suppliers and key workmen. The output of this stage is the specific knowledge type required for solving a given site management problem.

Stage 4: Identify the characteristics of knowledge

The aim of this stage is to provide a structured approach for identifying the characteristics of the knowledge required. The implementation of this stage is supported by the CLEVER framework (Anumba *et al.*, 2005). The CLEVER framework enables the identification of the characteristics of the knowledge required and the key dimensions and transfer issues associated with it. Three key dimensions have been identified as critical for the knowledge transfer issues (Al-Ghassani *et al.*, 2005):

- Knowledge conversion types (the tacit-explicit dimension);
- Knowledge ownership forms (the ‘personal-shared’ dimension); and
- Knowledge transfer domains (the ‘internal-external dimension’).

The main output of this stage is a set of characteristics of the required knowledge.

Stage 5: Select applicable KM processes

Stage 5 is aimed at facilitating a structured approach to the selection of applicable KM processes. The selection stage uses ‘generic process models’ developed within the CLEVER framework environment (Anumba *et al.*, 2005). There are four steps involved

in this stage: Identify how knowledge is acquired, Identify knowledge sources, Identify resistors and enablers and select appropriate KM processes. A clear identification of the 'source' and 'destination' of knowledge to be transferred will determine whether it is people-to-people transfer, people-to-paper transfer, etc. This stage also identifies 'resistors' and 'enablers' that may affect the transfer of knowledge. This enables the site manager to develop an action plan for implementing the selected KM processes. The main output of this stage is a set of appropriate KM processes for addressing a particular site management problem.

Stage 6: Identify KM techniques and technologies

The aim of Stage 6 is to identify KM techniques and technologies for the selected KM processes. There is a preponderance of KM techniques (non-IT tools) and KM technologies (IT tools) available to support knowledge management (Al-Ghassani *et al.*, 2005). While the classification is debatable, it represents a useful framework for discussing IT and non-IT support for knowledge management. It is difficult to select the most appropriate initiatives for a specific problem. The selection of KM initiatives requires clear identification of site management problems and at the same time requires explicating the KM dimension for each problem. The selection of KM techniques and technologies adopted the 'KM Tool Selector' a part of the SeLEKT framework developed at Loughborough University (Al-Ghassani *et al.*, 2005). SeLEKT incorporates a comprehensive database of KM tools, which are divided into Technologies (IT tools) and Techniques (non-IT tools) and are placed in the database according to the KM dimensions that they support. The main output of this stage is a set of applicable KM technologies and techniques.

Stage 7: Implement KM initiatives

The aim of this stage is to implement KM initiatives to assist the site manager in resolving the existing site management problems. The first question at this stage (What is the action plan?) asks the site manager to develop a clear action plan before implementing KM initiatives. It is important to develop an action plan of what is to be

carried out before a KM initiative is implemented. There are two main components of the action plan: available methods and generic sub-activities for each KM process (i.e. generic sub-activities for locating knowledge, sharing knowledge, and updating knowledge). For example, if the site manager selects sharing 'people to people' knowledge as relevant for tackling a given problem on the construction site, the framework will suggest established methods such as mentoring, communities of practice or story-telling. The main output of this stage is an implemented KM initiative for a given problem.

Stage 8/9: Monitor, review and revise KM initiatives

Stage 8 (Monitor and review KM initiatives) and Stage 9 (Revise KM initiatives) of the reactive approach are similar to the processes described for the proactive approach section.

6.3.5 Framework Validation

Validation of the integrated KM framework was undertaken to determine its appropriateness and functionality in improving construction site management practices. Four site managers from the case study organisations and 10 construction management researchers were involved in the evaluation workshop. The participants were encouraged to suggest improvements during the workshop session. The evaluation result showed that the integrated framework can be used as a tool for addressing site management problems. Overall, the proactive KM approach was highly rated at 77% while the reactive KM approach was rated at 71%. The main suggestion was to develop a more generic KM framework on the construction site, which would allow the site manager to customise the construction site management processes. The key suggestions for the improvement to the framework were as follows:

- Consider customisation of the site management processes;
- Improve guidance on the selection of proactive or reactive KM approach; and

- Simplify some structures of the proactive and reactive KM approaches to ensure that they are easily used.

Suggestion 1 was addressed by modifying the generic model of the construction site management processes such that site managers can specify additional construction site management processes. Suggestion 2 was addressed by providing more guidance within the 'Help' facility so that site managers can select the most appropriate KM approach based on the circumstance of the site management problems (i.e. whether pre-construction or during construction stage). Suggestion 3 was overcome in the development of the computer-based prototype system.

6.3.6 The Potential Benefits of the Integrated KM Framework

The rationale underpinning the integrated KM approach is based on a number of issues arising from the literature review and semi-structured interviews with site managers on the construction site. According to Bennett (2000), the best way of dealing with issues and site management problems is to anticipate them, and get teams to practice and rehearse solutions. Also, rehearsal often means that a ready-made answer or solution already exists. Emmitt and Gorse (2003) assert that site management teams should highlight potential problems at the earliest opportunity and work with the organisation to resolve them. It is believed, therefore, that the proposed framework is capable of acting as a structured approach to capturing, storing, sharing and disseminating construction knowledge that is entrenched deep in the construction site management processes. From the validation, the potential benefits of the framework above include:

- Provides a structured KM approach at an operational level that is simple to use, requires a relatively short time to implement, is scalable to any type of project and easily deployable as a problem-solving methodology usable on any construction site;
- Provides robust methods for relating KM initiatives to SM problems to enable site managers to tackle root causes (rather than the symptoms) of the problems;

- Provides for a selection of supporting KM techniques and tools that support the implementation of an effective KM system on the construction site;
- Allows a site manager to select from a range of alternative measures;
- Allows a site manager to monitor and revise existing KM initiatives or measures so as to improve their effectiveness in a given situation;
- Facilitates both a proactive and reactive approach to integrating KM into construction site management practices; and
- Builds on the existing CLEVER and SELEKT knowledge management frameworks.

Further development of the framework involves implementing the framework as a computer-based prototype system; and evaluating the resulting prototype system to establish its benefits and limitations.

6.5 Summary

This chapter has described an attempt to integrate knowledge management processes into site management practices, starting with a critical examination of the existing KM frameworks in construction industry. It was discovered that none of the existing KM frameworks addressed all the key stages of the construction site KM framework proposed in the Chapter 5, section 5.4. The study observed that the CLEVER framework was tailored to the construction site KM framework needs and was found helpful for establishing KM issues and developing KM initiatives. Another framework (SELEKT) was adopted to identify the critical criteria (KM dimensions) required for the tool selection in the framework. Drawing from literature on knowledge management, site management practices, together with the case study findings, the study identified two key benefits of the framework for integrating KM into site management practices. First, the proposed framework provides a platform to make past solutions and standard procedures to solving problems easily accessible (explicit knowledge to solve site management problems). Second, the designed framework can increase the ability of the site manager to learn from his/her environment and to incorporate knowledge into site management practices. The framework also helps site

managers to reduce the number of problems that occur and minimise the negative impact of unpredictable problems. The next chapter examines the prototype system development and system operation in order to simplify the format and use of the integrated KM framework.

CHAPTER SEVEN

Prototype System Development

7.1 Introduction

This chapter describes the development of a prototype system, 'site-KM' that is based on the conceptual framework for integration knowledge management processes into construction site management. It starts by examining the choice of the system development environment. It goes on to describe the system architecture and system development processes for the prototype system. The chapter also demonstrates the operation of the prototype system and concludes with the testing of the prototype system using several problems that often occur on the construction site.

7.2 Objective and Choice of Development Environment

The primary objective of the KM-based construction site management system (also known as 'site-KM') is to facilitate site managers in adopting a knowledge management approach to addressing site management problems. The aim of the prototype system developed in this research is to simplify the format and use of the integrated KM framework for integrating KM processes into site management practices. The specific objectives of the prototype include:

- Clarification of the decision route to be selected;
- Identification of relevant measures;
- Identification of KM dimension and the required knowledge;
- Establishment of KM issues;
- Implementation measures/KM initiatives;

- Establishment of monitor and review strategy;
- Future integration of the system with other systems.

The prototype system was designed for a number of tasks closely linked with the specific objectives stated above. The system was designed to:

- Provide sufficient and user-friendly guidance on how to use the system;
- Allow entry, storage, viewing, and editing information at any stage in the processing activity;
- Allow for easy identification of the characteristics of knowledge;
- Allow for implementing KM initiatives for the generic models within the KM process;
- Allow for easy search and identification of KM tools based on selected 'characteristics of the knowledge';
- Facilitate the selection of available measures to avoid site management problems;
- Allow for monitoring and reviewing the implemented measures/KM initiatives;
- Facilitate the revision of implemented measures/KM initiatives;
- Facilitate the generation of reports that can be viewed at the different stages; and
- Allow for future integration with other KM tools.

The prototype system involves three stages. The first stage guides the site manager in selecting the most appropriate KM approach, with a view to deciding, whether to adopt a proactive or reactive KM approach to site management problems. The second stage allows the site manager to implement the proactive KM approach, which consists of the following processes: specify site management process, measures taken, implementation plan, monitor and review and revise measures. The third stage allows the site manager to implement the reactive KM approach which consists of the following processes: identify KM dimension, determine knowledge, identify type of knowledge, identify characteristics, select KM processes, identify KM tools, implement KM initiatives, monitor and review and revise KM initiatives. The main role of the prototype system is to support the site managers in addressing site management problems; by providing a

systematic and effective problem-based knowledge management system on the construction site.

The hardware tools and components are very important for KM systems as they form a platform for the software tools to perform and the medium for the storage and transfer of knowledge. A personal computer or workstation is used to provide a platform for the development of the prototype system. The prototype system has been designed to operate on a Personal Computer (PC) running Windows XP or better. It requires the full installation pack of Microsoft Visual Basic, Version 6.0 and Microsoft Word 2003 (or above) to be installed. About 32Mb of RAM is required to run Visual Basic, Version 6.0 and full installation of the program requires about 200 Mb of disk space. The operation of Visual Basic, Version 6.0 is the same in all versions of Microsoft Windows applications.

Visual Basic is a graphics-program environment that makes it easy to build the front panel of a 'virtual document' with its forms, links, glossary, help facility on a computer screen. Rather than having to write numerous lines of code to describe the appearance and location of interface elements, the researcher can simply add prebuilt objects into place on the screen. Papadopoulos and Limniou (2002) are of the view that the Visual Basic is an environment that provides the necessary tools to build very rapidly user-friendly interfaces in the Windows operating system. The applications that are created run on Windows PC without additional licensing. It also helps to quickly develop the prototype at minimal expense, and the fact that Microsoft Visual Basic 6 has been used in similar research by Al-Ghassani (2003), Papadopoulos and Limniou (2002), and Al-Khlaifat and Alrifai (2002). Visual Basic was selected to be the environment for the development of the prototype system and the selection was based on the following rationale:

- Microsoft Visual Basic provides graphics-program environments that make it easy to build user interface for 'virtual KM system' rather than having to write numerous lines of code using a character-based programming language (e.g. COBOL, BASIC, and FORTRAN);

- The capacity of Visual Basic is sufficient to facilitate future integration with database software product such as Excel and Access;
- In-built design tools facilitate in the development of forms and the generation of reports to meet varying specifications;
- Version 6.0 of Visual Basic enables the connection to the internet via an integration with others programming language such as Java, hypertext markup language (HTML), and Extensible Markup Language (XML)
- It is supplied as a complete programming language containing all requirements to create fully-functioning, stand alone Window EXE application.

Before developing a prototype system, it is important to understand the key elements of Visual Basic. The following section illustrates how easy it can be to create a useful prototype system for site management practices using Visual Basic. Basically, there are two crucial elements of Visual Basic programming language. These are:

Form

The form acts as a window that permits the program operator to communicate with the computer and the instrument to which it is interfaced. Rather than writing numerous lines of code to describe the appearance and location of interface elements, the researcher can simply add prebuilt objects into place on a screen (e.g. element to select characteristics of knowledge, element to select KM technologies, etc.). Visual Basic provides a set of tools that the researcher can use at design time to place controls on a form. Forms and controls are the basic building blocks used to create the user interface, the visual part of the application with which the user will interact. The researcher uses the tool box to draw an option button and a label on the form, as shown in Figure 7.1.

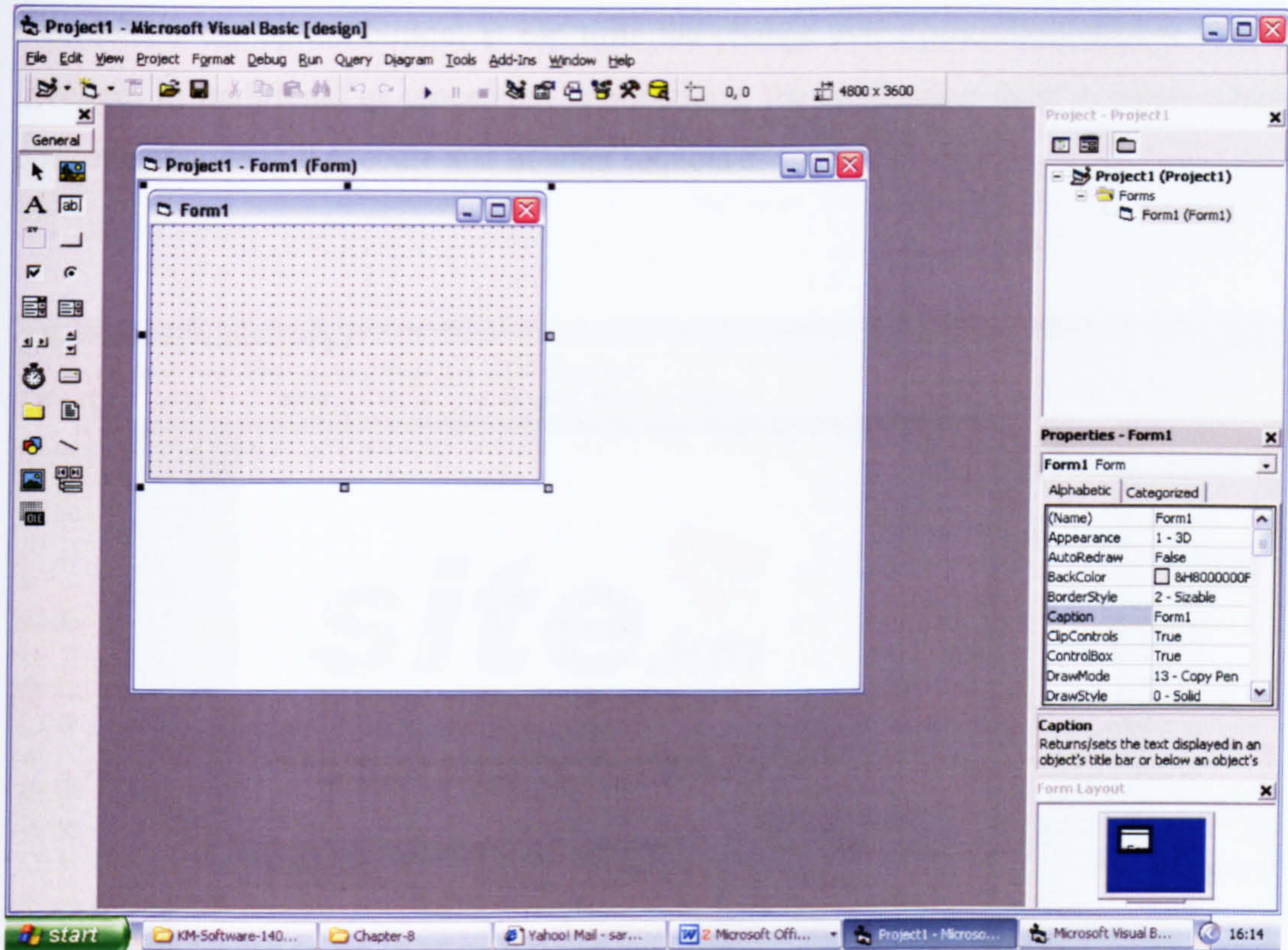


Figure 7.1: Form Designer Window.

Coding events

Code in Visual Basic is stored in modules. Simple applications can consist of just a single form, and all of the code in the application resides in that form module (Morris, 2001). Code that is not related to a specific form or control can be placed in a different type of module, a standard module. Standard modules are containers for procedures and declarations commonly accessed by other modules within the application. They can contain global (available to the whole application) or module-level declarations of variables, constants, types, external procedures, and global procedures. The code that is written in a standard module is not necessarily tied to a particular application; if the researcher is careful not to reference forms or controls by name, standard module can be reused in many different applications. Each form and control in Visual Basic has a predefined set of events. If one of these events occurs and there is a code in the associated event procedure, Visual Basic invokes that code. For example, whenever the

user selects the option button, at run time the change event procedure (Figure 7.2) is invoked. In traditional or procedural applications, the application itself controls which portions of code will execute and in what sequence.

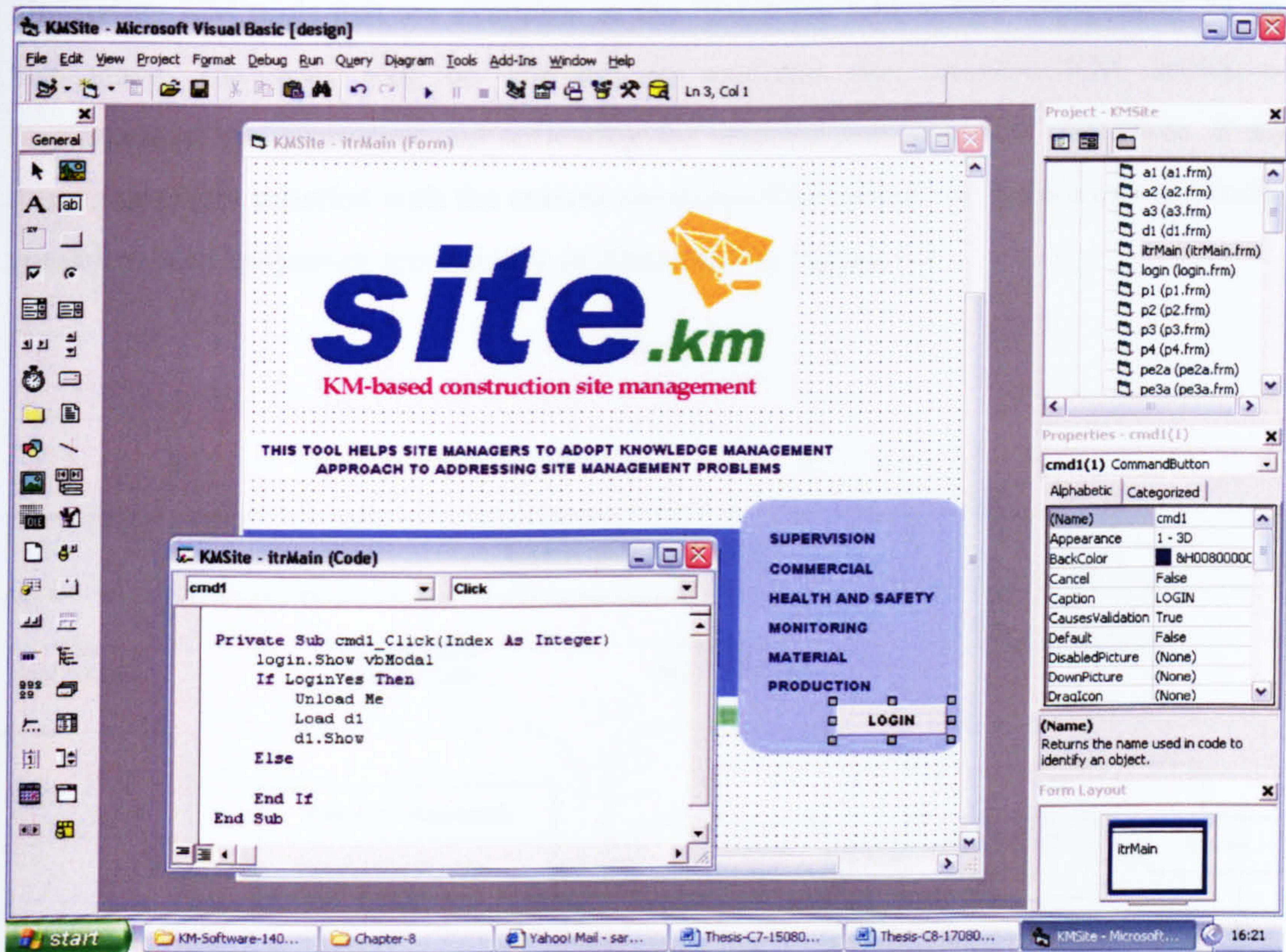


Figure 7.2: Coding Events Procedure in Visual Basic.

7.3 System Architecture

To ensure that the desired features and objectives of the prototype are accomplished, system architecture for the prototype, illustrated in Figure 7.4 was developed. There are four main components that provide the means for developing a KM strategy in construction site management practices. These components are 'Site Management Problem', 'Establish KM Issues', 'Develop Initiatives', and 'Evaluation'.

The solid arrows linking the four components indicate that entry and viewing of information is done forwards. However, the dash arrows at the bottom of the components show that the user can go backwards to edit previous input for any component or part of element. For example, the user thinks that the KM tools are not appropriate to implement KM initiatives, he/she can go backwards to re-select the alternative KM tools that are available in the 'Establish KM Issues' component. In the last stage, the user will be allowed to evaluate the measures/KM initiatives implemented by monitoring and reviewing the selected measures/KM initiatives. If the user is not fully satisfied with the current measures/KM initiatives, he/she can revise the measures/KM initiatives accordingly as illustrated in Figure 7.3.

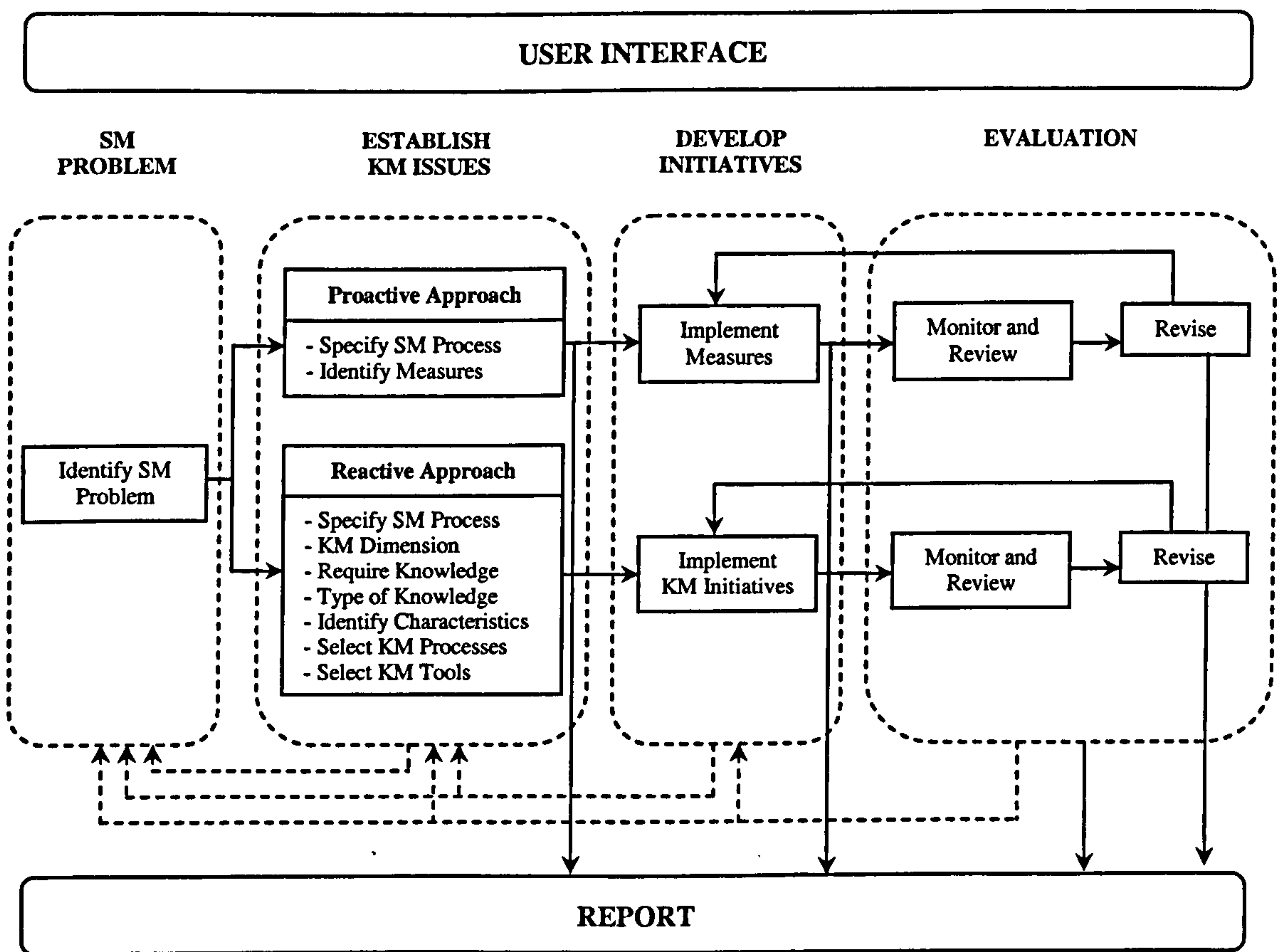


Figure 7.3: System Architecture of the 'site-KM' Prototype.

The arrows linking the elements to the report show that the input, once entered, is immediately sent to the report and instantly modified if input is edited during the process. This report can also be used as a reference document for the site managers when developing a problem-based knowledge management strategy on the construction site.

7.4 System Development

The complete development of the KM system requires a rigorous and formal requirement analysis, predefined specifications, and tight controls over the system building process. It is also costly, time consuming, inflexible and labour intensive. In order to overcome these problems, prototyping is an appropriate approach to developing a working version system of a KM system. Turban and Aronson (1998) argue that the prototyping approach aims at building a knowledge management system in a series of short steps, with immediate feedback from users to ensure that the development is proceeding correctly. According to Smith (1991) a prototyping system is helpful in designing knowledge management system's end-user interface. It also encourages end-user participations in a building the system, and it is more likely to produce systems that fulfil user requirements (e.g. function requirements, data requirements, organisational needs, and operation requirements).






More specifically, by interacting with the prototype system, users can get a better idea of their information requirements. The main feature of a prototype system is that prototyping replaces unplanned rework with plan iteration, with each version more accurately reflecting users' requirements. The iterative process includes the following four tasks (Turban and Aronson, 1998):

- *Select an important sub-problem to be built first:* The researcher identifies a sub-problem for which the initial KM system is constructed;
- *Develop a small but usable system for the decision maker:* No major system analysis or feasibility analysis is involved;

- *Evaluate the system constantly:* Evaluation is an integral part of the development process, and is the control mechanism for the entire iterative design process; and
- *Refine, expand and modify the system in cycles:* Subsequent cycles expand and improve the original version of the KM system.

The development of the 'site-KM' prototype followed the general procedure for developing a Visual Basic program. A Visual Basic program is a coordinated set of forms, macros and reports. In this context, the user interacts with the system through the main forms. Other forms are embedded within the main forms and activated by the use of command buttons. There are several standard controls of the Visual Basic toolbox which are used to design the forms (Morris, 2002). Table 7.1 shows common standard controls used to design the prototype system:

Table 7.1: Common Standard Controls (Morris, 2002).

Standard Controls	Features	Description
Command Button		This control is used for performing actions. A procedure is attached to each command button and is executed when the user clicks on the button.
Option Button		This control usually appears in groups of two or more, and all the buttons on a form are interrelated. The control consists of a circle with a piece of text next to it.
Check Box Button		This control works in a similar way to the option buttons, the main difference being that they operate independently of each other. As a result, the user may select several boxes at the same time by clicking on them or turning all boxes off.
Text Box Button		This control provides the simplest method for the user to enter data and information. When this control has the focus, a vertical cursor is displayed and the user can make an entry.
Frame Button		This control allows the developer to group controls together. Frame is needed if the developer wants more than one set of option buttons on a screen. Frames can also be used to improve the appearance of the window.

The development of a Visual Basic involves the information needs of the system with reference to the flow of data and information, and design of the database objects that will solve those information problems. There are three main types of forms which are developed: input forms, output forms and help forms. The main roles of such forms are to input, edit and view the information. In order to guide users to use the system effectively, the help forms were embedded within the input forms and describe the tasks to be undertaken in the input forms. Controls, event procedures and general procedures were used to design the forms. Table 7.2 provides a summary of how the desired features of the 'site-KM' prototype were implemented in the development process.

Table 7.2: Summary of How Required Features for 'site-KM' were Implemented.

Required Features	How Achieved
Provide sufficient and user-friendly guidance on how to use the system	<ul style="list-style-type: none"> • In relevant forms, help buttons are embedded within input forms to provide guidance on completing the forms
Allow entry, storage, viewing, and editing information at any stage in the processing activity	<ul style="list-style-type: none"> • Designed forms allow display and editing of stored data • Command buttons inserted in the forms allow easy navigation between the forms at any stage of the activity
Facilitate the selection of the available measures to avoid site management problems	<ul style="list-style-type: none"> • Four option buttons are used to select available measures • Database of measures are located in the Visual Basic application based on site management processes
Allows for easy identification of characteristics of knowledge	<ul style="list-style-type: none"> • Five option buttons are used to select the characteristics of the knowledge
Allow for implementing KM initiatives for the generic models within the KM process	<ul style="list-style-type: none"> • A 'Check box' button describing the generic KM processes can be activated by clicking it
Allow for easy search and identification of KM tools based on selected 'characteristics of the knowledge'	<ul style="list-style-type: none"> • Five option buttons are used for identifying the characteristics of the knowledge • Locations of the option button are used to search the database
Allow for monitoring and reviewing the implemented measures/KM initiatives	<ul style="list-style-type: none"> • Three option buttons are used to assess the impact of measures/KM initiatives in assisting the site managers to addressing problems
Facilitate the revision of the implemented measures/KM initiatives	<ul style="list-style-type: none"> • A command button, in the last form, allows for revise measures/KM initiatives, which is then fed back to the implement measures/KM initiatives forms
Facilitate the generation of report that can be viewed at the different stages	<ul style="list-style-type: none"> • A 'Report Preview' button can be activated at the end of the any stages in the proactive and reactive KM approach forms.
Allow for future integration with other KM tools	<ul style="list-style-type: none"> • As a Microsoft product, Visual Basic can be easily linked to other packages such as Microsoft Access, Microsoft Word, Web browser, etc.

The Visual Basic has automatic code generation capability. The codes are generated automatically when, for example, the applications forms and controls are created. Other codes for handling decisions have been developed. The following sections describe an example of how the 'site-KM' prototype would function in a real-life application. Details of the important codes developed for handling major decision stages are listed in **Appendix 5**. A common feature of Windows applications is to have windows within the main window program. In the Visual Basic, this is achieved through MDI – Multiple Document Interface – Forms, as shown in Figure 7.4.

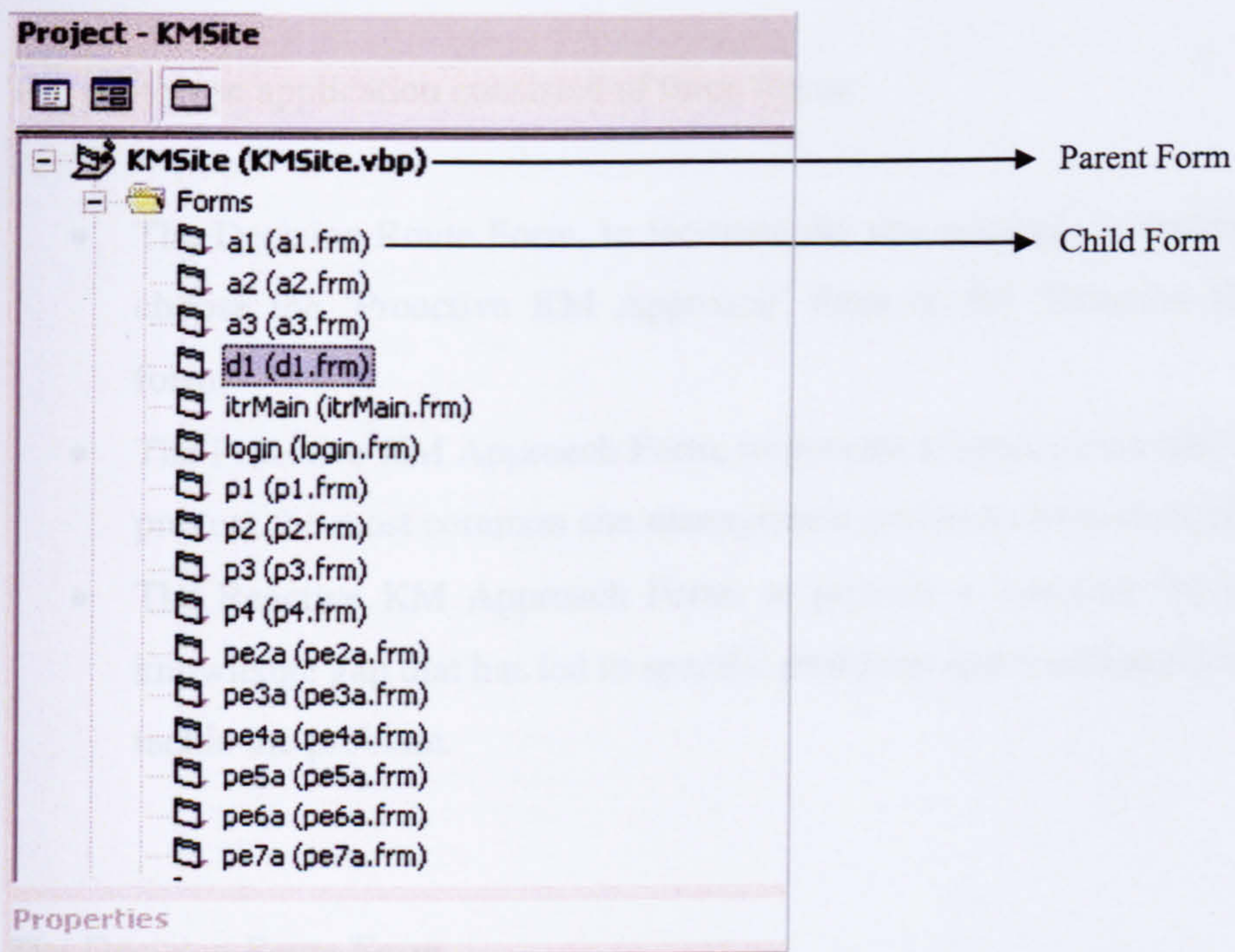


Figure 7.4: Multiple Document Interface (MDI) Forms.

Child forms are designed and used largely as normal. At design stage, the form is handled as a separate entity, but at runtime stage, size and position can be adjusted using layout controls. When the program is executed, the child form will be shrunk to fit within the MDI form.

In this system development, most of the events coding were made using the **If...Then...End If** set of statements (Figure 7.5), which take the form:

<p>If <i>condition</i> Then Statements End If</p>

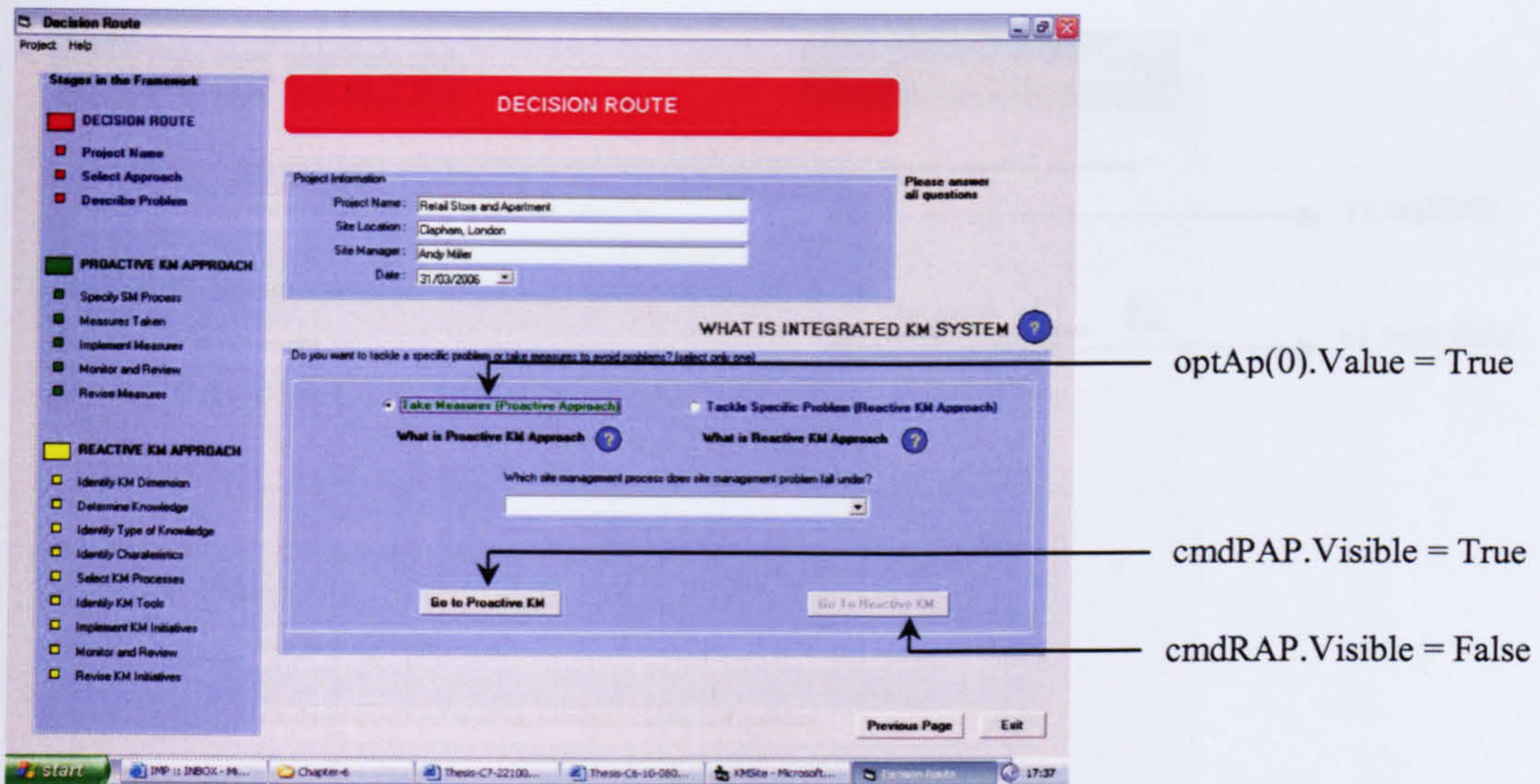
Figure 7.5: 'If...Then...End If' Set of Statements.

The prototype application consisted of three forms:

- The Decision Route Form, to facilitate the site manager in deciding whether to choose the 'Proactive KM Approach' form or the 'Reactive KM Approach' form;
- The Proactive KM Approach Form, to provide a structure for taking measures to prevent the most common site management problems from occurring; and
- The Reactive KM Approach Form, to provide a structure for identifying the knowledge gap that has led to specific problems and recommending measures to tackle the problem.

The Decision Route Form

In order to facilitate site managers dealing with site management problems in an effective way, The Decision Route Form was designed to provide a decision point, whether to adopt a proactive or reactive KM approach to solve problems. In this context, if the user select 'Proactive Approach' option button labelled as 'IbIPAP', the system will direct the user to the 'Proactive KM approach' path as shown in Figure 7.6. The option button labelled as 'IbIRAP' is coded to direct user to the 'reactive KM approach' path. All forms related to the 'IbIRAP' are coded as 'False' in 'IbIPAP' event. In this context, most of the time there are options to be made and, as a result, statement to be executed only if a condition is true.



```

Private Sub optAp_Click(Index As Integer)
    If optAp(0).Value = True Then
        lblPAP.Visible = True
        cbo1.Visible = True
        lblRAP.Visible = False
        cmbRAP.Visible = False
        cmdPAP.Enabled = True
        cmdRAP.Enabled = False
    Else
        lblPAP.Visible = False
        cbo1.Visible = False
        lblRAP.Visible = True
        cmbRAP.Visible = True
        cmdPAP.Enabled = False
        cmdRAP.Enabled = True
    End If
End Sub

```

Figure 7.6: Decision Route Events.

The Proactive KM Approach Form

The Proactive KM approach Form provides a proactive way of dealing with site management problems. The form was designed to allow site managers to access the structured 'set of alternative measures' stored in the permanent database system as illustrated in Figure 7.7. An important goal of 'site-KM' is to help site managers in addressing site management problems using previous experience in a structured way.

PROACTIVE APPROACH

P 1 2 3 4 5

Site management problem to be avoided

Please answer all questions

Difficulty in monitoring and enhancing awareness of Health and Safety Plan → r1.txtSMP

Relevant site management process is:

Health and Safety Management

What are site management processes ? → r1.txtRSMP

Select/specify measures to avoid the problem from available measures

Please select one measure only.

Measure 1 Employ safety specialists

Measure 2 Conduct training and induction for sub-contractors, suppliers and operatives

Measure 3 Distribute safety bulletin monthly or weekly

Other (Specify) → txtSol

```

Private Sub cmbRAP_Click()
    r1.txtSMP.Clear
    If UCCase(cmbRAP.Text) = UCCase("Management, Supervision And Administration") Then
        r1.txtSMP.AddItem "Lack of cooperation and motivation"
    ElseIf UCCase(cmbRAP.Text) = UCCase("Health and Safety Management") Then
        r1.txtSMP.AddItem "Difficult in monitoring and enhance awareness of Health and Safety Plan"
    ElseIf UCCase(cmbRAP.Text) = UCCase("Planning, Monitoring And Control") Then
        r1.txtSMP.AddItem "Inability to accurately resource plan and schedule"
    ElseIf UCCase(cmbRAP.Text) = UCCase("Delivery and Materials' Handling") Then
        r1.txtSMP.AddItem "Materials damage and defects"
        r1.txtSMP.AddItem "Poor quality of materials"
    ElseIf UCCase(cmbRAP.Text) = UCCase("Production On-site and Off-site") Then
        r1.txtSMP.AddItem "Lack of quality control"
    Else

    End If
    r1.txtSMP.AddItem "Others (Please Specify)..."

```

Figure 7.7: Structured Common Site Management Problems Code.

More specifically, the 'Proactive KM Approach' form can facilitate the site managers in two different ways:

- Using a structured database of common site management problems stored in the system;
- Using a description of the problem and suggested measure by site managers.

The structured database of common site management problems comprises a search module and a solution module. The search module provides the site managers with a search capability that can be used to retrieve solutions to the problems. The designated administrators have authorisation to create and update databases for the structured information.

The code listed in Figure 7.7 extracts all the relevant site management problems from the database. By breaking down tasks into procedures, it facilitates the developer in making the program code more modular and readable. In this form, certain tasks need to be repeated several times in the program; the code is located inside the procedure, then the code is duplicated to the events in the program. Then each time the task needs to be performed the code in the procedure is run, or 'called'.

The Reactive KM Approach Form

The Reactive KM Approach form contains the site management problem and the details of the KM dimension, type of knowledge, characteristics of knowledge, KM processes, KM tools, and implement KM initiatives. Figure 7.8 shows the design view of the reactive KM approach form.

Selecting a particular site management problem (i.e. Materials damage and defects) displays the type of knowledge required to solve problem. `txtSMP.Text` is a Text box to display the site management problem that the user plans to solve. This control also allows the user to specify the problem that he/she plans to resolve. When clicked, its code will suggest `txtKMKR.Text`; type(s) of knowledge required to solve a given problem by searching in the system database. Option buttons are designed to ensure that only one event can be selected at any one time. The option buttons are placed within

frames as each framed set is treated separately. The user needs to select one of the provided option buttons in order to move to the next stage.

```

Private Sub txtSMP_Click()
    txtKMKR.Clear
    If txtSMP.Text = "Others (Please Specify)..." Then txtSMP.Text = ""
    If txtSMP.Text = "Lack of cooperation and motivation" Then
        txtKMKR.AddItem "Knowledge of site supervision"
        txtKMKR.AddItem "Knowledge of site communication"
        txtKMKR.AddItem "Knowledge of motivational techniques"

    ElseIf txtSMP.Text = "Materials damage and defects" Then
        txtKMKR.AddItem "Knowledge of material storage and materials handling"
    ElseIf txtSMP.Text = "Poor quality of materials" Then
        txtKMKR.AddItem "Knowledge of reputable suppliers, checking and control systems for
material requisition"
    End If
    txtKMKR.AddItem "Other Knowledge (Please Specify)..."
    txtKMKR.Text = txtKMKR.List(0)
    Call txtSMP_Change
End Sub

```

Figure 7.8: Design View of the Reactive KM Approach Form.

7.5 System Operation

Running the 'site-KM' requires the installation of Microsoft Visual Basic, Version 6, although it is possible to convert it into a stand-alone application using the Windows EXE applications. When the file containing 'site-KM' is opened, a main screen, which

provides a gateway to other forms in the applications, is displayed. Figure 7.9 shows the main screen of 'site-KM' prototype system. The main screen contains the primary objective of the 'site-KM', construction site management processes and 'Log In' button. The 'Log In' button provides a gateway to other forms in the application and requires users to write a specific password to run the application.



Figure 7.9: 'site-KM' Main Screen.

7.5.1 Decision Route

This stage starts with the input information on the project; project name; site location, site manager's name; and date. This stage guides the site managers either to select a proactive KM approach or a reactive KM approach. Figure 7.10 shows the forms for entering, viewing and editing the project information and the two main KM approaches: proactive approach (to take measures to avoid problems); and reactive approach (to

tackle a specific problem). The help button 'What is Integrated KM System' provides enough guidance for facilitating the site manager in deciding whether to select a proactive or reactive KM approach. The stages in the prototype system are based on three different colour codes, red for decision route stage, green for proactive approach stage, and yellow for reactive approach stage, reflecting different stages of the 'site-KM' prototype system.

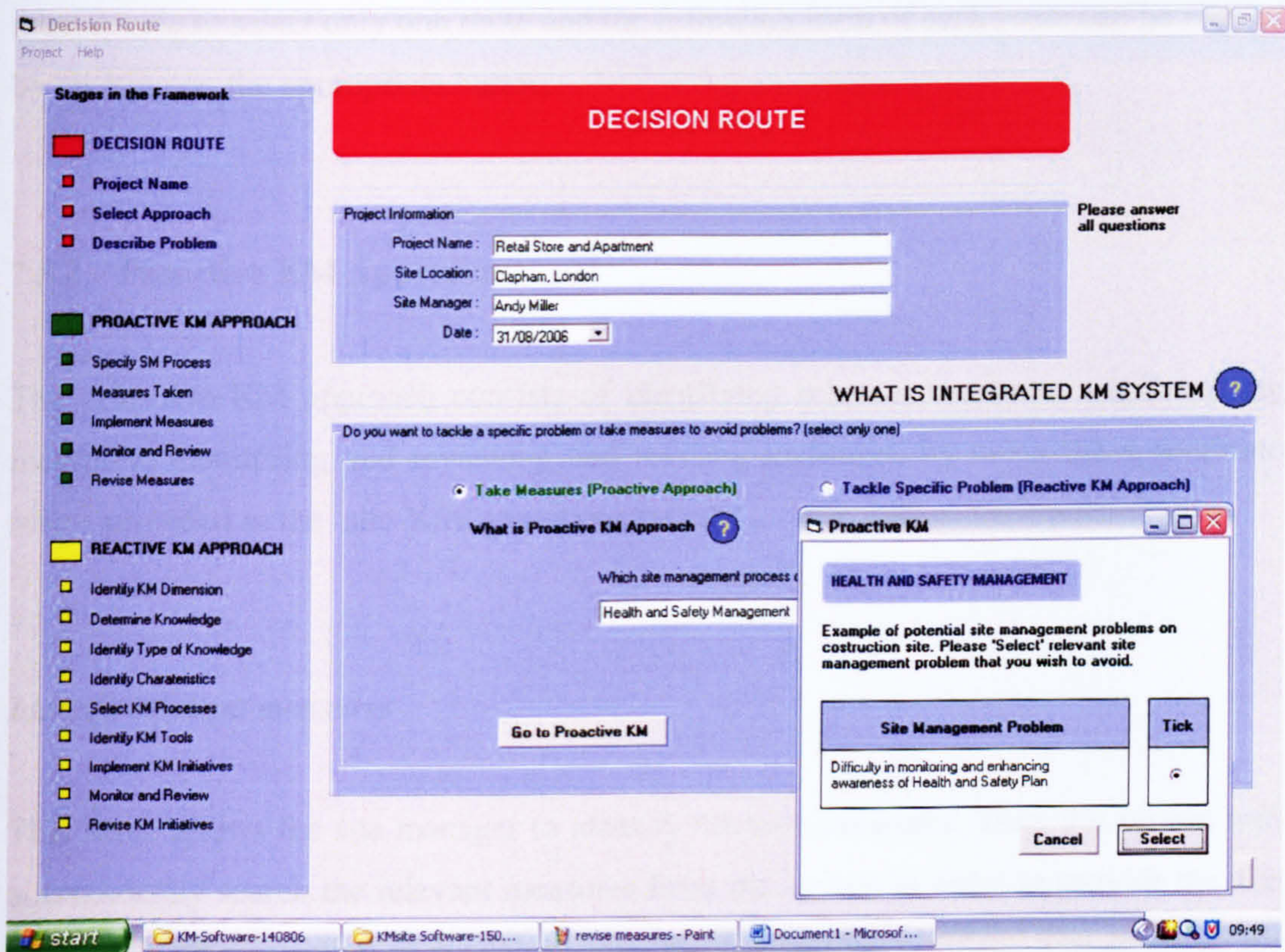


Figure 7.10: Decision Route Page.

The rationale for this stage is that the site management problems occur in different contexts within site management practices. An integrated KM framework will help solve and avoid the problems associated with site management practice. This function provides an opportunity for the site manager to address site management problems based on a proactive approach or reactive approach. The site manager is then required to specify which site management process he/she wishes to focus on. Based on the site

management process selected by the site manager, the system is capable of searching the database to provide a list of site management problems associated with that construction site process. For example, when the site manager clicks the cursor on the selected site management process in the list box, a pop-up form will open (Figure 7.6) providing the site manager examples of potential site management problems with that particular construction site management process. However, if the site manager thinks that the suggested problem is not relevant, the system also allows the site manager to describe the type of problem that he/she needs to resolve. Finally, the site manager must decide to select only one route and the following form of each route can be viewed by clicking on the appropriate button.

7.5.2 Proactive KM Approach

The proactive KM approach consists of identifying relevant measures, implementing measures, monitoring and reviewing and revising measures, by using the appropriate forms provided in the 'site-KM' prototype system.

Identify relevant measures

This stage allows the site manager to identify relevant measures. Then the system will automatically search the relevant measures from the system in order to provide the site manager with a selection of available measures to avoid the problem. The rationale for this function is that the alternative measures will help the site manager to think in a wider picture to avoid problems from occurring. However, it is not a requisite for the site manager to select the available measures; he/she also can suggest the best knowledge from his/her experience to solve the problems by describing the nature and type of knowledge to be used. This could be a general statement, which does not need to be very specific at this stage as it will be refined later. After the available measure has been specified, by clicking 'Report Preview' button, the site manager can view a report on the information entered and also can proceed to the following forms by clicking 'Next' button as illustrated in Figure 7.11.

The screenshot shows the 'Proactive KM' software interface. On the left, a navigation pane lists 'Stages in the Framework' with three main sections: 'DECISION ROUTE' (Project Name, Select Approach, Describe Problem), 'PROACTIVE KM APPROACH' (Specify SM Process, Measures Taken, Implement Measures, Monitor and Review, Revise Measures), and 'REACTIVE KM APPROACH' (Identify KM Dimension, Determine Knowledge, Identify Type of Knowledge, Identify Characteristics, Select KM Processes, Identify KM Tools, Implement KM Initiatives, Monitor and Review, Revise KM Initiatives). The 'PROACTIVE KM APPROACH' section is currently active.

At the top, a progress indicator shows a 'P' followed by steps 1 through 5. A 'PROACTIVE APPROACH' button is visible in the top right. The main form area contains the following elements:

- Site management problem to be avoided:** A text box containing 'Difficulty in monitoring and enhancing awareness of Health and Safety Plan'.
- Relevant site management process is:** A text box containing 'Health and Safety Management'.
- Select/specify measures to avoid the problem from available measures:** A section titled 'Please select one measure only.' with three radio button options:
 - Measure 1: Employ safety specialists
 - Measure 2: Conduct training and induction for sub-contractors, suppliers and operatives
 - Measure 3: Distribute safety bulletin monthly or weekly
 - Other (Specify): [Empty text box]

Navigation buttons at the bottom include 'Previous', 'Report Preview', and 'Next'. A status bar at the bottom shows the Windows taskbar with the Start button, open applications (KM-Software-140806, KMsite Software-150..., decision-route - Paint), and system tray icons (VirusScan On-Access Scan is enabled, 09:38).

Figure 7.11: Identify Relevant Measures Stage.

Implement measures

To ensure that the specified/chosen relevant measures are implemented in a systematic and structured way, the site manager is required to complete a number of tasks for each problem that he/she has decided to avoid. Each task consists of a set of questions or issues about:

- Who is involved;
- List of tasks; and
- List of available resources.

While completing the forms, the site manager has an opportunity to return to the previous form to modify the input. For example, if the site manager thinks that the

selected measure to avoid the problem is not appropriate for the problem occurring on the construction site, he/she can return to the previous form by clicking 'Previous' button. At this stage, the site manager will be allowed to view the reports on the information selected and entered on the previous form. The main reason is so that the site manager can discuss with the site management team in order to obtain relevancy and relationship between the chosen measures and implementation plan. That is, the selected measures must provide a clear justification for the associated implementation plan. Figure 7.12 shows the 'Implement measures' stage in the proactive KM approach.

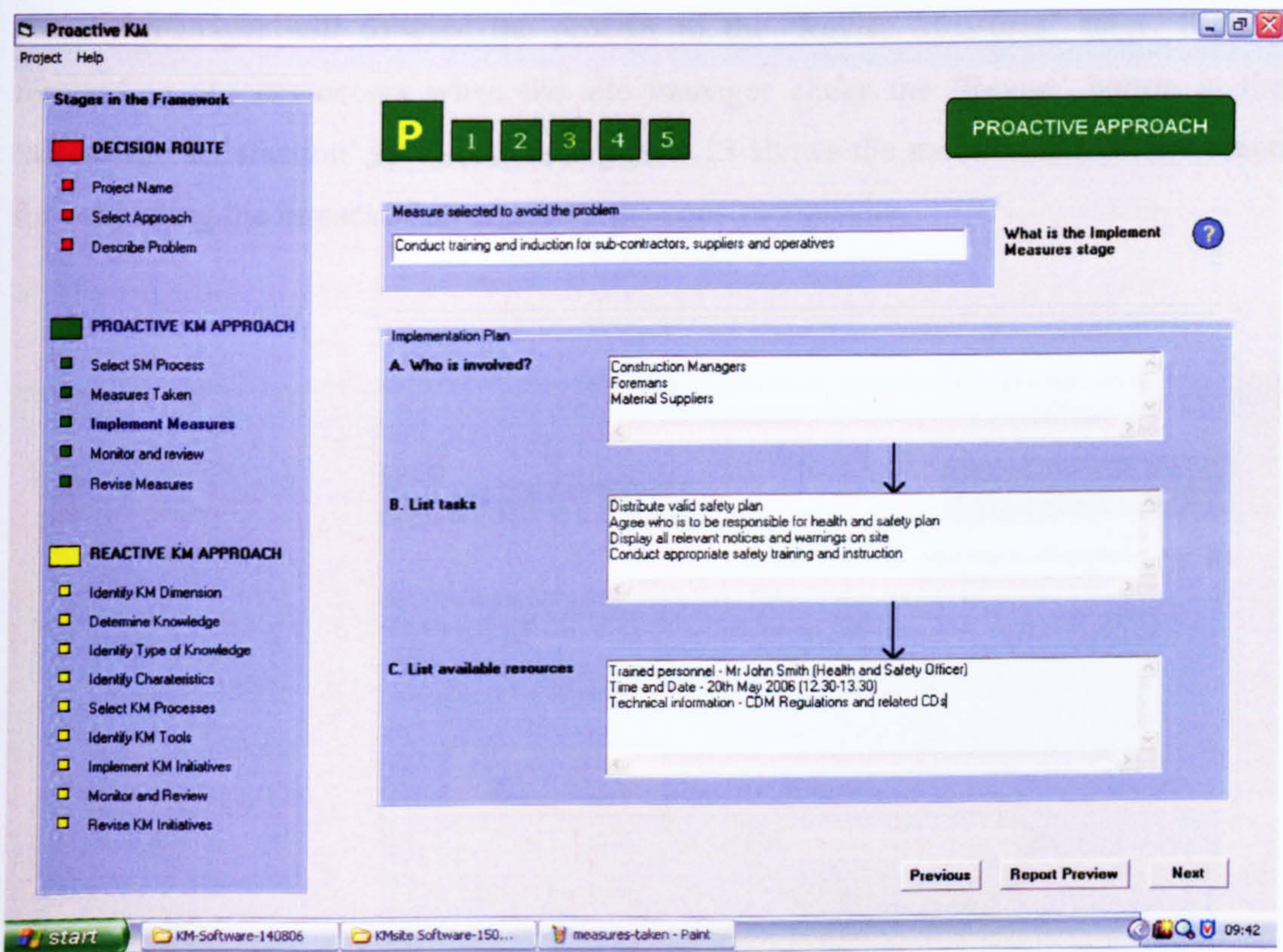


Figure 7.12: Implement Measures Stage.

Monitor and review

This task involves a process of monitoring and reviewing the selected/chosen measures to determine the effectiveness in avoiding site management problems. The system

provides a simple and relevant evaluation tool consists of a set of tick box to assess the impact of measures to allow the site manager to avoid a problem. Two main aspects were considered in designing the evaluation tools; ease of use and appropriateness to the site management context. In this stage, the evaluation has been divided into two levels of assessment, first and second. The first level is to assess the ability of the chosen measures to avoid the identified problems. The second level is to assess the satisfaction level of the site manager with current measures in avoiding identified problems specific to the construction site in question. For example, if the site manager clicks the 'No' button in the 'assess the ability of chosen measures' level, the system will direct the site manager to the 'Revise Measures' button; once this button is clicked, the site manager will forward the process to the 'Revise Measures' stage. Similar forwarding process occurs when the site manager clicks the 'Revise' button in the 'assess the satisfaction' level button. Figure 7.13 shows the monitor and review stage for evaluating the impact of measures on the construction site.

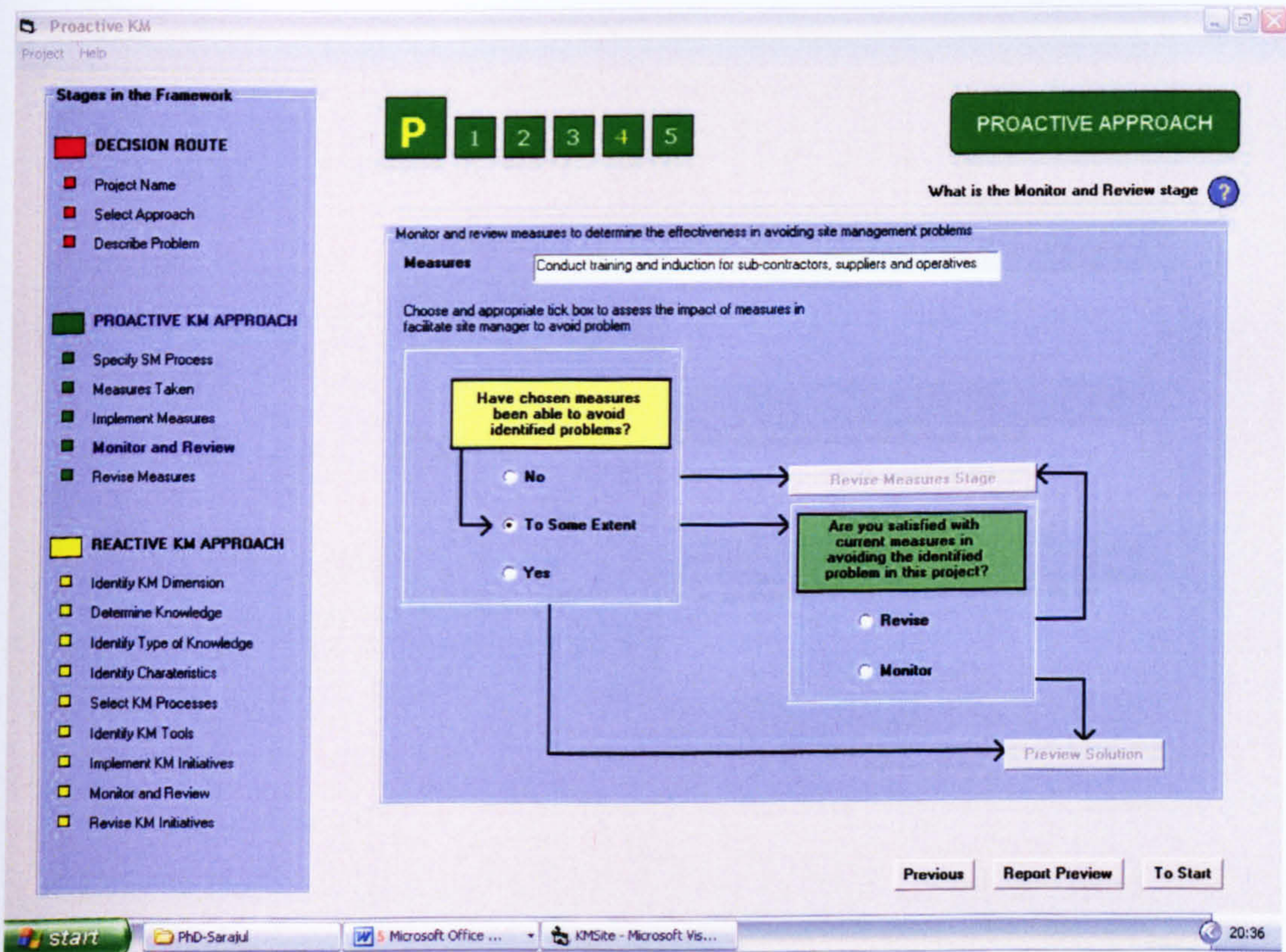


Figure 7.13: Monitor and Review Measures Stage.

Revise measures

This form has been incorporated in the system to add flexible features and an updating facility so that site managers can, based on their experience, modify or replace existing measures so as to improve their effectiveness. In this stage, the site manager is required to complete a number of key diagnostic questions for measures that are adjudged to be ineffective in addressing a given problem. The key diagnostic questions are:

- Why are the existing measures ineffective;
- What additional issues need to be addressed;
- What measures can address the outstanding issues.

The output of this stage is fed back to the 'Implement Measures' forms and the site manager can also produce a detailed report by clicking on 'Report Preview' or 'Preview Solution' buttons as shown in Figure 7.14.

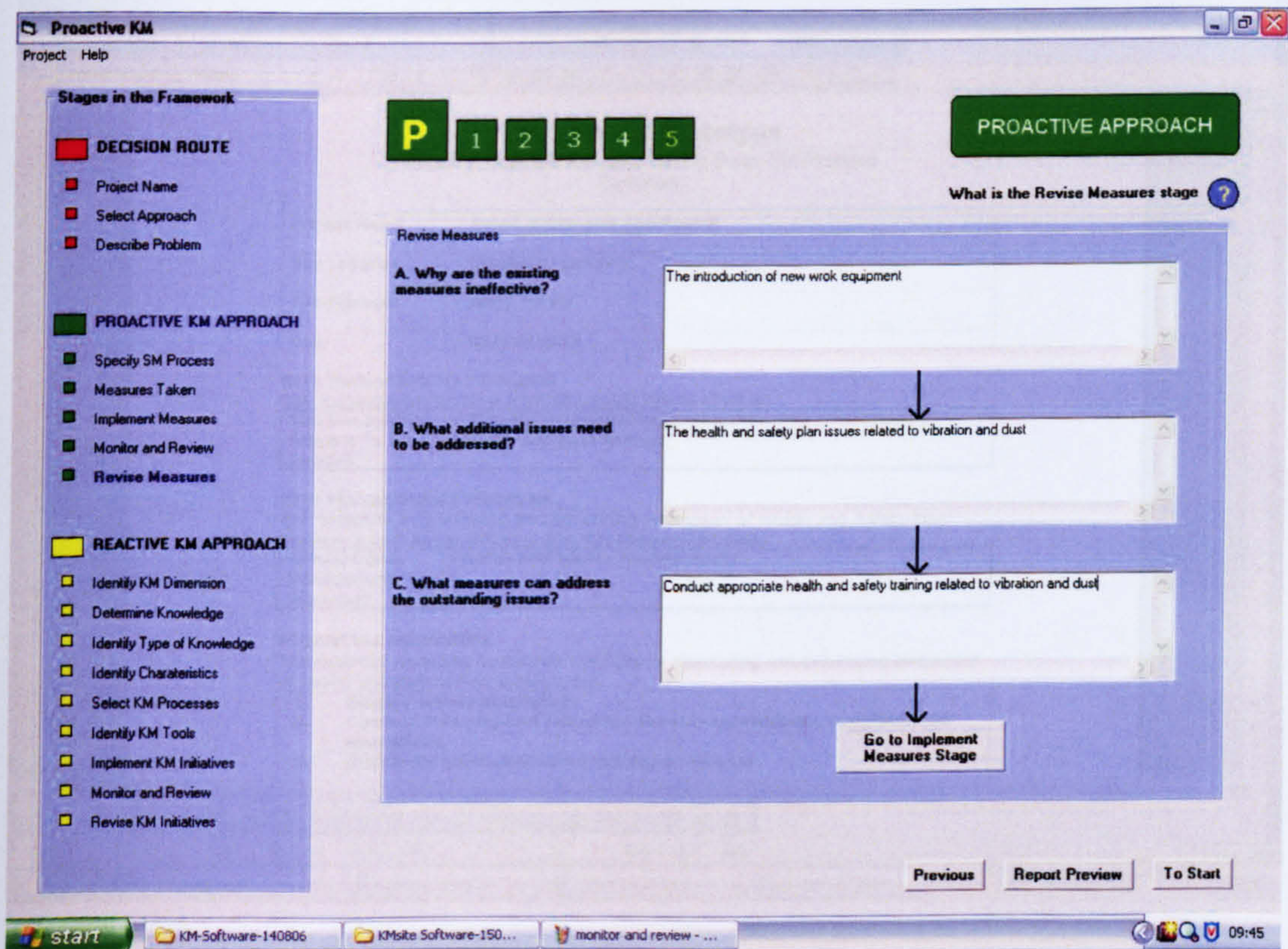


Figure 7.14: Revise Measures Stage.

Generating a Report for Proactive KM Approach

Finally, the prototype is able to produce a detailed report (Figure 7.15) for proactive KM approach containing:

- The project information
- Site management problem
- Site management process
- Potential Measures
- Selected Measures
- Monitor and review
- Revise Measures
- Summary

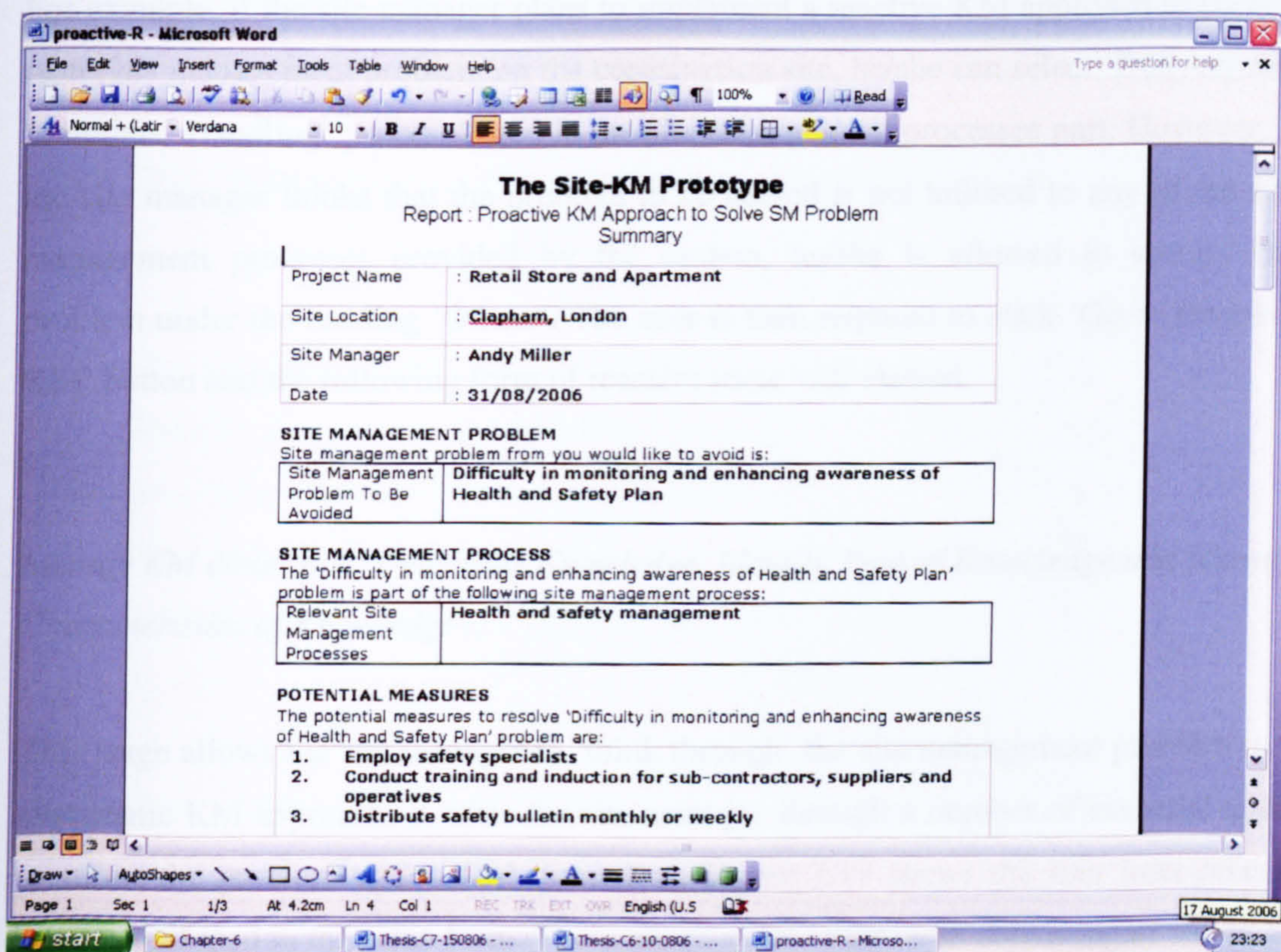


Figure 7.15: A Screen-Shot of a Report for Proactive KM Approach.

7.5.3 Reactive KM Approach

The reactive KM approach consists of a nine-stage KM approach including: identify KM dimension, determine knowledge, identify type of knowledge, identify characteristics of knowledge, select KM processes, identify KM tools, implement KM initiatives, monitor and review, and revise KM initiatives, using the inter-related forms provided in the 'site-KM' prototype system.

Decision Route and Specify Site Management Process

The stage guides the site manager to select a reactive KM approach to solving site management problems. Once the site manager clicks 'Tackle Specific Problem (Reactive Approach)' button, a pop up form will be appear (Figure 7.16) asking the site manager to specify the site management processes under which the problem falls. For example, if the site manager plans to implement a reactive KM approach to solve a materials management problem on the construction site, he/she can select 'Delivery and Materials' Handling' process listed in the site management processes part. However, if the site manager thinks that the problem to be solved is not tailored to any of the site management processes provided by the system, he/she is allowed to specify the problem under the heading 'Others'. The user is then required to click 'Go to Reactive KM' button and the following form of reactive route will viewed.

Identify KM dimension, Determine Knowledge, Identify Type of Knowledge and Identify Characteristics of Knowledge

This stage allows the site manager to 'think through' the site management problem in a systematic KM approach. It takes the site manager through a number of essential tasks to refine the problem with a KM dimension. Figure 7.17 shows the four inter-related stages combined in the same form. There are five important tasks consisting of issues or a set of questions that the site manager needs to select and justify:

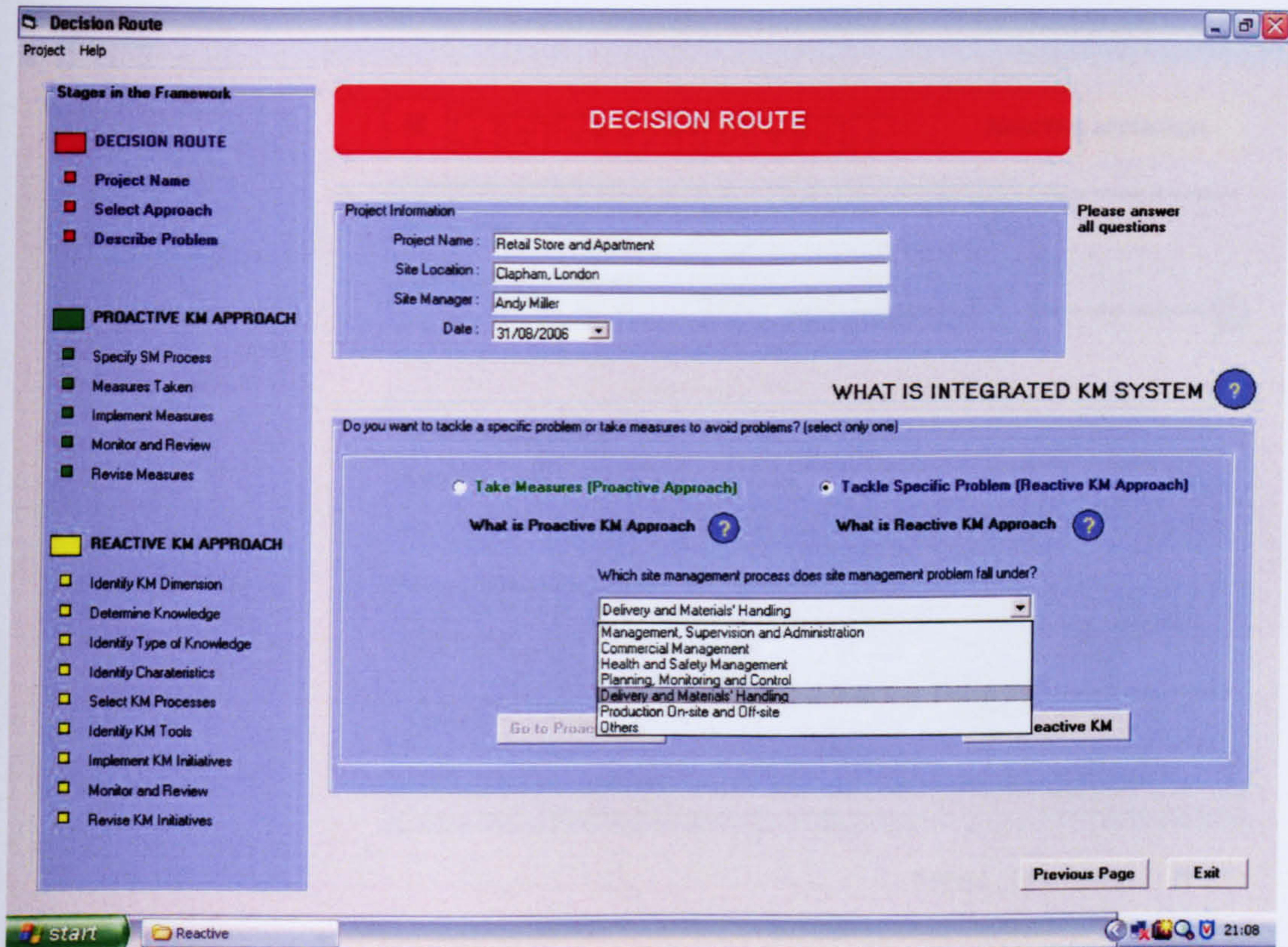


Figure 7.16: Decision Route and Specify Site Management Process Stage.

- Site management problem to be solved;
- The KM dimension to the problem;
- Determine if required knowledge is available;
- Identify type of knowledge; and
- Identify the characteristics of knowledge.

The system displays the questions or issues in separate ‘frames’ which the user completes. Four ‘frames’ are used to input, edit, and view the information. While completing the ‘frame’, the user will have the opportunity to return to any previous ‘frame’ to modify the input. The ‘Help’ button is provided to facilitate the site managers in accomplishing this task.

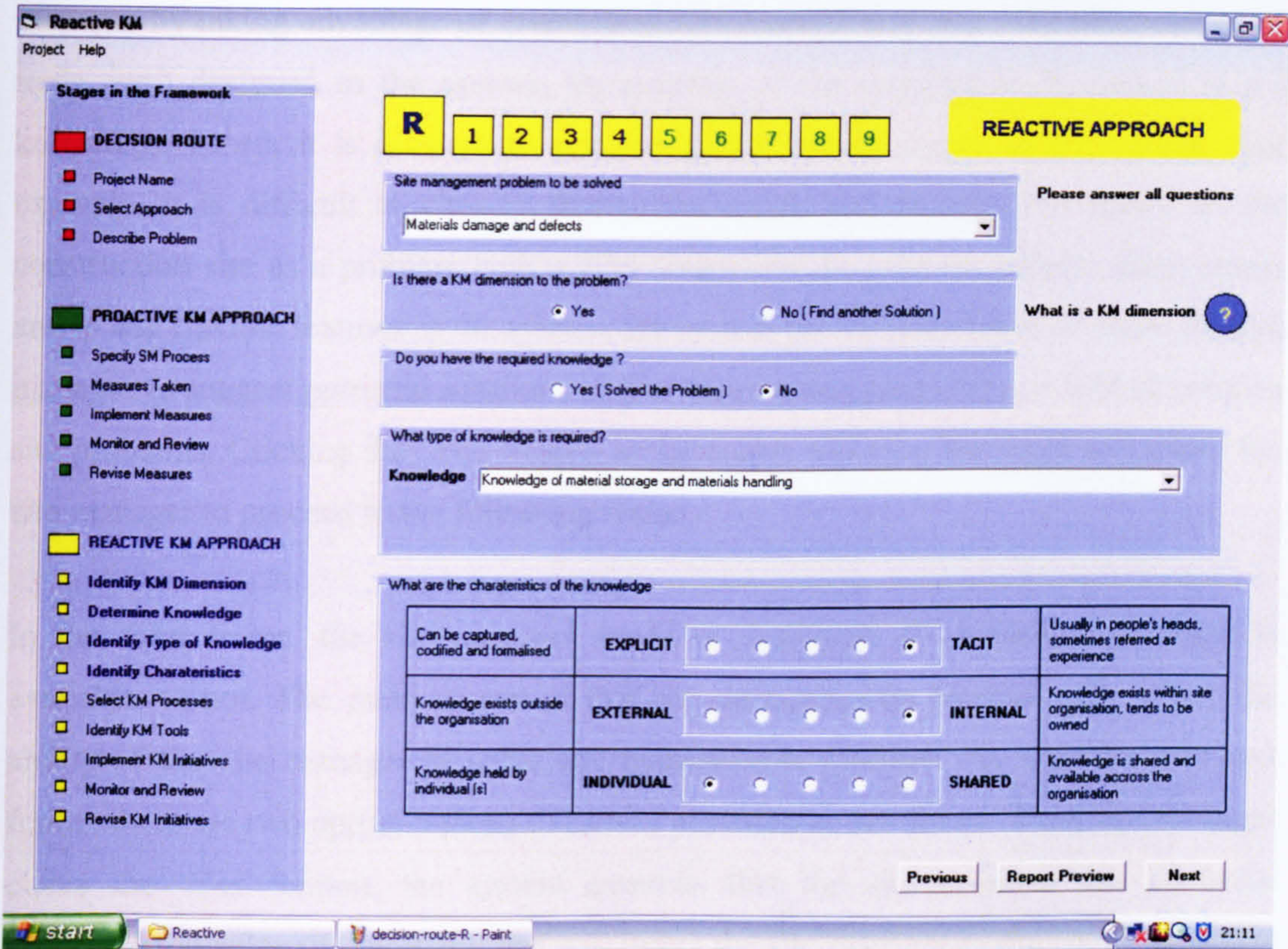


Figure 7.17: The Key Stages of Reactive KM Approach in ‘site-KM’ Prototype System.

First, the site manager needs to select or describe the site management problem to be solved. For this task, the designed system has the capability to search from the database, a list of common site management problems that occur on the construction site. The list of common problems has been categorised into six major construction site processes. Providing a list of common problems helps the site managers to think more broadly about the site management problems and will encourage them to adapt solutions and methods practised and learned in previous project experience. However, if the problem to be solved is not available in the system, the site manager can describe the problem by clicking the ‘Others’ part in the list box.

Then, the site manager is required to identify the KM dimension of a given problem. The frame provides two option buttons (Yes/No) which allow the site manager to formulate simple subjective analysis of the associated KM dimension. The rationale for

this function is that the knowledge-based site problem can be solved by the site manager by taking advantage of established KM mechanisms (e.g. KM processes, KM tools, etc.) designed in the system. By contrast, if the problem to be solved is not knowledge based, it is difficult to proceed to the further stages in the system. For example, it is difficult to classify motivation issues and absenteeism issues on the construction site as a problem with a KM dimension. In order to address these issues and to add flexible features in the system, the system has been designed to allow the site manager to suggest potential solutions and develop action plans for non KM dimension site problems. Clicking the 'Yes' button in the frame will save the input and allow the site manager to proceed to the following frame.

In the third frame, the site manager needs to determine if required knowledge is available or not. The main reason is that the determination process will reflect the ability of the site manager to solve site management problem. As with the previous frame, there are two option buttons (Yes/No) provided in this frame. If the site manager clicks the 'Yes' button, the system assumes that the site manager has adequate knowledge to solve the problem, and will direct the site manager to the 'develop action plan' form. By clicking the 'No' button, the system assumes that the site manager does not have the required knowledge to solve site management problems and the site manager can proceed to the following frame.

The next frame allows the site manager to identify type(s) of knowledge required to solve the site management problem. The main function of this frame is to describe the type and nature of the required knowledge. The site manager needs to describe the knowledge required very briefly and does not need to be very specific. The most important thing is to consider one site management problem at a time. The system provides two alternative ways of describing the type of required knowledge. First, the system searches from the database, the most appropriate knowledge to be use to solve the site management problem. Second, the site manager is allowed to suggest the types of knowledge required to solve the site management problem.

The last frame in this form (Figure 7.17) requires the site manager to identify the characteristics of the knowledge i.e. knowledge conversion types (explicit-tacit), knowledge transfer domains (external-internal) and knowledge ownership forms

(individual-shared). A five-point scale is provided to facilitate the site manager in selecting the position that best describes the required knowledge. For example, knowledge can be completely tacit, mostly tacit, half tacit, mostly explicit and completely explicit. A brief definition is given alongside each dimension. For example, tacit knowledge exists ‘usually in people’s heads, sometimes referred to experience’.

Identify ‘Sources’ and ‘Destination’ of Knowledge and ‘Resistors’ and ‘Enablers’

This form consists of two inter-related frames and matrices. It investigates the relationships between the sources and users of knowledge as shown in Figure 7.18.

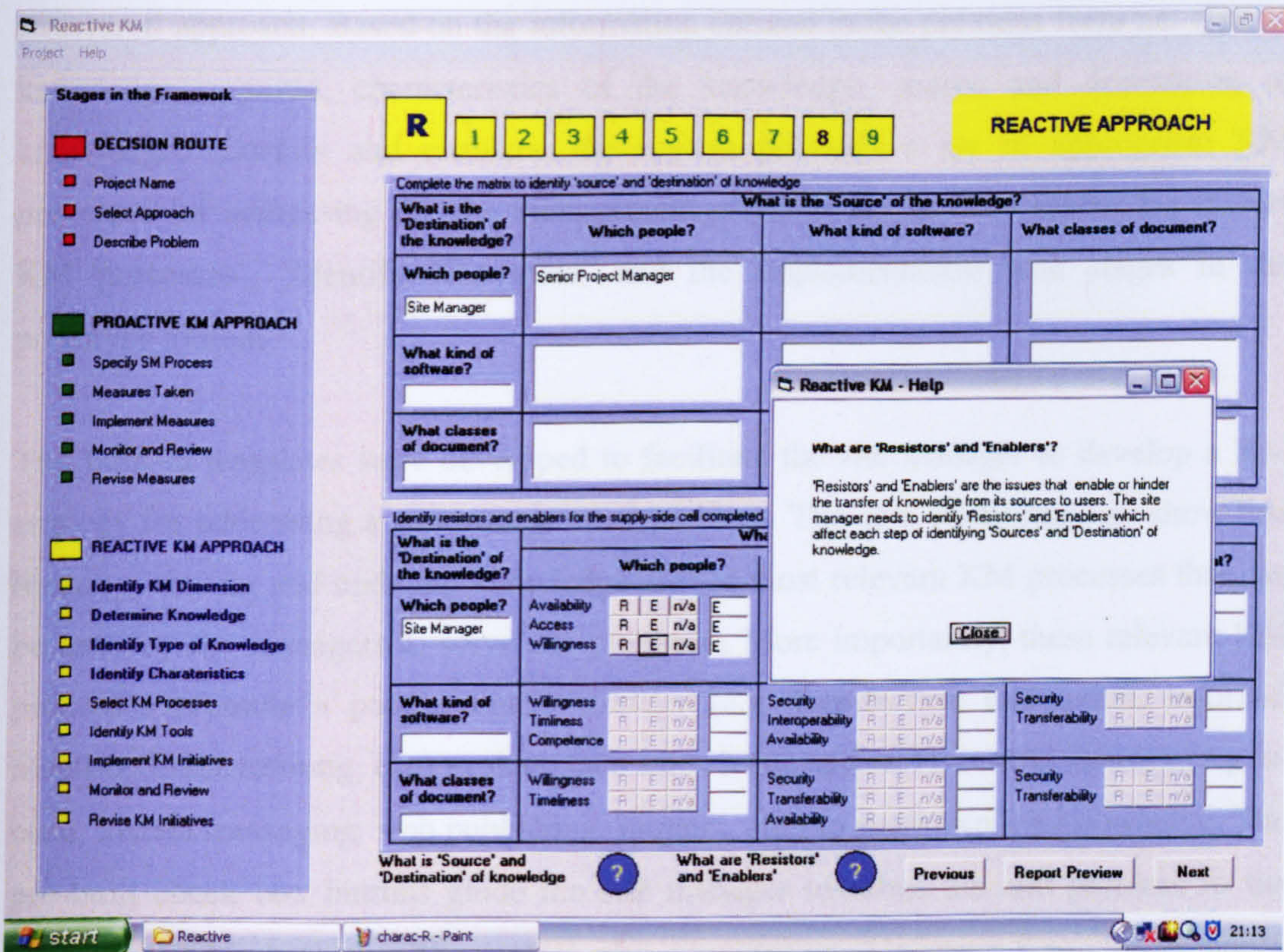


Figure 7.18: Identify ‘Source’ and ‘Destination’ of Knowledge Stage.

The first matrix explicates where the knowledge comes from and who/what uses it. The 'source' and 'destination' of knowledge can be individual, software or paper. In the second matrix, the site manager is required to identify the enablers and resistors that enable or resist the transfer of knowledge from its source to users. The main function of this matrix is to facilitate the site manager to identify enablers and resistors at the earlier stages of developing a KM strategy in order to reinforce the enabler and to overcome the resistor. The 'Help' buttons are provided for guidance to the site manager on completing the forms.

Select KM Processes and Identify KM Tools

This form facilitates the site manager in selecting the relevant KM processes in a structured approach. Based on the information entered in the previous form i.e. type of knowledge required, characteristics of the knowledge, source and destination of knowledge, resistors and enablers, the system provides a set of appropriate KM processes for addressing the site management problem. Figure 7.19 shows the 'Select KM processes', 'Identify KM tools' and the implementation plan stages in the prototype system.

The built-in templates were developed to facilitate the site manager to develop a KM strategy for addressing a site management problem. The case study findings show that locating, sharing and updating knowledge are the most relevant KM processes that can be used by site managers to solve site problems. More importantly, these relevant KM processes promote a people-centric strategy (e.g. face-to-face interaction, informal meeting, brainstorming, etc.) to share tacit knowledge and an IT-centric strategy (e.g. e-mail, instant messaging, web publishing, intranet, etc.) to share explicit knowledge. The pre-built check box buttons guide the site manager to relate the site problem to the applicable KM processes. The system also provides an 'Updating Knowledge' check box to facilitate the site manager in developing a KM strategy for knowledge updating. The main reason is that some of the site problems (e.g. health and safety law, building regulations, etc.) need a regular updating process to maintain their relevancy to the construction site management context.

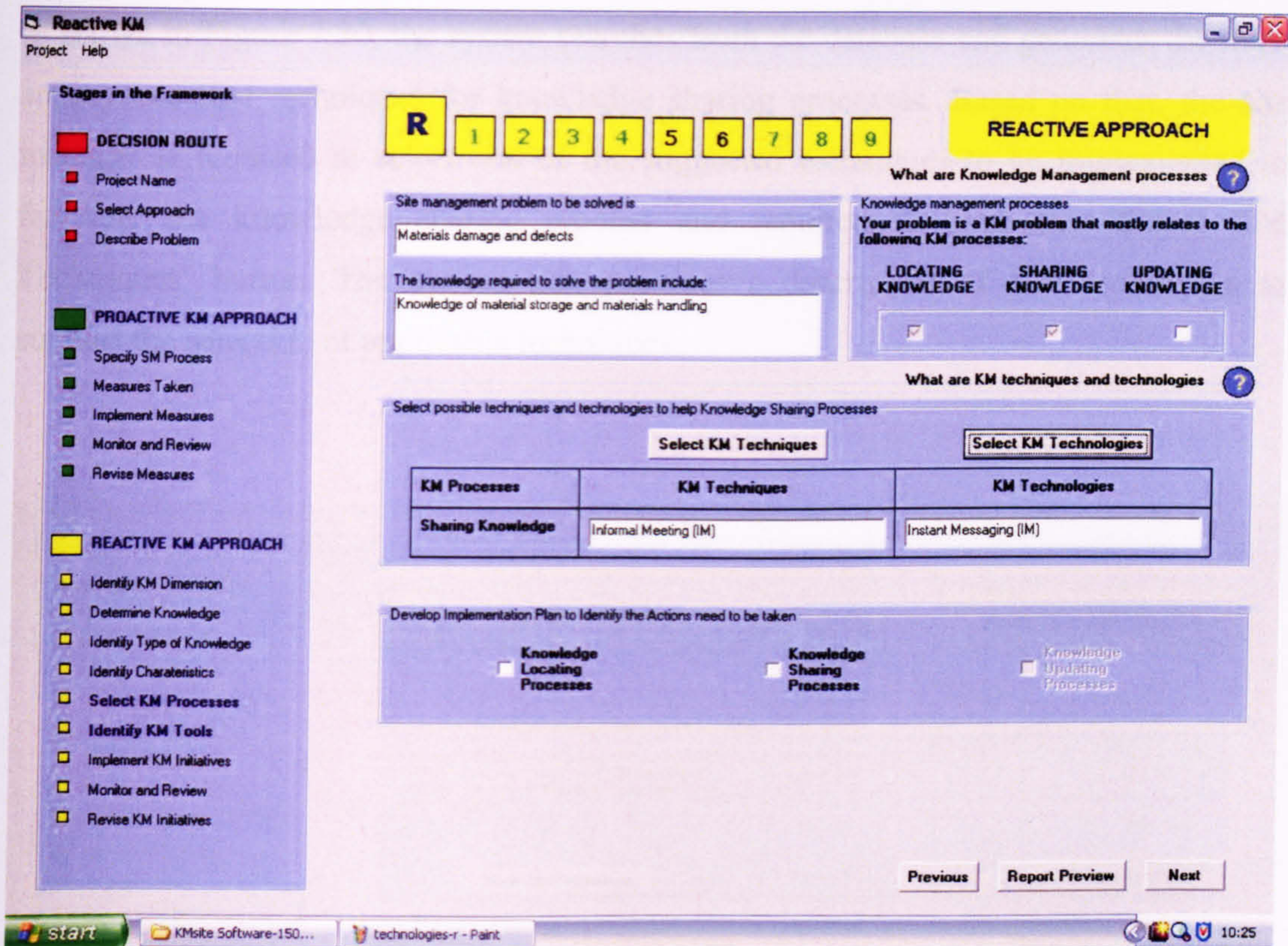


Figure 7.19: Select KM Processes; Identify KM Tools and Implementation Plan Stage.

The next frame allows the site manager to select possible techniques and technologies to help the knowledge sharing process. The system contains a systematic database of KM techniques and KM technologies organised according to the specific KM dimensions they support (as described in the SELEKT approach in Chapter 6, section 6.2.1c). If the site manager clicks the 'Select KM Techniques' button, the forms containing the relevant KM techniques for knowledge sharing in addressing the site problem will appear. In this form, the characteristics of the knowledge are automatically generated by the system based on three KM dimensions selected by the site manager in the 'identify characteristics of the knowledge' stage: knowledge conversion types (tacit-explicit), knowledge transfer domains (internal-external) and knowledge ownership form (individual-shared). For example, to share completely tacit knowledge, from completely internal sources and kept completely by an individual within the organisation will lead to the selection of the KM techniques shown in Figure 7.20 and

KM technologies shown in Figure 7.21. By clicking the 'Show KM Techniques' button as shown in Figure 7.20, the system searches from the database and generates the most appropriate KM techniques for knowledge sharing processes. Based on that, the site manager is required to select one of the suggested techniques to be implemented to facilitate the knowledge sharing process and required to click the 'Select KM Techniques' button. The system also provides a description of KM techniques to support the selection of applicable techniques.

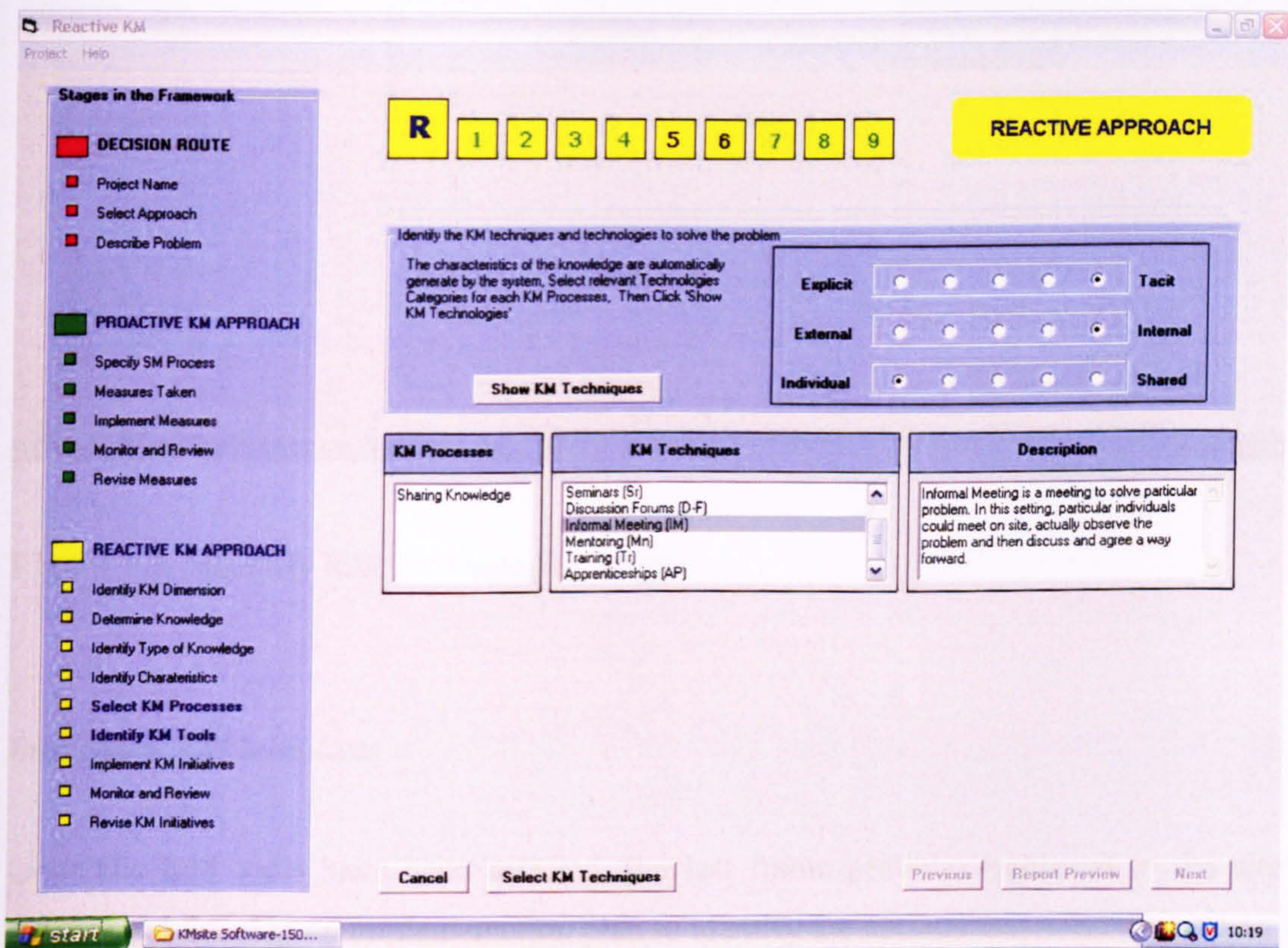


Figure 7.20: Identify KM Techniques Stage.

The processes for KM technologies selection shown in Figure 7.21 are similar to the processes described for the selection of KM techniques.

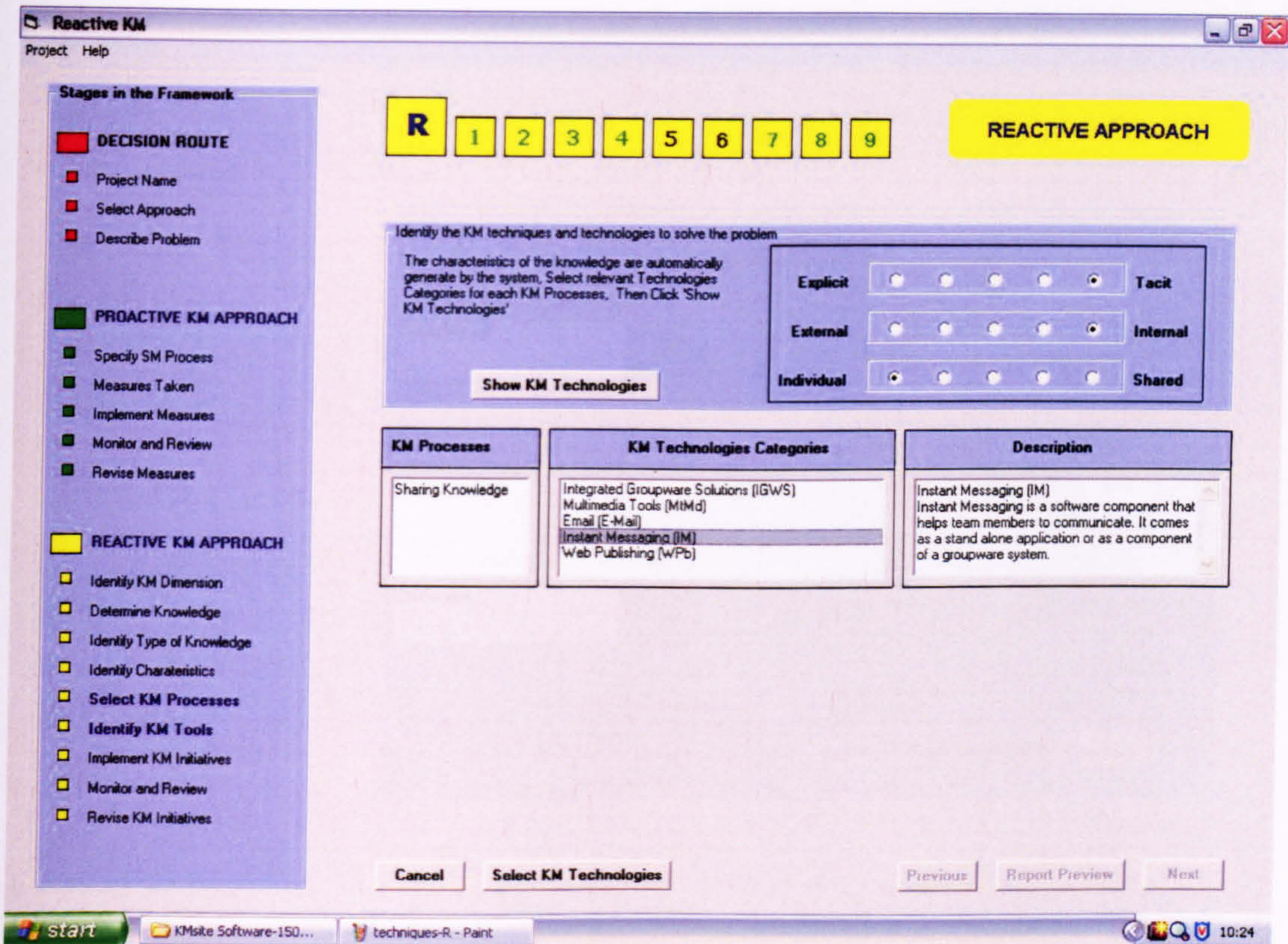


Figure 7.21: Identify KM Technologies Stage.

Implement KM Initiatives

Once the KM tools have been selected, the last frame provides guidance to the site manager to develop an implementation plan to identify the actions that need to be taken. Clicking 'Knowledge Locating Processes' text will open a form consisting of an action plan and generic activities involved to locate knowledge sources and knowledge destination as shown in Figure 7.22. The system provides a built-in generic activities for each KM processes (i.e. generic activities for 'Locate Knowledge Source' and 'Locate Knowledge Destination'), which facilitate the site managers developing an appropriate KM strategy to solve site management problem.

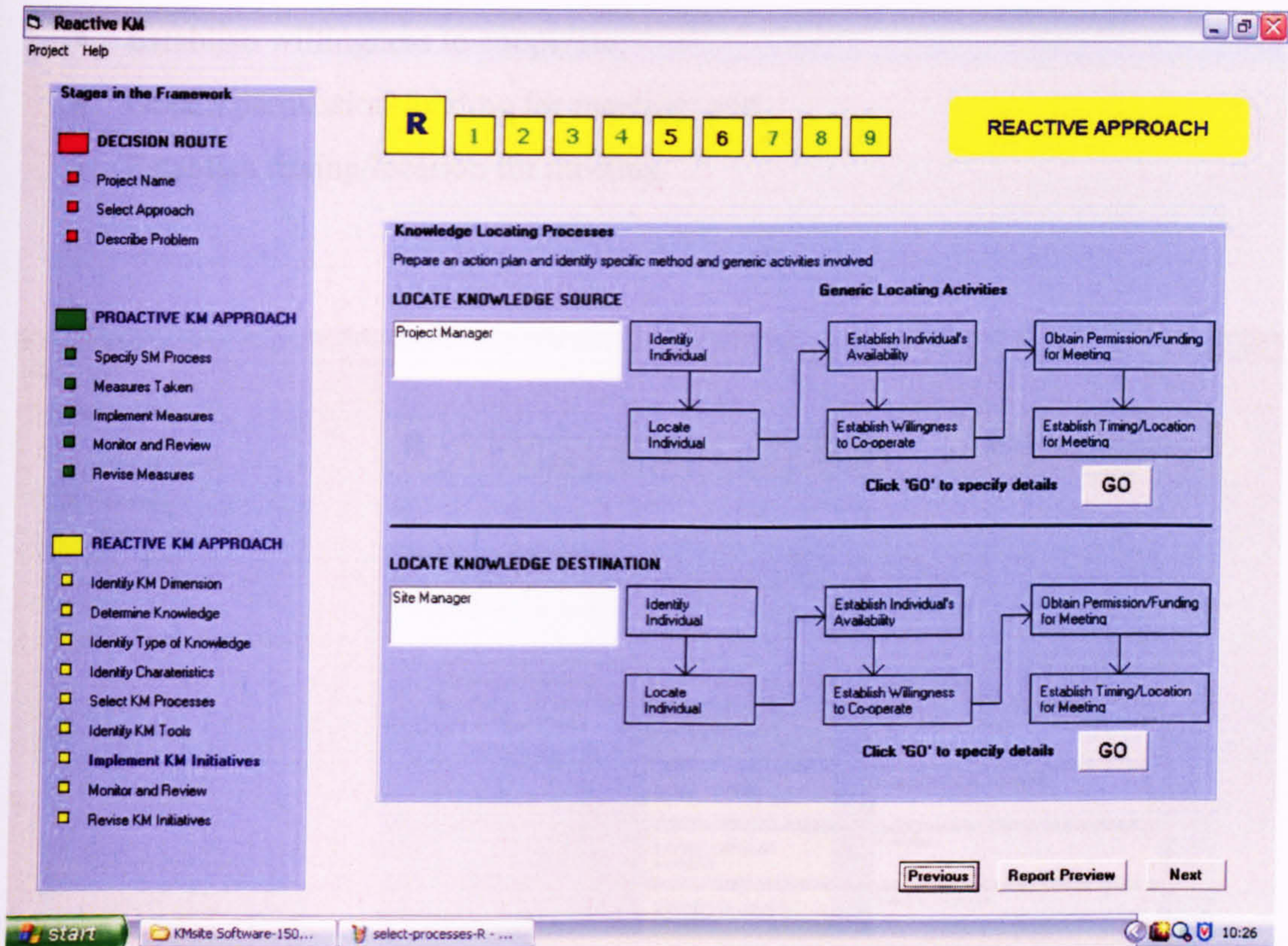


Figure 7.22: Knowledge Locating Processes Stage.

Then, the site manager needs to click the 'GO' button to specify details of the implementation plan for each generic activity. For example, if the site manager clicks the 'GO' button for specifying details of locating activities of knowledge source, the related form will open, as shown in Figure 7.23. The system will show the actions needed to locate the knowledge source under three main headings: source of knowledge; generic locating activities; and description. The site manager needs to describe the action plan based on the generic locating activities provided by the system. For example, an action plan for 'Locate Knowledge Source' (i.e. from senior Project Manager) consists of six main generic activities that need to be accomplished by the site manager. These include:

- Identify individual;
- Locate individual;

- Establish individual’s availability;
- Establish willingness to cooperate;
- Obtain permission/funding for meeting; and
- Establish timing/location for meeting

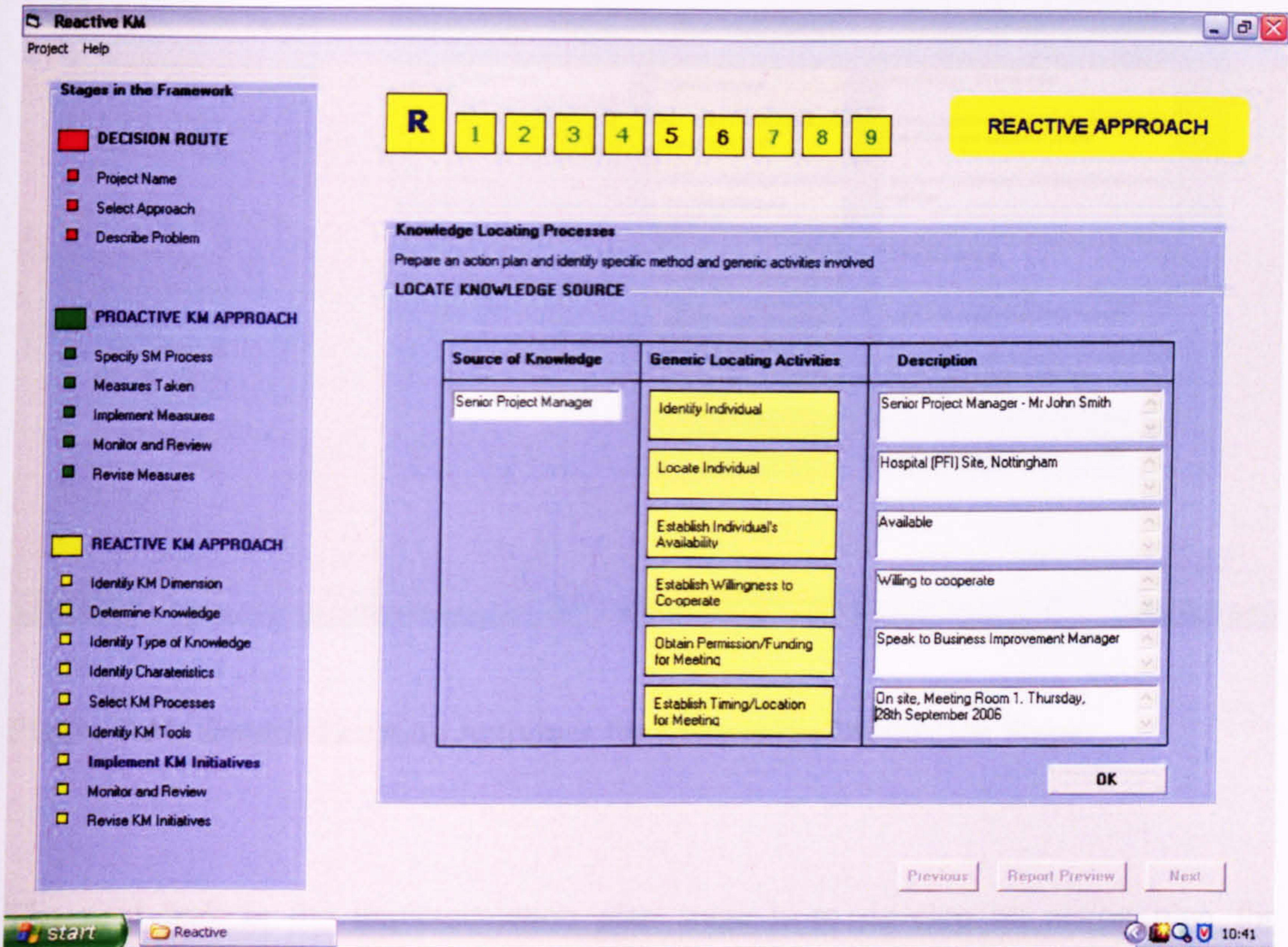


Figure 7.23: Generic Locating Activities for Knowledge Source Stage.

The processes for ‘Locate Knowledge Destination’, including its main generic activities, are similar to the processes of ‘Locate Knowledge Sources’ described above. Figure 7.24 shows the action plan for that ‘Locating Knowledge Destination’ processes. By clicking the ‘GO’ button, the action plan for knowledge sharing processes will open.

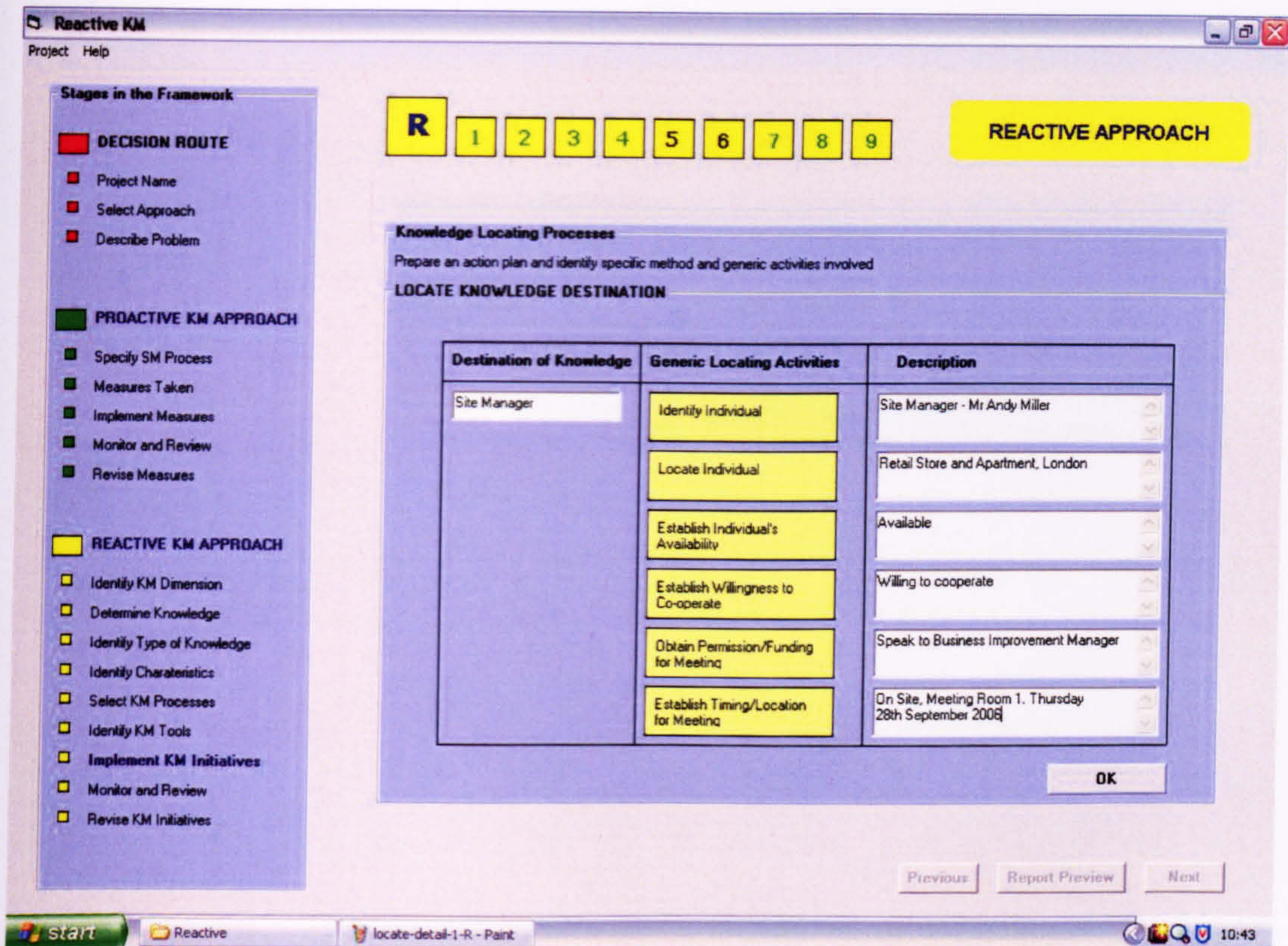


Figure 7.24: Generic Locating Activities for Knowledge Destination Stage.

The next task in the implementation plan stage is to develop an action plan for knowledge sharing processes. This task adapts a set of generic processes for knowledge transfer as discussed in the Chapter 6, section 6.2.1b. The system allows the site manager to select three share methods: people-to-paper; people-to-software; and people-to-people as shown in Figure 7.25. The system will automatically suggest to the site manager the knowledge share methods, based on a clear identification of the 'source' and 'destination' knowledge to be shared. For example, if the site manager describes 'Senior Project Manager' as a source of knowledge and 'Site Manager' as a destination of knowledge, the system will categorise this event as a 'People to People' share method.

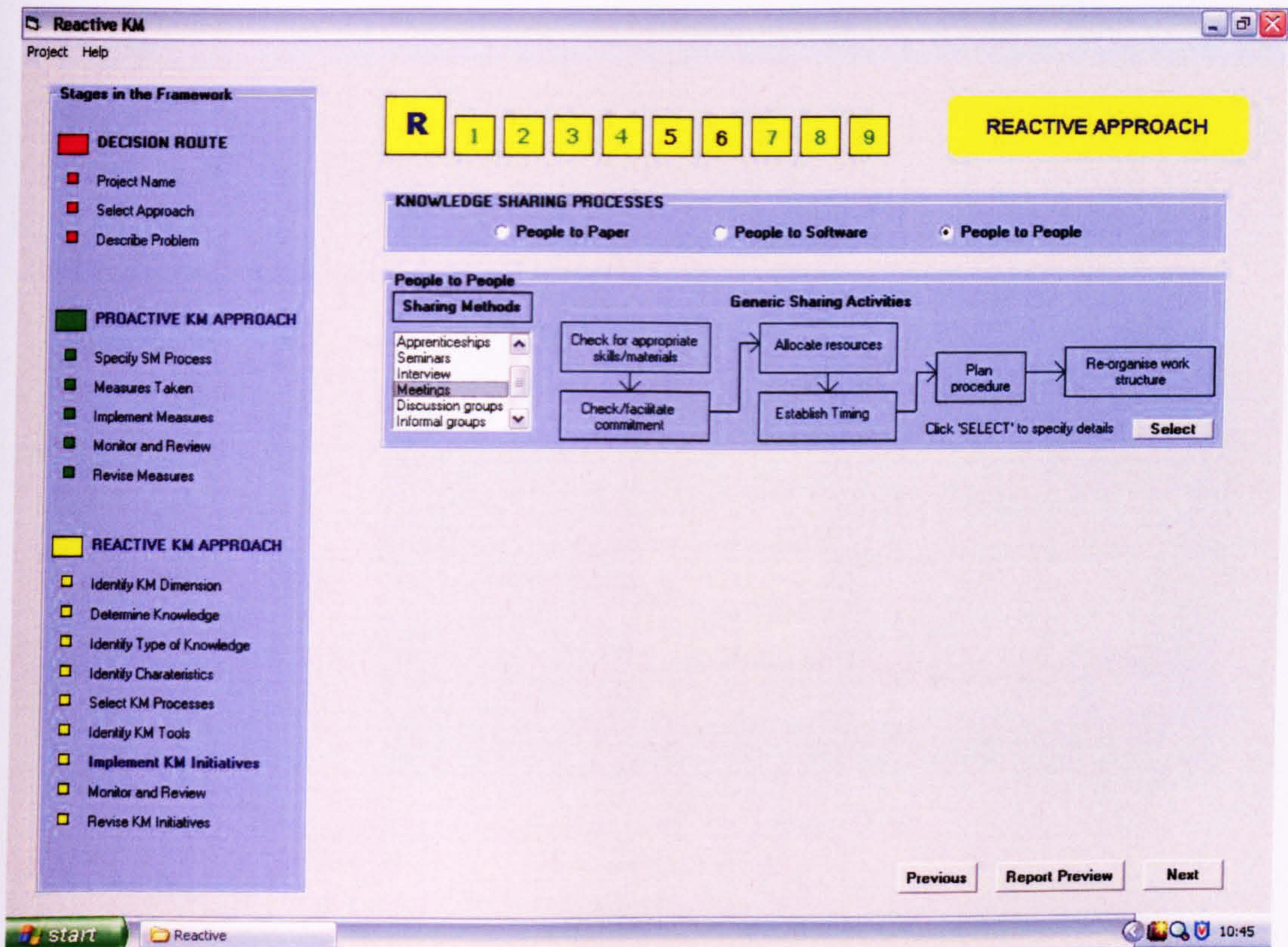


Figure 7.25: Knowledge Sharing Processes Stage.

Once the site manager clicks on the 'Select' button, the system will present a generic sharing activities map for 'people-to-people' knowledge sharing processes. The generic sharing activities include six main activities as shown in Figure 7.25:

- Check for appropriate skills/materials;
- Check/facilitate commitment;
- Allocate resources
- Establish timing;
- Plan procedure;
- Re-organise work structure.

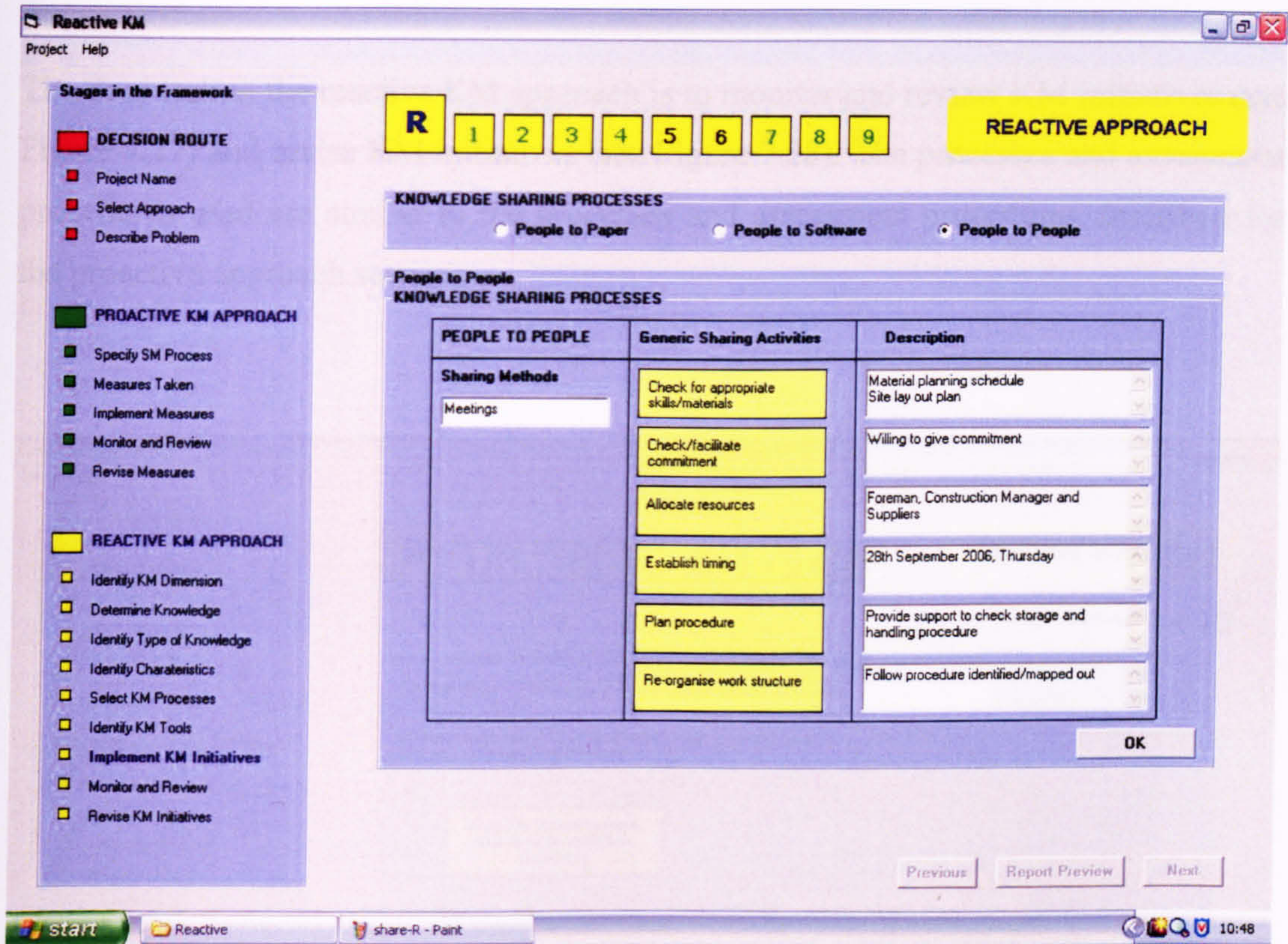


Figure 7.26: Generic Sharing Activities for ‘People-to-People’ Knowledge Sharing Processes.

The site manager needs to give short and relevant information in the ‘Description’ part of the form as shown in Figure 7.26. The rationale for this function is to develop a structured action plan of what tasks need to be undertaken before implementing a KM strategy. The system also allows the site manager to produce a detailed report by clicking the ‘Report Preview’ button. Clicking the ‘OK’ button of a form saves the described generic sharing activities and opens the next form to assess the effect of the KM initiatives in relation to what was meant to be achieved.

Monitor, Review and Revise KM Initiatives

The final task in the reactive KM approach is to monitor and review KM initiatives (see Figure 7.27) and revise KM initiatives (see Figure 7.28). The processes and assessment procedures used are similar to the processes and assessment procedures described for the proactive approach section.

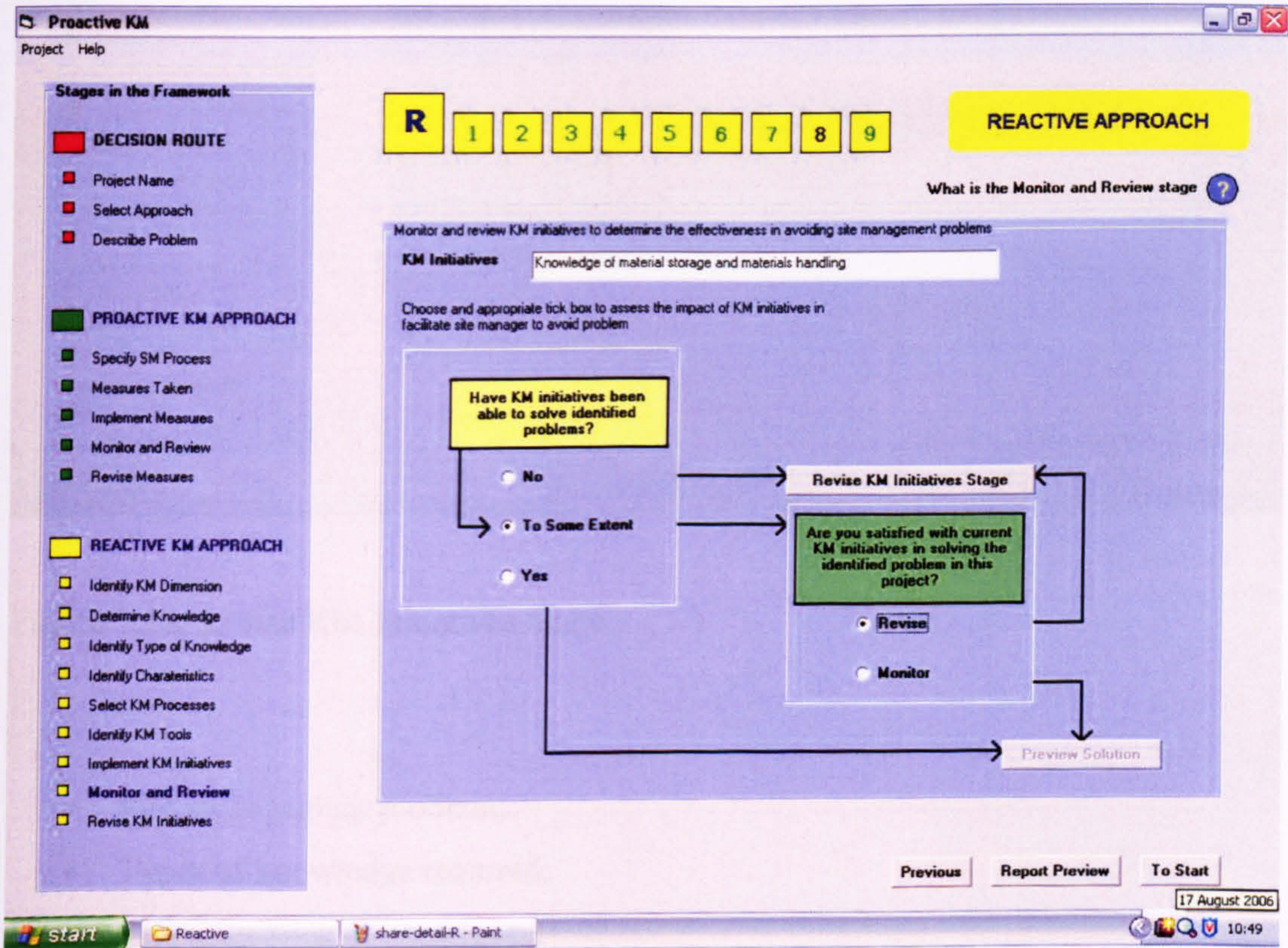


Figure 7.27: Monitor and Review KM Initiatives Stage.

Generating a Report for a Reactive KM Approach

The generation of a reactive KM approach report concludes the structured approach in solving site management problem based on KM strategy as shown in Figure 7.29. The contents of the report include:

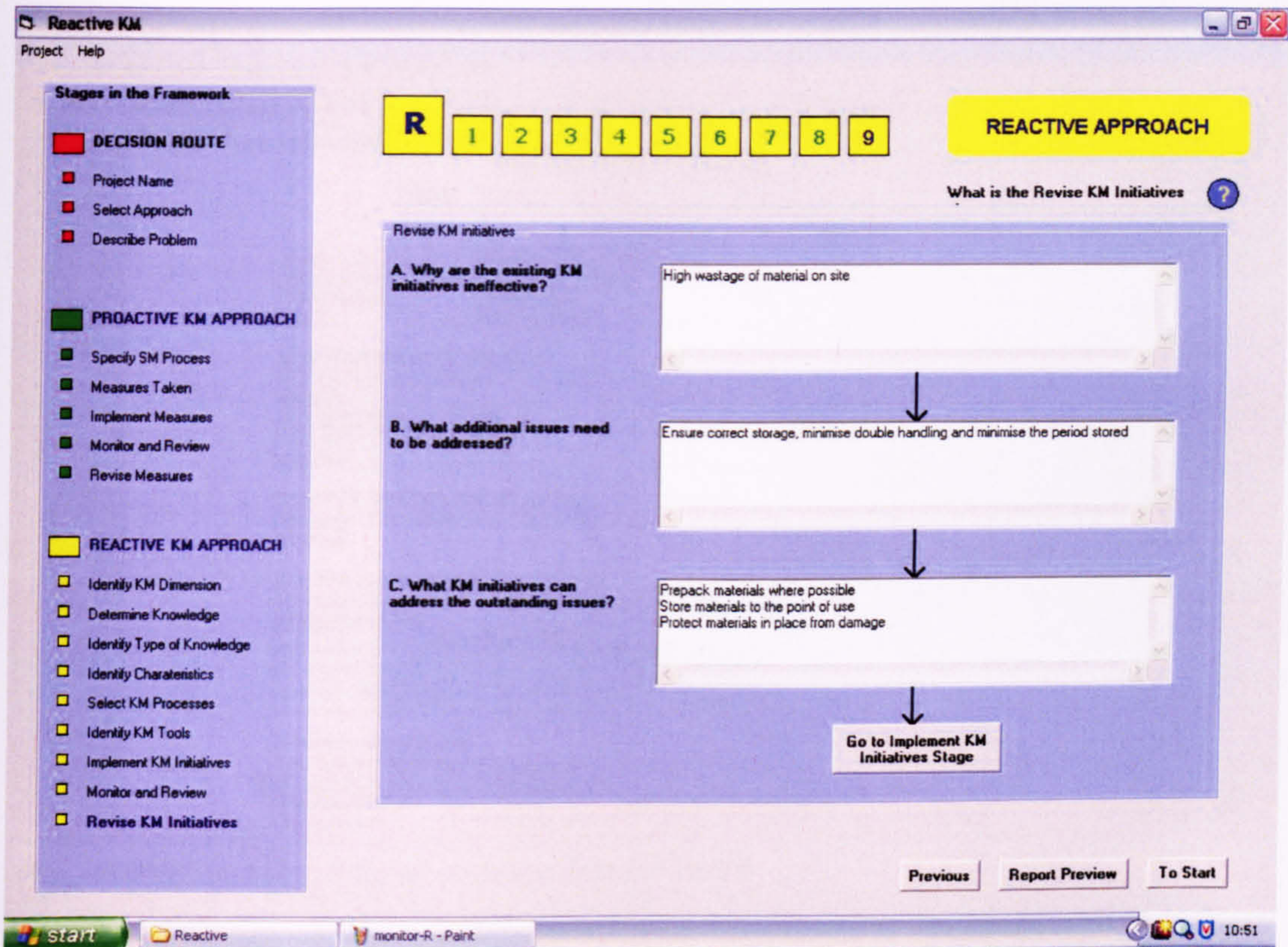


Figure 7.28: Revise KM Initiatives Stage.

- Site management problem;
- Types of knowledge required;
- Characteristics of knowledge;
- Knowledge matrix;
- Knowledge management processes;
- KM techniques and technologies;
- KM implementation plan;
- Monitoring and review;
- Revise KM initiatives; and
- Summary.

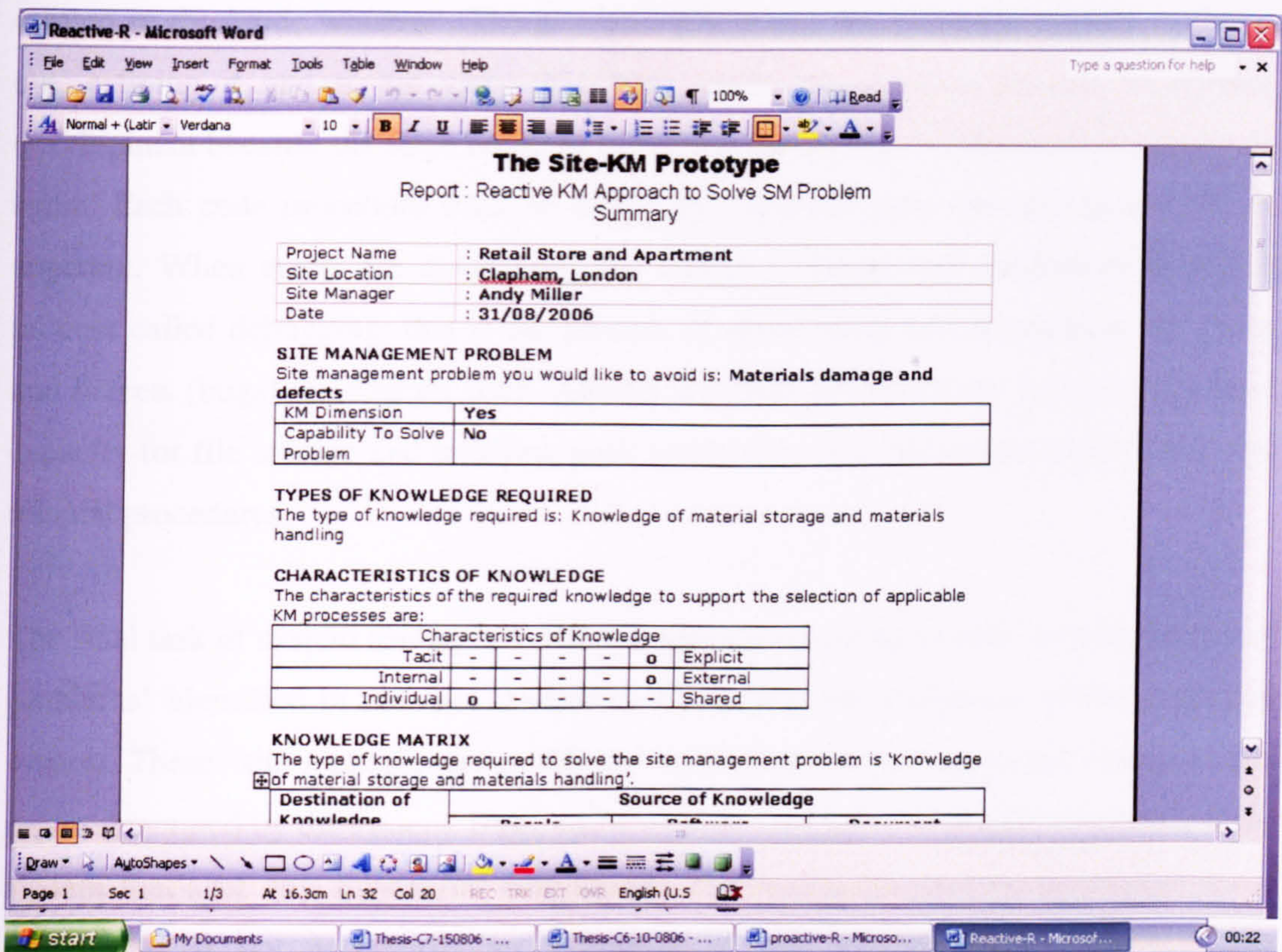


Figure 7.29: A Screen-Shot of a Report for Reactive KM Approach.

7.6 System Testing

System testing tests the functioning of the prototype system as a whole. There are two levels of system testing: Pre-design test and post-design test. First, in a pre-design test, the testing begins during the design stage. The paper-based system was designed to review the specification and design documents which aim to develop a workable KM system on the construction site. It tries to determine if discrete modules will function together as planned and whether discrepancies exist between them way the system actually works and the way it was conceived.

Second, in a post-design test, once coding begins, 'coding walkthroughs' can be used to review program code. The 'coding walkthroughs' process is a review of a program code by the expert carefully selected based on the skills needed for the particular objectives

being tested. The links between two forms have been established and procedures are created in the 'code window'. The process of building the prototype system, testing it out, refining it and trying again has been called an iterative process of systems development because the steps required to build a system can be repeated over and over again. Each code procedure must be tested by computer runs and any errors will be apparent. When errors are discovered, the source is found and eliminated through a process called debugging; this is the process of discovering and eliminating the errors and defects (bugs) in program code. Among the areas examined are performance time, capacity for file storage and handling peak loads, recovery and restart capabilities, and manual procedures.

The final task of system testing is to run the application using several 'site management problems' identified in the case studies as a case for self-evaluation of the prototype system. These 'site management problems' were tested in the prototype system and a report generated by the system. Bugs and errors are inevitable in the development of the system that's of any substantial complexity. If a testing process in uncovered those errors, this is not necessarily an indication of bad system design but show the effectiveness of the system testing. The prototype system can be used to provide relevant knowledge to facilitate in addressing site management problems. It can be concluded that most of the system features were highly effective and necessary to satisfy the primary objective of the KM-based construction site management system.

7.7 Summary

The main objective of the prototype system and choice of development environment were discussed at the beginning of the chapter to give an overview of the system. The chapter has also described the system architecture and the process of system development with a view to establishing required features of the prototype system. Then, the operation of the prototype system, which consists of the decision route, the proactive KM, and the reactive KM, was presented. The testing of the prototype system was also undertaken. The next chapter discusses the evaluation of the prototype system.

CHAPTER EIGHT

System Evaluation

8.1 Introduction

This chapter presents the evaluation of the prototype system. The chapter starts with an introduction to the aim and objectives of the system evaluation. It is followed by an examination of the methodology adopted in the evaluation process. The key results and discussion on the overall evaluation process are also presented. The chapter concludes with a discussion of the benefits and limitations of the prototype system, followed by a discussion on the appropriateness of the evaluation approach.

8.2 Evaluation Aim and Objectives

The aim of the evaluation was to determine the appropriateness and functionality of the developed prototype system in improving construction site management practices. To achieve this aim, the specific objectives of the evaluation were:

- To determine the relevance and applicability of the integrated KM framework for the prototype system in addressing site management problems on the construction site;
- To assess the capability of the prototype in addressing all the stages identified in the integrated KM framework (see Chapter 6);
- To assess the ease with which the prototype can be used; and
- To obtain comments and recommendations for improving the prototype system.

It was therefore important to adapt an appropriate evaluation methodology in order to achieve the above specific objectives.

8.3 Evaluation Methodology

According to Gediga *et al.* (1999) evaluation plays an important part in software development. The main role of evaluation is to eliminate any problems that may be present in a system (Faulkner, 1998). In this context, Anumba and Scott (2001) take the view evaluation as an important aspect of knowledge-based system development that is required to prove whether or not a system fulfils its original objectives. The evaluation activity involves exploring the code, and examining the reasoning processes, intermediate results and conclusions of the system, to help detect errors as early as possible in the development cycle. From a practical point of view, the end-users want to be convinced that a system is getting the right answers for the correct reasons; otherwise they will not use the system.

There are two main categories of evaluation of software systems; formative and summative (Obonyo *et al.*, 2005 and Gediga *et al.*, 1999). Figure 8.1 illustrates the proposed general framework for the life cycle of a prototype system. The framework makes a distinction between two main types of system evaluation activity, primarily in terms of when they take place in a standard linear model of the system life cycle. First, formative evaluation involves assessing the shape of a system whilst in the development process itself. Although formative evaluation will primarily review issues of functionality, this assessment will continuously be shaped by notions of a systems' usability and utility formulated in the changing context of some organisations. Second, summative evaluation occurs after a system has been implemented. For this reason it is sometimes referred to as post-implementation evaluation. Traditional approaches to summative evaluation involve signing off some system against its specification/objective. Summative evaluation may also produce ideas for new systems and/or components.

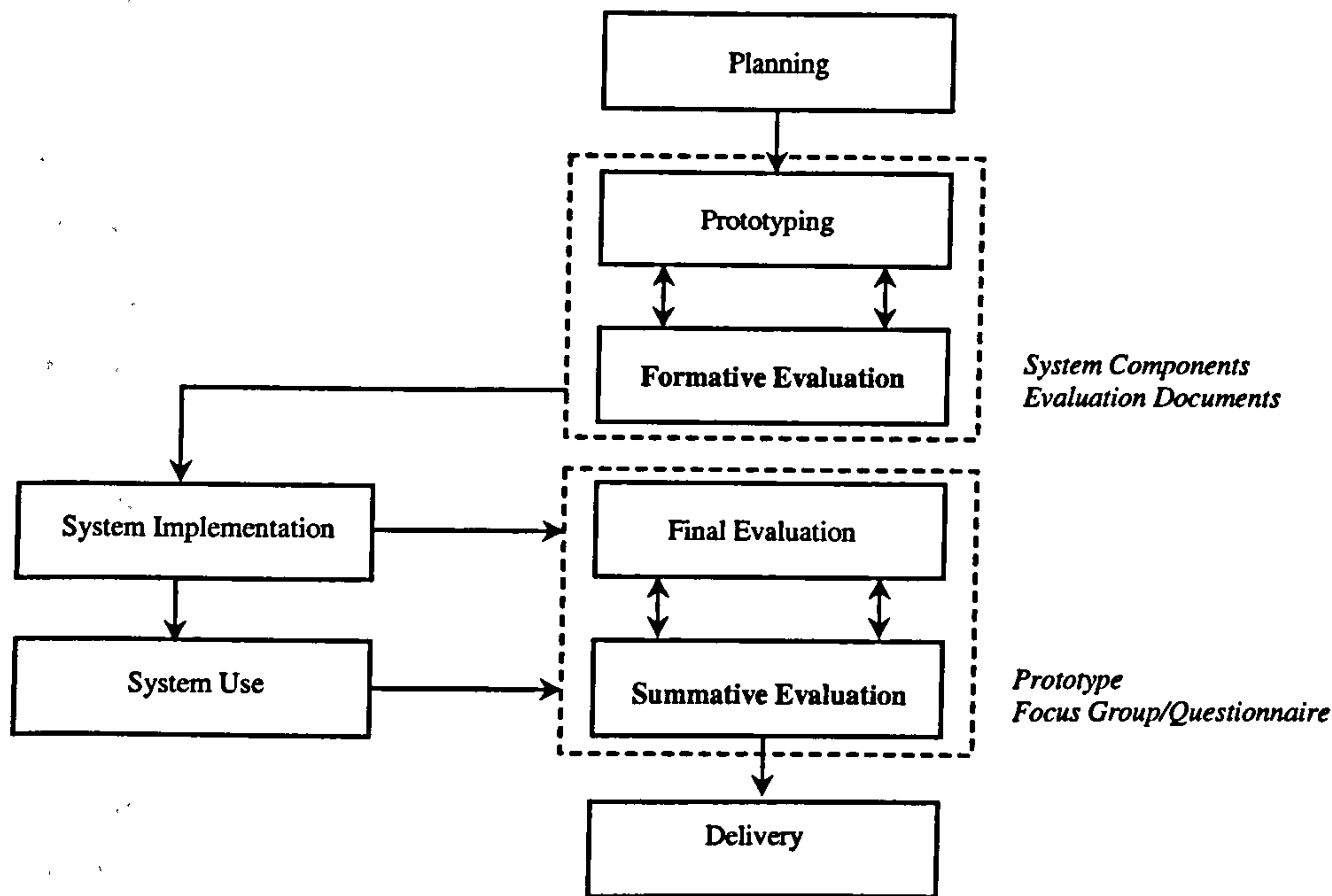


Figure 8.1: A General Prototyping Framework and Evaluation Approach (adapted from Davies *et al.*, 2004 and Smith, 1991).

Formative evaluation

This evaluation is undertaken during the development phase in order to improve a system iteratively, until the desired design objectives are reached and weaknesses of the software are eliminated (Anumba and Scott, 2001). Throughout the development of the prototype system, formative evaluation was an integral part of the evaluation methodology. The formative evaluation process has three key characteristics (Remenyi and Smith, 1999)

- Formative evaluation applied correctly is a frequent, if not quasi-continuous process;
- An evaluator's perception of what is being evaluated changes and the value put on his/her perceptions changes as he/she learn more about the project; and
- The objectives of the system development will evolve during the formative evaluation process.

Summative evaluation

Summative evaluation is treated as a major tactic in project disengagement. This evaluation is an evaluation of a final design regarding guidelines, standards, or other objectives of the evaluation (Gediga *et al.*, 1999). According to Remenyi and Smith (1999) the purpose of the summative evaluation is to assess and confirm or refute the value of the realised system. This evaluation may be performed just before system installation, just after installation, and even some time after installation, i.e. after the system has had a chance to settle down. Davies *et al.* (2004) assert that much of the summative evaluation is managed and performed by those who have designed the system being implemented. The most frequently evaluated criteria seem to be those of information quality criteria (e.g. accuracy, timelines, adequacy and appropriateness) along with facilitating criteria, such as user satisfaction and attitudes.

8.3.1 Evaluation Approach

The summative evaluation was conducted when the 'site-KM' prototype system was considered virtually complete, with all three sub-components implemented, and could deal with cases from start to finish in a stable approach. Initially, the prototype system (i.e. the researcher) entered a number of random site management problems from the case study findings. The problem selected was different in terms of the site management processes, knowledge dimension and characteristics of the knowledge. The 'site-KM' prototype system generally dealt with the problem well; the report was generated for proactive and reactive KM approach. The main aim of the summative evaluation was to test the capability of the prototype for addressing all stages of the KM identified in the integrated KM framework. The summative evaluation was also undertaken to evaluate the performance of the system or ensure that it performed with an acceptable level of accuracy. There were two main stages in the evaluation process. The first stage involved validation of the framework, which sought to determine the appropriateness and relevance of the developed framework for the prototype system. The second part involved evaluation of the prototype system to establish how well it met the original development objectives. Evaluating the prototype system based on user feedback in the

prototype stages can save cost and unnecessary rework. The evaluation approaches adopted by the researcher are illustrated in Figure 8.2.

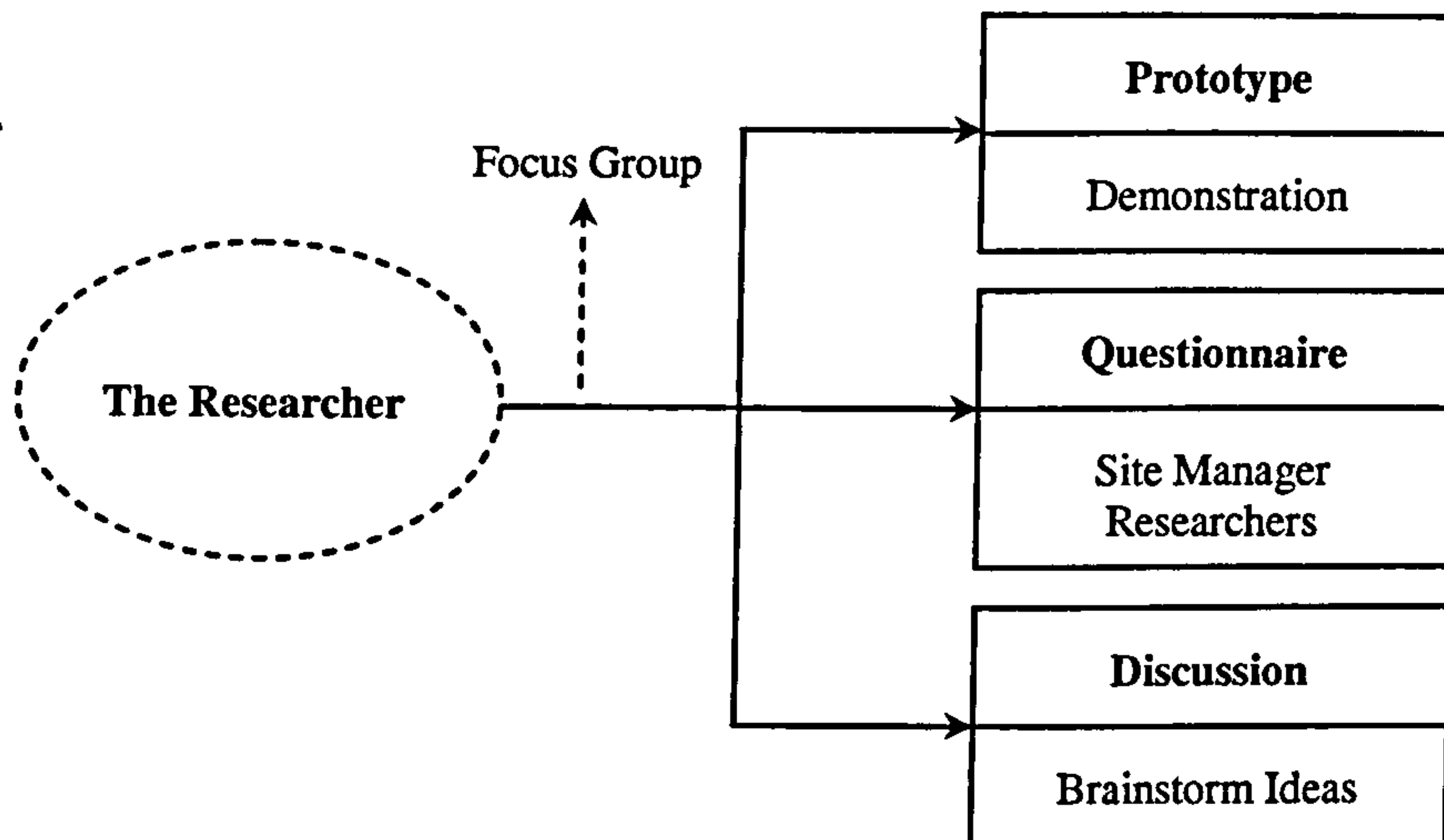


Figure 8.2: Evaluation Approach Adopted for the Prototype System.

A total of 14 participants from two different groups were involved in the evaluation workshop sessions. Noble (1999) argued that a skilled practitioner will use a combination of methods and groups to evaluate the effectiveness of a programme. The first group comprised four construction site managers while the second group comprised 10 university-based researchers. For the first group, the evaluation was carried out with the same organisations involved in the case studies stage. The Business Improvement Manager/Knowledge Manager of five construction organisations were contacted by email and follow-up by telephone explaining the aim of evaluation workshop. The evaluation approach was designed to obtain feedback from the domain experts. Of these five, four gave final approval and appropriate site managers were suggested to participate. Two of suggested site managers were involved in case studies stage in this research. The involvement of the same site managers was aimed at testing the internal validity of the research. The case study findings yielded allow the researcher to draw an accurate framework and could confirm that the prototype system was designed based on relevant findings. Another two independent site managers were used to indicate whether the developed prototype system is applicable to external organisations and therefore increases the validity of the system in a real-life situation.

The combination (e.g. site managers involved with case studies and randomly selected site managers) provided the opportunity of exploring variations in the experts' feedback when evaluating system performance. It is also attempted to seek the advice of parties internal and external to the system on:

- What they liked about the system;
- What they thought would work; and
- What they thought would not work in a commercial scenario.

In addition, Anumba and Scott (2001) are of the view that evaluation sessions with experts are useful in highlighting: areas of knowledge missing from the systems; areas of the system which are not being used (covered); and whether the knowledge is consistent with that of experts. In contrast, the selection of university-based researchers was aimed at obtaining feedback from the external end user perspective. This group helped the researcher to determine the appropriateness of the system for use by younger site managers; who may have little experience in managing construction sites. Initially, five construction site managers were invited to attend the evaluation workshop conducted at Loughborough University. The participants from the other two case study organisations (i.e. Organisations D and E) were unable to participate due to unforeseen circumstances. The researcher made a special visit to one of them and used the same approach to evaluate the system. Another one of the site managers could not be involved in the evaluation workshop due to internal constraints in the organisation. Background information about the evaluation workshop and participants involved is presented in Table 8.1.

Table 8.1: Details of Participants Involved and Evaluation Approach.

Group	Detail of Participants	Remarks
Group 1 4 Construction Site Managers	<ul style="list-style-type: none"> • Organisation A • Organisation B • Organisation C • Organisation E* 	<i>Evaluation Approach</i> <ul style="list-style-type: none"> • Focus group • Presentation on the background to the framework and prototype system
Group 2 10 University-based Researchers	<ul style="list-style-type: none"> • 6 participants with Civil Engineering background • 2 participants with QS and Construction Management background • 2 participants with Computer Science background 	<ul style="list-style-type: none"> • Demonstration of the prototype • Evaluation questionnaire • Brainstorm ideas <p>*Made a special visit to Organisation E prior to time constraints.</p>

The workshop started with a presentation on the background and justification for the developed integrated KM framework for construction site management. Prior to each group session, the participants were given brief notes describing the objectives and system development process of the prototype. This was followed by a demonstration of the software and the participants completed a brief questionnaire. Lastly, the participants were encouraged to participate by giving their suggestions and ideas for improvement during the workshop session.

8.3.2 Questionnaire Design

The design of the questionnaire was based on the aim and specific objectives of the evaluation stated in Section 8.2. A sample of the evaluation questionnaire is provided in Appendix 6. The questionnaire was structured into six main sections as follows:

- *Section A:* This section requested information about the participant's name, position in their organisation, business address, experience and email or contact number.
- *Section B, C, and D:* This section contained 20 questions regarding various aspects of the prototype system. For each question in these sections, participants were required to tick the box that best represented their assessment on the scale of 1 (poor), 2 (fair), 3 (satisfactory), 4 (good) and 5 (excellent). The details of these sections can be described as follows:
 - Section B was aimed at assessing the overall framework which consisted of both proactive and reactive KM frameworks;
 - Section C was aimed at assessing the prototype system of the proactive KM approach including its general features;
 - Section D was aimed at assessing the prototype system of the reactive KM approach including its general features;
- *Section E:* This section consisted of five general questions related to the integrated prototype system; and

- *Section F*: This section required participants to give comments on improvement of the overall framework, the main benefits of the prototype system, and ways to improve the prototype system.

8.4 Evaluation Results

This section presents feedback from the participants of the workshops in response to the questions and gives comments for further improvements. Table 8.2 shows the results from sections B, C, D and E in the evaluation questionnaire. The table presents the percentage (%) from construction site managers (Group 1) and university-based researchers (Group 2), with regard to the assessment scale. An analysis of answers given by both groups is presented in Section 8.4.1 under the following sections:

- An integrated KM framework;
- Capability of the prototype system (proactive approach and reactive approach);
- System usability; and
- Suggestions for improvement.

8.4.1 Responses to the KM System

Objective 1: To determine the relevance and applicability of the integrated KM framework.

The participants in both groups were satisfied with the performance of the integrated KM framework in addressing site management problems.

Table 8.2: The Responses to Evaluation Questions.

No	Evaluation Questions	Rating													
		1 Poor		2 Fair		3 Satisfactory		4 Good		5 Excellent					
		SM	Res.	SM	Res.	SM	Res.	SM	Res.	SM	Res.				
1	How useful do you consider the overall framework														
2	How useful is it to have both a proactive and reactive approach to addressing site management problems?	25%		25%		50%	40%	25%	80%	50%	50%	25%	10%	10%	
3	To what extent will having a proactive KM approach help in avoiding SM problems?						20%	100%	80%						
4	To what extent will the reactive KM approach help Site Managers in solving specific problems?				20%	25%	20%	50%	60%	25%	25%				
5	How appropriate is the facility for monitoring and review of (KM) initiatives?					50%	30%	50%	70%						
6	How useful is the 'Revise KM Initiatives' stage in modifying existing initiatives?					25%	50%	75%	20%					30%	
Section C. Proactive KM Approach															
7	How well does the system help in avoiding site management problems?			25%	30%	75%	50%								
8	How well does the system help in identifying common problems that occur on construction site?			25%	10%	75%	40%								
9	How well do available solutions help in avoiding potential SM problems?			25%	20%	50%	40%								
10	How well does the system help in developing an implementation plan for selected solution?					25%	50%	75%	50%	75%	25%	40%	50%		
11	How well does the system help in monitoring and reviewing existing measures?				20%	75%	30%	25%	40%	25%	40%	40%	40%	10%	
12	How useful is the 'Revise Measures' stage in modifying existing measures?				10%	25%	40%								
General (Proactive KM Approach)															
13	How appropriate is the proactive KM system for site managers?			50%	30%	50%	20%								
14	What is your overall rating of the proactive KM sub-system?			25%	10%	50%	50%	25%	30%	25%	50%	30%	30%	10%	

Key
 SM - Site Manager
 Res - Researcher

Table 8.2: The Responses to Evaluation Questions (continued).

No	Evaluation Questions	Rating													
		1 Poor		2 Fair		3 Satisfactory		4 Good		5 Excellent					
		SM %	Res. %	SM %	Res. %	SM %	Res. %	SM %	Res. %	SM %	Res. %				
15	How well does the system help in solving specific site management problems?			25%	10%	75%	50%								
16	How well does the system help in identifying the type of knowledge required?			50%			50%	50%							
17	How appropriate are the types of knowledge required for solving a given problem?			25%	20%	75%	40%								20%
18	How well does the system help in identifying the characteristics of knowledge?			25%	10%	50%	40%	25%							10%
19	How well does the system help in identifying the sources and destination of knowledge?			25%		25%	60%	50%							
20	How well does the system relate characteristics of knowledge to applicable KM processes?			25%	20%		30%	75%							10%
21	How well does the system identify the KM techniques and technologies required for solving a site management problem?			25%			40%	75%							
22	How well does the system help in developing KM implementation plan for resolving site management problem?			25%	10%	50%	40%	25%							
23	How well does the system help in monitoring and reviewing KM initiatives?			25%	10%		40%	75%							10%
24	How useful is the 'Revise KM Initiatives' stage in modifying existing KM initiatives?			25%		25%	40%	50%							30%
General (Reactive KM Approach)															
25	How appropriate is the reactive KM system for site managers?			75%			60%	25%							20%
26	What is your overall rating of the reactive KM system?			50%		25%	50%	25%							10%
Section E. General Questions on the Integrated Prototype System															
27	How attractive is the graphical user interface of the system?			25%	30%	50%	30%	25%							20%
28	How easy is it to navigate between the different stages within the system?					25%	20%	75%							30%
29	How effective is the on-screen help in facilitating the use of the system?					25%	40%	75%							50%
30	How convinced are you that site managers can use the system?			25%	40%	50%	30%	25%							
31	To what extent does it represent an improvement in site management practices?			25%		50%	50%	25%							10%

Figure 8.3 shows the overall rating from site managers on the systems' performance with regard to Questions B1 to B6. Participants took the view that both proactive and reactive KM approaches could help them in managing construction knowledge in site management practices. The majority of the site managers assessed the system as 'Good' and 'Satisfactory'. However, one of the site managers graded the integrated system as 'Poor' and this situation may indicate that some of the site managers who have work experience of more than 20 years are less confident on how site problems can be managed effectively in construction site management practices. Figure 8.4 shows the overall rating given by researchers. The majority of them gave ('Satisfactory' and 'Good') ratings to the integrated KM framework. In terms of performance of the integrated KM framework, it can be concluded that the developed integrated framework gave an overall 'Good' performance.



Figure 8.3: Overall Rating for an Integrated KM Framework Performance (Site Managers).

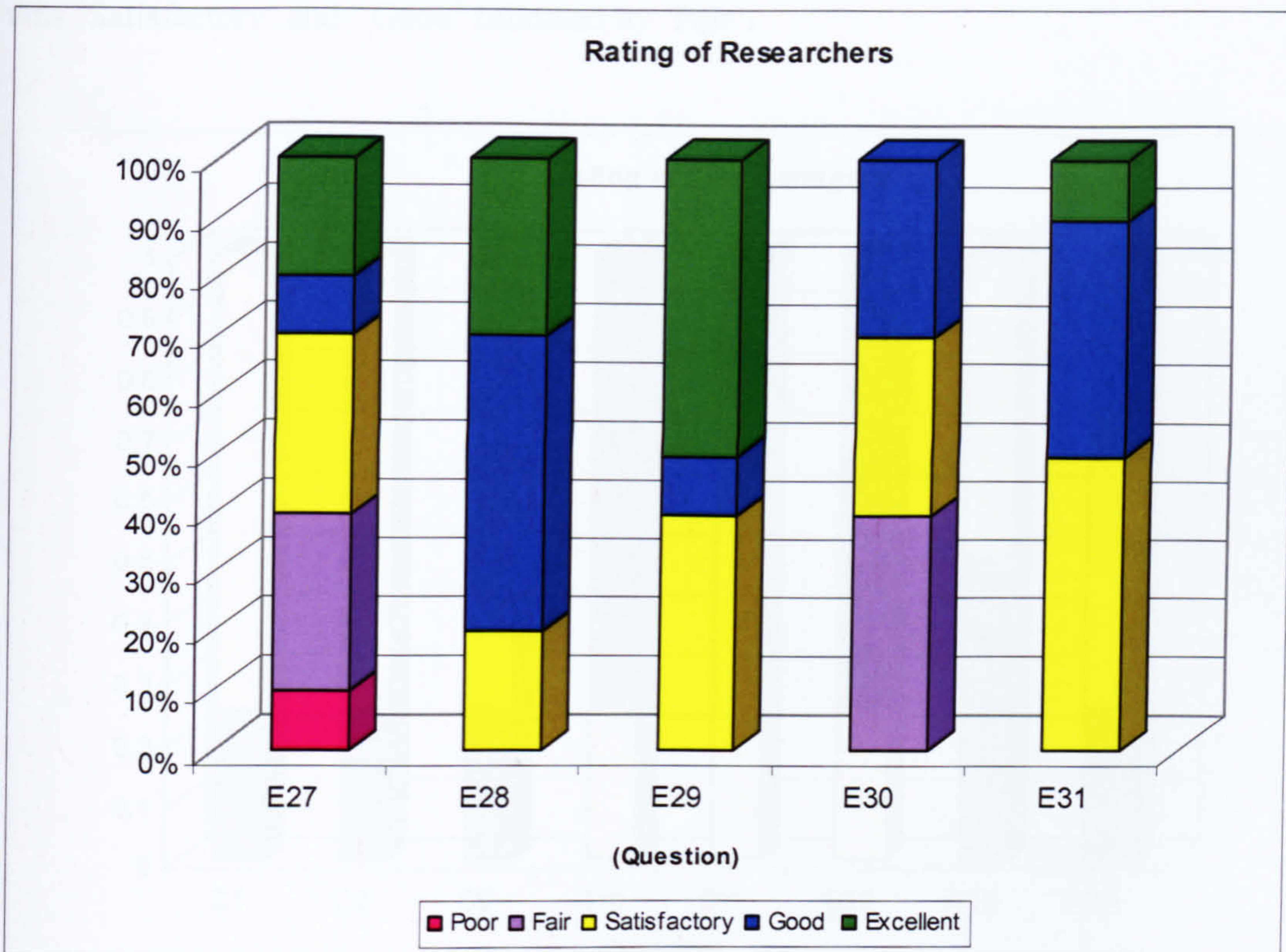


Figure 8.4: Overall Rating for an Integrated KM Framework Performance (Researchers).

Objective 2: To assess the capability of the prototypes for addressing all stages of the KM identified in the integrated KM framework (Proactive approach and Reactive approach).

The capability of the prototype system for addressing all stages of the KM identified in the integrated KM framework was also viewed positively, both from the site managers' and researchers' groups. The assessment was divided into two main parts: a proactive KM approach and a reactive KM approach.

Figure 8.5 shows the overall rating given by site managers when asked to assess the performance of the proactive KM approach part of the prototype system. The findings

show that the majority of site managers judged that the proactive part of the KM system was 'Satisfactory' and 'Good' followed by 'Fair'.

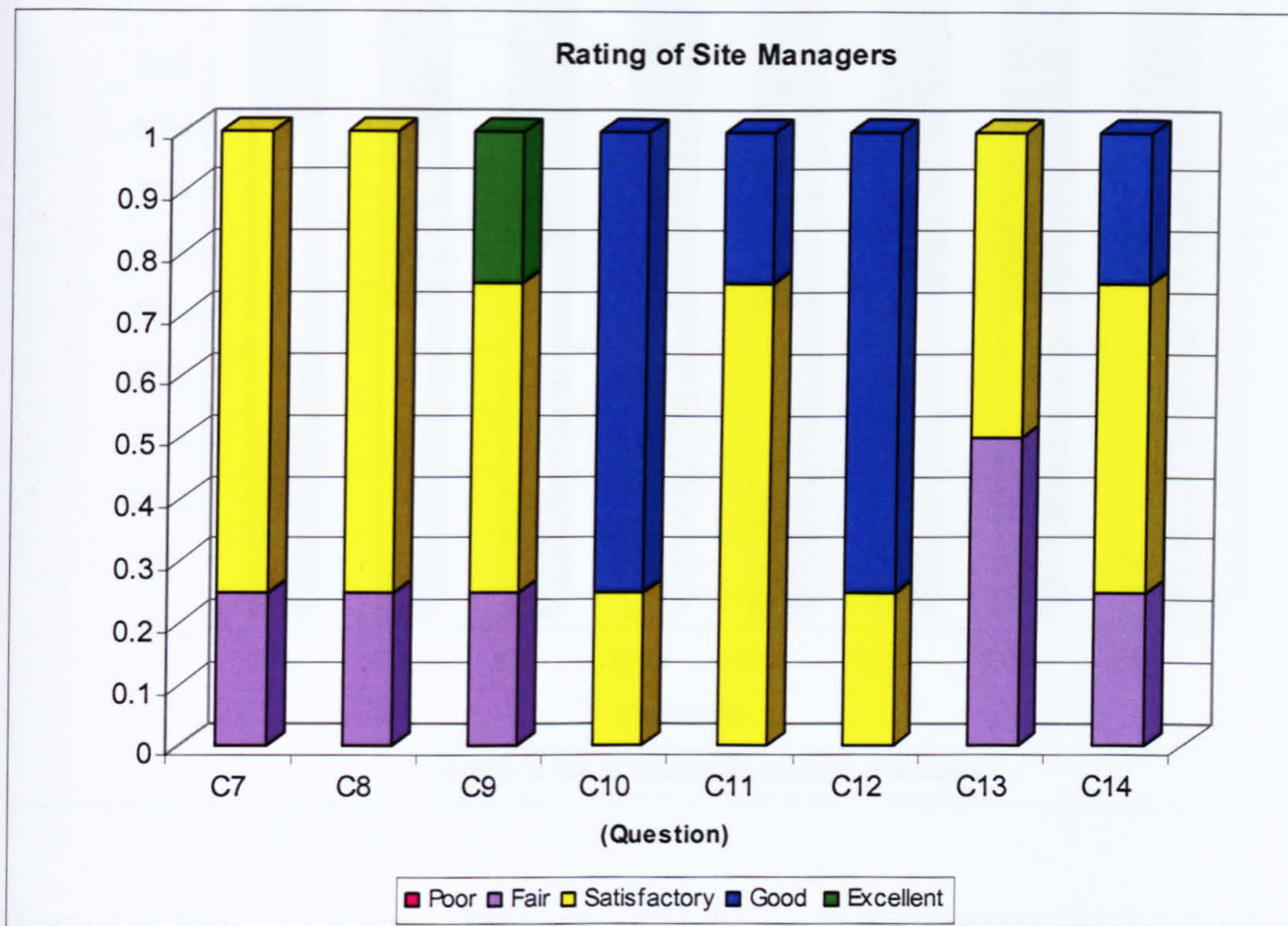


Figure 8.5: Prototype System of Proactive KM Approach Performance (Site Managers).

Figure 8.6 show that the researchers also gave the same trend of ratings as the site managers. When comparison was made between groups of different levels of work experience on construction sites, the results showed that the group with less experience (researchers) had judged the proactive KM system as a useful system in avoiding site management problems; over 50% of the researchers group judged the proactive KM approach as 'Good'. These results indicated that both groups of participants felt that it was important to adopt a proactive KM system in managing construction site knowledge.

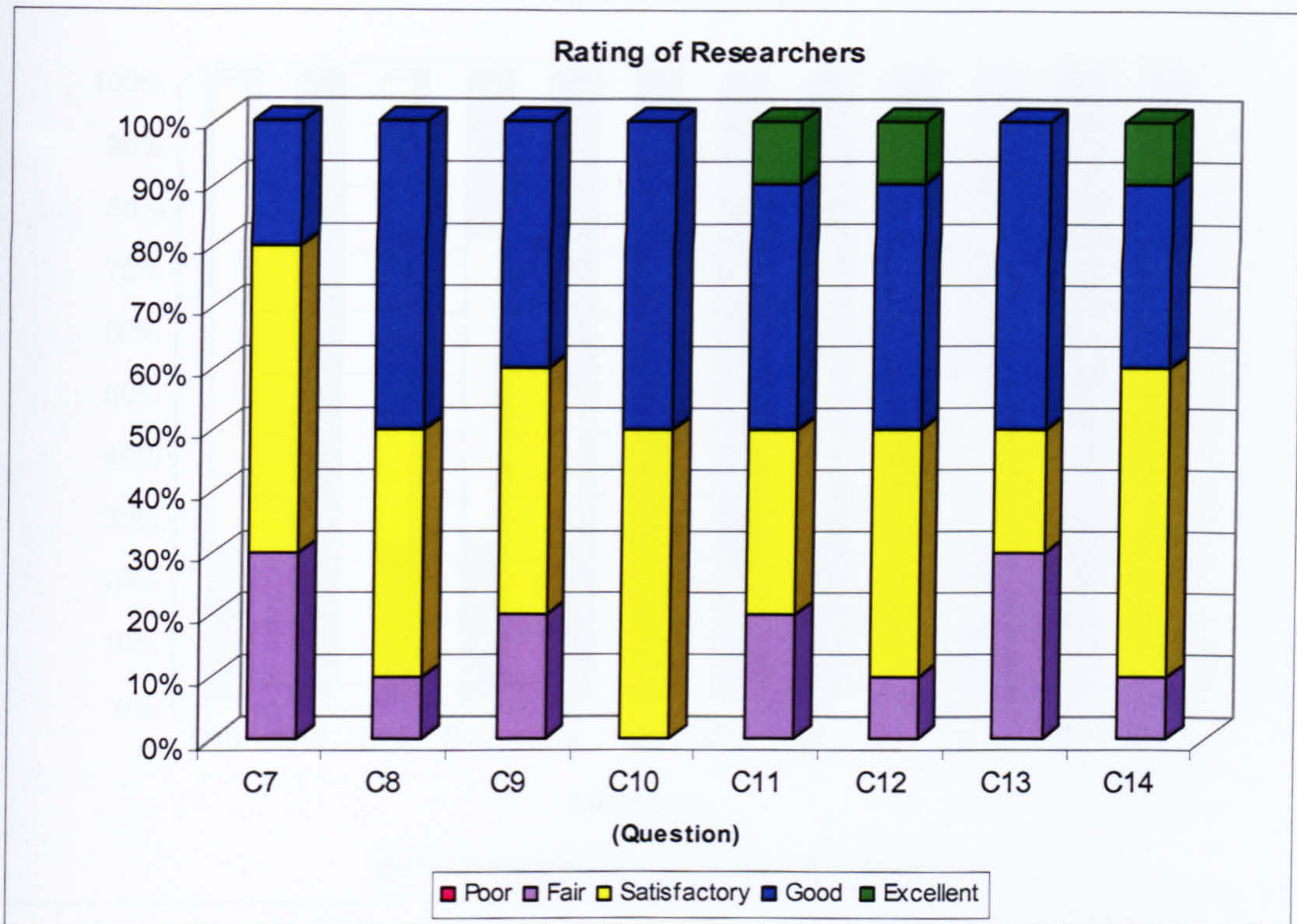


Figure 8.6: Prototype System of Proactive KM Approach Performance (Researchers).

The participants were also required to assess the reactive KM approach part in the prototype system. Figure 8.7 shows the overall rating given by site managers to the reactive KM approach part of the prototype system. Participants were asked to assess the capability of the prototype for addressing all stages of the reactive KM approach. The findings showed that site managers gave ratings of 'Fair', 'Satisfactory' and 'Good'. In contrast, Figure 8.8 shows that researchers rated them as 'Fair', 'Satisfactory', 'Good' followed by 'Excellent'. With regard to the 'experience' interference, it was found that the trend of participants who judged the reactive approach part as 'Good' and 'Satisfactory' for solving site management problems was similar between groups. However, the 'Excellent' judgement came from the researchers' group that had less experience in construction site management and this result indicates that they need a systematic problem-based KM approach to tackling site problems.

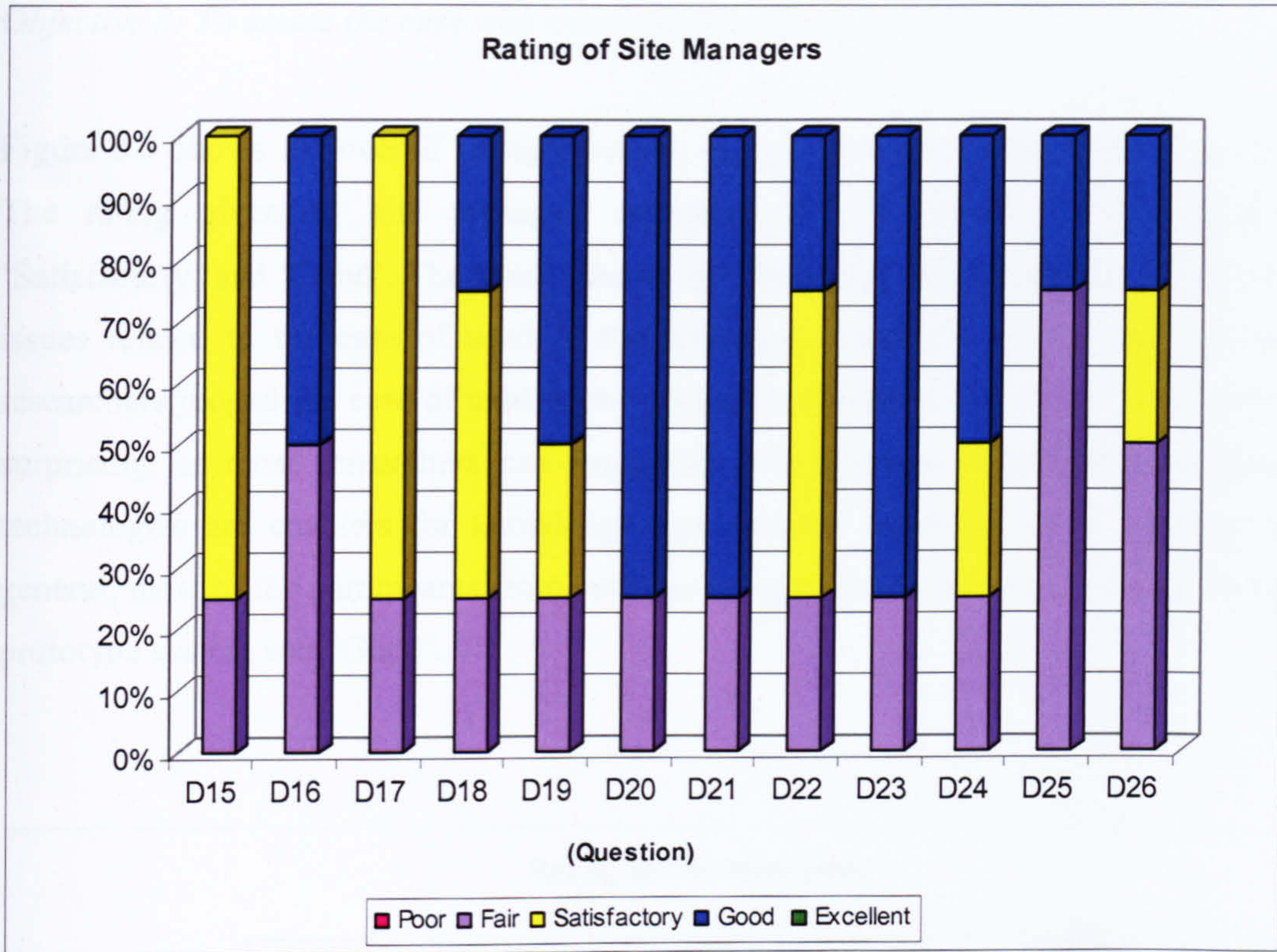


Figure 8.7: Prototype System of Reactive KM Approach Capability (Site Managers).

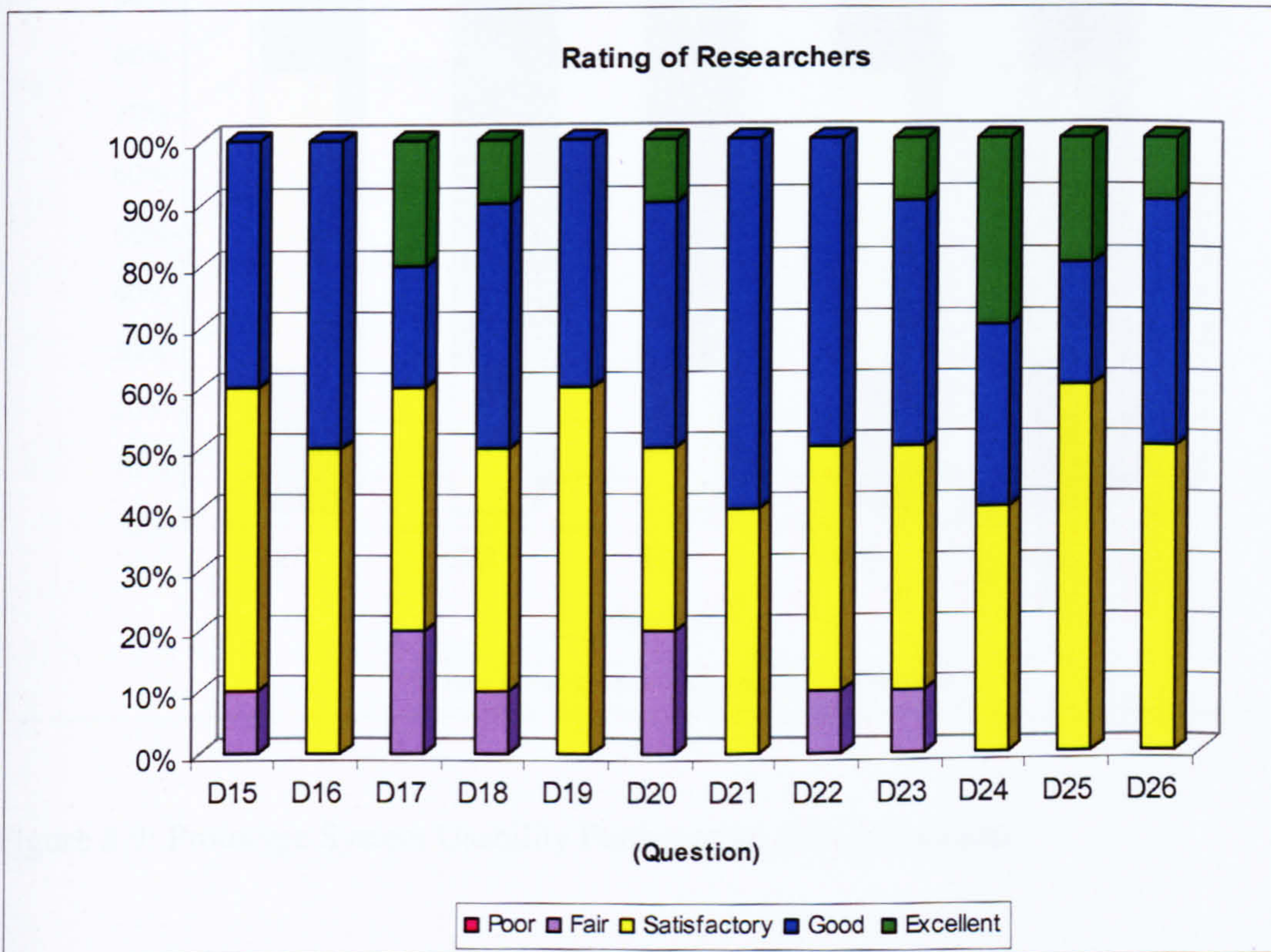


Figure 8.8: Prototype System of Reactive KM Approach Capability (Researchers).

Objective 3: To assess the ease with which the prototypes can be used.

Figure 8.9 shows the overall rating given by the site managers (Questions 27 to 31). The rating given by site managers regarding this section was mainly 'Fair', 'Satisfactory' and 'Good'. The results shown in Figure 8.10 show some similarity with issues related to the ease of used of the prototype system. However, some of the researchers judged the ease of used of the prototype system as 'Excellent'. This is not surprising, as most researchers can appreciate that information and communication technologies are enablers for knowledge management. Based on these findings, in general, most of the participants from both groups agreed that the overall rating for the prototype system was 'Good'.

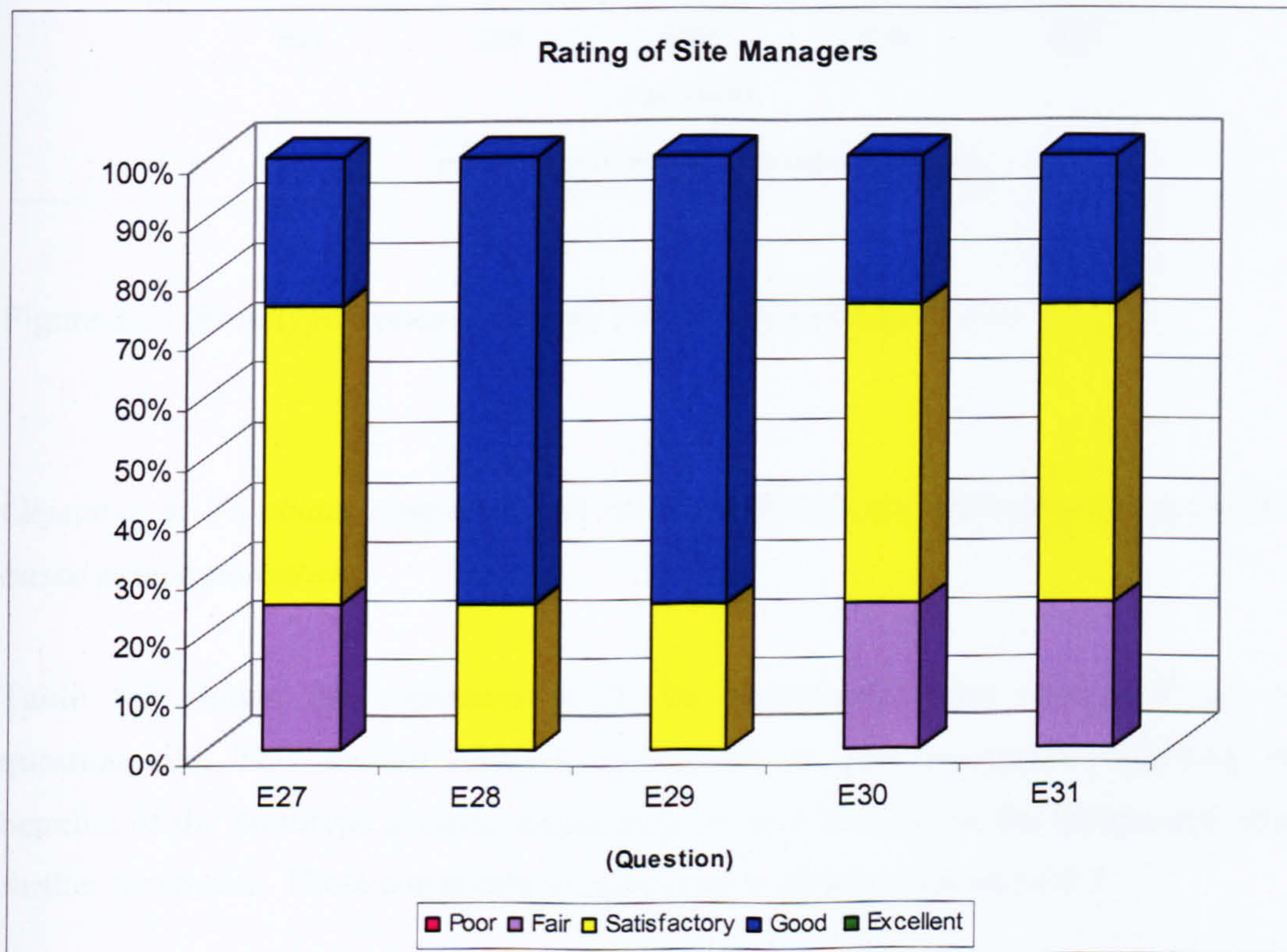


Figure 8.9: Prototype System Usability Performance (Site Managers).

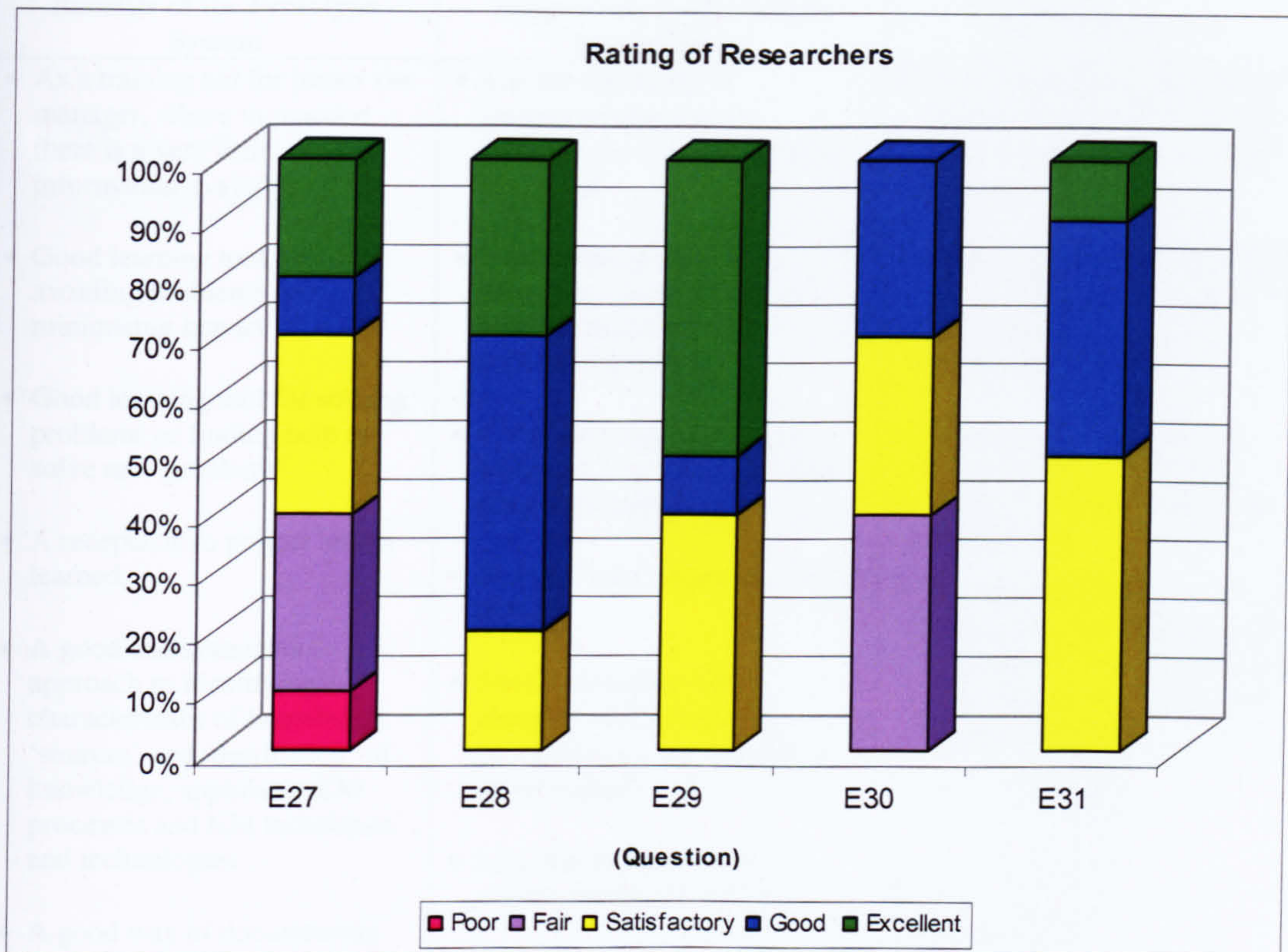


Figure 8.10: Prototype System Usability Performance (Researchers).

Objective 4: To obtain comments and recommendation for improving developed KM based prototype system.

Table 8.3 shows the comments made by participants from Section F of the questionnaire. This section requires participants to give comments regarding the benefits of the prototype system, suggestions on how to improve the system and other further comments. These comments are discussed in detail in Section 8.4.2.

Table 8.3: Comments from Participants Regarding the Prototype System.

Benefits of the Prototype System	Suggestions for Prototype Improvement	Other Comments
<ul style="list-style-type: none"> • As a training aid for junior site manager, where in practice there is a very little information available • Good learning tool for avoiding problems and minimising impact • Good learning tool for solving problems or finding help to solve new problems • A receptacle to project lesson learned. • A good and systematic approach to identifying characteristics of knowledge, 'sources' and 'destination' of knowledge, applicable KM processes and KM techniques and technologies • A good way of documenting and presenting the processes that site managers should follow when addressing problems on site • Provide base of information for young engineers to learn from site environment 	<ul style="list-style-type: none"> • Add the capability to restructure the original template for site management processes • Need appropriate education/training before implementation on the construction site • Consider categorisation of problems, e.g. design category, planning category, etc. • Reduce 'user' selection of options • Should consider 'others' category of construction processes (e.g. knowledge of environment) • Link and integrate into existing intranet/extranet • Dynamically updated fields (e.g. tools in the KM techniques and technologies database) 	<ul style="list-style-type: none"> • The system when used in the industry will improve by the input of further data as more projects are included • Suggested that the model needs more evaluation workshops before developed as commercial software • Include knowledge of 'tolerance' for relevant elements of construction site management • Provides incentives for site managers to use proactive KM approach and encourages them to use this approach as a first alternative measure

8.4.2 Suggestions for Improvement

Majority of the participants made at least one comment in the evaluation questionnaire and the discussion session as presented earlier in Table 8.3. The findings revealed that the participants' had given a positive feedback and gave their full cooperation during the evaluation process. The main suggestion was to develop more generic KM system on construction site, which allows the site manager to customise the construction site management processes as described earlier in Chapter 6, section 6.5.5. The majority of the site managers also suggested that the site management team needed proper training before implementation on construction site. The other suggestions for

prototype improvement related to the future development of the prototype system. A participant suggested integrating the prototype system into existing intranet/extranet on the construction site. Others suggest conducting evaluation workshop to refine and improve the prototype system before developed commercial software. These suggestions have been carefully considered for future research.

8.5 Benefits of the Prototype Systems

The 'site-KM' prototype system is essentially a problem based knowledge management framework for construction site managers. The relevance and capability of these tools for addressing site management problems have been confirmed and verified through the evaluation workshop. Moreover, through the evaluation workshop the participants identified several benefits of the prototype system, which include:

- The system provides an innovative approach for avoiding site management problems and/or minimising the impact of any problems that occur;
- The system can be used by site managers as a problem solving methodology on any construction site and is scalable for any type of project;
- The systems can be used as a training tool, particularly for junior site managers, who have limited experience and access to appropriate guidance;
- The system provides site managers with a well defined and systematic approach to identifying the characteristics of knowledge, 'sources' and 'destination' of knowledge, applicable KM processes and KM techniques and technologies;
- The system provides guidance in the development of KM initiatives/measures within construction organisations (e.g. action plan, tools required, etc.);
- The system provides a structured and workable approach to documenting and presenting the processes that site managers should follow in addressing problems on site; and
- The system provides a simple tool for evaluating KM initiatives or measures so as to improve their effectiveness in a given situation. The evaluation processes supported by a 'key diagnostic checklist' to assess the effectiveness of the KM initiatives/measures.

8.6 Limitations of the Prototype System

The comments regarding the limitations of the prototype systems were made during discussion sessions in the evaluation workshop. The participants highlighted that the prototype system is difficult to use without adequate training. They also commented that the developed prototype system is very structured and required too many details for developing a problem based KM strategy. Another limitations encountered in the evaluation was the possibility of participant's bias against the system. Bias was particularly apparent with the site managers' (Group 1) workshop, and was reflected in their ratings and comments during the evaluation. In this context, there is the need for more objective evaluation to be undertaken in different construction site organisations to obtain a more accurate result of the evaluation.

8.7 Discussion

8.7.1 Evaluation Results

The fourteen evaluators were generally satisfied with the effectiveness of the prototype system in addressing site management problems; although there were suggestions for improvements to the system design and user interface. Table 8.3 shows the analysis of average ratings of the participants (i.e. arithmetic means of their responses to key diagnostic questions) against the objectives of the prototype system. The average scores can be summarised as follows:

- The validity and relevancy of the integrated KM framework is 3.68 out of possible maximum of 5;
- The capability of the prototypes for addressing all stages of the KM identified in the integrated KM framework is 3.36 out of possible 5; and
- The ease with which the prototypes can be used is 3.53 out of possible maximum of 5.

Table 8.4: Objectives for Prototype Systems and Key Questions.

No	Objectives for Prototype System and Key Questions	Average Rating (Out of 5)
<i>To determine the relevance and validity of the prototype system (average score)</i>		3.68
1	How useful do you consider the overall framework	3.64
2	How useful is it to have both a proactive and reactive approach to addressing site management problems?	3.57
3	To what extent will having a proactive KM approach help in avoiding SM problems?	3.86
4	To what extent will the reactive KM approach help Site Managers in solving specific problems?	3.57
5	How appropriate is the facility for monitoring and review of (KM) initiatives?	3.64
6	How useful is the 'Revise KM Initiatives' stage in modifying existing initiatives?	3.79
<i>To assess the capability of the prototypes for addressing all stages of the KM identified in the integrated KM framework (average score)</i>		3.36
7	How well does the system help in avoiding site management problems?	2.86
8	How well does the system help in identifying common problems that occur on construction site?	3.21
7	How well do available solutions help in avoiding potential SM problems?	3.21
9	How well does the system help in developing an implementation plan for selected solution?	3.57
10	How well does the system help in monitoring and reviewing existing measures?	3.36
11	How useful is the 'Revise Measures' stage in modifying existing measures?	3.57
12	How well does the system help in solving specific site management problems?	3.14
13	How well does the system help in identifying the type of knowledge required?	3.36
14	How appropriate are the types of knowledge required for solving a given problem?	3.21
15	How well does the system help in identifying the characteristics of knowledge?	3.36
16	How well does the system help in identifying the sources and destination of knowledge?	3.36
17	How well does the system relate characteristics of knowledge to applicable KM processes?	3.43
18	How well does the system identify the KM techniques and technologies required for solving a site management problem?	3.57
19	How well does the system help in developing KM implementation plan for resolving site management problem?	3.29
20	How well does the system help in monitoring and reviewing KM initiatives?	3.50
21	How useful is the 'Revise KM Initiatives' stage in modifying existing KM initiatives?	3.71
<i>To assess the ease with which the prototypes can be used (average score)</i>		3.53
22	How attractive is the graphical user interface of the system?	3.00
23	How easy is it to navigate between the different stages within the system?	4.00
24	How effective is the on-screen help in facilitating the use of the system?	4.29
25	How convinced are you that site managers can use the system?	2.93
26	To what extent does it represent an improvement in site management practices?	3.43

The above evaluation results show that the participants agreed that the system offered a useful and systematic approach to solving site management problems based on KM. The inviting formats, clear guidance, reduced input duplication, and automated report generation were found to have potential for attracting site management teams to use the system. It should be pointed out that because the evaluation workshop was not based on actual software utilisation by the participants, but on the demonstration on its use, these rating can only be indicative. However, the evaluation result shows that the 'site-KM' prototype system does facilitate the tackling of site management problems.

8.7.2 Appropriateness of the Evaluation Approach

The evaluation undertaken was successful and achieved its set objectives. This was revealed by the positive feedback and cooperation received from the participants. Appropriateness in this context means that the objectives were clearly defined, measurable and quantifiable. Although there were limitations, further evaluation and improvement of the system would facilitate the use of the prototype for practical purposes. The researcher used a combination of methods to evaluate the effectiveness of the prototype system. The evaluation approach conducted highlighted several points including:

- *Focus group*: This technique was aimed at providing a platform for participants to discuss their ideas and views on the prototype system. The benefits of this approach are that all participants, i.e. site managers and academic researchers involved in the task of delivering KM benefits to the site management practices;
- *Questionnaire*: The questionnaire covered all the major aspects of the prototype that needed to be evaluated and was useful for obtaining essential feedback from participants. The combination of close questions and open-ended questions give appropriate space for participants to give accurate answers and good feedback; and
- *Respondents*: All the participants especially the site managers had considerable experience in managing construction sites. Most of the site managers were involved in the case-study interviews described in Chapter 5. The evaluation allowed them to state whether the system addressed the needs of construction site managers.

8.8 Summary

This chapter has described the approach adopted in the evaluation of a 'site-KM' prototype system. The research adopted focus group discussions and a questionnaire in the evaluation the prototype system. The general principles considered in the evaluation of the prototype system were introduced. The findings from the evaluation show that the prototype system has a high degree of functionality and is capable of addressing site

management problems, although there are some limitations. In terms of relevance, the prototype was highly rated at 3.68 out of a possible maximum of 5. In terms of capability, the prototype was given a rating of 3.36. Finally, the comments and suggestions from the participants involved were used to refine the prototype system. The next chapter summarises the conclusions and recommendations of the research.

CHAPTER NINE

Conclusions and Recommendations

9.1 Introduction

This chapter concludes the thesis. It starts with a brief summary of the overall findings of the research, followed by the conclusions drawn from the research. The last section of the chapter presents the limitations of the research and makes recommendations for further research.

9.2 Summary

The aim of this research was to investigate the improvement of construction site management practices through an integration of applicable knowledge management processes. The rationale for undertaking this research was the need for well defined and systematic methods for managing knowledge on the construction site. To fulfil this need, the research developed a well defined and structured framework for managing construction site knowledge; underpinned by case study findings from construction organisations that have implemented KM. The aim was achieved through several specific objectives of the research including

- To review current site management practices, focusing on the key processes and actors involved and existing management procedures with a view to identifying current problems, and opportunities for improvement;
- To investigate knowledge management processes with a view to identifying those which are applicable at the construction site level;
- To develop a framework for improving site management practices based on an integration of KM processes;

- To encapsulate the framework in a computer-based prototype system; and
- To evaluate the prototype system and underlying model using industry practitioners and researchers.

The specific tasks undertaken in this research, with respect to research objectives are summarised below

Objective 1: To review current site management practices, focusing on the key processes and actors involved and existing management procedures with a view to identifying current problems, and opportunities for improvement.

The literature review on current site management practices revealed that managing a construction site offers a wide range of interesting management, technical and communications problems to be solved. Poor communication, poor information and inaccurate planning were identified as the major problems occurring within the construction site environment. The main contributory factors for these problems included the many types of project being undertaken, their varied locations, the types of materials and plant, and the changing nature of the project as it progresses. It is important to understand the underlying cause of problems before incorporating any management approach into site management practices. *Chapter 3* presented various management approaches (e.g. total quality management, just-in-time approach, business process re-engineering, concurrent engineering, etc.) to improve construction site management with a view to identifying its focus and benefits of implementation. It is equally important to examine the management of knowledge in construction site management practices. Construction knowledge both explicit (i.e. captured in drawings, specifications, etc.), and tacit (held in people's heads) is being practised within construction site management practice. It was revealed that the site managers are the best personnel to implement KM initiatives in site organisations as they can play the role of either knowledge broker or technical expert capable of dealing with practical problem solving. The expertise and experiences, both administrative and technical, can certainly be utilised to manage knowledge in construction site management practices.

Objective 2: To investigate knowledge management processes with a view to identifying those which are applicable at the construction site level.

The investigation of key concepts of knowledge, knowledge management processes and knowledge management tools was presented in *Chapter 4* with a view to identifying applicable KM processes and relevant KM tools to be integrated into site management practices. From a well structured synthesis of knowledge taxonomy, it was observed that the knowledge types relevant to site management practices include process knowledge, product knowledge and people knowledge. The review process also revealed that knowledge capturing, knowledge sharing, and knowledge creation provides an interesting opportunity for integration into site management practices. Furthermore, construction site organisations can use already established KM tools for managing construction site knowledge because the construction site management practices involve several knowledge-intensive activities. However, it is important to identify the techniques (non-IT tools) and technologies (IT tools) needed, including their appropriateness within the specific-problem context of the construction site, before implementing a KM strategy on the site. A potential knowledge management system (that can be deployed as the technological means) for managing both explicit and tacit knowledge, as part of an organisation's knowledge management initiatives, was reviewed in *Chapter 4*. The reviews revealed that current research work on implementing a KM strategy on the construction site does not adequately fulfil the KM needs for construction site management practices.

Case studies were used to investigate the possibilities of deploying KM initiatives at the construction site level, as described in *Chapter 5*. All of case study organisations had implemented KM in their organisations. The case studies carried out confirmed that existing site management practices can be improved through knowledge management. The case studies were based principally on semi-structured interviews with one site-based project manager from each of five different construction organisations. Different types of construction site provided a chance to explore the knowledge resource variations within and across construction site organisations. The case study findings revealed that professional workers (e.g. engineers, architects, quantity surveyors, estimators, etc) and operative workers (e.g. plasterers, plumbers, bricklayers, roofers, carpenters, etc.) required both explicit and tacit knowledge, although more than 50% of

construction site knowledge was considered as tacit. Organisations obtained the required knowledge mostly via informal ways although those adopting KM used a mixture of informal and formal methods. Informal and formal meetings were the most common mechanism used to solve site management problems. Project procedures (e.g. quality control procedure, health and safety procedure, material delivery procedure, etc) were used by the site manager as a source of explicit knowledge to solve site management problems. Therefore, it was important to develop an appropriate mechanism for managing tacit and explicit knowledge in different ways on the construction site. The case study findings also uncovered the relevant issues for a structured and effective KM framework for construction site management practices. These relevant issues included:

- Identifying the most significant site management problems which can attributed to a knowledge gap;
- Establishing KM issues related with the problems;
- Developing appropriate KM initiatives that will bridge the knowledge gap; and
- Developing an action plan for implementation.

The researcher used the findings from the case studies as a guide to developing a well defined and structured construction site KM framework.

Objective 3: To develop a framework for improving site management practices based on an integration of KM processes.

This research reviewed various KM frameworks for construction as presented in *Chapter 6*. Investigation and analysis of existing KM frameworks showed that no KM framework addresses all KM needs for construction site management practices although a few of them address some important needs of a construction site KM framework. This resulted in the adoption of existing CLEVER and SeLEKT frameworks. Adaptation of these frameworks addressed relevant needs of the KM framework on the construction site. It also helped to develop an effective and systematic KM framework on the construction site.

A problem-based KM framework was found essential for site managers to adopt knowledge management approach to addressing site management problems. The framework developed as an integrated KM framework consisting of both proactive and reactive KM approaches. The proactive KM approach was intended to support the institution of KM initiatives that would prevent the most common site management problems from occurring and to reduce the impact of those problems which do occur. The reactive KM approach aimed to identify the knowledge gap that has led to specific problems and to recommend measures to tackle the problem. Moreover, the development of a KM framework at the construction site level should fulfil the three important needs: addressing all stages of a KM framework; adequate level of detail and sufficient details; and to be useful and effective. It was also important that the developed framework should be comprehensive but easy to use by the site manager.

Objective 4: To encapsulate the framework in a computer-based prototype system.

Based on the site management practices needs identified during the interviews, the integrated KM framework was encapsulated into a computer-base prototype system using Microsoft Visual Basic program. The proposed prototype system was named 'site-KM'. The development of the prototype system was based on the system lifecycle methodology. Details of system development and system operation were presented in *Chapter 7*. This automation facilitated the use of the integrated KM framework, and enhanced its functionality. After the prototype system was completed, several 'real' site management problems were tested in the prototype system and built-in report facilities were generated to provide a written record of the KM strategy developed by the site manager. The testing results showed that the prototype system can perform all the operations on addressing site management problems as designed and that the prototype system is prepared for the evaluation.

Objective 5: To evaluate the prototype system and underlying model using industry practitioners and researchers.

The prototype system was evaluated by relevant end-users. The evaluation of the prototype system was carried out when the 'site-KM' prototype system was considered virtually complete as presented in *Chapter 8*. The approaches adopted were focus

groups, and evaluation questionnaires to evaluate the prototype system using evaluation workshops. There were two groups of participants involved in the evaluation workshops. The first group comprised four construction site managers while the second group comprised 10 university-based researchers. The first group was selected to obtain feedback from the internal end-user perspective on the usability and heuristic features of the system. The second group was selected to obtain feedback from the external end user perspective related to the usability of the system. The evaluation results confirmed that the participants were generally satisfied with the effectiveness of prototype system in addressing site management problems; although there were suggestions for improvements to the system design and user interface. The prototype system also provided many benefits, was well defined and structured and has great potential for use in addressing site management problems.

9.3 Conclusions

This research investigated the improvement of construction site management practices through an integration of applicable KM processes. The following conclusions can be drawn from the research:

- The KM-based construction site management system provides a robust and an innovative approach for addressing the identified site management problems and for preventing new problems from occurring; by having early identification of KM problems to be avoided;
- The prototype system provides a practical tool for the site manager and it integrates the information, processes, and technology components of a KM system to optimise knowledge sharing and organisational learning;
- The prototype system developed provides a structured problem-solving methodology from knowledge management perspectives for addressing site management problems; even when the knowledge is in the mind of the site manager, this improves the accuracy and timeliness of the decision made;

- Most of the existing KM frameworks for construction are focused on best practices and ‘lesson learned’ approach, with nothing available on developing a problem-solving KM framework;
- The integrated KM framework developed provides the site manager with an effective, structured, and systematic problem-based KM framework that could improve site management practices. Both proactive and reactive KM approaches help to resolve site management problems that may occur and minimise the unpredictable problems that may occur on the construction site;
- Knowledge management processes can be effectively used on the construction site to enable knowledge to be captured, shared and created. KM implementation at the construction site level should be problem-oriented rather than technology-oriented. However, the role of KM technologies as a key enabler remains essential. Indeed, both KM techniques and technologies need to cohabit to support each other;
- Knowledge management processes can be effectively used on the construction site to enable knowledge to be captured and reused in the future. However, the culture of organisations and business goals are two key ‘soft’ factors that need to be addressed, if the benefits of knowledge management are to be realised;
- KM has potential to solve management, technical and communication problems on the construction site. Some of the benefits that KM provides to site management practices are:
 - Reduced number of problems and minimising their impact;
 - Reduced number of mistakes and defects;
 - Preventing the ‘re-invention of the wheel’;
 - Developing easy problem solving methodology for common site management problems; and
 - Making past solutions and a structured approach to addressing particular problems easily accessible.

- Knowledge management is an integral part of continuous performance improvement through project learning and innovation. It is important to recognise that KM strategy adopted should facilitate collaboration between individuals, teams and communities of specialists, both inside and outside the organisation.

9.4 Limitations of the Research

All research studies have their limitations, and this study was no exception. The main limitations were as follows:

- Difficulties in sharing information as the case study organisations did not have a detail knowledge management strategy;
- The prototype system focused on using six construction site management processes (management, supervision and administration of sites; commercial management; health and safety management; planning, monitoring and control; delivery and materials' handling; and production on-site and off-site). However, there are many other construction site management processes i.e. environmental, sustainability. It is important to allow site managers to customise the construction site processes based on their company's goal and objectives; and
- The prototype system did not provide a dynamic and real-time database management system. The system developer was the only person with authorisation to update and maintain the system.

9.5 Recommendations for Further Study

This study has explored the use of knowledge management to improve construction site management practices. There is scope for others to build on the work reported in this

thesis. In this section, recommendations are made for both industry practitioners and researchers.

9.5.1 Recommendations for Industry Practitioners

The following recommendations apply to the problem-based KM approach and implementation of knowledge management in construction site management practices:

- It is important to establish the requirements for each construction site, project and organisation, as KM is context specific. It is equally important to link the construction site KM framework to any existing KM framework at the strategic and tactical levels in the organisation;
- Knowledge management is relevant for addressing site management problems and therefore it should be seriously considered;
- The selection of KM initiatives requires clear identification of site management problems and at the same time requires explicating KM dimension for each problem;
- It is important to follow a structured approach for developing KM initiatives to avoid implementing unnecessary initiatives and/or missing important ones; and
- The evaluation of KM initiatives/measures should be done periodically in order to monitor their effectiveness so that changes can be made as appropriate.

9.5.2 Recommendations for Researchers

There is considerable scope for further research, which extends the study reported here. Further work can include the following:

- Further improvements can be made to the prototype system with respect to:
 - Creating intelligent customisation to the construction site management processes in the proactive and reactive KM approach;
 - Adding more dynamic features to the system database (e.g. database of common site management problems, database of KM techniques and database of KM technologies) so that the system automatically update when relevant information entered; and
 - Improvement of the user interface by incorporating features to check the data/information entered at the previous stages.
- Further testing of the prototype on real site management problems with various types of construction site is considered necessary. The feedback from these can further demonstrate the system's applicability in different type of problem scenario;
- Integrating the prototype system with other project management systems (e.g. computer aided design, project scheduling system, email system, etc.). This would enhance the usefulness of the prototype system and could lead to commercialisation of the prototype system;
- Extend the research on capturing and sharing knowledge between professional workers and operatives on the construction site;
- Investigate the potential of KM as a collaboration platform between the site management, design, and maintenance teams. This could be done through a wider case study covering different units in the construction organisations; and
- Develop personal knowledge management system for the site managers to store his/her tacit and explicit knowledge.

9.6 Concluding Remarks

An improvement of construction site management practices was demonstrated through optimising KM initiatives in this research. The problems on the construction, procedures used and aspects of knowledge management within site management practices were identified from case studies conducted. The case study findings, underpinned by the literature review have directed the development of an integrated KM framework that helps site managers to adopt a knowledge management approach to addressing site management problems. Then, the developed framework was encapsulated into a computer-based prototype system to provide site managers with a practical tool for resolving site management problems, based on the KM perspective. The developed prototype system provides site managers with a structured and systematic KM approach that could improve the current approach to solving site management problems. It also provides a good opportunity for applying KM initiatives to help in training inexperienced site managers to provide solutions to site management problems.

References

- Abdullah, A. (2003) *Intelligent Selection of Demolition Techniques*. Phd Thesis, Loughborough University, Loughborough.
- Abdullah, M.S., Kimble, C., Benest, I. and Paige, R. (2006) Knowledge-Based Systems: A Re-Evaluation. *Journal of Knowledge Management*, Vol. 10, No. 3, p.p. 127-142.
- Agapiou, A., Price, A.D.F. and McCaffer, R. (1995) Planning Future Construction Skill Requirements: Understanding Labour Resource Issues. *Construction Management and Economics*, Vol. 13, pp. 149-161.
- Akintoye, A. (1995) Just-In-Time Application and Implementation for Building Material Management. *Construction Management and Economics*, Vol. 13, pp. 105-113.
- Alasuutari, P. (1998) *An Invitation to Social Research*, Sage Publications, London.
- Alavi, M. and Leidner, D.E. (2001) Knowledge Management and Knowledge-Management Systems: Conceptual Foundations and Research Issues. *MIS Quarterly*, Vol. 25, No. 1, pp. 107-136.
- Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J. and Carrillo, P.M. (2006) Prototype System for Knowledge Problem Definition. *Journal of Construction Engineering and Management*, Vol. 132, Issue 5, pp. 516-524.
- Al-Ghassani, A.M., Anumba, C.J., Carrillo, P.M. and Robinson, H.S. (2005) Tools and Techniques for Knowledge Management. *Knowledge Management in Construction*, Anumba, C.J., Egbu, C. and Carrillo, P.M., (Eds), Blackwell Publishing, Oxford, pp. 83-102.
- Al-Ghassani, A.M. (2003) *Improving the Structural Design Process: Knowledge Management Approach*. Phd Thesis, Loughborough University, Loughborough.
- Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J. and Carrillo P.M. (2002) A Tool for Developing Knowledge Management Strategies. *Electronic Journal of Information Technology in Construction*, Vol. 7, pp. 69-82.
- Al-Khlaifat, A. and AlRifai, R. (2002) A Case Study in the Chemical Engineering Frsehman Course Using Enhanced Excel with Visual Basic and Power Point. *Journal of Chemical Educator*, Vol. 7, pp. 384-386.
- Amaratunga, D., Baldry, D., Sarshar, M. and Newton, R. (2002) Quantitative and Qualitative Research in the Built Environment: Application of 'Mixed' Research Approach. *Work Study*, Vol. 51, No. 1, pp. 17-31.

References (continued)

- Amaratunga, D. and Baldry, D. (2001) Case Study Methodology as a Means of Theory Building: Performance Measurement in Facilities Management Organisations. *Work Study*, Vol. 50, No. 3, pp. 95-104.
- Anumba, C.J., Kamara, J.M. and Carrillo, P.M. (2005) Knowledge Management Strategy Development: A CLEVER Approach. *Knowledge Management in Construction*, Anumba, C.J., Egbu, C. and Carrillo, P.M., (Eds), Blackwell Publishing, Oxford, pp. 151-169.
- Anumba, C.J. and Scott, D. (2001) Performance Evaluation of a Knowledge-Based System for Subsidence Management. *Structural Survey*, Vol. 19, No.5, pp. 222-232.
- Anumba, C.J., Bloomfield, D., Faraj, I., and Jarvis P. (1998) *Managing Your Knowledge Assets: Knowledge Based Decision Support Techniques for the Construction Industry*, BR 382, Construction Research Communications Ltd.
- Anumba, C.J. and Evbuomwan, N.F.O. (1997) Concurrent Engineering in Design-Build Projects. *Construction Management and Economics*, Vol. 15, pp. 271-281.
- Armistead, C. (1999) Knowledge Management and Process Performance. *Journal of Knowledge Management*, Vol. 3, No. 2, pp. 143-154.
- Ashworth, A. (2001) *Contractual Procedures in the Construction Industry: 4th Edition*. Longman, Harlow.
- Barber, P., Tomkins, C., and Graves, A. (1999) Decentralised Site Management: A Case Study. *International Journal of Project Management*, Vol. 17, No. 2, pp. 113-119.
- Baskerville, R.L. and Harper, A.T. (1996) A Critical Perspective on Action Research as a Method for Information Systems Research. *Journal of Information Technology*, Vol. 11, pp. 235-246.
- Belle, R.A. (2000) Benchmarking and Enhancing Best Practices in the Engineering and Construction Sector. *Journal of Management in Engineering*, Vol. 16, Issues 1, pp. 40-47.
- Bennett, J. (2000) *Construction: The Third Way, Managing Cooperation and Competition in Construction*. Butterworth-Heinemann, Oxford.
- Bennett, J. (1991) *International Construction Project Management: General Theory and Practice*. Butterworth-Heinemann, Oxford.
- Betts, M. and Harper, T.W. (1994) Re-engineering Construction: A New Management Research Agenda. *Construction Management and Economics*, Vol. 12, pp. 551-556.

References (continued)

- Bhatt, G.D. (2001) Knowledge Management in Organisations: Examining the Interaction between Technologies, Techniques, and People. *Journal of Knowledge Management*. Vol. 5, No. 1, pp. 68-75.
- Bixler, C.H. (2005) Developing a Foundation For a Successful Knowledge Management System. *Creating The Discipline of Knowledge Management: The Latest in University Research*, Stankosky, M. (Ed.) Elsevier Butterworth-Heinemann, Oxford.
- Blackler, F. (1993) Knowledge and the Theory of Organisations: Organisations as Activity Systems and the Reframing the Management. *Journal of Management Studies*. Vol. 30, No. 6, pp. 863-884.
- Blumberg, B., Cooper, D.R. and Schindler, P.S. (2005) *Business Research Methods*. McGraw Hill Education, Berkshire.
- Boyd, D., Egbu, C.O., Chinyio E., Xiao H. and Lee C.C.T. (2004) Audio Diary and Debriefing for Knowledge Management in SMES, *Proceedings, 20th ARCOM Annual Conference*. Heriot-Watt University, 1st-3rd September, pp. 740-757.
- Bresnen, M. and Marshall, N. (2001) Understanding the Diffusion and Application of New Management Ideas in Construction. *Engineering, Construction and Architectural Management*, Vol. 8, No. 5/6, pp. 335-345.
- Bryman, A. (2004) *Social Research Methods, 2nd Edition*. Oxford University Press, Oxford.
- Carrillo, P. and Chinowsky, P (2006) Exploiting Knowledge Management: The Engineering and Construction Perspective. *Journal of Management in Engineering*, Vol. 22, No.1, pp. 2-10.
- Carrillo, P. (2004) Managing Knowledge: Lessons From the Oil and Gas Sector. *Construction Management and Economics*, Vol. 22, pp. 631-642.
- Carrillo, P.M, Anumba, C.J. and Kamara, J.M. (2000) Knowledge Management Strategy for Construction: Key I.T. And Contextual Issues. *Proceedings, International Conference of Construction Information Technology (CIT 2000)*, Reykjavik, Iceland, 28th-30th June, pp. 155-165.
- CIRIA (2001) *Faster Construction on Site by Selection of Methods and Material*, CIRIA Report C560. CIRIA, London.
- Clarke, R.H. (1988) *Site Supervision*. Thomas Telford, London.
- Construction I.T. (1996) *Benchmarking Best Practices Construction Site Processes*. Construct I.T. Centre of Excellence, University of Salford, Salford.

References (continued)

- Creswell, J. (1998) *Qualitative Inquiry and Research Design: Choosing Among Five Traditions*. SAGE Publications, Thousand Oaks, California.
- Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*. Sage Publications, Thousand Oaks, California.
- Davenport, T.H. and Prusak, L. (1998) *Working Knowledge: How Organisations Manage What They Know*. Harvard Business School Press, Boston.
- Davies, P.B., Owens, I. and Williams, M.D. (2004) Information Systems Evaluation and The Information Systems Development Process. *The Journal of Enterprise Information Management*, Vol. 17, No. 4, pp. 276-282.
- Dawood, N., Akinsola, A. and Hobbs, B. (2002) Development of Automated Communication of System for Managing Site Information Using Internet Technology *Automation in Construction*. Vol. 11, pp. 557-552.
- Djrbani, R. (1996) The Impact of Stress in Site Management Effectiveness. *Construction Management and Economics*, Vol. 14, pp. 281-293.
- Dent, R. and Montague, K. (2004) *Benchmarking Knowledge Management Practice in Construction*. CIRIA 620 Report, London.
- Druker, P.F. (1993) *Post-Capitalist Society*. Harper Business, New York.
- Easterby-Smith, M., Thorpe, R. and Lowe, A. (2001) *Management Research: An Introduction*. Sage Publications, London.
- Egbu, C.O. and Robinson, H.S. (2005) Construction as a Knowledge-Based Industry. *Knowledge Management in Construction*, Anumba, C.J., Egbu, C. and Carrillo, P.M., (Eds), Blackwell Publishing, Oxford, pp. 31-49.
- Egbu, C.O., Hari, S. and Renukappa, S.H. (2005) Knowledge Management for Sustainable Competitiveness in Small and Medium Surveying Practices. *Structural Survey*, Vol. 23, No. 1, pp. 7-21.
- Egbu, C.O. and Botterill, K. (2002) Information Technologies for Knowledge Management: Their Usage and Effectiveness. *Electronic Journal of Information Technology in Construction*, Vol. 7, pp. 125-136
- Emmit, S. and Gorse, C. (2003) *Construction Communication*. Blackwell Publishing, Oxford.
- Evbuomwan, N.F.O. and Anumba, C.J. (1998) An Integrated Framework for Concurrent Life-Cycle Design and Construction. *Advances in Engineering Software*, Vol. 29, No. 7-9, pp. 587-597.

References (continued)

Creswell, J. (1998) *Qualitative Inquiry and Research Design: Choosing Among Five Traditions*. SAGE Publications, Thousand Oaks, California.

Creswell, J. (1994) *Research Design: Qualitative and Quantitative Approaches*. Sage Publications, Thousand Oaks, California.

Davenport, T.H. and Prusak, L. (1998) *Working Knowledge: How Organisations Manage What They Know*. Harvard Business School Press, Boston.

Davies, P.B., Owens, I. and Williams, M.D. (2004) Information Systems Evaluation and The Information Systems Development Process. *The Journal of Enterprise Information Management*, Vol. 17, No. 4, pp. 276-282.

Dawood, N., Akinsola, A. and Hobbs, B. (2002) Development of Automated Communication of System for Managing Site Information Using Internet Technology *Automation in Construction*. Vol. 11, pp. 557-552.

Djrbani, R. (1996) The Impact of Stress in Site Management Effectiveness. *Construction Management and Economics*, Vol. 14, pp. 281-293.

Dent, R. and Montague, K. (2004) *Benchmarking Knowledge Management Practice in Construction*. CIRIA 620 Report, London.

Druker, P.F. (1993) *Post-Capitalist Society*. Harper Business, New York.

Easterby-Smith, M., Thorpe, R. and Lowe, A. (2001) *Management Research: An Introduction*. Sage Publications, London.

Egbu, C.O. and Robinson, H.S. (2005) Construction as a Knowledge-Based Industry. *Knowledge Management in Construction*, Anumba, C.J., Egbu, C. and Carrillo, P.M., (Eds), Blackwell Publishing, Oxford, pp. 31-49.

Egbu, C.O., Hari, S. and Renukappa, S.H. (2005) Knowledge Management for Sustainable Competitiveness in Small and Medium Surveying Practices. *Structural Survey*, Vol. 23, No. 1, pp. 7-21.

Egbu, C.O. and Botterill, K. (2002) Information Technologies for Knowledge Management: Their Usage and Effectiveness. *Electronic Journal of Information Technology in Construction*, Vol. 7, pp. 125-136

Emmit, S. and Gorse, C. (2003) *Construction Communication*. Blackwell Publishing, Oxford.

Evbuomwan, N.F.O. and Anumba, C.J. (1998) An Integrated Framework for Concurrent Life-Cycle Design and Construction. *Advances in Engineering Software*, Vol. 29, No. 7-9, pp. 587-597.

References (continued)

- Faulkner, C. (1998) *The Essence of Human-Computer Interaction*. Prentice Hall, Hertfordshire.
- Fellows, R. and Liu, A. (2003) *Research Methods for Construction*. Blackwell Publishing, Oxford.
- Forster, G. (1989) *Construction Site Studies, Production, Administration and Personnel: 2nd Edition*. Longman Scientific and Technical, Essex.
- Fryer, B. (2004) *The Practice of Construction Site Management: 4th Edition*. Blackwell Publishing, Oxford.
- Galliers, R. (1993) Research Issues in Information Systems. *Journal of Information Technology, Vol. 8, No.2*, pp. 92-98.
- Gallupe, B. (2001) Knowledge Management Systems: Surveying the Landscape. *International Journal of Management Reviews, Vol. 3, Issue 1*, pp.61-77.
- Gediga, G., Hamborg, K.C. and Duntsch, I. (1999) The IsoMetrics Usability Inventory: An Operationalisation of ISO 9214-10 Supporting Summative and Formative Evaluation of Software Systems. *Behaviour and Information Technology, Vol. 18, No. 3*, pp. 151-164.
- Gill, J. and Johnson, P. (2002) *Research Methods for Managers: 3rd Edition*. Sage Publications, London.
- Gratton, L. and Ghoshal, S. (2005) Beyond Best Practice. *MIT Sloan Management Review, Spring 2005*, pp. 49-57.
- Gray, C. (1992) *Site Management and Sub-Contracting: The Practice of Site Management, Volume 4*. The Chartered Institute of Building, London, pp. 5-13.
- Gray, P. (2001) A Problem-Solving Perspective on Knowledge Management Practice. *Decision Support Systems, Vol., 31, Issue 1*, pp. 87-102.
- Greenfield, T. (1996) A View of Research. *Research Methods: Guidance for Postgraduates*, Greenfield, T. (Ed), Arnold Hodder, London, pp. 1-6.
- Griffith, A. and Sidwell, T. (1995) *Constructability in Building and Engineering Projects*. Macmillan, Basingstoke.
- Griffith, A. and Watson, P. (2004) *Construction Management: Principles and Practices*. Palgrave MacMillan, New York.
- Hadikusumo, B.H.W. and Rowlinson, S. (2004) Capturing Safety Knowledge Using Design-for-Safety Process Tool. *Journal of Construction Engineering and Management, Vol. 130, No. 2*, pp. 281-289.

References (continued)

- Hammer, M. and Champy, J. (1993) *Reengineering the Corporation: A Manifesto for Business Revolution*. Brealey Publishing, London.
- Handzic, M. and Zhou, A.Z. (2005) *Knowledge Management: An Integrative Approach*. Chandos Publishing, Oxford.
- Hansen, M.T., Nohria, N. and Tierney, T. (1999) What's Your Strategy For Managing Knowledge?, *Harvard Business Review*, pp. 107-116.
- Harrington, H.J. (1991) *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity and Competitiveness*. McGraw Hill Inc, New York.
- Harris, F. and McCaffer, R. (2001) *Modern Construction Management, 5th Edition*. Blackwell Science, Oxford.
- Heron, J. (1996) *Co-operative Inquiry: Research Into the Human Condition*. Sage Publications, London.
- Hicks, B.J., Culley, S.J., Allen, R.D. and Mullineux, G. (2002) A Framework for the Requirements of Capturing, Storing and Reusing Information and Knowledge in Engineering Design. *International Journal of Information Management*. Vol. 22, pp. 263-280.
- Holroyd, T.M. (1999) *Site Management for Engineers*. Thomas-Telford, London.
- Hyde, K.F. (2000) Recognising Deductive Processes in Qualitative Research. *Qualitative Market Research: An International Journal*, Vol. 3, No. 2, pp. 82-89.
- Illingworth, J.R. (2000) *Construction Methods and Planning, 2nd Edition*. E&F Spon, London.
- Jashapara, A. (2004) *Knowledge Management: An Integrated Approach*. Prentice Hall, Harlow.
- Johnston, W.J., Leach, M.P. and Liu, A.H. (1999) Theory Testing Using Case Studies in Business-to-Business Research. *Industrial Marketing Management*, Vol. 28, pp. 201-213.
- Kagioglou, K., Cooper, R., Aoud, G. and Sexton, M. (2000) *Rethinking Construction: The Generic Design and Construction Process Protocol*. Engineering, Construction and Architectural Management, Vol. 7, No. 2, pp. 141-153.
- Kamara, J.M., Anumba C.J. and Carrillo, P.M. (2005) Cross-Project Knowledge Management. *Knowledge Management in Construction*, Anumba, C.J., Egbu, C. and Carrillo, P.M., (Eds), Blackwell Publishing, Oxford, pp. 103-120.

References (continued)

Kamara, J.M., Anumba, C.J., and Evbuomwan, N.F.O. (2001) Assessing the Suitability of Current Briefing Practices in Construction Within a Concurrent Engineering Framework. *International Journal of Project Management*, Vol. 19, pp. 337-351.

Kamara, J.M., Anumba, C.J. and Carrillo, P.M. (2000) Integration of Knowledge Management within Construction Business Processes, *Proceedings, UK National Conference on Objects and Integration for Architecture, Engineering and Construction*, 13rd-14th March, Building Research Establishment Ltd., pp. 95-105.

Kaming, P.F., Holt, G.D., Kometa, S.T. and Olomolaiye, P.O. (1998) Severity Diagnosis of Productivity Problems: A Reliability Analysis. *International Journal of Project Management*, Vol. 16, No.2, pp. 107-113.

Kasvi, J.J., Vartiainen, M. and Hailikari, M. (2003). Managing Knowledge and Knowledge Competences in Projects and Project Organisations. *International Journal of Project Management*, Vol. 21, pp. 571-582.

Kazi, A.S., Koivuniemi, A. and Moksen, P. (2005) Use of Social Processes for Good Practice Capture in Project Based Businesses: The Case of YIT Construction. *Proceedings, CIB W102 International Conference and General Meeting on Information and Knowledge Management in a Global Economy*. Instituto Superior Technico, Lisbon , 19th-20th May, pp. 45-54.

Khalfan, M.M.A., Bouchlagem, D.M., Anumba, C.J., and Carrillo, P.M. (2002) A Framework for Managing Sustainability Knowledge: The C-Sand Approach. *Proceedings, e-SMART 2002*, 19th-21st November, University of Salford, Salford.

Keppel, G. (1991) *Design and Analysis: A Researchers Handbook, 3rd Edition*. Prentice Hall, New Jersey.

Klien, H.K. and Myers, M.D. (1999) A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. *MIS Quarterly*, Vol. 23, No. 1, pp. 67-94.

KPMG (1998) *Knowledge Management Research Report 1998*, KPMG.

Kuluganga, G.K. and McCaffer, R. (2001) Measuring Knowledge Management for Construction. *Engineering, Construction and Architectural Management*. Vol. 8, No.5, pp. 346-354.

Laudon, K.C and Laudon, J.P. (2002) *Management Information System: Managing The Digital Firms, 7th Edition*, Prentice Hall, New Jersey.

Leedy, P.D. and Ormrod, J.E. (2001) *Practical Research, Planning and Design, 7th Edition*. Prentice-Hall, New Jersey.

References (continued)

- Li, H. and Love, P.E.D. (1998) Developing a Theory of Construction Problem Solving. *Construction Management and Economics*, Vol. 16, pp. 721-727.
- Liao, S.H. (2002) Problem Solving and Knowledge Inertia. *Expert Systems with Applications*. Vol. 22, pp. 21-31.
- Liebowitz, J. (2005) Conceptualizing and Implementing Knowledge Management, in Love, P.E.D., Fong, P.S.W. and Irani, Z. (Eds), *Management of Knowledge in Project Environments*, Elsevier Butterworth-Heinemann, Oxford, pp.1-18.
- Liebowitz, J. (2001) Knowledge Management and Its Link to Artificial Intelligence. *Expert Systems with Applications*, Vol. 20, Issue 1, pp. 1-6.
- Ling, J. (1991) *Construction: Guidelines for the Management Construction Projects*. HMSO Publication, London.
- Love, P.E.D., Holt, G.D. and Li, H. (2002) Triangulation in Construction Management Research. *Engineering, Construction and Architectural Management*, Vol. 9, No. 4, pp. 294-303.
- Love, P.E.D., Gunasekaran, A. and Li, H. (1998) Concurrent Engineering: A Strategy For Procuring Construction Projects. *International Journal of Project Management*, Vol. 16, No. 6, pp. 375-383.
- Mackenzie, S., Kilpatrick, A.R. and Akintoye, A. (2000) UK Construction Skills Shortage Response Strategies and An Analysis of Industry Perceptions. *Construction Management and Economics*, Vol. 18, No. 7, pp. 853-862.
- Maqsood, T., Walker, D.H.T. and Finegan, A. (2004) Project Histories and Project Learning: A Knowledge Management Challenge. *Proceedings, 20th ARCOM Annual Conference, 1st-3rd September, Heriot-Watt University*, pp. 561-570.
- McClintock, K.C., Brandon, D. and Maynard, M.S. (1979) Applying the Logic of Sample Surveys to Qualitative Case Studies: The Case Cluster Method, *Administrative Science Quarterly*, Vol. 24, No. 4.
- McKenzie, G., Powell, J. and Usher, R. (1997) *Understanding Social Research: Perspectives on Methodology and Practice*, Falmer Press, London.
- Melville, S. and Goddard, W. (1996) *Research Methodology: An Introduction for Science and Engineering Students*. Creda Press, Cape Town.
- Meredith, J. (1998) Building Operations Management Theory Through Case and Field Research. *Journal of Operations Management*, Vol. 16, pp. 441-454.
- Mohamed, S. (2002) Safety Climate in Construction Site Environments. *Journal of Construction Engineering and Management*, Vol. 128, Issue, 5, pp. 375-384.

References (continued)

- Mohamed, S. (1996) Benchmarking and Improving Construction Productivity. *Benchmarking for Quality Management and Technology*. Vol. 3, No. 3, pp. 50-58.
- Mohamed, S.F. and Anumba, C.J. (2005) Opportunities of Improving Site Management Practices through Knowledge Management, *Proceedings, CIB W102 International Conference and General Meeting on Information and Knowledge Management in a Global Economy*. Instituto Superior Technico, Lisbon, 19th-20th May, pp. 465-474.
- Morris, S. (2001) *Visual Basic 6: Made Simple*. Butterworth-Heinemann, Oxford.
- Mustapha, F.H. and Naoum, S. (1998) Factors Influencing The Effectiveness of Construction Site Managers. *International Journal of Project Management*, Vol. 16, No. 1, pp. 1-8.
- Naoum, S.G. (1998) *Dissertation Research Writing for Construction Students*. Butterworth-Heinemann, Oxford.
- Nemati, H.R., Steiger, D.M., Iyer, L.S. and Herschel, R.T. (2002). Knowledge Warehouse: An Architectural Integration of Knowledge Management, Decision Support, Artificial Intelligence and Data Warehousing. *Decision Support Systems*. Vol. 33, pp. 143-161.
- Neuman, W.L. (2006) *Social Research Methods: Qualitative and Quantitative Approaches: 6th Edition*. Pearson Education, Boston.
- Newcombe, R., Langford, D. and Fellows, R. (1993) *Construction Management: Organisation Systems*. BT Batsford, London.
- Noble, P. (1999) Towards An Inclusive Evaluation Methodology. *Corporate Communications: An International Journal*, Vol. 4, No. 2, pp. 14-23.
- Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company: How Japanese Company Create the Dynamics of Innovation*. Oxford University Press, Oxford.
- Obonyo, E., Anumba, C.J. and Thorpe, T. (2005) APRON: An Agent-Based Specification and Procurement System for Construction Products. *Engineering, Construction and Architectural Management*, Vol. 12, No. 4, pp. 329-350.
- Ogunlana, S.O. and Olomolaiye, P.O. (1989) A Survey of Site Management Practice on Some Selected Sites in Nigeria. *Journal of Building and Environment*, Vol. 24, No. 2, pp. 191-196.
- Papadopoulos, N. and Limniou, M. (2002) How to Use Visual Basic To Interface Scientific Instruments To a Personal Computer. *Journal of Chemical Educator*, Vol. 7, pp. 288-291.

References (continued)

- Patton, M.Q. (2002) *Qualitative Research and Evaluation Methods, 3rd Edition*. Sage Publications, London.
- Perry, C. (1998) Processes of a Case Study Methodology for Postgraduate Research in Marketing. *European Journal of Marketing*, Vol. 32, No. 9/10, pp. 785-802.
- Pheng, L.S. and Hui, M.S. (1999) The Application of JIT Philosophy to Construction: A Case Study in Site Layout. *Construction Management and Economics*, Vol. 17, pp. 657-668.
- Punch, K.F. (1999) *Introduction to Social Research: Quantitative and Qualitative Approach*. Sage Publications, London.
- Remenyi, D. and Smith, M.S. (1999) Maximise Information System Value By Continuous Participative Evaluation. *Logistics Information Management*, Vol. 12, No.1/2, pp. 14-31.
- Robinson, H.S., Carrillo, P.M., Anumba, C.J. and Al-Ghassani, A.M. (2005) Knowledge Management in Large Construction Organisations. *Engineering, Construction and Architectural Management*. Vol. 12, No. 5, pp. 431-445.
- Robinson, H.S., Carrillo, P.M., Anumba, C.J. and Al-Ghassani, A.M. (2004) Developing a Business Case for Knowledge Management: The IMPaKT Approach. *Construction Management and Economics*, Vol. 22, No. 7, pp. 733-743.
- Robinson, H.S., Carrillo, P.M., Anumba, C.J. and Al-Ghassani, A.M. (2001) Knowledge Management: Towards an Integrated Strategy for Construction Project Organisations. *Proceedings, 4th European Project Management Conference (PMI)*, 6th-7th June, Café Royal, London.
- Rowley, J. (2002) Using Case Studies in Research. *Management Research News*, Vol. 25, No. 1, pp. 16-27.
- Rubenstein-Monatno, B., Leibowitz, F., Buchwalter, F., McCaw, D., Newman, B. and Rebeck, K. (2001) SMARTVision: A Knowledge Management Methodology. *Journal of Knowledge Management*, Vol. 5, No. 4, pp. 300-310.
- Ruggles, R. (1997) *Working Paper: Knowledge Tools: Using Technology to Manage Knowledge Better*, Center for Business Innovations, Ernst and Young LLP
- Rwelamila, P.D. and Hall, K.A. (1995) Total Systems Intervention: An Integrated Approach to Time Cost and Quality Management. *Construction Management and Economics*, Vol.13, pp. 235-241.
- Sallis, E. and Jones, G. (2002) *Knowledge Management in Education: Enhancing Learning and Education*. Kogan Page, London.

References (continued)

- Schaefer, W.F. (1993) Instruments for the Management of Knowledge, *Automation in Construction*, Vol. 2, pp.187-198.
- Santos, A.D., Powell, J.A. and Sarshar, M. (2002) Evolution of Management Theory: The Case of Production Management in Construction. *Management Decision*. Vol. 40, No. 8, pp. 788-796.
- Scott, J.N., Bradley, D.A., Adelson, R.M. Pengelly, M. and Seward, D.W. (1995) Issues in the Development of Data Flow Simulation of Construction Sites: The Pursuit of Quality. *International Journal of Project Management*. Vol. 13, No. 5, pp. 535-539.
- Sekaran, U. (1984) *Research Methods for Managers: A Skill-Building Approach*. John Wiley and Sons, New York.
- Sheehan, T., Poole, D. and Lyttle, I (2005) Strategies and Business Case for Knowledge Management. *Knowledge Management in Construction*, Anumba, C.J., Egbu, C. and Carrillo, P.M., (Eds), Blackwell Publishing, Oxford, pp. 50-64.
- Shelbourn, M.A., Bouchlaghem, D.M., Anumba, C.J., Carrillo, P.M., Khalfan, M.M.K. and Glass, J. (2005) Managing Knowledge in the Context of Sustainable Construction. *Electronic Journal of Information Technology in Construction*. Vol. 11, pp. 51-71.
- Smith, M.F. (1991) *Software Prototyping: Adoption, Practice and Management*. McGraw-Hill, Berkshire.
- Snider, K.F. and Nissen, M.E. (2003) Beyond The Body of Knowledge: A Knowledge-Flow Approach to Project Management Theory and Practice. *Project Management Journal*, Vol. 34, No. 2, pp. 4-12.
- Stenbacka, C. (2001) Qualitative Research Requires Quality Concepts of Its Own. *Management Decision*, Vol. 39, No. 7, pp. 551-555.
- Storey, J. and Barnett, E. (2000) Knowledge Management Initiatives: Learning from Failure. *Journal of Knowledge Management*, Vol. 4, No. 2, pp. 145-156.
- Styhre, A. and Josephson, P.E. (2006) Revisiting Site Manager Work: Stuck in the Middle? *Construction Management and Economics*, Vol. 24, No. 5, pp. 521-528.
- Sun, M. and Howard, R. (2004) *Understanding I.T. in Construction*. Spoon Press, London.
- Tah, J.H.M. and Carr, V. (2001) Towards a Framework for Project Risk Knowledge Management in the Construction Supply Chain. *Journal of Advancing in Engineering Software*, Vol. 32, pp. 835-846.
- Tiwana, A. (2002) *The Knowledge Management Tool Kit, 2nd Edition*. Pearson Education, New Jersey.

References (continued)

Toma, M.S., Seymour, D. and Clark, L. (1998) Obstacles To Implementing Total Quality Management in the UK Construction Industry. *Construction Management and Economics*, Vol. 16, pp. 177-192.

Trauner, T.J. (1993) *Managing The Construction Project: A Practical Guide for the Project Manager*. John Wiley and Sons, New York.

Tserng, H.P. and Lin, Y.C. (2004) Developing An Activity-Based Knowledge Management System for Contractors. *Automation in Construction*, Vol. 13, pp. 780-802.

Turban, E. and Aronson, J.E. (1998) *Decision Support Systems and Intelligent Systems, 5th Edition*, Prentice Hall, New Jersey.

Ulrich, F. (2006) Improving Shared Service Implementation: Adopting Lessons From the BPR Movement. *Business Process Management Journal*, Vol. 12, No. 2, pp. 191-205.

UMIST, (1999) *KLICON - Knowledge Learning In Construction, The Role of Information Technology in Knowledge Management within Construction Industry*. Centre for Research in the Management of Projects (CRMP). UMIST.

Vorbeck, J. and Finke, I. (2001) Sharing Process Knowledge in Production Environments: Roche Diagnostics Laboratory Systems. *Knowledge Management: Best Practices in Europe*, Mertins, K., Heisig, P. and Vorbeck, J. (Eds), Springer, New York, pp. 192-220.

Walker, A. (2002) *Project Management in Construction, 4th Edition*. Blackwell Publishing, Oxford.

Walker, D.H.T. (1997) Choosing an Appropriate Research Methodology. *Construction Management and Economics*, Vol. 15, pp. 149-159.

Ward, M.J., Thorpe, A., Price, A.D.F. and Wren, C. (2003) SHERPA: Mobile Wireless Data Capture for Piling Works. *Computer-Aided Civil Engineering and Infrastructure Engineering*, Vol. 18, No. 4, pp. 299-312.

Webb, S.P. (1998) *Knowledge Management: Linchpin of Change*. The Association for Information Management (ASLIB), London.

Weber, R., Aha, D.W. and Fernandez, I.B. (2001), Intelligent Lessons Learned Systems. *Expert Systems with Applications*. Vol. 20, Issue 1, pp. 17-34.

Whetherill, M., Rezgui, Y., Lima, C. and Zarli, A., (2002) Knowledge Management For The Construction Industry: The E-COGNOS Project, *Electronic Journal of Information Technology in Construction* Vol. 7, pp. 183-196.

References (continued)

William, T. (2004) Identifying the Hard Lessons From Projects: Easily. *International Journal of Project Management*. Vol. 22, pp. 273-279.

Wong, K.W. and Aspinwall, E. (2006) Development of a Knowledge Management Initiative and System: A Case Study. *Expert Systems with Applications*, Vol. 30, pp. 633-641.

Woo, J.H., Clayton, M.J., Johnson, R.E., Flores, B.E. and Ellis, C. (2004) Dynamic Knowledge Map: Reusing Experts' Tacit Knowledge in the AEC Industry. *Automation in Construction*, Vol. 13, Issue 2, pp. 203-207.

Wright, G. and Ayton, P. (1987) Eliciting and Modelling Expert Knowledge. *Decision Support Systems*, Vol. 3, Issue 1, pp. 13-26.

Yin, R.K. (2003) *Case Study Research: Design and Methods: 3rd Edition*. Sage Publications, California.

Zack, M.H. (1999) Managing Codified Knowledge. *Sloan Management Review*, Summer, pp. 45-58.

Appendix 1
List of Publications Arising from the Research

Appendix 1: List of Publications Arising from the Research.

Refereed Journal

1. **Mohamed, S.F. and Anumba, C.J. (2006) The Potential for Improving Site Management Practices Through Knowledge Management. *Construction Innovation*. Vol. 6, No. 4, pp. 232-249.**
2. **Mohamed, S.F. and Anumba, C.J. (2006) Conceptual Framework for Integration of Knowledge Management into Construction Site Management. *Knowledge Management Research and Practice*. (Paper accepted).**

Forthcoming Refereed Journal Publications

3. **Mohamed, S.F. and Anumba, C.J. (2006) A Knowledge Management Approach To Improved Site Management. *Construction Management and Economics*.**
4. **Mohamed, S.F. and Anumba, C.J. (2006) An Integrated Knowledge Management Systems for Improving Site Management. *Automation in Construction*.**

Conference Proceedings

5. **Mohamed, S.F. and Anumba, C.J. (2006) The Need for An Effective Knowledge Management Framework for Construction Site Management, *Proceedings, 6th International Postgraduate Research Conference*, TU-Delft, The Netherlands 6th-7th April, p.p.720-729.**
6. **Mohamed, S.F. and Anumba, C.J. (2006) A Problem-Based Knowledge Management Approach to Improved Site Management, *Proceedings, ARCOM Doctoral Workshop*, University of Salford, Manchester, 10th November, pp. 25-37.**
7. **Mohamed, S.F. and Anumba, C.J. (2005) Opportunities for Improving Site Management Practices Through Knowledge Management, *Proceedings, CIB W102 Meeting and International Conference on Information and Knowledge Management in a Global Economy*, 19th –20th May, Instituto Superior Technico, Lisbon, p.p. 465-474.**
8. **Mohamed, S.F. and Anumba, C.J. (2004) Towards a Framework for Integrating Knowledge Management Processes into Site Management Practices, *Proceedings, 20th ARCOM Annual Conference*. Heriot-Watt University, 1-3rd September. p.p. 45-54.**

Appendix 2
Template for Semi-Structured Interviews for Case Studies

Appendix 2: Template for Semi-Structured Interviews for Case Studies

BACKGROUND OF RESPONDENT

Name of Respondent	
Position	
Company Name /Address	
Contact No.	
Email	
Date	

A. BACKGROUND OF RESPONDENT AND CONTEXT

1. What is your experience in managing construction sites (number of years) and how does your experience help you in managing the construction site ?
2. What are your functions and responsibilities on the current construction site?

B. SITE MANAGEMENT – PROBLEMS, PROCEDURES & ACTORS INVOLVED

3. What are your biggest problems in managing the construction site? Please list the top 5 problems that occur on your construction site (in rank order).
4. What is the nature of these problems and what is the impact on your site?
5. How do you address these problems? (e.g. using previous experience, consulting colleagues or seniors, refer to experts, etc.)
6. What is your site organisational structure for site management? (*List or provide sketch/flow chart of their duties*) and how do you run your site project?
7. How often do you hold meetings with sub-contractors, team leaders, clerk of works and etc.?
8. How do you manage your relationships with the Client/Client representative in terms of site arrangements, job quality, delay and extra cost ?
9. How do you communicate information from the engineer, architect and quantity surveyor to trade workers (plasterers, plumbers, bricklayers, etc.)
10. How can your site management practices be improved?

C. KM PROCESSES WITHIN THE SITE MANAGEMENT PRACTICES

11. In managing the construction site, how much knowledge of construction is embedded in the minds of your workers and how much knowledge is in written documents (e.g. specifications, drawings, bill of quantities and etc.)?
12. When make mistake, how do you capture that mistake and what is your action-plan to avoid repeating selfsame errors?
13. How often do you get together with site personnel (general foreman, gangers) to discuss problems that occur on your site?
14. How do you share your construction knowledge (e.g. health and safety, construction technology, etc) with other site personnel especially the knowledge gained from training and previous experience?
15. How do you organise induction training for new workers and what specific methods do you use to train new workers? (Apprenticeship, mentoring, training and etc.)
16. What types of methods of reporting are used on site?
17. Do you use computers/information technology (IT) in any site management activities?

18. Does your organisation have an Intranet and what is the role of the Intranet in managing the construction site?

Appendix 3

Proactive KM Framework

Appendix 3: Proactive KM Framework

Stage 1, 2, and 3: Specify SM process, relevant measures and implement measures

Site Management Processes	SM problems	Measures
<p>A. Management, supervision and administration</p>	a) Lack of co-operation and motivation	<ul style="list-style-type: none"> ● Financial incentives ● Good working facilities
	b) Poor design management and information	<ul style="list-style-type: none"> ● Use electronic information management ● Implement quality control and information checklist
	c) Services obstruction	<ul style="list-style-type: none"> ● Mark services lines with pegs or other suitable means ● Provide protection to service lines ● Consult utility services authorities
	d) Lack of information on subcontractor	<ul style="list-style-type: none"> ● Refer to the subcontractor's record in previous projects ● Get information from other projects (e.g. technical capability, financial status, track record etc.)
	e) Local residents	<ul style="list-style-type: none"> ● Appoint site supervisor to take responsibility for public relations ● Produce progress reports and encourage residents to visit the site ● Minimise environmental problems – noise, dust, smoke, and vibration
	f) Poor site communication	<ul style="list-style-type: none"> ● Use RFI (request for information) and CFI (confirmation for information) as tools to supply necessary information to particular sub-contractors ● Produce simple and complete reports on progress of the project, health and safety, risk assessment, cost etc. ● Provide notice board to communicate with sub-contractors and foreman ● Use appropriate communication devices (e.g. PDA, mobile phones and SMS)
	g) Complexity of design regulations	<ul style="list-style-type: none"> ● Joint inspection and site visit with local authority representative to provides procedures for all activities and working practices related to design control ● Early notifications to authorities' representatives before execution of the works ● Consult colleagues on similar types of projects

Site Management Processes	SM problems	Measures
	h) Shortage of labour resources	<ul style="list-style-type: none"> • Consider return to direct employment and apprenticeships • Make greater use of ethnic minorities • Make greater use of labour only sub-contractors • Participate in craft operative training and apprenticeships
	j) Misunderstanding of designs and specifications	<ul style="list-style-type: none"> • Collect suitable information for quick reference as soon as possible on the award of contract • Record design information using a system which allows immediate retrieval • Clarify poor design details with design team early • Clarify ambiguous specifications early
B. Commercial management	a) Cost cutting and control	<ul style="list-style-type: none"> • Implement a cost control system • Provide incentives for cost saving measures • Measure weekly progress and undertake activity costing
	b) Unpredictable final cost and hand over	<ul style="list-style-type: none"> • Monitor cost on a weekly and daily basis • Provide cost information (e.g. material invoices) to procurement department
C. Health and safety management	a) Difficulty in monitoring and enhance awareness of Health and Safety Plan	<ul style="list-style-type: none"> • Employ safety specialists • Communicate Health and Safety Plan to all site workers • Monitor safety performance on daily basis • Conduct training and induction for sub-contractors, suppliers and operatives • Present knowledge of safety graphically • Distribute safety bulletin monthly or weekly
D. Planning, monitoring and control	b) Inability to accurately resource plan & schedule	<ul style="list-style-type: none"> • Establish resource requirements early • Develop resource acquisition control and monitoring arrangement • Establish available resources early
	c) Poor planning of works	<ul style="list-style-type: none"> • Allow adequate time for critical activities • Determine the method, sequence, labour, plant and equipment early. • Provide detailed programme of site works early
	d) Inaccurate planning of work commencement	<ul style="list-style-type: none"> • Establish effective site layout and facilities • Consult the estimator, contracts managers etc. before work actually commences on site. • Ensure time is allowed for detailed planning
	e) Unpredictable on-site conditions	<ul style="list-style-type: none"> • Ensure detailed site investigations have been undertaken • Consult colleagues/ other firms who have done work in the same area

Site Management Processes	SM problems	Measures
E. Delivery and materials' handling	<p>a) Poor quality of materials</p> <p>b) Materials damage and defect</p>	<ul style="list-style-type: none"> ● Request material sample from suppliers ● Strictly monitor materials management ● Use reputable suppliers ● Materials' checks should be an ongoing routine ● Constant check on materials' utilisation ● Minimise the amount of materials stored on site ● Protect all finished work
F. Production on-site and off-site	a) Lack of quality control	<ul style="list-style-type: none"> ● Implement quality procedure system, make a checking process regularly and make a comparison with specifications provided by client ● Provide statutory training (induction and relevant skills) ● Select reputable sub-contractors ● Conduct regular quality meeting and joint inspection with the client ● Rectify any workmanship defects immediately ● Use off-site production facilities as much as possible or whenever possible ● Proper checking systems and recording procedures ● Delegate responsibility of production and related issues to the general foreman

Appendix 3: Proactive KM Framework

Stage 4 and P5: Monitor and review

Measures	Diagnostic Question	Evaluation
	Have chosen measures been able in avoiding the problem?	1. No (Revise) 2. To some extent (next question) 3. Yes
	Are you satisfied with current KM initiatives in solving particular problem in this project?	1. Revise 2. Monitor

Stage P5 – Revise KM initiatives

Measures	Diagnostic Question	Description
	Why is the existing KM initiative ineffective?	
	What additional issues need to be addressed?	
	What KM initiative can address the outstanding issues?	

Appendix 4
Reactive KM Framework

**Appendix 4: Reactive KM Framework
Stage 1, 2,3, and 4 (adopt CLEVER framework to support this stage, Anumba et al., 2005)**

SM problems	Types of knowledge required	The characteristics of this knowledge									
A. Management, supervision and administration											
1. Lack of cooperation and motivation	<ul style="list-style-type: none"> • Knowledge of site supervision, site communication and motivational techniques 	Explicit External Individual									Tacit Internal Shared
2. Poor information management	<ul style="list-style-type: none"> • Knowledge of control and co-ordinate information 	Explicit External Individual									Tacit Internal Shared
3. Services obstruction	<ul style="list-style-type: none"> • Knowledge of site investigation, general site topography and environment 	Explicit External Individual									Tacit Internal Shared
4. Lack of information on sub-contractor	<ul style="list-style-type: none"> • Knowledge of sub-contractors track records 	Explicit External Individual									Tacit Internal Shared
5. Local residents	<ul style="list-style-type: none"> • Knowledge of environmental and health and safety 	Explicit External Individual									Tacit Internal Shared
6. Poor site communication	<ul style="list-style-type: none"> • Knowledge of sub-contractors relationship and relationship with other parties 	Explicit External Individual									Tacit Internal Shared
7. Complexity of design regulations	<ul style="list-style-type: none"> • Knowledge of working practices related to design regulations 	Explicit External Individual									Tacit Internal Shared
8. Shortage of labour resources	<ul style="list-style-type: none"> • Knowledge of critical activities on site that use a great number of labour and knowledge of sources of labour 	Explicit External Individual									Tacit Internal Shared
9. Misunderstanding of designs and specifications	<ul style="list-style-type: none"> • Knowledge of design process and construction process 	Explicit External Individual									Tacit Internal Shared

Appendix 4: Reactive KM Framework
Stage 5 - (Detailed knowledge transfer processes (people-paper; people-software; people-people))

Select Transfer Methods		
People to Paper	People to Software	People to People
Transfer Method <ul style="list-style-type: none"> • Report • Manual • Memos 	Transfer Methods <ul style="list-style-type: none"> • Knowledge bases • Databases • Models 	Transfer Methods <ul style="list-style-type: none"> • Knowledge bases • Mentoring • Apprenticeships • Seminars • Interview • Meetings • Discussion groups • Informal groups • Storyboards • Etc.
Generic Transfer Activities <ol style="list-style-type: none"> 1. Check/ facilitate commitment 2. Check for appropriate skills/ materials 3. Allocate resources 4. Establish timing 5. Plan procedure 	Generic Transfer Activities <ol style="list-style-type: none"> 1. Choose representation form 2. Choose knowledge elicitation techniques 3. Check appropriate skills/materials 4. Check/facilitate ownership/trust 5. Establish timing 6. Plan procedure 7. Allocate resources 8. Re-organise work structure 	Generic Transfer Activities <ol style="list-style-type: none"> 1. Check for appropriate skills/materials 2. Check/facilitate commitment 3. Allocate resources 4. Establish timing 5. Plan procedure 6. Re-organise work structure

Appendix 4: Reactive KM Framework

Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)

KM Sub-processes	KM Technique	Applicability to Construction Site	KM Technologies	Application Software
Locating & Accessing Existing Knowledge	Face to Face Interaction (F-F)	✓	Experts Directory (ED)	✓
	Discussion Forums (DF)	✓	Data Warehouses (DW)	*
	Site Observation (SO)	✓	Web Crawler (WC)	*
	Formal Meeting (FM)	✓	Data and Text Mining (D/T M)	*
	Informal Meeting (IM)	✓	Knowledge Mapping (KMpp)	*
				Knowledge Discovery Packages (KDP)
Capturing Existing Knowledge			Intranet and Extranet (INRA/EXRA)	✓
			Taxonomy and Ontological Tools (T/O T)	*
			Search Engines (SE)	✓
			Web Mapping Tools (WMT)	*
			Electronic Document Management System (EDMS)	✓
			Electronic Mail (E-Mail)	✓
	Post-Project Review (PPR)	✓	Word Processors (WP)	✓
	Recruitment (Rt)	✓	Case-Based Reasoning (CBR)	*
	Discussion Forums (DF)	✓	Knowledge Mapping (KMpp)	*
	Apprenticeships (Ap)	✓		
	Mentoring (Mn)	✓		
	Training (Tr)	✓		

Legend

- ✓ Applicability to construction site was based on: literature review and case study findings of five construction sites (Part C: KM Practices within SM)
- * Usually not applicable but may be available where site IT systems are well connected to main office systems

Appendix 4: Reactive KM Framework
Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)

KM Sub-processes	KM Technique	Applicability to Construction Site	KM Technologies	Applicability to Construction Site	
Sharing Knowledge	Communities of Practice (CoPs)	✓	Web Publishing (WPb)	✓	
	Face to Face Interaction (F-F)	✓	Communities of Practice (CoPs)	✓	
	Seminars (Sr)	✓	Intranet/Extranet (INRA/EXRA)	✓	
	Discussion Forums (DF)	✓	Web-Based File Sharing Tools (WBFS)	✓	
	Apprenticeships (AP)	✓	Instant Messaging (IM)	✓	
	Mentoring (Mn)	✓	Integrated Groupware Solutions (IGWS)	✓	
	Training (Tr)	✓	Multimedia Tools (MtMd)	✓	
			Electronic Mail (E-Mail)	✓	
		Brainstorming	✓	Data and Text Mining (D/T M)	*
				Knowledge Mapping (KMpp)	*
Updating Knowledge			Mind Mapping Applications (MMA)	*	
			Data Warehouses (DW)	*	

Legend

- ✓ Applicability to construction site was based on: literature review and case study findings of five construction sites (Part C: KM Practices within SM)
- * Usually not applicable but may be available where site IT systems are well connected to main office systems

Appendix 4: Reactive KM Framework
Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)

KM Dimension		Required											
Internal	Transfer Domain	Ownership Form	Internal				External						
			Individual	Group	Individual	Group	Individual	Group					
	Knowledge Type	KM Sub-Process	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	
Internal	Tacit	Locate	F-F, FM										
		Share	F-F, DF, SO, IM	Sr, FM		DF			Sr				
		Update											
	Explicit	Locate											
		Share											
		Update											
Group	Tacit	Locate			DF						DF		
		Share			CoPs, Sr						Sr		
		Update				Br							
	Explicit	Locate											
		Share											
		Update											
External	Tacit	Locate											
		Share			Sr								
		Update		DF									
	Explicit	Locate											
		Share											
		Update											
Group	Tacit	Locate											
		Share			Sr								
		Update											
	Explicit	Locate											
		Share											
		Update											

ILLOGICAL COMBINATIONS

- Legend**
- F-F Face to Face Interaction
 - FM Formal Meeting
 - DF Discussion Forum
 - SO Site Observation
 - IM Informal Meeting
 - Sr Seminars
 - CoPs Communities of Practice
 - Br Brainstorming

Appendix 4: Reactive KM Framework
Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)

KM Dimension		Applicable KM Techniques		
Transfer Domain				
Ownership Form	Knowledge Type	KM Sub-Process		
	Internal	Individual	Tacit	Locate Share Update
Explicit			Locate	Post-Project Review (PPR), Formal Meeting (FM)
			Share	Communities of Practice (CoPs), Seminars (Sr), Formal Meeting (FM)
			Update	Formal Meeting (FM), Brainstorming (Bs)
Locate			Face to Face Interaction (F-F), Post-Project Review (PPR), Discussion Forums (D-F), Apprenticeships (AP), Mentoring (Mn)	
Group		Share	Face to Face Interaction (F-F), Seminars (Sr), Discussion Forums (D-F), Mentoring (Mr)	
		Update	Formal Meeting (FM), Brainstorming (Bs)	
		Locate	Face to Face Interaction (F-F), Discussion Forums (D-F)	
		Share	Communities of Practice (CoPs), Face to Face Interaction (F-F), Seminars (Sr), Discussion Forums (D-F)	
		Update	Formal Meeting (FM), Brainstorming (Bs)	
External	Individual	Tacit	Locate Share Update	
		Explicit	Locate	Discussion Forums (D-F), Formal Meeting (FM), Seminars (Sr)
			Share	Seminars (Sr), Discussion Forums (D-F), Formal Meeting (FM)
			Update	Formal Meeting (FM), Brainstorming (Bs)
		Locate	Face to Face Interaction (F-F), Formal Meeting (F-M), Discussion Forums (D-F), Training (Tr)	
	Group	Share	Seminars (Sr), Discussion Forums (D-F), Formal Meeting (FM)	
		Update	Formal Meeting (FM), Brainstorming (Bs)	
		Locate	Discussion Forums (D-F), Formal Meeting (FM), Seminars (Sr)	
		Share	Seminars (Sr), Discussion Forums (D-F), Training (Tr)	
		Update	Formal Meeting (FM), Brainstorming (Bs)	
	Individual	Tacit	Locate Share Update	
		Explicit	Locate	Discussion Forums (D-F), Seminars (Sr), Training (Tr)
			Share	Seminars (Sr), Discussion Forums (D-F), Training (Tr)
			Update	Formal Meeting (F-M), Brainstorming (Bs)
		Locate	Face to Face Interaction (F-F), Formal Meeting (FM), Post-Project Review (PPR), Training (Tr), Discussion Forums (D-F)	
	Group	Share	Seminar (Sr), Discussion Forums (D-F), Training (Tr)	
		Update	Formal Meeting (FM), Brainstorming (Bs)	
		Locate	Discussion Forums (D-F), Seminars (Sr), Training (Tr)	
		Share	Seminars (Sr), Discussion Forums (D-F), Training (Tr)	
		Update	Formal Meeting (F-M), Brainstorming (Bs)	

Appendix 4: Reactive KM Framework
Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)

KM Sub-processes	KM Technique	Description of KM Technique
Locating and Accessing Knowledge	Face to Face Interaction (F-F)	Face to Face Interaction is a traditional approach for sharing the tacit knowledge (socialisation) owned by organisation's employee. It usually takes an informal approach and is very powerful. Face to Face Interaction also helps in increasing the organisation's memory, developing trust and encouraging effective learning.
	Discussion Forums (DF)	A discussion forum is a message board where an individual posts a question or starts a discussion about a particular issue and other respond. Although there are web-based, they are usually described as techniques rather than technologies.
	Informal Meeting (IM)	Informal Meeting is a meeting to solve particular problem. In this setting, particular individuals could meet on site, actually observe the problem and then discuss and agree a way forward
	Site Observation (SO)	Site Observation is a process of visiting the site and inspects the work before deciding on a course of action and then issuing the appropriate instruction to the contractor.
	Recruitment (Rt)	Recruitment is an easy way for knowledge buy-in. This is a tool for acquiring external tacit knowledge especially of expert
	Post-Project Review	Post-Project Review is debriefing sessions used to highlight lessons learnt during the course of a project. These reviews are important to capture knowledge about, causes of failures, and the best practices identified in a project
Sharing Knowledge	Communities of Practice (CoPs)	Communities of Practice (CoPs) are also called knowledge communities, knowledge networks, learning communities, communities of interest and thematic groups. These consist of a group of people of different skill sets, development histories and experience backgrounds that work together to achieve commonly shared goals
	Face to Face Interaction (F-F)	As Above
	Seminars (Sr)	Seminars are meeting for the exchange of ideas. These are discussion-based session in which presenters lead a small group participant in a discussion about a defined topic.
	Discussion Forums(DF)	As Above
	Informal Meeting (IM)	As Above

Appendix 4: Reactive KM Framework
Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)

KM Sub-processes	KM Technique	Description of Technique
Sharing Knowledge (continued)	Mentoring (Mn)	Mentoring is a process where a trainee or a junior staff is attached or assigned to a senior member of an organisation for advice related to career development
	Training (Tr)	Training helps in improving staff skills and therefore increasing their knowledge. Training usually takes a formal format and can be internal where senior train juniors within the organisation or external where employees attend courses managed by professional organisations.
	Apprenticeship (Ap)	Apprenticeships are a form of training in a particular trade carried out mainly by practical experience or learning by doing (not through formal instruction).
Updating Knowledge	Formal Meeting (FM)	Formal Meeting is a well planned and structured meeting and recorded (as minutes of the meeting) with clear point of action and timeframes in which to complete the tasks.
	Brainstorming (Bs)	Brainstorming is a process where a group of people meet to focus on a problem, and then intentionally come up with as many deliberately unusual solutions as possible through pushing the ideas as far as possible.

Appendix 4: Reactive KM Framework
 Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005)
 Relating KM Technology Categories to Combination of Knowledge Characteristics (External)

KM Dimension		Required													
Transfer Domain		Internal					External								
Ownership Form	Knowledge Type	Individual		Group		Tacit	Individual		Group						
		Tacit	Explicit	Tacit	Explicit		Tacit	Explicit	Tacit	Explicit					
Individual	Tacit	KM Sub-Process	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	
															IGWS, MtMd
Group	Explicit	KM Sub-Process	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	
															IGWS, MtMd
External	Tacit	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	
															IGWS, MtMd
	Explicit	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share
	Tacit	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate
	Explicit	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share
	Tacit	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate
Explicit	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	
															IGWS, MtMd
Tacit	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	
															IGWS, MtMd
Explicit	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	Locate	Share	
															IGWS, MtMd

ILLOGICAL COMBINATIONS

Legend

- ED Experts Directory
- DW Data Warehouses
- WC Web Crawler
- D/T M Data and Text Mining
- KMpp Knowledge Mapping
- KDP Knowledge Discovery Packages
- INRA/EXRA Intranet and Extranet
- T/OT Taxonomy and Ontological Tools
- SE Search Engines
- WMT Web Mapping Tools
- EDMS Knowledge Discovery Packages
- E-Mail Intranet and Extranet
- WPb Taxonomy and Ontological Tools
- CoFs Search Engines
- WBFS Web Mapping Tools
- EDMS Electronic Document Management System
- E-Mail Electronic Mail
- WPb Web Publishing
- CoFs Communities of Practice
- WBFS Web-based File Sharing Tools
- IM Instant Messaging
- IGWS Integrated Groupware Solutions
- MtMd Multimedia Tools
- MMA Mind Mapping Applications

Appendix 4: Reactive KM Framework

Stage 6 (adopt SELEKT framework to support this stage, Al-Ghassani et al., 2005) Description of KM Technology

KM Technology	Description
Experts Directory (ED)	Also called Skill's Yellow Pages, Experts Group Directory. ED consists of a listing of individuals, their expertise, and contact information. Please visit www.askme.com for more information.
Data Ware Houses (DW)	A logical collection of information – gathered from many different operational databases that support business analysis and decision-making tasks. Please visit www.syncsort.com for more information.
Web Crawler	Web-based tool that facilitates intelligent searching with extensive use of meta-data and indexing. Please visit www.metacrawler.com for more information.
Data and Text Mining (D/T M)	A technique to extract meaningful knowledge from masses of data. Please visit www.semio.com for more information
Knowledge Mapping (KMpp)	A graphical representation of procedures and processes to enable free flow of information and sharing of knowledge. Please visit www.kanisa.com for more information.
Knowledge Discovery Packages (KDP)	This is a suite or a group of tools designed to work together. They support several activities due to the different features provided by the individual tools. Please visit www.lotus.com for more information.
Intranet and Extranet (INRA/EXTRA)	Intranet is an internal organisational Internet that is guarded against outside access by special security software (firewall). Extranet is an Intranet with limited access for outsiders, making it possible for these to collect and deliver certain information on the Intranet. Please visit www.opentext.com for more information.
Taxonomy and Ontological Tools (T/OT)	This tool serves multiple purposes in an organisation. They can be used as a corporate glossary holding detail description of every key term used in the organisation. Please visit www.autonomy.com for more information.
Search Engines (SE)	These are web application. Some perform automatic text-only searches while other rely on human 'interpreters' who could access web pages and then analyse and classify them. Please visit www.google.com for more information
Web Mapping Tools (WMT)	This tool organise URLs into knowledge rather than information. Please visit www.eastgate.com/squirrel for more information.
Electronic Document Management System (EDMS)	Systems that collect, store and distribute the artefacts of knowledge contained in an organisation. They provide version control, authentication and translation. Please visit www.documentum.com for more information.
Electronic Mail (E-Mail)	Electronic Mail is a message that is sent from one computer to another. The message can include text graphics and/or other attachments. Please visit www.eudora.com for more information.
Web Publishing (WP)	Tools that support the representing and delivering of recorded knowledge. Please visit www.knowledgebase.net for more information.
Communities of Practice (CoPs)	A virtual environment consisting a group of people of different skill sets, development histories and experience backgrounds who work together to achieve commonly shared goals. Please visit www.askme.com for more information.
Instant Messaging (IM)	Instant Messaging is a software component that helps team members to communicate. It comes as a stand alone application or as a component of a groupware system. Please visit www.netlert.com for more information.
Integrated Groupware Solutions (IGWS)	A software product that helps people to communicate, share information, perform their work efficiently and effectively and to work together to make decisions using IT. Please visit www.novell.com for more information.
Multimedia Tools (MtMd)	Software that support interactive peer-to-peer meetings through computer. Please visit www.instinctive.com/html/eroom.html for more information.
Mind Mapping Applications (MMA)	A process of focussing on a problem, and the deliberately coming up with as many deliberately unusual solutions as possible and by pushing the ideas as far as possible. Please visit www.mindjet.com for more information.
Web-Based File Sharing Tools (WBFS)	A collaborative way of sharing files over the internet to allow dispersed users to access these files freely. Please visit www.knowledgedisk.com for more information.

Appendix 4: Reactive KM Framework
Stage 7 – Implement KM initiatives

KM Sub-processes	Source of Knowledge	Methods	Generic activities
Action Plan for Locating Knowledge	Paper	<ol style="list-style-type: none"> 1. Report 2. Manual 3. Memos 	<ol style="list-style-type: none"> 1. Check/ facilitate commitment 2. Check for appropriate skills/ materials 3. Allocate resources 4. Establish timing 5. Plan procedure 6. Monitor effectiveness of transfer
Action Plan for Sharing Knowledge	Software	<ol style="list-style-type: none"> 1. Knowledge bases 2. Databases 3. Models 	<ol style="list-style-type: none"> 1. Choose representation form 2. Choose knowledge elicitation techniques 3. Check appropriate skills/materials 4. Check/facilitate ownership/trust 5. Establish timing 6. Plan procedure 7. Allocate resources 8. Re-organise work structure 9. Monitor effectiveness of update/maintenance
Action Plan for Updating Knowledge	People	<ol style="list-style-type: none"> 1. Knowledge bases 2. Mentoring 3. Apprenticeships 4. Seminars 5. Interview 6. Meetings 7. Discussion groups 8. Informal groups 9. Storyboards 10.Etc. 	<ol style="list-style-type: none"> 1. Check for appropriate skills/materials 2. Check/facilitate commitment 3. Allocate resources 4. Establish timing 5. Plan procedure 6. Re-organise work structure 7. Monitor effectiveness of update/maintenance

Appendix 4: Reactive KM Framework

Stage 8 – Monitor and Review

KM Initiatives	Review Question	Evaluation
	Have KM initiatives been able to solve the problem?	1. No (Revise) 2. To some extent (next question) 3. Yes
	Are you satisfied with current KM initiatives in solving particular problem in this project?	1. Revise 2. Monitor

Stage 9 – Revise KM initiatives

KM Initiatives	Diagnostic Question	Description
	Why is the existing KM initiative ineffective?	
	What additional issues need to be addressed?	
	What KM initiative can address the outstanding issues?	

Appendix 5: Visual Basic Program Code

Appendix 5: Visual Basic Program Code.

Notes:

- This appendix shows only examples of the codes used for the major decisions made by the system
- Simple codes are not shown e.g. codes for loading, unloading, showing, hiding forms, copying text, selecting menu items etc.

Starting the Program

```
Private Sub cmd1_Click(Index As Integer)
    login.Show vbModal
    If LoginYes Then
        Unload Me
        Load d1
        d1.Show
    Else

    End If
End Sub
```

DECISION ROUTE

Select Proactive Route

```
Private Sub optAp_Click(Index As Integer)
    If optAp(0).Value = True Then
        lblPAP.Visible = True
        cbo1.Visible = True
        lblRAP.Visible = False
        cmbRAP.Visible = False
        cmdPAP.Enabled = True
        cmdRAP.Enabled = False
    Else
        lblPAP.Visible = False
        cbo1.Visible = False
        lblRAP.Visible = True
        cmbRAP.Visible = True
        cmdPAP.Enabled = False
        cmdRAP.Enabled = True
    End If
End Sub
```

Select Reactive Route

```
Private Sub optAp_Click(Index As Integer)
    If optAp(0).Value = True Then
        lblPAP.Visible = True
        cbo1.Visible = True
        lblRAP.Visible = False
        cmbRAP.Visible = False
        cmdPAP.Enabled = True
        cmdRAP.Enabled = False
    Else
        lblPAP.Visible = False
        cbo1.Visible = False
        lblRAP.Visible = True
        cmbRAP.Visible = True
        cmdPAP.Enabled = False
        cmdRAP.Enabled = True
    End If
End Sub
```


Appendix 5: Visual Basic Program Code (continued).

PROACTIVE KM APPROACH

Stage 1: Specific Site Management Processes

```
Private Sub cmbRAP_Click()  
    r1.txtSMP.Clear  
    If UCase(cmbRAP.Text) = UCase("Management, Supervision And Administration") Then  
        r1.txtSMP.AddItem "Lack of cooperation and motivation"  
        r1.txtSMP.AddItem "Poor information management"  
        r1.txtSMP.AddItem "Services obstruction"  
        r1.txtSMP.AddItem "Lack of information on sub-contractor"  
        r1.txtSMP.AddItem "Local residents"  
        r1.txtSMP.AddItem "Poor site communication"  
        r1.txtSMP.AddItem "Complexity of design regulations"  
        r1.txtSMP.AddItem "Shortage of labour resources"  
        r1.txtSMP.AddItem "Misunderstanding of designs and specifications"  
    ElseIf UCase(cmbRAP.Text) = UCase("Commercial Management") Then  
        r1.txtSMP.AddItem "Cost cutting and control"  
        r1.txtSMP.AddItem "Unpredictable final cost and hand over"  
    ElseIf UCase(cmbRAP.Text) = UCase("Health and Safety Management") Then  
        r1.txtSMP.AddItem "Difficult in monitoring and enhance awareness of Health and Safety Plan"  
    ElseIf UCase(cmbRAP.Text) = UCase("Planning, Monitoring And Control") Then  
        r1.txtSMP.AddItem "Inability to accurately resource plan and schedule"  
        r1.txtSMP.AddItem "Poor planning of works"  
        r1.txtSMP.AddItem "Inaccurate planning of work commencement"  
        r1.txtSMP.AddItem "Unpredictable on-site condition"  
    ElseIf UCase(cmbRAP.Text) = UCase("Delivery and Materials' Handling") Then  
        r1.txtSMP.AddItem "Materials damage and defects"  
        r1.txtSMP.AddItem "Poor quality of materials"  
    ElseIf UCase(cmbRAP.Text) = UCase("Production On-site and Off-site") Then  
        r1.txtSMP.AddItem "Lack of quality control"  
    Else  
  
    End If  
    r1.txtSMP.AddItem "Others (Please Specify)..."  
End Sub
```

Stage 2: Identify Relevant Measures

```
Private Sub Command3_Click(Index As Integer)  
    p2.txtSMP.Text = ""  
    For i = 0 To 3  
        If optSelSol(i) Then  
            p2.txtSMP.Text = Me.txtSol(i).Text  
            Exit For  
        End If  
    Next i  
    Me.Hide  
    Load p1  
    p2.Show vbModal  
End Sub
```


Appendix 5: Visual Basic Program Code (continued).

Measures Taken

```
Private Sub Command3_Click(Index As Integer)
    p2.txtSMP.Text = ""
    For i = 0 To 3
        If optSelSol(i) Then
            p2.txtSMP.Text = Me.txtSol(i).Text
        Exit For
    End If
Next i
Me.Hide
Load p1
p2.Show vbModal
End Sub
```

Stage 3: Implement Measures

```
Private Sub Command1_Click()
    p3.txtSMP.Text = p2.txtSMP.Text
    Me.Hide
    p3.Show vbModal
End Sub
```

```
Private Sub Command1_Click()
    p3.txtSMP.Text = p2.txtSMP.Text
    Me.Hide
    p3.Show vbModal
End Sub
```

Stage 4: Monitor and review

```
Private Sub optKMI_Click(Index As Integer)
    Select Case Index
        Case 0
            Frame3.Enabled = False
            cmdPreviewSol.Enabled = False
            cmdKMStage.Enabled = True
            optKMI2(0).Value = False
            optKMI2(1).Value = False
        Case 1
            Frame3.Enabled = True
            cmdPreviewSol.Enabled = False
            cmdKMStage.Enabled = False
            optKMI2(0).Value = False
            optKMI2(1).Value = False
        Case 2
            Frame3.Enabled = False
            cmdPreviewSol.Enabled = True
            cmdKMStage.Enabled = False
            optKMI2(0).Value = False
            optKMI2(1).Value = False
    End Select
End Sub
```


Appendix 5: Visual Basic Program Code (continued).

Stage 4: Monitor and review (continued)

```
Private Sub optKMI2_Click(Index As Integer)
    Select Case Index
        Case 0
            cmdPreviewSol.Enabled = False
            cmdKMStage.Enabled = True
        Case 1
            cmdPreviewSol.Enabled = True
            cmdKMStage.Enabled = False
    End Select
End Sub
```

Stage 5: Revise Measures

```
Private Sub txtIssues_Change()
```

```
End Sub
```

```
Private Sub txtReason_Change()
```

```
End Sub
```

REACTIVE KM APPROACH

Stage 1: Identify KM Dimension

```
Private Sub optKMD_Click(Index As Integer)
    If txtSMP.Text = "" Then
        MsgBox "Enter the Problem to be solved in 2.1 Text Box", vbCritical
    End If
    Select Case Index
        Case 0
            frameKMK.Enabled = True
        Case 1
            a1.Show vbModal
            frameKMK.Enabled = False
    End Select
    frameKMT.Enabled = False
    frameKMC.Enabled = False
End Sub
```

Stage 2: Determine If Required Knowledge is Available

```
Private Sub optKMK_Click(Index As Integer)
    Select Case Index
        Case 0
            frameKMT.Enabled = False
            a2.Show vbModal
        Case 1
            frameKMT.Enabled = True
    End Select
    frameKMC.Enabled = False
End Sub
```


Appendix 5: Visual Basic Program Code (continued).

Stage 3: Identify Type of Knowledge

```
Private Sub txtKMKR_Change()  
    If txtKMKR.Text = "" Then  
        frameKMC.Enabled = False  
    Else  
        frameKMC.Enabled = True  
    End If  
End Sub
```

```
Private Sub Label5_Click(Index As Integer)  
    If d1.cmbRAP.Text = "Management, Supervision and Administration" Then  
        re1.Show vbModal  
    ElseIf d1.cmbRAP.Text = "Commercial Management" Then  
        re2.Show vbModal  
  
    Else  
  
    End If  
End Sub
```

Stage 4: Identify the Characteristics of Knowledge

```
Private Sub optExtInt_Click(Index As Integer)  
    Select Case Index  
        Case 0 To 2  
            Exnal = True  
        Case 3 To 5  
            Exnal = False  
    End Select  
End Sub
```

Stage 5: Select Applicable KM Processes

```
Private Sub chkKMP_Click(Index As Integer)  
    If Index = 2 Then chkKP(Index).Enabled = chkKMP(2).Value  
    ' Select Case Index  
    ' Case 0  
    ' Case 1  
    ' Case 2  
    '     chkKP(Index).Enabled = chkKMP(2).Value  
    ' Case 3  
    '     Me.Hide  
    '     Load r7a  
    '     r7a.Show vbModal  
    ' Case 4  
    '     Me.Hide  
    '     Load r7b  
    '     r7b.Show vbModal
```

Stage 5: Select Applicable KM Processes (continued)

```
    ' Case 5  
    '     Me.Hide  
    '     Load r7c  
    '     r7c.Show vbModal  
    ' End Select  
End Sub
```


Appendix 5: Visual Basic Program Code (continued).

Stage 6: Identify KM Techniques/Technologies

```
Private Sub lstSKTechniques_Click()
```

```
    If lstSKTechniques.Text = "Face to Face Interaction (F-F)" Then
```

```
        txtSKDes.Text = "Face to Face Interaction is a traditional approach for sharing the tacit knowledge (socialisation) owned by organisation's employee. It usually takes an informal approach and is very powerful. Face to Face Interaction also help in increasing the organisation's memory, developing trust and encouraging effective learning."
```

```
    ElseIf lstSKTechniques.Text = "Discussion Forums (D-F)" Then
```

```
        txtSKDes.Text = "A discussion forum is a message board where an individual posts a question or starts a discussion about a particular issue and other respond. Although there are web-based, they are usually described as techniques rather than technologies."
```

```
    ElseIf lstSKTechniques.Text = "Informal Meeting (IM)" Then
```

```
        txtSKDes.Text = "Informal Meeting is a meeting to solve particular problem. In this setting, particular individuals could meet on site, actually observe the problem and then discuss and agree a way forward."
```

```
    Else
```

```
        txtSKDes.Text = ""
```

```
    End If
```

```
    Call updateTechniques
```

```
End Sub
```

Stage 7: Implement KM Initiatives

```
Private Sub cmdLK_Click(Index As Integer)
```

```
    txtSoK(Index).Text = txtLKSR2(Index).Text
```

```
    ' txtLM(Index).Text = lstLKST(Index).Text
```

```
    Select Case Index
```

```
        Case 0
```

```
            frameLKS.Top = 2640
```

```
            frameLKS.Left = 4440
```

```
            frameLKS.Visible = True
```

```
        Case 1
```

```
            frameLKD.Top = 2640
```

```
            frameLKD.Left = 4440
```

```
            frameLKD.Visible = True
```

```
    End Select
```

```
    Command2(1).Enabled = False
```

```
    Command3(1).Enabled = False
```

```
    Command4(1).Enabled = False
```

Stage 8: Monitor and Evaluation

```
Private Sub optKMI_Click(Index As Integer)
```

```
    Select Case Index
```

```
        Case 0
```

```
            Frame3.Enabled = False
```

```
            cmdPreviewSol.Enabled = False
```

```
            cmdKMStage.Enabled = True
```

```
            optKMI2(0).Value = False
```

```
            optKMI2(1).Value = False
```


Appendix 5: Visual Basic Program Code (continued).

Stage 8: Monitor and Evaluation (continued)

Case 1

```
Frame3.Enabled = True  
cmdPreviewSol.Enabled = False  
cmdKMStage.Enabled = False  
optKMI2(0).Value = False  
optKMI2(1).Value = False
```

Case 2

```
Frame3.Enabled = False  
cmdPreviewSol.Enabled = True  
cmdKMStage.Enabled = False  
optKMI2(0).Value = False  
optKMI2(1).Value = False
```

End Select

End Sub

Stage 9: Revise KM Initiatives

```
Private Sub txtReason_Change()
```

End Sub

Appendix 6: Evaluation Questionnaire

Evaluation Questionnaire

A Framework and Prototype System for Integrating KM into Site Management Practices

The completion of this questionnaire should follow a demonstration on the prototype system

BACKGROUND INFORMATION

Name	
Position	
Company Name /Address	
Experience in SM (years)	
Email/Contact No.	
Date	

Please tick the box that best indicate your opinion to a question. Larger score reflect more positive response.

RATING
1: Poor 2: Fair 3: Satisfactory 4: Good 5: Excellent

OVERALL FRAMEWORK

1	How useful do you consider the overall framework	①	②	③	④	⑤
2	How useful is it to have both a proactive and reactive approach to addressing site management problems?	①	②	③	④	⑤
3	To what extent will having a proactive KM approach help in avoiding SM problems?	①	②	③	④	⑤
4	To what extent will the reactive KM approach help Site Managers in solving specific problems?	①	②	③	④	⑤
5	How appropriate is the facility for monitoring and review of (KM) initiatives?	①	②	③	④	⑤
6	How useful is the 'Revise KM Initiatives' stage in modifying existing initiatives?	①	②	③	④	⑤

PROACTIVE KM APPROACH

1	How well does the system help in avoiding site management problems?	①	②	③	④	⑤
2	How well does system help in identifying common problems that occur on construction site?	①	②	③	④	⑤
3	How well do available solutions help in avoiding potential SM problems?	①	②	③	④	⑤
4	How well does the system help in developing a KM implementation plan for selected solution?	①	②	③	④	⑤
5	How well does the system help in monitoring and reviewing existing initiatives?	①	②	③	④	⑤
6	How useful is the 'Revise KM Initiatives' stage in modifying existing initiatives?	①	②	③	④	⑤

General (Proactive KM Approach)

7	How appropriate is the proactive KM system for site managers?	①	②	③	④	⑤
8	What is your overall rating of the proactive KM sub-system?	①	②	③	④	⑤

REACTIVE KM APPROACH

9	How well does the system help in solving specific site management problems?	①	②	③	④	⑤
10	How well does the system help in identifying the type of knowledge required?	①	②	③	④	⑤
11	How appropriate are the types of knowledge required for solving a given problem?	①	②	③	④	⑤
12	How well does the system help in identifying the characteristics of knowledge?	①	②	③	④	⑤
13	How well does the system help in identifying the sources and destination of knowledge?	①	②	③	④	⑤
14	How well does the system relate characteristics of knowledge to applicable KM processes?	①	②	③	④	⑤
15	How well does the system identify the KM techniques and technologies required for solving a site management problem?	①	②	③	④	⑤
16	How well does the system help in developing KM implementation plan for resolving site management problem?	①	②	③	④	⑤
17	How well does the system help in monitoring and reviewing KM initiatives?	①	②	③	④	⑤
18	How useful is the 'Revise KM Initiatives' stage in modifying existing KM initiatives?	①	②	③	④	⑤

General (Reactive KM Approach)

19	How appropriate is the reactive KM system for site managers?	①	②	③	④	⑤
20	What is your overall rating of the reactive KM system?	①	②	③	④	⑤

GENERAL QUESTIONS ON THE INTEGRATED PROTOTYPE SYSTEM

21	How attractive is the graphical user interface of the system?	①	②	③	④	⑤
22	How easy is it to navigate between the different stages within the system?	①	②	③	④	⑤
23	How effective is the on-screen help in facilitating the use of the system?	①	②	③	④	⑤
24	How convinced are you that site managers can use the system?	①	②	③	④	⑤
25	To what extent does it represent an improvement in site management practices?	①	②	③	④	⑤

F. GENERAL COMMENTS

What improvements can be made to the overall framework?

What do you consider the main benefits of the integrated (proactive and reactive KM) prototype system?

In what ways can the system be improved?

Further comments
