IMPROVING THE STRUCTURAL DESIGN PROCESS:

A KNOWLEDGE MANAGEMENT APPROACH

AHMED MOHSIN AL-GHASSANI

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

May 2003

ABSTRACT

Knowledge is crucial for structural design, yet existing methodologies for managing it are neither comprehensive nor do they adequately address the requirements of structural engineers. This knowledge exists in different forms and repositories therefore requiring special consideration as to how it should be managed. Poor management of structural design knowledge can result in many problems such as increased design time, reduced quality and decreased scope for innovation. Knowledge Management (KM) remains largely unexplored within the context of structural design although it is a valuable concept. The research in this thesis was aimed at developing a structured approach to managing structural design knowledge.

The research methodology adopted consisted of various methods. Literature on structural design and KM was first reviewed. Case studies involving thirteen organisations were then undertaken to investigate the potential of KM for managing structural design knowledge and to develop a conceptual framework and methodologies for formulating KM strategies and evaluating the impact of KM initiatives. Rapid prototyping (based on MS Visual Basic) was used to encapsulate the methodologies into prototype systems, which were evaluated by industry practitioners. The evaluation established that the systems do proffer many benefits to the construction industry and facilitate the development of a KM strategy for managing the very specialised knowledge of structural design.

It is concluded that the process of structural design suffers from several problems where managing the tacit and explicit knowledge involved in the process did not receive adequate attention. The research also concludes that KM has the potential to improve the structural design process and that the framework developed and its associated prototypes help to clarify a KM problem, identify goals for implementing KM, develop a KM strategy and evaluate the strategy. The prototypes also support KM at both the strategic and tactical levels, unlike other existing IT tools, which support KM primarily at the operational level. Recommendations for future research include further improvement to the prototypes, additional evaluation using a wider range of real cases and integrating the two prototypes into one system.

DEDICATION

To my father (Mohsin) who told me the importance of stacked books,
my mother (Khadija) who taught me love and kindness,

my wife (Hana) who gave support even though she needed it more,

our sons (Laith and Muayad) for their understanding, and
our daughter (Ishraq) for her welcome arrival during the research period.

ACKNOWLEDGEMENTS

I would like to register my appreciation of thanks to the Ministry of Manpower (Oman), the Engineering and Physical Sciences Research Council (EPSRC-UK) and the Department of Civil and Building Engineering (Loughborough University) for providing the financial support for this work.

Numerous people have contributed in a variety of ways in the realisation of the research outcome. I would like to thank my supervisors, Professor Chimay J. Anumba and Dr Patricia M. Carrillo for providing guidance and information for the research. I owe a deep debt to both of them. Thanks also go to other members who provided a stimulating and supportive academic and social environment. Certain people deserve special mention here: Dr Herbert S. Robinson and Dr John M. Kamara. Many thanks also go to the academic and administrative staff within the Department of Civil and Building Engineering.

I am also grateful for the comments and assistance received from industrial participants who provided access for the case studies, especially Ms Faith Wainwright (Arup), Mr Neil Bonner (Taylor Woodrow Plc), Mr Richard McWilliams (Whitby Bird and Partners), Mr Peter Whatling (Hyder Consulting Ltd) and Mr Jeff Peters (Curtins Consulting).

I am very much indebted to many people in Oman who supported my studies by different means, especially H.E. Mr Jumaa Ali Al-Jumaa (Minister of Manpower), H.E. Dr Muneer Al-Maskery (Undersecretary of Manpower), H.E. Dr Mohammed Al-Dahab (Advisor at Manpower) and Professor Hassan Tantawi (Dean of Salalah College of Technology). Finally, my family and friends deserve a special thought for providing me with enormous moral support, and I will ever be so grateful for their understanding.

At a personal level, I have enjoyed my stay at the university and I am grateful for the opportunity that I have been given. My UK years carry many happy memories that I will never forget but have been punctuated with some difficulties. Faith in 'Allah' and His Guidance has always helped me in overcoming difficulties.

TABLE OF CONTENTS

CHAPTER 4: KNOWLEDGE MANAGEMENT

CHAPTER 5: INDUSTRIAL CASE STUDIES

CHAPTER 6: METHODOLOGY AND PROTOTYPE DEVELOPMENT

CHAPTER 7: OPERATION AND EVALUATION OF PROTOTYPES

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 GENERAL INTRODUCTION

This chapter introduces the research reported in the thesis. It briefly presents a background to the research, justification for undertaking it, aim and objectives, methodology, and a guide to the contents of the thesis.

1.2 BACKGROUND

Design is a knowledge-intensive process (Garrett and Smith, 1996) that has impacts on the whole lifecycle of a project. The design of construction projects involves several inter-related sub-processes such as architectural, electrical and structural design. The latter is a complex process that requires extensive knowledge in order to produce safe and stable structures. It is knowledge that makes one design better and more innovative than others and therefore it needs to be available and accessible to designers at the moment of requirement. Otherwise, a designer will spend a lot of time searching for knowledge that is available elsewhere within the organisation. If the designer is not aware of the existence of such knowledge within the organisation, a lot of re-inventing of the wheel and repeating mistakes may take place.

The importance of knowledge has always been recognised. However, the actual process of retaining and using it remains a challenge yet to be adequately addressed. One approach for capturing and storing the knowledge of experts is achieved through Expert Systems. These are Artificial Intelligence (AI) tools that use case-based and rule-based reasoning to support the process of decision-making (Wang and Howard, 1988). Several expert systems were developed to capture the knowledge of structural designers. Examples of such systems were developed by Sriram (1986), Wang and Howard (1988), Kumar and Topping, (1988) and Maher and Gomez (1996). Expert systems, however, were not very successful as Turban (1992) estimated the failure rates of expert systems at over 80 percent. Expert systems were not successful because of several reasons (Diaper, 1988; Adeli, 1988; Allwood, 1989; Adelman, 1992). Firstly, they did not consider the richness of knowledge as they dealt with it as a static product that can be controlled easily. Secondly, they focused on the tacit knowledge of experts and almost neglected the other types of explicit knowledge and the interactions between tacit and explicit knowledge. Thirdly, they disregarded the cultural and organisational issues surrounding knowledge. Fourthly, they focused on narrow domains and hence their use was limited to specific professionals and/or specific problems.

The rationale for undertaking this research stems from the need to improve the management of the structural design process. A promising approach that has not been researched within the context of structural design is Knowledge Management (KM). KM identifies the richness of knowledge and its different characteristics and sees its management as a continuous process that requires careful and extensive planning. KM helps in easily locating, accessing, sharing, and using the required knowledge so that optimisation can be achieved in terms of execution, quality, cost and maintenance.

1.3 JUSTIFICATION FOR THE RESEARCH

Structural design is an important task within the design process as it provides safe and stable structures. Improving the process of structural design does not only contribute to increased safety and improved stability but also saves design time and provides scope for innovation. Time can be saved, for example, by reducing the number of design cycles or by cutting the time spent on searching for the required knowledge. The time saved can be used to improve the design. This section presents a brief background to structural design with emphasis on the knowledge involved in it. It then describes the importance of managing knowledge. It also discusses the reasons for and benefits from managing structural design knowledge.

1.3.1 Structural Design

Structural design is a sub-process of the design of any construction project and is carried out based on the requirements of the proposed project. It consists of many interrelated activities (Bell and Plank, 1985; Kumar and Topping, 1991; Evbuomwan and Anumba, 1996; Austin *et al.*, 2002) such as preliminary design, analysis and detailed design (Fraser, 1981; Maher *et al.*, 1988; Payne, 1989). These activities are influenced by factors that are linked to human intelligence and knowledge such as experience and engineering judgment (Bell and Plank, 1985). The availability of knowledge is one of the most important factors that determine the design quality and the number of design cycles. Even experienced engineers face difficulties when the required knowledge is not available and this can result in assumptions or judgments that may be disproved when knowledge becomes available (Kumar and Topping, 1991).

Structural design knowledge takes many forms e.g. experiences, best practices, lessons learned, drawings, documents etc. and is either developed within the design office or on construction sites. Knowledge developed within a design office is easy to access by individuals or groups working within the same office but those located in geographically dispersed offices will not have the same ease of access. Knowledge generated on a construction site is rarely shared with designers and this can result in the loss of this knowledge. If a problem relevant to the performance of a structure occurs on a construction site, structural designers in the design office need to know about this problem; its nature, why it occurred and how it was solved. Improving the 'knowledge flow' within an organisation adds value, increases the ability to compete and helps to improve future designs. This shows an emergent need for an approach that facilitates knowledge sharing.

1.3.2 Knowledge Management

Knowledge Management (KM) is referred to as a theory (von Krogh *et al.*, 1996; Holtham and Courtney, 1998; Erno-Kjolhede, 2000; van der Velden, 2002) and a concept (Lenz, 2001; Castillo and Clodfelter, 2001; Egbu, 2002; Luan and Serban, 2002). It considers knowledge as a valuable asset needing to be managed in order to improve organisational business performance (Manasco, 1996; Leavy, 1996; Davenport and Prusak, 1998; Sheehan, 2000; Tiwana, 2000; Anumba *et al.*, 2002; Robinson *et al.*, 2002a). KM distinguishes knowledge from information and data in the sense that knowledge is rich, context sensitive and more difficult to manage. KM is a systematic "process or practice of creating, acquiring, capturing, sharing and using knowledge, wherever it resides, to facilitate problem solving and decision-making and therefore enhance performance in organisations" (Scarbrough *et al.*, 1999). It helps to increase innovation (Egbu, 2000c; Egbu *et al.*, 2001c) and customer satisfaction (TFPL, 1999) through enabling the intellectual capital/assets of an organisation to be used effectively, creatively and consistently (Egbu, *et al.*, 1999). It is believed that, in the evolving new economy, knowledge will replace other resources (e.g. capital, land, buildings, etc) as the organisations' most valuable asset (Drucker, 1993; Skyrme and Amidon, 1997; Hjertzen and Toll, 1999; Scarbrough and Swan, 1999).

Several reasons make it of critical importance to implement KM. An employee may not find the relevant knowledge at the moment of requirement. Furthermore, knowledge that is generated in a particular situation will be lost if not properly captured, stored, and made available to others. More critically, the knowledge of staff members is mobile and this mobility needs to continuously track where this knowledge exists. The promises of the benefits provided by KM and its many successful cases have resulted in increased interest in its implementation. A recent survey shows that a significant proportion of engineering and construction organisations have or plan to have a strategy for KM (Carrillo *et al.*, 2003b). Strategies for implementing KM vary from one organisation to another depending on the organisational goals and objectives. The clearer the business goals from KM, the most likely a KM strategy will succeed in achieving real benefits.

1.3.3 Managing Structural Design Knowledge

Although the term 'KM' is relatively new to construction organisations (Carrillo *et al.*, 2000), many have adopted strategies for its implementation. These have adopted KM to manage the different types of knowledge available organisation-wide. The implementation of KM for improving the process of structural design is an area that has not been researched (Al-Ghassani *et al.*, 2002a). This requires an investigation into how knowledge is currently managed within organisations involved in structural design. Although consultants are more involved in structural design, contractors may also be involved depending on the procurement method used. For example, contractors involved in 'design and build' projects may be heavily involved in structural design while those involved in 'partnering' projects share the responsibility with the designers and therefore need to make input into design with regards to best practice, most suitable materials and buildability concerns. The more knowledge is available at this stage the greater the potential for innovative designs.

Organisations involved in structural design, can benefit from KM by implementing initiatives that help in capturing knowledge that is generated during the different stages of a project lifecycle to make it available and accessible to structural designers in a timely fashion, throughout the organisation. Two types of strategy are usually used for managing organisational knowledge: personalization and codification (Hansen *et al.*, 1999). Personalization supports the transfer of tacit knowledge from one person to another through face-to-face interactions, net-meetings etc. whilst codification enables the capture and storage of tacit and explicit knowledge to make it widely accessible to others through IT and non-IT tools. In order for personalisation and codification to be properly implemented, a clear strategy has to be developed. The development of a strategy is the most critical KM activity as this strategy will determine whether KM will achieve its goals or not (Al-Ghassani *et al.*, 2002c). To develop such a strategy, a detailed and structured approach is required.

In the light of the foregoing, there is a need for a framework or a structured approach to help construction organisations develop strategies for managing their structural design knowledge. It is this need that the reported research seeks to address.

1.4 RESEARCH AIM AND OBJECTIVES

The aim of this research project is to develop a structured approach for managing and sharing structural design knowledge using the concept of knowledge management. The following specific objectives were defined:

1. To understand the nature of the process of structural design and to identify the knowledge involved in it and the existing approaches for managing this knowledge;

2. To review the concept of knowledge management and to identify the supporting tools for its implementation;

3. To explore the potential of knowledge management for structural design knowledge;

4. To develop a conceptual framework and to support its use by detailed methodologies for managing structural design knowledge;

5. To encapsulate the developed methodologies into prototype systems; and

6. To evaluate the developed methodologies and their supporting prototypes using appropriate tools.

1.5 RESEARCH METHODOLOGY

The research focused on the development of a structured approach for managing structural design knowledge. The methodology is intended to facilitate the formulation of a proactive KM strategy that takes into account the whole process of KM. To achieve the research objectives, various research tools were adopted including: literature review; case studies; rapid prototyping; and questionnaires. A summary of the research objectives and the research tools used to achieve them is illustrated in Table1.1.

Table 1.1: Research objectives and the research tools used to achieve them

Tools / Objectives	Literature Review	Case studies	Rapid Prototyping	Questionnaires
Understand structural design process, knowledge involved & approaches for its management	✔			
Review concept of Knowledge Management and identify tools for implementation	✔			
Explore potential of Knowledge Management for structural design knowledge		✔		
Develop a framework and a detailed methodology for managing structural design knowledge		✔		
Encapsulate the developed methodology into a prototype system		✔	✔	✔
Evaluate the methodology and prototype using appropriate tools		✔		✔

A brief description of the research tools used is given in this section. The research methodology adopted is described in more detail in Section 2.4.

1. An extensive literature review focused on two major areas. First, it developed an understanding of the nature of the process of structural design, the knowledge involved in the process and the existing approaches for its management. Second, it facilitated the review of the concept of KM and the identification of the tools required for its implementation. Review of the literature was achieved through several sources: Loughborough OPAC (Loughborough University Library Catalogue); COPAC (merged online catalogues of 22 major university libraries in UK, Ireland and the British Library); CD-ROM based information products; Bids Ei Compendex for databases; the Internet and zetoc alert by MIMAS (alert to the British Library's electronic table of contents of new publications). The required publications were obtained from the university library or through inter-library loans.

2. The case study approach is very useful for exploratory and investigative research. It helps to gain understanding of underlying reasons and motivations. Thirteen case study organisations were used in this research to achieve four objectives. Firstly, five case studies were conducted to identify the knowledge involved in structural design and the potential of KM for managing such knowledge. Secondly, these case studies were used as the basis for developing a conceptual framework for managing structural design knowledge and formed the ground for introducing detailed methodologies, which were then encapsulated into prototype systems, for developing and implementing a KM strategy. Thirdly, another eight case study organisations were used to refine the methodologies and their associated prototypes. Fourthly, the case studies used for developing the conceptual framework were used for evaluating the methodologies developed and their associated prototypes.

3. Rapid Prototyping is used in software development. It is developed quickly and demonstrated to users at an early stage for additional features and refinements (Connell and Shafer, 1995). Rapid prototyping was used to encapsulate two methodologies into prototype systems. The prototypes were developed on a personal computer (PC) and the implementation environment was Microsoft Visual Basic. After the prototypes were developed they were presented to eight case study organisations to further refine them and enhance their functionalities. The prototypes were also evaluated using four organisations involved in structural design.

4. Questionnaires were used to achieve two objectives. Firstly, to capture suggestions from participants on how the developed prototypes could be refined. Secondly, they were used for evaluating the final version of the prototypes for their usefulness, efficiency and effectiveness to develop strategies for managing structural design knowledge.

1.6 THESIS LAYOUT AND CONTENTS

This thesis is divided into eight chapters as follows:

Chapter 1, *Introduction*, introduces the research project and briefly describes its background. It then justifies the need for the research and explains its aim, objectives, and the methodology adopted. It also presents the thesis layout and contents.

Chapter 2, *Research Methodology*, consists of two main sections. First, it introduces the concept of research and also describes the different types of research methodologies. Then, it presents a description of the research methodology used for this project and its supporting tools. It concludes with a summary of the methodology adopted.

Chapter 3, *The Structural Design Process*, reviews the process of structural design and describes its two stages: concept design and detailed design. It highlights the types of knowledge involved in each stage and describes the different approaches for improving the process. It concludes with identifying the need for managing structural design knowledge.

Chapter 4, *Knowledge Management*, reviews the concept of knowledge management, its importance to the different business organisations, barriers to its implementation, and the tools required for implementation. It concludes with identifying KM as a potential concept for managing organisational knowledge.

Chapter 5, *Industrial Case Studies*, presents the findings from five case-study organisations, which are involved in structural design. It identifies the problems requiring new knowledge during the structural design process, discusses the potential of KM for managing structural design knowledge and uncovers a need for an approach for KM strategy formulation. It concludes with introducing a conceptual framework for developing and implementing a KM strategy.

Chapter 6, *Methodology and Prototype Development,* analyses the existing methodologies of KM strategy formulation and implementation. It then presents two methodologies namely CLEVER (Cross-sectoral Learning in the Virtual Enterprise) and IMPaKT (Improving Management Performance through Knowledge Transfer) for developing and implementing a KM strategy. Rapid prototyping was used for refining the methodologies and for enhancing their functionalities. The objectives, features, and development of the prototypes are described.

Chapter 7, *Operation and Evaluation,* provides details on the utilisation of the prototypes with a 'walk-through' demonstration. It then describes the evaluation process. It summarises the key findings and discusses how each prototype will help in managing structural design knowledge.

Chapter 8, *Conclusions and Recommendations,* provides the summary and conclusions of the research. It presents a general summary of the research, a summary of the prototypes' advantages, conclusions, contribution to knowledge and limitations of the research. It finishes with recommendations for further research and concluding remarks.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 INTRODUCTION

This chapter provides on overview of the research methodology. It describes the different research methods and highlights the research method adopted. The chapter ends with a summary of the main issues.

2.2 RESEARCH

Research relates to investigation and is concerned with "seeking solutions to problems or answers to questions" (Allison, 1995). Chambers English Dictionary defines it as "a systematic investigation towards increasing the sum of knowledge" (Fellows and Liu, 1997). Mainly, there are two types of research (Fellows and Liu, 1997; Moore, 2000): pure research (mostly undertaken by academics) and applied research (mostly undertaken by practitioners and industrialists). Pure research aims at developing a "theoretical explanation" or "understanding" of an issue while applied research relates to problems and their solution. Moore (2000) identifies a third type of research namely social research which is about monitoring developments in the world around us to develop better understanding of what is going on. Four important terms usually associate any research; bias, generalisation and particularisation, validity and rigour.

Bias is a natural feature created by the research itself (Kitchenrr, 1994). It is usually a result of personal views, mis-perceptions, mis-interpretations, and use of ambiguous data

(Miles and Huberman, 1994). It cannot be completely eliminated and therefore researchers need to identify the sources of bias and reduce them as much as possible. Also, researchers need to take into account the possible impact of the bias that cannot be eliminated.

Generalisation and particularisation (Normann, 1970; Argyris *et al.*, 1985) are two opposite techniques for judging a research outcome. Generalisation can be achieved by a quantitative approach, based on a large number of observations or measurements to determine how much, how often and how many or a qualitative approach, based on exhaustive investigations and analysis to identify certain phenomena that are suspected to exist in similar situations. Particularisation, on the other hand, advocates that social phenomena are part of a specific situation and are far too liable to change to permit meaningful generalisations.

Validity is a test or measure to the research quality. It provides a faithful description of how others perceive the goodness of the data (Berdie et al, 1986). Validity tests are: construct validity (use of appropriate research method); internal validity (demonstration of cause and effect relationships); external validity (type of and extent to which the research findings are capable of generalisation beyond the area of study); and reliability (others repeating the same research should obtain the same findings).

Rigour is an important feature of research. Bennett (1991) defines it as the adherence of the method employed to the fundamental requirements of research design. He also states that 'there is no one best method, appropriateness is the role'.

2.3 RESEARCH METHODOLOGY

Research Methodology is about the way research is carried out. There are three types of research methodology: quantitative, qualitative, or a combination usually called the triangulation or hybrid method. Although, the dividing line between quantitative and qualitative methods is not always clear (Linn and Erickson, 1990; Easterby-Smith *et al.*, 1991; Moore, 2000) there are some features that distinguish them. This section describes the main characteristics of these research methodologies and the tools usually used to implement them.

2.3.1 Quantitative Methods

The quantitative method is also called 'realistic' and is used to collect information about things that are easy to count. However, it is possible to take a quantitative approach to many issues that are qualitative in nature (Moore, 2000). A quantitative method is about gathering factual data and studying relationships between facts in order to find out how these facts and relationships agree with theories of previous research findings (Fellows and Liu, 1997). Systematic measurement, experimental and quasi-experimental methods, statistical analysis, and mathematical models are all tools for quantitative research (Linn and Erickson, 1990). The effectiveness of the selected quantitative method greatly depends on the nature of the research. For example, if the research results are to be generalised then a broad rather than a deep research will be required. Several qualitative decisions should be made when using quantitative methods e.g. the questions to pose, the design to implement, the measures to use, the analytical procedures to employ, and the interpretations to stress (Linn and Erickson, 1990). The main features/advantages of quantitative methods are illustrated in Table 2.1.

2.3.2 Qualitative Methods

The qualitative method is also called 'idealistic' and is concerned with information about things that are less easily understood by counting them. A qualitative method seeks to understand how people see and interact with 'the world' (Fellows and Liu, 1997). It is the research method that consists of 'detailed descriptions of situations, events, people, interactions, and observed behaviour' (Patton, 1992). Naturalistic observation, case studies, ethnography, and narrative reports are all tools for qualitative research (Linn and Erickson, 1990). However, certain quantitative summaries, classifications, and analyses can be useful for qualitative research (Linn and Erickson, 1990). Analysis of qualitative data is more difficult than quantitative data, requiring a lot of filtering, sorting and other manipulations to prepare them for analytical techniques (Fellows and Liu, 1997). The main features/advantages of qualitative methods are illustrated in Table 2.1.

Table 2.1: Main features of quantitative and qualitative research methods

	Quantitative Methods	Qualitative Methods
Objective/ purpose	• To quantify data • To measure the incidence of views/options in a sample. • To generalise results.	• To gain understanding of underlying reason and motivations. • To uncover prevalent trends in thought and opinion. • To provide insights into the settings of a problem, generating ideas/ hypothesis for later quantitative research.
Sample	• Large number • Representative of the population. • Randomly selected respondents.	• Small number • Non-representative of the population. • Respondents selected to fulfil a given requirement.
Data collection	• Structured questionnaires.	• Unstructured or semi-structured interviews.
Data Analysis	• Statistical.	• Non-statistical.
Outcome	• Findings are conclusive • Findings can be generalised • Used to recommend a final course of action.	• Findings are not conclusive • Findings cannot be generalised. • Exploratory and/or investigative.

2.3.3 Triangulation Methods

The triangulation method is also called 'hybrid' and characterises the use of a mixture of quantitative or qualitative tools. Although some scholars insist that either a quantitative or qualitative research method should be used, a combination has proven to be effective in many cases depending on the research objectives (Lee, 1991; Cavaye, 1996). The triangulation method (Figure 2.1) combines the two methods to reduce or eliminate the disadvantages of each individual method and at the same time to provide the advantages of each.

This combination also offers a multi-dimensional view of the subject gained through synergy (Fellows and Liu, 1997). It is a useful method because it gives an added dimension and adds considerable value to the research results (Moore, 2000). The triangulation method provides both breadth and depth to a research (Moore, 2000). For example, as a questionnaire (quantitative method) helps in getting a broad idea about a research matter, interviews and case studies (qualitative methods) offer deeper investigation into the same area. Again, the research objectives determine the most suitable research methodology.

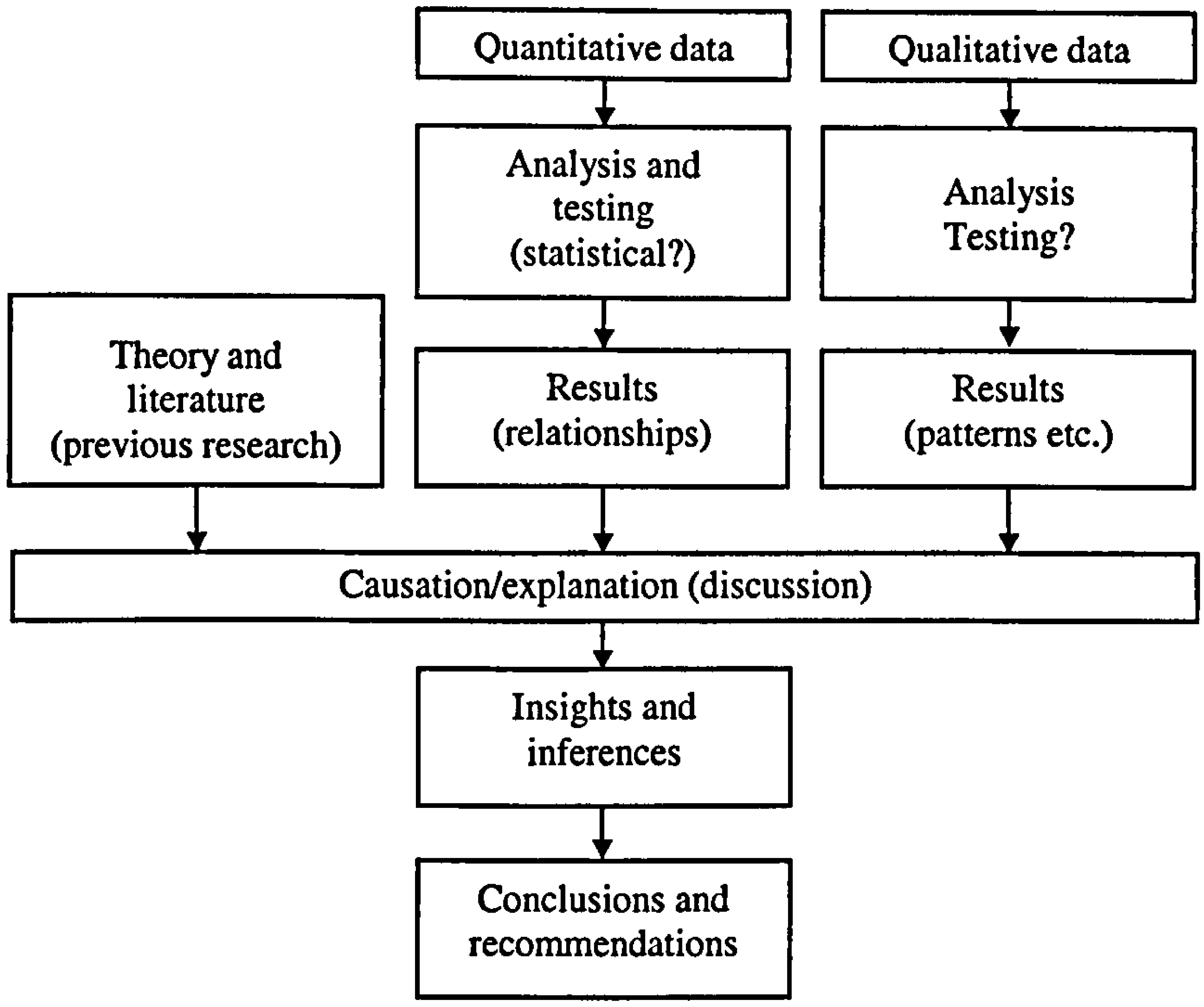

Figure 2.1: The Triangulation Method. (reproduced from: Fellows and Liu, 1997)

The next section describes the research method adopted and its associated tools.

2.4 RESEARCH METHOD ADOPTED FOR ACHIEVING THE OBJECTIVES

The reported research aimed at developing a structured approach for managing structural design knowledge. To achieve the research objectives, several research methods were considered. The research was about investigating and enhancing an existing practice (structural design). It sought to develop a conceptual framework, which is based on a concept (KM) that has not previously been implemented in the context of the reported research. Therefore a purely quantitative method was not appropriate. The qualitative method was the most appropriate to address the research objectives although some quantitative methods (questionnaire) were used to refine and evaluate the developed methodologies. The various methods adopted are literature review, case studies, rapid prototyping and questionnaires. These methods were presented in Table 1.1 in the previous chapter and were also described in Section 1.5 in the same chapter.

Figure 2.2 illustrates the research objectives and the tools used to achieve each of them. The figure also indicates the chapters covering these objectives. The following sections describe how every objective was achieved.

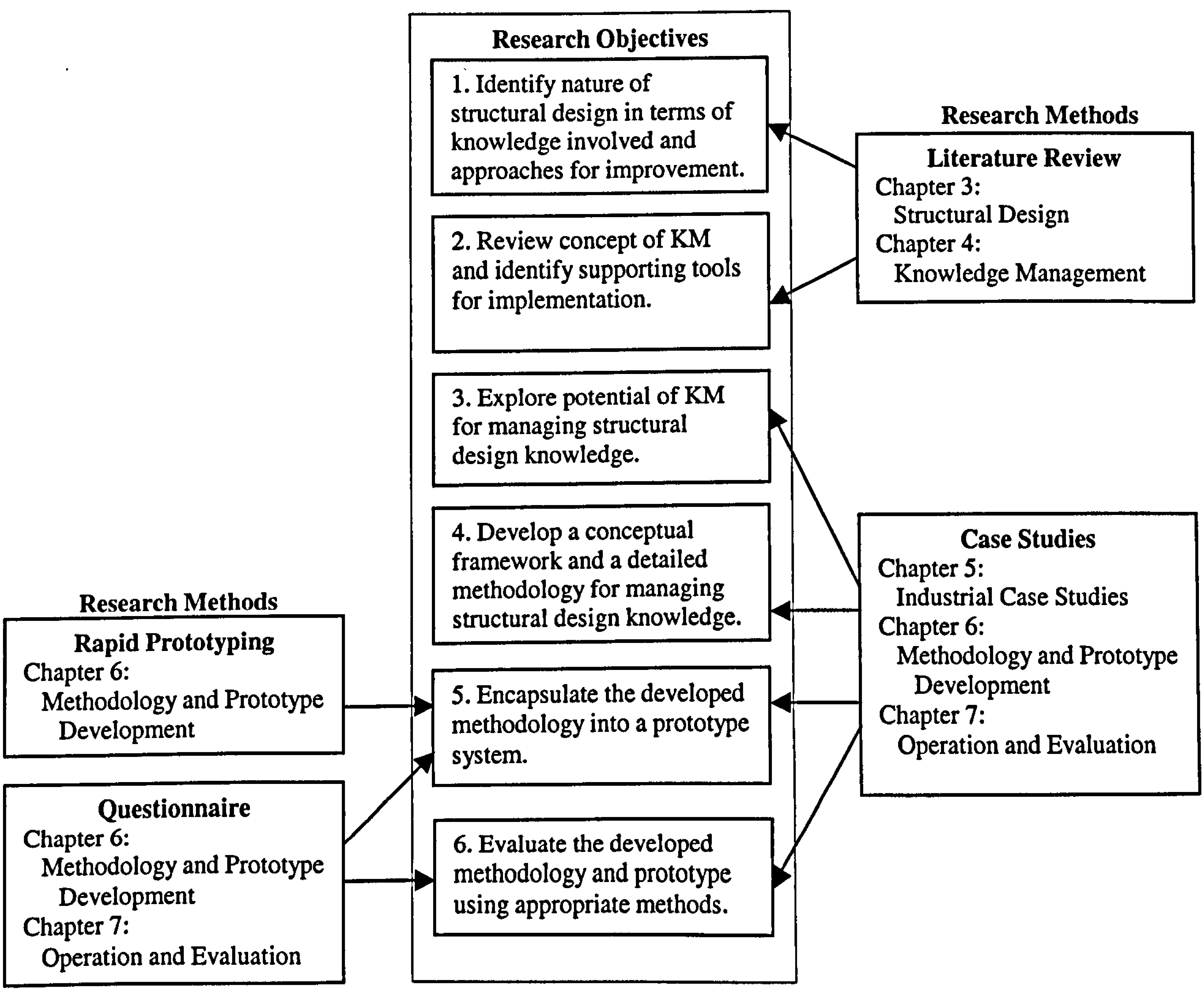

Figure 2.2: Research objectives and methods

2.4.1 Understanding the Process of Structural Design

The first objective of investigating the process of structural design, how it relates to the other sub-processes within design, the knowledge involved in the process and existing approaches to its improvement was carried out through extensive literature review. The literature review helped in building up a theoretical background to the process of structural design and how it is implemented in construction organisations. It was also used to investigate the nature of knowledge involved during the concept design and the detailed design. It also identified the existing approaches for improving the process of structural design in general and for managing the knowledge involved in it, in particular. The review was based on 'personal document analysis', a qualitative analysis to review and analyse current theories and literature (Keppel, 1991; Dainty *et al.*, 1997).

2.4.2 Review of the Concept of Knowledge Management

The second objective, review of the concept of knowledge management, was carried out through literature review supported by discussions with participants in international conferences and researchers within the KM research group at Loughborough University. This provided a coherent understanding of the principles supporting KM and helped in identifying the tools and techniques that support its implementation. This also aided in recognising the barriers to implementing KM and identified how organisations currently select their KM tools. The literature review included research review to identify the existing methodologies for KM strategy formulation and implementation.

2.4.3 Exploring the Potential of KM for Structural Design Knowledge

Case studies were used to achieve the third objective, exploring the potential of KM for structural design knowledge. Case study interviews with five organisations heavily involved in structural design helped in identifying the nature of the knowledge involved in structural design and explored the potential of KM for managing it. The case studies covered construction organisations (consultants and contractors) that are at different stages of implementing knowledge management. The case studies were based on semi-structured interviews and were carried out with senior structural engineers. These engineers were at different levels of involvement in their organisations' KM systems. Some were just using the system while others where in charge for its development.

2.4.4 Framework and Methodology Development

The fourth objective, development of a conceptual framework and detailed methodologies for KM strategy formulation, was achieved though case studies and discussions with the industrial collaborators. The framework was developed based on the findings from the analysis of the industrial case studies. This resulted in a four-stage framework. This was followed by an investigation into the existing methodologies to find out if any of them addresses all the stages of the conceptual framework. A refinement to an existing methodology (Cross-sectoral Learning in the Virtual Enterprise - CLEVER) and the development of a new methodology (Improving Management Performance through Knowledge Transfer - IMPaKT) were then carried out.

2.4.5 Encapsulating the Methodologies into Prototype Systems

The fifth objective, encapsulating the methodologies into prototype systems, was achieved through rapid prototyping. The two methodologies were encapsulated into two prototype systems. The prototyping consisted of several stages: designing the system architecture, identifying the implementation environment and developing the prototype.

The prototypes were developed on a PC and the implementation environment was Microsoft Visual Basic. Case studies covering eight organisations were then used for the actual refinement of the prototypes. The case studies consisted of 3-4 hour workshops where the participants were allowed to use the prototypes. A questionnaire was given to the participants at the end of the workshops where several suggestions were received for refinement. The suggestions were examined and carried out as appropriate.

2.4.6 Evaluating the Methodologies and Prototypes

Evaluating the methodologies and their associated prototypes was achieved through the same case study organisations that were used for developing the conceptual framework. Participants were allowed to use the prototypes and then they were allowed to ask questions. A questionnaire was then given to the participants to allow them to give their views on the usefulness, effectiveness and efficiency of the methodologies and their associated prototypes. The evaluation focused on investigating the potential for developing a KM strategy for managing structural design knowledge.

2.5 SUMMARY

The concept of research was introduced and the different types of research methodologies were described. Different research methods were used for carrying out the reported research. This included a literature review to the process of structural design and the concept of KM, case studies at the different stages of development, rapid prototyping to facilitate the use of the methodologies and questionnaires to refine and to evaluate them.

CHAPTER 3: THE STRUCTURAL DESIGN PROCESS

3.1 INTRODUCTION

This chapter reviews the literature on the structural design process. It first describes the design process in terms of definitions, nature, stages and the team members involved in it. Then, it describes the process of structural design, highlights the problems that take place during the process and discusses the approaches used to solve these problems. The chapter concludes with a summary of the main issues.

3.2 THE DESIGN PROCESS

3.2.1 Definition

Design is one of the most intelligent tasks that humans carry out (Kumar and Topping, 1991). The term 'Design' can be defined in different ways depending on the context in which it is used. The Oxford English Dictionary (OED, 1989) includes several definitions to design as a noun and as a verb. For example, when defined as a noun, design is 'A plan or scheme conceived in the mind and intended for subsequent execution; the preliminary conception of an idea that is to be carried out into effect by action; a project' (OED, 1989). Another definition is 'A preliminary plan or sketch for the making or production of a building, a machine etc (OED, 1989).

When defined as a verb, OED (1990) defines 'to design' as 'To form a plan or scheme of; to conceive and arrange in the mind, to originate mentally, plan out, contrive' or 'The creation of almost any product: a building, a machine, a picture, a garment'. A more technical definition is introduced by the Academic Press Dictionary of Science and Technology (APDST) as 'A scheme for the construction and ornamentation of a building, composed of plans, evaluations, rendering and other drawings' (APDST, 1991).

The British Standards (BS) states that 'to design' is 'to generate information from which a product can become a reality' (BS7000, 1989). Another states that design is 'the activities required to convert design input into design output' (BS7000, 1994).

Different views also exist when design is defined by academics and practitioners. Some definitions that describe the human intellectual activity involved in design are:

> *'The design process is the intellectual attempt to meet certain demands in the best possible ways'*
>
> (Pahl and Beitz, 1988)

> *'The design process is a unique combination of problem solving, creative, need fulfilling and human activity processes'*
>
> (Holt, 1990)

> *'The design process is that creative and personal activity of taking the client's brief to develop a three dimensional interpretation'*
>
> (Gray *et al.*, 1994)

A definition illustrating both mental and physical activities involved in design is presented by French (1991):

> *'The design process is the conception, invention, visualisation, calculation, marshalling, refining and specifying of details which determine the form of an engineering design project'*
>
> (French, 1991)

The relationship between the design activities and their information requirements is highlighted in a definition by Chandrasekaran (1989) who states:

> *"The design problem is specified by a set of functions to be delivered by an artefact, a set of constraints to be satisfied by the artefact during its functioning, and a repertoire of components assumed to be available and a vocabulary of relations between components. The solution to the design problem consists of a complete specification of the set of components and their relations, which together describe the instance of the artefact, which satisfies the requirements of its functions and constraints."*
>
> (Chandrasekaran, 1989)

These definitions provide an initial idea of what design is. Further understanding will be achieved through investigating the nature and stages of the process.

3.2.2 Nature of the Design Process

Literature shows an argument about whether the design process is the same in the different domains. Usmani and Winch (1994) identified two groups of thought about the nature of the design process namely 'integrators' and 'separators'. Integrators such as Gregory (1966), Stauffer (1989) and Newton (1995) believe that the nature and characteristics of design are the same for all professions. Separators such as Cross (1984) believe that design processes are fundamentally different between industries. Cross (1984) argues that architectural and engineering designs are intrinsically different. Newton (1995) states that Cross and Roozenburg (1992) later contradicted this view when they combined the two extremes in a single consensus model of the design process.

Newton (1995) insists that the basic properties of all design processes, at the highest level of abstraction, are the same. He identifies common properties in design processes irrespective of the domain:

- generally begins with a need;
- results in information that ultimately leads to a physical process;
- is never comprehensively specified;
- never has a single optimum solution;
- is never a single problem but is a series of sub-problems; and
- is an iterative process.

Lawson (1990) identifies six properties of the design process - some of which are similar to those identified by Newton as follows:

The process is endless

Design problems defy comprehensive description and offer an exhaustive number of solutions. Therefore there is an indefinite number of designs to a problem and searching for a perfect solution is potentially endless.

There is no infallibly correct process

The solution to a design problem is not just the logical outcome of the problem. Hence no specific sequence of operations can guarantee a result.

The process involves finding as well solving problems

Design requires identifying problems as well as producing solutions. These processes happen simultaneously in a non-sequential manner. The design process can therefore be described as one that demands the highest levels of creative thinking.

Design inevitably involves subjective value judgement

Questions about the most important problems and the best solutions to resolve them are often value-laden. Answers to such questions, which the designers must give, are therefore frequently subjective. Complete objectivity demands dispassionate detachment but designers are human beings and therefore find it hard to remain either dispassionate about, or detached from, their work.

Design is a perspective activity

Designers usually deal with questions like what might be; what could be; and what should be rather than questions that address what is; how; and why. This makes design a perspective activity where a designer may be seen to prescribe or create the future rather than understand the present and predict the future, which is purely a descriptive.

Designers work in the context of a need for action

Design is not an end in itself, and the whole point of the design process is that it will result in some action to change the environment in some way, whether by formulation of policies or the construction of buildings.

Design is an iterative process

Lawson (1990) adds a seventh characteristic describing design as an iterative process. In fact, many authors agree that one of the most important properties of design is its iterative nature (Gibson, 1968; Kumar and Topping, 1988; Lawson, 1990; Newton, 1995; Austin *et al.*, 2002).

3.2.3 Stages of the Design Process

Design consists of several stages where the number of these stages and the activities that take place within them differ from one author to another. Manning (1995) divides design into three levels: conceptual, intermediate and detailed. Sabouni and Al-Mourad (1997) divide it into: preliminary design, structural analysis, and detailed design. Gray *et al.* (1994) divide it to concept (scheme) design and engineering design. They then divide engineering design to: detailed design by the architect, engineers and other specialist consultants within the design team; and detailed design by the specialist contractors e.g. workshop/fabrication drawings.

The most popular and widely recognised design activities in construction projects in the UK have been set out by the Royal Institute of British Architects (RIBA, 2000). RIBA's 'Plan of Work' (also referred to as the RIBA Stages of Work) divides the stages in a construction project into Pre-Design, Design and Construction where the design stage subdivides into six activities as shown in Figure 3.1. The activities that are 'directly design activities' are: outline; detailed; and final design.

Pre-design	1. Appraisal
	2. Strategic briefing
Design	3. Outline proposal
	4. Detailed proposals
	5. Final Design
	6. Production information
	7. Tender documentation
	8. Tender Action
Construction	9. Mobilisation
	10. Construction to practical completion
	11. After practical completion to final fee settlement

Figure 3.1: The stages in a construction project. Reproduced from RIBA (2000)

A recent work that builds on RIBA's Plan of Work is the Process Protocol (1998). It describes the lifecycle of a construction project in four main phases which are described in ten phases as shown in Figure 3.2:

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

Figure 3.2: The phases in a construction project. Adapted from Process Protocol (2000)

The main difference between the Plan of Work identified by RIBA and Process Protocol is that the Plan of Work is orientated towards the design process while the Process Protocol is orientated more towards client processes as it adds client decision phases to the process model (Carr and Winch, 1998).

A best practice guide developed by CIRIA (2000b) divides a project life cycle into three phases, namely Pre-Tender, Tender and Implementation where three design activities take place within these phases: Concept Design at the Pre-Tender Phase; Definitive Design at the Tender Phase; and Detailed Design at the Implementation Phase.

The above description of the stages of the design process confirms the existence of three main stages although they might take different names. These are summarised according to their authors in Table 3.1 below:

Table 3.1: Design stages/phases by different authors

Author	Design Phases/Activities
RIBA	Outline Design Detailed Proposal Final Design
Process Protocol	Outline Conceptual Design Full Conceptual Design Coordinated Design
CIRIA	Concept Design Definitive design Detailed Design

3.2.4 The Design Team

The design of construction projects involves several inter-related processes such as architectural, structural, electrical, mechanical, and sanitation design and therefore involves different team members. Based on a survey conducted by Perera (1989), the design team consists of:

- The Project Director/Project Manager;
- Architect;

- Structural Engineer;
- Electrical and Mechanical Engineer(s); and
- Quantity Surveyor.

Roles and responsibilities of the design team members are described below:

Project Director

This is a senior engineer. In state organisations the project director could be a civil engineer or an architect. The Project Director is responsible to the client for the whole project during design and construction. This responsibility includes preparing the general layout in sketch plan, getting approvals from statutory authorities, forming the design team with other professionals and producing contract documents and drawings.

Architect

This is an architect other than the project director who works closely with the project director at the briefing and sketch design stages. The architect is responsible for producing detail architectural design drawings at the production of working drawings stage.

Structural Engineer

The structural design is responsible for advising the project director on the technical feasibility of the site and other matters related to the structure and for producing structural drawings at the detail design stage.

Mechanical, Electrical Sanitation and Water Engineers

These mainly advise the project director during sketch design and perform related designs at the production of working drawings stage.

Quantity Surveyor

The quantity surveyor gives cost advice to the project director and prepares cost estimates and bills of quantities at the end of the working drawings.

3.3 STRUCTURAL DESIGN

Structural design is a complex process that is carried out to produce safe and stable structures. It commences with a search for suitable schemes for transferring loads in a space to a support or foundation (Maher *et al.*, 1988). At this stage, decisions are made about the physical form of the structure and its components to ensure that the structure is fit for its intended purpose and that it satisfies the functional specifications, which are usually expressed in terms of design rules and criteria (Bell and Plank, 1985; Bahl and Beitz, 1988).

Structural design is carried out based on the requirements of and constraints on the proposed project. These requirements and constraints are surrounded by many uncertainties e.g. change of client requirements, environmental factors, assumed live and wind loads, partially investigated soil area, unpredictable earthquakes, etc. These constraints are also influenced by several factors that are linked to human intelligence such as experience and engineering judgment (Bell and Plank, 1985; Bahl and Beitz, 1988) and regulations such as codes of practice and design standards. Due to the constraints surrounding it, structural design usually consists of more than one design cycle to achieve an accepted final design (Grierson and Cameron, 1988).

Structural design consists of several stages, which consist of many interrelated activities (Bell and Plank, 1985; Kumar and Topping, 1991; Evbuomwan and Anumba, 1996; Al-Ghassani *et al.*, 2002a; Austin *et al.*, 2002). Grierson and Cameron, (1988) considered three stages: the identification of the nature and scope of the design task, the formulation of the mathematical statement of the design problem, and the evaluation of the design results to determine the adequacy of the developed solution. Fraser, (1981), Maher *et al.* (1988) and Payne (1989) also considered three stages but they named them preliminary design, analysis, and detailed design.

Austin *et al.* (2002) considered two stages in the ADEPT technique: the early design stage (concept and scheme), and the late design stage (detailed design and production information). This categorisation combines concept and scheme to one stage usually called 'concept design' and analysis and design to one stage named 'detailed design'. This categorisation is also used by other authors e.g. Gray *et al.* (1994).

For the purpose of this research, structural design will be considered as a two-stage process consisting of concept design and detailed design. This puts the activities of similar nature -in terms of the type of knowledge involved- in their relevant design stages. In this context, concept design is more dependent on the experience and expertise i.e. the '*tacit knowledge*' of the engineers while detailed design depends on mathematical formulae and codes of practice i.e. the '*explicit knowledge*' of design.

3.3.1 Concept Design

This stage is regarded as the most creative stage in structural design (Harty and Danaher, 1994). It produces a feasible structural arrangement that addresses the requirements of the proposed structure. Here, decisions are based on rules of thumb and experience of designers and largely affect the quality of a structure much more than the subsequent stages (Kummar and Topping, 1991; Austin *et al.*, 2002). This stage has effects on the remainder of the project (Austin *et al.*, 2002) because the detailed design stage generally aims to satisfy the constraints imposed by the concept design (Bell and Plank, 1985; Bahl and Beitz, 1988). Although there is no consistent approach to concept design within the building industry (Austin *et al.*, 2001), there are some common activities involved where it is very likely that the designer would return to an earlier design stage and reconsider decisions made at that stage. The common activities in concept design are:

- Designers think of possible solutions relying on their experience in previous projects (Bell and Plank, 1985; Kumar and Topping, 1991). Various alternatives are generated for the structure such as alternative structural configurations, component sizes, and material selections e.g. steel, concrete, masonry, timber (Garrett and Smith, Kumar and Topping, 1991). This may involve a brainstorming session as a tool for creating new ideas;

- Designers evaluate the feasibility of the possible solutions. Their evaluation relies on simple calculations and past experience (Bell and Plank, 1985; Kumar and Topping, 1991). This evaluation depends on the internal (imposed by the designer through wanting to work in a particular way or with particular materials or technologies) and external (clients' needs, technology and the construction process) constraints (Bell and Plank, 1985; Kumar and Topping, 1988);

- Designers select the ideal solution based on engineering judgement (Bell and Plank, 1985; Kumar and Topping, 1991). This depends on the designers' ability to foresee the best possible solution that addresses the project's requirements. Once the solution has been selected, its details will be transferred to those involved in detailed design.

3.3.2 Detailed Design

Detailed design can be undertaken by less experienced engineers compared to concept design which is usually undertaken by senior engineers. Detailed design is an iterative process that normally consists of more that one cycle. The number of cycles depends on several factors such as the nature of uncertainties involved in the project and availability of information and knowledge. Detailed design consists of several activities:

- Detailed analysis for calculating the loads on the structure and then analysing them to identify the values that inform design e.g. deflections, vibrations, shearing stresses, bending moments, etc. (Bell and Plank, 1985; Kumar and Topping, 1988; Kumar and Topping, 1991; Garrett and Smith, 1996);

- Sizing and proportioning are achieved through using design codes and standards to decide the dimensions of the individual elements of the structure. For reinforced concrete members, this will be followed by detailing the steel reinforcement required i.e. type, number, diameters of steel bars, their location etc. (Bell and Plank, 1985; Kumar and Topping, 1988; Kumar and Topping, 1991); and

- Checks for satisfying the different constraints e.g. requirements for safety, engineering and physical laws, or other local constraints are achieved through investigating the individual members as well as the structure as a whole. (Bell and Plank, 1985; Kumar and Topping, 1988; Kumar and Topping, 1991).

3.4 PROBLEMS DURING STRUCTURAL DESIGN

The complex process of structural design is associated with many problems that take place during both concept and detailed design. This section highlights the key problems identified.

3.4.1 Overlapping Process Activities

Structural design consists of several interrelated activities. These activities do not usually follow a linear pattern and therefore there are significant differences between the natures of the individual phases during the progression from concept design to detailed design (Austin *et al.*, 2002). This complexity is mainly due to overlaps between the different activities that take place during design. Another factor is that design includes some waste activities that are difficult to identify and remove. These are due to the lack of appropriate techniques for identifying ways of capturing, understanding and repeating design activities in terms of integration, decision-making and reductions in re-work (Baldwin *et al.*, 1997).

3.4.2 Complex Analysis and Design

Detailed structural design is a sophisticated multi-disciplinary process (Hegazy *et al.*, 2001). It requires databases of construction materials (e.g. steel, concrete, timber etc), databases of properties of materials (e.g. weights, strengths, moments of inertia etc) and codes of design (e.g. British Standards, Eurocodes etc). This is an iterative process that is highly dependent on the effective aggregation of individual designs to produce coherent final design (Hegazy *et al.*, 2001). During detailed design, changes are frequently introduced and they need to be properly managed among the various members of the design team (Hegazy *et al.*, 2001). This results in several design cycles and hence consumes large amounts of time.

3.4.3 Fragmentation in the Process

The chronic problem of fragmentation in the construction industry affects its efficiency (Howard *et al.*, 1989; Winter, 1989; Brandon and Betts, 1995; Eastwood, 1997; Kamara *et al.*, 1999). This fragmentation occurs within the design process as well as between design and construction. This has resulted in many clients being unsatisfied with the consultants' performance.

Egan (1998) states that more than one third of the major clients are not satisfied with the performance of consultants in:

- co-ordinating teams,
- design and innovation,
- providing a speedy and reliable service; and
- providing value for money.

This fragmentation can cause serious problems. Some of these are:

- loss of important design information through the lack of co-ordination between the functional disciplines involved in a project (Ashworth, 1991; Anumba and Evboumwan, 1995; Kamara, 1999);

- failure to consider downstream life-cycle issues early on in the process, resulting in late and expensive design changes, claims, disputes, and litigation (Cherns and Bryant, 1988; Anumba and Evboumwan, 1995; Latham, 1994; Akinsola *et al.*, 1994; Kamara, 1999);

- reduced productivity and competitiveness in the industry, thereby increasing the costs to the entire economy (Howard *et al.*, 1989; Brandon and Betts, 1995; Kamara, 1999); and

- limitations and delays in the flow of information between project team members and across stages in the project life-cycle (Anumba *et al.*, 1997; Kamara, 1999).

3.4.4 Knowledge Intensive Tasks

Structural design involves many knowledge-dependent tasks. This knowledge exists in many forms where authors named different types of knowledge. For example, declarative knowledge was identified by Hansen *et al.* (1999), strategic knowledge was discussed by Zack (1999), relationship knowledge was highlighted by Johannessen *et al.* (1999), Mode 1 (a form of knowledge production) and Mode 2 (knowledge produced in the context of application) were described by Gibbons (1994). The most widely accepted knowledge types are those identified by Polanyi (1967) and elaborated by Nonaka (1991) and Nonaka and Takeuchi (1995). They explain that knowledge exists in two forms: 'tacit' knowledge, which is stored in the brains of people e.g. experience of engineers and their skills in performing certain tasks, and 'explicit' knowledge, which is codified in documents, drawings, databases and expert systems e.g. design regulations, design codes, etc. Kumar and Topping (1988) identify two inter-dependent basic types of knowledge that are required to solve problems in structural design: theory of structures; and design codes. Knowledge on the theory of structures can be divided into two categories: theoretical knowledge consisting of different theorems of the analysis of structures, and heuristics or rules of thumb acquired by experience. Knowledge of design codes is largely dependent upon the designer's interpretation where this interpretation depends on knowledge and understanding of the principles as well as experience, which basically consists of heuristics acquired over the years.

The complexity of structural design depends on the type of the structure, purpose of its use, internal and external constraints etc. Furthermore, the way a structure is designed depends on the availability of construction materials, equipment, and accessibility to data, information, and knowledge. Structural design problems that are knowledge dependent involve but are not limited to the following:

- Design is based, in many situations, on assumptions (Kumar and Topping, 1991) and engineering judgment (Tyson, 1991). These are usually based on knowledge and experience. However, even experienced engineers face difficulties when the required knowledge is not available and this can result in assumptions or judgments that may be invalidated when knowledge becomes available (Kumar and Topping, 1991).

- Knowledge generated during the construction and maintenance stages is not usually shared with designers. A structural failure may occur because of inappropriate design. Knowledge about this failure (why it occurred, how it could have been avoided, etc) needs to be shared with the other designers within the organisation and externally so that mistakes are not repeated.

- Improper management of design knowledge results in its loss (Bliznakov, 1996; Hegazy *et al.*, 2001). Design consulting firms are knowledge-intensive organisations where improvement in design depends on the availability of knowledge. Not having this knowledge easily accessible does not only result in less innovative designs but also leads to deterioration and gradual loss of the knowledge.

3.5 APPROACHES TO STRUCTURAL DESIGN IMPROVEMENT

The previous section identified the key problems that take place during structural design. Literature shows that there are several approaches to solving these problems and hence improving the structural design process. Table 3.2 summarises the main problems identified and the approaches used to solve them. These approaches are described below.

Table 3.2: Problems during structural design and approaches to solving them

Problem	Approach for solving the problem
Overlapping process activities	Techniques for modelling the process
Complex analysis and design	Algorithms for the analysis and design
Fragmentation in the process	Approaches for integrating the process
Knowledge intensive tasks	Systems for capturing knowledge

3.5.1 Techniques for Modelling the Process

The problem of complex and overlapping process activities has attracted the attention of some researchers. Modelling the design process has therefore been researched by several authors e.g. Mostow (1985) and Austin *et al.* (2002). One of the research projects in this area was the Generic Design and Construction Process Protocol (GDC*PP*) being developed by Salford and Loughborough Universities in conjunction with a number of industrial collaborators (Process Protocol, 1998). GDCPP defines the design and construction process as four broad phases , which are further categorised into ten discrete phases. Austin *et al.* (2002) introduced three frameworks that build on the Process Protocol to model the design process. The first framework is a generic process model that clusters the design activities in relation to the manner in which they were commonly addressed. The second assists in improving coordination as the project advances. It represents a network of tasks connected by the flow of information between them. The third is an Analytical

Design Planning Technique (ADePT), which helps in improving the planning of projects (Austin *et al.*, 2002).

3.5.2 Algorithms for the Analysis and Design

The complex process of analysis and design encouraged researchers to investigate automating the process. This resulted in many software tools for structural analysis and design. Surveys show that such tools are used by many structural engineers (AEC, 1988; Survey, 1989). These tools support the analysis, modelling, and design of structures. Some of them only support one or two of these stages while others support all three stages. Examples of such tools are S-Frame, CADRE, STAAD, etc. These tools base their calculations on the input received from the user and the selection from available features. This also involves several assumptions based on the user's knowledge, experience, and engineering judgment. Although these tools are very useful for facilitating detailed design, three limitations have been identified (Tyson, 1991): lack of interactivity for the user to control analysis and design processes; lack of a database that permits the user to extract segments for processing; and lack of special purpose routines for the analysis and design of simple elements.

3.5.3 Approaches for Integrating the Process

To solve problems of the fragmented design process several approaches have been identified: computer integration strategies; use of new tools and techniques; and concurrent engineering (Kamara, 1999). These are discussed in turn below:

- *Computer integration strategies.* These are based on the use of computer technology to integrate the construction process (Howard *et al.*, 1989; Sanvido and Madeiros, 1990; Miyatake and Kangari, 1993; Evbuoman and Anumba, 1996). This provides opportunity for the electronic sharing of data and design decisions in both directions at the design-construction interface. On the other hand, the complex design of structures consisting of many interacting subsystems requires integrating many different disciplines. This resulted in the development of computer based collaborative design environments for: integrating the different participants in conceptual design using a shared graphical description of the design (Fruchter, 1996); and integrating engineering software design from conceptual design through detailed design and design documentation (Aouad *et al.*, 1994; Ford *et al.*, 1994; Sanvido, 1995; Evbuomwan and Anumba, 1996; Kelly, 1997).

- *Concurrent engineering (CE).* This is also called collaborative engineering, simultaneous engineering or parallel engineering. It is an approach that focuses on bringing together all concerns throughout the project lifecycle concurrently during the design stage (Kannapan and Marshek, 1992). This is a relatively new business process, which facilitates the integration of the construction process and the techniques and technologies that can bring about this integration. For structural design, it helps in improving design and reducing the number of design cycles (Evbuomwan and Anumba, 1996).

- *New management approaches.* These involve the adoption of a wide range of approaches to enhance collaboration and improve efficiency and quality. These include Partnering, Total Quality Management (TQM), Just-In-Time (JIT), Lean Construction and Sustainable Construction (Baxter and Macfarlane, 1992; Hellard, 1993; CIB, 1997; Koskela, 1997; Melles, 1997; Bennett and Jayes, 1998; CM, 1998, Khalfan, 2003). These approaches have received different levels of interest from the construction industry. The most popular is 'Partnering' where the client, consultant and contractor and other members of the supply chain work together as one team for improving their performance through mutual objectives.

3.5.4 Systems for Capturing Knowledge

Literature shows Expert Systems have been used to capture and re-use knowledge. Several Expert Systems have been used in the construction industry (Bouchlaghem, 1995) where some of these were used for structural design knowledge e.g. Sriram (1986), Wang and Howard (1988), Kumar and Topping, (1988) and Maher and Gomez (1996). Knowledge-based expert systems are Artificial Intelligence (AI) tools that try to capture how experts approach problems in their day-to-day practice (Kumar and Topping, 1988). Expert systems for structural design are based on the assumption that the non-numeric and often symbolic criteria that drive the structural design process can be handled in a system that can use them to make decisions and solve problems (Grierson and Cameron, 1987).

There are two types of expert systems namely, rule-based systems which contain design-independent knowledge, and case-based systems which contain design-dependent knowledge Wang and Howard (1988). Rule-based systems capture knowledge 'abstract reasoning rules' independent of specific designs. This assumes that the designer has generalised some of her/his experience into 'abstract reasoning rules' and that these can be captured and written down into 'if-then' rules. For example, a rule can be: IF the component is a column THEN the moment of inertia and depth are the critical dimensions. On the other hand, case-based systems are based on the assumption that most of the experience of designers is still in the form of knowledge about specific previous designs. This represents a memory of good and bad designs. Examples of structural design expert systems are HI-RISE, FLODER, LOCATOR, STRUPLE (Maher and Fenves, 1985; Maher, 1987; Maher *et al.*, 1988), DESTINY (Sriram, 1986) and DESDEX (Kumar and Topping, 1988). Expert systems were not successful due to several reasons:

- They could not solve problems the same way experts do (Kumar and Topping, 1988);
- Users were not able to access the stored knowledge and re-use in another way to develop their own solutions;
- Knowledge lost its richness and context when written down;
- Codified knowledge got outdated very quickly;

- The dynamic interaction between tacit and explicit knowledge was not addressed;
- The knowledge already available in documents, drawings, multimedia tools was not appropriately addressed; and
- Focus on expert systems resulted discounting the importance of the interaction between those who have the knowledge and those who need it.

3.6 TOWARDS A KNOWLEDGE MANAGEMENT APPROACH

The problems identified within the structural design process and the approaches used to address them show that there is need for improving the process. One of the areas that has not received enough attention is the management of the structural design 'knowledge'. Knowledge Management (KM) is a relatively new concept that revolves around making knowledge available to users whenever they require it. It focuses on creating, acquiring, sharing and using the different types of knowledge, wherever it resides, to enhance learning and performance in organisations (Scarbrough *et al.*, 1999, Tiwana, 2000, Davenport and Prusak, 1998).

Knowledge management seems to be a promising approach for addressing the limitations of expert systems (Al-Ghassani *et al.*, 2002a) and hence requires further investigation to explore its potential for structural design.

3.7 SUMMARY

The literature on structural design was discussed followed by the structural design process. It identified that several problems take place during the structural design process. These are related to: overlapping activities; complex analysis and design; fragmentation; and existence of knowledge intensive activities. Several approaches have been identified for solving these problems. Structural design knowledge, however, did not receive enough attention.

CHAPTER 4: KNOWLEDGE MANAGEMENT

4.1 INTRODUCTION

This chapter reviews the literature on Knowledge Management (KM). It defines knowledge, describes the concept of KM, and highlights its importance. The barriers to its implementation are then discussed. Information technology (IT) and non-IT tools that support the implementation, the current methods for identifying the most appropriate tools, and the limitations in these methods are also discussed. The chapter concludes with a summary to its contents.

4.2 KNOWLEDGE

4.2.1 Definition

The importance of knowledge has long been recognised. Over sixty years ago, a futurist dreamt of a 'depot' for storing, summarising, digesting and clarifying knowledge and ideas in order to solve the all the 'mighty' problems. He described the importance of knowledge management as follows:

> *"An immense and ever-increasing wealth of knowledge is scattered about the world today; knowledge that would probably suffice to solve all the mighty difficulties of our age, but it is dispersed and unorganised. We need a sort of mental clearing house: a depot where knowledge and ideas are received, sorted, summarized, digested, clarified and compared."*
>
> (Wells, 1940)

Later, early in the seventies, Churchman (1971) described the complexity involved in knowledge and related it to how people do things i.e. their skills and experiences:

> *"Knowledge resides in the user and not in the collection [of information]. It is how the user reacts to a collection of information that matters."*
>
> (Churchman, 1971)

One of the recent definitions describes knowledge as 'power' (Drucker, 1995). In fact, it is this power that caused the increasing attention to retaining knowledge and making more benefits from using it.

> *"Knowledge is power, which is why people who had it in the past often tried to make a secret of it. In post-capitalism, power comes from transmitting information to make it productive, not from hiding it."*
>
> (Drucker, 1995)

Davenport and Prusak (1998) suggest the knowledge does not provide power to individuals only but also to organisations. A working definition that describes the nature of knowledge suggests that:

> *"Knowledge is 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. It originates and is applied in the minds of knowers. In organisations, it becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms".*
>
> (Davenport and Prusak, 1998)

In computer science, there is a tendency to define knowledge by relating it to data and information. Data are 'raw materials' (Kanter, 1999) or discrete facts about events (McConalogue, 1999) which when processed and given relevant associations and patterns become information (Blumentritt and Johnston, 1999). Information is therefore 'finished goods' (Kanter, 1999) or data with meaning, which is added through conceptualising, categorizing, calculating, correcting, and condensing. Knowledge, on the other hand, is the 'actionable finished goods' (Kanter, 1999) or 'actionable information' (O'Dell *et al.*, 1998) or information with context that gives one the power to act and to make decisions so as to produce value to the individual and to the organisation as a whole (Kanter, 1999). It is a combination of using data and information, with the potential of people's skills, competencies, ideas, intuitions, commitments and motivations (Vail III, 1999).

4.2.2 Types

Authors have identified several types of knowledge e.g. declarative knowledge (Hansen *et al.*, 1999), strategic knowledge (Zack, 1999), relationship knowledge (Johannessen *et al.*, 1999), Mode 1 (a form of knowledge production) and Mode 2 (knowledge produced in the context of application) (Gibbons, 1994). However, the most widely accepted knowledge types are tacit or explicit identified by Polanyi (1967). Tacit knowledge – also called implicit- is stored in people's brains as mental models, experience and skills and is difficult to communicate externally while explicit knowledge is encoded in organisational formal models, rules, documents, products, services, facilities, systems and processes and can be easily communicated externally (Vail III, 1999).

Knowledge can be converted from one type to another. Nonaka and Takeuchi (1995) identified four modes for knowledge conversion (Figure 4.1). One individual's tacit knowledge can be converted to another person's tacit knowledge (socialisation) or to explicit knowledge (externalisation). Socialisation takes place during face-to-face interactions while externalisation takes place when an individual's knowledge is codified e.g. in written documents, or stored in software. Capturing tacit knowledge (e.g. in meetings, phone calls and other synchronous interactions) and leveraging it for the enterprise is one of the greatest challenges to KM (Bair and O'Connor, 1998).

On the other hand, explicit knowledge can be converted to another type of explicit knowledge (combination) or to tacit knowledge (internalisation). Combination takes place when two sources of codified knowledge are synthesised to form new knowledge while internalisation takes place when an individual reads and understands codified (written) knowledge. The management of explicit knowledge, although requires several resources, is easier than tacit knowledge because it is already codified into documents, drawings, software tools, knowledge bases, videos clips, virtual reality tools etc.

From \ To	Tacit	Explicit
Tacit	**Socialisation**	**Externalisation**
Explicit	**Internalisation**	**Combination**

Figure 4.1: Modes of knowledge conversion (Source: Nonaka and Takeuchi, 1995)

4.3 KNOWLEDwoGE MANAGEMENT (KM)

Knowledge Management (KM) is a relatively new concept, which emerged from business process re-engineering and a variety of other ideas first introduced by management consulting firms (Wensley and Verwijk-O'Sullivan, 2000). Nonaka wrote his first paper on KM in 1991 (Nonaka, 1991) and followed it by a book entitled 'The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation' (Nonaka and Takeuchi, 1995). The book explained the different types of knowledge, their interactions, and the philosophy of KM. In 1998, Davenport and Prusak wrote their first book on KM 'Working Knowledge: How Organisations Manage What They Know'. It provided guidelines to organisations on how to manage their knowledge (Davenport and Prusak, 1998). Many other books and academic papers were written later.

Knowledge Management (KM) is referred to as a theory (von Krogh *et al.*, 1996; Holtham and Courtney, 1998; Erno-Kjolhede, 2000; van der Velden, 2002) and a concept (Lenz, 2001; Castillo and Clodfelter, 2001; Egbu, 2002; Luan and Serban, 2002). It considers knowledge as a valuable asset needing to be managed in order to improve organisational business performance (Manasco, 1996; Leavy, 1996; Davenport and Prusak, 1998; Sheehan, 2000; Tiwana, 2000; Anumba *et al.*, 2002; Robinson *et al.*, 2001b and 2002a). KM distinguishes knowledge from information and data in the sense that knowledge is rich, context sensitive and more difficult to manage. KM is a systematic "process or practice of creating, acquiring, capturing, sharing and using knowledge, wherever it resides, to facilitate problem solving and decision-making and therefore enhance performance in organisations" (Scarbrough *et al.*, 1999) and increase innovation

(Egbu, 2000c; Egbu *et al.*, 2001c) and customer satisfaction (TFPL, 1999). It therefore enables the intellectual capital/assets of an organisation to be used effectively, creatively and consistently (Egbu, *et al.*, 1999). It is believed that, in the evolving new economy, knowledge will replace other capital (e.g. land, buildings, etc) as the organisations' most valuable asset (Drucker, 1993; Skyrme and Amidon, 1997; Hjertzen and Toll, 1999; Scarbrough and Swan, 1999).

The main driver for implementing KM is that an employee may not find the relevant knowledge at the moment it is required. Furthermore, knowledge that is generated in a particular situation will be lost if not properly captured, stored, and made available to others. More critically, the knowledge of staff members is mobile and this mobility needs continuously tracking where it exists. The promises of the benefits provided by KM and its many successful cases have resulted in increased interests in its implementation.

4.3.1 Definition

A review of literature shows that there is no one universally agreed definition of KM. In fact, depending on the experience, background, and organisational context, KM can have several interpretations, which may sometimes conflict (Tsui, 2002a). Tsui observed that employees working for the same organisation might have different interpretations depending on their position in the management hierarchy. For example, a managing director may see KM as the measurement and tracking of intellectual capital within the organisation, while a middle level manager may perceive it as the consolidation of best practices and/or the enhancement of customer services. At the operational level, employees may see KM as a process for reducing down time, and increasing quality and productivity. In academia, KM is defined in four ways namely; the process approach, the outcome approach, the combined approach and the traditional approach (Al-Ghassani *et al.*, 2002b):

Process approach. This approach defines KM with respect to its process (Tsui, 2002a). For example, KM is a process of controlling the creation, dissemination, and utilisation of knowledge (Newman, 1991; Kazi *et al.*, 1999). Snowden (1998) introduces another definition stating that KM is the "... identification, optimisation, and active management of intellectual assets, either in the form of explicit knowledge held in artefacts or as tacit knowledge possessed by individuals or communities to hold, share, and grow the tacit knowledge".

Outcome approach. An outcome-based definition emphasizes the benefits that an organisation gets from managing its knowledge. This approach focuses on the measurement of intellectual capital, and how to identify and transfer hidden and/or unused knowledge in an organisation for improved business performance (Tsui, 2002a). Examples of an outcome-based definition are "the ability to create and retain greater value from core business competencies" (Klasson, 1999) and the "management of organisational knowledge for creating business value and generating competitive advantage" (Tiwana, 2000).

Combined approach. This brings together both the process and outcome. It describes the components of the process and highlights the expected outcomes. An example of a combined approach definition is "any process or practice of creating, acquiring, capturing, sharing and using knowledge, wherever it resides, to enhance learning and performance in organisations" (Scarbrough *et al.*, 1999). Another defines KM as "... identification, optimisation, and active management of intellectual assets, either in the form of explicit knowledge held in artefacts or as tacit knowledge possessed by individuals or communities to hold, share, and grow the tacit knowledge (Snowden, 1998).

Traditional approach. This considers splitting the term "Knowledge Management" and then treating its constituent words separately by identifying the relationship between "knowledge" and associated concepts such as information, and data and then linking them to the "Management" functions of planning and control. This approach has been identified by Tsui (2002a) although he did not name it. A definition following the traditional approach describes KM as 'turning data (raw material) into information (finished goods) and from there into knowledge (actionable finished goods). The implication is that knowledge gives one the power to act and to make decisions that produce value to the individual and to the organisation as a whole.' (Kanter, 1999).

Regardless of the different approaches to defining KM, all definitions focus on the fact that knowledge is a valuable asset that needs to be managed and that managing this knowledge is important to improve organisational performance (Davenport and Prusak, 1998; Scarbrough *et al.*, 1999; Tiwana, 2000; Al-Ghassani *et al.*, 2002b; Khalfan, 2002).

4.3.2 KM in the Wider Debate

The concept of KM is located in the wider debate of other concepts (Scarbrough *et al.*, 1999) as shown in Figure 4.2. The Figure illustrates the way these concepts relate to one another. For example, the information age has a broad impact and affects all firms while the management of Research and Design (R&D) has a focused impact and is relevant to a limited number of firms. The figure shows that the impact of KM is focused with only some firms benefiting from it. This can be argued as many organisations can benefit from KM. In fact, even Small-and-Medium Enterprises (SMEs) can benefit from KM (Prenninger *et al.*, 1998; Chan, 1999; Egbu, 2000b; Magnusson, 2003).

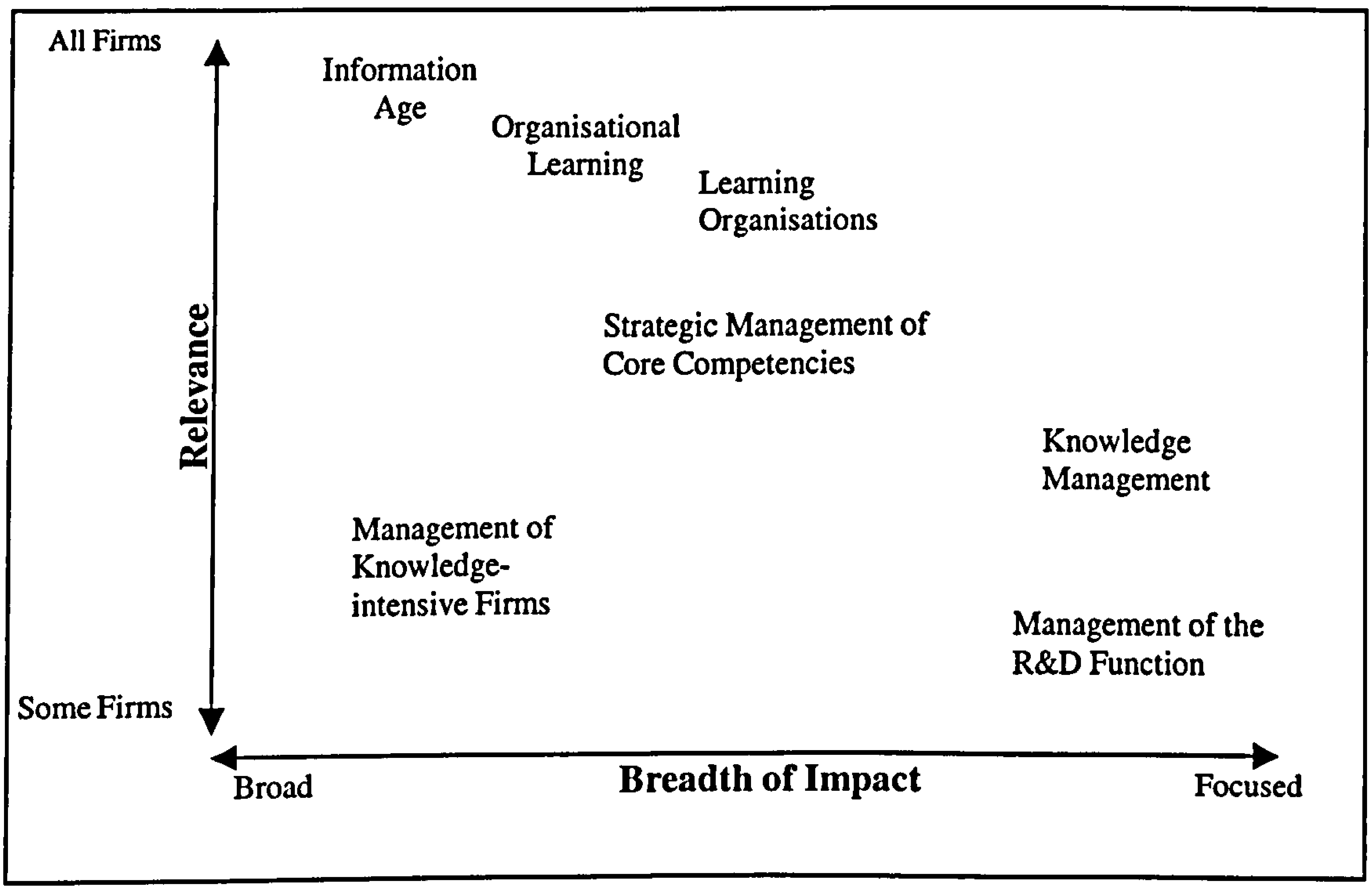

Figure 4.2: KM in a wider debate. (Source: Scarbrough *et al.*, 1999)

4.3.3 Importance of KM

Knowledge increases in value if appropriately shared (Tiwana, 2000) and KM supports this growth of organisational memory. Larry Prusak, the executive director of the Institute for Knowledge Management, states that "In the emerging economy, a firm's only advantage is its ability to leverage and utilise its knowledge". In fact, "...knowledge is critical to business success and possibly to business survival" (Davenport and Prusak, 1998). This suggests that KM "has moved from being an optional extra for managers to a strategic necessity" (Cannon, 1999). KM helps in reducing duplication and mistakes, increasing innovation, and improving business performance and hence adding competitiveness (Manasco, 1996; Leavy, 1996; Davenport and Prusak, 1998; Sheehan, 2000; Tiwana, 2000; Anumba *et al.*, 2002; Robinson *et al.*, 2002a). Therefore those not implementing KM would lose their business because their competitors who accept knowledge's value would leave them far behind (Tiwana, 2000). Tiwana recommends organisations to either adopt KM or begin counting the years to the closure of their business. Many surveys were undertaken to investigate how organisations perceive the importance of KM. The findings of some of the key surveys are discussed below.

Surveys show that there is a strong belief in the benefits of KM (Murray and Myers, 1997; KPMG, 1998; TFPL, 1999; Gottschalk, 1999; Carrillo *et al.*, 2003a; Robinson *et al.*, 2001a; Egbu, 2002). A survey by Information Systems Research Centre (ISRC) of Cranfield School of Management in September 1997 shows that 79 percent of the respondents thought that KM was not a passing fad (Murray and Myers, 1997). Another survey of leading UK organisations representing different industry sectors with turnover exceeding £200 million a year was undertaken by KPMG Management Consulting (KPMG, 1998). The results of the 100 respondents show that KM is not seen as a fad any more but increasingly taken seriously. This was confirmed by 43% of the respondents who considered their organisations to have KM initiatives in place. The survey also shows that the awareness of KM increases with the size of organisation. It also revealed that some organisations implementing KM have already seen real benefits.

Another survey by TFPL Ltd covered 500 organisations implementing KM or equivalent initiatives from all business sectors around the world (TFPL, 1999). Of the 80 respondents, 29% had corporate-wide KM programs and 18% were planning a corporate-wide KM program. 50% had no corporate-wide KM, but of them 42% had another corporate program with similar objectives. The survey concludes that the level of interest in KM and the number of organisations implementing its initiatives was growing exponentially. Moreover, many chief executives placed KM as second on their list of 'must-dos' after globalisation.

Other surveys that focused on particular industry sectors show similar results. A survey covering 73 respondents from 256 Norwegian law firms shows that there was a strong belief in the potential benefits of KM (Gottschalk, 1999). A survey of UK project-based organisations reveals that about 50 % of the respondents thought that KM would result in new technologies and new processes that will improve their business (Egbu, 2002). Another survey covering 170 construction organisation (consultants and contractors) shows that about 40% already had a KM strategy, another 41% had plans for a strategy within a year, and 19% did not have a strategy (Carrillo *et al.*, 2003a). The survey also found that about 50% of UK construction organisations had already appointed a Knowledge Manager or a special group with responsibility for implementing their KM strategy.

It is therefore obvious that KM is an important concept that improves business and therefore attracts an increasing number of organisations (Tiwana, 2000; Robinson *et al.*, 2002b; Carrillo *et al.*, 2003a). KM implementation, however, faces several difficulties. The next section discusses these difficulties.

4.4 BARRIERS TO IMPLEMENTING KNOWLEDGE MANAGEMENT

Organisations implementing KM face many barriers. The strength of these barriers depends on many factors such as the type of business processes, products and clients. A number of barriers are identified in the literature (Davenport, 1997; Scarbrough *et al.*, 1999; Carrillo *et al.*, 2000; CIRIA, 2000a; Patel *et al.*, 2000; Storey and Barnet, 2000; Tiwana, 2000; Robinson *et al.*, 2001a). However, they can be categorized into three main "barrier-groups" (Al-Ghassani *et al.*, 2004): Knowledge Status, Knowledge Domains, and Organisational Culture (Figure 4.3). These are discussed in turn below.

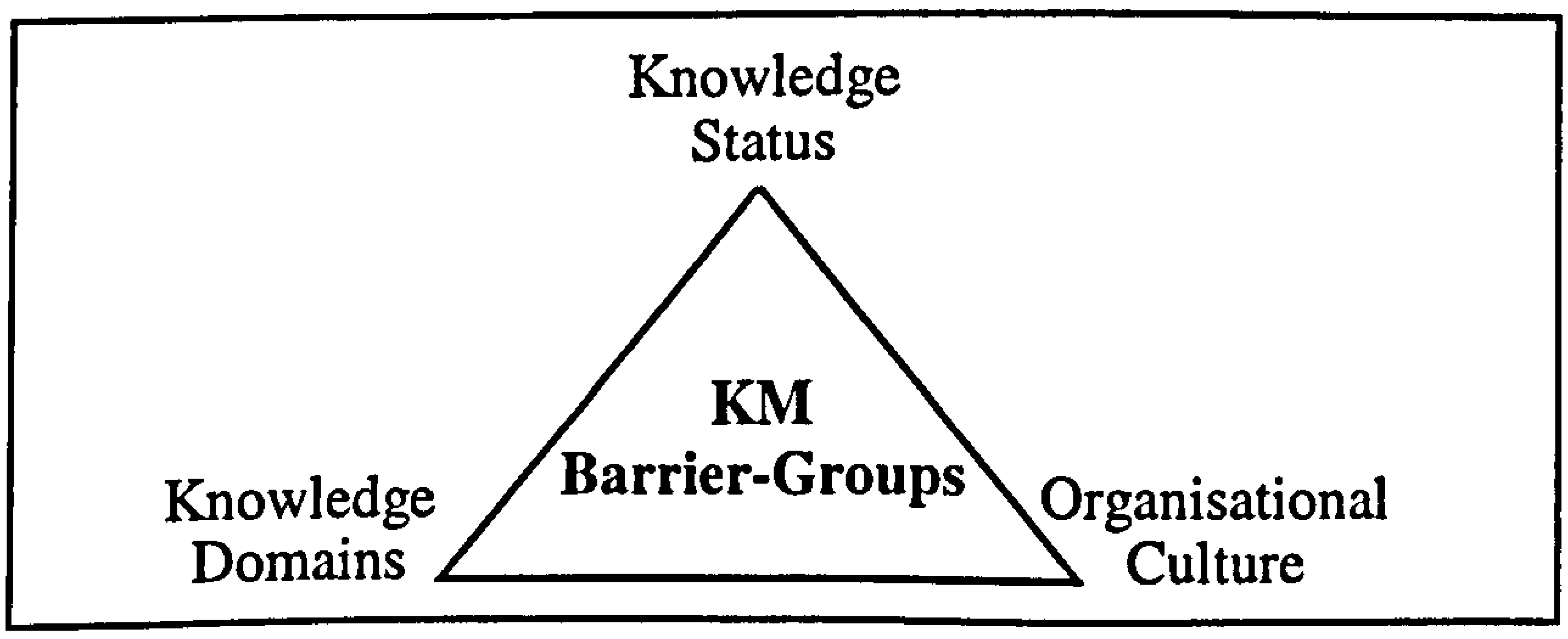

Figure 4.3: Barrier-Groups to implementing KM (Source: Al-Ghassani *et al.*, 2004)

4.4.1 Knowledge Status

Knowledge exists as tacit or explicit (Polanyi, 1967; Nonaka and Takeuchi, 1995; Vail III, 1999) and the easy conversion from one status (type) to another is important to allow for effective management. Every knowledge type has its own characteristics, which support or resist the conversion process as described below.

1. *Tacit knowledge.* Capturing tacit knowledge and codifying it (converting to explicit) is one of the greatest challenges to KM (Bair and O'Connor, 1998). Capturing this knowledge, whether already 'developed' (during previous tasks) or 'under-development' (in on-going tasks) faces several barriers. Capturing 'developed' tacit knowledge is very difficult because it is stored in peoples' heads and therefore difficult to document. Furthermore this knowledge, when codified, loses some of its context and also gets outdated very quickly. On the other hand, capturing 'under-development' tacit knowledge requires strategies that facilitate knowledge capture on a day-to-day basis e.g. during meetings, phone calls, discussions etc (Bair and O'Connor, 1998). One proposal is to encourage staff e.g. site engineers to sit down at the end of everyday or task to record the new knowledge they gained. This was found to create additional tasks to the congested agenda of employees and they also found it difficult to 'translate' what they knew into a written document (McConalogue, 1999).

2. *Explicit knowledge.* Although, the management of explicit knowledge is easier than that of tacit knowledge (Vail III, 1999), it still requires several resources such as time, technology, and commitment. The management of 'developed' explicit knowledge

faces the difficulty of gathering, updating, indexing and storing the different sources of knowledge e.g. documents, drawings, etc that was created over a long period of time. This also requires the use of suitable tools to facilitate the search and retrieval of the knowledge after it is stored. In contrast, the management of 'under-development' knowledge is relatively easier provided a KM system is already in place so that new knowledge can be immediately stored into its appropriate location within the KM system.

4.4.2 Knowledge Domains

Knowledge exists in different sources and is required by different users. One source of knowledge can also be a user of another knowledge. For example, a human is a source when s/he provides it to users such as software but s/he is a user when taking knowledge from a source, the software in this case. The transfer of knowledge from its sources to users is usually obstructed by domains being geographically dispersed (Carrillo *et al.*, 2000; Conheeney *et al.*, 2000; Patel *et al.*, 2000) as discussed below.

1. Geographically dispersed sources. These include: offices, employees, clients etc. The coordination of the process of capturing knowledge from geographically dispersed sources is obstructed by many barriers. For example, having dispersed sources of knowledge e.g. offices located in different countries makes it difficult to monitor the process of capturing and storing different types of knowledge so as to ensure that correct and valid knowledge is collected. Furthermore, offices in some countries face problems of slow networks and therefore they cannot easily link to other knowledge sources within the same organisation thereby making the process of monitoring even slower if a central system is to carry out this process.

2. *Geographically dispersed users.* Organisations with geographically dispersed offices and employees require knowledge to be safely delivered to users and that this knowledge is made available to them whenever they require it. Making this knowledge available to users creates several challenges. A key challenge is the methodology of knowledge transfer and sharing. E-mails have been used for a while but their capabilities are limited, as seekers for knowledge need to wait for a response. Net-meetings have also been used to facilitate the transfer of tacit knowledge but many people did not have access to them. Intranets/Extranets are now identified as a potential solution for the use of geographically dispersed users (Tiwana, 2000). However, they are expensive to acquire and maintain and also require users to have access to a computer and to the Internet.

4.4.3 Organisational Culture

KM requires an open culture based on trust (Carrillo *et al.*, 2000; Al-Ghassani at al, 2001b, Robinson *et al.*, 2001a; Egbu, 2002) and creating such culture is not easy because it requires people to change their views on many issues. In fact, many organisations identified cultural change as the most difficult barrier to overcome. The key cultural barriers are (Scarbrough *et al.*, 1999; Tiwana, 2000; Carrillo *et al.*, 2000; CIRIA, 2000a):

1. *Willingness to share.* "Why would I give my knowledge to others?" This is a typical question that is asked by people when they are informed about the benefits of KM.

Most of the literature focuses on the organisational benefits of KM neglecting the fact that tacit knowledge cannot be captured unless its holders realize that they also benefit. People think that knowledge is power and that by sharing their knowledge they will 'share themselves out of a job' (McConalogue, 1999). It is therefore important for organisations to explain to their employees that shared knowledge grows (Tiwana, 2000). Furthermore, people like to be rewarded or recognized for their contribution to a knowledge base (Lank, 1997; Scarbrough *et al.*, 1999; McConalogue, 1999) and this makes convincing them to share their knowledge without being rewarded very difficult.

2. *Availability of time.* Employees find themselves under pressure of increased job tasks and delivery deadlines (Carrillo *et al.*, 2000). Codifying tacit knowledge and storing and indexing the codified knowledge are difficult and time consuming. Many organisations therefore find difficulties in allocating staff time to contribute to the knowledge base. Employees also need to be trained in understanding the KM system so that they can use it efficiently. Employees who need to search for an answer to a question also find that they do not have enough time to search the knowledge base. Instead, they normally prefer to ask an experienced colleague.

3. *Type and nature of business.* Organisations differ in the way they do business. Some organisations have most of their work indoors (e.g. software vendors, engineering design offices etc.) while others have it outdoors (e.g. civil contractors). Organisations that are involved in outdoor tasks such as construction organisations face the problem

staff mobility within the construction site. Furthermore, project-based organisations form a temporary team for every project where team members may be from different offices. Once the job is complete, the team members may be spread over several projects or moved to other offices. One of the difficulties in capturing knowledge from project-based organisations is due to the continuously changing teams members (Egbu, *et al.*, 1999; Egbu, *et al.*, 2001a). This results in many organisations not having a suitable environment for capturing knowledge or even for accessing a knowledge base.

4. *Technology infrastructure.* Technology is a key enabler for implementing KM (Skyrme and Amidon, 1997; Kanter, 1999; Anumba *et al.*, 2000; Egbu, 2000a; Storey and Barnet, 2000). In fact, many of the KM sub-processes depend on technology to allow for faster storage, retrieval, and transfer (Junnarkar and Brown, 1997). Technology therefore provides support for KM with a range of hardware and software tools. However, many organisations find it difficult to identify the tools that address their needs since this requires an understanding of the KM requirements for the organisation and recognising what these tools can offer. Using inappropriate tools can result in a technology infrastructure that is not compatible with the existing technology within the organisation or that does not address the organisation's goals from KM (Al-Ghassani *et al.*, 2001a).

5. *Size of organisation.* The amount of knowledge available in an organisation is directly proportional to the size of the organisation (Davenport and Prusak, 1998). Knowledge within a large organisation is scattered throughout offices and is therefore more

difficult to manage. This necessitates that organisations identify what knowledge they need to manage and where it exists in order to achieve the organisational business goals. This identification may not be a straightforward process as managing more than one knowledge type may be required. In this case, an organisation needs to prioritise these types of knowledge based on the priorities of its business goals.

6. *Reward schemes may also create a barrier.* Short-term rewards (e.g. monetary) are not the principal motivation of knowledge workers (Lank, 1997; McConalogue, 1999). In fact, short-term rewards would create a generation of staff who are too oriented towards receiving rewards and this could create a new barrier. Therefore, rewarding schemes need to be carefully designed. Professional recognition and the opportunity to work in challenging areas are more motivating and are more efficient in the long-run (Sheehan, 2000).

Other barriers such as the high cost of KM systems are not considered as main barriers because they are easier to address e.g. allocating a budget for the system.

The many barriers that obstruct the implementation of KM (Davenport, 1997; KPMG, 1998; Gottschalk, 1999; TFPL, 1999; Scarbrough *et al.*, 1999; Carrillo *et al.*, 2000; CIRIA, 2000a; Patel *et al.*, 2000; Storey and Barnet, 2000; Tiwana, 2000; Robinson *et al.*, 2001a) can result in loosing trust in the concept of KM if not properly addressed (McConalogue, 1999; Storey and Barnet 2000). New barriers can also result in poor practices or badly designed systems. Overcoming KM barriers is not an easy task and requires extensive planning (Al-Ghassani *et al.*, 2002a, Al-Ghassani *et al.*, 2003). This necessitates a full understanding of the nature of the knowledge that needs to be managed and the barriers that resist its implementation. The importance of early identification of the barriers to KM implementation comes from the fact that rectifying or altering a KM system is difficult, if at all possible, time-consuming, and expensive (CIRIA, 2000a). Furthermore, it is extremely difficult to recover staff trust in a system after it fails.

4.5 TOOLS FOR IMPLEMENTING KNOWLEDGE MANAGEMENT

Very few authors have defined KM tools. Gallupe (2001) states that they are not simply information management tools as they should be 'capable of handling the richness, the content, and the context of the information and not just the information itself'. A popular definition by Ruggles (1997) describes them as the technologies used to enhance and enable the implementation of the sub-processes of KM (e.g. knowledge generation, codification, and transfer). He highlights that not all KM tools are IT based as a paper, pen and video can be utilised to support KM. He, however, thinks that IT tools are worth closer investigation because they have quick evolution, dynamic capabilities and are more expensive.

In fact, most authors use the term KM tools to mean IT tools. In this research, KM tools will be used to refer to both 'non-IT tools' and 'IT tools'. To distinguish between them, the terms 'KM techniques' and 'KM Technologies' will represent 'non-IT tools' and 'IT tools' respectively. The main differences between KM techniques and technologies are presented in Table 4.1 and discussed thereafter.

Table 4.1: KM Tools: Techniques and Technologies.

KM Tools	
KM Techniques	**KM Technologies**
• Require strategies for learning	• Require IT infrastructure
• More involvement of people	• Require IT skills
• Affordable to most organisations	• Expensive to acquire/maintain
• Easy to implement and maintain	• Sophisticated implementation/maintenance
• More focus on tacit knowledge	• More focus on explicit knowledge
• Examples of tools:	• Examples of tools:
– Brainstorming	– Data and text mining
– Communities of Practice	– Groupware
– Face to face interactions	– Intranets/Extranets
– Recruitment	– Knowledge bases
– Training	– Taxonomies/ontologies

4.5.1 KM Techniques

The importance of KM techniques (non-IT tools), according to Table 4.1, comes from several factors. Firstly, they are affordable to most organisations. This is because little infrastructure is required although some techniques require more resources than others (e.g. training requires more resources than face-to-face interactions). Secondly, KM techniques are easy to implement and maintain due to their simple and straightforward nature. Thirdly, they focus on retaining and increasing the organisational tacit knowledge, a key asset to organisations.

KM techniques are not new, as organisations have been managing knowledge, to a greater or lesser degree for some time. However, their use has been under the umbrella of other management approaches. Using these tools for the management of organisational knowledge requires improving the way they are used so that benefits from them, in terms of knowledge gain/increase, are achieved. Some KM techniques are described below:

Brainstorming is a process where a group of people meet to focus on a problem, and then intentionally proposing as many deliberately unusual solutions as possible through pushing the ideas as far as possible. The participants shout out ideas as they occur to them and then build on the ideas raised by others. All the ideas are noted down and are not criticized. Only when the brainstorming session is over are the ideas evaluated. Brainstorming helps in problem solving and in creating new knowledge from existing knowledge (Tsui 2002a & b). The following rules are important to brainstorm successfully:

- A leader should take control of the session and keep it on course. Initially the problem to be solved is defined with any criteria that must be met. He or she should encourage an enthusiastic, uncritical attitude among brainstormers and encourage participation by all members of the team. The session should be announced as lasting a fixed length of time, and the leader should ensure that no train of thought is followed for too long. The leader should try to keep the brainstorming on subject, and should try to steer it towards the development of some practical solutions.

- Participants in the brainstorming process should come from as wide a range of disciplines with as broad a range of experience as possible. This brings many more creative ideas to the session.

- Brainstormers should be encouraged to have fun brainstorming, coming up with as many ideas as possible, from solidly practical ones to wildly impractical ones in an environment where creativity is welcomed.
- Ideas must not be criticised or evaluated during the brainstorming session. Criticism introduces an element of risk for a group member in putting forward an idea. This stifles creativity and cripples the free running nature of a good brainstorming session.

- Brainstormers should not only come up with new ideas in a brainstorming session, but also should 'spark off' from associations with other people's ideas and develop other people's ideas.

- A record should be kept of the session either as comprehensive notes or a tape recording. This should be studied subsequently for evaluation. It can also be helpful to write down and explore the ideas on a board, which can be seen by all brainstormers.

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 (Ruggles, 1997). These groups are different from teams and task forces. People in CoPs can perform the same job or collaborate on a shared task (software developers) or work together on a product (engineers, marketers, and manufacturing specialists). They are peers in the execution of "real work." What holds them together is a common sense of purpose and a real need to know what each other knows. Usually, there are many communities of practice within a single company and most people normally belong to more than one.

Face to face interaction is a traditional approach for sharing the tacit knowledge (socialisation) owned by an organisation's employees. It usually takes an informal approach and is very powerful. Face-to-face interactions also help in increasing the organisation's memory, developing trust and encouraging effective learning. Lang (2001) considers it to provide strong social ties and tacit shared understandings that give rise to collective sense-making. This can also lead to an emergent consensus as to what is valid knowledge and to the serendipitous creation of new knowledge and, therefore, new value. This provides an environment within an organisation where participants see the firm as a human community capable of providing diverse meanings to information (i.e. knowledge).

Post-Project Reviews are debriefing sessions used to highlight lessons learnt during the course of a project. These reviews are important to capture knowledge about, causes of failures, how they were addressed, and the best practices identified in a project. This increases the effectiveness of learning as knowledge can be transferred to subsequent projects. However, if this technique is to be effectively utilised, adequate time should be allocated for those who were involved in a project to participate. It is also crucial for post-project review meetings to take place immediately after a project is completed as project participants may move or be transferred to other projects or organisations.

Recruitment is an easy way for knowledge buy-in. This is a tool for acquiring external tacit knowledge especially of experts. This approach adds new knowledge and expands the organisational knowledge base. Another benefit is that other members within the organisation can learn from the recruited member formally and informally so that some knowledge will be transferred and retained if the individual leaves the organisation. Some organisations also try to codify the recruited person's knowledge that is of critical importance to their business.

Apprenticeship is a form of training in a particular trade carried out mainly by practical experience or learning by doing (not through formal instruction). Apprentices often work with their masters and learn craftsmanship through observation, imitation, and practice. They focus on improving the skills of the individuals so that they can later perform tasks on their own. This process of skill building requires continuous practice by the apprentices until they reach the required level.

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. The mentor provides a coaching role to facilitate the development of the trainee by identifying training needs and other development aspirations. This type of training usually consists of career objectives given to the trainee where the mentor checks if the objectives are achieved and provides feedback.

Training helps in improving staff skills and therefore increasing their knowledge. Its implementation depends on plans and strategies developed by the organisation to ensure that employees' knowledge is continuously updated. Training usually takes a formal format and can be internal where seniors train juniors within the organisation or external where employees attend courses managed by professional organisations.

4.5.2 KM Technologies

KM technologies depend heavily on IT. Examples of KM technologies for capturing knowledge are Knowledge Mapping Tools, Knowledge Bases, and Case-Based Reasoning. Although there is a debate about the degree of importance of such technologies, many authors consider them as very important enablers to support the implementation of a KM strategy (Skyrme and Amidon, 1997; Kanter, 1999; Anumba *et al.*, 2000; Storey and Barnet, 2000; Egbu, 2000a; Egbu, *et al.*, 2001b) as they consume one third of the time, effort and money that are required for a KM. The other two-thirds mainly relate to people and organisational culture (Davenport and Prusak, 1998; Tiwana, 2000). From a return on investment (ROI) perspective, there is a need for the organisations to capitalise and exploit IT for KM. With the evolution in IT hardware and software, IT tools can act as dynamic capabilities or core competencies for organisations, if effectively exploited. KM technologies consist of a combination of hardware and software technologies.

Hardware technologies and components are very important for a KM system as they form the platform for the software technologies to perform and the medium for the storage and transfer of knowledge. Some of the hardware requirements for a KM system according to Lucca *et al.* (2000) are:

- Personal computer or workstation to facilitate access to the required knowledge;
- Highly powerful servers to allow the organisation to be networked;
- Open architecture to ensure interoperability in distributed environments;
- Media rich applications requiring Integrated Services Digital Network (ISDN) and fibre optics to provide high speed;
- Asynchronous Transfer Mode (ATM) as a multi media switching technology for handling the combination of voice, video, and data traffic simultaneously; and
- Use of the public network technology (e.g. Internet) and private network technologies (e.g. Intranet, Extranet) to facilitate access to and sharing of knowledge.

Software technologies play an important part in facilitating the implementation of KM. The number of software applications has increased considerably in the last few years. Solutions provided by software vendors take many forms and can perform different tasks. The large number of vendors that provide KM solutions makes it extremely difficult to identify the most appropriate applications. This has resulted in organisations adopting different models for establishing KM systems. Tsui (2002b) identifies five emerging models for deploying organisational KM systems where one or a combination may be adopted:

- *Customised Off The Shelf (COTS)* – This is the traditional and most popular way of deploying application services. Based on the organisational needs, the applications will be identified and then examined against the functional needs of the organisation. A short-period test may follow to identify the most suitable application. Once an application is acquired, customisation on the standard features is usually performed to integrate it into the organisation's system.
- *In-house Development* – These systems are developed within the organisation, usually with external technical help. Examples are Lotus Notes, Domino, and Intranet applications. However, there are several reasons that make this option generally less attractive to organisations. This includes the difficulty of establishing KM system' requirements, high cost, risk, and the complexity often associated with developing bespoke systems.
- *Solution Re-engineering* – This involves adapting, with the help of KM consultants and technical architects, an existing generic solution that matches the organisation's requirements. Although similar to COTS, the adapted solution is not packaged as a product that can be marketed. Examples are Online Knowledge Communities, and Virtual Collaboration Tools.

- *Knowledge Services* – These are knowledge applications provided by a third party that hosts the application on the Web. The user accesses the service via a thin-client (e.g. a browser). The main benefits are the waived software licensing fee and the avoidance of in-house maintenance. However, many organisations do not find this option attractive because of the reduced security and privacy.

- *Knowledge Marketplace* – Modelled in the E-Business NetMarket concept, several knowledge-trading places have been established recently. In a Knowledge Marketplace, a third party vendor hosts a web site grouping together many suppliers of knowledge services. Suppliers may include expert advisors, vendors providing product support services, KM job placement agencies, procedures of evaluations of KM and portal software, and research companies providing industry benchmarks and best practice case studies. Two types of Knowledge Marketplace exist. One provides common information and services to all industries while the other offers only certain services to a specific industry.

KM software technologies have seen many improvements since the year 2000 due to many alliances, and mergers and acquisitions between KM and Portal tool vendors (Tsui, 2002b). However, none of them provide a complete solution to KM. These tools are better described within technology groups such as data and text mining, groupware etc. Some of these are described below.

Data and text mining is a technology to extract meaningful knowledge from masses of data or text. Data are single facts (structured) about events while text refers to unstructured data. The process of data/text mining enables meaningful patterns and associations of data (words and phrases) to be identified from one or more large databases of 'knowledge bases'. The approach is also very useful for identifying hidden relationships between data and hence creating new knowledge. It is mostly used in business intelligence, direct marketing and customer relationship management applications. However, this technology is not widely used because it is difficult to access data via an enterprise-wide corporate portal where most organisations only have a small group of data miners (Tsui, 2002 a & b).

Groupware is a software product that helps groups of people to communicate and share information (Haag and Keen, 1996). This is useful for group decision-making. Groupware supports distributed and virtual project teams where team members are from multiple organisations and in geographically dispersed locations. Groupware tools usually contain email communications, instant messaging, discussion areas, file area or document repository, information management tools (e.g. calendar, contact lists, meeting agendas and minutes) and search facilities (Tsui, 2002a).

Intranet is an inter-organisational network that is guarded against outside access by special security tools called firewalls (Haag *et al.*, 1998). **Extranet** is an Intranet with limited access to outsiders, making it possible for them to collect and deliver certain knowledge on the Intranet. This technology is very useful for making organisational knowledge available to geographically dispersed staff members and is therefore used by many organisations.

Knowledge bases are repositories that store knowledge about a topic in a concise and organized manner. They present facts that can be found in a book, a collection of books, web sites or even human knowledge. This is different from the knowledge bases of expert system, which incorporate rules as part of the inference engine that searches the knowledge base to make decisions.

Taxonomy is a classification of terms (and the relationships between them) that are commonly used in an organisation. Examples of a relationship are 'hierarchical' (where one term is more general hence subsumes another term), 'functional' (where terms are indexed based on their functional capabilities), and 'networked' (where there are multiple links between the terms defined in the taxonomy).

Ontologies also define the terms and their relationships but in addition, they support deep (refined) representation (for both descriptive and procedural knowledge) of each of the terms (concepts) as well as defined domain theory or theories that govern the permissible operations with the concepts in the ontology.

There are at least three ways to develop a **taxonomy/ontology**: manually constructed (using some kind of building tools), automatically discovered (from a repository of knowledge assets), or purchased off-the-shelf. Taxonomies/Ontologies serve multiple purposes in an organisation. They can be used as a corporate glossary holding detailed descriptions of every key term used in the organisation. They can also be used to constrain the search space of search engines and prune search results, identify and group people with common interests, and act as a content/knowledge map to improve the compilation and real time navigation of Web pages. (Tsui, 2002 a & b).

The next section describes the existing methods for selecting the most suitable KM tools for an organisation.

4.5.3 Selecting the Appropriate Tools

When developing a KM strategy, the organisation needs to identify the tools (techniques and technologies) required. The selection of techniques and technologies will be informed, for example, by the goal of the KM strategy, the nature and location of knowledge and the capabilities of tools.

Selecting KM techniques

In many organisations, the selection of the most appropriate KM techniques does not follow a structured approach. This is probably because of the relatively low initial capital outlay of such techniques and the ease of their implementation. Another reason is that most organisations already implement some KM techniques and therefore develop plans for improving the use of these techniques. This can cause the improvement of some techniques that may not be critical to the KM system.

Selecting KM technologies

The selection of the most appropriate KM technologies requires a clear identification of the organisation's knowledge management needs. It also requires an awareness of the technologies available and their functional capabilities. Existing methods for selecting KM technologies vary between organisations. However, there are some common methods. There two main approaches for selection; according to KM sub-processes and according to technology families. The former categorises the technologies in terms of the KM sub-processes they support while the latter classifies them into general technology families that support KM.

Selection of KM technologies according to KM sub-processes

This method is popular because it allows users to identify the KM sub-processes that they need to use and then select the most appropriate technologies. After identifying the KM sub-processes, opinion is divided on the method for selecting appropriate technologies. One group (Table 4.2) identifies the software applications without putting the software into technology categories. The other group (Table 4.3) identifies the technology categories, without naming the software applications. Ruggles (1997) is probably the first to follow the pattern of the former group. Wensley and Verwijk-O'Sullivan (2000) adopted the same pattern in their consideration of web-based software applications.

Table 4.2: Software applications classified by KM sub-processes

Author	KM Sub-processes	KM Software Applications
Ruggles (1997)	Generation	GrapeVine, IdeaFisher, Inspiration, Idea Generator, MindLink
	Codification	KnowledgeX, Excalibur RetrievalWare & Visual RetrievalWare, TeleSim
	Transfer	(Lotus) Notes, NetMeeting, EnCompass
Wensley and Verwijk-O'Sullivan (2000) (web-based KM tools)	Acquire	Aeneid, Networker, Infoscout, Arbortext tools, Documentum
	Store	2 Share 2.0, Beehive, Action Technologies Tools, WebOS, Aeneid, Networker, Infoscout, Arbortext tools, Autonomy, Documentum
	Deploy	2 Share 2.0, Beehive, Action Technologies Tools, WebOS, Networker, Infoscout, Arbortext tools, Autonomy, Documentum
	Add Value	Action Technologies Tools, WebOS, Autonomy, Documentum

The second group (Table 4.3) identifies categories of KM technologies that support the KM sub-processes without naming the software applications, also includes some technology categories that are not originally developed for KM but support its sub-processes. Jackson (1998) and Laudon and Laudon (2000) adopted this pattern. A similar attempt by Tsui (2002a) focuses on the Personal KM technologies (PKM) rather than the Enterprise KM technologies.

Table 4.3: KM technologies classified by KM sub-processes

Author	KM Sub-processes	KM Technologies
Jackson (1998)	Gathering	Pull, Searching, Data entry/OCR
	Storage	Linking, Indexing, Filtering
	Communication	Sharing, Collaboration, Group Decisions
	Dissemination	Push, Publishing, Notification
	Synthesis	Analysis, Creation, Contexualisation
Laudon and Laudon (2000)	Creation	Knowledge Work Systems: Computer Aided Design (CAD), Virtual Reality, Investment Workstations
	Knowledge capturing and codifying	Artificial Intelligence Systems: Expert Systems, Neural Nets, Fuzzy Logic, Genetic Algorithms, Intelligent Agents
	Knowledge distribution	Office Automation Systems: Word Processing, Desktop Publishing, Imaging and Web Publishing, Electronic Calendars, Desktop Databases
	Knowledge sharing	Group Collaboration Systems: GroupWare, Intranets
Tsui (2002a) (PKM Tools)	Creation	Associative Links, Information capturing and sharing, Concept/Mind Mapping
	Codification/ Representation	Associative Links, Information capturing and sharing, Concept/Mind Mapping, E-Mail Management, Analysis and Unified
	Classification/Indexing	Index/Search, Meta-Search, Associative Links, Information capturing and sharing, Concept/Mind Mapping, E-Mail Management, Analysis and Unified
	Search and Filter	Index/Search, Meta-Search, E-Mail Management, Analysis and Unified
	Share/Distribute	Index/Search, Meta-Search, Associative Links, Information capturing and sharing, E-Mail Management, Analysis and Unified

Selection of KM technologies according to KM technology families

Technology families are categories of commercial KM software applications such as document management, groupware and search facilities. Table 4.4 provides examples of different classifications of technology families. Jackson's (1998) classification presents six technology families and identifies a few examples of commercial software applications for every category. Bair and O'Connor (1998) followed this method but in a more detailed way. They introduced identifiable technology families and then categorised KM software applications accordingly through identifying software vendors and classifying them according to the capacity for collaboration over time and across the organisation. The classification by Wensley and Verwijk-O'Sullivan (2000) focuses on web-based technologies. Gallupe's (2001) classification is based on a three-level model of KM systems. The three levels are tools, generators, and the specific KM system. He identifies tools and generators as the technologies that are used to acquire, store, and distribute knowledge. In this context, tools are basic technological building blocks for the KM system where individual tools can be combined to form a specific KM system that performs particular functions. On the other hand, generators are self-contained technologies and can be used to generate or build a variety of specific KM systems. A generator therefore consists of a number of tools such as document management, intelligent agent, and groupware. For example, Lotus Notes is a generator that contains a number of KM features that can be combined in various ways to make different KM systems. Tsui's (2002b) classification is based on the origin of technologies, alignment with business processes, and capabilities of the commercial KM software.

Table 4.4: KM technology families by different authors

Author	KM Technology families
Jackson (1998)	Document management e.g. Documentum, Panagon JetForm Information management e.g. SAP, Baan Searching and indexing e.g. Fulcrum, Retrievalware, Verity Communications and collaborations e.g. Notes, Exchange, Eudora Expert systems e.g. Trajecta, Cognos Systems for managing intellectual property.
Bair and O'Connor (1998)	Knowledge Retrival (KR) (e.g. Fulcrum, Verity, Excalibur) Document Management (DM) (e.g. Documentum) GroupWare (GW) (e.g. Lotus, Autonomy, GrapeVine) Integrated Systems: KR+DM+GW+Data Management (e.g. Lotus, Netscape)
Wensley and Verwijk-O'Sullivan (2000) (Web-based tools)	Traditional database tools Process modelling and management tools Workflow management tools Enterprise Resource Management Tools Agent tools Search Engines, Navigation Tools and Portals Visualising tools Collaborative Tools Virtual Reality Tools
Gallupe (2001)	Intranets Information Retrieval Programs Database Management Systems Document Management Systems Groupware Intelligent Agents Knowledge-Based or Expert Systems
Tsui (2002a & b)	Search Meta/Web Crawler Process Modelling and Mind Mapping Case-Based Reasoning (CBR) Data and Text Mining Taxonomy/Ontological Tools Groupware Measurement and reporting E-Learning

4.5.4 Limitations in Existing Methods for Tool Selection

The above existing methods for identifying the most appropriate KM tools show that these methods do not fulfil many of the requirements for developing a KM strategy. Limitations in the current methods are described below.

KM Techniques

The most important limitations in existing methods for selecting KM techniques are:

- They do not follow a structured approach and are therefore exposed to many interpretations;

- In many cases, they depend on improving existing techniques without investigating if they are needed for the KM system; and

- The way these techniques are selected does not link the selection process to the organisational goals from implementing KM.

KM Technologies

The most important limitations in existing methods for selecting KM technologies are:

- Classifications according to KM sub-processes do not link the technology families to their commercial software applications. This is probably because KM tools are still in the infancy stage and hence any list of commercial software may get outdated in a very short period;

- Classifications according to technology families are generic and therefore not very useful for organisations that seek practical methods for identifying the most appropriate tools;

- Classifications by the technology families also identify technology families without naming the software applications that support them although, in some cases, reference to examples of applications is given. This is probably due to two reasons: the large and increasing number of software products and the overlap between their functions; and

- The existing methods are easy to use but do not link the selection to the organisational requirements from KM.

The limitations identified in existing methods for selecting the most appropriate KM tools indicate a need for a new approach that takes these limitations into account.

4.6 SUMMARY

In this chapter the concept and importance of knowledge management (KM) have been reviewed. The barriers to implementing KM have been discussed and the tools for its implementation have been investigated. It was established that knowledge is an important asset needing to be managed and that managing this knowledge is important to improve the performance of any business organisation. It was also found that managing organisational knowledge is faced by many barriers and that the existing methods for selecting the most appropriate KM tools are preliminary and do not link the selection process to the organisational goals from KM. The potential of KM for any business organisation, the barriers facing its implementation, and the inappropriate methods for tool selection necessitate careful planning before developing a KM strategy. The next chapter investigates, through examining the experience of leading construction organisations, the potential of KM for managing structural design knowledge, the barriers involved and the tools used.

CHAPTER 5: INDUSTRIAL CASE STUDIES

5.1 INTRODUCTION

This chapter presents the experience of five case study organisations involved in structural design. The cases are described individually then similarities and differences between them are discussed. A conceptual framework for developing and implementing KM strategies is then introduced.

5.2 CASE STUDIES

The third and fourth objectives of the research were to explore the potential of knowledge management for structural design knowledge and to develop a framework that supports a better management of this knowledge. The case study method was selected because it provides deeper investigation into a problem. The case studies undertaken meant to explore the knowledge involved in structural design and how this knowledge is currently managed. They also seek to identify how KM could improve the current approaches that the organisations follow.

Five organisations were considered for the proposed study. These cases include consulting and contracting organisations that are heavily involved in the structural design process. Background information about the organisations investigated is presented in Table 5.1. The organisations are at various levels of implementing KM ranging from not implementing to very advanced in implementation.

Table 5.1: Details of organisations involved in case studies.

Organisation	Type of Business	Number of Employees	Annual Turnover (£M)
A	Consulting	200	8
B	Consulting	310	17
C	Consulting	2600	100
D	Contracting	6000	2000
E	Consulting	7000	350

The choice of these case studies was based on the willingness of individuals within these organisations to collaborate and make information available to the research project. To capture the required information, semi-structured interviews were used based on the template shown in Appendix A2. The questions were divided into four sections: context; structural design; knowledge management; and Role of IT. Every section was subdivided into a number of questions.

The first section, context, was aimed at capturing general information about the organisations such as number of employees, number of structural designers, types of projects involved in, annual turnover etc. The second section, structural design, was meant to develop an understanding about issues of structural design such as the problems that require new knowledge and how the investigated organisations obtained this knowledge. The third section, knowledge management, investigated the implementation of KM within the organisations and explored the benefits that KM could offer to structural designers. It also investigated the KM techniques and approaches used for sharing structural design knowledge. The last section, Role of IT, explored the role of KM technology in sharing structural design knowledge and identified what technologies were used.

The approach to case study introduced by Brookes and Backhouse (1998) was generally adopted as described below where the last two actions were necessary to remove any bias made:

- initial contact with interviewees;
- in-depth interviews recorded on tape;
- review of relevant documents supplied by interviewees;
- further discussions to clarify unclear issues; and
- confirming the contents of the report with the interviewees.

5.2.1 Company Case A

Background

Case 'A' employs 200 people in 11 offices around the UK and has an annual turnover of £8M. It specialises in construction consulting with a focus on structural design.

Structural Design

The process of structural design within the organisation depends on the type and size of the project being designed. For large projects, the project team consists of members from several offices where the Regional Manager normally heads the project. Given the relatively small number of staff within the office, there is always a fair idea of the composition of the team members. The procurement method used (e.g. Design and Build, Partnering etc) also affects the leadership role of structural designers. Usually, structural engineers start structural design after the architects have completed architectural design.

Structural design knowledge is required when a new scenario is faced. Structural design problems are approached either formally in project meetings or informally through asking colleagues. In usual designs, the project manager develops the concept design while graduates and other engineers develop the detailed design. If a problem or a new scenario were faced then the solution would be sought using consulting colleagues within the same office. If no convincing answers were found, an e-mail describing the problem would be sent to the other offices. During concept design, most of the strategic decisions are based on using tacit knowledge (estimated to be 80%), which, in turn, depends on basic concepts of how the project would be put together and includes fundamental design decisions e.g. whether to use a concrete frame or a steel frame, predicting loading conditions, behaviour of structure, etc. The organisation uses several methods for locating and accessing tacit knowledge. The organisation formerly used a paper database of 'who knows what' to locate the tacit knowledge of designers. However, this database got outdated very quickly and was not thereafter used. Detailed design involves more explicit knowledge (estimated to be 80%) and some tacit knowledge (estimated to be 20%). The explicit knowledge includes codes of design, safety regulations, etc.

Role of KM for Structural Design

The organisation does not have a formal strategy for managing its knowledge. However, there are some KM activities, which are not labelled as KM. One of the initiatives that the organisation is planning to implement is to use the Internet for information and knowledge sharing. Although the organisation is not planning to use an Intranet, they think that using it might come fairly soon. The organisation is currently working with technicians in Vietnam where a lot of the drawing work is being done. Communication of information and knowledge between the offices in UK and those in Vietnam take place through e-mails. The organisation is also investigating whether a Web-based information hub would be a better way of sharing information and keeping track of what is going on. Although the organisation is currently looking at these issues, it does not have a strategy that it would necessarily follow. In fact, the organisation is still looking at the different options for sharing information and knowledge.

Role of IT

The organisation did not have a KM strategy or system in place and therefore there was no role for IT in supporting KM.

5.2.2 Company Case B

Background

This organisation consists of 310 employees located in 6 offices in the UK with an annual turnover of £17M. It is a consulting engineering firm involved in several international projects and has 170 structural engineers.

Structural Design

The organisation has three structural engineering specialist groups namely bridge, facade (a combination of structural engineers and architects), and specialist structural groups for small jobs. Structural designers are involved at the early stages of design as architects contact them with regards to buildability issues.

Structural design problems occur when knowledge is required for new scenarios and this is approached using previous experience of the individuals with no re-use of design. Also, engineers tend to prefer to ask a colleague rather than doing a search that may not bring the required knowledge. If no individual can be found to have the required knowledge within the organisation then first principles would be used. The way structural design problems are approached involves a mixture of formal and informal techniques. Formal techniques include lead designers attending early meetings and key design meetings. Also, there is a formalised process of quality reviews, which are also led by senior engineers who would ask questions about why a certain method was adopted, discuss possible alternative options etc. Informal techniques include consulting a colleague and using previous experiences. The organisation, in this context does not face a problem of identifying 'who knows what' because of the relatively small number of staff and also due to the monthly management reviews of projects, which allow managers to be aware of the different experiences available in the other offices. The organisation relies heavily on tacit knowledge during concept design (approximately 80%) of projects while similar level of reliance on explicit knowledge takes place during detailed design. The tacit knowledge is based on the experience of the individuals while the explicit knowledge relies on design codes and contract conditions.

Role of KM for Structural Design

The organisation sees KM as a very important approach for sharing structural design knowledge. They see it as a means of reducing the design cycles and as a facilitator to delivering better design solutions to the client in a design context. Although the organisation does not have a formal or documented KM strategy, they implement some basic KM activities that support the sharing of structural design knowledge. Skills database (pointers to expertise) on the Intranet are used for identifying the individuals and groups having a particular knowledge. Group meetings are used to facilitate the communication of ideas. Also, informal discussions are widely used and encouraged to facilitate the sharing of tacit knowledge. The organisation's Intranet contains a 'technical area' used for sharing: some design details of projects; some technical notes produced by the organisation; standard templates as design guides; manufacturer's information; and links to technical indices. The organisation does not have short-term plans for implementing KM because they think that the supporting infrastructure is not available within the organisation.

Role of IT in Supporting a KM Strategy

Although the organisation does not have a formalised KM strategy or a plan for implementing it in the short term, they realise its importance. They also see IT as an important facilitator. However, they emphasise that the use of IT should be thoroughly planned to make sure that the system would be used. The first check is to ensure that people would use an application in a paper format then they are most likely to use it if automated. They also see the Intranet as an important part of a KM system but think that their Intranet needs to be re-launched if it is to support KM.

5.2.3 Company Case C

Background

Organisation 'C' has 2600 employees distributed in 29 offices and has an annual turnover of about £100M. The organisation's offices are spread in Asia, Australia, Europe, the Middle East and UK. This is a management consultancy and engineering design organisation with 500 structural engineers spread throughout the organisation's offices.

Structural Design

The organisation does not have formal structural engineering groups although there is some specialisation in some of the offices. For example, one of the offices specialises in bridges and civil structures that are mainly associated with transportation, highways, and railways. Another office specialises in buildings. The role of structural engineers is either leading or support depending on the type of the structure. For example, for highway projects, a highways engineer will lead the project and the structural engineers would provide support. In a major bridge project, structural engineering would be the lead department. In buildings, an architect would lead and structural engineers would work under the project management of an architect.

The main problems faced are the need for quick knowledge at concept design and tender design due to the limited time at this stage. Also, there is need for knowledge when new scenarios are faced. These problems are approached using the knowledge and experience of senior engineers involved in a project. This approach follows a formal design management system that includes value management at the concept stage. So, the design team starts with the value management meetings, which include brainstorming sessions to allow experts to push new ideas. This process starts during concept design but as the team proceeds in design, value-engineering meetings take place to review what is done, to decide whether it can be improved and to identify what needs to be changed. The value engineering process is a part of the design management processes where the work carried out is reviewed up to a point to make sure that it satisfies all the client demands and the demands of any other stake holders and also to check that it is the most economical solution for the particular project and that it satisfies the required environmental requirements. The organisation is also in the process of launching a formal Design Management Procedure. The organisation relies more on tacit knowledge during the concept design (approximately 70%) with less reliance is on explicit knowledge at this stage (30%). These figures are reversed during the detailed design stage.

Role of KM for Structural Design

The organisation has a plan for implementing KM by January 2003. KM has been investigated by the organisation for the last three years and the interviewee, a senior structural engineer, has taken on the role of developing the organisation's strategy for implementing KM. The organisation believes that KM will support all their structural design activities. Firstly, from the tacit point of view, there is the need for expertise to be captured and or communicated. The organisation has a very primitive knowledge database, which contains information about 'who knows what' and they think that this needs to be much more detailed. The database is on the organisation's Intranet and is available to everyone within the organisation. Secondly, KM helps to make explicit knowledge more accessible through web-based systems. Example of such knowledge is past design reviews, good details from past design reviews, standard ways of analysing particular situations, and reference to technical useful documents. The KM system can also help in producing basic details very quickly for concept design and tender design. This will save a lot of the search time at this stage. KM will also support detailed design because detailed design consumes 90-95% of the manpower used during design. Also, detailed design relies more on explicit knowledge that can be obtained from the KM system.

Knowledge sharing within the structural design process is very informal and follows the approach of asking colleagues, sending emails etc. It is believed that this informal approach can be made more structured by the KM system. For example, if the 'experts register' is updated then people will be more directed to where to send their questions. The organisation also has plans to improve the knowledge sharing process through the implementation of KM. In fact, within the company as a whole, the structures department is actually piloting the implementation of KM. The experience within this department will inform other departments of the possible benefits. The organisation has prepared a detailed strategy for implementing KM. The contents of the system will be entirely function dependent and agreed by each function on the basis of perceived benefit to it. A typical list of content areas will be:

- Standard details (CAD);
- Standard drawing templates;

- CAD manuals;
- Design notes and manuals;
- Model calculations (in editable form, spreadsheets or other documents);
- Model forms and reports;
- Computer software guidance;
- The organisation's design rules (for areas where codes and standards are silent or ambiguous; e.g. is it a beam, is it a slab);
- Project Close Out Reports or principal features, lessons etc. extracted from them;
- Copies of references and links to relevant papers;
- Links to useful websites; and
- FAQs (e.g. how to solve common problems).

The system will be piloted within the Bridges and Civil Structures function and its performance will be reviewed regularly in order to ensure the continuous development and expansion of the system. The Key Performance Indicators and improvement procedures are suggested as:

- Number of hits per function/topic/content area; and
- Growth of knowledge database.

Role of IT in Supporting a KM Strategy

IT is considered as a strong enabler for implementing KM. The organisation already has its own Intranet. The contents of the Intranet will be replaced with new ones to take account of KM to facilitate knowledge sharing. The organisation is not considering buying any KM software products at this stage. In fact, the organisation does a lot of in-house software development. So, the IT tools required will probably be developed internally. The organisation believes that structural designers will use the KM system extensively because it will be developed with them in mind as the end-users.

5.2.4 Company Case D

Background

The organisation employs over 6000 staff members in 23 offices worldwide and has an annual turnover of £2 billion. This is a large international company with its primary business as house building. The organisation has 30 structural engineers within the design teams in the UK offices.

Structural Design

This contracting company is involved in many design tasks especially when 'design and build' projects are involved. The organisation has two main structural design groups in the UK; one specialised in nuclear engineering and the other in buildings. The design teams in these two offices are involved in design and build, internal consulting, independent consulting to clients, and partnering in some projects. The latter takes place for a few specific contracts only. The role of structural engineers within the design process is similar to other building projects. The normal process is that a client selects their organisation. If the client has his own consultants, then structural engineers within the organisation are not usually involved. In a 'design and build' contract, the front end is usually architecturally led where structural engineers start their job after the architects have designed the space plan.

The main problems faced during structural design are when there is need to develop new and innovative designs or when high risk is involved in the project being designed. The organisation approaches structural design problems by first defining the problem. Then, a senior engineer investigates it and advises on the best person to solve it. If the problem involves risk then the approach is more formal including investigation of what the risks are, why a particular solution will be adopted, why it is better than the other solutions, etc. The different tools used to solve a problem are previous experience, previous jobs, fundamental engineering, asking a colleague etc. Given the small number of structural engineers within the organisation, the approach for solving structural design problems is more informal. At the concept design there is more reliance on tacit knowledge (approximately 95%) with little of explicit knowledge (5%). However, at the detailed design there is more reliance on explicit knowledge (approximately 95%) where the codes become more important as there will be less reliance on tacit knowledge (5%)

Role of KM for Structural Design

Members of the structural design team are aware of a KM strategy within the organisation but they do not feel it is a user-friendly strategy. They rarely use the knowledge provided in the organisation's Intranet. Also, they think that the directory of 'who knows what' is not very helpful to them because they already know who knows what due to the small number of structural engineers within the organisation. Knowledge sharing takes place in the traditional way as younger engineers ask their seniors. The interviewee says "we don't have something like 3000 engineers like some companies". Structural engineers think that KM can support the process of structural design if their requirements of knowledge are considered when planning and developing the implementation of KM.

The design team suggests that for the KM system to be used within their division more training is required to allow the engineers to understand what they can get from the system. They also think that integrating the use of KM to the work practice aspects would increase its use. However, this may add to the cost. The conclusion is that more resources are required to facilitate the use of KM within the division. The division has plans to explore the use of discussion forums to enhance the process of knowledge sharing in terms of best practices and construction based tips.

Role of IT in Supporting a KM Strategy

The organisation has an Intranet but it is rarely used by the structural engineers as they tend to rely on using the Internet because they usually look for information about specific products. The company's KM system is based on its Intranet, which is used by several divisions within the organisation. Structural engineers within the organisation feel that the

Intranet is a very important tool for KM but they think that its contents do not fulfil their requirements.

5.2.5 Company Case E

Background

Organisation 'E' employs 7000 people spread in 70 offices and has an annual turnover of £350M. This large organisation is involved in consulting engineering and design and has between 1100 and 1800 structural engineers worldwide.

Structural Design

Case 'E' has a long history as a leader in structural engineering. The organisation has two major groups: the building engineering group and the building services group. The organisation is biased towards projects that are more complex and innovative. Given the organisation's history as a leader in structural engineering, there is a stronger role for structural engineers in the leadership role rather than services engineers. Also, the organisation encourages active interaction between team members (e.g. structural engineers, architects etc) from the early stages of design.

Structural design problems are faced very often. Firstly, problems are faced when complex designs are encountered. Secondly, problems are faced when innovative designs are required. The approach towards structural design problems usually follows first principles. The organisation also recognises that they do a lot of re-inventing the wheel when approaching structural design problems. They try to use previous experiences in two ways. Firstly, in a broader experience that helps to come up with better designs.

Secondly, to make something that has been done before, an easy design routine. The organisation has a formal way to approach structural design problems although it is not strictly followed, as there is more reliance on experience. The organisation also has a structural skills network, which is particularly powerful in the organisation's network. There is also a question and answer forum on the web where the number of structural engineers using it toward problem solving is continuously increasing. There is more reliance on tacit knowledge during concept design (approximately 90%) where explicit knowledge only uses 10%. The influence of explicit knowledge is more obvious during detailed design. The organisation uses the design codes only as a guide and always tries to come up with innovative solutions.

Role of KM for Structural Design

Structural designers are aware of the KM system within the organisation. The organisation also has a Knowledge Development Team and a skills network, which is a very formal part of the KM system. The skills network was implemented before KM was implemented. The frequency of using the KM system depends on the experience of the users. For example, younger engineers (under 30 years old) tend to use it on a regular basis, weekly if not daily. The skills network is placed on the organisation's Intranet and is different from the skills database, which is called 'OrganisationName People'. This contains a web page for each person where the person can write her/his details including what s/he knows about (in detail). This is different from the skills network, which receives more attention from the organisation. The interviewee is the leader of the skills network group and she administers the budget spent on technical development projects, writing guidance notes, organising meetings between different offices, and sometimes putting more money into getting design review happening between offices. In fact, the structural engineering skills network within the organisation has driven KM largely. It is obvious that the efforts to capture knowledge and to generate the knowledge networks are driven by the structural skills network. Of the budget allocated to different networks and knowledge initiatives, the structural skills network has the biggest single budget compared to the other networks and initiatives.

The organisation follows two main methods for sharing structural design knowledge. Firstly, they use design reviews. This is similar to brainstorming meetings to discuss a concept in a reasonably formal manner. Secondly, there are more *ad hoc* methods of people having dialogue with each other. Thirdly, there is the use of forums within communities of practice where less experienced staff would ask questions and the experienced ones would provide answers. Also, as mentioned above, there is the structural skills network and skills database. The organisation has several plans for improving the sharing of structural design knowledge. Firstly, to re-organise the large amounts of knowledge contained in the Intranet so that it can be accessed more intuitively. Secondly, the organisation is developing a standard template that captures specific knowledge about every project. This is to extract knowledge from the existing comprehensive database of projects and the people worked on them. The importance of doing so is that the current database is mostly designed in a way that it is more used by the marketing people with difficulty in extracting the technical knowledge. Thirdly, the organisation plans to make everything searchable and accessible to anyone within the organisation. This will include details of about 120,000 projects. Fourthly, to encourage engineers to volunteer knowledge about lessons learned and the way purely internal –not reported– problems were solved. Although the organisation has a very collaborative environment, staff still find it difficult to write down what they know. Also, there is a move towards knowledge branding in the organisation so that all the different documents that are available on the Intranet can be found under several brands. The organisation's brands will be: project specific documents, people specific documents, network specific documents, corporate information, and 'insight'. Insight will contain knowledge that has been verified as being appreciative technical knowledge. It is about knowledge that should not be ignored because it has a good value that was verified to some degree. If someone seeks knowledge on underground car park then s/he can search the projects that had car parks, or the people who worked on car parks or s/he can search the 'insight' to pick up a guidance note about the design of underground car park. One of the difficulties is that many contributors do not see how their knowledge would be used. If they know, they will identify what is relevant and what level of detail is required or whether the knowledge might be mis-used. These staff need to know how the knowledge contributed will be used and by whom. The organisation thinks that this is an important issue needing further investigation.

Role of IT in Supporting a KM Strategy

The organisation considers IT as a key facilitator for storing and sharing knowledge. The Intranet is seen as the main IT tool for KM. Searching the Intranet was facilitated by using a taxonomy software application called 'Autonomy'. In fact, the organisation's intranet is a large website with massive amounts of information and knowledge that is either collected out of meetings or extracted from projects. This knowledge includes scheme design reports, presentations, minutes of meetings, and materials of training courses. A major barrier in IT faced by the organisation is the speed of links in some parts of the world, especially when large files are downloaded. This makes it very difficult for some of the organisation's offices worldwide to use the system on a regular basis.

5.3 FINDINGS FROM CASE-STUDIES

The case study interviews represent a spectrum of organisations, which are of different sizes and are at different levels of implementing KM. The cases are summarised in Table 5.2 and are discussed thereafter in order to identify areas of similarities, dissimilarities and areas that require further research and/or development. The discussion focuses on three main areas and therefore is structured as follows:

- Main Knowledge Problems within the Structural Design Process;
- Potential of KM for Addressing the Knowledge Problems; and
- Role of IT in Supporting a KM Strategy.

Table 5.2: Summary of case study interviews

		Case A	Case B	Case C	Case D	Case E
1. Knowledge Problems within Structural design	**(a) Problems**	• Facing new scenarios	• Facing new scenarios	• Facing new scenarios • Limited design time at concept and tender design	• New/ innovative designs • Risk involved in some designs	• Innovative projects • Complex designs • Excessive use of first principles • Re-inventing the wheel
	(b) Solving the problems	• Consulting colleagues • Previous experiences • Sending emails	• Consulting colleagues • Previous experiences • First principles • Skills database • Early design meetings • Key design meetings • Quality reviews • Monthly management reviews • Group meetings	• Consulting colleagues • Previous experiences • Sending email • Value management/engineering	• Consulting colleagues • Previous experiences • Previous jobs • Formal approach for risky design • Fundamental engineering	• Previous experience • First principles • Skills database • Design reviews • Structural skills network • Web-based Q&A forum
	(c) Type of knowledge involved in the problems	• Concept design: 80% tacit, 20% explicit • Detailed design: 20% tacit, 80% explicit	• Concept design: 80% tacit, 20% explicit • Detailed design: 20% tacit, 80% explicit	• Concept design: 70% tacit, 30% explicit • Detailed design: 30% tacit, 70% explicit	• Concept design: 95% tacit, 5% explicit • Detailed design: 5% tacit, 95% explicit	• Concept design: 90% tacit, 10% explicit • Detailed design: 10% tacit, 90% explicit
2. Potential of KM for addressing the Knowledge problems	**(a) Expected/ achieved benefits from KM**	• Not fully aware of the concept	• Sharing structural design knowledge • Reducing design cycles • Better solutions • Satisfied clients	• Improving design activities • Capturing technical expertise • Sharing experiences • Expanding knowledge base • Identifying experts • Finding explicit knowledge • Quick retrieval of knowledge • Reducing design time	• Structural engineers feel that KM can support structural design provided the required knowledge is available in the system • KM may not be very critical for a small number of employees	• Better designs • Develop easy design routines • Very useful to younger engineers

Table 5.2 (continued): Summary of case study interviews

		Case A	Case B	Case C	Case D	Case E
2. Role of KM for structural design knowledge	**(b) Approach for sharing structural design knowledge**	• No formal way followed • Consulting colleagues • Sending Emails • Paper database of experts	• No documented KM strategy • Skills database on Intranet • Group meetings • Informal discussions • The Intranet.	• Very informal • Asking colleagues • Sending emails • Skills database/ experts register • Intranet	• Traditional ways • Consulting colleagues	• Consulting colleagues • Design reviews • Q&A forums within CoPs • Structural skills network • Skills database • Intranet
	(c) Future plans	• No plan	• Update skills database on Intranet • Prepare the infrastructure	• Enhance knowledge sharing • Detailed KM strategy developed • KM will be launched by Jan 2003 • A Design Management Procedure will be launched • Intranet contents will be replaced	• Training for using the system • Explore use of discussion forums	• Re-designing the Intranet • Standard template for capturing knowledge from repositories • Enhance the search facilities • Knowledge branding • Encourage knowledge contribution
3. Role of IT in KM	**(a) Role of IT**	• No KM system in use	• Important facilitator	• IT is seen as a strong enabler	• Electronic discussion forums may be important • Internet/ Intranet are important	• Facilitates storing and sharing • Intranet is the main tool
	(b) Systems/ software used	• None	• None • Intranet but not for KM	• Intranet • In-house development of tools	• Intranet	• Intranet is the main tool • Autonomy for searching the Intranet

5.3.1 Knowledge Problems within the Structural Design Process

Problems

One of the objectives of the case study interviews was to identify the knowledge problems that are faced during structural design and how designers overcome them. Table 5.2 shows some similarities between the problems faced within organisations. Cases (A) and (B) usually require new knowledge when new scenarios are faced while the other organisation cases require new knowledge more frequently. This could be due to the relatively small size of organisations (A) and (B) which employ 200 and 310 people respectively as this is reflected in the types of projects they undertake, usually standard projects. Larger organisations such as Cases (C), (D) and (E) which employ between 2600 and 7000 people require new knowledge in more occasions probably because they are involved in more sophisticated and innovative projects. The problems that require obtaining new knowledge during structural design are:

- Facing new scenarios;
- Limited design time at concept and tender design;
- Designing innovative projects;
- Risk involved in the project being designed;

- Carrying out complex designs;
- Using first principles excessively; and
- Re-inventing the wheel again and again.

Solving the problems

The approach towards solving the problems encountered differs from one organisation to another. Organisation (A) follows informal simple and traditional approaches, which are consulting colleagues, using previous experiences and sending enquiry emails. The other organisations also follow the approach of asking colleagues and sending emails although Cases (B) and (E) do this in a more structured way. For example, Case (B) uses a skills database to identify who should be asked whilst Case (E), in addition to the skills database, uses other approaches such as structural skills network and question and answer forum on the Intranet. Also, all organisations rely heavily on previous experiences to solve problems. Case (E) uses previous experiences in a more mature way. They use it in two ways: they use broader experiences for better designs; and use these experiences to develop easy design routines. The other organisations follow a mixture of formal and informal approaches. Organisations also rely on various management methods for sharing structural design knowledge such as early design meetings, quality reviews, monthly reviews, value engineering meetings etc. The methods used for solving problems that require obtaining new structural design knowledge can be summarised as:

Informal Methods

- Previous experiences;
- Consulting colleagues;
- Sending emails; and
- First principles;

Formal Methods

- Early design meetings;
- Key design meetings;
- Quality reviews;
- Monthly management reviews;
- Skills databases;
- Group meetings;

- Design management systems with value engineering meetings during concept design;
- Value engineering meetings during detailed design;
- Design management procedures;
- Structural skills networks; and
- Question and answer forums on the Web.

Types of knowledge involved in the problems

Knowledge is either tacit or explicit as identified in the literature review. All organisations agree that more tacit knowledge is required at concept design, which is usually done by senior and experienced engineers. Detailed design relies more on design standards, codes, regulations etc and hence involves more explicit knowledge. Although the interviewees gave different figures for the percentages of tacit and explicit knowledge involved in the design stages, these figures remain within a predictable range. The reason for the different figures is that this is a subjective measure, which completely depends on the interviewees' perceptions. Combining the figures, it can be said that at least three quarters (between 70% and 95%) of the knowledge involved during concept design is tacit and that at least three quarters of the knowledge involved during detailed design is explicit knowledge. Therefore, more tacit knowledge needs to be communicated with those involved in concept design whilst more explicit knowledge needs to be made available the engineers involved in detailed design.

5.3.2 Potential of KM for Addressing the Knowledge Problems

The preceding section shows that engineers involved in structural design face several knowledge problems and that these problems are solved in different ways. This section investigates the possible role of KM for solving such problems. The discussion covers three areas: the benefits that KM can offer to solve problems related to structural design knowledge; how the case study organisations actually share their knowledge; and the future plans of these organisations to improve the sharing of their structural design knowledge.

Expected/achieved benefits from KM

All interviewees except one (Case A) agreed that KM is very useful for managing structural design knowledge. Of the five cases investigated, Case (A) and Case (B) did not have KM strategies. Case (A) was not aware of the concept of KM and therefore could not identify the role of KM for structural design. Case (B) was aware of the concept but did not have a strategy because they feel that their infrastructure needs to be improved before implementing KM. Case (B), however, sees KM as very important for sharing structural design knowledge. Cases (C), (D) and (E) are at different stages of implementing KM. Case (C) has investigated the concept very deeply and a detailed strategy for implementing KM was developed by the Bridges and Civil Structures Group with a leader who is a senior structural engineer. Case (D) was at an advanced level of implementing KM. However, the structural engineering groups within the organisation were not actively involved in KM. They believe that KM is important for sharing structural design knowledge but the system in their organisation did not address their needs and they therefore rarely use it. This is due to the fact that this is a contracting company where the majority of its works takes place on site. The organisation employs about 30 structural engineers compared to a total of 6000 employees within the organisation. This is about 0.5% of the manpower within the organisations and this explains why the organisation did not pay enough attention to the requirements of structural engineers compared to project managers and site engineers. Structural engineers feel that if they were consulted before the KM strategy was developed, then the system would have been able to serve them as well as the others. Case (E) is a leader in structural engineering and employs around 1500 structural engineers making more than 20% of the manpower in the organisation. The organisation is at a very advanced level of implementing KM where the structural engineering group believes that KM provides several benefits to them. The structural engineering division within the organisation has driven KM largely as most of the efforts to capture knowledge and to generate the knowledge networks are through this division. This reflects the increasing benefits achieved from implementing KM. From the cases investigated, it is concluded that the benefits of KM can be divided into two groups: specific benefits to structural engineers; and generic benefits:

The specific benefits to structural engineers can be identified as follows:

- Obtaining design knowledge quickly (concept and tender design);

- Improving design activities;
- Capturing and communicating the technical expertise of senior engineers (tacit knowledge for concept design and detailed design);
- Expanding organisational memory;
- Identifying 'who knows what';
- Reducing design cycles (detailed design);
- Reducing design time (concept and detailed design);
- Developing easy design routines (detailed design);
- Making past design reviews and standard ways of analysing particular situations easily accessible (explicit knowledge mostly for detailed design); and
- Improving and accelerating the learning process (practical sharing of tacit and explicit knowledge).

The benefits to structural engineers and other include:

- Making better designs/solutions;
- Increasing satisfaction in clients;
- Expanding the organisation's memory; and
- Identifying 'who knows what';

Approaches used for sharing structural design knowledge

Cases (A) and (B) did not have a KM strategy but used some basic approaches which may be considered as KM activities e.g. skills databases and the Intranet for information sharing. Case (C) has a detailed strategy, which explains how structural knowledge can be shared. Examples of the approaches identified in the strategy are expanding the skills database (experts register), using the Intranet to facilitate communication, promoting the capture of tacit knowledge and making explicit knowledge easily searchable and accessible. Case (D) had a KM strategy system, which was not used by the structural engineers because it did not address their requirements. Case (E) followed different ways for sharing structural design knowledge. In fact, Cases (C) and (E) had more structured approaches and are more serious about sharing structural design knowledge. The KM activities adopted for sharing structural design knowledge within the investigated organisations are:

- Skills databases;
- Intranets as a main tool for sharing knowledge;
- Promoting the capture of tacit knowledge;
- Making explicit knowledge easily searchable and accessible;
- Using question and answer forums within CoPs; and
- Using structural skills networks;

Future plans

Cases (A) and (B) did not have plans for KM. Case (D) had a KM system which was not being used by structural engineers. The structural engineering division had simple plans such as training their engineers to use the system and exploring the use of discussion forums. Future plans for Case (C) revolve around piloting and launching the KM system by January 2003 while plans for Case (E) revolve around improving the existing system. The improvement plan consists of re-designing the Intranet, developing a standard template for capturing specific knowledge about every project from existing knowledge bases, enhancing the search facilities within the system, and encouraging engineers to contribute knowledge that is not captured in reports. The organisation also has plans for branding its knowledge so that a particular knowledge can be found under several categories.

5.3.3 Role of IT in Supporting a KM Strategy

All the case study organisations agree that IT is an important facilitator for implementing KM and they identified Intranets as the main IT tool. One of the organisations used 'Autonomy' to search to contents of its Intranet. The companies investigated did not use any other KM tools or software applications. The interviews show that organisations are confused by the large number of software applications available in the market place. Therefore they decided to either consider Intranets as an alternative to these software applications or to adopt in-house software development although this solution is very expensive and risky in many cases. One of the interviewees says 'we will develop our own system rather than buying one which may not work'.

5.3.4 Need for a Methodology for KM Strategy Formulation

The discussion of the case organisations shows that the organisations involved in structural design face problems during concept design and detailed design. These organisations follow different ways for solving these problems where KM is seen as a potential approach for sharing structural design knowledge. The KM activities adopted and the future KM plans developed by the organisations indicate that there are some issues that need to be taken into account when developing a KM strategy:

Firstly, organisations need to identify what knowledge to manage at the early stages of developing a strategy. Case (A) did not have a KM system or a plan for such system due to being unaware of the concept of KM and also being unsure whether they really need to share a particular knowledge. Case (B) was aware of the importance of KM but did not take it seriously because they did not see how KM would solve specific KM problems. Case (C) developed a detailed KM strategy but this strategy remains generic because it did not identify what specific knowledge they need to manage. For Case (D), structural engineers did not really benefit from the organisation's KM system because the knowledge they are interested in was not in the system. Case (E) stated that they would re-design their Intranet because there were many things placed on it, which were not required by users.

Secondly, organisations should identify the goals for managing their knowledge. Case (D) developed a system, which was not used by its structural engineers. One of the reasons for not using the system was that it did not identify the goals of the structural engineering group for using the system. Case (E) shows that one of the difficulties identified is that many contributors to the knowledge base did not see how their knowledge would be used. This is due to the fact that the organisations did not identify specific goals for managing their knowledge.

Thirdly, organisations need to develop detailed strategies of how their KM would be implemented. Such strategies should include several issues like identification of the KM initiatives, people needed, tools required etc. Cases (C), (D) and (E) had detailed strategies for KM. These strategies identified the people who should develop the system and focused on using Intranets. Other issues such as the various tools required and changing organisational culture were not properly addressed. Cases (D) and (E) had some problems when they started implementation. Case (D) realised, after implementation, that they should have considered using discussion forums as one of the tools for sharing tacit knowledge while Case (E) realised that the search tool they used for finding the explicit knowledge stored within the KM system was not ideal. In fact, this is one of the key weaknesses in most KM strategies; they produce plans for implementation but minimum effort is spent on understanding the different tools (IT and non-IT) that are required.

Fourthly, organisations need to assess and evaluate the appropriateness of the developed strategy. It is possible that many of the problems encountered during the implementation of a KM strategy are due to the strategy not satisfying what the organisations were aiming for. Therefore, these strategies need to be evaluated to ensure that they deliver the organisational business goals.

From the issues identified above, it is evident that there is a need for a detailed methodology for organisations interested in implementing KM. This methodology needs to be developed within the context of an acceptable framework. Based on the findings from the case study interviews, the features of the required framework have been identified and the framework has been developed as illustrated in Figure 5.1.

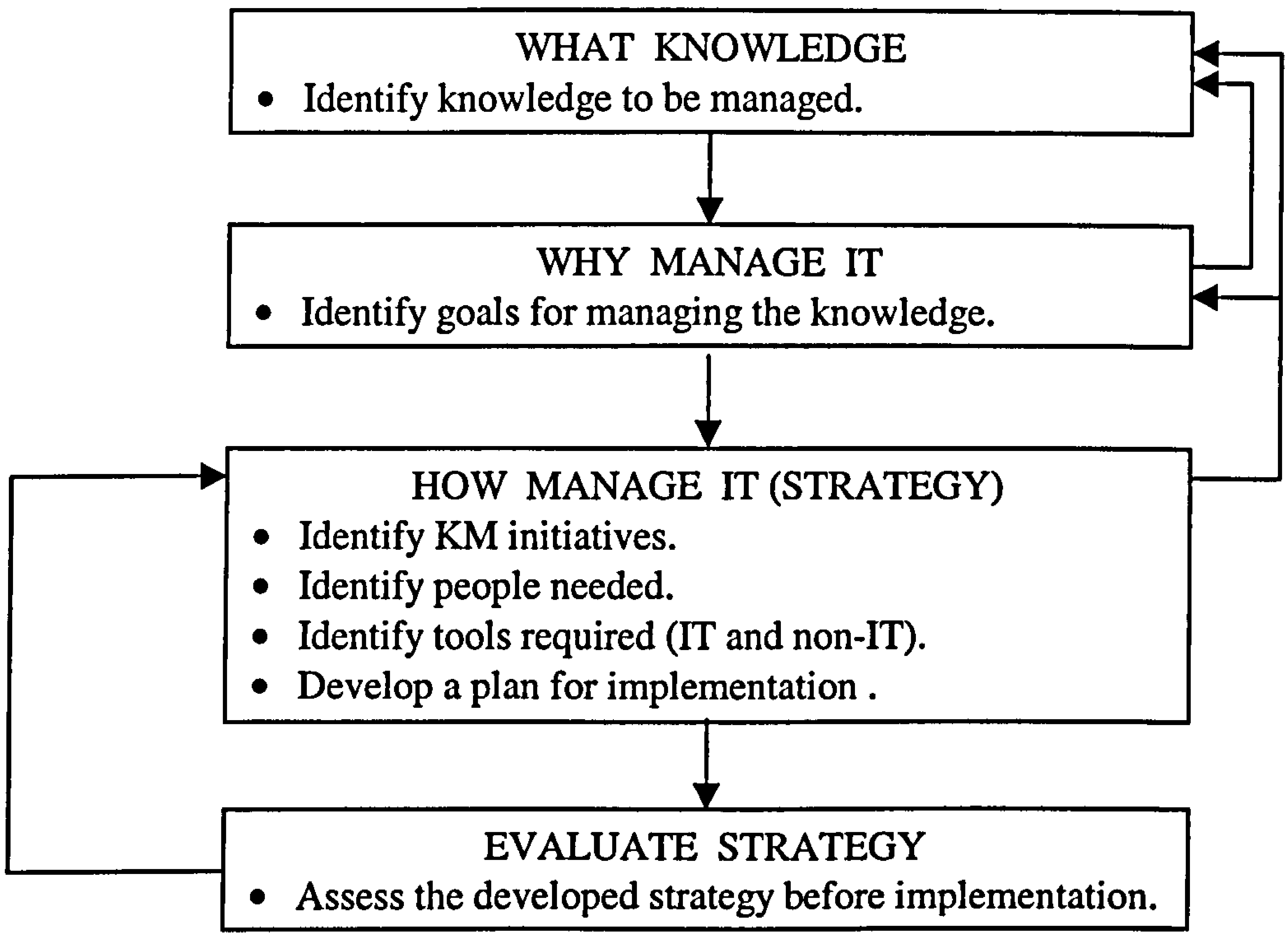

Figure 5.1: Conceptual framework for developing and implementing a KM strategy

5.4 SUMMARY

The aim of this chapter was to investigate the potential of KM for managing structural design knowledge. Findings from the five case study organisations show that they agree on the importance of KM for sharing structural design knowledge. Some of these organisations had already tailored their KM strategies towards structural design. However, several problems were faced during implementation. This informs of an urgent need for a framework that guides organisations through developing their KM strategies. Findings from the case study organisations helped in identifying the features of such framework. Based on the features identified, a conceptual framework for developing and implementing KM strategies was developed.

CHAPTER 6: METHODOLOGY AND PROTOTYPE DEVELOPMENT

6.1 INTRODUCTION

The conceptual framework developed in the previous chapter needs a detailed methodology that supports the implementation of its different stages. This chapter describes some of the existing KM methodologies with an analysis of their main features. It then presents a new methodology and describes how it was encapsulated into a prototype system.

6.2 EXISTING METHODOLOGIES

6.2.1 Description of Existing Methodologies

Methodologies are more detailed and comprehensive than frameworks where good methodologies are usually built on coherent frameworks (Rubenstein-Montano *et al.*, 2001). The conceptual framework developed in Chapter 5 (Section 5.3.4) requires a detailed methodology developed within its context so that it can be implemented effectively. The aim of this research is to develop a structured approach or a methodology for sharing structural design knowledge. But the case studies discussed and the conceptual framework developed show that organisations involved in structural design need a generic methodology that guides them through developing a KM strategy that suits their own needs. However, before any methodology can be developed, it is important to investigate some of the key existing methodologies.

Literature identifies several methodologies for developing and implementing KM strategies. Some of these were developed without being supported by a framework while others are being supported by coherent frameworks (e.g. Rubenstien-Montano *et al.*, 2000, Anumba *et al.*, 2001). Also, several methodologies were developed by organisations for their own use or as commercial products. For example, Xerox Connect (1999) (a consulting, integration and outsourcing arm of Xerox) developed their X5 methodology as a commercial product. This methodology links KM to business goals and consists of five steps:

- Discovery – identify business goals, challenges and opportunities;
- Definition – determine key requirements and scope of the project;
- Start up – develop detailed project plan;
- Delivery – implement the plan; and
- Evaluation – ensure that results meet expectations and facilitate knowledge transfer.

Dataware Technologies Inc (1998), provided a fairly detailed KM methodology consisting of the following stages:

- Identify the business problem;

- Prepare for change – obtain executive support and make the shift to a sharing culture;

- Create the team – people responsible for leading KM;

- Perform a knowledge audit – identify what knowledge is missing and organise the knowledge;

- Define key features required for the technological infrastructure;

- Implement KM activities – e.g. improve Return on Investment (ROI) on existing knowledge assets, enhance the process of locating applicable knowledge, enable faster access to critical knowledge, etc.; and

- Link people to knowledge – knowledge directory and content management.

Rubenstein-Montano *et al.* (2001), developed a detailed methodology consisting of several phases and multiple feedback loops. The methodology is based on a framework consisting of five KM phases namely strategise, model, act, revise and transfer. Each KM phase consists of specific procedures, sub-procedures and outputs. The procedures within each phase are illustrated below:

- Strategise – perform strategic planning, business needs analysis, and conduct cultural assessment;

- Model – perform conceptual modelling, and physical modelling;

- Act – capture and secure, represent, organise and store, combine, create, share, learn and loop back to capture and secure knowledge;

- Revise – pilot operational use of KM system, conduct knowledge review, and perform KM system review; and

- Transfer – publish knowledge, coordinate KM activities and functions, use knowledge to create value for the enterprise, monitor KM activities via metrics, conduct post-audit, expand KM initiatives, continue to learn and loop back through the phases.

Wiig *et al.* (1997) identified a methodology for implementing what they call the 'parts of KM'. The methodology emphasises the knowledge flows between these parts. This methodology was developed within the context of a framework consisting of four stages:

- Review – monitor organisational performance internally and against external benchmarks. Lessons learnt can be a useful tool;

- Conceptualise – Organise the different levels of knowledge in the organisation. Identify knowledge assets and link them to business processes that use them. Analyse strong and weak points in the knowledge inventory. A set of knowledge 'bottlenecks' should be identified;

- Reflect – establish a plan to address and mitigate the bottlenecks. Prioritise the parts of the improvement plan; and

- Act – implement the improvement plan. Different parts of the organisation may be responsible for performing different parts of the plan.

Tiwana (2000) introduced a well-structured framework described as the KM roadmap and consisting of ten steps. This framework is supported by a detailed methodology encapsulated in an entire book describing how it could be implemented (Tiwana, 2000). The methodology does not tell organisations what to do at every stage but explains what needs to be considered. The ten steps are:

- Analyse an existing infrastructure;

- Align knowledge management and business strategy;

- Design the knowledge management infrastructure;

- Audit existing knowledge assets and systems;

- Design the knowledge management team;
- Create the knowledge management blueprint;
- Develop the knowledge management system;
- Deploy, using the Results-driven incremental methodology;
- Manage change, culture and reward structures; and
- Evaluate performance, Measure ROI and incrementally refine the KM system.

Another well-structured methodology for developing KM strategies was developed by Anumba *et al.* (2001). It targets developers of KM initiatives at both tactical and strategic levels such as Knowledge Managers and Chief Knowledge Officers (CKOs). CLEVER (Cross-sectoral Learning in the Virtual Enterprise) is a framework supported by a detailed methodology for the development of KM strategies. It focuses on construction and manufacturing organisations as the end users but can be used by any business organisation. It consists of four stages where several decisions are required at every stage. Each of these stages has a clear aim and defined outputs. CLEVER uses many templates which provide a set of outcomes that form a part of the organisation's KM strategy. The main four stages of CLEVER are:

- Clarifying the KM problem and linking it to business drivers/goals;

- Identifying dimensions of the knowledge of interest;
- Identifying critical migration paths to achieve the desired dimension; and
- Developing initiatives for the KM sub-processes to address the knowledge migration paths.

6.2.2 Analysis of Existing Methodologies

A recent analysis of existing KM methodologies identifies three key limitations (Rubenstein-Montano *et al.*, 2001):

- Lack of an overseeing framework;
- Failure to address the entire KM process; and
- Lack of detail.

Lack of an overseeing framework and failure to address the entire KM process in existing methodologies indicate the need for a methodology that is both sound and complete. This methodology needs to have sufficient details. However, these details should not result in unnecessary complexity. From the case studies described in Chapter 5 and from the limitations identified by Rubenstein-Montano *et al.* (2001) a KM methodology needs to:

- Address all stages of a KM strategy;

- Contain sufficient details; and
- Be easy to use.

This section investigates the capacity of existing methodologies for fulfilling these criteria. Table 6.1 compares existing KM methodologies. The ratings are based on an analysis of the published information on each of these.

Table 6.1: Comparison between existing methodologies for developing KM strategies

		Xerox's X5 (1999)	Dataware (1998)	Rubenstein-Montano *et al.* (2001)	Wiig *et al.* (1997)	Tiwana (2000)	Anumba *et al.* (2001) CLEVER
1. Conceptual Framework	Identify what knowledge to manage		✓				✓✓✓
	Identify goals for managing knowledge	✓		✓		✓	✓✓✓
	Develop detailed strategy	✓	✓	✓	✓	✓	✓✓
	Evaluate the developed strategy	✓				✓	
2. Level of Detail		Not disclosed	Not disclosed	✓	✓	✓✓	✓✓✓
3. Ease of use		Not disclosed	Not disclosed				✓
Comments/Status		Commercial product	Commercial product	Academic Research	Academic Research	Academic Research	Academic Research being converted into a commercial product

✓ : Good
✓✓ : Fairly Good
✓✓✓ : Very Good

a. Addressing all stages of a KM strategy

The stages of a KM strategy have been identified in the conceptual framework developed in Section 5.3.4. These stages are shown in Table 6.1. The Table shows that no existing methodology addresses all four stages of a KM strategy. The methodologies developed by Xerox and Dataware Technologies are commercial products and therefore most of their details were not published and hence cannot be properly investigated. The methodology by Rubenstein-Montano *et al.* (2001) addresses stages 2 and 3 while that by Wiig *et al.* (1997) addresses stage 3 only. Tiwana's (2000) methodology addresses stages 2, 3 and 4. This methodology was well explained in his book but using it requires more understanding and investigation of the guidelines provided in the methodology. The CLEVER methodology addresses stages 1, 2 and some elements of stage 3. CLEVER contains built-in templates, which distinguish it from the other methodologies. These templates provide a highly structured way for guiding users to use the methodology and to select the most appropriate options. CLEVER addresses stages 1 and 2 very well but addresses stage 3 partly because it only provides generic models to be followed for developing KM strategies.

b. Level of detail

Some of the methodologies investigated were very detailed. Again, the methodologies by Xerox and Dataware Technologies were not published although some indications were given in the companies' websites. Tiwana and CLEVER methodologies are very detailed. Tiwana's methodology consists of ten steps where a description of how each step can be achieved is given. This methodology is more of an academic guide to the possible options available at the different stages of the KM lifecycle. The methodology describes these options in detail but does not provide sufficient guidance for identifying the most appropriate ones for a specific organisation. On the other hand, the level of detail in CLEVER 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) from implementing KM. CLEVER also consists of a group of knowledge migration paths (672 paths) based on the identification of which relevant KM sub-processes can be identified. Built-in generic models can then be used for developing KM strategy.

c. Ease of use

The methodologies identified by Xerox and Dataware technologies were not investigated in terms of their ease of use due to their inaccessibility barrier as commercial products. All the other methodologies were not easy to use due to several factors. The methodology by Rubenstein-Montano *et al.* (2001) had procedures and sub-procedures of how to achieve certain outcomes. These procedures and their sub-procedures need more structured approaches to guide users to achieve the required outcomes. The methodology by Wiig *et al.* (1997) is more generic and is therefore difficult to use without additional guidance. Tiwana's (2000) methodology is very difficult to use and requires extensive understanding of the different concepts described within the methodology. It contains many details, which depend on understanding the different options and what every one of them could do. The CLEVER methodology is rather easier to use when compared to the other methodologies because of its built-in templates. However, using this methodology requires multiple inputs resulting in input duplication, cross-relating items resulting in confusion, and selection from a large number of built-in models (e.g. 56 migration path cells, 672 migration paths etc) resulting in the consumption of a considerable amount of time.

6.2.3 Findings from the Analysis

The above analysis of existing methodologies for developing and implementing KM strategies shows different levels of maturity in these methodologies. The three criteria considered for the analysis confirm that:

- No methodology addresses all the stages of the conceptual KM framework developed in Section 5.3.4;
- The CLEVER methodology is very detailed and well structured and fully addresses stages 1 and 2 of the conceptual KM framework;
- All methodologies partly address stage 3 of the conceptual KM framework;
- Stage 4 of the conceptual KM framework has not received adequate attention; and
- No methodology is 'practically' easy to use.

The findings indicate the need for a better methodology that addresses all the stages required for developing and implementing a KM strategy. This methodology should include sufficient details and be easy to use. To introduce a robust methodology for developing and implementing a KM strategy the following five ' actions' are important:

1. *Considering the CLEVER methodology suitable for addressing stages 1 and 2 and some elements of stage 3.*

2. *Encapsulating CLEVER into a prototype system to facilitate its use and to refine it.*

3. *Examining the different elements of CLEVER and consider refining them if required.*

4. *Developing a new methodology that addresses the missing parts of stage 3 and at the same time addresses stage 4.*

5. *Encapsulating the new methodology into a prototype system.*

The subsequent sections describe how these actions were applied.

6.3 THE CLEVER METHODOLOGY

6.3.1 Overview of CLEVER

The aim of CLEVER was to support the development and implementation of KM strategies with special emphasis on construction and manufacturing organisations (Anumba *et al.*, 2001; Kamara *et al.*, 2001). In order to achieve its aim, CLEVER had several objectives:

- Identifying the KM problem and linking it to business drivers/goals;
- Identifying the current and required knowledge dimensions;
- Identifying the critical knowledge migration paths to achieve the required dimensions; and
- Using generic models for developing strategies for the migration paths identified.

These objectives formed the four main stages of CLEVER as illustrated in Figure 6.1. The first stage, "identify KM problem", aims to clarify the overall KM problem within a business context to deliver a refined KM problem and a distilled set of KM issues from the overall problem. The second stage, "identify current and required knowledge dimension", aims to identify the current and required status of a range of knowledge dimensions to highlight the problem areas, which need more focus so as to deliver a set of concerns or specific KM components of the problem. The third stage, "identify critical knowledge migration paths", aims to identify a set of the most critical paths for each specific KM problem and an overall set of paths for the whole problem. The last stage, "Select Generic KM Sub-processes", aims to help in selecting the appropriate models for developing the strategies. These models can be tailored to a particular organisations need. Each stage consists of a main template, guidelines and a glossary.

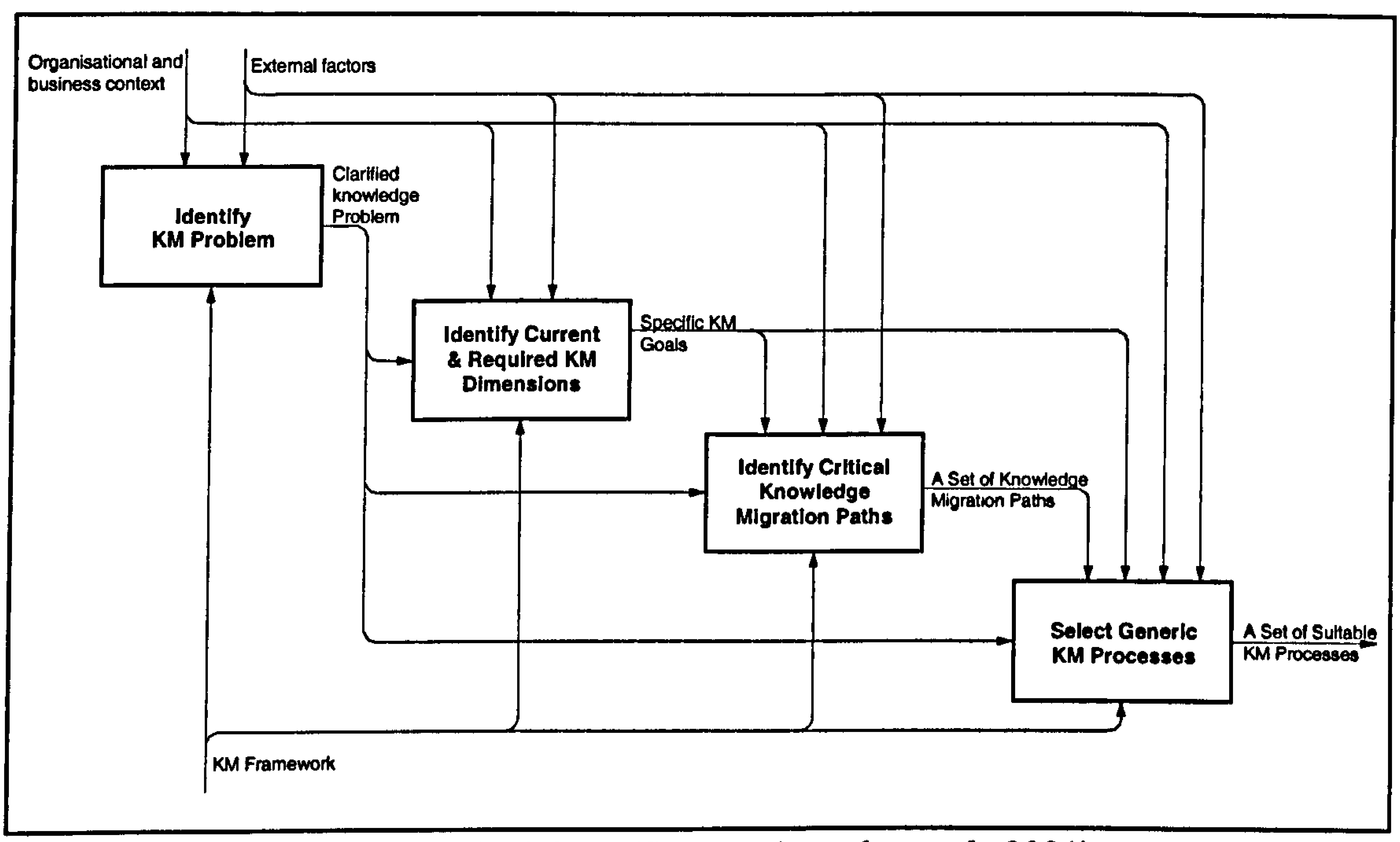

Figure 6.1: The CLEVER Methodology (Source: Anumba *et al.*, 2001)

Each of the CLEVER stages has an aim and outcomes. The specific aims and outcomes are shown in Table 6.2.

Table 6.2: Specific aims and outcomes of CLEVER

Stage	Aim	Outcomes
1. The Problem Definition	To define the overall KM problem within a business context	• Clarification of the KM problem • Distillation of a set of KM issues from the overall problem
2. Identify Current and Required knowledge Dimensions	To identify required status on a range of knowledge dimensions and to highlight areas of future focus.	• Set of specific organisational KM goals
3. Identify Critical Knowledge Migration Paths.	To identify critical migration paths for each organisational goal	• Set of key migration paths for each organisational goal • Overall set of migration paths for all the organisational goals
4. Select generic models to develop KM Strategy	To help in selecting the appropriate KM models to develop a strategy for the identified goals and their migration paths	• Set of appropriate KM models, which, when tailored to a particular organisations need, will form its km strategy

CLEVER consists of four inter-related stages. These are described below.

Stage 1: The Problem Definition

This stage represents an approach for clarifying the overall KM problem within an organisational business context. It aims to assist users to 'think through' the problem in a 'structured way'. It covers issues that are important for the proper definition of KM problems. In order to address these issues, the process consists of several activities (Figure 6.2) each comprising a set of questions that address relevant KM issues. The developed approach requires the user to (Anumba *et al.*, 2001):

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

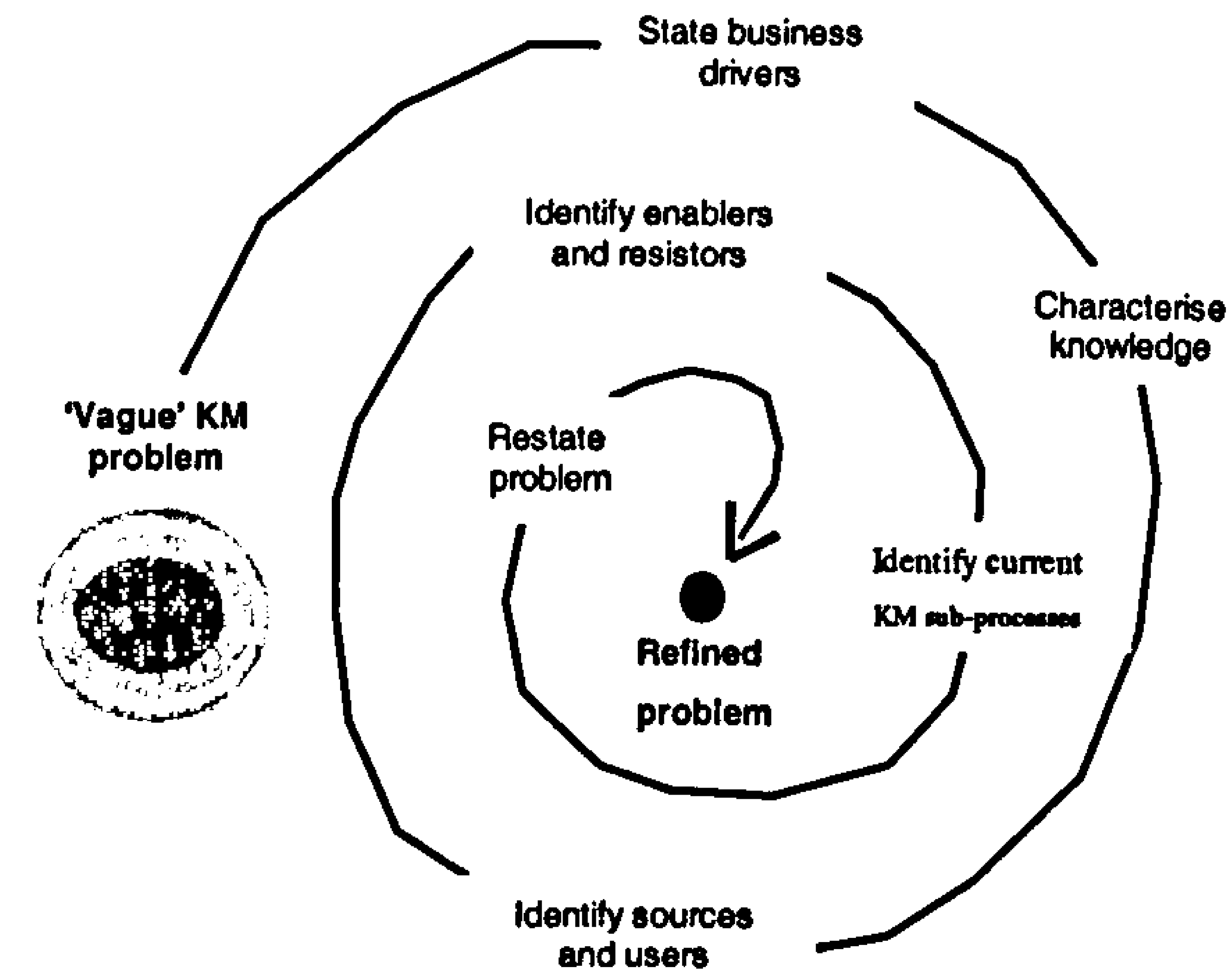

Figure 6.2 Process of clarifying KM problems. Reproduced from: Anumba *et al.* (2001)

Stage 2: Identify Current and Required Knowledge Dimensions

This stage helps in identifying the organisational goal(s) from implementing KM. It is used to confirm the knowledge dimensions of the current status and to identify the required status with regard to organisational strategy and policy. A clear set of organisational goals are extracted and prioritised, and these are used to identify migration paths for each identified goal.

Stage 3: Identify Critical Knowledge Migration Paths

This stage focuses on defining how the organisation proceeds from the current to the required knowledge status. A set of 56 pre-defined templates is included to help in identifying the knowledge migration paths. Each organisational goal is considered at a time and the overall set of migration paths are mapped out for the overall KM problem under consideration.

Stage 4: Select Generic Models to Develop KM Strategy

This stage deals with the selection of appropriate KM process(es) to move along each migration path. Thus for each migration path defined in the previous stage, the relevant KM sub-process is selected from a list of sub-processes. Organisational enablers/resistors that may affect the implementation of the selected process are also identified. Every KM process is supported by a set of generic models that can be followed to develop a KM strategy.

6.3.2 Application of the Methodology

The implementation of each stage of the methodology requires the use of various pre-defined templates. These are: the problem definition template (PDT); the knowledge dimensions guide; the migration path identifier; and the generic KM process models.

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 based on the understanding gained through using the template.

The Knowledge Dimensions Guide

The 'knowledge dimensions guide' consists of eight knowledge dimensions where every dimension is described by two contrasting words e.g. tacit versus explicit. Also each dimension is complemented by information on the organisational implications of the dimension. 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 e.g. to transfer tacit knowledge to be more explicit in order to aid the decision making process. It is also possible to prioritise the goals based on the 'distances' between the current and required status on the dimensions' scales.

The Migration Path Identifier

The 'migration path identifier' consists of 56 cells that define the possible migration paths for the knowledge dimensions. Every cell allows selecting from 12 possible paths. The cells also include descriptions of each path so that users can easily identify the relevant paths.

KM Process Models

The last set of templates in CLEVER is the 'KM process models'. 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.

6.3.3 Objectives and Features of the CLEVER Prototype

The second 'action' identified in Section 6.2.3 requires encapsulating the CLEVER methodology into a prototype system to facilitate its use. The aim of prototype is to simplify the format and use of the CLEVER methodology and to refine it. To achieve its aim, the prototype was designed to address the following objectives:

- clarification of the knowledge that needs to be managed;
- identification of the organisational goals from managing the knowledge;
- development of a KM strategy; and
- future integration of the system with other systems.

To achieve the outlined objectives of the CLEVER prototype, the system was designed to:

- Provide sufficient and user-friendly guidance on how to use the system;
- Allow for convenient entry, viewing, and editing of information at any stage;
- Facilitate the refinement of a KM problem;
- Allow for easy identification of current and required status of knowledge dimensions;

- Facilitate the identification and prioritisations of organisational goal(s) from implementing KM;

- Facilitate the investigation of every knowledge dimension against other dimensions;

- Allow for easy selection of knowledge migration paths;

- Allow for developing KM strategies for the generic models within the KM process;

- Facilitate the generation of a report that can be viewed at the different stages; and

- Allow for future integration with other KM tools.

6.3.4 Prototype Software Development

The development of prototype software follows two approaches namely evolutionary prototyping and rapid prototyping (CrinINION, 1991). Evolutionary prototyping follows very structured approaches for building the prototype and requires detailed documentation of the development process.

Software rapid prototyping is 'a dynamic, interactive, visual model of the user's requirements as an implemented design' where a useful rapid prototype has the following characteristics (Connell and Shafer, 1995):

- built quickly and demonstrated early;

- provides mechanisms for users to try out proposed parts of a system, and then give direction for additional features and refinement;

- easy to modify; and

- initially intentionally incomplete.

Several implementation environments can facilitate the development of prototypes and general systems. These include (Britton and Doake, 1996):

- Programming in a procedural, third-generation language (3GL) (e.g. FORTRAN) where the programmer has to carry out detailed design of how every task is performed;

- Programming in a problem-oriented fourth generation language (4GL) (e.g. C, C++, MS Visual Basic) where the programmer merely has to define what must be done;

- Using a general-purpose integrated package which incorporates facilities such as word processing, spreadsheets, database and report generators; and

- Use and customisation of specific application (commercial packages).

In the development of the prototype, Object Oriented Programming (OOP) was selected as the programming paradigm. OOP is not tied to any particular programming language and theoretically, almost any language can be used for OOP. A number of such languages are currently available. Microsoft Visual C++, Borland Delphi, and Microsoft Visual Basic are most commonly used by Microsoft Windows developers. Therefore OOP implementation by other software procedures closely follow the guidelines set down by Microsoft and Borland.

Microsoft Visual Basic, version 6, was selected to be the environment for the development and the selection was based on the following rationale:

- As one of Microsoft products, it allows future integration with potential software products such as Word, Excel, Access, Visual C++, and Visual J++;

- Microsoft Visual Basic is more self contained than Visual C++ and Borland Delphi; and

- It is supplied as a complete programming language containing all requirements to create a fully-functioning, stand alone Windows EXE applications.

6.3.5 Development of CLEVER within MS Visual Basic

a. System Architecture

To accomplish the objectives of the prototype, the system architecture, shown in Figure 6.3, was developed. The four main elements provide a means for developing a KM strategy. These elements are 'KM Problem', 'KM Goals', 'Migration Paths', and 'Developing Strategy'. The solid arrows linking the four elements indicate that entry and viewing of information is done forwards. However, the dashed arrows at the bottom of the elements show that the user can go backwards to edit previous input for any element or part of an element. The arrows linking the elements to the report show that the information, once entered, is immediately sent to the report and is instantly modified if input is edited.

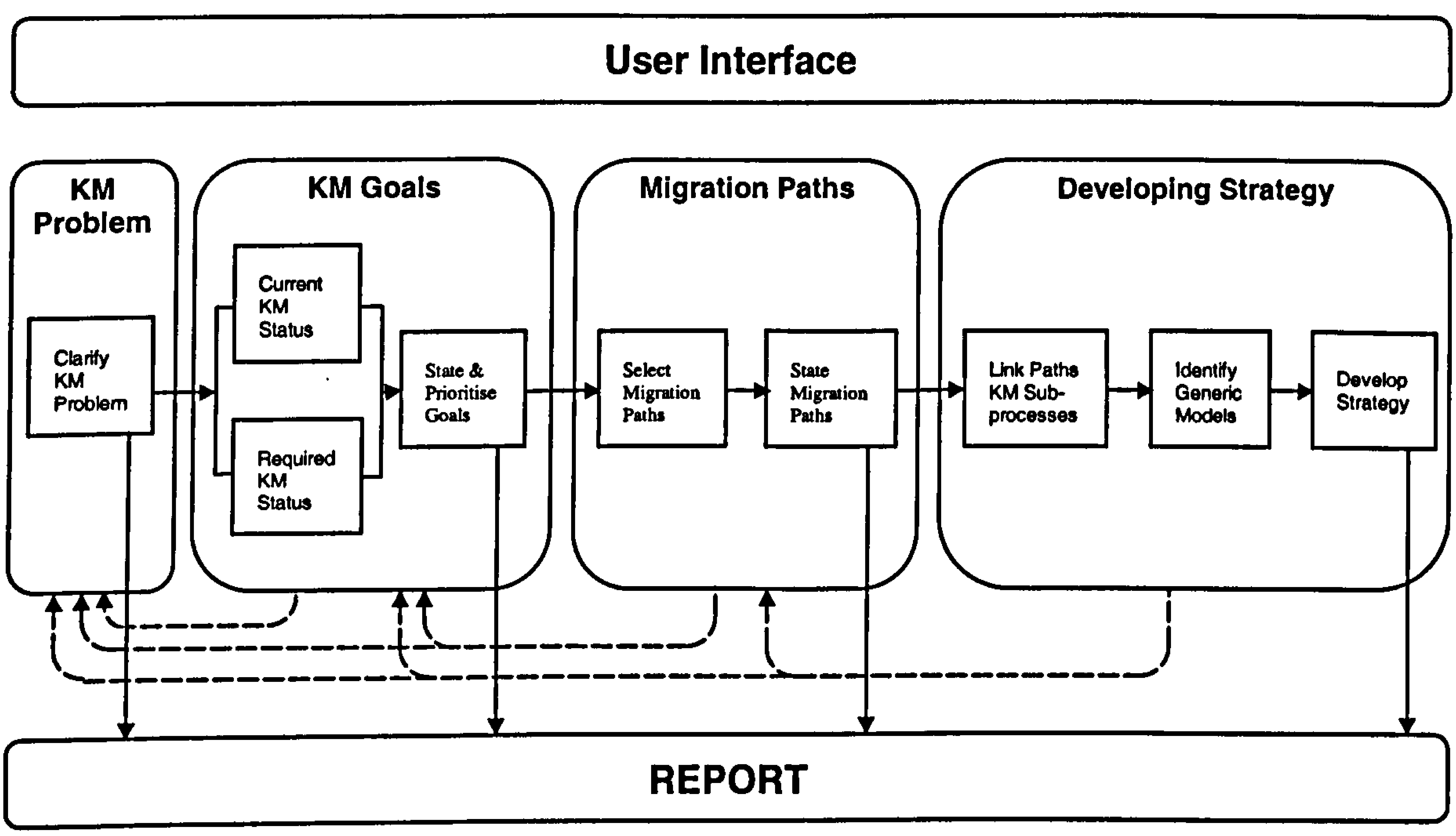

Figure 6.3: System architecture of the CLEVER prototype

b. User-Interface Design

The prototype was developed in Microsoft Visual Basic by means of creating, forms, macros, and reports. Users interact with the system through the main forms. Other forms were embedded within the main forms and activated by the use of command buttons. Forms are used to input, edit, and view the information. Three main types of forms were developed namely; input forms, output forms, and help forms. The help forms, embedded within the input forms, were used to allow for effective guidance for using the system. Controls, event procedures and general procedures were used to design the forms. Sliders, command buttons, option buttons, labels, text boxes, and some drawing features were also used.

c. Code Development

MS Visual Basic has automatic code generation capability. The codes are generated automatically when, for example, the application forms and controls are created. Other codes for handling decisions have been developed. Some of the codes developed for handling major decision steps are listed in Appendix A3.

6.3.6 Refinement of CLEVER

The third 'action' identified in Section 6.2.3 requires to examine the different elements within CLEVER and to refine it. This can be best done through using the automated version of CLEVER. This section describes the approach used to refine the CLEVER methodology through using its automated version.

1. Refinement Approach

Organisations from construction and manufacturing industries were approached in order to refine the prototype. Selected organisations were contacted to establish willingness to participate, then arrangements were made for workshops. Four workshops were conducted. These included 12 staff members and consisted of 'guided' and 'free use' of the prototype.

Case F[1]

This four-hour workshop was conducted in the organisation's office with 6 participants. The work experience of the participants ranged between 6 and 35 years. Participants consisted of the Key Account Manager (North America), Quality Manager, Sales Office Manager, Business Development Manager, Technical Manager, and Quality Manager. The workshop started with a presentation on KM because some of the participants were new to the concept. This was followed by another presentation on the CLEVER methodology. A demonstration about the prototype system was then made. The participants made use of the prototype by working through a specific problem on a consensus basis. They also completed a questionnaire at the end of the workshop.

Case G

Two participants were involved in a three-hour workshop in the company's office. The participants were the Continuous Improvement Manager and Business Improvement Manager. They had 14 and 36 years of experience within the construction industry. Both participants were involved in a KM initiative within the organisation. The workshop consisted of a presentation on the CLEVER methodology and a demonstration on the prototype system. Participants then used the prototype to work on a specific KM problem, with one of them having hands-on-use in inputting information to the system to allow for direct interaction. Participants also completed a questionnaire at the end of the workshop.

[1] Case-study organisations start with the letter (F) to avoid confusion with those described in Chapter 5.

Case H

The Knowledge Manager of a leading construction organisation was involved in a two-hour demonstration. The participant had 15 years of experience within the construction industry. The participant was one of the CLEVER project collaborators and therefore had a background of the paper format of CLEVER. The demonstration was followed by an open discussion of how the methodology could be improved. He also completed a questionnaire.

Case I

This two-hour workshop involved three participants. The participants were the Knowledge Manager, Knowledge Editor, and Research Manager. They had work experience, within the construction industry ranging between 15 and 25 years. All participants were involved in a KM initiative within the company. The workshop consisted of a presentation on the CLEVER methodology followed by a demonstration of the prototype. The participants then used the prototype to go through a specific problem after which they completed a questionnaire.

2. Refinement Questionnaire

A questionnaire (Appendix A4) was designed to obtain the views of end-users on the usefulness of the methodology and how it could be improved. The questions were based on a five-point-scale from poor to excellent. The questionnaire was divided into sections covering the prototype subsystems and a general section on the whole system. The questions on the subsystems covered their specific features and how well they supported the system's functionality. The section on the overall system, on the other hand, covered issues on the management of the system interaction, its effectiveness, and clarity and accuracy of outcomes. At the end of every section, participants were allowed to suggest how the system could be improved. They were also encouraged to add further comments at the end of the questionnaire.

3. Findings

The workshops proved that the CLEVER methodology is very useful for an organisation or a unit within an organisation. It is also agreed that encapsulating the methodology into a prototype system enhances its functionality and makes its use far easier. The prototype delivers a well-defined knowledge management problem, goals for implementing KM, knowledge migration paths, and generic models to be followed for developing a KM strategy. The methodology was very much welcomed by the participants involved. Given the small sample, this outcome cannot be generalised at this stage. It, however, gives an indication that the system can be easily used either in its current form or by linking it to other KM methodologies.

It is also evident from the response received from participants that the CLEVER methodology and its supporting prototype:

- Provide a potential tool for clarifying 'vague' KM problems into specific issues;

- Facilitate the identification of the organisational goals from KM;

- Give a very structured approach towards developing a KM strategy;

- Present a generic prototype that can be used by any business organisation; and

- Offer a new KM tool that organisations would find very useful.

In fact, all participants responded to the questions by giving scores between three and five with most of the questions given scores of four out of five. On the other hand, some modifications were suggested to improve the methodology and its supporting system. Suggestions for improving CLEVER Methodology are:

1. To ensure consistency in the terminologies used (e.g. consistent names of KM sub-processes in stages 1 and 4);

2. To link the problem definition template to the subsequent stages; and

3. To combine the KM sub-processes 'modify' and 'maintain' to one sub-process and to combine the 'propagate' and the 'transfer' sub-processes.

The first suggestion was addressed through reviewing all terminologies used. Few were found to cause the confusion e.g. the use of 'group knowledge' and 'shared knowledge' to mean the same thing. These have been addressed. The second suggestion was addressed through recalling the main elements of the problem definition template (business drivers, enablers and resistors matrix and current KM sub-processes) when developing a KM strategy. The third suggestion was done.

Suggestions for improving CLEVER Prototype are:

1. To show the 'Organisational Goal' next to the relevant knowledge dimensions;

2. To show the 'Organisational Goal' when selecting knowledge migration paths;

3. To add more help commands to explain the terminologies in the system and to give more description on how to use it; and

4. To allow users to 'add' their own dimensions/ideas to the given ones.

All the suggested modifications were addressed. However, it should be noted that the fourth suggestion might not always be useful. For example, if a knowledge dimension is added to the existing eight dimensions, the user cannot identify the knowledge migration paths for that dimension, as these are built-in within the system. However, the system will give a warning when the user adds a new dimension.

6.3.7 CLEVER and the Objectives and Features of the Prototype

The CLEVER prototype was designed to satisfy the required objectives and features for the prototype, set out in Section 6.3.3. A summary of the desired features of the prototype and the way in which they were achieved is shown in Table 6.3.

Table 6.3: Summary of how desired features of the CLEVER prototype were achieved

Desired	How achieved
Provide sufficient and user-friendly guidance on how to use the system	• Whenever required, help buttons where embedded within input forms to provide guidance on completing the forms
Allow for convenient entry, viewing, and editing of information at any stage	• Designed forms allowed the display and editing of stored data • Command buttons inserted in the forms allowed easy navigation between the forms at any stage of the activity
Facilitate the refinement of a KM problem	• A command button, in the last form, allows for re-stating the KM problem, which is then fed back to the main form
Allow for easy identification of current and required status of knowledge dimensions	• Two sliders are used select the current and required knowledge status
Facilitate the identification and prioritisations of organisational goal(s) from implementing KM	• Locations identified for the two sliders are used to state the organisational goals • Distance between the two sliders is used to calculate its priority
Facilitate the investigation of every goal against other goals	• A 'Go' button next to every goal activates the relevant forms
Allow for easy selection of knowledge migration paths	• Option buttons guided by arrows and written text help in identifying the knowledge migration paths
Allow for developing KM strategies for the generic models within the KM process	• 'Labels' describing the generic KM sub-processes can be activated by clicking them • Clicking a label would activate a form for information entry, which once entered, is immediately sent to a report form
Facilitate the generation of a report that can be viewed at the different stages	• A 'Report' button can be activated at the end of any of the following stages: defining the KM problem, identifying the KM goals, stating the migration paths, identifying the KM sub-processes, and developing KM strategy
Allow for future integration with other KM tools	• As a Microsoft product, Visual Basic can be easily linked to other packages

6.4 THE IMPAKT METHODOLOGY

6.4.1 Overview on IMPaKT

The fourth 'action' identified in Section 6.2.3 requires the development of a new methodology that addresses the missing parts of stage 3 and at the same time addresses stage 4 of the conceptual framework developed in Section 5.3.4. This led to the development of the IMPaKT (Improving Management Performance through Knowledge Transfer) methodology.

IMPaKT is a new methodology developed within a research project entitled Knowledge Management for Improved Business Performance (KnowBiz). The methodology was developed by the KnowBiz Team, which includes the author. His responsibility focused on aspects related to the assessment of the business problem in the context of a knowledge management strategy. This included development of the KM Tool Selector, refinement of the IMPaKT methodology and the development and implementation of the software architecture for the IMPaKT methodology.

IMPaKT is a three-stage methodology for linking KM to performance measurement (Figure 6.4). The aim of the methodology was to assess the impact of knowledge management on organisational performance. It has the following objectives:

- Determining if the business strategy of an organisation has a KM dimension;
- Developing a KM Strategy; and
- Evaluating the impact of KM strategy on the performance of the organisation.

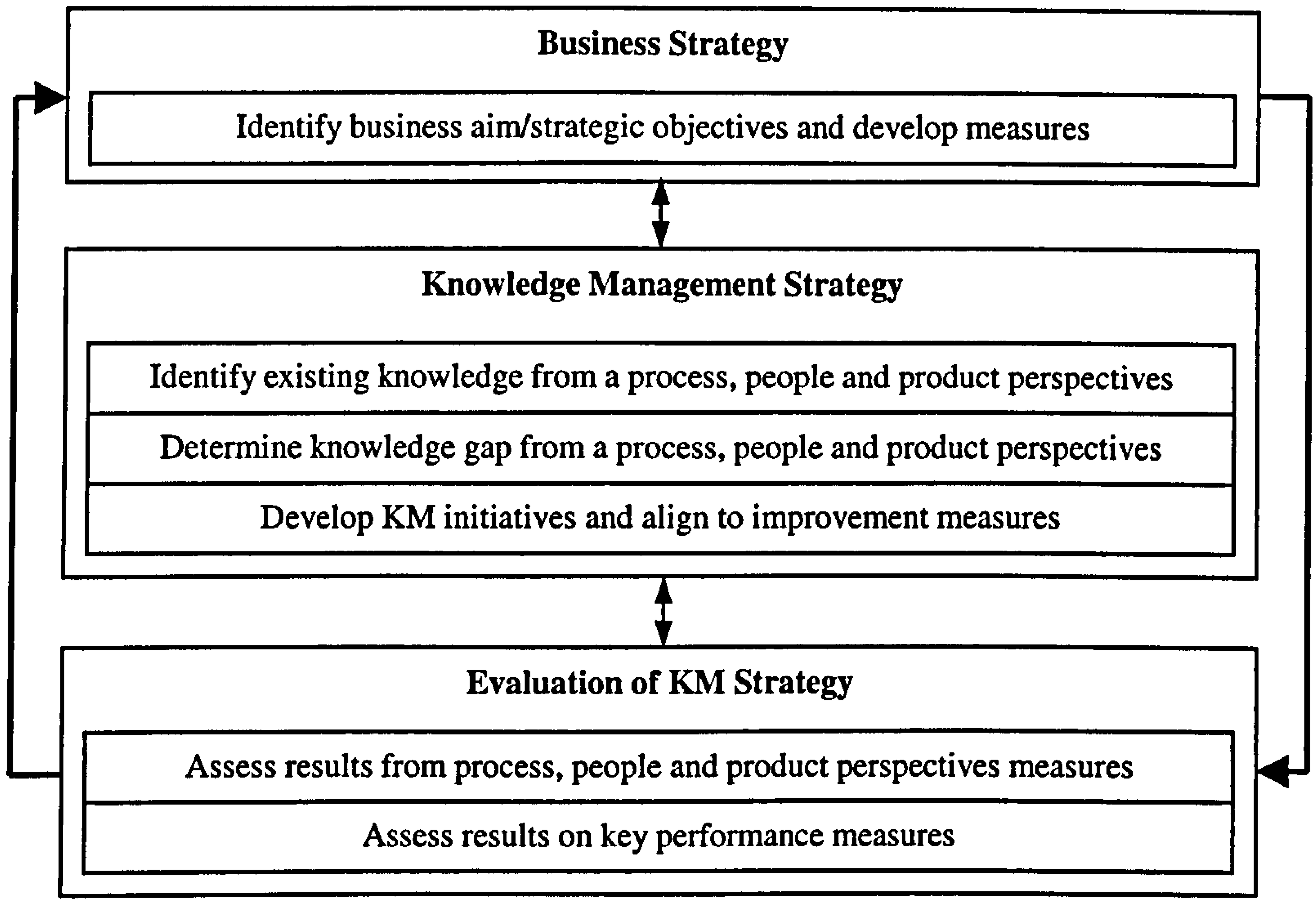

Figure 6.4: Framework for the IMPaKT methodology

Each of the IMPaKT stages has an aim and outcomes as shown in Table 6.4.

Table 6.4: Specific aims and outcomes of IMPaKT

Stage	Aim	Outcomes
Identification of Business Strategy	To provide a structure for formulating a strategic business plan by defining strategic objectives and developing performance measures for monitoring business improvement	• Business improvement plan with performance targets and measurable indicators to assess progress
Development of KM Strategy	To clarify whether a business problem has a knowledge dimension and to develop specific KM initiatives to address the business problem	• KM strategic plan with a set of initiatives and implementation tools to support business improvement
Evaluation of KM Strategy	To provide a structured approach for evaluating the impact of KM initiatives on business performance	• Evaluation and review plan with expected impact of KM initiatives on business performance and implementation priorities

IMPaKT stages are described below.

Stage 1: Identification of Business Strategy

Stage 1 was aimed at providing a structure for formulating a strategic business plan by identifying the external business drivers, defining strategic objectives, identifying critical success factors and developing measures for monitoring performance improvement. The first step in Stage 1 is to choose a business problem and to analyse the knowledge dimension of the problem. The next step involves putting the business problem in its strategic context by relating it to the strategic objectives, critical success factors and business drivers. The selection of measures for performance monitoring is also a crucial aspect of Stage 1. The improvement measures are driven by the firm's strategy and will therefore reflect the strategic objectives of the organisation.

Stage 2: Development of KM Strategy

The aim of Stage 2 is to clarify whether the business problem has a knowledge dimension and to develop specific KM initiatives to address the business problem. First it is important to identify the KM sub-processes involved. The next step is to identify the KM initiatives required. KM initiatives are systematic goal-directed efforts for addressing a KM problem in order to achieve business improvement. Then it is necessary to identify the KM tools required for implementing the initiatives. It is also important to develop an action plan of what is to be carried out before a KM strategy is implemented. The action plan is developed against the reform needed, resources required and results monitoring mechanism.

Stage 3: Evaluation of KM Strategy

The aim of Stage 3 is to provide a structured approach for evaluating the impact of KM initiatives on business performance. The outcome of Stages 1 and 2 is a business improvement strategy underpinned by KM. Two distinct types of performance measures are identified; measures of effectiveness and measures of efficiency. Measures of Effectiveness are outcome-based measures relating to the degree to which target performance measures are achieved but does not take account of the cost of implementation. Measures of Efficiency are process-based measures relating to the nature of the KM system used in implementation and are a ratio of expected benefit or utility per unit of KM investment.

6.4.2 Application of the Methodology

The implementation of each stage of IMPaKT requires the use of various tools. These are: a Glossary, KM Problem Diagnostic Questionnaire, KM Tool Selector (SeLEKT), Action Plan Developer, Cause and Effect Map, KM Cost and Benefit/Utility Matrices, and Evaluation Method Identifier.

Glossary

The Glossary consists of the terminologies used by the methodology to ensure that users understand these terminologies in the relevant context. The glossary does not only contain definitions but also includes examples supported with further explanations.

KM Problem Diagnostic Questionnaire

This questionnaire consists of several questions reflecting the different sub-processes of KM. Based on the answers, users can identify the KM sub-processes that are involved in the business problem already identified. For example, giving a 'yes' answer to questions such as 'is there difficulty in transferring tacit knowledge across the organisation?' or 'is there problem in the learning process across the organisation' means that the organisation's business problem relates to the KM sub-process 'knowledge sharing'.

KM Tool Selector-SeLEKT

SeLEKT (Selecting and Locating Effective Knowledge Tools) is a comprehensive database of KM tools. These 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. Three dimensions have been identified as critical for the selection of the most appropriate tools. These are 'knowledge transfer domains' (between internal and external), 'knowledge ownership forms' (between individuals and groups) and 'knowledge conversion types' (between tacit and explicit). Each dimension has four possible combinations (e.g. internal to internal, internal to external, external to internal, and external to external) and all three dimensions together have 64 possible combinations as shown in Table 6.5. The shaded cells in the right bottom corner represent illogical combinations in this context, as organisations are not expected to transfer knowledge from an 'external' source to an 'external' destination.

Table 6.5: KM Dimensions and their possible combinations (The SeLEKT Approach)

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

After an organisation's KM dimensions have been identified, a database is searched to identify the most appropriate tools for every KM sub-process. Two databases are included; one for technologies and another for techniques. The database of technologies consists of technology categories and their supporting software applications for every KM sub-process. The database of KM technologies was developed in three stages:

- Identifying Technology Categories and Software Applications that support the KM sub-processes – Appendix A5 (light version) and Appendix A6 (full version). This was carried out based on subjective analysis[2];

- Identifying the KM dimensions supported by every Technology Category – Appendix A7. This was also based on subjective analysis; and

[2] The subjective analysis was based on: literature review, software exhibitions, interviews with vendors, product brochures, websites and demo versions of products.

- Relating the Technology Categories to the appropriate combinations of KM dimensions – Appendix A8.

Figure 6.5 illustrates the SeLEKT approach for selecting KM technologies.

A similar approach is followed for selecting the KM techniques. However, in this case, the last stage in Figure 6.5 will consist only of two elements: 'relevant KM sub-processes' and 'techniques for the KM sub-processes'. The database of KM techniques was developed in three stages:

- Identifying the KM sub-processes and their supporting techniques – Appendix A9;

- Identifying the Dimensions supported by each KM Technique – Appendix A10; and;

- Relating KM Techniques to the appropriate combinations of KM Dimensions – Appendix A11.

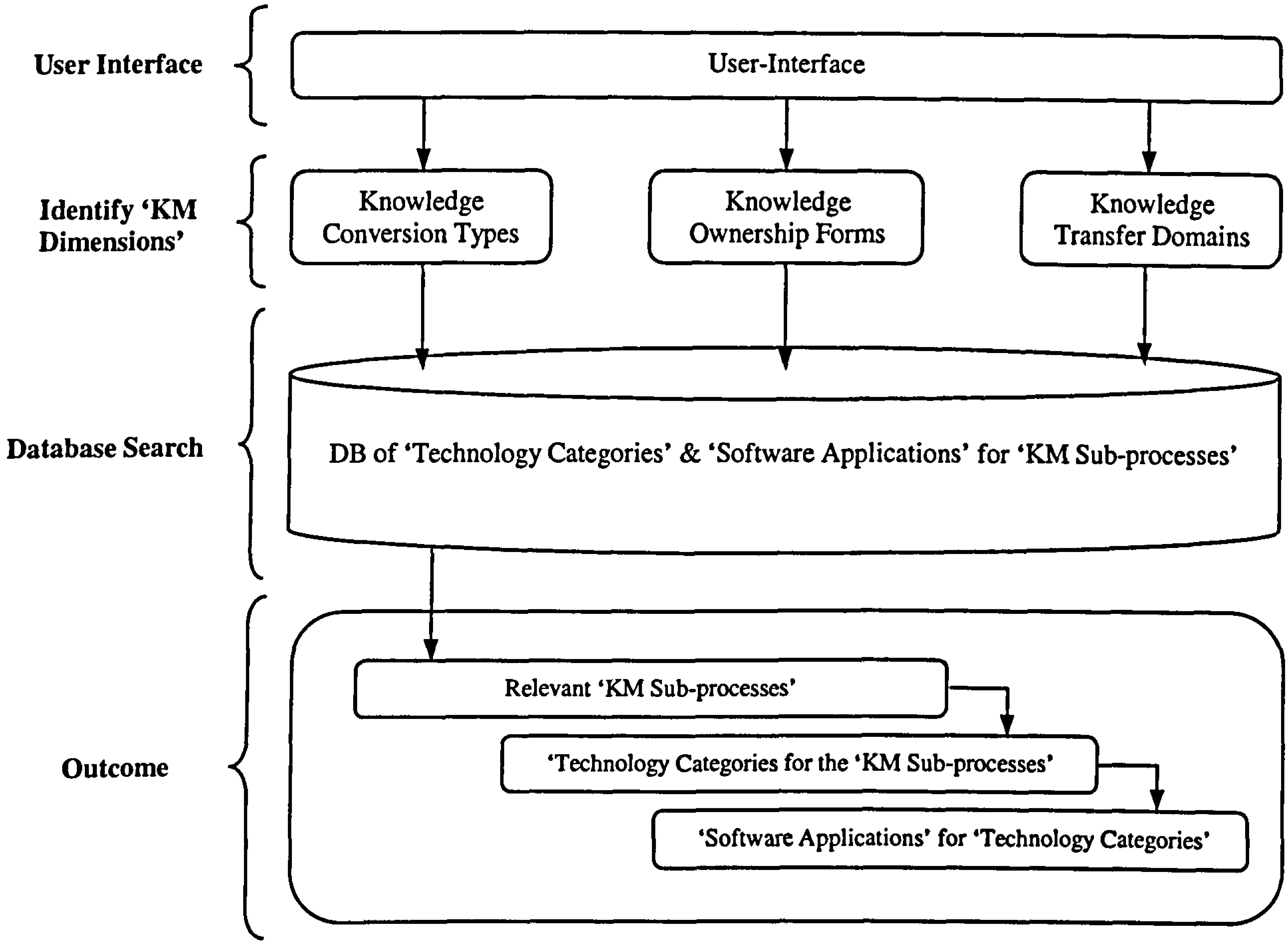

Figure 6.5: The SeLEKT approach for identifying KM technologies

KM Action Plan Developer

The KM Action Plan Developer consists of three sets of questions about the reform needed, the resources required and the results monitoring mechanisms. Based on the answers to the questions, users can identify if they are ready to implement KM and can recognise the actions that they need to carry out.

Cause and Effect Map

This map is developed to encourage users to identify the relationship between three main issues: the strategic objectives, KM initiatives and performance measures. Identifying the relationships between these makes it easier to recognise the KM initiatives that have more influence on the objectives and helps in understanding their interaction with the performance measures.

KM Cost and Benefit/Utility Matrices

These are two matrices namely the KM Cost Checklist and the KM Benefit/Utility Checklist. They are used for calculating the effectiveness and efficiency of the KM initiatives. Identifying the effectiveness and efficiency of the KM initiatives helps in prioritising them.

Evaluation Method Identifier

The evaluation guide is a flowchart that helps in identifying the most appropriate evaluation method. The guide includes four evaluation methods: cost minimisation analysis, cost benefit analysis, cost effectiveness analysis and cost utility analysis.

6.4.3 Objectives and Features of the IMPaKT Prototype

The fifth 'action' identified in Section 6.2.3 requires the encapsulation of the new methodology (IMPaKT) into a prototype system to facilitate its use. The prototype was designed to address the following objectives:

- Facilitate the development of a business improvement strategy;

- Enable the development of detailed KM strategy;
- Evaluate the impact of the KM strategy on the performance of the organisation; and
- Allow future integration of the system with other systems that could complement it.

To achieve the outlined objectives of the IMPaKT prototype, the system was designed to have the following specific features:

- Provide sufficient and user-friendly guidance on how to use the system;
- Allow for convenient entry, viewing, and editing of information at any stage;
- Allow for easy assessment of performance gaps;
- Facilitate the identification of KM sub-processes involved in a business problem;
- Allow for the easy search and identification of KM tools based on the specific requirements of the organisation;
- Facilitate the development of an action plan and status of preparedness;

- Allow the easy mapping of relationships between strategic objectives, KM initiatives and performance measures;
- Facilitate the prioritisation of KM initiatives;
- Facilitate the generation of a report that can be viewed at the different stages; and
- Allow for future integration with other KM tools.

6.4.4 Development of IMPaKT within MS VisualBasic

a. System Architecture

The system architecture shown in Figure 6.6 was developed to achieve the objectives of the prototype. The three main stages provide a means for developing a business improvement strategy, developing a KM strategy and evaluating the strategy. The first stage requires more input from the user while the second and third stage are more guided by the system's built-in templates. The solid arrows linking the three stages indicate that entry and viewing of information is done forwards. However, users can go backward to modify input at any stage of the project. The dashed arrows show the interaction between the individual elements of the system. The arrows linking the stages to the report show that the information, once entered, is immediately sent to the report and is instantly modified if input is edited.

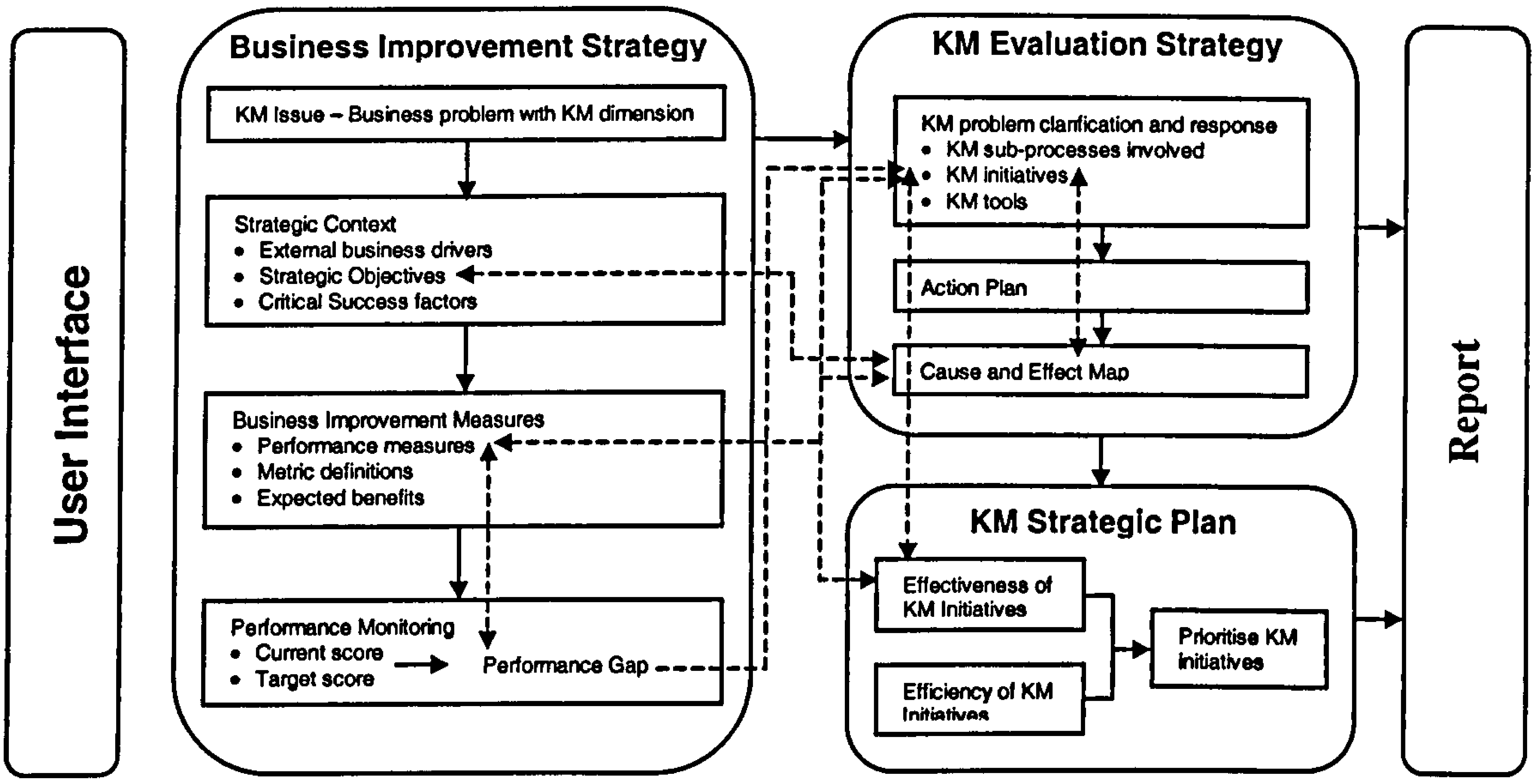

Figure 6.6: System architecture of the IMPaKT prototype

b. User-Interface Design and Code Development

Development of the user-interface and programming code followed a similar approach to that adopted for CLEVER prototype. Codes developed for handling major decisions steps are also shown in Appendix A3.

6.4.5 Refinement of IMPaKT

The IMPaKT methodology was investigated to explore the need for further improvement. This was carried out through presenting the prototype system to industrial participants to capture their views on how it could be refined.

1. Refinement Approach

To refine the developed methodology a three-hour workshop consisting of participants from industrial organisations was undertaken at Loughborough University. Four companies were involved. The first was a leading construction company where the participant had 20 years of experience within the industry. The participant was the organisation's Business Improvement Manager. The second organisation was represented by a Senior Research Engineer having 11 years of experience in designing building projects. The third was an organisation specialised in civil engineering works where the participant who is the Head of Business Systems had 30 years of experience and was involved in many international projects. The fourth was an organisation that also specialises in civil engineering works. The participant was the Business Improvement Manager and had an experience of 11 years within the industry. The workshop started with a 30-minute demonstration of the developed methodology then an open discussion of nearly two hours took place. Participants then completed a questionnaire.

2. Refinement Questionnaire

Obtaining views of the participants about the methodology and how it could be improved was through the use of a questionnaire (Appendix A12). The questions were based on a five-point-scale from poor to excellent. The questionnaire was divided into four sections: the Business Improvement Strategy; KM Strategic Plan; the KM Evaluation Strategy and a General Section on the whole system. The questions covered the specific features of the system and how well they supported its functionality. The general section, on the other hand, covered issues on the management of the system interaction, its effectiveness, and clarity and accuracy of outcomes. At the end of every section, participants were allowed to suggest how the system could be improved. They were also encouraged to add further comments at the end of the questionnaire.

3. Findings

All participants agreed that the IMPaKT prototype introduces a new knowledge management tool, which appropriately addresses many important KM issues that other tools have ignored. The prototype delivers a business improvement plan with performance targets and measurable indicators to assess progress. It also provides a KM strategic plan with a set of initiatives and implementation tools to support business improvement. Furthermore, it develops an evaluation and review plan with expected impact of KM initiatives on business performance and implementation priorities.

The post-workshop discussion and the completed questionnaires confirmed that the IMPaKT methodology and its supporting prototype:

- Offer a very helpful tool for developing a business improvement plan;
- Facilitate the development of a KM strategy in a very structured approach;
- Provide a very potential tool for linking the business improvement strategy to the KM strategy;
- Present a sound approach for evaluating a KM strategy;
- Introduce a generic prototype that can be used by any business organisation; and
- Provide an innovative KM tool that will help many organisations.

Participants responded to the questions by giving high scores with most questions given scores of four or five out of five. However, some suggestions were made. One suggestion was received for improving the methodology: to link the methodology to other methodologies that may complement its use (i.e. methodologies that help in identifying the knowledge to be managed and the goals from managing it).

The CLEVER methodology seems best to be linked to the IMPaKT. However, there are several issues that need to be considered. First, a new framework should be developed to incorporate the link. This framework should investigate any overlaps between the two methodologies and how their elements should be integrated. Also, the framework should carefully design the flow of information between the two methodologies. This suggestion was beyond the scope of this research. Furthermore, it could not be addressed given the limited timeframe.

Suggestions for improving the prototype are:

1. To include a brief guide about the IMPaKT methodology and how it works;

2. More guidance is required for identifying the probability of success of KM initiatives;

3. More explanation is required about the evaluation guide for selecting the most appropriate evaluation tool to calculate the efficiency of KM initiatives; and

4. To allow the system to being linked to other systems within an organisation so that existing systems for determining effectiveness and efficiency can be imported.

The first three suggestions are about including more explanation about the methodology and its different elements. These have been addressed so that first time users can use the prototype with minimum external support. However, it is not expected that first time users will be able to use the prototype without external help. In fact, users of such new systems need training in order to achieve maximum benefits. The fourth suggestion proposes allowing the system to be linked to other systems. This has been considered when developing the system provided that the other systems have an open architecture.

6.4.6 IMPaKT and the Objectives and Features of the Prototype

The IMPaKT prototype was designed to satisfy the required features established in Section 6.4.3. A summary of the features and how they were achieved is presented in Table 6.6 below.

Table 6.6: Summary of how desired features of the IMPaKT prototype were achieved

Desired	How achieved
Provide sufficient and user-friendly guidance on how to use the system	• Help can be called at any stage using the menu bar • Help buttons were embedded within input forms to provide guidance on completing the forms
Allow for convenient entry, viewing, and editing of information at any stage	• Forms allowed the display and editing of stored data • Command buttons inserted in the forms allowed easy navigation between the forms at any stage of the activity
Allow for easy assessment of performance gaps	• Built-in 'values' are used for 'quantitative' assessment of the performance gap • Built-in 'items' are used for 'qualitative' assessment of the performance gap
Facilitate the identification of KM sub-processes involved in a business problem	• Check boxes are used to capture answers which are used to identify and state the sub-processes involved
Allow for easy search and identification of KM tools based on organisational requirements	• Six sliders are used for identifying the organisational needs • Locations of the sliders are used to search the database
Facilitate the development of an action plan and status of preparedness	• Five-point scale sliders are used to to state actions needed • Traffic light colours are also used to show level of preparedness • The system also gives a statement on preparedness
Allow easy mapping of relationships between objectives, KM initiatives and performance measures	• Command buttons are used to draw or delete relationships • Another command button is used to add more entries
Facilitate the prioritisation of KM initiatives	• Drag-and-drop method is used for prioritising KM initiatives based on calculations of effectiveness and efficiency
Facilitate the generation of a report that can be viewed at the different stages	• A 'Report' button can be activated at the end of any of the following stages: defining the KM problem, identifying the KM goals, stating the migration paths, identifying the KM sub-processes, and developing KM strategy
Allow for future integration with other KM tools	• As a Microsoft product, Visual Basic can be easily linked to other packages

6.5 SUMMARY

This chapter has described and critically examined the existing KM methodologies. No existing methodology was found to address all the stages of the conceptual framework developed in Chapter 5 (Section 5.3.4) namely, identify what knowledge to manage, identify goals for managing knowledge, develop detailed strategy and evaluate the strategy. The CLEVER methodology was found helpful in addressing stages 1 and 2 and some elements of stage 3. CLEVER was therefore encapsulated into a prototype system and was refined after being presented to several case study organisations. Another methodology (IMPaKT) was developed to address the missing elements of stage 3 and to address stage 4. IMPaKT was also encapsulated into a prototype system and was refined after a workshop with industrial organisations. The next chapter describes utilisation of the developed methodologies and discusses the evaluation results.

CHAPTER 7: OPERATION AND EVALUATION OF PROTOTYPES

7.1 INTRODUCTION

This chapter describes the operation of the prototypes developed and illustrates their main features. Evaluation of the prototypes is then presented describing the objectives of evaluation, methodology, results, benefits, limitations and a discussion.

7.2 OPERATION OF THE PROTOTYPES

7.2.1 Running the CLEVER Prototype

When the prototype is started, a 'welcome screen' and a help screen are displayed (Figure 7.1). The user can either (a) click on 'Tell me more' for each stage of interest to read about the selected stage or (b) click on 'Close this window'. Clicking 'Start' takes the user to the first stage 'Define a KM problem'.

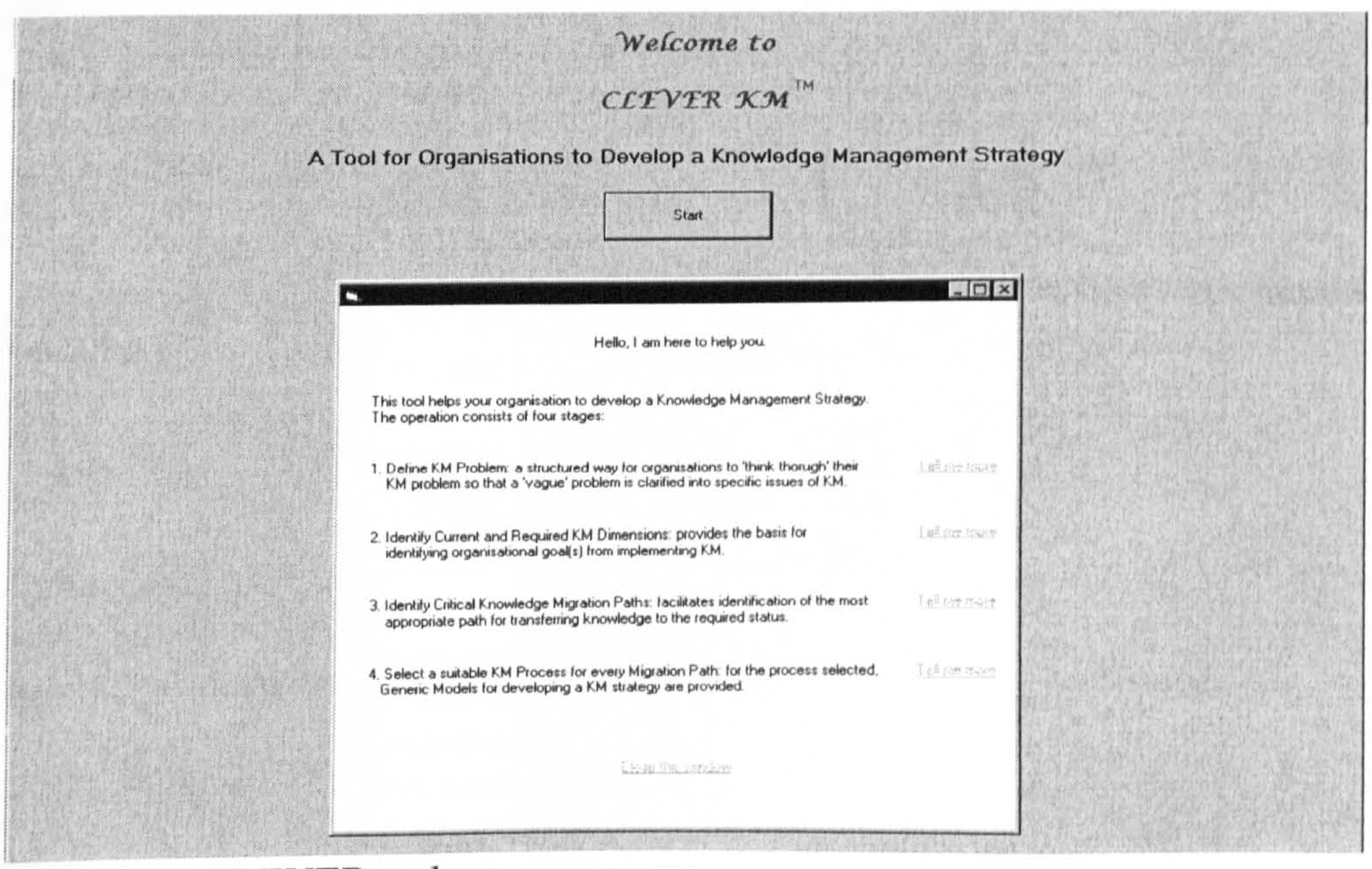

Figure 7.1: CLEVER welcome screen

Stage 1: Defining a KM Problem

This stage allows the user to state a KM problem. Then it takes the user through a number of tasks to refine the problem. Each task consists of a set of questions or issues about:

- The characteristics of knowledge,
- Suppliers and users of knowledge,
- Enablers and resistors; and
- The current sub-processes for managing knowledge.

The system displays the questions in "forms" which the user completes. Four forms are used to input, edit, and view information. While completing the forms, the user will have the opportunity to return to any previous form to modify the input. The easy-to-follow labels in addition to the 'Help' buttons give enough guidance for completing the forms. Figure 7.2 shows the first screen of this stage.

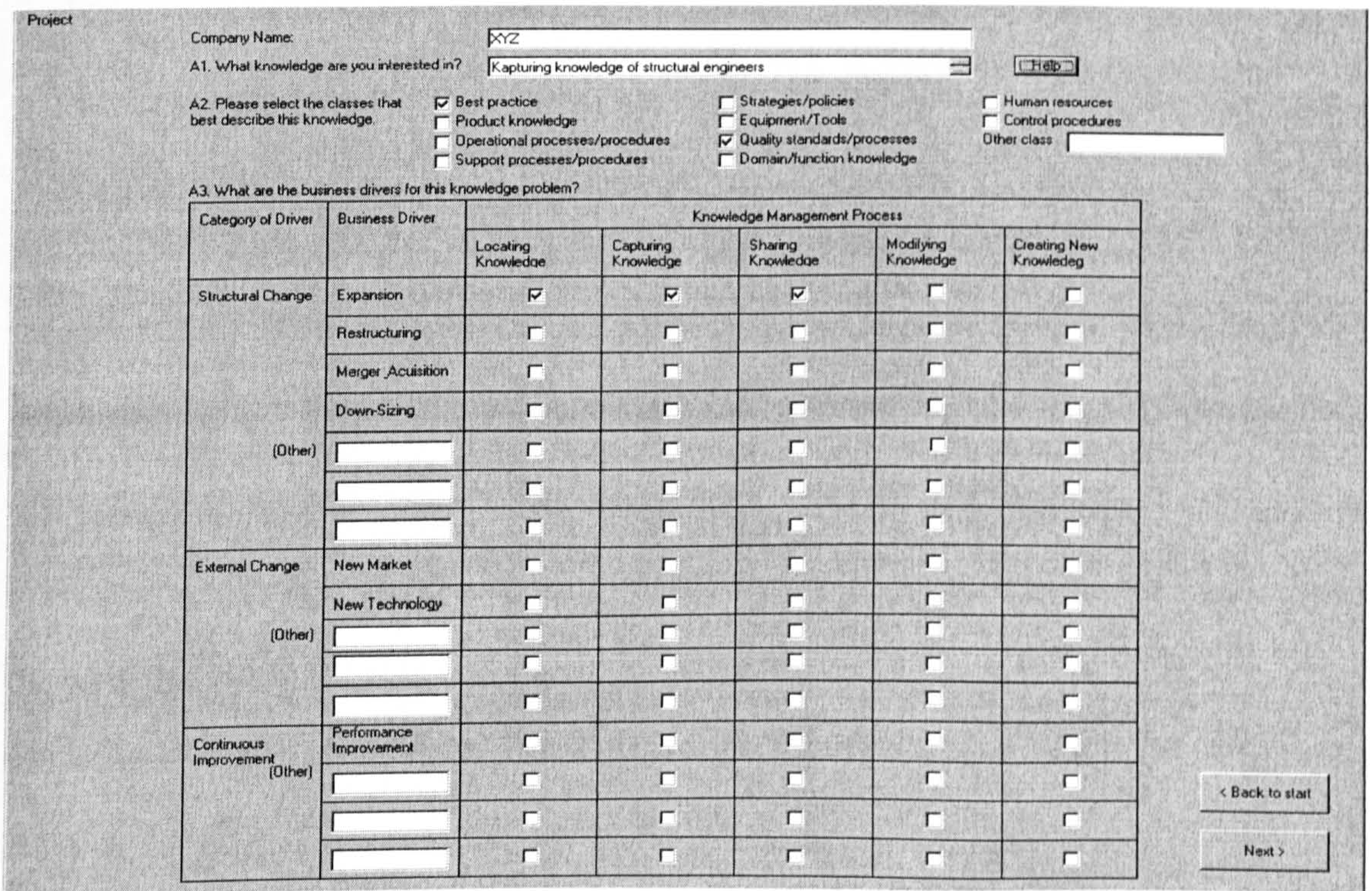

Figure 7.2: Sample screen for identifying the knowledge problem

First, the type and nature of the knowledge problem is to be described. This could be a general statement, which does not need to be very specific at this stage as it will be refined later. Establishing a general statement helps the user to start a wider thinking about the KM problem. It also ensures that one KM problem is treated at a time. After the general statement has been specified, the user is required to select, from a set of given tick boxes, the classes that best describe the knowledge of interest. Several classes of knowledge have been built-in within the prototype e.g. best practice, product knowledge, operational processes/procedures, etc. Other classes of knowledge may be added.

The user is then required to identify the business drivers that relate to this knowledge. Several categories of drivers are identified by the system e.g. structural change, external change, etc. The business driver(s) for every category should then be identified. These vary from one organisation to another for example, the business drivers that can affect structural change could be expansion, re-structuring, merger and acquisition, etc. while those that can affect external change could be new market, new technology, etc. The system also allows the user to add other business drivers. To ensure that KM is linked to the organisational business drivers, the user is required to relate them to the relevant KM sub-processes i.e. what KM sub-processes are affected by the business drivers. For example sharing knowledge could be affected by an organisation's expansion or restructuring. Clicking the 'Next' button at the bottom of the form saves the input, closes the form and opens the next one.

In the next form (Figure 7.3), the user is required to identify the knowledge dimensions i.e. its characteristics, location, and how knowledge is currently acquired. The identification of these dimensions is important because these define the organisation's current status and therefore helps in recognising the required status. Identification is done through selecting, from a five-point scale, the position that best describes the current status. For example, knowledge can be completely tacit, mostly tacit, half-tacit, mostly explicit or completely explicit. Definitions are given at the alongside of each dimension. For example, tacit knowledge exists 'usually in people's heads, sometimes referred to as experience'. The system also allows users to add further dimensions that reflect the specific characteristics of their organisation's knowledge.

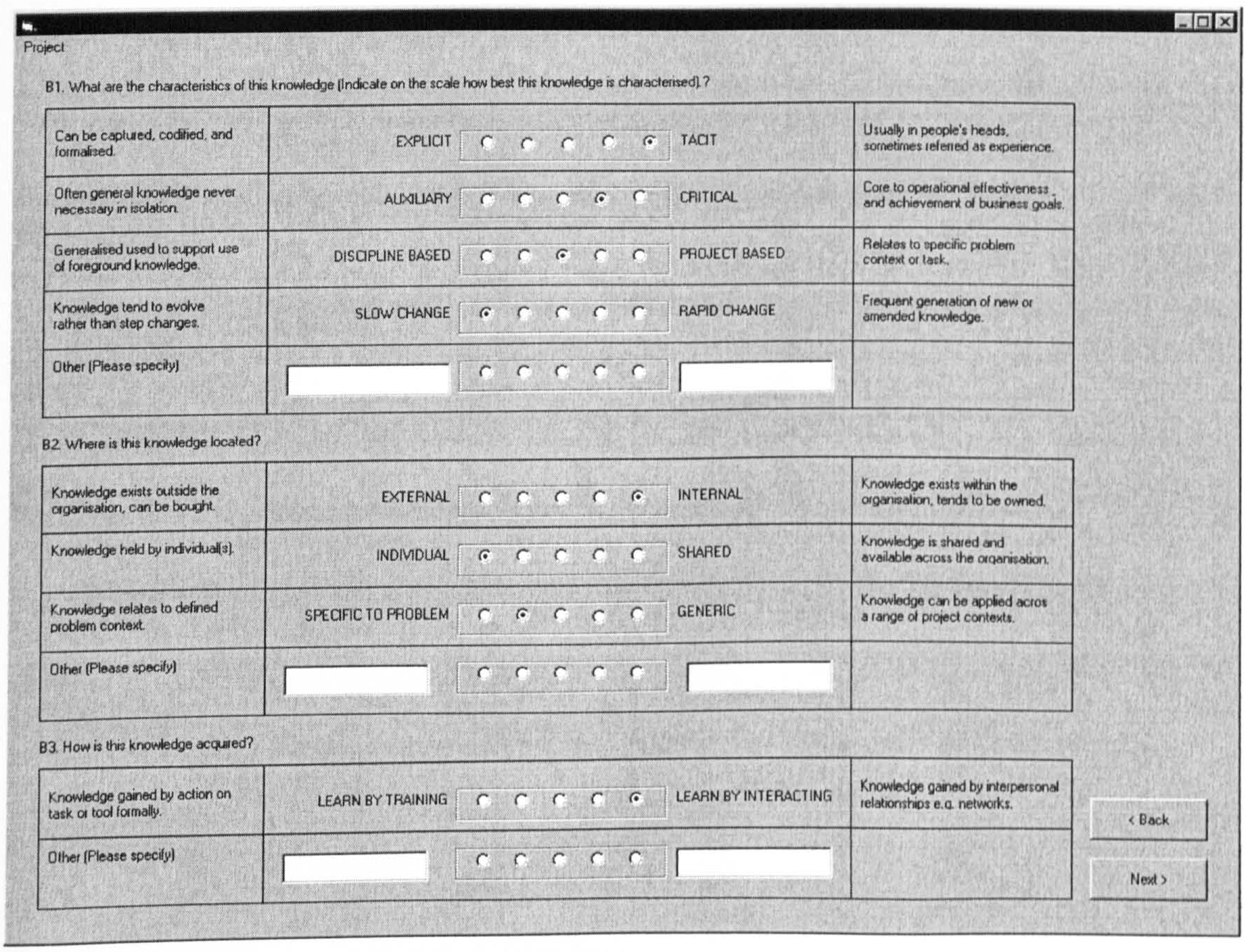

Figure 7.3: Interface for identifying current knowledge dimensions

The next form (Figure 7.4.) investigates the relationships between the sources and users of knowledge. Two matrices are used. The first investigates where the knowledge comes from and who/what uses it, while the second investigates the enablers and resistors that influence the transfer of knowledge from its sources to users. A source can be an individual, software, or paper. In the second matrix, the user is required to identify the enablers and resistors that enable or hinder the transfer of knowledge from its sources to users. Using this matrix promotes a wider thinking about the enablers that may need to be reinforced and resistors that need to be overcome. The user is then required to elaborate issues arising from these two matrices. This allows developing an overall view with regards to the key sources of knowledge, their intended users, and the potential enablers and resistors. Help buttons are provided for guidance on completing the forms.

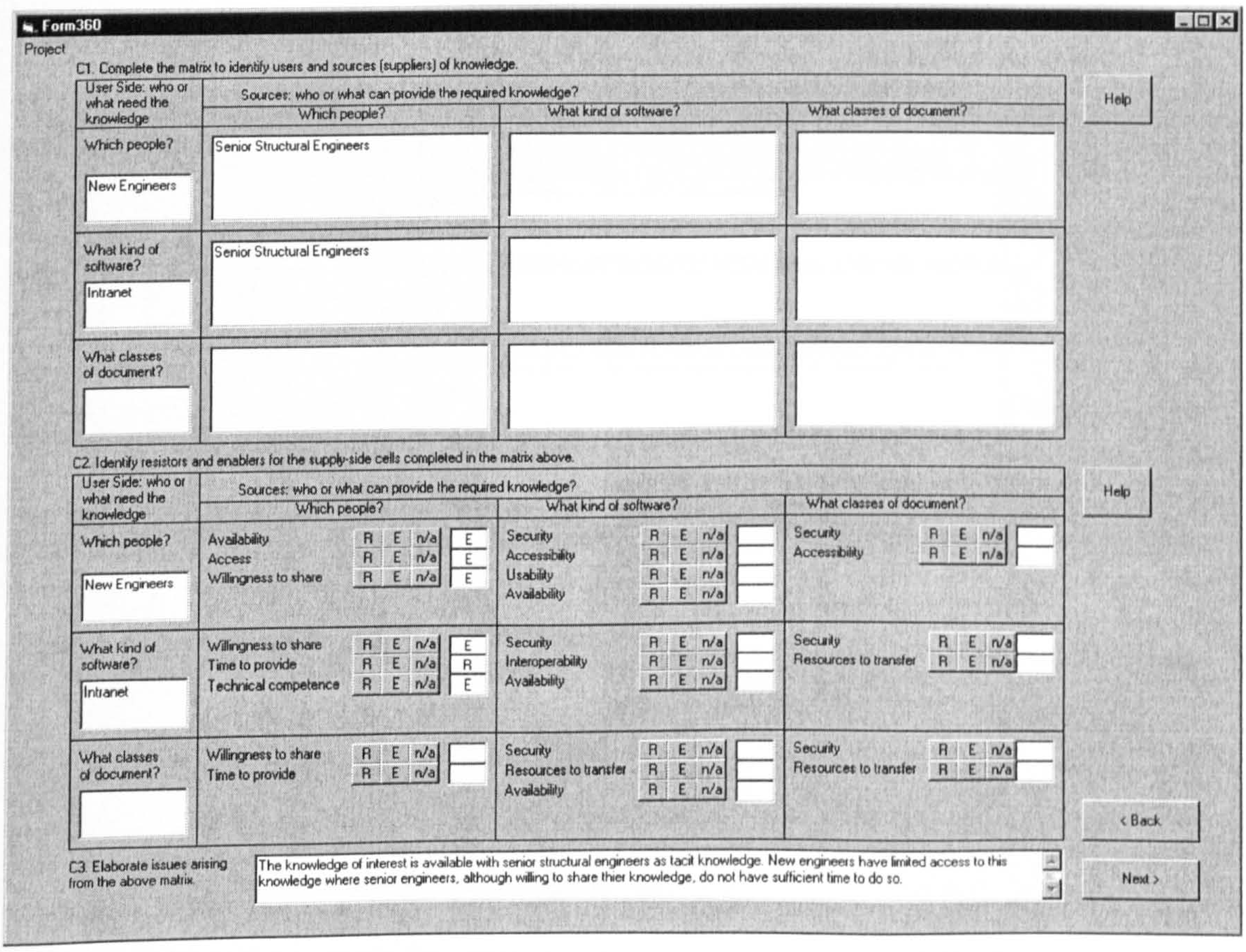

Figure 7.4: Identifying sources and users of knowledge

The last form in stage one (Figure 7.5) investigates whether the organisation currently uses any processes to manage its knowledge and asks the user to describe how these processes are performed. This helps the organisation to understand its existing KM initiatives so that the KM strategy will be built on existing tasks that support KM. Five KM sub-processes are introduced but users are allowed to add new ones. After the four forms are completed, the user can click 'Restate the KM Problem' button, which presents the problem that was input at the beginning of the first form (Figure 7.2) and asks the user to refine it based on the understanding gained after completing the forms. The refinement case studies described in Section 6.3.6 confirmed that all organisations concluded with a statement different from that they started with. For example 'capturing knowledge of structural engineers' may become 'sharing tacit knowledge of senior structural engineers with new engineers in order to reduce design cycles'.

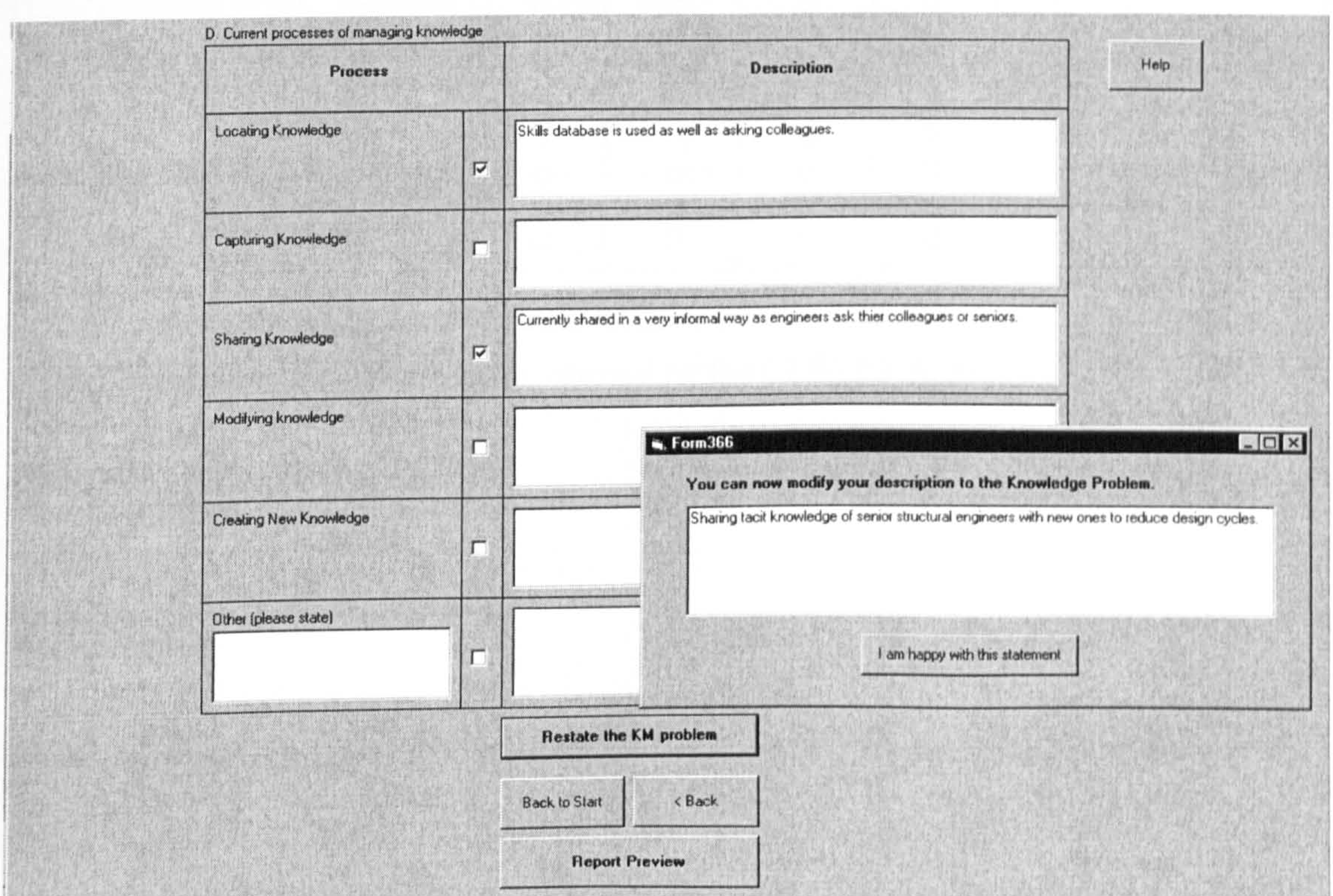

Figure 7.5: Identifying KM sub-processes being used and re-stating the KM problem

Finally, the system is able to produce a report containing a clarified KM problem and a refined set of KM issues. This report can be used as a reference point for the organisation when developing methods and strategies for KM. Figure 7.6 shows a screen-shot of a report created by the system.

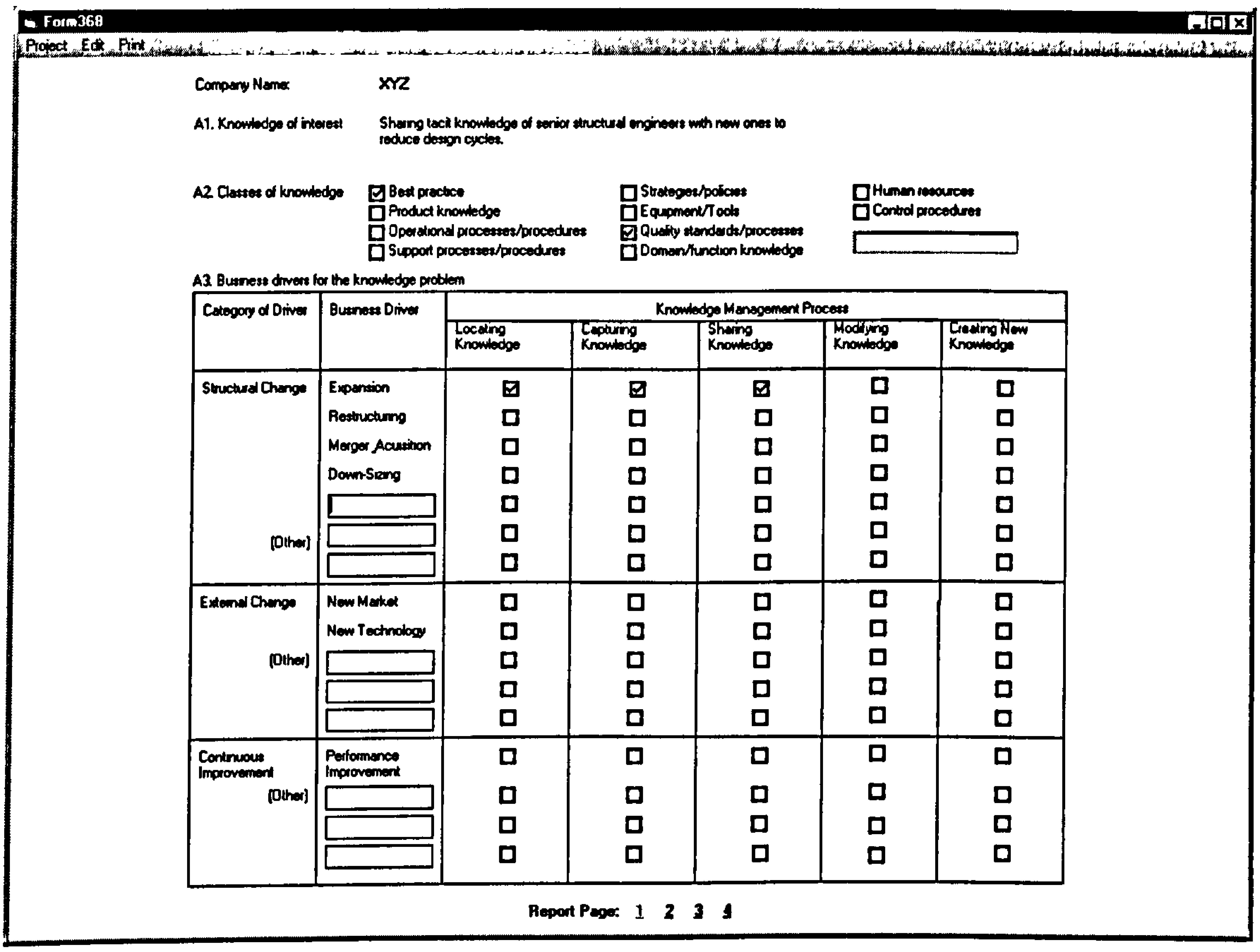

Figure 7.6: A screen-shot of a report created by the CLEVER prototype

Stage 2: Identifying Current and Required KM Dimensions

The second stage in CLEVER seeks to identify the current and required knowledge dimensions so as to state the organisational goals from KM. This stage starts with presenting the eight knowledge dimensions (Figure 7.7) identified in the previous stage (Figure 7.3) each with two sliders: the top slider reflects the current status (already positioned according to the identification in the previous stage) and the bottom slider identifies the required status.

The user can also change the status already identified. Each dimension has an organisational impact at the strategic or policy level as shown in brackets below the sliders of each dimension.

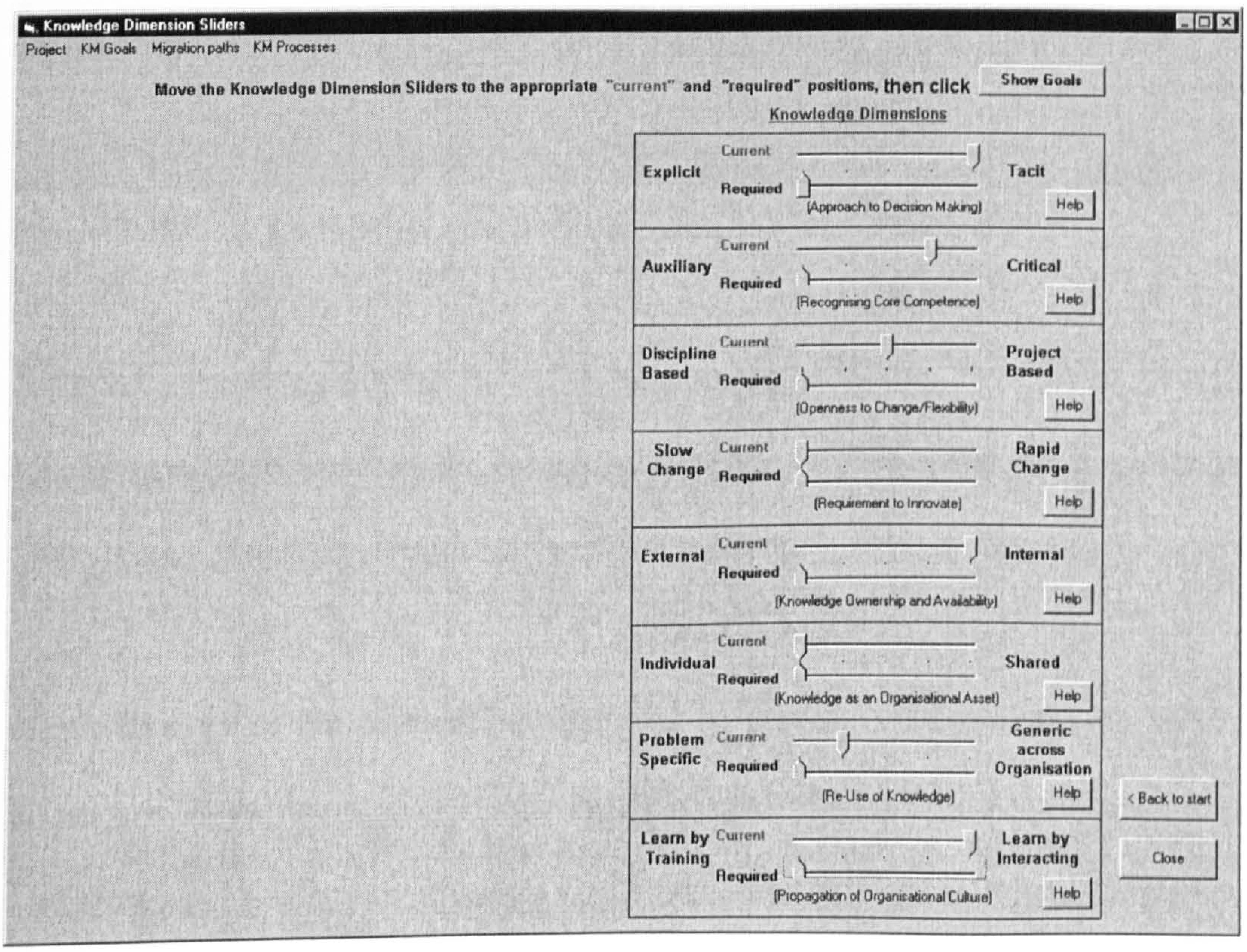

Figure 7.7: Identifying required knowledge dimensions

Every dimension is also supported by a 'Help' button, which gives a detailed description. Clicking 'Help' for the first dimension will show the form presented in Figure 7.8.

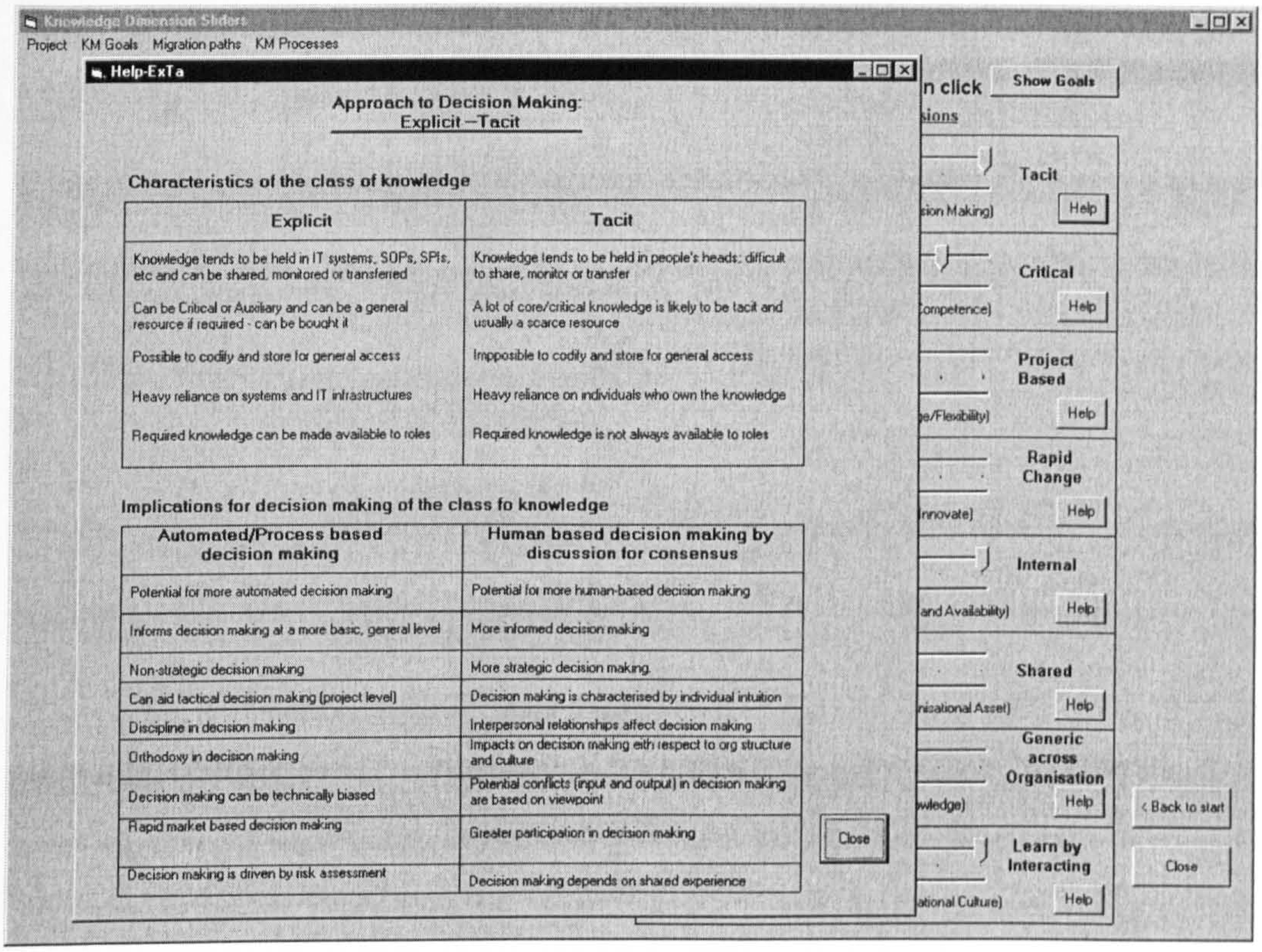

Figure 7.8: Help for the first knowledge dimension - tacit versus explicit

After the sliders are moved to the corresponding positions, the 'Show Goals' button should be clicked to allow the system to state the organisational goals and to prioritise them (Figure 7.9). Prioritisation is made according to distance between the current and required knowledge status. The 'N/A' statement means that both current and required dimensions are at the same status reflecting no change. Goals having the same priority figure are of the same importance to the organisation. A 'Go' button next to every 'organisational goal' can be clicked to investigate the relevant knowledge dimension against the other dimensions. Users are not forced, however, to start with the first priority.

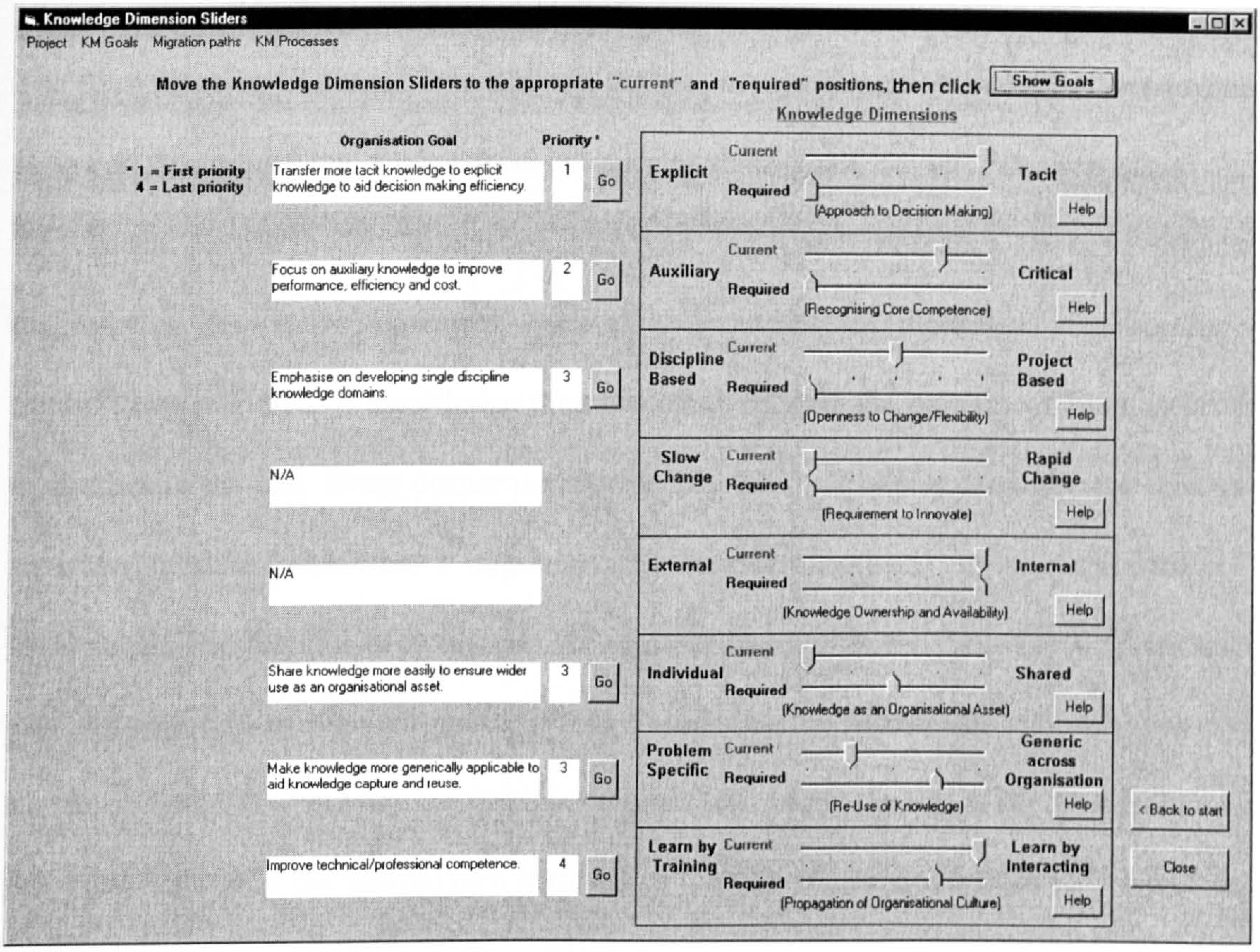

Figure 7.9: Identifying KM goals and their priorities

Stage 3: Selecting the Knowledge Migration Paths

The third stage in CLEVER is to identify the knowledge migration paths that need to be followed to transfer knowledge from its current to required status. For example, if the 'Go' button next to the first dimension is clicked, the system presents a cell to investigate the relevant knowledge dimension against the next selected dimension e.g. auxiliary-critical (Figure 7.10). A knowledge migration path reflects the movement from a corner to another in the cell. Every corner is described by two words. For example, the selected arrow in the figure represents a migration path from 'tacit-critical' to 'explicit-auxiliary' knowledge. The features of every corner are described within the model to help the user identifying the most relevant paths. While completing the forms, the user can return to any previous form to modify the input using the menu bar at the top of the form. Clicking the 'Next' button at the bottom of a form saves the selected migration path and opens the next form to investigate further selected KM dimensions.

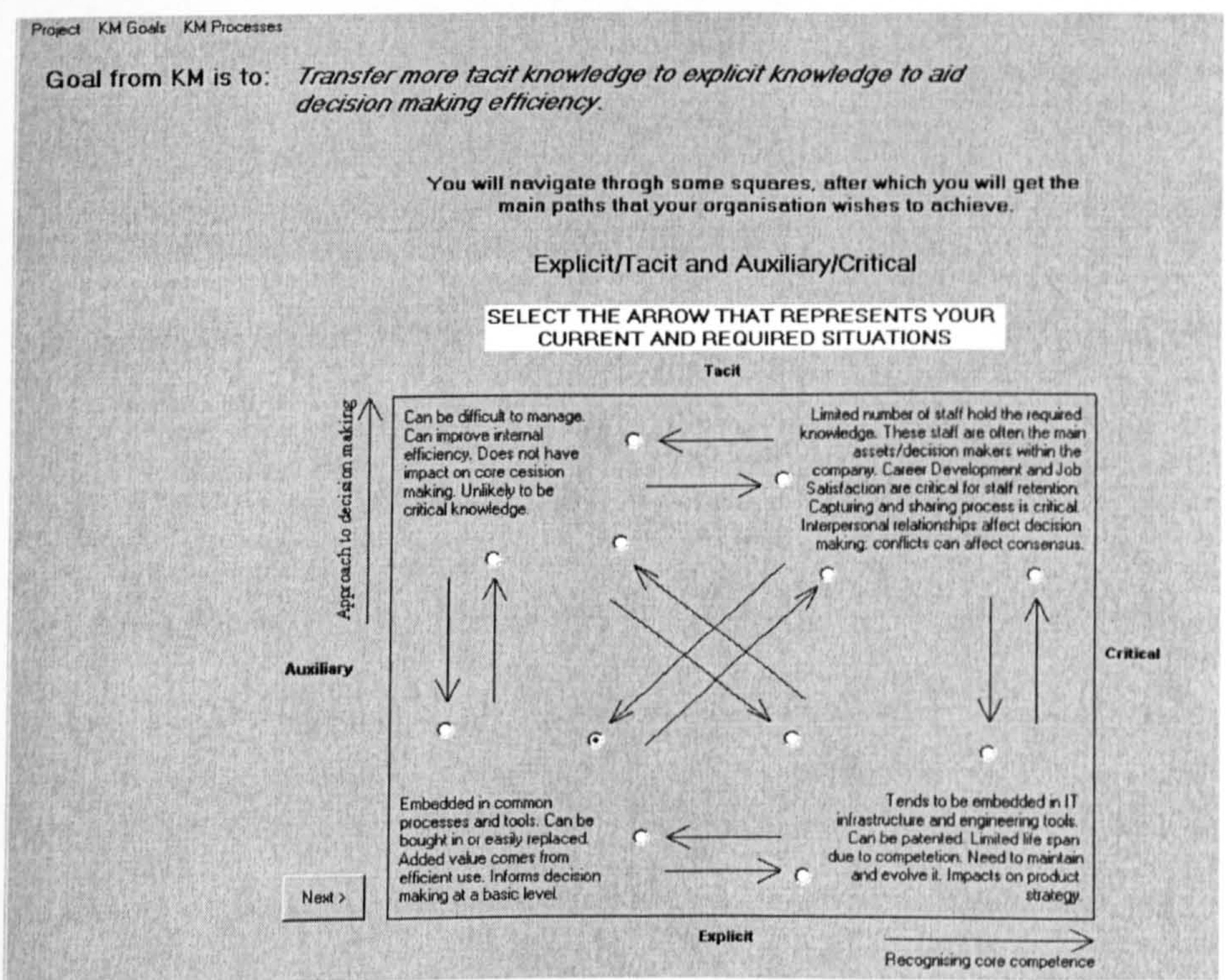

Figure 7.10: Identifying knowledge migration paths

Upon investigating all the selected knowledge dimensions, the user can click 'Show Migration Paths' at the bottom of the last cell to see a list of migration paths for the KM goal under investigation (Figure 7.11).

At the bottom of the list the user can select from three options; Print, Back to Goals, or Derive Generic Processes. Selecting 'Back to Goals' takes the user to KM goals identifies i.e. Figure 7.9. Clicking 'Derive Generic Processes' takes to the last stage of CLEVER.

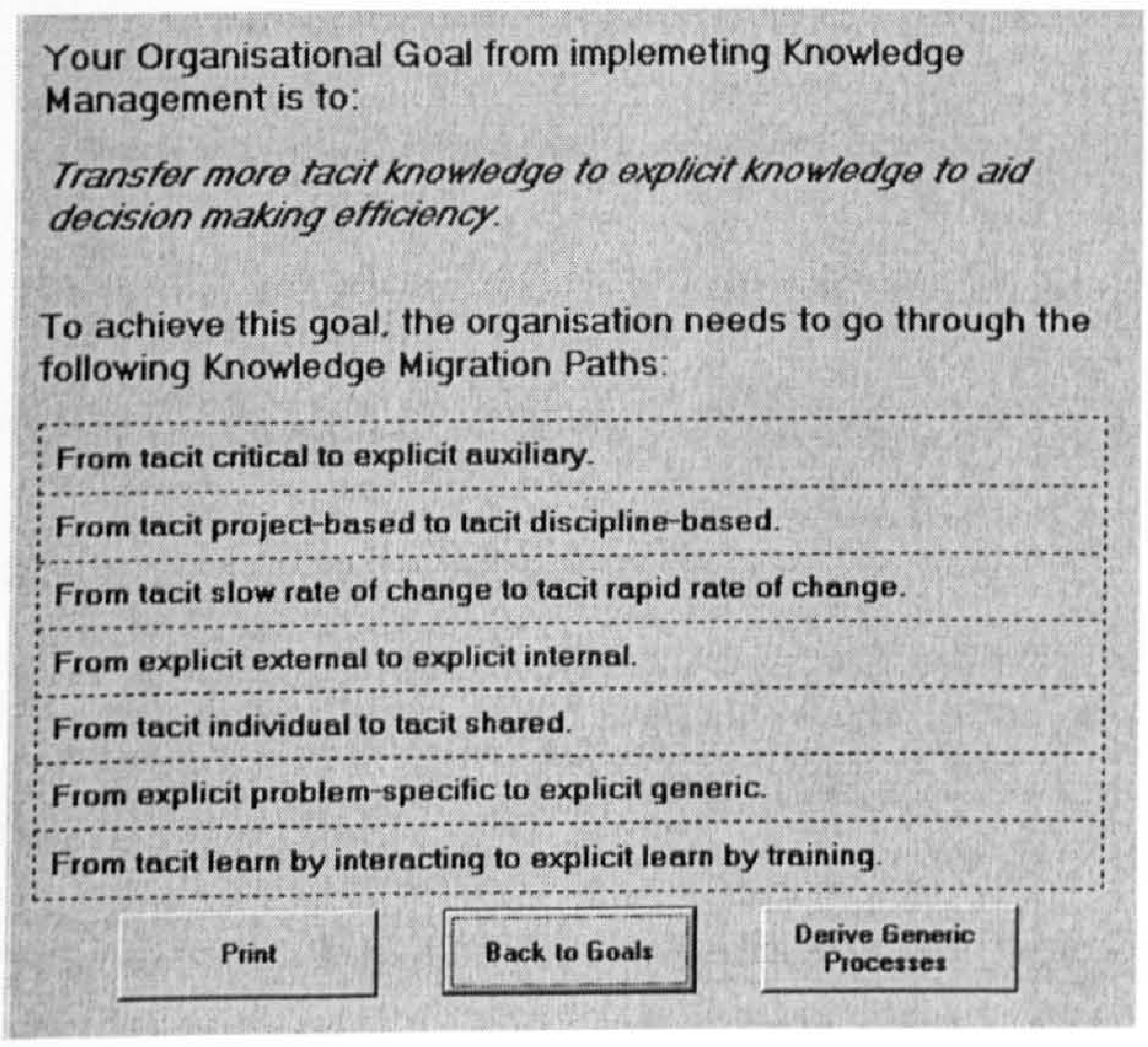

Figure 7.11: A set of knowledge migration paths for a KM goal

Stage 4: Developing a Strategy for Implementation

The last stage in CLEVER is to identify the relevant KM sub-processes for the selected knowledge migration paths and to follow a set of generic models for developing a KM strategy. Selecting 'Derive Generic Processes' in the above screen allows the system to show a table of the KM sub-processes (Figure 7.12). The user can identify the KM process relevant to each migration path by choosing from the option buttons.

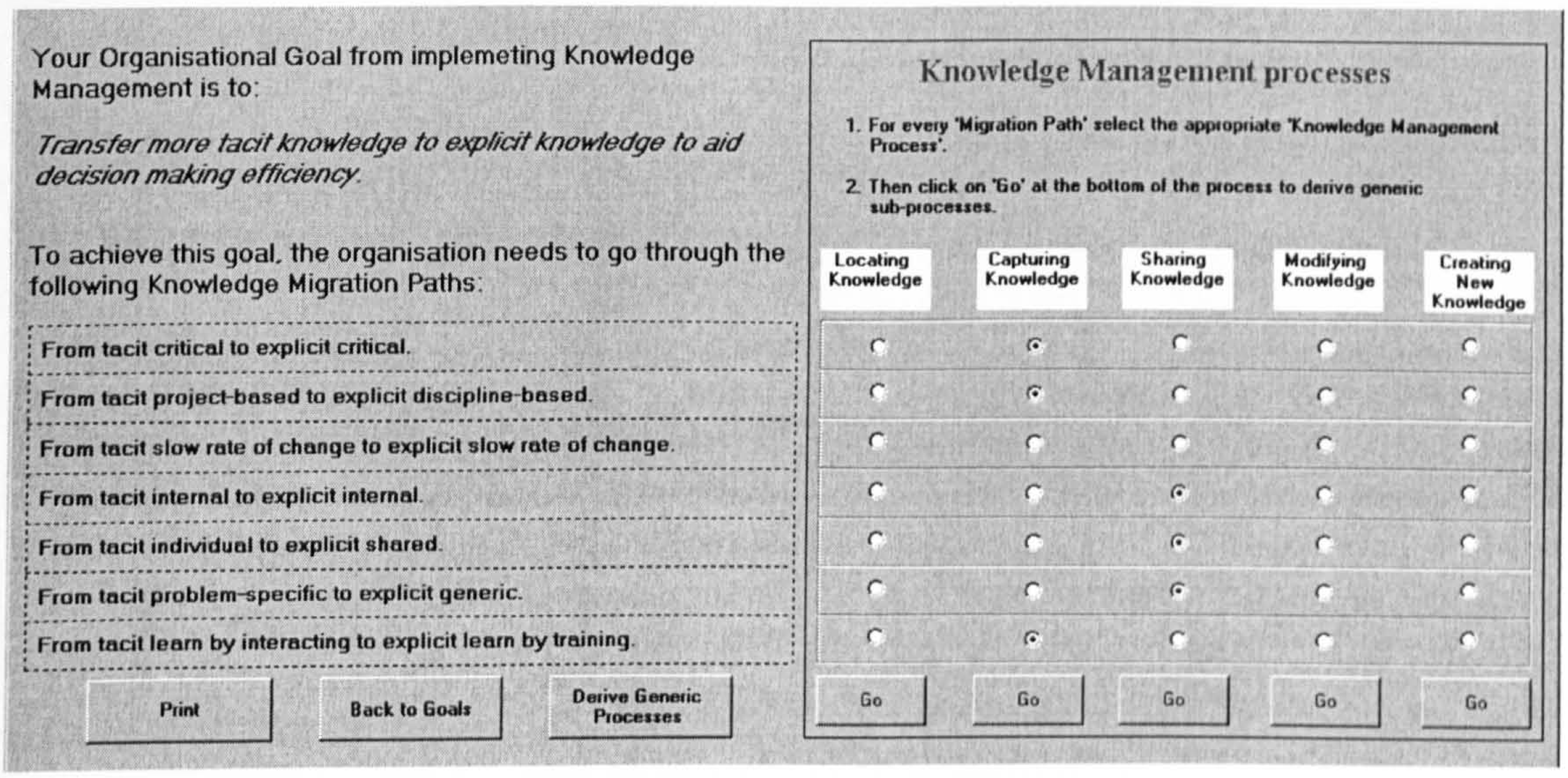

Figure7.12: Knowledge migration paths and KM sub-processes

For the selected KM process, the system introduces a chart illustrating generic guidelines to be followed. For example, for the KM process 'capturing knowledge', the system presents the generic guidelines (the white boxes) shown in Figure 7.13. Clicking any of the guidelines changes its colour and activates an input box asking the user to enter the element of KM strategy that addresses that guideline.

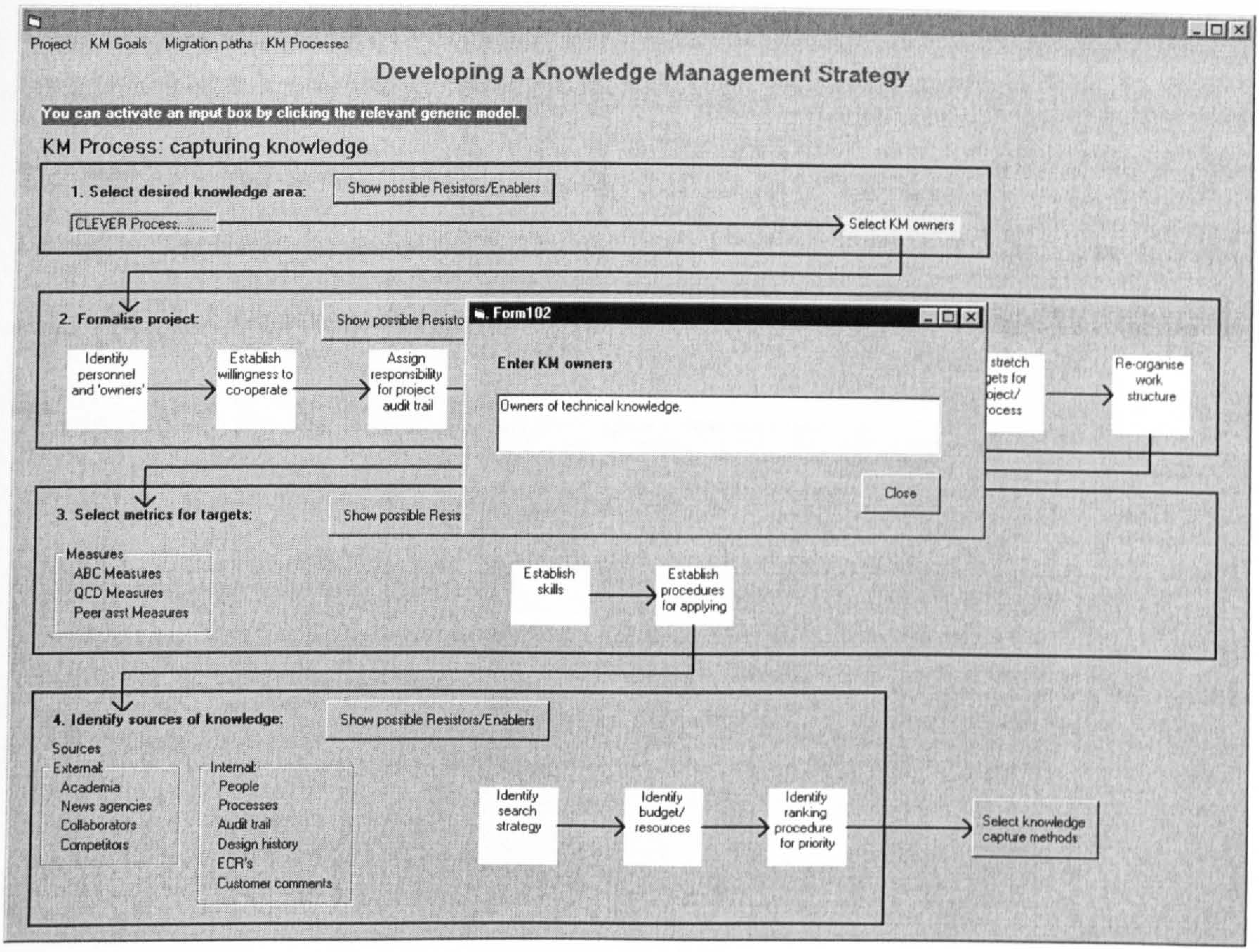

Figure 7.13: Generic guidelines for developing a KM strategy

Generating a Report

Finally, the prototype is able to produce a detailed report (Figure 7.14) containing:

- The KM problem;
- Goals and their priorities;
- Knowledge migration paths for every goal;
- The KM sub-processes and their generic guidelines; and
- A KM strategy.

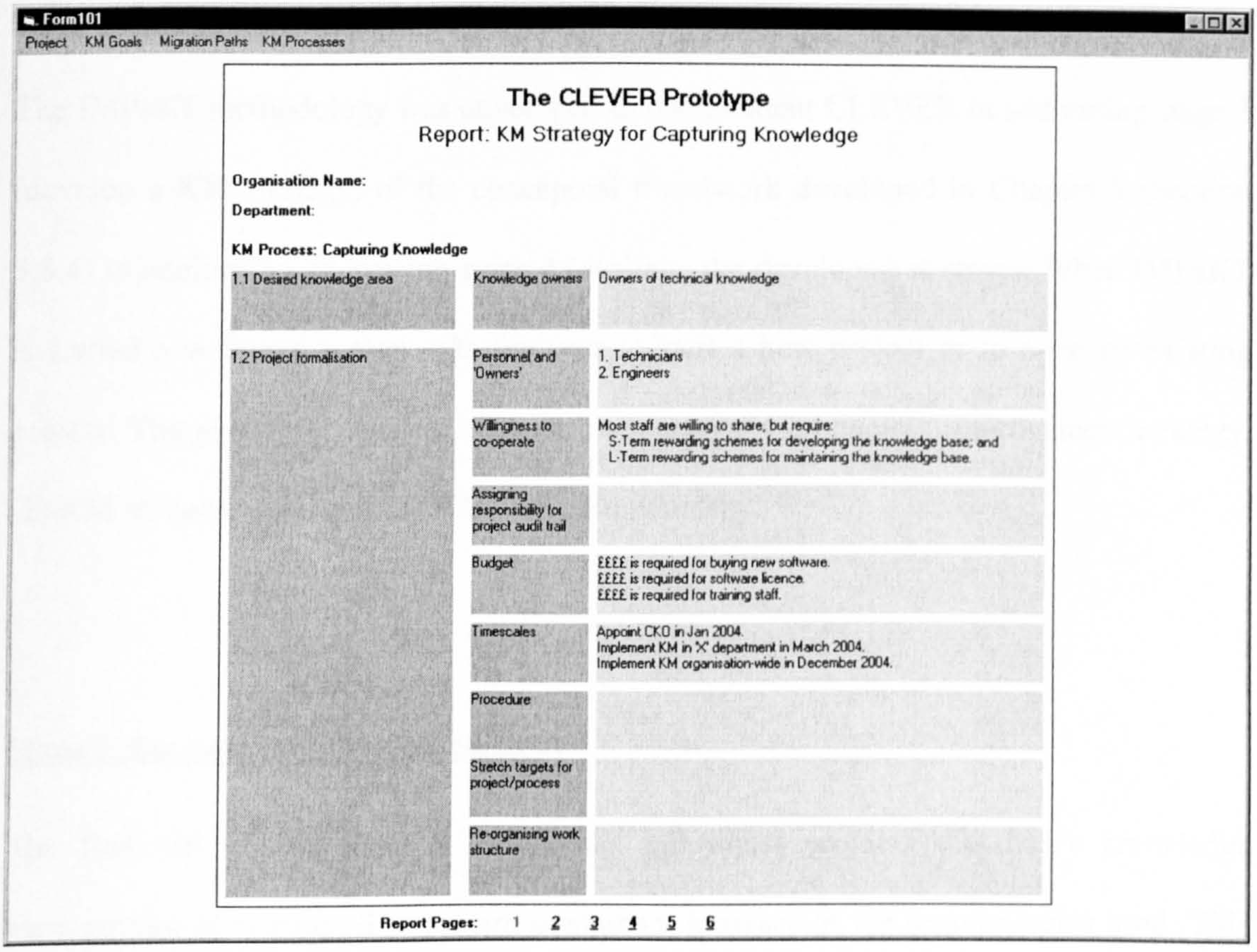

Figure 7.14: A screen-shot of a report showing a strategy for Capturing Knowledge

7.2.2 Running the IMPaKT Prototype

The IMPaKT methodology was developed to complement CLEVER in addressing stage 3 (develop a KM strategy) of the conceptual framework developed in Chapter 5 (Section 5.3.4) in addition to addressing stage 4 (evaluate the developed strategy). When IMPaKT is started a welcome screen asks the user to start a new project or to open an existing project. The prototype consists of three main stages: (1) business improvement strategy, (2) KM strategic plan, and (3) KM evaluation strategy.

Stage 1: Business Improvement Strategy

The first task in this stage is to identify a business problem that has a knowledge management dimension. The system contains a glossary of the terminologies used. This glossary can be activated through the menu bar or by clicking the term under question. The first screen with a glossary defining a 'business problem with a KM dimension' is shown in Figure 7.15. Next, the user needs to put the identified business problem into a strategic context by identifying the external business drivers, strategic objectives and critical success factors. After that, it is important to identify the performance measures, their associated metric definitions, the expected benefits, the business processes relating to the performance measures, and to establish the process sponsors. Examples are shown in Figure 7.16.

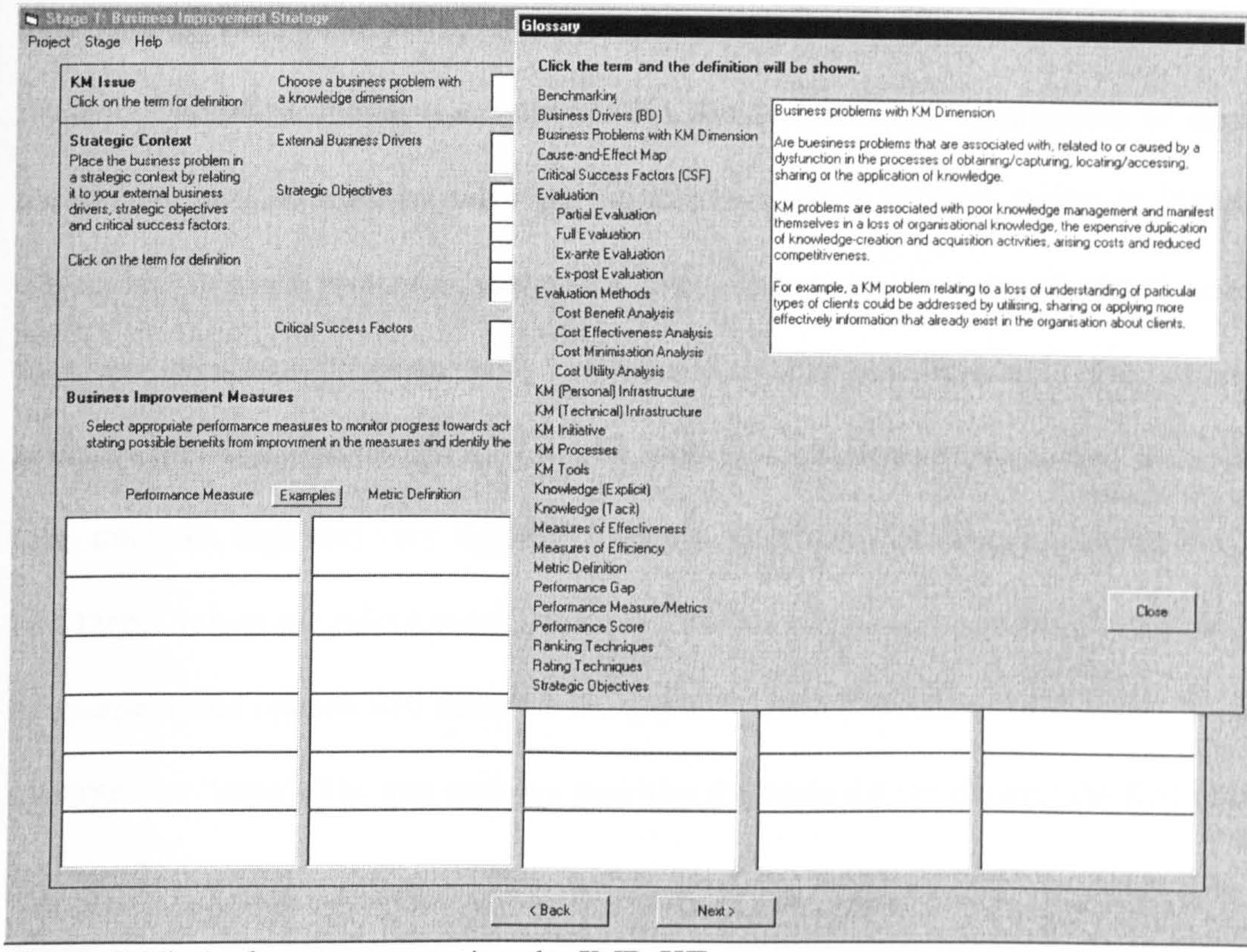

Figure 7.15: A glossary supporting the IMPaKT prototype

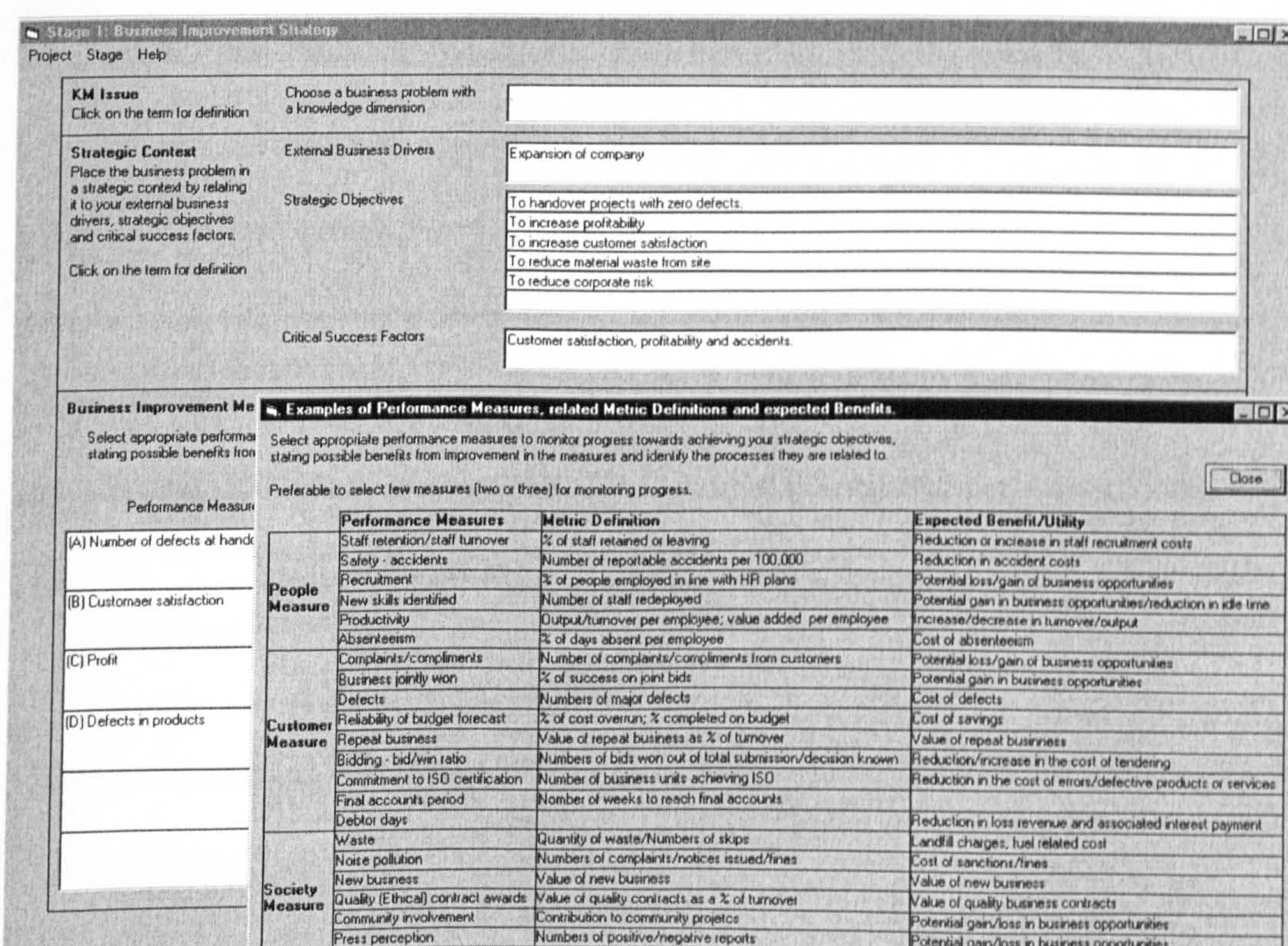

Figure 7.16: Examples of performance measures, related metric definitions and benefits

The user is then required to establish the performance gaps. For every performance measure identified above, it is important to decide whether a quantitative or qualitative assessment will be used by selecting the relevant option buttons shown in Figure 7.17. There are four performance scores for every measure: current and target scores are required whereas previous and benchmark scores are optional. For quantitative assessment, the scores are from 0 to 100 while for qualitative assessment the scores are low, medium, high and very high. By clicking 'Gap' the differences between the current and target values are calculated for the quantitative assessment option. For the qualitative assessment, the system will describe the gap as: 'small', 'small-to-moderate', 'moderate-to-large', or 'large'. The gap analysis provides the basis for developing the KM initiatives in stage 2.

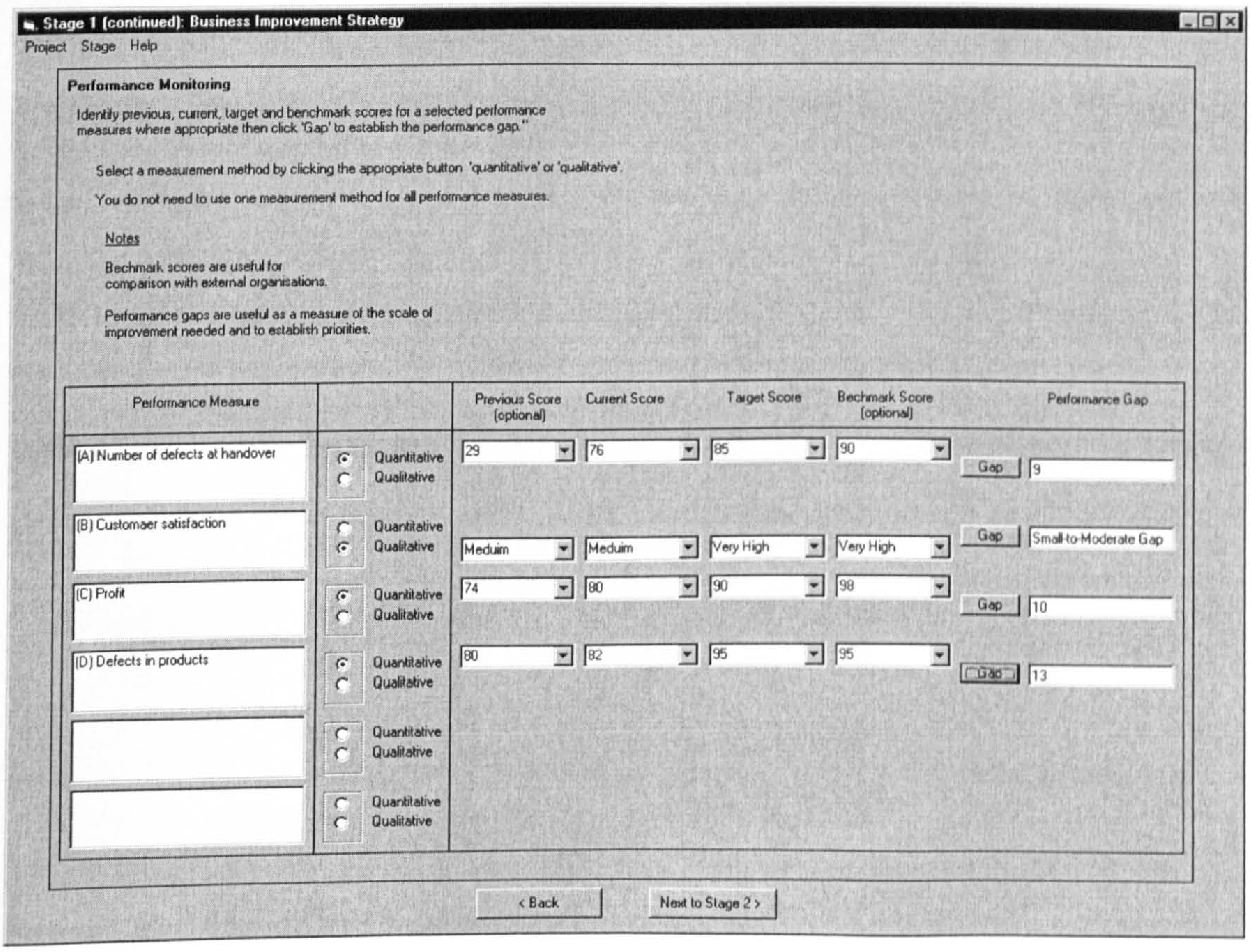

Figure 7.17: Calculation/determination of performance gaps

Stage 2: KM Strategic Plan

The second stage involves developing a strategy for implementing KM. First it is important to identify the KM sub-processes associated with the business problem identified in stage one. Clicking 'Identify Processes Involved' will open the 'KM Problem Diagnostic Questionnaire' (Figure 7.18), which consists of 25 questions reflecting the KM sub-processes. The user needs to respond to the questions that represent their organisation's status. By clicking 'Identify Processes', the system is able to state the KM process associated with the business problem. For the example illustrated in Figure 7.18, the KM sub-processes are locating, capturing and sharing knowledge. This questionnaire is simple and useful for those who may be confused by the overlaps between the KM sub-processes.

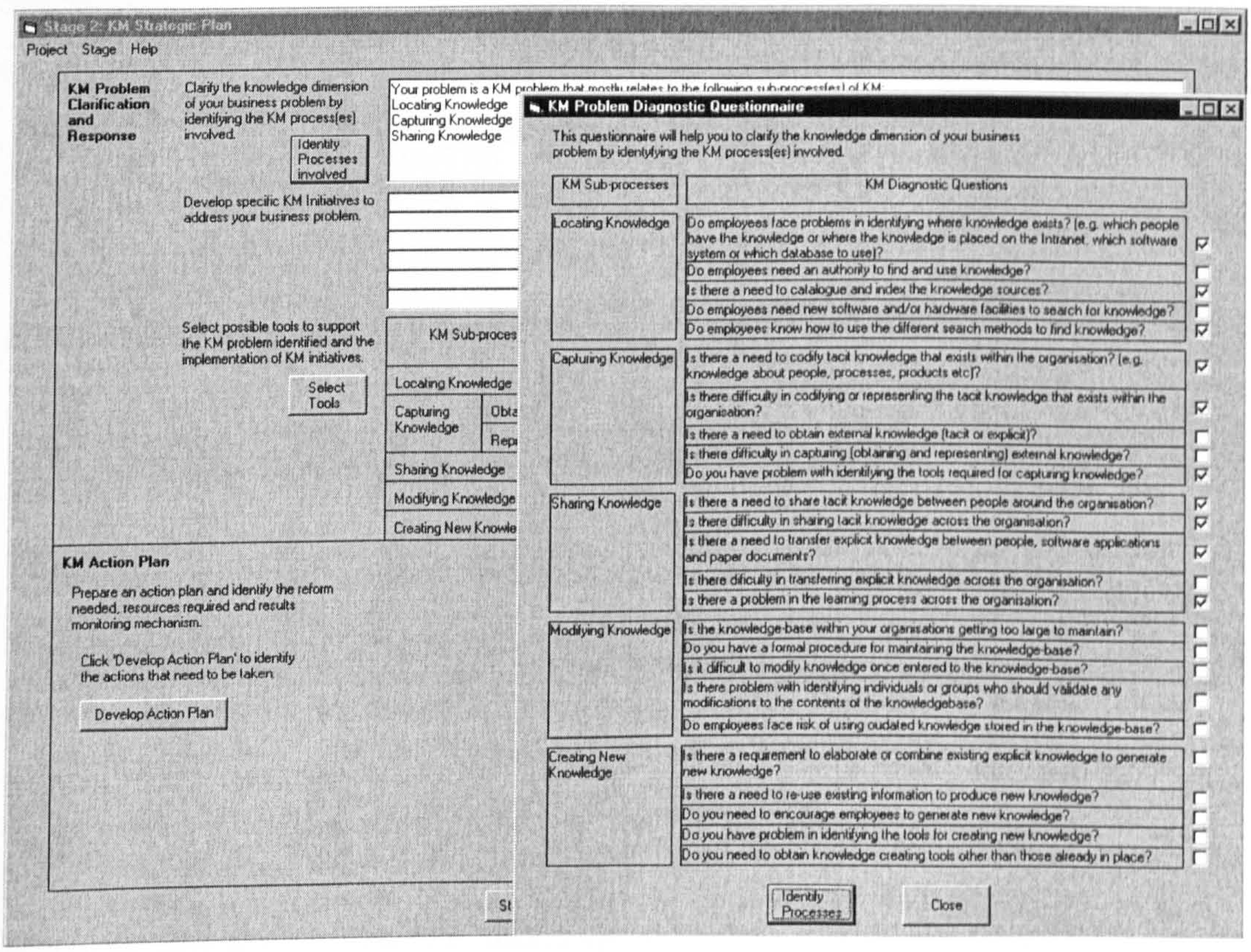

Figure 7.18: KM problem diagnostic questionnaire

Having identified the KM sub-processes involved, the user needs to develop specific KM initiatives to address the business problem identified in stage one. It is critical at this stage to develop KM initiatives to address the performance gaps. When the user places the cursor on the first line to input an initiative, a pop-up form will open (Figure 7.19) reminding the user about the performance gaps identified. The next task is to identify the Tools required (IT and non-IT) for implementing KM. The system contains a large database of tools organised according to the specific KM dimensions they support as described in the SeLEKT approach in Section 6.4.2.

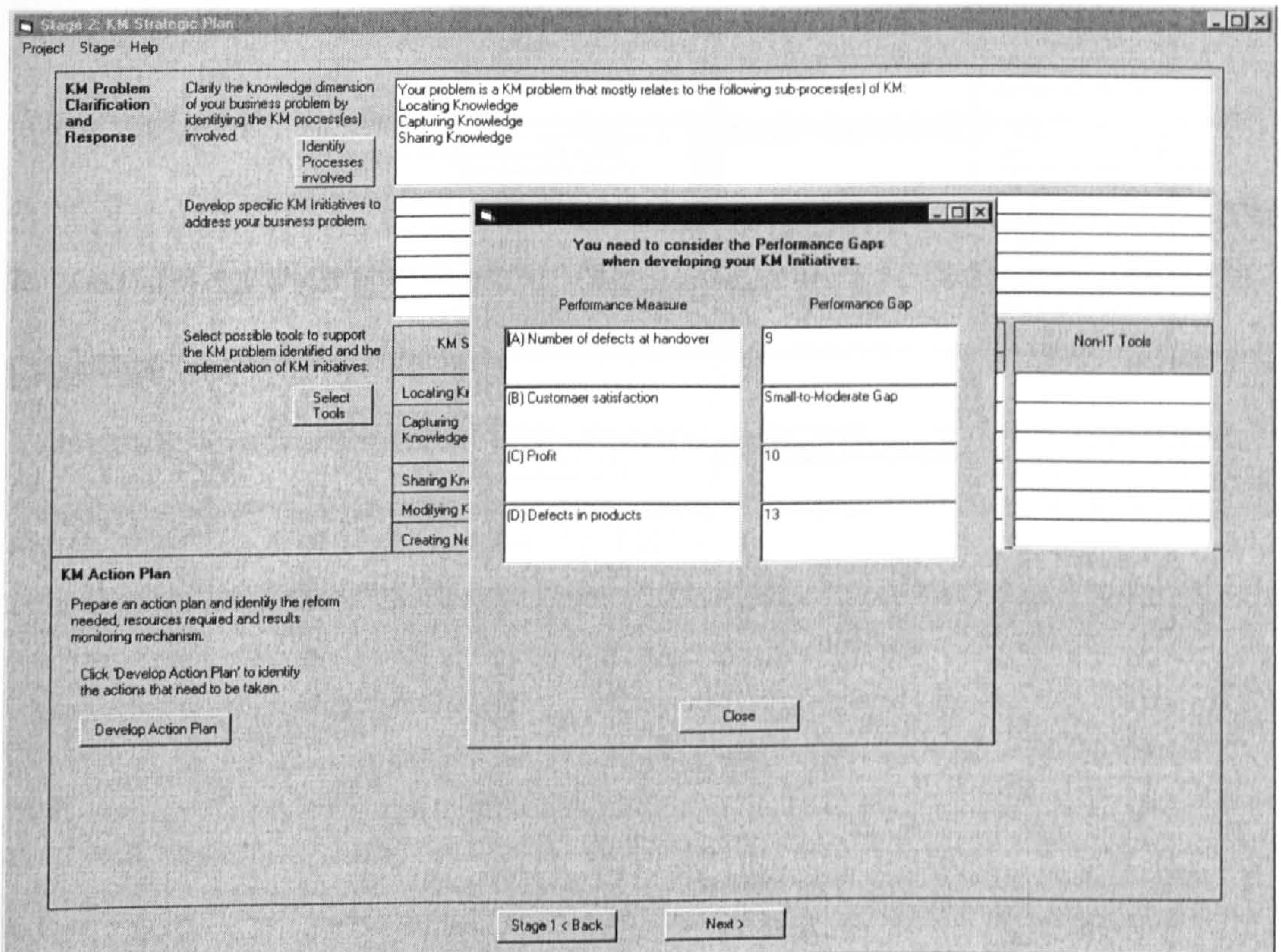

Figure 7.19: Pop-up form showing previously identified performance gaps

If 'Select Tools' (Figure 7.19) is clicked the 'KM Tool Selector' will open. The user needs to identify the current and required status based on three KM dimensions: knowledge conversion types (tacit-explicit), knowledge ownership forms (individual-group) and knowledge transfer domains (internal-external). For example, to transfer knowledge from tacit to explicit, individual to group and keeping it internal within the organisation will lead to the selection of the IT tools shown in Figure 7.20 and the non-IT tools shown in Figure 7.21.

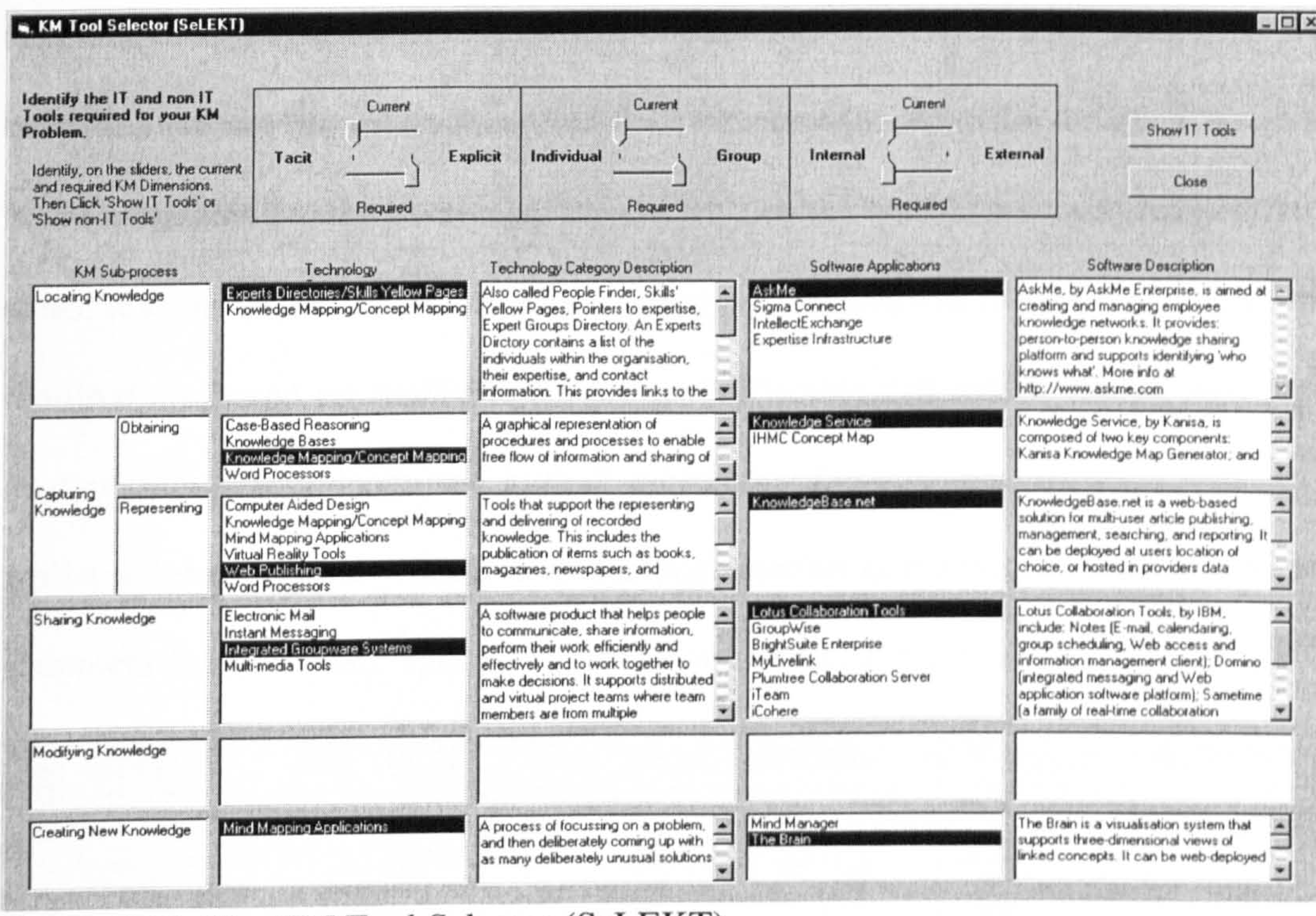

Figure 7.20: The KM Tool Selector (SeLEKT)

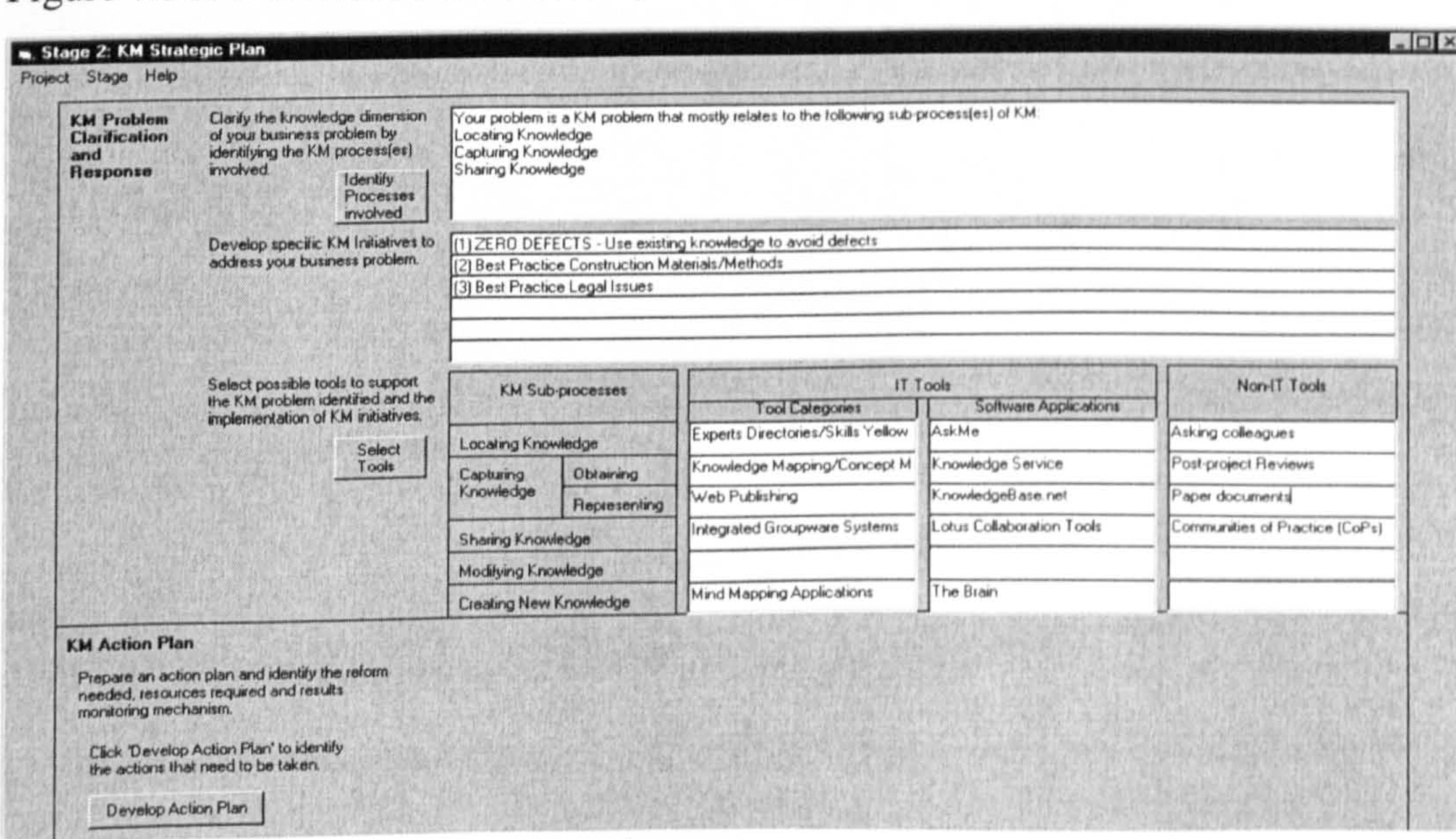

Figure 7.21: KM Tools selected by the system

Once the KM tools have been identified, an action plan can be developed to determine what is required before implementing KM. Clicking 'Develop Action Plan' will open a form consisting of 15 statements, with a 'no' or 'yes' answers. The response could also be between yes and no to reflect different levels of readiness. For example, consider this statement: 'Organisational and cultural barriers to KM have been identified'. If the barriers have not been fully identified then the response would be between No and Yes. Upon responding to the statements the system will show the actions needed in three main areas: reform; resources; and results monitoring mechanisms (Figure 7.22). The actions required are based on 'traffic lights' system reflecting different levels of organisational readiness. A predominant 'red output' means that the organisation is not ready for KM whilst a 'green output' means that the organisation is ready. The system generates a statement on the overall readiness of the organisation, which is also colour-coded.

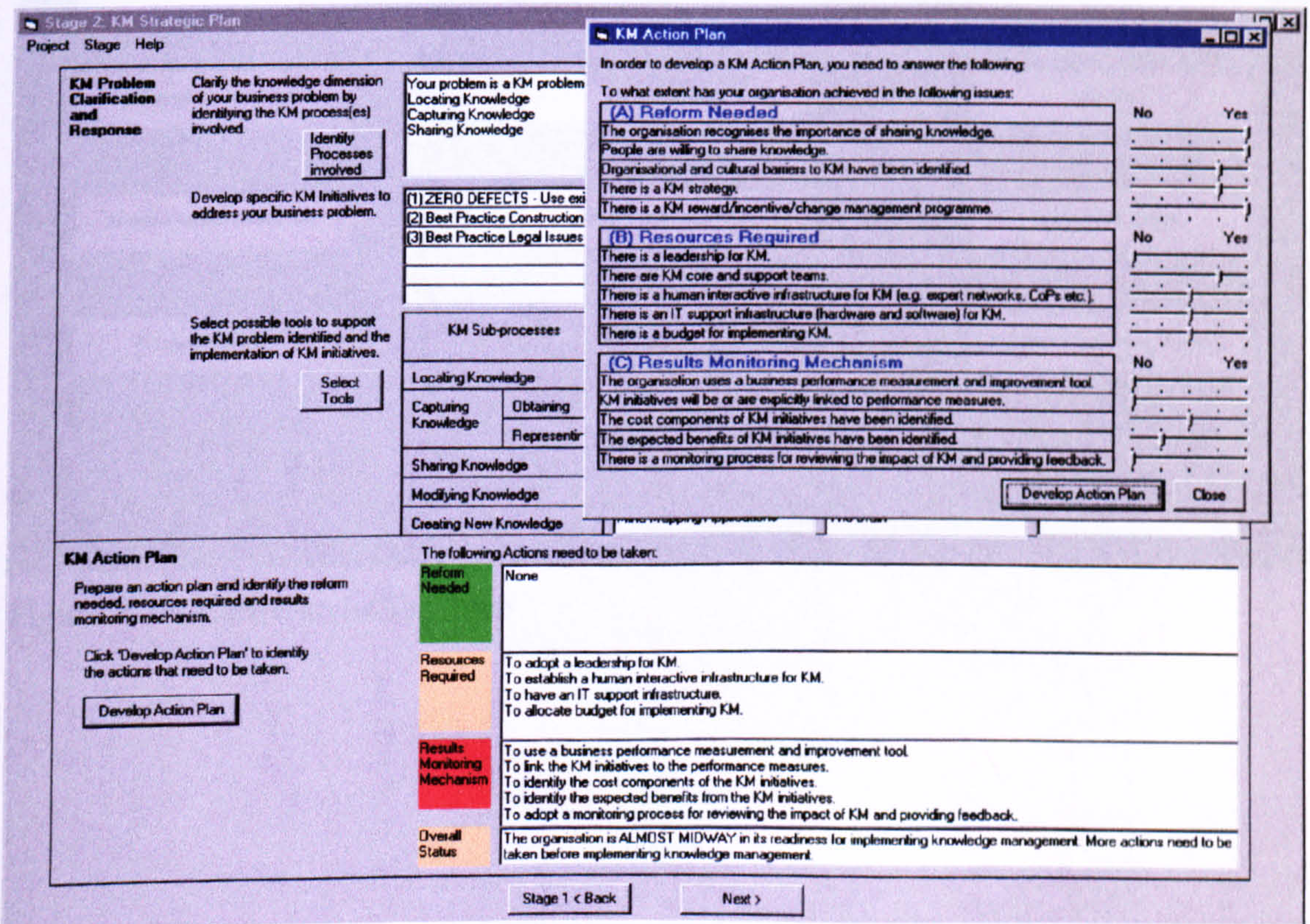

Figure 7.22: Action plan for implementing KM

The final task in stage two is to relate the strategic objectives to the KM initiatives (causes) and performance measures (effects) using the cause-and-effect map. The system presents a map where the user can draw lines to define and clarify the relationships between the strategic objectives, KM initiatives and performance measures (Figure 7.23). The user can also alter the map or add to it by clicking 'Show more boxes'. Objectives, initiatives, or measures added at this stage will automatically result in changes to the previous stages.

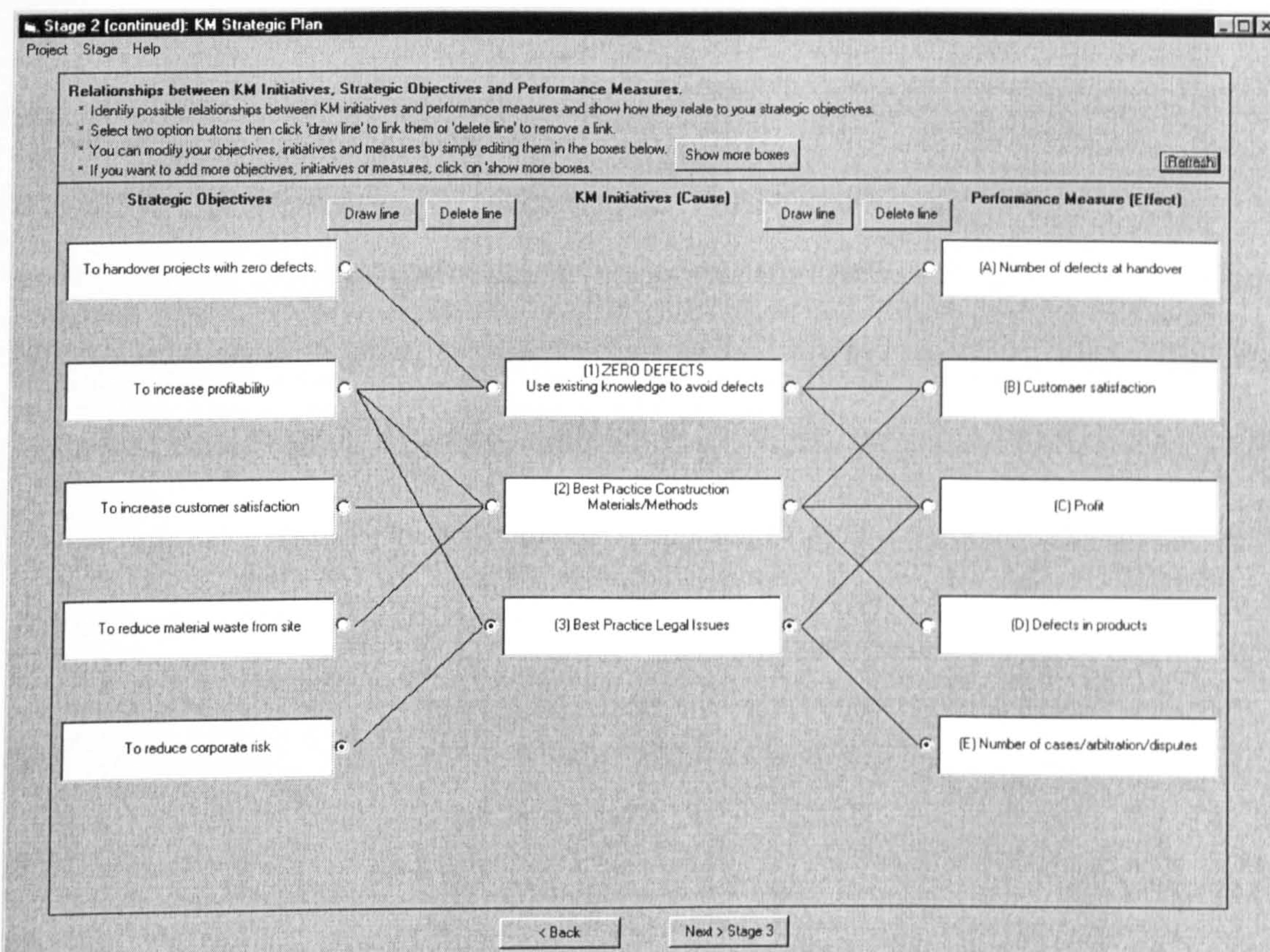

Figure 7.23: Cause-and-effect map

Stage 3: KM Evaluation Strategy

The aim of this stage is to evaluate the KM strategy and prioritise its initiatives using the effectiveness and efficiencies of KM initiatives. Effectiveness is based on the probability of success of the initiatives and their contributions to performance measures (Figure 7.24).

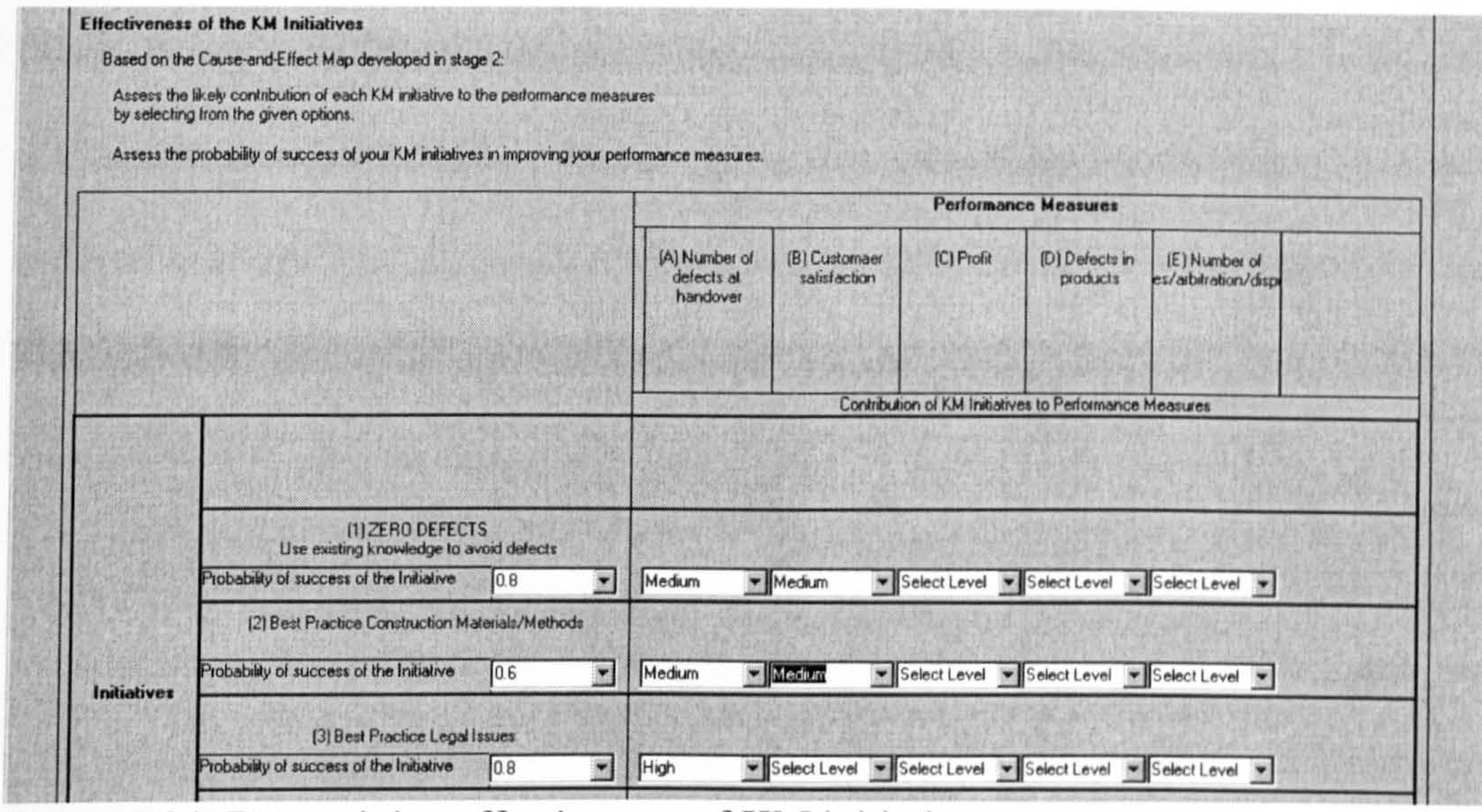

Figure 7.24: Determining effectiveness of KM initiatives

To determine the efficiencies it is important to identify an appropriate evaluation method. The method could be identified using the evaluation guide shown in Figure 7.25.

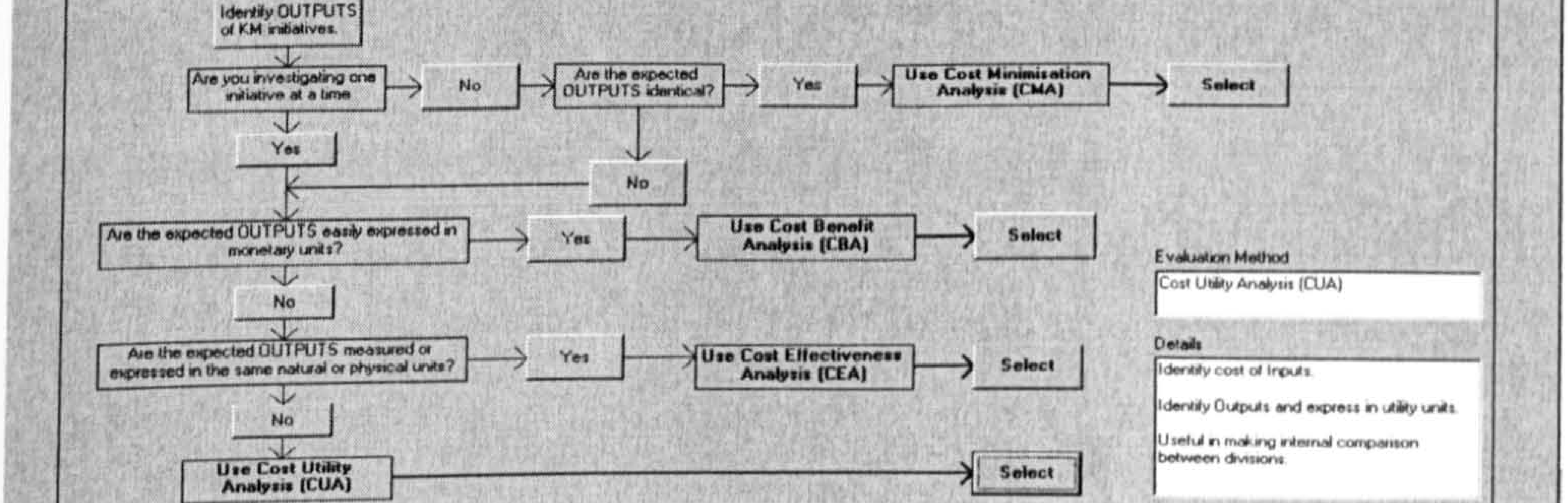

Figure 7.25: Evaluation guide for selecting appropriate evaluation methods

Once the evaluation method is selected, the user can determine the efficiency of KM initiatives. This involves identifying the cost of the inputs for the KM initiatives and the Benefit or Utility contribution arising from the outputs of the KM (Figure 7.26). Benefits are measured in monetary units whilst utilities are measured in non-monetary units.

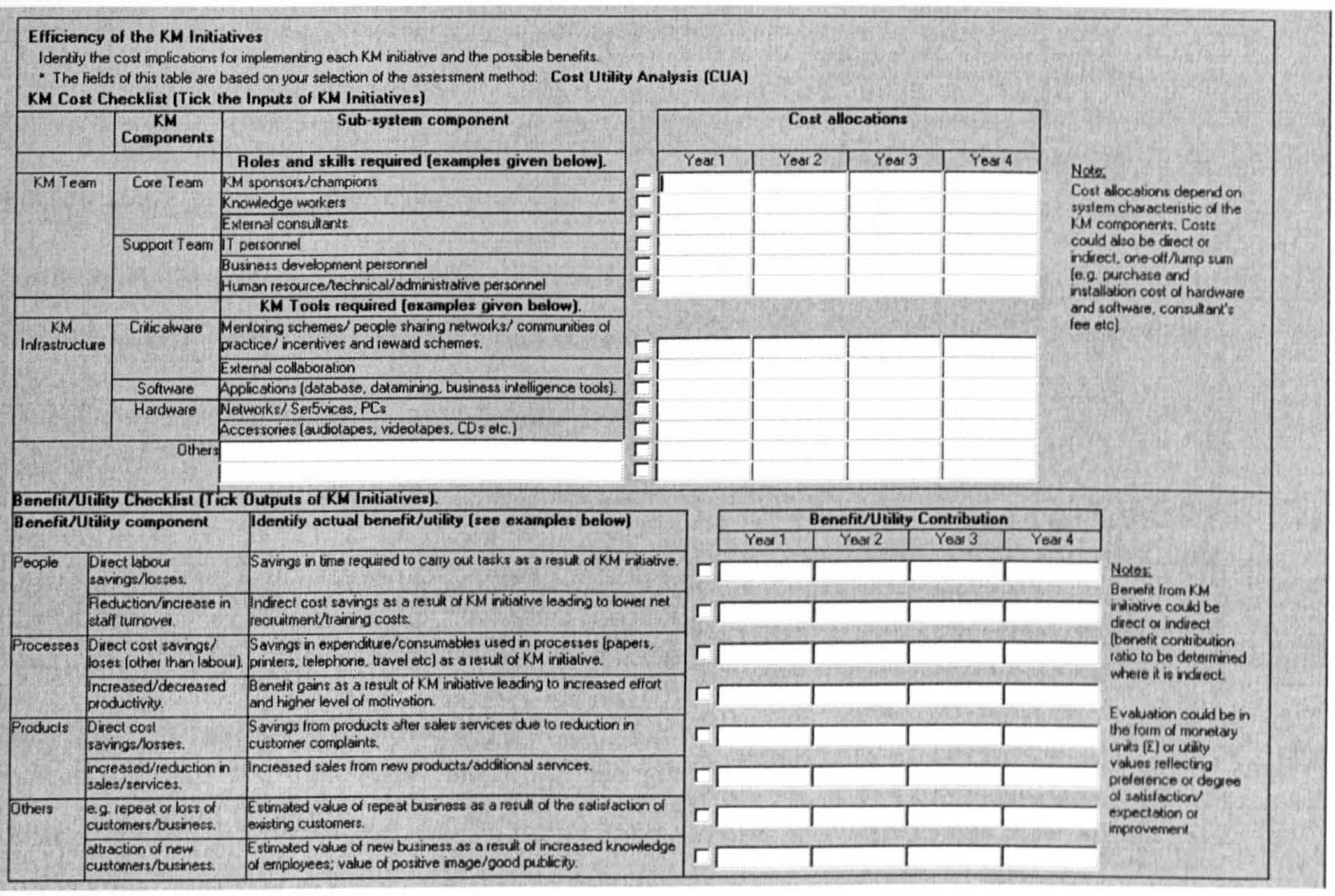

Figure 7.26: Determining efficiencies of KM initiatives

Additional feature has been incorporated in the system to add flexibility has been incorporated in the system so that users can, based on their judgement, prioritise the KM initiatives. A drag-and-drop operation where the user can drag the KM initiative to the relevant corner in the matrix facilitates this (Figure 7.27).

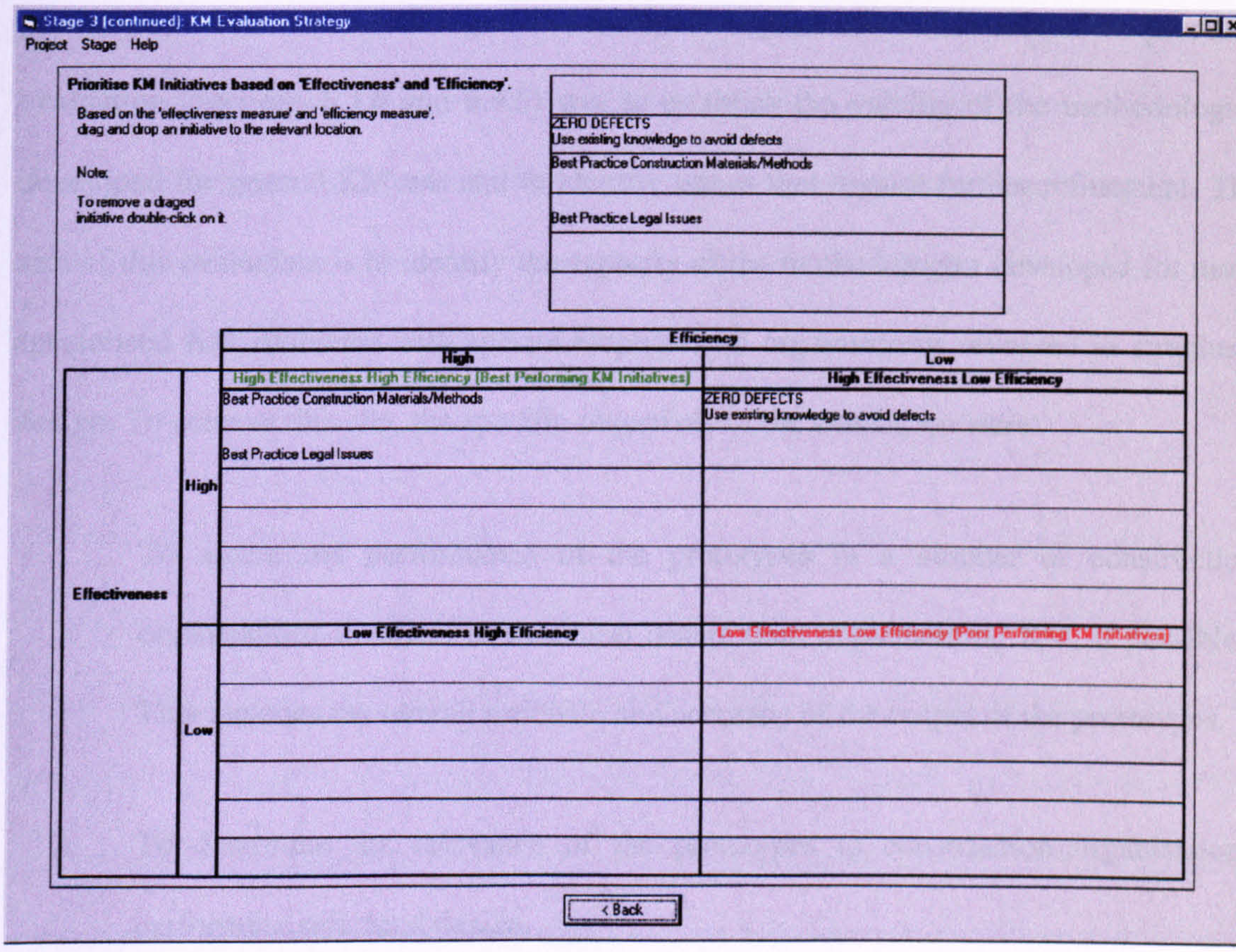

Figure 7.27 Prioritising KM initiatives

7.3 EVALUATION OF THE PROTOTYPES

This section describes the evaluation of the methodologies developed and their associated prototype systems. The evaluation was undertaken by a selection of industry practitioners who participated in the case study organisations described in Chapter 5, which resulted in the development of the conceptual framework described in Section 5.3.4. The evaluation objectives are first described.

7.3.1 Objectives of Evaluation

The CLEVER and IMPaKT prototypes are computer-based systems for developing and implementing KM strategies. These prototypes were first evaluated by industry practitioners from manufacturing and construction organisations. The aim of the previous evaluation (Sections 6.3.6 and 6.4.5) was to establish the validity of the methodologies developed for general KM use and to identify issues that require further refinement. The aim of this evaluation is to identify the capacity of the methodologies developed for more specialised KM problems with special emphasis on organisations involved in structural design. To achieve this aim, the specific objectives of the evaluation were:

1. To assess the performance of the prototypes in a number of construction organisations involved in structural design (and implementing KM, if possible). This includes the overall rationale and accuracy of the output of the prototypes.

2. To determine the relevance of the prototypes to construction organisations performing structural design.

3. To assess the capability of the prototypes for addressing all stages of KM identified in the conceptual framework developed in Section 5.3.4.

4. To assess the ease with which the prototypes can be used.

5. To identify and address any errors or weaknesses in the prototypes.

7.3.2 Evaluation Methodology

For the evaluation to be truly useful it is necessary to use appropriate organisations. These organisations should be involved in structural design and have a KM strategy. To investigate if the prototypes can solve the problems identified in the case studies of

Chapter 5 and at the same time address all the stages of the conceptual framework developed in Section 5.3.4, it was not appropriate to approach organisations 'in the cold'. Therefore, the evaluation was carried out with the same organisations used for the case studies. The participants were the same people interviewed although one (Case A) could not participate due to unforeseen reasons.

7.3.2.1 Evaluation procedure

The organisations involved in the case studies were asked during the interviews if they would be interested in evaluating the research outcome. All had shown interest and were senior structural engineers with different responsibilities in the KM system within their organisations. After the prototypes were developed, these contacts were approached and dates agreed. The evaluations took place in the organisations' offices. Every evaluation consisted of three parts lasting approximately one and a half hours. First, a ten-minute introduction was given. Then, the interviewee was allowed to use the prototypes for about fifty minutes. The author was seated next to the interviewee to provide guidance. This was very helpful in giving the user a feel for the system. This was followed by an open discussion for twenty minutes. The last ten minutes were used for completing the evaluation questionnaire.

7.3.2.2 Constraints in the evaluation

The evaluation was constrained by the evaluators' time. To use the prototypes for a real life problem requires one to two days per organisations due to the many details available within the systems and the many decisions to be taken during the process. The time offered by the evaluators was one hour and half for three evaluators and two hours for the fourth. To get as much as possible from the evaluators, they were encouraged to use the prototypes in the presence of the author. Although, they did not use the prototypes for a real life problem, the evaluators felt that they understood the prototypes and therefore provided very useful feedback.

7.3.2.3 Questionnaire design

A questionnaire (Appendix A13) was designed so that the CLEVER and IMPaKT prototypes were evaluated against the requirements for developing and implementing KM strategies for sharing structural design knowledge. The questionnaire was divided into four sections. Section A requested information about the participant's professional role and industrial experience. Section B consisted of nine questions about the CLEVER prototype. This was divided into the following sub-headings: KM Problem and Goals Identification; KM Strategy Development; and a General Section. Section C also consisted of 9 questions about the IMPaKT prototype. It was divided into: KM Strategy Development; KM Strategy Evaluation and a General Section. For each question in Sections B and C, participants were asked to tick the box that best reflects their assessment on a scale of 1 (poor) to 5 (excellent). The last section requested comments on ways to improve the prototypes and allowed for further comments.

7.3.3 Evaluation Results

This section summarises feedback from the evaluation participants. It includes responses to the questions and comments for further improvement.

7.3.3.1 Responses to questions

All participants were generally satisfied with the performance of both prototypes and felt that they are relevant to organisations involved in structural design in terms of clarifying the KM problem, identifying goals from implementing KM, developing a strategy for implementation and evaluating the strategy. Table 7.1 provides the average ratings of the prototypes with respect to the specific questions in the questionnaire. A detailed analysis of the various sections of the questionnaire is presented below.

Table 7.1: Summary of responses to evaluation questions

Questions		Average Rating (Out of 5)	Equivalent %
The CLEVER Prototype KM PROBLEM AND GOALS IDENTIFICATION			
1	How well does the system clarify problems of structural design knowledge?	4.00	80
2	How relevant to structural design are the knowledge characteristics used in the system?	4.25	85
3	How well does the system relate structural design knowledge to organisational business drivers?	3.75	75
4	How well does the system help in identifying the organisational goals for managing structural design knowledge?	3.75	75
KM STRATEGY DEVELOPMENT			
5	How well does the system help in developing a KM strategy for sharing structural design knowledge?	4.00	80
6	How well does the system help in identifying the sources of knowledge?	3.50	70
7	How well does the system help in identifying the users of knowledge?	4.00	80
GENERAL			
8	How appropriate is the system for structural design departments/divisions?	3.75	75
9	What is your overall rating of the system?	3.50	70
The IMPaKT Prototype KM STRATEGY DEVELOPMENT			
10	How well does the system help in developing a KM strategy for sharing structural design knowledge?	3.75	75
11	How well does the system identify the tools required for managing structural design knowledge?	4.00	80
12	How well does the system help in identifying an action plan for implementation?	4.50	90
13	How well does the system relate the KM initiatives to strategic objectives and performance measures?	4.50	90
KM STRATEGY EVALUATION			
14	How useful do you think the system will be in evaluating a KM strategy before implementation?	4.25	85
15	How useful do you think the system will be in evaluating a KM initiative after implementation?	3.25	65
16	How well does the system help in prioritising KM initiatives?	4.00	80
GENERAL			
17	How appropriate is the system for structural design firms/departments/divisions?	3.75	75
18	What is your overall rating of the system?	3.75	75

THE CLEVER PROTOTYPE

KM Problem and Goals Identification

A high average rating of 4.00 (80%) for the first question indicates that the CLEVER prototype effectively facilitated the clarification of problems regarding structural design knowledge. The individual scores were 4, 3, 4, and 5. It was also accepted by participants that the knowledge characteristics used are relevant to structural design. Participants gave scores of 4, 5, 4, and 4 making an average rating of 4.25 (85%). The third question received scores of 4, 4, 4 and 3 making an average of 3.75 (75%). This shows that the participants were satisfied that the prototype properly relates structural design knowledge to organisational business drivers. Participants also indicated that the prototype is useful in identifying the organisational goals from managing structural design knowledge. The scores given were 4, 3, 4 and 4 with an average of 3.75 (75%).

KM Strategy Development

The participants found the prototype extremely helpful for developing a KM strategy for sharing structural design knowledge. Individual marks of 4, 5, 4 and 4 were given to this question showing an average of 4.00 (80%). The sixth question about the prototype's potential for identifying the sources of knowledge has also received high marks of 4, 3, 4 and 3 with an average of 3.50 (70%). However, the participants felt that the system is more useful in identifying the intended users of knowledge by giving an average of 4.00 (80%). All participants responded to this question by scoring it four out of five.

General

In general, CLEVER was received as an appropriate tool for structural design departments/divisions at an average level of 75% and an average rating of 3.75. The overall rating of the system was 3.5 (70%).

THE IMPaKT PROTOTYPE

KM Strategy Development

The IMPaKT prototype was also recognised as very helpful in developing a KM strategy for sharing structural design knowledge. A high average rating of 4.00 (80%) was given with individual scores of 4, 3, 4 and 5. The prototype was also found very useful for identifying the KM tools (IT and non-IT) required for managing structural design knowledge. Scores of 5, 3, 4 and 4 were given representing an average rating of 4.00 (80%). Questions 12 and 13 received the highest scores with an average rating of 4.50 (90%). This confirms that the prototype was highly successful in developing an action plan of the preparations required before implementing KM. The individual scores received for this question were 4, 5, 5 and 4. Also, the system was very useful in relating the organisational KM initiatives to the strategic objectives and performance measures. This question received individual scores of 4, 5, 4 and 5.

KM Strategy Evaluation

All participants agreed that the IMPaKT prototype was very useful in evaluating a KM strategy before implementation by giving an average rating of 4.25 (85%) with individual scores of 4, 5, 4 and 4. However, the participants felt that the prototype is less useful in evaluating a KM strategy after implementing KM by giving an average rating of 3.25 (65%) with scores of 3, 3, 4 and 3. This reflects a concern that it may be too late to evaluate the KM strategy after it is implemented and that rectifying such a strategy might be of high cost. This does not, however, suggest that a KM strategy should not be evaluated after implementation. The prototype was also found helpful in prioritising KM initiatives. An average rating of 4.00 (80%) and individual scores of 4, 5, 4 and 3 were given.

General

In general, IMPaKT was perceived as a potential tool for structural design departments/divisions at an average level of 75% and an average rating of 3.75. This is consistent with the feedback received on the CLEVER prototype. The overall rating of the IKPaKT prototype was 3.75 (75%).

7.3.3.2 Suggestions for improvement

Participants described the CLEVER and IMPaKT prototypes as: 'overall excellent products', 'very logical flow', and 'potentially very useful'. However, few suggestions for improvement were received. The reason for the small number of suggestions is that the prototypes and their supporting methodologies have already been refined using industrial practitioners as described in Sections 6.3.6 and 6.4.5. The received suggestions were:

- It is important to provide a list of possible knowledge problems for the first question where the user can select the relevant one and refine it;

- Ensure that the questions asked in a stage are used in subsequent stages i.e. check for redundant questions or entries;

- Allow users to navigate easily between the different forms;

- Provide more explanation on the performance measures and different types of knowledge dimensions; and

- Integrate both prototypes into one system to benefit from their individual strengths.

Some of these suggestions are being taken on board in the commercial development of the CLEVER and IMPaKT prototypes.

7.4 BENEFITS OF THE PROTOTYPES

Although there is room for improvement, the prototype systems provided an effective tool for developing and implementing KM strategies for any knowledge type and any business organisation. This effectiveness can be linked to the high ratings of the questions in the questionnaire. The validity of these tools for developing a strategy for managing structural design knowledge has also been confirmed.

Through the evaluation of the systems, several practical benefits were demonstrated. These include:

- The systems provide a new and innovative tool for developing a strategy for managing structural design knowledge and can also be used in other areas;

- The systems support KM at both strategic and tactical levels unlike other tools which focus at the operational level of implementing KM;

- The systems can be used by any business organisation or a unit within the organisation;

- The systems include much built-in information that can be tailored to address the requirements of the organisations using it;

- The systems help users to clarify a KM problem in a new and guided way that encourages more thinking about the problem;

- The systems support the identification of organisational goals from implementing KM in a direct and straightforward way;

- The systems provide a highly structured approach to developing a KM strategy using built-in generic models;

- The systems provide several details required when developing a KM strategy (e.g. action plan, tools required, etc); and

- The systems provide a novel tool for evaluating a KM strategy based on the effectiveness and efficiency of the KM initiatives; and

Finally, it is evident that the systems have a potential commercial value. This is being explored by Loughborough University.

7.5 LIMITATIONS OF THE PROTOTYPES

The comments made by the evaluation participants have highlighted some of the limitations of the prototype systems, which include:

- The user-interface needs further enhancement so that users can easily navigate between the system elements;

- The system cannot be used without external help. However, it should be noted that even if more 'Help' commands are added to the system, the need for a short period of training cannot be eliminated;

- Neither the CLEVER nor IMPaKT prototypes provide a complete solution if used alone; and

- Using the CLEVER prototype and then moving to IMPaKT could result in input duplication unless they are integrated into one system.

7.6 DISCUSSION

7.6.1 Results

Overall, the evaluation results are very positive. Participants in the evaluation were satisfied with the performance and effectiveness of the prototypes. The high ratings received from the evaluation questionnaire confirmed that the system is suitable to a wide range of organisations although customisation may be required for some business cases. The system's performance showed that it is able to fulfil all the requisite functions efficiently. Suggestions and comments have been received on various aspects of the system and could provide the basis for further work.

From the results of the evaluation, it is evident that the objectives set out in Section 7.3.1 have been achieved, as discussed below.

Achieving objective one

The first objective was to assess the performance of the prototypes developed. The performance of the prototypes was assessed in four construction organisations heavily involved in structural design and already implementing KM. The overall ratings of 3.83 (76.67%) for the CLEVER prototype and 3.97 (79.44%) for the IMPaKT prototype reflected the overall satisfactory performance of the prototypes.

Achieving objective two

The second objective was to determine the relevance of the prototypes developed to construction organisations involved in structural design activities. Both prototypes were given a similar average rating of 3.75 (75%) and this shows that both can be used for developing and implementing KM strategies for managing structural design knowledge.

Achieving objective three

This objective focuses on assessing the capability of the prototypes to address all KM stages identified in the conceptual framework developed in Section 5.3.4. The average ratings for these stages show that the prototypes address all of them. The ratings received for each stage are:

- KM problem identification: 4.00 (80%)
- KM goals identification: 3.75 (75%)
- KM strategy development: 3.83 (76.67%) for CLEVER and 4.19 (83.75%) for IMPaKT
- KM strategy evaluation: 3.83 (76.67%)

Achieving objective four

The fourth objective of the evaluation was to assess the ease with which the prototypes could be used. This was assessed by allowing the evaluators to use the prototypes. The comments received for improving the system were minor confirming that they were easy to use.

Achieving objective five

The last objective of the evaluation was to identify and address any errors or omissions made during the development of the prototypes. All known errors and omissions were located by the author, during and after the evaluations. Where appropriate, these have been addressed.

7.6.2 Appropriateness of the Evaluation Approach

The evaluation was considerably successful. This was manifested by the positive responses obtained from the evaluators. Although there were limitations, the evaluators were of the view that future improvements would further facilitate the use of the prototypes. The chosen evaluation approach helped to test all aspects of the system required in the evaluation objectives. The reflections from the whole evaluation process include:

- The questionnaire covered all the major aspects of the system that needed to be evaluated and was useful for obtaining the essential feedback from the evaluators;

- All evaluators were involved in the case-study interviews described in Chapter 5. This evaluation allowed them to point out if the system addressed the needs identified earlier; and

- All evaluators had considerable experience in the field of structural design and its knowledge requirements and this ensured a relatively accurate assessment of the system.

The only known limitation in the evaluation approach was being unable to evaluate the system on a real life case due to evaluators' limited time.

7.7 SUMMARY

This chapter has demonstrated the use of the prototype systems developed, by describing the user interface and user interaction with the system. This served to aid understanding of the operation of the systems and illustration of their key features. It also described the evaluation process using four construction organisations heavily involved in structural design. Although the system has some limitations, the evaluation result shows that it effectively facilitated the development of a KM strategy for managing the technical and highly specialised knowledge area of structural design. Overall, the prototypes were highly rated at 78%.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This chapter concludes the research project, which investigated the potential of knowledge management for improving the structural design process. The investigation resulted in two prototype systems for the development and implementation of a KM strategy. The findings of the research are summarised. Also included is a summary of the systems' advantages, conclusions from the research, contribution to knowledge, limitations of the work, recommendations for further work and concluding remarks.

8.2 SUMMARY

The aim of this research project was to develop a tool for sharing structural design knowledge using the concept of knowledge management. The rationale for undertaking this research was based on the need to improve the highly complex and knowledge intensive process of structural design. It resulted in the creation of a conceptual framework for developing and implementing a KM strategy and the development of a detailed methodology within the context of the framework supported by two prototype systems. Various research methodologies, strategies and tools were adopted to achieve the defined objectives of the research. These included: extensive literature reviews; discussions and interviews with practitioners in the construction industry; rapid prototyping; case studies; questionnaires; participation at workshops; seminars and conferences to interact with other researchers and professional in similar research areas; and peer reviews of published work. The specific tasks undertaken in the development of the conceptual framework, methodology and prototype systems, with respect to the objectives of the research are summarised below.

Literature review on the structural design process revealed that several problems are faced during the different stages of structural design. These are: overlapping process activities; complex analysis and design; fragmentation in the process; and the involvement of many knowledge-dependent tasks. It was also found that many approaches have been used to overcome these problems specifically: techniques for modelling the process; algorithms for the analysis and design; approaches for integrating the process; and expert systems for capturing knowledge. The only reported research effort with regard to structural design knowledge was the use of expert systems. These Artificial Intelligence (AI) tools attempted to codify the abstract reasoning processes of experts into 'if-then' rules to support decision-making. They, however, were not successful due to several reasons, mainly: focusing on codification of the tacit knowledge of experts and ignoring, in many cases, the explicit knowledge available in documents, drawings, multimedia tools etc; and disregarding the interactions between tacit and explicit knowledge. Furthermore, codifying the tacit knowledge of experts resulted in losing the richness and context of knowledge in addition to the fact that codified knowledge gets outdated very quickly. Consequently, expert systems failed to address the complex nature of knowledge and were therefore not suitable for structural design knowledge.

Knowledge Management (KM) is a relatively new concept receiving increased attention. It considers knowledge as a valuable asset needing to be managed and that shared knowledge increases therefore expanding an organisation's memory. KM helps in reducing duplication and mistakes, increasing innovation, improving business performance and adding competitiveness. Two knowledge types are distinguished, namely tacit and explicit where knowledge can be converted from one type to another. KM also recognises the complex nature of knowledge and identifies the richness and context associated it. KM is not a solely IT-based solution nor is it a solely human-based solution. It requires the consideration of a combination of issues including IT, people, and organisational culture. This combination makes KM difficult to implement but at the same time more beneficial in practice. It is evident that KM can play an important role in improving the way knowledge is created, captured, shared and used within and across organisations. It therefore overcomes some of the shortcomings of expert systems. The many benefits of KM resulted in many leading construction organisations adopting its strategies to improve their business. However, literature shows that the potential of KM for highly specialised knowledge such as that in structural design has yet to be explored.

To investigate the potential of KM for sharing structural design knowledge, five case organisations, extensively involved in structural design, were studied. Some of them had a KM strategy in place while others did not. The case studies carried out confirmed the existence of several problems that involve obtaining new knowledge during structural design. Both tacit and explicit knowledge were required although three quarters of the knowledge involved during concept design was considered tacit and three quarters of that involved during detailed design was considered explicit. Organisations obtained the required knowledge mostly via informal ways although those adopting KM used a mixture of informal and formal methods. It was evident that KM has the potential to support the way knowledge is used and that KM can provide several benefits to structural designers such as accelerating concept and tender design, reducing the number of design cycles, developing easy design routines etc. However, all organisations believed that they still needed to improve the way this knowledge is managed.

The case studies also uncovered the need for a comprehensive framework that supports the development and implementation of KM strategies. Four stages were found necessary for a robust conceptual framework: identifying the knowledge to be managed; identifying goals for managing it; developing a strategy; and evaluating the strategy. On the other hand, such a framework needed a detailed methodology developed within its context. Investigation and analysis of existing methodologies showed that no methodology addresses all stages of the developed framework although a few of them address some stages or elements within a stage. This resulted in the adoption of an existing methodology (CLEVER) and development of a new methodology (IMPaKT). Together, they address all stages of the conceptual framework developed.

CLEVER and IMPaKT were encapsulated into two prototype systems using Microsoft Visual Basic. Development of the prototypes was influenced by the principles of software development, particularly rapid prototyping. This automation facilitated the use of the methodologies, and enhanced their functionality. Following their development, the prototypes were presented and used in several workshops involving eight organisations. This resulted in more refinement to the methodologies and the associated prototypes. An evaluation by four construction organisations extensively involved in structural design and already implementing KM was then undertaken. The evaluation confirmed that, in spite of the improvement required to make the prototypes fully operational, they do proffer many benefits in developing and implementing a KM strategy for sharing structural design knowledge.

8.3 BENEFITS OF THE PROTOTYPS

The benefits that the prototype systems offer to individuals, departments or organisations involved in structural design can be summarised as follows. They:

- provide a new and innovative tool for developing and implementing a KM strategy;
- support KM at both strategic and tactical levels unlike other tools which focus on the operational level;
- can be used by any business organisation or a unit within the organisation;
- include much built-in information that can be tailored to address the requirements of the organisations using it;
- help users to clarify a KM problem in a new and guided way that encourages more thinking about the problem;

- support the identification of organisational goals from implementing KM in a direct and straightforward way;
- provide a highly structured approach to developing a KM strategy using built-in generic models;
- provide several details required when developing a KM strategy (e.g. action plan, tools required, etc); and
- provide a novel tool for evaluating a KM strategy based on the effectiveness and efficiency of the KM initiatives.

Finally, it is evident that the systems have a potential commercial value. This is being explored by Loughborough University.

8.4 CONCLUSIONS

The following conclusions could be drawn from the research:

1. The process of structural design is associated with many problems such as overlapping process activities, complex analysis and design, fragmentation and the existence of many knowledge intensive tasks that require a coherent approach for managing existing and new knowledge.

2. Current approaches for improving the structural design process are suitable for dealing with some of the problems identified. However, they do not adequately address the problems of managing the tacit and explicit knowledge associated with the structural design process because of the following:

   - they do not address all elements of KM that are essential for design process improvement;
   - there is a lack of KM framework for structural design processes; and
   - there is a lack of a detailed methodology for the implementation of KM.

3. KM has the potential to solve problems in highly specialised domains such as structural design. Some of the benefits that KM provides to structural design are:
   - reduced number of design cycles;
   - reduced design time;
   - developing easy design routines; and
   - making past design reviews and standard ways of analysing particular situations easily accessible.

4. The conceptual framework for developing and implementing a KM strategy and the associated prototypes (CLEVER and IMPaKT) provide a detailed methodology and a unique and innovative approach for developing a strategy for managing structural design knowledge and addressing the problems identified.

5. The developed prototypes have the potential to provide better, more effective and efficient implementation of KM in structural design in particular and within the construction industry in general.

8.5 CONTRIBUTION TO KNOWLEDGE

Knowledge is crucial for structural design, yet existing methodologies for managing it are neither comprehensive nor do they adequately address the requirements of designers. Knowledge management remains largely unexplored although it is a valuable concept. For a knowledge management strategy to be effective, it must address all the stages required for such strategy. A framework was therefore introduced as an alternative to existing ones, which do not address all stages. A methodology developed within the context of this framework was important. Refinement of the CLEVER methodology and development of the IMPaKT methodology served this need. In contrast to existing methodologies, CLEVER and IMPaKT provide an integrated methodology that addresses the four critical stages required for a successful KM strategy. The methodologies were encapsulated into prototype systems.

Investigation into the potential of knowledge management for sharing structural design knowledge is original. A more significant contribution is the conceptual framework for developing and implementing a KM strategy, which is more appropriate than existing frameworks because it was developed based on the experience of organisations which are heavily involved in structural design and are at different levels of implementing KM. Also, there is originality in the refinement of CLEVER and the development of IMPaKT. Another contribution is the practical value of the prototypes for clarifying the knowledge of interest, identifying the goals from implementing KM, developing a detailed strategy and evaluating the strategy. Better strategies can therefore be formulated to facilitate the implementation of KM in any business sector and certainly for construction organisations involved in structural design. The prototype systems also provide an IT tool that supports knowledge management at the strategic and tactical level, unlike other existing IT tools which support it at the operational and implementation level.

8.6 LIMITATIONS OF THE STUDY

A research project by its nature has some limitations and is bound to uncover issues that need to be investigated further. This PhD research project is no exception, as a number of issues have been identified to improve the methodology developed. In analysing the evaluation results, it was apparent that while the methodologies and their associated prototype systems represent a feasible proposition and are also robust, they were incomplete. The main limitations are discussed below.

1. The prototypes cannot be used without guidance. This is due to the following reasons:

   - the many tasks involved in the prototypes;
   - the user-interfaces need further refinement (e.g. rejecting improper data, error messages for invalid inputs, etc).

2. Although, consistency of the comments received from the participants in the refinement and evaluation of the prototypes indicate that the findings can be generalised, it is not possible make such a statement at this stage because the methodologies and their supporting prototypes were:

   - Refined and evaluated only with few organisations; and
   - were not tested on real life problems.

8.7 RECOMMENDATIONS

Several issues have been identified from the findings of this research in order to improve the management of structural design knowledge. Recommendations to the industry include the following:

- The many scenarios that require obtaining new knowledge during structural design necessitate the implementation of strategies that assist in locating and using this knowledge;

- Knowledge management is valid for the highly technical knowledge of structural design and therefore it should be seriously considered;

- Knowledge management needs to be carefully planned and properly implemented in order to achieve the organisation's KM goals;

- It is important to follow a structured approach for developing a KM strategy to avoid implementing unnecessary strategies and/or missing important ones; and

- The CLEVER and IMPaKT prototypes provide many benefits to construction organisations and it is recommended that they consider adopting these.

8.8 FURTHER RESEARCH

The research project has revealed a number of areas for further research and development including the following areas:

1. Further improvements to the systems with respect to:

   - adding more intelligence to the problem definition template in the CLEVER prototype so that the system does not only help in refining a KM problem but also carries out some analysis;

   - creating more links between the items identified in the problem definition template and the other stages;

   - enhancing user-friendly functions to smooth system implementation difficulties (e.g. examine and reject improper data, generate a warning message when the system has insufficient or illogical inputs etc); and

   - improvement of the user interface through better screen layouts and better user guidance.

2. Further testing using a wider range of real cases is considered necessary as the feedback from these can further demonstrate the system's applicability to different scenarios.

3. Investigation into the requirements for integrating CLEVER and IMPaKT prototypes. This includes:

- identifying how the individual elements within the prototypes would be linked;

- removing any duplications or overlaps between the prototypes' elements; and

- ensuring consistency within the integrated system including the terminologies used and activities involved.

4. The actual integration of the CLEVER and IMPaKT prototypes into one prototype system to ensure synergy from their individual strengths.

5. Extend the research on KM Tools (IT and non-IT) to update the list developed and to assess these tools by organisations already using them. This can be done through an industrial survey covering a wide range of organisations.

6. Investigate the potential of KM for other aspects of the construction process and not just structural design. This may be done through a wider scale of case studies covering the different sectors within the construction industry.

8.9 CONCLUDING REMARKS

The process of structural design is important for safe and stable structures. This process is associated with several problems where current approaches are suitable for dealing with some of these problems. Current approaches do not adequately address the problems of structural design knowledge and although the construction-sector organisations recognise the importance of managing this knowledge, many are uncertain about the best way of doing it. This thesis has demonstrated the potential of knowledge management for facilitating the management of structural design knowledge. A conceptual framework for developing and implementing a KM strategy was introduced, with structured methodologies for implementation. The methodologies were encapsulated into prototype systems, which represent a substantial advance over existing approaches. Construction organisations will achieve much improved performance and market leadership should they adopt the methodologies developed and their associated prototypes.

REFERENCES

AEC Computer Market Study (1988), *Engineering News-Record: Research Report*, McGraw-Hill Inc, pp. 11-20.

Adelman, L. (1992), *Evaluating Decision Support and Expert Systems*, John Wiley &Sons, Inc, New York.

Adeli, H. (1988), Expert Systems in Construction and Structural Engineering, Chapman and Hall, London.

Akinsola, A.O., Potts, K.F. and Ndekugri, I. (1994), Variations on Construction Projects: A Review of Empirical Studies, *Building Research and Information*, Vol. 22, No. 5, pp.269-271.

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2001a), An Innovative Tool for Knowledge Problem Definition, *Proceedings of the First International Conference on Innovation, in AEC*, Loughborough University, Loughborough, UK, 18-20 July, Anumba, C.J., Egbu, C., and Thorpe, T., eds., pp. 249-256.

Al-Ghassani, A.M., Carrillo, P.M., Anumba, C.J., and Robinson, H.R. (2001b), Software Requirements for Knowledge Management in Construction Organisations, *Proceedings of the 17th Annual ARCOM Conference*, Salford University, Salford, UK, 5-7 September, Akintoye, A., ed., pp. 199-206.

Al-Ghassani, A.M., Anumba, C.J., Carrillo, P.M., and Robinson, H.S. (2002a), Improving Structural Design Processes through Knowledge Management, *Proceedings of the 3rd International Conference on Concurrent Engineering in Construction (CEC 2002)*, University of California, Berkeley, USA, 1-2 July, Tommelein I.D., ed., pp. 169-180.

Al-Ghassani, A.M., Robinson, H.S., Carrillo, P.M., and Anumba, C.J. (2002b), A Framework for Selecting Knowledge Management Tools, *Proceedings of the 3rd European Conference on Knowledge Management (ECKM 2002)*, Trinity College Dublin, Ireland, 24-25 September, pp. 37-48.

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2002c), A Tool for Developing Knowledge Management Strategies, *Electronic Journal of Information Technology in Construction (ITcon), A Special Issue of the "ICT for Knowledge Management in Construction"*, Vol. 7, pp. 69-82.

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2003), A Structured Approach for Identifying Knowledge Management Problems, *International Journal of Innovation in ACE.* (paper accepted).

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2004), System Prototype for Knowledge Problem Definition, *Journal of Construction Engineering and Management, American Society of Civil Engineers (ASCE)*, (in review process).

Allison, B. (1995), *Research Methods*, De Montfort University Library, Leicester.UK.

Allwood, R.J. (1989), *Techniques and Applications of Expert Systems in the Construction Industry*, Ellis Harwood Ltd, Chichester.

Anumba, C.J. and Evbuomwam, N.F.O. (1995), The Manufacture of Constructed Facilities, *Proceedings of the ICAM '95*, pp. 1-8.

Anumba, C.J., Baron, G. and Evbuomwam, N.F.O. (1997), Communications Issues in Concurrent Life-Cycle Design and Construction, *BT Technology Journal*, Vol. 15, No. 1, pp. 209-216.

Anumba, C.J., Bloomfield, D., Faraj, I. and Jarvis, P. (2000), *Managing Your Knowledge Asset: Knowledge Based Decision Support Techniques for the Construction Industry*, BR 382, Construction Research Communications Ltd.

Anumba, C.J., Carrillo, P.M., Backhouse, C.J., Brookes, N.J. and Sinclair, M.A. (2001), *Cross Sectoral Learning in the Virtual Enterprise*, EPSRC Final Report, Loughborough University, UK.

Anumba, C.J., Carrillo, P.M., Robinson, H.S. and **Al-Ghassani, A.M.** (2002), A Performance-Based Approach to Knowledge Management, *Proceedings of the eSMART Conference*, Salford University, Manchester, UK, November, pp. 134-145.

Aouad, G.F., Kirkham, J.A., Child, T., Cooper, G.S. and Ford, S. (1994), An Object Oriented Model of Building Procurement, *Microcomputers in Civil Engineering*, Vol. 9, pp. 401-411.

APDST, (1991), *Academic Press Dictionary of Science and Technology*, Harcourt Brace Jovanovich Publishers, London.

Ashworth, A. (1991), *Contractual Procedures in the Construction Industry*, Second Edition, Longman, London.

Austin, S., Newton, A., Steele, J., and Waskett, P. (2002), Modelling and Managing Project Complexity, *International Journal of Project Management*, Vol. 20, pp. 191-198.

Austin, S., Steele, J., Macmillan, S., Kirby, P. and Spence, R. (2001), Mapping the Conceptual Design Activity of Interdisciplinary Teams, *Design Studies*, Vol. 22, No. 3, pp. 211-232.

Bair, J.H. and O'Connor, E. (1998), The State of the Product in Knowledge Management, *Journal of Knowledge Management*, Vol. 2, No. 2, December, pp 20-27.

Baldwin, A., Austin, S., Pendlebury, M. (1997), The Interface of Early Stage Design and Cost Advice in the Building Design Process, *Proceedings of the 13th ARCOM Annual Conference*, Cambridge, Vol. 2, pp. 395-404.

Baxter, L.F. and Macfarlane, A.W. (1992), Just in Time for the Construction Industry, *CIOB Construction Papers*, No. 14, The Chartered Institute of building, UK

Bell, T., and Plank, R.J. (1985), *Microcomputers in Civil Engineering*, Construction Press, London and New York.

Bennett, J. and Jayes, S. (1998), *The Seven Pillars of Partnering*, Thomas Telford Publishing, London.

Bliznakov, P. (1996), *Design Information Framework to Support the Engineering Design Process*, PhD Thesis, Arizona State University, Tempe, Arizona.

Blumentritt, R. and Johnston, R. (1999), Towards a Strategy for Knowledge Management, *Technology Analysis and Strategic Management*, Vol. 11, No. 3, pp. 287-300.

Bouchlaghem, N.M. and Laptali, E. (1995), Expert Systems within the Construction Industry in the UK, *Automation in Construction*, Vol. 3, No. 4, pp. 321-325.

Brandon, P. and Betts, M. (1995), The Field of Integrated Construction Information: An Editorial Overview, Bradon, P. and Betts, M., eds., *Integrated Construction Information*, E & FN SPON, London.

Britton, C. and Doake, J. (1996), *Software System Development: A Gentle Introduction*, McGraw-Hill, London.

Brookes, N. J. and Backhouse, C. J. (1998), Understanding Concurrent Engineering Implementation: A Case-Study Approach, *International Journal of Production Research*, Vol. 36, No. 11, pp. 3035-3054.

BS7000 (1989), Part 1, *Guide to Managing Product Design*, British Standard Institute (BSI), London.

BS7000 (1994), Part 4, *Guide to Managing Design in the Construction Industry*, British Standard Institute (BSI), London.

Cannon, T., CEO, Management Charter Initiative. 1999.

Carr B. and Winch, G. (1998), Construction Benchmarking: An International Perspective, EPSRC IMI., University College of London, March, 1998

Carrillo, P. M., Anumba, C.J. and Kamara, J.M. (2000), Knowledge Management Strategy for Construction: Key I.T. and Contextual Issues, *Proceedings of the International Conference on Construction Information Technology (CIT2000)*, Reykjavik, Iceland, 28-30 June, Vol. 1, pp 155-165.

Carrillo, P.M., Robinson, H.S., Anumba, C.J. and **Al-Ghassani, A.M.** (2003a), IMPaKT: A Framework for Linking Knowledge Management to Business Performance, *Electronic Journal of Knowledge Management (EJKM)*, Vol. 1, Issue 1, March.

Carrillo, P.M., Robinson, H.S., **Al-Ghassani, A.M.**, Anumba, C.J. (2003b), Knowledge Management in Construction: Drivers, Resources and Barriers, *Project Management Journal.* (paper accepted).

Castillo, A. R. and Clodfelter, S. K. (2001), Implementing a Knowledge Management Concept for Distributed Mission Training, *Proceedings of I/ITSEC Conference*, 26-29 November, Orlando, Florida.

Cavaye, A. L. M. (1996), Case Study Research: A Multi Faceted Research Approach for IS, *Introduction to System Journal*, Vol. 6, pp. 227-242.

Chan, R. (1999), Knowledge Management for Implementing ERP in SMEs, *3rd Annual SAP Asia Pacific Institutes of Higher Learning Forum 'Maximizing the Synergy between Teaching, Research and Business'*, Singapore, North Sydney, Australia, 1-2 November, pp. 21-39.

Chandrasekaran, B. (1989), A Framework for Design Problem Solving, In Gero, J.S., ed., *Proceedings of the Workshop on Research Directions for AI in Design*, March 1989, University of Sydney, Australia.

Cherns, A.B. and Bryant, D.T. (1988), *The Construction Project Team as a Temporary Multiorganisation: The Role of the Client System*, Final Report on SERC Project, No. GR/C/88352.

Churchman, C.W. (1971), *The Design of Inquiring Systems: Basic Concepts of Systems and Organization*, Basic Books, New York.

CIB (1997), *Partnering the Team* (Working Group 12), Construction Industry Board, Thomas Telford, London.

CIRIA (2000a), *Applying Knowledge Management to the Construction Industry*, Workshop Report, Construction Productivity Network, London, UK.

CIRIA (2000b), *Civil Engineering Design and Construct: A Guide to Integrating Design into the Construction process*, CIRIA Report No C534, The Chamelon Press Ltd, London

CM (1998), Definitive guide to Partnering Reveals 50% Savings, *Construction Manager*, Vol. 4, No. 4, pp. 3.

Conheeney, K., Stephenson, P., and Griffiths, A. (2000), Issues in Knowledge Transfer within a Construction Training and Learning Organisation, *Proceedings of the International Conference CIT2000*, Reykjavik, Iceland, 28-30 June, G. Gudnason, ed., Vol. 1, pp. 229-240.

Connell, J.L. and Shafer, L.I. (1995), *Object-Oriented Rapid Prototyping*, Yourdon Press, Prentice Hall Building, New Jersey.

Crinínion, J. (1991), *Evolutionary Systems Development: A Practical Guide to the Use of Prototyping within a Structured Systems Methodology*, Pitman Publishing, UK.

Cross, N. (1984), *Developments in Design Methodology*, Wiley, Chichester, UK.

Cross, N. and Roozenburg, N. (1992), Modelling the Design Process in Engineering and Architecture, *Journal of Engineering Design*, Vol. 3, No. 4, pp. 325-337.

Dainty, A.R.J., Bagilhole, B.M. and Neale, R.H. (1997), Analytical Strategies of Dealing with Qualitative Data in Construction Management Research, *Proceedings of the 13th ARCOM Conference*, Vol. 2, pp. 491-500.

Dataware Technologies Inc., (1998), Seven Steps to Implementing Knowledge Management in your Organisation, *Corporate Executive Briefing*, http://www.dataware.com [25/01/2001].

Davenport, T.H. (1997), Secrets of Successful Knowledge Management. *Issue of Knowledge Inc.*, Feb, <http://webcom.com/quantera/secrets.html> [04/09/2000].

Davenport, T.H. and Prusak L. (1998), *Working Knowledge: How Organisations Manage What They Know*, Harvard Business School Press, Boston, Massachusetts, USA

Diaper, D. (1988), The Promise of POMESS, *Proceedings of Human and Organisational Issues of Expert Systems*, Stratford England.

Drucker, P.F. (1993), *Post-Capital Society*. Butterworth-Heinemann, Oxford.

Drucker, P.F. (1995), The Post-Capitalist Executive, *Managing in a Time of Great Change*, Penguin, New York.

Easterby-Smith, M., Thorpe, R. and Lowe, A. (1991), *Management Research: An Introduction*, SAGE Publications, London.

Eastwood, R.C.A. (1997), Feature: Fragmentation of Design Responsibilities, *The Structural Engineer*, Vol. 75, No. 8, pp. 136-137.

Egan, J. (1998), *Rethinking the Construction*. Report of the Construction Task Force on the Scope for Improving the Quality and Efficiency of UK Construction, Department of the Environment, Transport and Regions (DETR), London, UK.

Egbu, C., Sturges, J. and Bates, M. (1999), Learning from Knowledge Management and Trans-Organisational Innovations in Diverse Project Management Environments, *Proceedings of the 15th Annual Conference of the Association of Researchers in Construction Management*, John Moores University, Liverpool, 15-17 September, Hughes, W.P., ed., pp. 95-103.

Egbu, C. (2000a), The Role of Information Technology in Strategic Knowledge Management and its Potential in the Construction Industry, *Proceedings of the UK National Conference on Objects and Integration for Architecture, Engineering and Construction*, Building Research Establishment Ltd., 13-14 March, Faraj, I and Amor, B., eds., pp. 106-114.

Egbu, C. (2000b), Knowledge Management in Construction SMEs: Coping with the Issues of Structure, Culture, Commitment and Motivation. *Proceedings of the 16th Annual ARCOM Conference*, Glasgow Caledonian University, Scotland, 6-8 September 2000, Volume 1, pp. 83-90.

Egbu, C. (2000c), The Role of Tacit and Explicit Knowledge in Improving Organisational Innovations in Architecture, Engineering and Construction, *Joint Meeting of CIB W55/W65 and TG31/TG35*, Reading, UK, 15 September

Egbu, C.O., Bates, M. and Botterill, K. (2001a), A Conceptual Research Framework for Studying Knowledge Management in Project-Based Environments, *Proceedings of the International Postgraduate Research Conference in the Built and Human Environments*, 15-16 March, University of Salford, UK.

Egbu, C., Gaskell, C. and Howes, J. (2001b), Information Technology for Improving Teamworking in Construction: Opportunities and Challenges for Practice and for Research, *Proceedings of the RICS Foundation-Construction and Building Research Conference (COBRA)*, Glasgow Caledonian University, 3-5 September, Kelly, J. and Hunter, K., eds., Vol. 2, pp. 702-710.

Egbu, C, Botterill, K. and Bates, M. (2001c), The Influence of Knowledge Management and Intellectual Capital on Organisational Innovations, *Proceedings of the 17th Annual ARCOM Conference*, University of Salford, UK, Akintoye, A., ed., Vol. 2, pp. 547-555.

Egbu, C.O. (2002), Knowledge Management, Intellectual Capital and Innovation: Their Association, Benefits and Challenges for Construction Organisations, Proceedings of the 10th International Symposium on Construction Innovation and Global Competitiveness, W65/W55, Cincinnati, Ohio, USA. 9-13 September, Vol. 1, pp. 57-70.

Erno-Kjolhede, E. (2000), *Project Management Theory and the Management of Research Projects*, MPP Working Paper, No. 3/2000, January.

Evbuomwan, N.F.O. and Anumba, C.J. (1996), Towards an Integrated Engineering Design Environment, *Proceedings of the International Conference on IT in Civil and Structural Engineering Design: Taking Stock and Future Directions*, Glasgow, Scotland, August, Kumar, B. and Retik, A., eds., pp. 127-134.

Fairclough, J. (2002), *Rethinking Construction Innovation and Research*, A Review of Government R&D Policies and Practices, DTI and DTLR, London.

Fellows, R. and Liu A. (1997), *Research Methods for Construction*, Blackwell Science Ltd, Oxford.

Ford, S., Aouad, G.F., Kirkham, J.A., Cooper, G.S., Brandon P.S. and Child, T. (1994), An Object-Oriented Approach to Integrating Design Information, *Microcomputers in Civil Engineering*, Vol. 9, pp. 413-423.

Fraser, D. (1981), *Conceptual Design and Preliminary Analysis of Structures*, Pitman Publishing, Massachusetts.

French, M. (1991), *Conceptual Design for Engineers*, Second Edition, The Design Council, London.

Fruchter, R. (1996), Conceptual, Collaborative Building Design through Shared Graphics, *IEEE Expert: Intelligent Systems and their Applications*, June, Vol. 11, No. 3, pp. 33-41.

Gallupe, R.B. (2001), Knowledge Management Systems: Surveying the Landscape, *International Journal of Management Reviews*, March, Vol. 3, No. 1, pp 61-67.

Garrett, J. H. and Smith, I.F.C. (Guest Editors) (1996), Introduction: AI Applications in Structural/Construction Engineering, *IEEE Expert: Intelligent Systems and their Applications*, June, Vol. 11, No. 3, pp. 20-22.

Gibson, J.E. (1968), *Introduction to Engineering Design*, Holt, Rinehart, and Winston, New York.

Gobbons, M. (1994), Innovation and the Developing System of Knowledge Production, Proceedings of the Summer Institute on innovativeness, competitiveness and sustainability in the North American Region, Simon Fraser University. Published on line at http://edie.cprost.sfu.ca/summer/papers/Michael.Gibbons.html

Gottschalk, P. (1999), Use of IT for Knowledge Management in Law Firms, *Journal of Information, Law and Technology (JILT)*, Issue 3, <http://elj.warwick.ac.uk/jilt/99-3/gottschalk.html> [21/04/2003].

Gray, C., Hughes, W. and Bennet J. (1994), *The Successful Management of Design: A Handbook of Building Design Management*, Centre for Strategic Studies in Construction, University of Reading, UK.

Gregory, S. (1966), A More Detailed View of Design, in *The Design Method*, Gregory, S., ed., Butterworths, London.

Grierson, D.E. and Cameron, G. E. (1987), A Knowledge-Based Expert System for Computer Automated Structural Design, *Proceedings of AI CIVIL-COMP 87*, September, Topping, B. H. V., ed., pp. 93-97,

Grierson, D.E. and Cameron, G. E. (1988), An Expert System for Structural Steel Design, *AI in Engineering: Design*, Gero, J.S., ed., Computational Mechanics Publications, Southampton, pp. 279-293.

Haag S., Cummings M., and Dawkins J. (1998), *Management Information Systems for the Information Age*, McGraw-Hill, USA.

Haag S. and Keen P. (1996), *Information Technology: Towards Advantage Today*, McGraw-Hill, USA.

Harty, N. and Danaher, M. (1994), A Knowledge-Based Approach to Preliminary Design of Buildings, *Proceedings of the Institution of Civil Engineers: Structures and Buildings*, Vol. 104, pp. 135-144.

Hansen, M.T. Nohria, N. Tierney, T. (1999), What's Your Strategy for Managing Knowledge, *Harvard Business Review*, Vol. 77, No. 2, pp106-116.

Hegazy, T., Zaneldin, E., and Grierson, D. (2001), Improving Design Coordination for Building Projects, Part I: Information Model, *Journal of Construction Engineering and Management, ASCE*, Vol. 127, No. 4, pp. 322-329.

Hellard, R.B. (1993), *Total Quality in Construction Projects*, Thomas Telford, London.

Hjertzen, E. and Toll, J. (1999), *Measuring Knowledge Management at Cap Gemini AB*, MSc thesis, Linkoping University, Sweden, *http://i94emahj.island.liu.se/thesis/paper.html*, [20/12/2000].

Holt, K. (1990), The Nature of the Design Process, In *Design Management: A Handbook of Issues and Methods*, Oakley, M., ed., Blackwell, Oxford, UK.

Holtham, C. and Courtney, N. (1998), Developing Managerial Competencies in Applied Knowledge Management: A Study of Theory and Practice, *Proceedings of AIS Americas Conference*, Baltimore.

Howard, H.C., Lewitt, R.E., Paulson, B.C., Pohl, J.G. and Tatum, C.B. (1989), Computer Integration: Reducing Fragmentation in AEC Industry, *Journal of Computing in Civil Engineering*, Vol. 3, No. 1, pp. 18-32.

Jackson, C. (1998), Process to Product: Creating Tools for Knowledge Management, *Proceedings of The 2nd International Conference on Technology Policy and Innovation, Assessment, Commercialisation and application of Science and Technology and the Management of Knowledge*, 3-5 August, Lisbon, Portugal.

Johannessen, J.A., Olsen, B. and Olaisen, J. (1999), Aspects of Innovation Theory based on Knowledge Management, *International Journal of Information Management*, Vol. 19, pp. 121-139.

Junnarkar B., Brown C.V. (1997), Re-Assessing the Enabling Role of Information Technology in KM, Journal of Knowledge Management, Vol. 1, No. 2, December 1997.

Kamara, J.M. (1999), *Client Requirements Processing for Concurrent Life-Cycle Design and Construction*, PhD Thesis, School of Science and Technology, University of Teesside.

Kamara, J.M., Anumba, C.J. and Carrillo, P.M. (2001), Selection of a Knowledge Management Strategy for Organisations, *Proceedings of the Second European Conference on Knowledge Management*, Remenyi D., ed., Bled, Slovenia, 8-9 November, pp. 243-254.

Kannapan, S.M. and Marshek, K.M. (1992), A Schema for Negotiation between Intelligent Design Agents in Concurrent Engineering, Proceedings of the IFIP Working Conference on Intelligent Computer Aided Design, Brown, D.C. Waldron, M. and Yoshikawa, H., Columbus, Ohio, IFIP, North Holland, pp. 1-25.

Kanter, J. (1999), Knowledge Management: Practically Speaking, *Information Systems Management*. Vol. 16, No. 4, pp. 7-15.

Kazi, A. S., Hannus, M., and Charoenngam, C. (1999), An Exploration of Knowledge Management for Construction, *Proceedings of the 2nd International Conference on CE in Construction (CEC-99)*, CIB Publication 236, Espoo, Finland, 25-27 August, pp. 247-256.

Kelly, G. (1997), Integrating Construction Software, *Construction Computing*, No. 57, pp. 24-25.

Keppel, G. (1991), *Design and Analysis: A Researcher's Handbook*, 3rd edition, Englewood Cliffs, Prentice Hall, New Jersey.

Khalfan, M.M., Bouchlaghem, N.M., Anumba, C.J. and Carrillo, P.M., (2002), A Framework for Managing Sustainability Knowledge: the C-Sand Approach, *Proceedings of the eSM@RT Conference*, Salford University, UK, pp. 112-122.

Khalfan, M.M.A., Bouchlaghem, N.M., Anumba, C.J. and Carrillo, P.M. (2003), Knowledge Management for Sustainable Construction: The C-SanD Project, *Proceedings of the Construction Research Congress*, Honolulu, Hawaii, 19-21 March [CD-ROM].

Klasson, K. (1999), Managing Knowledge for Advantage: Content and Collaboration Technologies, *The Cambridge Information Network Journal*, Vol. 1, No. 1, pp 33-41.

Koskela, L. (1997), Lean Production in Construction, Alarcon, L., ed., *Lean Construction*, A.A. Balkema, Rotterdam.

KPMG (1998), *Knowledge Management Research Report*, KPMG Management Consulting.

Kumar, B., and Topping, B.H.V. (1988), Issues in the Development of a Knowledge-based System for the Detailed Design of Structures, *AI in Engineering: Design*, Gero, J.S., ed., Computational Mechanics Publications, Southampton, pp. 295-314.

Kumar, B., and Topping, B.H.V. (1991), Knowledge-based Processing for Structural Design, *Proceedings of the Institute of Civil Engineers*, Part 1, Vol. 90, April, pp. 421-446.

Lang, J. C. (2001), Managerial Concerns in Knowledge Management, *Journal of Knowledge Management*, Vol., Number 1, pp 43-57

Lank, E. (1997), Leveraging Invisible Assets: The Human Factor. *Long Range Planning*, Vol. 30, No. 3, pp. 406-412.

Latham, M. (1994), *Constructing the Team*, Final Report on Joint Review of Procurement and Contractual Arrangements in the UK Construction Industry, HMSO, London, UK.

Laudon, K. C. and Laudon, P. L. (2000), *Management Information Systems*, 6th edition, Prentice-Hall, New Jersey.

Lawson, B. (1990), *How Designers Think – The Design Process Demystified*, 2nd Edition, Butterworth Architecture, Oxford.

Leavy, B. (1996), *Key Processes in Strategy*, International Thomson Business Press, London.

Lee, A. S. (1991), Integrating Positive and Interpretative Approach to Organisational Research, *Organisation Science*, Vol. 2, No. 4, pp. 342-365.

Lenz, K. (2001), *Managing Knowledge: How to Implement a Knowledge Management Concept*, Bestell.

Linn, R.L. and Erickson, F. (1990), *Research in Teaching and Learning*, Vol. 2, The American Educational Research Association, Collier Macmillan Publishers, London.

Luan, J. and Serban, A. (2002), Knowledge Management: Concept, Models and Applications, *42nd Associate of Institutional Research International Conference*, Toronto, Canada, June.

Lucca, J., Sharda, R. and Weiser, M. (2000), Coordinating Technologies for Knowledge Management in Virtual Organisations, *Proceedings of the Academia/Industry Working Conference on Research Challenges CAIWORC'00*, Buffalo, New York, 27-29 April, pp. 21-26.

Magnusson, J. (2003), To Facilitate or Intervene: A Study of Knowledge Management Practice in SME Networks, *Journal of Knowledge Management Practice*, February.

Maher, M. L. (1987), Expert Systems for Structural Design, Journal of Computing in Civil engineering, Vol. 1, No 4, pp. 270-283.

Maher, M. L. and Fenves, S. J. (1985), HI-RISE: An Expert System for the Preliminary Structural Design of High Rise Buildings, *Knowledge Engineering in Computer-Aided Design, Gero, J.S., ed.*, North Holland, Amsterdam.

Maher, M. L., Fenves, S. J. and Garrett, J. H. (1988), Expert Systems for Structural Design, *Expert Systems in Construction and Structural Engineering,* Adeli, H. ed., Chapman and Hall, pp. 85-120.

Maher, M.L., and Gomez, A. (1996), Developing Case-Based Reasoning for Structural Design, *IEEE Expert: Intelligent Systems and Their Applications*, June, Vol. 11, No. 3, pp. 42-52.

Manasco, B. (1996), Leading Firms Develop Knowledge Strategies, *Knowledge Inc.*, October 1996. http://webcom.com/quantera/apqc.html [15/11/2002]

Manning, P. (1995), Environmental Design as Routine, *Building and Environment*, Vol. 30, No. 2, pp 181-196.

McConalogue, N. H. (1999), Knowledge Management in the Construction Industry: A Study of Major UK Contractors, MSc Thesis, Department of Civil and Building Engineering, Loughborough University, UK.

Melles, B. (1997), What do we Mean by Lean Production in Construction, Alarcon, L., ed., *Lean Construction*, A.A. Balkema, Rotterdam.

Miyatake, Y. and Kangari, R. (1993), Experiencing Computer Integrated Construction, Journal of Construction engineering and Management, Vol. 119, No. 2, pp. 307-322.

Moore, N. (2000), *How to Do Research: The Complete Guide to Designing and Managing Research Projects*, 3rd edition, Library Association Publishing, London.

Mostow, J. (1985), Towards Better Models of the Design Process, *AI Magazine, American Association of Artificial Intelligence*, Spring 85, pp. 44-57.

Murray, P. and Myers, A. (1997), The Knowledge Barrier: What Stands Between You and the Fruits of Your Business Knowledge, *The Economist*, London, pp. 26-33.

Newman, B. D. (1991), An Open Discussion of Knowledge Management, *The Knowledge Management Forum*, <http://www.3-cities.com/~bonewman/what_is.htm> [05/10/01].

Newton, A.J. (1996), *Planning and management of detailed building design*, PhD Thesis, Department of Civil and Building Engineering, Loughborough University, UK.

Nonaka, I. (1991), The Knowledge Creating Company, *Harvard Business Review*, Vol. 69, November-December, 96-104.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York.

O'Dell, C.S., Essaides, N., Ostro, N. and Grayson, C. (1998), *If Only We Knew What We Know: The Transfer of Internal Knowledge and Best Practice*, Free Press.

OED (1989), *The Oxford English Dictionary*, Second Edition, Clarendon Press, Oxford, UK.

Pahl, G. and Beitz, W. (1988), *Engineering Design: A Systematic Approach*, The Design Council, London.

Patel, M. B., McCarthy, T. J., Morris, P.W.G., Elhag, T.M.S. (2000), The Role of IT in Capturing and Managing Knowledge for Organisational Learning on Construction Projects, *Proceedings of the International Conference on Construction Information Technology (CIT2000)*, Reykjavik, Iceland, 28-30 June, Vol. 2, pp. 674-685,

Patton, M. (1992), Qualitative Methods and Approaches: What They Are, *New Direction for Institutional Research*, Wiley InterScience, London.

Payne, P.N. (1989), Structural Design using Intelligent Objects, *Artificial Intelligence Techniques and Applications for Civil and Structural Engineers*, Topping, B. H. V., ed., Civil-Comp Press, pp. 177-187.

Perera, A.A. (1989), *Cost effective designs*, PhD Thesis, Department of Civil and Building Engineering, Loughborough University, UK.

Polanyi, M. (1967), *The Tacit Dimension*, Routledge & Kegan Paul, London.

Process Protocol (1998): EPSRC IMI Generic Design and Construction Process Protocol, University of Salford, Manchester, September 1998.

Prenninger, J., Polterauer, A., Prieto, J., Hauss, I. and Rohrborn, D. (1998), MaKe-IT SME Management of Knowledge Using Integrated Tools for SMEs, European Commission ESPRIT Programme Project Number 25734 report, December.

RIBA (2000), *The Architect's Plan of Work – for the procurement of feasibility studies, a fully designed building project, employers requirements or contractors proposals*, RIBA Publications, London.

Robinson, H.S., Carrillo, P.M, Anumba, C.J., and **Al-Ghassani, A.M.** (2001a), Perception and Barriers in Implementing Knowledge Management Strategies in Large Construction Organisations, *Proceedings of RICS COBRA Conference*, Glasgow, United Kingdom, 3-5 September, Kelly, J., and Hunter, K., eds., pp. 451-460.

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2001b), A Conceptual Framework for Improving Management Performance through Knowledge Transformation, *Proceedings of the 2nd European Conference on Knowledge Management*, The IEDC Bled School of Management, Bled, Slovenia, 8-9 November, [published on CD]

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2002a), Knowledge Management for Continuous Improvement in Project Organizations, *Proceedings of the W65 10th International Symposium*, Cincinnati, Ohio, USA, 9-13 September, pp. 680-697.

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2002b), Evaluating Knowledge Management Strategies: An IMPaKT Assessment, *Proceedings of the 3rd European Conference on Knowledge Management (ECKM 2002)*, Trinity College Dublin, Ireland, 24-25 September, pp. 586-598.

Rubenstein-Montano, B., Leibowitz, F., Buchwalter, F., McCaw, D., Newman, B. and Rebeck, K. (2001), SMARTVsion: A Knowledge Management Methodology, *Journal of Knowledge Management*, Vol. 5, No. 4, pp.300-310.

Ruggles, R. (1997), Knowledge Tools: Using Technology to Manage Knowledge Better, *Working paper for Ernst and Young*, <http://www.businessinnovation.ey.com/mko/html/toolsrr.html> [26/8/2000].

Sabouni, A.R., Al-Mourad, O.M. (1997), Quantitative Knowledge Based Approach for Preliminary Design of Tall Buildings, *Artificial Intelligence in Engineering*, Vol. 2, pp. 143-154.

Sanvido, V. (1995), From Modelling to Applications, Brandon, P. and Betts, M. eds., Integrated Construction Information, E & FN SPON, London.

Sanvido, V.E., Medeiros, D.J. (1990), Ap;lying Computer-Integrated Manufacturing Concepts to Construction, *Journal of Construction Engineering and Management*, Vol. 116, No. 2, pp. 365-375.

Scarbrough, H. and Swan, J. (1999), *Case Studies in Knowledge Management.* Institute of Personal Development (IPD), London.

Scarbrough, H., Swan, J. and Preston, J. (1999), *Issues in People Management: Knowledge Management: A Literature Review,* Institute of Personnel and Development, The Cromwell Press, Wiltshire.

Sheehan, T. (2000), Building on Knowledge Practices at Arup, *Knowledge Management Review,* Vol. 3, No. 5, pp. 12-15.

Skyrme, D. J. and Amidon, D. D. (1997), *A Report on Creating the Knowledge-Based Business,* Business Intelligence Ltd., London.

Snowden, D. (1998), A Framework for Creating a Sustainable Programme, In Rock S. ed., *Knowledge Management: A Real Business Guide,* Caspian Publishing, London, pp. 6-18.

Sriram, D. (1986), *Knowledge-Based Approaches for Integrated Structural Design,* PhD Thesis, Department of Civil Engineering, Carnegie-Mellon University, Pittsburgh, PA.

Stauffer, L. (1989), The Commonality of Design in Diverse Domains, *Proceedings of the International Conference on Engineering Design (ICED 89),* Harrogate, Vol. 1, pp. 447-466.

Storey, J. and Barnet, E. (2000), Knowledge Management Initiatives: Learning from Failure, *Journal of Knowledge Management,* Vol. 4, No. 2, pp. 145-156.

Survey Studies Use of Structural Analysis Software (1989), *CE Computing Review,* ASCE, Vol. 1, No. 2, pp. 7-8.

TFPL Ltd (1999), *A report on: Skills for Knowledge Management-building a knowledge economy*", London, 1st edition.

Tiwana, A. (2000), *The Knowledge Management Toolkit.* Prentice Hall Inc., New Jersey.

Tsui, E. (2002a), Tracking the Role and Evolution of Commercial Knowledge Management Software, Holsapple, C.W., ed., *Handbook on Knowledge Management,* Springer-Verlag, Berlin/Heidelberg.

Tsui, E. (2002b), Technologies for Personal and Peer-to-Peer (P2P) Knowledge Management, *CSC Leading Edge Forum Technology Grant Report.* <http://www2.csc.com/lef/programs/grants/finalpapers/tsui_final_p2pkm.pdf [06/06/2002].

Turban, E. (1992), *Expert Systems and Applied Artificial Intelligence*, Macmillan, New York.

Tyson, T. R. (1991), Effective Automation for Structural Design, *Journal of Computing in Civil Engineering*, ASCE, Vol. 5, No. 2, pp. 132-140.

Usmani, A. and Winch, G. (1994), The Management of the Design Process: The Case of Architectural and Urban Projects, *Bartlett Research Paper* 1, UCL, London.

Vail III, E. F. (1999), Knowledge Mapping: Getting Started with Knowledge Management, *Information Systems Management*, Vol. 16, No. 4, pp. 16-23.

van der Velden, M. (2002), Knowledge Facts, Knowledge Fiction: The Role of ICT in Knowledge Management for development, *The Special Issue of Journal of International development on 'ICTs and Development'*, John Wiley and Sons Ltd.

von Krogh, G., Roos, J., and Wathne, K. (1996), Towards a Theory of Knowledge Transfer in a Cooperative Context, Managing Knowledge: Perspectives on Cooperation and Competition, Sage, London, pp. 55-81.

Wang, J. and Howard, H.C. (1988), Design-dependent Knowledge for Structural Engineering Design, In Gero J.S., ed., *AI in Engineering Design,* Computational Mechanics Publications, Southampton, pp. 267-278.

Wells, H.G. (1940), The Brain: Organization of the Modern World.

Wensley, A.K.P. and Verwijk-O'Sullivan, A. (2000), *Tools for Knowledge Management*, Internal report, Rotman, J.L., School of Management, University of Toronto, Ontario. <http://www.icasit.org/km/toolsforkm.htm> [25/06/02].

Wiig, K., de Hoog, R. and van der Spek, R. (1997), Supporting Knowledge Management: A Selection of Methods and Techniques, *Expert Systems with Applications*, Vol. 13, No. 1, pp. 15-27.

Winter, J. (1989), New Roles in Contracting, In Uff, J. and Capper, P., eds., *Construction Contract Policy: Improved Procedure and Practice*, Centre of Construction Law and Management, King's College, London.

Xerox Corporation, (1999), The X5 Methodology™ focuses the power of Xerox Connects's Knowledge on Your Business, <http://www.xeroxconnect.com/company_method.html> [18/03/2003].

Zack, M.H. (1999), Developing a Knowledge Strategy, California Management Review, Vol. 41, pp. 125-145.

Appendix A1

List of Publications Arising from the Research

Appendix A1: List of Publications Arising from the Research

1. Published (or submitted)

Al-Ghassani, A.M., Carrillo, P.M., Anumba, C.J., and Robinson, H.R. (2001), Software Requirements for Knowledge Management in Construction Organisations, *Proceedings of the 17th Annual ARCOM Conference*, Salford University, Salford, UK, 5-7 September, Akintoye, A., ed., pp. 199-206.

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2001), An Innovative Tool for Knowledge Problem Definition, *Proceedings of the 1st International Conference on Innovation in AEC.*, Loughborough University, Loughborough, UK, 18-20 July, Anumba, C.J., Egbu, C., and Thorpe, T., eds., pp. 249-256.

Al-Ghassani, A.M. (2001), A Strategic Tool for Knowledge Management, *Proceedings of the 1st KMSS2001*, The European KM Forum, Bari, Italy, 17-21 September, proceedings published on-line.

Al-Ghassani, A.M. (2001), Knowledge Management for Improved Productivity and Performance, ARCOM Doctoral Research Workshop on Performance and Productivity, Wolverhampton University, Wolverhampton, 8th June, pp 12-14.

Robinson, H.S., Carrillo, P.M, Anumba, C.J., and **Al-Ghassani, A.M.** (2001), Perception and Barriers in Implementing Knowledge Management Strategies in Large Construction Organisations, *Proceedings of RICS COBRA Conference*, Glasgow, UK, 3-5 September, Kelly, J., and Hunter, K., eds., pp. 451-460.

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2001), A Conceptual Framework for Improving Management Performance through Knowledge Transformation, *Proceedings of the 2nd European Conference on Knowledge Management*, The IEDC Bled School of Management, Bled, Slovenia, 8-9 November. [Published on CD].

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 of the 4th European Project Management Conference (PMI)*, Café Royal, London, 6-7th June, [Published on CD].

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2001), Linking Knowledge Management Strategy to Business Performance in Construction Organisations, *Proceedings of the 17th Annual ARCOM Conference*, Salford University, Salford, UK, Akintoye, A., ed., 5-7th September.

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 (ITcon), A special issue of the "ICT for Knowledge Management in Construction", Vol. 7, pp. 69-82. <http://www.itcon.org/2002/5/paper.pdf>

Al-Ghassani, A.M., Anumba, C.J., Carrillo, P.M., and Robinson, H.S. (2002), Improving Structural Design Processes through Knowledge Management, *Proceedings of the 3rd International Conference on Concurrent Engineering in Construction CEC 2002*, University of California, Berkeley, USA, 1-2 July, Tommelein I.D. (ed.), pp. 169-180.

Al-Ghassani, A.M., Robinson, H.S., Carrillo, P.M., and Anumba, C.J. (2002), A Framework for Selecting Knowledge Management Tools, *Proceedings of the 3rd European Conference on Knowledge Management (ECKM 2002)*, Trinity College Dublin, Ireland, 24-25 September, pp. 37-48.

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2002), Evaluating Knowledge Management Strategies: An IMPaKT Assessment, *Proceedings of the 3rd European Conference on Knowledge Management (ECKM 2002)*, Trinity College Dublin, Ireland, 24-25 September, pp. 586-598.

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2002), Business Improvement through Innovation in Construction Firms: The 'Excellence' Approach, *Proceedings of the W65 10th Int. Symposium*, Ohio, USA, 9-13 September, pp. 3-18.

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2002), Knowledge Management for Continuous Improvement in Project Organizations, *Proceedings of the W65 10th Int. Symposium*, Ohio, USA, 9-13 September, pp. 680-697.

Anumba, C.J., Carrillo, P.M., Robinson, H.S. and **Al-Ghassani, A.M.** (2002), A Performance-Based Approach to Knowledge Management, *Proceedings of the eSMART conference*, Salford University, Manchester, UK, pp. 134-145.

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J. and Carrillo, P.M. (2003), A Structured Approach for Identifying Knowledge Management Problems, *International Journal of Innovation in ACE*, (paper accepted).

Carrillo, P.M., Robinson, H.S., Anumba, C.J. and **Al-Ghassani, A.M.** (2003), IMPaKT: A Framework for Linking Knowledge Management to Business Performance, *Electronic Journal of Knowledge Management (EJKM.)*, Vol.1, No. 1, pp. 1-12.

Carrillo, P.M., Robinson, H.S., **Al-Ghassani, A.M.** and Anumba C.J. (2003), Knowledge Management in Construction: Drivers, Resources and Barriers, *Project Management Journal*. (*accepted*)

Al-Ghassani, A.M., Kamara, J.M., Anumba, C.J., and Carrillo, P.M. (2004), System Prototype for Knowledge Problem Definition, *Journal of Construction Engineering and Management*, American Society of Civil Engineers (ASCE) (under review)

Robinson, H.S., Carrillo, P.M., Anumba, C.J., and **Al-Ghassani, A.M.** (2003), Knowledge Management Practices in Construction Organisations, *Journal of Management in Engineering*, American Society of Civil Engineers (ASCE), (*under review*).

2. Forthcoming Publications

Journals

Al-Ghassani, A.M., Carrillo, P.M., Anumba, C.J. and Robinson, H.S., Managing Structural Design Knowledge, *Proceedings of the Institution of Civil Engineers.*

Al-Ghassani, A.M., Robinson, H.S., Anumba, C.J. and Carrillo, P.M., SeLEKT: A New Approach for Selecting and Locating Effective Knowledge Tools, *Journal of Knowledge Management.*

Al-Ghassani, A.M., Carrillo, P.M., Anumba, C.J. and Robinson, H.S., An Innovative Tool for Developing KM Strategies for Business Improvement, *Automation in Construction.*

Robinson, H.S., Carrillo, P.M., Anumba, C.J. and **Al-Ghassani, A. M.**, Performance Management in Engineering and Construction Organisations: Measures and Strategies, *Journal of Construction Innovation.*

Robinson, H.S., Anumba, C.J., Carrillo, P.M. and **Al-Ghassani, A.M.**, STEPS: A Knowledge Management Roadmap for Corporate Sustainability, *Business Process Management Journal.*

Book Chapters

Al-Ghassani, A. M., Anumba, C.J., Carrillo, P.M. and Robinson, H.S., Tools and Technologies for Knowledge Management, In *Knowledge Management in Construction*, Edited by Anumba, C.J., Egbu, C., and Carrillo, P.M.

Robinson, H.S., Carrillo, P.M. Anumba, C.J. and **Al-Ghassani, A. M.**, Measuring the Performance of Knowledge Assets and Knowledge Management Programmes, In *Knowledge Management in Construction*, Edited by Anumba, C.J., Egbu, C., and Carrillo, P.M.

Appendix A2

Template for Semi-Structured Interviews for Case Studies

Appendix A2: Template for Semi-Structured Interviews for Case Studies

1. Context

What is the size of the firm in terms of number of employees, number and locations of offices, annual turnover?

What is the number of structural engineers and where are they located?

How many of structural engineering groups do you have and where are they located?

What is your organisation's strategy in terms of the nature of design work that you get involved in (e.g. standard, complex, innovative projects)?

2. Structural Design

What role do structural engineers play within the design process in the organisation?

How do you approach structural design problems (e.g. using previous designs, first principles, consult colleagues or seniors, etc)?

Is the approach/consultation process (identified in the previous question) formal or informal?

To what extent do you rely on tacit knowledge i.e. experience of individuals?

To what extent do you rely on codified knowledge (e.g. design codes of practice, specifications, previous designs and drawings, databases, etc.)?

What is the balance between relying on tacit and codified knowledge?

3. Knowledge Management

Are you aware of a Knowledge Management strategy within your organisation?

What is the role of KM in supporting the design process within the organisation, especially structural design?

What specific methods do you use for knowledge sharing within the structural design process (brainstorming, dialogue, group meetings, communities of practice, experts database)?

What is your plan for improving the knowledge sharing process for structural design?

4. Role of IT

Is there a role for IT in the KM process?

How does IT support your KM process?

What IT systems/software tools do you use for supporting the KM process?

To what extent do structural engineers use these tools?

Appendix A3

Visual Basic Program Code

Appendix A3: 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

The CLEVER Prototype

Starting the Program

```
Private Sub Form_Load()
Dim Prompt, Password
Prompt = "Please enter password!"
Password = InputBox(Prompt)

   If Password = "cleverpassword" Then
      MsgBox ("Welcome to CLEVER KM Advisor")
      Form367.Show  'Start of program
      Form372.Show  'help/general background screen
   Else
      MsgBox ("Sorry, you are not authorised")
      End
   End If
End Sub
```

' Defining KM Problem

```
' Sending input text to report form
Private Sub Text2_Change()
Form368.Text2.Text = Form358.Text2.Text
End Sub

' Sending checked box to report form
Private Sub Check1_Click()
Form368.Check1.Value = Form358.Check1.Value
End Sub

' Sending selected radio button to report form
Private Sub Option1_Click()
Form369.Option1.Value = Form359.Option1.Value
End Sub

' Identifying a resistor
Private Sub Command74_Click()
Text40.Text = "R"
End Sub

' Identifying an enabler
Private Sub Command75_Click()
Text40.Text = "E"
End Sub

' Non-applicable enabler/resistor
Private Sub Command76_Click()
Text40.Text = "N/A"
End Sub
```

' <u>*Identifying Organisational Goals*</u>

'Generating statements about the goals

```
' Dimension 1 – codes for other 7dimensionm are similar but texts between " " will change.

If Slider1.Value > Slider2.Value Then
    Text1.Text = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form17.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form2.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form14.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form15.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form11.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form12.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form13.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Form16.Label19.Caption = "Transfer more tacit knowledge to explicit knowledge to aid decision making efficiency."
    Text1.Visible = True
    Command2.Visible = True
ElseIf Slider2.Value > Slider1.Value Then
    Text1.Text = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form17.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form2.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form14.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form15.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form11.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form12.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form13.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Form16.Label19.Caption = "Transfer more explicit knowledge to tacit to aid human based Decision Making efficiency."
    Text1.Visible = True
    Command2.Visible = True
Else: Text1.Text = "N/A"
    Text1.Visible = True
    Command2.Visible = False
End If

        ' Setting priorities of goals
' Dimension 1 – codes for other 7 dimensions are similar

If Slider1.Value - Slider2.Value = 4 Or Slider2.Value - Slider1.Value = 4 Then
  Text2.Text = "1"
  Text2.Visible = True
  Command2.Visible = True
ElseIf Slider1.Value - Slider2.Value = 3 Or Slider2.Value - Slider1.Value = 3 Then
  Text2.Text = "2"
  Text2.Visible = True
  Command2.Visible = True
ElseIf Slider1.Value - Slider2.Value = 2 Or Slider2.Value - Slider1.Value = 2 Then
  Text2.Text = "3"
  Text2.Visible = True
  Command2.Visible = True
ElseIf Slider1.Value - Slider2.Value = 1 Or Slider2.Value - Slider1.Value = 1 Then
  Text2.Text = "4"
  Text2.Visible = True
  Command2.Visible = True
Else: Text2.Text = ""
   Text2.Visible = False
   Command2.Visible = False
End If
```

' *Identifying Knowledge Migration Paths*

'Template 1 of 7 for first knowledge dimension (codes for the other 55 templates are not shown in the appendix due to space)

```
Private Sub Command1_Click()
If Option1.Value = True Then
        Form17.Label2.Caption = "From explicit critical to tacit critical."
    ElseIf Option10.Value = True Then
        Form17.Label2.Caption = "From tacit critical to explicit auxiliary."
    ElseIf Option11.Value = True Then
        Form17.Label2.Caption = "From explicit critical to tacit auxiliary."
    ElseIf Option12.Value = True Then
        Form17.Label2.Caption = "From tacit auxiliary to explicit critical."
    ElseIf Option2.Value = True Then
        Form17.Label2.Caption = "From tacit critical to explicit critical."
    ElseIf Option3.Value = True Then
        Form17.Label2.Caption = "From explicit critical to explicit auxiliary."
    ElseIf Option4.Value = True Then
        Form17.Label2.Caption = "From explicit auxiliary to explicit critical."
    ElseIf Option5.Value = True Then
        Form17.Label2.Caption = "from tacit auxiliart to explicit auxiliary."
    ElseIf Option6.Value = True Then
        Form17.Label2.Caption = "From explicit auxiliary to tacit auxiliary."
    ElseIf Option7.Value = True Then
        Form17.Label2.Caption = "From tacit critical to tacit auxiliary."
    ElseIf Option8.Value = True Then
        Form17.Label2.Caption = "From tacit auxiliary to tacit critical."
    ElseIf Option9.Value = True Then
        Form17.Label2.Caption = "From explicit auxiliary to tacit critical."
End If

End Sub
```

' *Developing KM strategy*

```
'Entering an element of a KM Strategy to a generic model
Label8.BackColor = &HC0E0FF                      'Changing the colour of the box
Form103.Show                                     'Showing the input box
Form103.Label1 = "Identify personnel and 'owners'"   'Asking user to develop a strategy for addressing the mentioned
End Sub

'Sending the developed strategy element to report form
Private Sub Command1_Click()
Form101.Label13.Caption = Text1
Form103.Hide
End Sub
```

The IMPaKT Prototype

'Business Improvement Strategy

```
'Adding values to Performance Measure combos

Private Sub Form_Load()
  Dim Score, I
    For I = 1 To 100        'Count from 1 to 100.
    Score = I               'Create Score.
  Combo1.AddItem Score   'Add the Score.
  Next I
End Sub

' Calculating Performance Gap
Private Sub Command7_Click()
Text15.Visible = True
Text15.Text = ""

                                  'calculating quantitative gap
If Option1.Value = True And Combo3.ListIndex >= Combo2.ListIndex Then Text15.Text = Combo3.ListIndex -
Combo2.ListIndex
If Option1.Value = True And Combo3.ListIndex < Combo2.ListIndex Then
  Text15.Text = ""
  ButtonClicked = MsgBox(Message, vbOKOnly, "Target Score should be higher than Current Score")
End If

                                  'calculating qualitative gap
A = Combo7.ListIndex - Combo6.ListIndex
If Option2.Value = True And A = 4 Then Text15.Text = "Large Gap"
If Option2.Value = True And A = 3 Then Text15.Text = "Moderate-to-Large Gap"
If Option2.Value = True And A = 2 Then Text15.Text = "Small-to-Moderate Gap"
If Option2.Value = True And A = 1 Then Text15.Text = "Small Gap"
If Option2.Value = True And A = 0 Then Text15.Text = "No Gap"

If Option2.Value = True And A = -1 Or A = -2 Or A = -3 Or A = -4 Then
  Text15.Text = ""
  ButtonClicked = MsgBox(Message, vbOKOnly, "Target Score should be higher than Current Score")
End If
End Sub
```

'KM Strategic Plan

```
'Identifying KM processes identified in a business problem

Private Sub Command1_Click()
I = "Your problem is a KM problem that mostly relates to the following sub-process(es) of KM:"
LC = "Locating Knowledge"
CP = "Capturing Knowledge"
SH = "Sharing Knowledge"
MD = "Modifying Knowledge"
CR = "Creating Knowledge "

A = Check1.Value + Check2.Value + Check3.Value + Check4.Value + Check5.Value
B = Check6.Value + Check7.Value + Check8.Value + Check9.Value + Check10.Value
C = Check11.Value + Check12.Value + Check13.Value + Check14.Value + Check15.Value
```

```
D = Check16.Value + Check17.Value + Check18.Value + Check19.Value + Check20.Value
E = Check21.Value + Check22.Value + Check23.Value + Check24.Value + Check25.Value

'no tick box checked = No KM Problem
If A + B + C + D + E = 0 Then Form3.Text1.Text = "Your problem is NOT a KM problem."

'Tick boxes checked for one sub-process only
If A >= 1 And B = 0 And C = 0 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC
If B >= 1 And A = 0 And C = 0 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & CP
If C >= 1 And A = 0 And B = 0 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & SH
If D >= 1 And A = 0 And B = 0 And C = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & MD
If E >= 1 And A = 0 And B = 0 And C = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & CR

'Tick boxes checked for the first sub-process (Locating) PLUS any subsequent sub-process
If A >= 1 And B >= 1 And C = 0 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP
If A >= 1 And C >= 1 And B = 0 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & SH
If A >= 1 And D >= 1 And B = 0 And C = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & MD
If A >= 1 And E >= 1 And B = 0 And C = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CR

'Tick boxes checked for the first PLUS second PLUS any subsequent sub-process
If A >= 1 And B >= 1 And C >= 1 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & SH
If A >= 1 And B >= 1 And D >= 1 And C = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & MD
If A >= 1 And B >= 1 And E >= 1 And C = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & CR

'Tick boxes checked for the first PLUS third PLUS any subsequent sub-process
If A >= 1 And C >= 1 And D >= 1 And B = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & SH &
vbCrLf & MD
If A >= 1 And C >= 1 And E >= 1 And B = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & SH &
vbCrLf & CR

'Tick boxes checked for the first PLUS fourth PLUS fifth sub-process
If A >= 1 And D >= 1 And E >= 1 And B = 0 And C = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & MD &
vbCrLf & CR

'Tick boxes checked for the first PLUS second PLUS third PLUS fourth OR fifth sub-process
If A >= 1 And B >= 1 And C >= 1 And D >= 1 And E = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & SH & vbCrLf & MD
If A >= 1 And B >= 1 And C >= 1 And E >= 1 And D = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & SH & vbCrLf & CR

'Tick boxes checked for the first PLUS second PLUS fourth PLUS fifth sub-process
If A >= 1 And B >= 1 And D >= 1 And E >= 1 And C = 0 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & MD & vbCrLf & CR

'All Tick boxes checked
If A >= 1 And B >= 1 And C >= 1 And D >= 1 And E >= 1 Then Form3.Text1.Text = I & vbCrLf & LC & vbCrLf & CP &
vbCrLf & SH & vbCrLf & MD & vbCrLf & CR

'Tick boxes checked for the second sub-process (Capturing) PLUS any subsequent sub-process
If B >= 1 And C >= 1 And A = 0 And D = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & SH
If B >= 1 And D >= 1 And A = 0 And C = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & MD
If B >= 1 And E >= 1 And A = 0 And C = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & CR
```

```
'Tick boxes checked for the second sub-process (Capturing) PLUS third PLUS any subsequent sub-process
If B >= 1 And C >= 1 And D >= 1 And A = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & SH &
vbCrLf & MD
If B >= 1 And C >= 1 And E >= 1 And A = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & SH &
vbCrLf & CR

'Tick boxes checked for the second sub-process (Capturing) PLUS third PLUS forth PLUS fifth
If B >= 1 And C >= 1 And D >= 1 And E >= 1 And A = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & SH &
vbCrLf & MD & vbCrLf & CR

'Tick boxes checked for the second sub-process (Capturing) PLUS fourth PLUS fifth PLUS fifth
If B >= 1 And D >= 1 And E >= 1 And A = 0 And C = 0 Then Form3.Text1.Text = I & vbCrLf & CP & vbCrLf & MD &
vbCrLf & CR

'Tick boxes checked for the third sub-process (Sharing) PLUS any subsequent sub-process
If C >= 1 And D >= 1 And A = 0 And B = 0 And E = 0 Then Form3.Text1.Text = I & vbCrLf & SH & vbCrLf & MD
If C >= 1 And E >= 1 And A = 0 And B = 0 And D = 0 Then Form3.Text1.Text = I & vbCrLf & SH & vbCrLf & CR

'Tick boxes checked for the third sub-process (Sharing) PLUS fourth PLUS fifth
If C >= 1 And D >= 1 And E >= 1 And A = 0 And B = 0 Then Form3.Text1.Text = I & vbCrLf & SH & vbCrLf & MD &
vbCrLf & CR

'Tick boxes checked for the fourth sub-process (Modifying) PLUS fifth sub-process
If D >= 1 And E >= 1 And A = 0 And B = 0 And C = 0 Then Form3.Text1.Text = I & vbCrLf & MD & vbCrLf & CR
End Sub

'Identifying Action Plan required

Private Sub Command1_Click()
'Calculating scores for 'reform needed', 'resources required', 'results monitoring mechanisms' respectively
A = (Slider1.Value + Slider2.Value + Slider3.Value + Slider4.Value + Slider5.Value)
AA = Round(A / 20 * 100, 0)       '20 because reform needed consists of 5 questions each having a value up to 4
B = (Slider6.Value + Slider7.Value + Slider8.Value + Slider9.Value + Slider10.Value)
BB = Round(B / 20 * 100, 0)
C = (Slider11.Value + Slider12.Value + Slider13.Value + Slider14.Value + Slider15.Value)
CC = Round(C / 20 * 100, 0)

'Stating actions to be taken
If Slider1.Value < 3 Then E = "To recognise the importance of sharing knowledge." & vbCrLf
If Slider2.Value < 3 Then F = "To motivate people to share knowledge." & vbCrLf
If Slider3.Value < 3 Then G = "To identify organisational and cultural barriers" & vbCrLf
If Slider4.Value < 3 Then H = "To establish a KM strategy." & vbCrLf
If Slider5.Value < 3 Then I = "To develop a KM reward/incentive/change management programme."
Form3.Text13.Text = E & F & G & H & I

If Slider6.Value < 3 Then J = "To adopt a leadership for KM." & vbCrLf
If Slider7.Value < 3 Then K = "To appoint a KM core and support team." & vbCrLf
If Slider8.Value < 3 Then L = "To establish a human interactive infrastructure for KM." & vbCrLf
If Slider9.Value < 3 Then M = "To have an IT support infrastructure." & vbCrLf
If Slider10.Value < 3 Then N = "To allocate budget for implementing KM." & vbCrLf
Form3.Text14.Text = J & K & L & M & N

If Slider11.Value < 3 Then O = "To use a business performance measurement and improvement tool." & vbCrLf
If Slider12.Value < 3 Then P = "To link the KM initiatives to the performance measures." & vbCrLf
```

```
If Slider13.Value < 3 Then Q = "To identify the cost components of the KM initiatives." & vbCrLf
If Slider14.Value < 3 Then R = "To identify the expected benefits from the KM initiatives." & vbCrLf
If Slider15.Value < 3 Then S = "To adopt a monitoring process for reviewing the impact of KM and providing feedback." &
vbCrLf
Form3.Text15.Text = O & P & Q & R & S

    'Colours representing the status for reform needed
If AA >= 0 And AA <= 16 Then
    Form3.Label14.BackColor = &HFF&
ElseIf AA >= 17 And AA <= 40 Then
    Form3.Label14.BackColor = &H8080FF
ElseIf AA >= 41 And AA <= 60 Then
    Form3.Label14.BackColor = &H80C0FF
ElseIf AA >= 61 And AA <= 85 Then
    Form3.Label14.BackColor = &H80FF80
ElseIf AA >= 86 And AA <= 100 Then
    Form3.Label14.BackColor = &HC000&
End If
    'Colours representing the status for resources required
If BB >= 0 And BB <= 16 Then
    Form3.Label15.BackColor = &HFF&
ElseIf BB >= 17 And BB <= 40 Then
    Form3.Label15.BackColor = &H8080FF
ElseIf BB >= 41 And BB <= 60 Then
    Form3.Label15.BackColor = &H80C0FF
ElseIf BB >= 61 And BB <= 85 Then
    Form3.Label15.BackColor = &H80FF80
ElseIf BB >= 86 And BB <= 100 Then
    Form3.Label15.BackColor = &HC000&
End If
    'Colours representing the status for results monitoring mechanisms
If CC >= 0 And CC <= 16 Then
    Form3.Label16.BackColor = &HFF&
ElseIf CC >= 17 And CC <= 40 Then
    Form3.Label16.BackColor = &H8080FF
ElseIf CC >= 41 And CC <= 60 Then
    Form3.Label16.BackColor = &H80C0FF
ElseIf CC >= 61 And CC <= 85 Then
    Form3.Label16.BackColor = &H80FF80
ElseIf CC >= 86 And CC <= 100 Then
    Form3.Label16.BackColor = &HC000&
End If
End Sub

  'Colour and statement for the overall status
D = (Slider1.Value + Slider2.Value + Slider3.Value + Slider4.Value + Slider5.Value + Slider6.Value + Slider7.Value +
Slider8.Value + Slider9.Value + Slider10.Value + Slider11.Value + Slider12.Value + Slider13.Value + Slider14.Value +
Slider15.Value)
DD = Round(D / 60 * 100, 0)
Form3.Text11.Text = DD & "%"
  If DD >= 0 And DD <= 16 Then
     Form3.Text12.Text = "The organisation is NOT READY AT ALL for implementing knowledge management."
     Form3.Label12.BackColor = &HFF&   'red colour
  ElseIf DD >= 17 And DD <= 40 Then
     Form3.Text12.Text = "The organisation is NOT READY for implementing knowledge management. Some actions have
        been taken but more is required."
     Form3.Label12.BackColor = &H8080FF  'pink colour
```

```
    ElseIf DD >= 41 And DD <= 60 Then
        Form3.Text12.Text = "The organisation is ALMOST MIDWAY in its readiness for implementing knowledge
            management. More actions need to be taken before implementing knowledge management."
        Form3.Label12.BackColor = &H80C0FF  'orange colour
    ElseIf DD >= 61 And DD <= 85 Then
        Form3.Text12.Text = "The organisation is NEARLY READY for implementing knowledge management. Few actions
            need to be taken before implementing knowledge management."
        Form3.Label12.BackColor = &H80FF80  'light green colour
    ElseIf DD >= 86 And DD <= 100 Then
        Form3.Text12.Text = "The organisation is READY for immediate implementation of knowledge management."
        Form3.Label12.BackColor = &HC000&   'green colour
    End If

' Selecting KM Tools - Sample of one combination out of 64 combinations for technologies and 64 for techniques. Code in
the program does not follow the same order here as it is extracted from several Private Sub Commands.

' Combination 1: Tacit to Tacit, Individual to Individual, Internal to Internal (keep knowledge within the organisation)

        ' Identifying the relevant technology categories for a specific combination
    If Slider1.Value = 1 And Slider2.Value = 1 And Slider3.Value = 1 And Slider4.Value = 1 And Slider5.Value = 1 And
    Slider6.Value = 1 Then
        List1.AddItem "Experts Directories/Skills Yellow Pages"
        List4.AddItem "Integrated Groupware Systems"
        List4.AddItem "Multi-media Tools"
    End If

' Description of first technology category
 If List1.Text = "Experts Directories/Skills Yellow Pages" Then
     Text6.Text = "Also called People Finder, Skills' Yellow Pages, Pointers to expertise, Expert Groups Directory. An Experts
                    Directory contains a list of the individuals within the organisation, their expertise, and contact information.
                    This provides links to the persons who have the knowledge in a particular area in order to facilitate knowledge
                    flow. They are simply a web-searchable electronic version of skills lists, albeit with a lot more context added
                    to them by past users. These are usually custom built bespoke systems or research prototypes."

     List6.AddItem "AskMe"              ' Software Applications that support the identified Technology Category
     List6.AddItem "Sigma Connect"
     List6.AddItem "IntellectExchange"
     List6.AddItem "Expertise Infrastructure"
End If

' Description of first software application
If List6.Text = "AskMe" Then
    Text11.Text = "AskMe, by AskMe Enterprise, is aimed at creating and managing employee knowledge networks. It
                   provides: person-to-person knowledge sharing platform and supports identifying 'who knows what'.
                   More info at http://www.askme.com"
End If

' KM Evaluation Strategy
' Dragging and dropping KM Initiatives to prioritise them
Private Sub Label11_DragDrop(Source As Control, X As Single, Y As Single)
  If TypeOf Source Is Label Then
     Label11.Caption = Source.Caption
  End If
End Sub

' Clearing a label from dragged item
Private Sub Label11_DblClick()
Label11.Caption = ""
End Sub
```

Appendix A4

Questionnaire for Refining the CLEVER Methodology and Prototype

Appendix A4: Questionnaire for Refining the CLEVER Methodology and Prototype

A Prototype System for Knowledge Management:

The completion of this questionnaire should follow a demonstration on the prototype system.

Information about Participants

Date of Evaluation ____________
Company Name ______________________________
Role carried out/position held ______________________
(e.g. project manager, design consultant, engineer)
Area of experience (e.g. civil engineering, building, design, etc) ____________
Experience in/with construction industry (years) ________________

A: THE PROBLEM DEFINITION SUB-SYSTEM

Please tick the box that best represents your response to a question.

Ranking: *Poor* 1 – 5 *Excellent*

		1	2	3	4	5
TYPE OF KNOWLEDGE						
1	How well does the system help in identifying the classes of knowledge?					
2	How well does the system support identifying the business drivers for KM?					
CHARACTERISTICS OF KNOWLEDGE						
3	How well do the five-point scales describe the characteristics of knowledge?					
4	How useful was it to have the definition of each characteristic next to it?					
SOURCES AND USERS OF KNOWLEDGE						
5	How effective were the two matrices in identifying the sources/users and the relevant enablers/resistors for knowledge transfer?					
6	How useful was the link between the two matrices?					
CURRENT PROCESSES FOR MANAGING KNOWLEDGE						
7	How easily does the system allow the description of the KM processes in-use?					
8	How easily does the system allow the input of other processes?					
9	How useful is it to include a review of current processes?					
GENERAL						
10	How useful was the re-statement of the KM problem at the end of the process?					
11	How well does the system facilitate capturing and identifying a KM problem?					
12	How well does the system encourage a wider thinking about the KM problem?					

In what ways can the Problem Definition Sub-system be improved?

____

____

____

B: THE STRATEGY DEVELOPMENT SUB-SYSTEM

Please tick the box that best represents your response to a question.

Ranking: *Poor* 1 – 5 *Excellent*

		1	2	3	4	5
ORGANISATIONAL GOALS:						
13	How appropriate were the sliders for identifying current and required KM status?					
14	How properly does the system state the organisational goals and priorities?					

KNOWLEDGE MIGRATION PATHS:

15	How helpful were the arrows in identifying the knowledge migration paths?					
16	How useful would it be to disable the arrows that are not applicable in a given situation?					
17	How favourable would it be if the arrows automatically indicated the most likely paths based on the selection using the sliders?					
18	How clearly does the system state the paths to achieve an organisational goal?					

DEVELOPING KM STRATEGY

19	How useful was the matrix of the migration paths and the KM processes?					
20	Would it be useful if the system suggested the KM process for every migration path?					
21	How useful was it to include the possible enablers/resistors for every KM process?					
22	How useful was it to allow the user to select a generic process to input strategy?					
23	How flexible was the system in enabling you to select a KM strategy/process?					

GENERAL

24	How useful was the structured approach followed by the system?					
25	How well does the system facilitate the development of a KM strategy?					

In what ways can the Strategy Development Sub-system be improved?

____

____

C: COMMON QUESTIONS ON THE SYSTEM

Please tick the box that best represents your response to a question.

		Ranking				
		Poor				*Excellent*
		1	2	3	4	5
	MANAGEMENT OF SYSTEM INTERACTION					
26	How attractive is the graphical user interface of the system?					
27	How simply can a user edit her/his input?					
28	How easily can a user add new elements (knowledge class, characteristic, etc)?					
29	How easy is it to navigate between the system's objects (forms, reports, etc)?					
30	How easily can the system generate a report?					
	EFFICIENCY					
31	How effective is the system in reducing duplication of input?					
32	How effective is the on-screen help in explaining how to use the system?					
33	How convinced are you that the system can be used by organisations?					
	OUTCOME					
34	How understandable were the generated reports?					
35	How accurate were the generated reports compared to what was expected?					
	GENERAL					
36	Rate how confident you are with computers (generally)					
37	How generic do you consider the system to be?					
38	What is your overall rating of the system?					

In what ways can the CLEVER KM Prototype be improved?

____

____

Further comments (*Please use the back of the sheet if required*):

____

____

Appendix A5

Technology Categories & Software Applications for KM Sub-processes (light version)

Appendix A5: Technology Categories & Software Applications for KM Sub-processes (light version

KM Sub-process	Technology Category	Application Software
Locating and Accessing	Experts Directory (ED)	AskMe, Sigma Connect, IntellectExchange, Expertise Infrastructure
	Data Warehouses (DW)	Syncsort: http://www.syncsort.com
	Web Crawler – Meta Search (WC)	MetaCrawler, SurfWax, Copernic Basic 2001, Livelink, Dogpile, Mamma, CNET Search
	Data and Text Mining (D/T M)	Data Mining: Knowledge SEEKER, RetrievalWare, XpertRule Miner, Clementine
		Text Mining: SemioMap, Intelligent Miner for Text, Megapture Intelligence
	Knowledge Mapping – Concept Mapping (KMpp)	Knowledge Service, IHMC Concept Map
	Knowledge Discovery Packages (KDP)	Knowledge Discovery Tools by Lotus IBM, Livelink by OpenText
	Intranet/Extranet (INRA/EXRA)	Livelink, Instant Intranet Builder, iLevel
	Search Engines (SE)	Google, Yahoo, FAST, Excite, AltaVista, Infoseek
	Taxonomy/Ontological Tools (T/O T)	Autonomy, SemioMap, RetrievalWare Suite
	Web Mapping Tools (WMT)	Web Squirrel, WINCITE
	Electronic Document Management Systems (EDMS)	Documentum, BASIS®, Dicom
	Electronic Mail (E-Mail)	Eudora, Microsoft Outlook
Capturing	Word Processors (WP)	MS Word, Word Perfect
	Case-Based Reasoning - Expert Systems (CBR)	CBR-Works, Kaidara
	Knowledge Bases (KB)	Assistum, KnowledgeBase.net, XpertRule Knowledge Builder
	Knowledge Mapping – Concept Mapping (KMpp)	Knowledge Service, IHMC Concept Map
Representing	Mind Mapping Applications –Brainstorming (MMA)	Mind Manager, The Brain
	Web Publishing (WPb)	KnowledgeBase.net
	Virtual Reality Tools (VR)	Maelstrom, 3ds max™ for Windows®
	Word Processors (WP)	MS Word, Word Perfect
	Computer Aided Design (CAD)	Autodesk products
	Spread-Sheets (SS)	MS Excel, StarOffice/OpenOffice Calc, Lotus 1-2-3
	Knowledge Mapping – Concept Mapping	Knowledge Service, IHMC Concept Map
Sharing	Web Publishing (KMpp)	KnowledgeBase.net
	Communities of Practice (CoPs)	AskMe
	Intranet/Extranet (INRA/EXRA)	Livelink, Instant Intranet Builder, iLevel
	Web-Based File Sharing Tools (WBFS)	KnowledgeDisk, Briefcase
	Instant Messaging (IM)	NetLert 3 Messenger, Trusted Messenger, ICQ, AOL Instant Messenger, Yahoo Messenger, MSN Messenger
	Integrated Groupware Solutions (IGWS)	A group of Lotus products (Notes, Domino, Sametime, QuickPlace), GroupWise, BrightSuite Enterprise, MyLivelink, Plumtree Collaboration Server, iTeam, iCohere
	Multi-Media Tools - Video Conferencing software (MtMd)	MS NetMeeting, AbsoluteBUSY, eRoom, WebEx Training Center, WebEx Meeting Center, WebDemo
	Electronic Mail (E-Mail)	Eudora, MS Outlook
Creating	Data and Text Mining (D/T M)	Data Mining: Knowledge SEEKER, RetrievalWare, XpertRule Miner, Clementine
		Text Mining: SemioMap, Intelligent Miner for Text, Megapture Intelligence
	Knowledge Mapping – Concept Mapping (KMpp)	Knowledge Service, IHMC Concept Map
	Mind Mapping Applications/Brainstorming (MMA)	Mind Manager, The Brain
	Data Warehouses (DW)	Syncsort

Appendix A6

Technology Categories & Software Applications for KM Sub-processes (full version)

Appendix A6: Technology Categories & Software Applications for KM Sub-processes (full version)

1. Technologies for Locating and Accessing Knowledge

KM Sub-process	Technology Category	Application Software
Locating /Accessing Knowledge	Experts Directory (ED): Also called People Finder, Skills' Yellow Pages, Pointes to expertise, Expert Groups Directory. ED consists of a listing of individuals, their expertise, and contact information. These provide links to the persons who have the knowledge in a particular area in order to facilitate knowledge flow. They are simply a web-searchable electronic version of skills lists, albeit with a lot more context added to them by past users (Davenport and Prusak, 1998). These are usually custom built bespoke systems or research prototypes (Tsui 2002-tracking).	AskMe by AskMe Enterprise: Aimed at creating and managing employee knowledge networks. It provides: person-to-person knowledge sharing platform and supports identifying 'who know what'. http://www.askme.com Sigma Connect: Enables staff within an organisation to create "personal home pages" in a short time, with no requirement for technical expertise. These home pages can then be searched in a variety of ways - both structured and unstructured, and can be linked to other web content in the usual way. It acts as both Expert Directory and web page generator for the individuals. It also integrates with existing directories (LDAP, MS Exchange etc.) to allow two-way updating of user information. http://www.sigmaconnect.com IntellectExchange: Enables organisations to locate and engage appropriate expertise quickly and easily whether inside the corporation, or outside. It provides three main tools: PEP; EEM; and CEE. Private Expertise Portal (PEP) helps employees to find external expertise in business, science, and technology around the world in a secured/customized environment. External Expertise Manager (EEM) allows managing the external experts already being used by the firm. Corporate Expertise Exchange (CEE) helps managing and locating expertise within the company. http://www.intellectexchange.com/ct-products.asp Expertise Infrastructure Software by 'Tacit': Taps into existing enterprise systems to automatically learn what each person in the organisation knows and does. It creates and continuously maintains a detailed expertise profile for each person. http://www.tacit.com
	Data Warehouses (DW): A logical collection of information –gathered from many different operational databases- that support business analysis activities and decision-making tasks (Haag, Cummings, and Dawkins 1998).	Syncsort: Syncsort Incorporated is a leading developer of high-performance business intelligence and data warehousing software for mainframe, UNIX, and Windows environments. SyncSort for Windows minimizes the sorting time for large volumes of data and significantly improves the performance of enterprise applications. Whether administering a very large database or data warehouse, or managing data from web sites and e-commerce, SyncSort provides high enterprise performance for data applications. The Visual SyncSort brings graphical ease of use to the applications of sorting/merging/copying/joining and recording the processing features. http://www.syncsort.com

Locating /Accessing Knowledge	*Web Crawler (WC) – Meta Search:* Web-based tool that facilitates intelligent searching with extensive use of meta-data and indexing. It can search for text as well as multimedia formats (voice, video, graphics). Web crawlers can place 'hooks' on targeted locations on the web, detect changes in the content, and notify the user of the change. Very useful for gathering market and competitive intelligence. It also conducts parallel searches on other major search engines, combine, prune (remove duplicates, delete dead links or replace dead links by cached results) and rank the final results for the user (Tsui 2002 a & b).	MetaCrawler: A meta-search engine that searches the Internet's top search engines such as About, Ask Jeeves, FAST, FindWhat, LookSmart, Overture and many more to provide the most relevant and comprehensive results. http://www.metacrawler.com SurfWax: SurfWax enables users to conduct searches that are more accurate across a broader range of content than many search technologies. SurfWax's unqiue SearchSets™ make it easy for users to harness the breadth and depth of multiple search sources by creating personal sets of search sources. Users can construct their own meta-search tools to meet their information needs. http://www.surfwax.com Copernic Agent Basic 2001: A free entry-level Web search tool that combines many search enhancement features along with an intuitive user interface, making Web searches faster and easier. www.copernic.com Livelink: This is more than a web crawler. A proactive, online search and retrieval package that reduces the amount of time required for locating key data. Effectively manages people, processes and information. Its tightly integrated services, including Livelink's MeetingZone, deliver true dynamic collaboration and knowledge sharing between individuals, teams and organisations. It is fully web-based and has an open-architecture, hence providing rapid deployment, accelerated adoption, and low cost of ownership. It allows individuals to set up automated tools to scan a variety of information sources and immediately advise them when these sources have been updated with critical information. Can be linked to the document collection manager, BASIS®. www.opentext.com Other popular Meta/Web Crawlers: Dogpile.com, Mamma.com, Search.com

Locating /Accessing Knowledge	**Data and Text Mining (D/T M):** A technique to extract meaningful knowledge from masses of data. It enables meaningful patterns and associations of data (words and phrases) to be identified from one or more large databases. Mostly used in business intelligence, direct marketing and customer relationship management applications. However, this technique is not widely used because it is difficult to access data via an enterprise-wide corporate portal as most organisations only have a small group of data miners. (Tsui 2002 a & b). The technique is also very useful for finding out the hidden relationships between data and hence helps in creating new knowledge. Notes: Data = structured data Text = unstructured data	<u>Data Mining:</u> Knowledge SEEKER by Angoss Knowledge Engineering: This is an artificially intelligent Knowledge Discovery and Data Mining tool. It helps to rapidly seek, analyse and understand the patterns in a data set and also enables users to apply powerful clustering, analytical and statistical algorithms to operational data. The system includes a Decision Tree Induction process, which generates automated queries, so managers do not have to manually construct the queries. This Decision Tree Induction process has the mathematical power and crunch power to construct and run the queries required. It accepts data from all major databases as well as from popular query and reporting, spreadsheets, statistical and OLAP & ROLAP tools. It can be used with the operating systems: Unix (AIX, HP-UX, Solaris) and Windows (3.1, 95, 98, NT, 2000. the system requires: CPU of 486 or higher, 64 MB of memory although not necessary for smaller data sets or stand-alone workstation use, and Disk space of 20 MB. http://www.angoss.com RetrievalWare (previously Excalibur) by Convera: Uses fuzzy searches to find relationships within <u>structured</u> data and provides text-based knowledge retrieval solutions. It creates a list of the enterprise assets, then enables users to search more than 200 document types on file servers, in groupware systems, relational databases, document management systems, web servers etc (all from a common user interface to satisfy access rights). This access is managed by RetrievalWare's Synchronizers, which recognize any changes, system-wide, and automatically update the index. http://www.convera.com XpertRule Miner by Attar: A graphical data-mining environment for discovering tree patterns from historic business data. It provides graphical support for the full data mining process from data exploration and preparation to pattern discovery and deployment. It is a scalable high performance tool and it allows data mining solutions to be embedded as ActiveX components within other applications. In addition, the 'mined trees' can be exported to Knowledge Builder. http://www.attar.com Clementine from SPSS inc.: A data-mining workbench that enables quickly developing predictive models using business expertise and deploying them to improve decision-making. It supports the entire data mining process and is designed around the de facto industry standard for data mining. http://www.spss.com/spssbi/clementine

Locating /Accessing Knowledge	...Continued Data and Text Mining (D/T M): A technique to extract meaningful knowledge from masses of data. It enables meaningful patterns and associations of data (words and phrases) to be identified from one or more large databases. Mostly used in business intelligence, direct marketing and customer relationship management applications. However, this technique is not widely used because it is difficult to access data via an enterprise-wide corporate portal as most organisations only have a small group of data miners. (Tsui 2002 a & b). The technique is also very useful for finding out the hidden relationships between data and hence helps in creating new knowledge. Notes: Data = structured data Text = unstructured data	Text Mining: SemioMap by Entrieva: Searches relationships within unstructured data. This software provides a graphical interface to view text collections. It allows discovering relevant information and knowledge from seemingly impenetrable mountains of text. It is used primarily by researchers and intelligence analysts to display how phrases interact across documents and to uncover meaning that is not readily apparent. www.semio.com Intelligent Miner for Text by IBM: Turns unstructured information into business knowledge for organisations. The knowledge-discovery "toolkit", within the software, includes components for building advanced text mining and text search applications. It consists of a wide range of text analysis tools for feature extraction, clustering, categorization and summarization. It contains Web-access tools, such as NetQuestion Solution and IBM Web Crawler. It also unlocks the business information that is trapped in emails, insurance claims, news feeds and Lotus Notes, as well as analysing patent portfolios, customer complaint letters, and even competitors' Web pages. http://www-3.ibm.com/software/data/iminer/fortext Megapture Intelligence: Provides solutions based on semantic network analysis, a method that uses Artificial Neural Networks to extract semantic ("meaning") information from the text. This information may then be used to create summarizations, concept-based searches, or even semantic text based navigations. http://www.megaputer.com
	Knowledge Mapping (KMpp) – Concept Mapping: A graphical representation of procedures and processes to enable free flow of information and sharing of knowledge. Knowledge maps are of various types namely Cognitive Maps, Concept Maps, Logic Flow Maps, Mission Maps, Sociometric Maps, Decision Trees, and Influence Diagrams. Among these, the Concept Maps, Decision Trees and Influence Diagrams are the most frequently used ones. http://www.kmindia.org/asci/km_zine/_zine_kno_map.htm 16/09/2002	Knowledge Service by Kanisa: Composed of two key components, Kanisa Knowledge Map Generator and Auto Classification Engine (ACE). The Knowledge Map Generator creates a Knowledge Map out of a set of overlapping taxonomies that describe the way the products, services and business processes relate to one another. ACE uses the Knowledge Map as an electronic blueprint to automatically organize and index all contents regardless of location. http://www.kanisa.com IHMC Concept Map The IHMC Concept Mapping Software empowers users to construct, navigate, share, and criticize knowledge models represented as Concept Maps. The toolkit is platform independent and network enabled, allowing users to build, and collaborate during the construction of concept maps with colleagues anywhere on the network, as well as, share and navigate through others' models distributed on servers throughout Internet. http://cmap.coginst.uwf.edu

Locating /Accessing Knowledge	**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.	**Knowledge Discovery Tools by Lotus IBM:** These tools include: Lotus Discovery Server, K-station, Domino.Doc, Domino Workflow, and Domino Extended Search Lotus Discovery Server: one of the most comprehensive knowledge servers for e-business users. It searches and browses for information and subject matter experts from multiple locations and supports instant collaboration with colleagues and hence increase knowledge sharing and decrease time spent looking for needed resources. K-station: A knowledge portal with powerful out-of-the-box collaborative capabilities. It uses a Web browser user interface to access virtually any information source: from Web applications to Microsoft Office documents to back-end data. It includes integrated instant collaboration features and a high customisable environment. Domino.Doc: Document and Records Management for the Distributed Enterprise. It helps in improving an organisation's efficiency through enhanced collaboration and information management. It delivers scalability, flexibility and low cost of ownership to support both enterprise-wide documents and records management, while serving as a foundation for knowledge management. Domino Workflow: A stand-alone product that works on top of Domino to provide the ability to develop, manage, and monitor business processes and help eliminate the downfalls of paper-based work. It visually represents each step in the workflow process changes with a point and a click. Domino Extended Search: Performs parallel searches across heterogeneous data sources. It locates and presents relevant information in a context familiar to the user. It also searches and retrieves documents from Lotus Notes, Domino.Doc, and R5 Domain Index, and can search external sources such as Microsoft index Server and Site Server, LDAP-compliant directories, 18 popular Web search sites and News sites, commercial content providers, and ODBC compliant databases. http://www.lotus.com Livelink by OpenText: A proactive, online search and retrieval package that reduces the amount of time required for locating key data. It effectively manages people, processes and information. Its tightly integrated services, including Livelink MeetingZone, deliver true dynamic collaboration and knowledge sharing between individuals, teams and organisations. The fully web-based and open-architecture system ensures rapid deployment, accelerated adoption, and low cost of ownership. It allows individuals to set up automated tools to scan a variety of information sources and immediately advises them when these sources have been updated with critical information. Can be linked to the document collection manager named, BASIS® which is provided by the same vendor. www.opentext.com

Locating /Accessing Knowledge	**Intranet/Extranet (INRA/EXRA):** **Intranet** is an internal organisational Internet that is guarded against outside access by special security software (firewall) (Haag, Cummings, and Dawkins 1998). **Extranet** is an Intranet with limited access for outsiders, making it possible for these to collect and deliver certain information on the Intranet.	**Livelink by Open Text Corporation:** Livelink is a highly scaleable and comprehensive collaborative environment for the development of Web-based intranets, extranets and e-business applications. http://www.opentext.com Instant Intranet Builder: An out-of-the-box software tool with powerful features to create, maintain, and manage an enterprise's Intranet. http://www.engbsolutions.com/ iLevel: Allows organisations to create, edit, manage, revise and publish Web sites and intranets. http://www.ilevelsoftware.com
	Search Engines (SE): These are web applications. Some perform automatic text-only searches while others rely on human 'interpreters' who could access web pages and then analyse and classify them. The second generation can do sophisticated searches in looking for specific terms and also related terms to identify more accurately what the questioner is looking for. They can also provide users with support as they navigate through a knowledge domain. They are sometimes described as knowledge navigators (Wensley 2000).	Google: The best and biggest search engine database on the web. Google is distinguished by its ranking algorithm based on how many other pages link to each page, along with other factors like the proximity of search keywords or phrases in the documents. It uses not only the number of other pages that link to a page, but also the importance of the other links (measured by the links to each of them). There is no way anyone can buy or influence the ranking of his or her page in Google (unlike some other search engines and directories). Google is the largest index of websites available on the World Wide Web and the industry's most advanced search technology. It delivers the fastest and easiest way to find relevant information on the Internet. Google now claims that their index contains 3 billion html-documents. Google has also set a new standard for search engines. It has partly eliminated the annoying "dead url-syndrome" by caching all indexed documents locally. If an "error" or "wrong url" message is obtained, the cached version could be clicked. This document has detailed information on which date it was cached. Hit summaries are also based on the search terms. This means that the search engine will look up the "thickest occurrence" of the search terms in the document! Furthermore, Google is one of few search engines that indexes PDF-files. It also converts PDF-files into html by clicking "view as html" in the hit list. Recently it started to index word, excel, power point, write and many other file types. http://www.google.com There are many other search engines. Some of the popular ones are: Yahoo http://www.yahoo.com (has integrated Google's fast and highly relevant wireless search technology into its wireless offerings), FAST http://www.alltheweb.com, Excite http://www.excite.com, AltaVista http://www.altavista.com, and Infoseek http://www.infoseek.go.com

Locating /Accessing Knowledge	Taxonomy/Ontological Tools (T/O T): **Taxonomy** is a collection of terms (and the relationships between them) that are commonly used in an organisation. Examples of a relationship are 'hierarchical' (where one term is more general hence subsumes another term), 'functional' (where terms are indexed based on their functional capabilities), and 'networked' (where there are multiple links between the terms defined in the taxonomy). **Ontologies** also define the terms and their relationships but in addition support deep (refined) representation (for both descriptive and procedural knowledge) of each of the terms (concepts) as well as defined domain theory or theories that govern the permissible operations with the concepts in the ontology. There are at least three ways to develop a taxonomy/ontology: manually constructed (using some kind of building tools), automatically discovered (from a repository of knowledge assets), or purchased off-the-shelf. Taxonomies/Ontologies serve multiple purposes in an organisation. They can be used as a corporate glossary holding detail descriptions of every key term used in the organisation. They can be used to constrain the search space of search engines and prune search results, identify and group people with common interests, and act as a content/knowledge map to improve the compilation and real time navigation of Web pages. Ontologies can also be used to support business process modelling. There are Industry-specific ontologies as well as stand-alone ontological toolkits (Tsui 2002 a & b).	Autonomy: Autonomy's technology enables the enterprise to automate operations on all forms of information used to conduct business. Autonomy is able to integrate and operate on sources as diverse as email, Word documents, PDF-files, voice and video extracts, (unstructured information) XML and metadata, (semi-structured information) and the information held in databases (structured information). Autonomy is a KM suite consists of several products. It automates operations on unstructured information in digital domains. It also automatically reads, categorises, hyperlinks, and personalises vast quantities of unstructured information and facilitates content-to-content, content-to-people, and people-to-people interactions. http://www.autonomy.com SemioMap by Entrieva: Performs text mining by Searching relationships within unstructured data. This software provides a graphical interface to view text collections. It allows discovering relevant information from seemingly impenetrable mountains of text. It is used primarily by researchers and intelligence analysts. It displays how phrases interact across document and uncovers meaning that is not readily apparent. http://www.semio.com RetrievalWare Suite (previously Excalibur) by Convera: Uses fuzzy searches to find relationships within structured data and provides text-based knowledge retrieval solutions. It creates a list of the enterprise assets, then enables users to search more than 200 document types on file servers, in groupware systems, relational databases, document management systems, web servers etc (all from a common user interface to satisfy access rights). This access is managed by RetrievalWare's Synchronizers, which recognize any changes, system-wide, and automatically update the index them. http://www.convera.com.
	Web Mapping Tools (WMT): Web Mapping Tools organise URLs into knowledge rather than information. They provide a dynamic tool which bookmarks, structures and displays the pathway through the Web, thus enabling users to quickly find their way back to pages of interest.	Web Squirrel by Eastgate Systems Inc.: Keeps track of the URLs, email addresses, and other resources. It builds spatial maps that visualize the resources. It adapts naturally to the users' changing needs and to changes on the web. (cost indication £35). http://www.eastgate.com/squirrel WINCITE: WINCITE is more than a web-mapping tool. The software supports the integration of a Relational Database with Web Intranet Services on a Global Basis. In addition, live links to web sites provide a means of automatically showing current information. Using stock ticker symbols, link can be made to number of valuable financial and news oriented web pages. The basic architecture of the system is a number of Topic/Subject screens that organize the information stored in a relational database. This is also a Data Base Management System. www.wincite.com

Locating /Accessing Knowledge	Electronic Document Management Systems (EDMS): Systems that collect, store and distribute the artefacts of knowledge contained in an organisation. They provide version control, authentication and translation (Jackson, 1998).	Documentum: An enterprise content management platform and a document management system that supports the management of all types of content (documents, web pages, XML files, and rich media) using one common content platform and repository. http://www.documentum.com BASIS® by OpenText: Robust document collection and high performance search and retrieval solution. It can be integrated with the knowledge discovery and collaboration tool named Livelink, which is provided by the same vendor. www.opentext.com Dicom by Dicom Group Plc: A software developed by a world's leading provider of data and document management solutions who is also, according to http://www.bcs.org.uk/bt/html/dialog.htm, the only UK document management distributor that is ISO9001 certified. http://www.dicom.co.uk
	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. It requires the sender and receiver to have computer addresses and a computer network connection.	Eudora The most popular and may be the best email system. It is licensed in three modes: Sponsored mode, Paid mode, (approx. £30) and Light mode. The new features in Eudora 5.1 for Windows are: SSL (Secure Socket Layer) support; Eudora Shell Extension to caution users about potential for introducing viruses when running a file in the "Attach" directory outside of Eudora; MIME (Multipurpose Internet Mail Extensions) digests; In-line flagging of offensive words or phrases; "Strikeout" style button to cross out a selected text with a horizontal line; and Drag/Drop of attachments out of messages into other locations. http://www.eudora.com Microsoft Outlook Outlook, part of Microsoft's Office suite, provides e-mail, calendaring, a to-do list and many other features, all in an integrated, easy-to-use environment. Outlook makes many tasks easier, including: sending and receiving attachments; organizing e-mail into folders; scheduling meetings; notifying attendees of a meeting invitation; and syncing desktop information with a portable digital assistant (PDA), such as a Palm Pilot (available in Outlook 2000 and above for the PC only). It also offers new and improved capabilities, including: the use of shared calendars, task lists, and e-mail groups to coordinate team responsibilities; the storage of information about people commonly interacted with through "contacts" and using this information in everyday activities such as e-mail and, in some cases, calendaring; sharing information with other people in the unit/department "public folders"; and the use of non-English fonts and other features of Outlook's foreign language support (available in Outlook 2000 and above for the PC only). http://www.microsoft.com

2. Technologies for Capturing Knowledge

KM Sub-process	Technology Category	Application Software
Capturing Knowledge	Word Processors (WP): Software tools that help in creating, editing, saving and printing documents that primarily consist of text (Haag and keen 1996).	Many word processors are available in the market such as MS Word (http://www.microsoft.com/office/word) by Microsoft and Word Perfect (http://www3.corel.com) by Corel.
	Case-Based Reasoning (CBR) - Expert Systems: Decision support technologies that help people to solve a problem by capturing and using the experience, logic patterns, and the thought processes of an expert (Haag and keen 1996). Knowledge of a human expert is contained in a program, which simulates human reasoning.	CBR-Works by empolis: A Decision Support System with Databases. It offers quick and easy access to the technology of Case-Based Reasoning (CBR). The domain-specific knowledge model describes concepts, similarities among them, and further relations of the application domain to allow use of a corporation's information assets. It is based on an object-oriented Client-Server architecture and is applicable to CD-ROM, and to the Intra-, Extra-, and Internet. The Graphical User Interfaces (GUIs), developed in Java, help the browser achieve comfortable user interfaces. It is compatible with the common operating systems and databases, and is easy to integrate into existing applications. it actively supports users as they search databases, letting the existing databases become intelligent support systems and knowledge bases. Information garnered through the search process is modelled and maintained in a knowledge model. With easily formulated queries, CBR-Works can deliver precise and meaningful answers. The intelligent behaviour of the system suggests potential alternatives from the searches. http://www.empolis.com Kaidara: Supports the capturing and using of knowledge. Capturing and maintaining a "case base" of experience is streamlined by powerful import capabilities and automatic, on-the-fly generation of decision trees. The system also supports automatic authoring of decision trees. Kaidara-powered systems are self-learning; as new experience is gained, it is automatically included in future responses. Question trees can be generated on-the-fly incorporating the latest product revisions automatically. Dialogs are maintained up-to-date with minimal effort. The virtual advisor allows the user to skip questions or take jumps in a decision tree. This flexibility allows the user to proceed without forcing a fixed script of questions. http://www.acknosoft.com

Capturing Knowledge	Knowledge Bases (KB): A repository to store knowledge about a topic in a concise and organized manner. It presents facts that can be found in a book, a collection of books, web sites or even human knowledge. This is different from the part of the expert system/case base reasoning (CBR) that stores the rules.	Assistum: A rule-based decision support system, which relies on AI and fuzzy logic. Revolves around creating and modifying k-bases. It consists of two main components: a Knowledge Viewer and a Knowledge Editor. The Viewer is for consulting Assistum knowledge bases. The Editor is for creating and modifying Assistum knowledge bases. It can be integrated into the enterprise solutions using MS VBA. KnowledgeBase.net: A web-based solution for multi-user article publishing, management, searching, and reporting. It can be deployed at users location of choice, or hosted in providers data centres. It empowers the customers, partners, and employees with the self-service ability to share and leverage knowledge. http://www.knowledgebase.net XpertRule Knowledge Builder by Attar: A graphical environment for developing knowledge based applications or components. Knowledge is represented as Trees, Rules and Cases supported by an integrated inference engine. The system provides graphical & customisable multi-user development environment for medium to large-scale knowledge applications and components, where knowledge bases are highly scalable and the knowledge objects are customisable. It allows flexible and scalable knowledge deployment options- PC standalone, COM+ Java Servlet or Java Applet, or using XML for data exchange. It also allows the importation of knowledge modules developed in XpertRule KBS or from XML files. http://www.attar.com
	Knowledge Mapping (KMpp) – Concept Mapping: A graphical representation of procedures and processes to enable free flow of information and sharing of knowledge. Knowledge maps are of various types namely Cognitive Maps, Concept Maps, Logic Flow Maps, Mission Maps, Sociometric Maps, Decision Trees, and Influence Diagrams. Among these, the Concept Maps, Decision Trees and Influence Diagrams are the most frequently used ones. http://www.kmindia.org/asci/km_zine/_zine_kno_map.htm 16/09/2002	Knowledge Service by Kanisa: Composed of two key components, Kanisa Knowledge Map Generator and Auto Classification Engine (ACE). The Knowledge Map Generator creates a Knowledge Map out of a set of overlapping taxonomies that describe the way the products, services and business processes relate to one another. ACE uses the Knowledge Map as an electronic blueprint to automatically organize and index all contents regardless of location. http://www.kanisa.com IHMC Concept Map The IHMC Concept Mapping Software empowers users to construct, navigate, share, and criticize knowledge models represented as Concept Maps. The toolkit is platform independent and network enabled, allowing users to build, and collaborate during the construction of concept maps with colleagues anywhere on the network, as well as, share and navigate through others' models distributed on servers throughout Internet. http://cmap.coginst.uwf.edu

3. Technologies for Representing Knowledge

KM Sub-process	Technology Category	Application Software
Representing Knowledge	Mind Mapping Applications (MMA) – Brainstorming: A process of focussing on a problem, and then deliberately coming up with as many deliberately unusual solutions as possible and by pushing the ideas as far as possible. Several tools help in structuring these ideas by providing visual environments for the ideas to be captured and shared, both at the individual and group levels (Tsui 2002a & b). They also provide a method for developing creative solutions to problems.	Mind Manager by Mindjet LLC.: This is a two dimensional graphical display of linked concepts. It supports the generation of concept maps (mind maps) as well as automatically generating documents, presentations, and web pages from these maps (Tsui 2002 tracking). This product is described as the best mind mapping tool (Tiwana 2000). http://www.mindjet.com The Brain: A visualisation system that supports three-dimensional views of linked concepts. The Brain can be web-deployed and is adopted in many organisations as a front end to the organisations' products (Tsui 2002). http://www.natraficial.com
	Web Publishing (WPb): Tools that support the representing and delivering of recorded knowledge. This includes the publication of items such as books, magazines, newspapers, and advertising flyers in an electronic format rather than in the print-on-paper format associated with traditional publishing processes (Haag, Cummings, and Dawkins 1998).	KnowledgeBase.net: A web-based solution for multi-user article publishing, management, searching, and reporting. It can be deployed at users location of choice, or hosted in providers data centres. It empowers the customers, partners, and employees with the self-service ability to share and leverage knowledge. http://www.knowledgebase.net
	Virtual Reality (VR): A three-dimensional computer simulation that provides sensory information (sight, sound, and/or others) to make the user feel in a "place". This requires a typical personal computer and a few items of specialized hardware: a 3D graphics card, a 3D sound card, a head-mounted display, and a 6D tracker. VR software is very useful to display the virtual environment. It can also be used to represent, and refine knowledge.	Maelstrom by Maelstrom Virtual Productions: Interactive Virtual Reality Software that assists in the processes of design and construction. It has produced software for developments such as stadia, hotel training facilities, retail design and layout, the London Futures Exchange, and planning permission approval. http://www.maelstrom.com 3ds max™ for Windows®: The world's best-selling, professional 3D modelling, animation and rendering software for creating visual effects, character animation and next generation game development. It delivers a fully collaborative 3D environment and new high-speed interactive rendering. Its completely customisable and extensible architecture allows for absolute artistic freedom. http://www.autodesk.com
	Word Processors (WP): Software tools that help in creating, editing, saving and printing documents that primarily consist of text (Haag and keen 1996).	Many word processors are available in the market such as MS Word (http://www.microsoft.com/office/word) by Microsoft and Word Perfect (http://www3.corel.com) by Corel.

Representing Knowledge	Computer Aided Design (CAD): A sophisticated graphics software that automates the creation and revision of designs (Laudon & Laudon, 1998). It provides an environment for two and three dimensional design and drafting. Architects, engineers, drafters, and other professionals involved with design use it to create, view from all angles, manage, plot or output, share, and reuse information/knowledge-rich drawings.	Autodesk products: Autodesk is one of the best providers of CAD solutions. The products come in different categories to support the different requirements of organisations. These categories are: General Design Products (AutoCAD, AutoCAD LT), Building Design Solutions (Autodesk Revit, Autodesk Architectural Studio, Autodesk Architectural, Desktop, Autodesk Buzzsaw), Manufacturing (Autodesk Inventor Series, AutoCAD Mechanical 6, AutoCAD Data Exchange), Geographic Information Systems (Autodesk GIS Design Server, Autodesk MapGuide, Autodesk Map, Autodesk Map Series, Autodesk Land Desktop, Autodesk Civil Design, Autodesk Survey, Autodesk OnSite Technology, Autodesk Raster Design), Viewing Tools and Entry Level CAD (QuickCAD, AutoSketch, Volo View, Volo View Express, Autodesk OnSite View), and Visualisation (3ds Max and Character Studio, Autodesk VIZ, Lightscape). http://www.autodesk.co.uk
	SpreadSheets (SS): A grid-based software tool that allows the user to organize information on a grid, make calculations, sort data and create graphs. Spreadsheets support calculations with numbers that can be instantly updated and they can sort names and other information alphabetically. They can be used to analyse data with simple-to-create graphs/charts. However, eventually a spreadsheet becomes too cumbersome to store records because they are flat files requiring the repetition of information for each row and hence are not very powerful with large amounts of repetitive information compared to databases.	Excel by Microsoft: Before Microsoft shoved it down the throat of PC users, Excel's only claim to fame was that it was the best spreadsheet for Macintoshes. When Windows took over the PC market, and Microsoft began pushing the Office suite of programs, Excel suddenly became very popular. It's a good spreadsheet, but may not be the best. http://www.microsoft.com/office/excel StarOffice/OpenOffice Calc: Includes the same range of analysis and graphic tools found in other professional spreadsheets. It runs on Windows, Linux, or Sun Solaris and stores its documents in XML, the fully open data storage format. It has excellent compatibility with MS Office files. It's available in two flavours: OpenOffice (free download - http://www.openoffice.org) and Sun StarOffice 6.0 (http://wwws.sun.com/software/star/staroffice/6.0) Lotus 1-2-3: This is the original "killer app" that legitimised PCs for business. While it no longer dominates the spreadsheet market (after Microsoft's advantage in creating and then bundling Windows applications), it's still a very powerful and capable analysis tool. It is a powerful tool and can be used along with Lotus Notes and the rest of Lotus' suite of applications. http://www.lotus.com.

Representing Knowledge	*Knowledge Mapping (KMpp) – Concept Mapping:* A graphical representation of procedures and processes to enable free flow of information and sharing of knowledge. Knowledge maps are of various types namely Cognitive Maps, Concept Maps, Logic Flow Maps, Mission Maps, Sociometric Maps, Decision Trees, and Influence Diagrams. Among these, the Concept Maps, Decision Trees and Influence Diagrams are the most frequently used ones. http://www.kmindia.org/asci/km_zine/_zine_kno_map.htm 16/09/2002	*Knowledge Service by Kanisa:* Composed of two key components, Kanisa Knowledge Map Generator and Auto Classification Engine (ACE). The Knowledge Map Generator creates a Knowledge Map out of a set of overlapping taxonomies that describe the way the products, services and business processes relate to one another. ACE uses the Knowledge Map as an electronic blueprint to automatically organize and index all contents regardless of location. http://www.kanisa.com IHMC Concept Map The IHMC Concept Mapping Software empowers users to construct, navigate, share, and criticize knowledge models represented as Concept Maps. The toolkit is platform independent and network enabled, allowing users to build, and collaborate during the construction of concept maps with colleagues anywhere on the network, as well as, share and navigate through others' models distributed on servers throughout Internet. http://cmap.coginst.uwf.edu

4. Technologies for Sharing Knowledge

KM Sub-process	Technology Category	Application Software
Sharing Knowledge	Web Publishing (WPb): Tools that support the representing and delivering of recorded knowledge. This includes the publication of items such as books, magazines, newspapers, and advertising flyers in an electronic format rather than in the print-on-paper format associated with traditional publishing processes (Haag, Cummings, and Dawkins 1998).	KnowledgeBase.net: A web-based solution for multi-user article publishing, management, searching, and reporting. It can be deployed at users location of choice, or hosted in providers data centres. It empowers the customers, partners, and employees with the self-service ability to share and leverage knowledge. http://www.knowledgebase.net
	Communities of Practice (CoPs) - (Knowledge Communities, Knowledge Networks, Learning Communities, Communities of Interest, Thematic Groups): A virtual environment consisting of a group of people of different skill sets, development histories and experience backgrounds who work together to achieve commonly shared goals.	AskMe by AskMe Enterprise: Aimed at creating and managing employee knowledge networks. It provides: person-to-person knowledge sharing platform and supports identifying 'who know what'. http://www.askme.com
	Intranet/Extranet (INRA/EXRA): **Intranet** is an internal organisational Internet that is guarded against outside access by special security software (firewall) (Haag, Cummings, and Dawkins 1998). **Extranet** is an Intranet with limited access for outsiders, making it possible for these to collect and deliver certain information on the Intranet.	Livelink by Open Text Corporation: Livelink is a highly scaleable and comprehensive collaborative environment for the development of Web-based intranets, extranets and e-business applications. http://www.opentext.com Instant Intranet Builder: An out-of-the-box software tool with powerful features to create, maintain, and manage an enterprise's Intranet. http://www.engbsolutions.com/ iLevel: Allows organisations to create, edit, manage, revise and publish Web sites and intranets. http://www.ilevelsoftware.com
	Web-Based File Sharing Tools (WBFS): A collaborative way of sharing files over the internet to allow dispersed users to access these files freely. Some of them support security features.	KnowledgeDisk: Multi-level, full security web-based file sharing tool. It provides a simple and easy way to share files over the internet, with no special software other than a standard internet browser. It includes multi-level folders, file security, and easy navigation. It is easy to install on any company website or can be used on a company server. www.knowledgedisk.com Briefcase: A free Web based file-sharing service. Each briefcase can hold up to 30Mb of files. Each file can stay in the briefcase for up to 2 weeks. Files older than 2 weeks are erased automatically. Useful when files will be accesses within few days. http://briefcase.wt.net

Sharing Knowledge	***Instant Messaging (IM):*** Instant messaging is a software component that helps team members to communicate (Haag, Cummings, and Dawkins 1998). It can come as a stand-alone application or as a component of a groupware system. It is a peer-to-peer application that allows network users to communicate in a fast effective manner, without the delays associated with email because it sends and receives messages over a network, without the need for a dedicated server.	NetLert 3 Messenger by by NetLert Communications, Inc: A secure, business grade, real-time collaboration software package that offers increased productivity through text chat (instant messaging), presence awareness and object sharing. NetLert 3 Messenger is easy-to-use server/client software that runs on multiple operating systems and is powered by the Sun ONE server engine. http://www.netlert.com Trusted Messenger: Real time messaging software designed for business use. This secure network messaging that allows for business communication. Because Trusted Messenger resides on the companies internal network or LAN, there are no security risks such as those associated with many other instant messaging applications. It features intuitive design and is easy to use. Individual users can customize the look and feel by selecting from a variety of predefined skins (icons). It can work on several Operating Systems, namely: Windows 95; 98; NT 2000; ME and XP). http://www.trusted-messaging.com ICQ: This is generic IM software and although not specifically designed for business uses, ICQ is considered as the best Instant Messaging software available. It has a *massive* global user-base and more features than any other instant messengers do. The software can be used to simply chat with friends, family members, and business partners. It can also be used to transfer files between users and to send SMS messages. AOL (America On Line) Instant Messenger: One of the best messengers, after ICQ. Yahoo Messenger: Not quite as feature packed as ICQ, but still a very good one. It is a much smaller file to download than ICQ and works in much the same way. MSN Messenger by Microsoft: Difficult to navigate and to find users unless their e-mail address or username is already known.

Sharing Knowledge	***Integrated Groupware Solutions (IGWS) (e.g. email, instant*** **messaging, net-meeting):** 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 (Haag and keen 1996). It supports distributed and virtual project teams where team members are from multiple organisations and in dispersed locations. Groupware tools usually offer email communications, instant messaging, discussion areas, file area or document repository, information management tools (e.g. calendar, contact lists, meeting agendas and minutes) and search (Tsui 2002- tracking).	***A group of Lotus products by IBM:*** Notes (E-mail, calendaring, group scheduling, Web access and information management client); Domino (integrated messaging and Web application software platform); Sametime (a family of real-time collaboration products providing instant awareness, communication, and document sharing capabilities); and QuickPlace (a self-service Web tool for instant collaboration). http://www.lotus.com GroupWise by Novell Pacific Coast: A secure, dynamic collaboration solution that offers support for communication over intranets, extranets and the Internet whether using personal computers or wireless devices, such as Internet-capable cellular phones or personal digital assistants. It contains improvements to the Windows Client, WebAccess, administration, and agent components of Novell's GroupWise collaboration software. Cost depends on number of users (e.g. £450 for 5 users and £2200 for 25 users. http://www.novell.com BrightSuite Enterprise (MS Access and MS SQL Server versions): A Web-based enterprise system integrating work process mapping, best practices, and document management. It supports: workflow diagrams, task management, discussion board, calendars, project reporting, news board, directories, best practices, experts database, links database, resource management, chat, photo galleries, online surveys, lessons learned, email, wireless access, instant messaging, reminders, and import/export to MS Outlook. Comes in 2 versions: The £670 works with either MS Access or SQL Server as the backend database. The £470 is configured only for MS Access. http://www.dcasoft.com MyLivelink by Open Text: myLivelink is the leading collaborative knowledge portal for e-business. It connects users to information within the enterprise business systems, intranets, extranets and global e-community all from a single Web interface. http://www.opentext.com Plumtree Collaboration Server by Plumtree Software, Inc: Allows portal users to collaborate on projects – setting schedules, sharing documents and exchanging ideas. http://www.plumtree.com iTeam by Documentum, Inc: iTeam is designed for the ability to collaborate real-time in a common project environment. http://www.documentum.com iCohere, inc: Web-based groupware collaboration software tools to create Communities of Practice (CoPs) and Learning communities. http://www.icohere.com

Sharing Knowledge	*Multi-Media Tools (MtMd) - (Video Conferencing software):* Software that supports interactive peer-to-peer meetings through computers (Haag and keen 1996).	*Microsoft's NetMeeting* Provides the most complete conferencing solution for the Internet and corporate Intranet. It allows to communicate with both audio and video, collaborate on virtually any Windows-based application, exchange graphics on an electronic whiteboard, transfer files, use the text-based chat program, etc. it also supports peer-to-peer conversations. http://www.microsoft.com/products/prodref/113_ov.htm absoluteBUSY - An out-of-the-box web based application, which includes a web based contact manager, an online project tracking tool and personal users pick lists and to do lists with scheduling. Information in all modules is linked together for quick navigation. http://www.absolutebusy.com eRoom by eRoom Technology (being acquired by Documentum): A web-based digital workplace for the extended enterprise, allowing organisations to quickly assemble a project team and manage the collaborative activities that support their complex and rapidly-changing business projects and processes. http://www.instinctive.com/html/eroom.html WebDemo by Linktivity (division of SpartaCom Technologies): A web-based, real-time conference and collaboration software that provides an effective way to deliver electronic presentations as well as interact with an audience of remote participants. http://www.linktivity.com WebEx Training Centre by WebEx: A Web based Training Centre that trains users with access to recorded training sessions. This helps to reduce training costs while increasing impact, scope, and frequency of training. It also ensures that customers, partners, and employees are always up-to-date on product releases, corporate initiatives, and soft skills. http://www.webex.com WebEx Meeting Centre by WebEx: Integrates data, voice, video, and live multimedia within a standard Web browser to facilitate real-time meetings over the Internet from virtually any laptop, desktop, or wireless handheld device. http://www.webex.com

Sharing Knowledge	***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. It requires the sender and receiver to have computer addresses and a computer network connection.	Eudora The most popular and may be the best email system. It is licensed in three modes: Sponsored mode, Paid mode, (approx. £30) and Light mode. The new features in Eudora 5.1 for Windows are: SSL (Secure Socket Layer) support; Eudora Shell Extension to caution users about potential for introducing viruses when running a file in the "Attach" directory outside of Eudora; MIME (Multipurpose Internet Mail Extensions) digests; In-line flagging of offensive words or phrases; "Strikeout" style button to cross out a selected text with a horizontal line; and Drag/Drop of attachments out of messages into other locations. http://www.eudora.com Microsoft Outlook Outlook, part of Microsoft's Office suite, provides e-mail, calendaring, a to-do list and many other features, all in an integrated, easy-to-use environment. Outlook makes many tasks easier, including: sending and receiving attachments; organizing e-mail into folders; scheduling meetings; notifying attendees of a meeting invitation; and syncing desktop information with a portable digital assistant (PDA), such as a Palm Pilot (available in Outlook 2000 and above for the PC only). It also offers new and improved capabilities, including: the use of shared calendars, task lists, and e-mail groups to coordinate team responsibilities; the storage of information about people commonly interacted with through "contacts" and using this information in everyday activities such as e-mail and, in some cases, calendaring; sharing information with other people in the unit/department "public folders"; and the use of non-English fonts and other features of Outlook's foreign language support (available in Outlook 2000 and above for the PC only). http://www.microsoft.com

5. Technologies for Creating New Knowledge

KM Sub-process	Technology Category	Application Software
Creating New Knowledge	Data and Text Mining (D/T M): A technique to extract meaningful knowledge from masses of data. It enables meaningful patterns and associations of data (words and phrases) to be identified from one or more large databases. Mostly used in business intelligence, direct marketing and customer relationship management applications. However, this technique is not widely used because it is difficult to access data via an enterprise-wide corporate portal as most organisations only have a small group of data miners. (Tsui 2002 a & b). The technique is also very useful for finding out the hidden relationships between data and hence helps in creating new knowledge. Notes: Data = structured data Text = unstructured data	<u>Data Mining</u>: Knowledge SEEKER by Angoss Knowledge Engineering: This is an artificially intelligent Knowledge Discovery and Data Mining tool that helps to rapidly seek, analyse and understand the patterns in a data set and also enables users to apply powerful clustering, analytical and statistical algorithms to operational data. It includes a Decision Tree Induction process, which generates automated queries. This Decision Tree Induction process has the mathematical power and crunch power to construct and run the queries required. It accepts data from all major databases as well as from popular query and reporting, spreadsheets, statistical and OLAP & ROLAP tools. It can be used with the operating systems: Unix (AIX, HP-UX, Solaris) and Windows (3.1, 95, 98, NT, 2000. the system requires: CPU of 486 or higher, 64 MB of memory although not necessary for smaller data sets or stand-alone workstation use, and Disk space of 20 MB. http://www.angoss.com RetrievalWare (previously Excalibur) by Convera: Uses fuzzy searches to find relationships within structured data and provides text-based knowledge retrieval solutions. It creates a list of the enterprise assets, then enables users to search more than 200 document types on file servers, in groupware systems, relational databases, document management systems, web servers etc (all from a common user interface to satisfy access rights). This access is managed by RetrievalWare's Synchronizers, which recognize any changes, system-wide, and automatically update the index. http://www.convera.com XpertRule Miner by Attar: A graphical data-mining environment for discovering tree patterns from historic business data. It provides graphical support for the full data mining process from data exploration and preparation to pattern discovery and deployment. It is a scalable high performance tool that allows data mining solutions to be embedded as ActiveX components within other applications. Also, the 'mined trees' can be exported to Knowledge Builder. http://www.attar.com Clementine from SPSS inc.: A data-mining workbench that enables quickly developing predictive models using business expertise and deploying them to improve decision-making. It supports the entire data mining process and is designed around the de facto industry standard for data mining. http://www.spss.com/spssbi/clementine

Creating New Knowledge	...Continued	
	Data and Text Mining (D/T M): A technique to extract meaningful knowledge from masses of data. It enables meaningful patterns and associations of data (words and phrases) to be identified from one or more large databases. Mostly used in business intelligence, direct marketing and customer relationship management applications. However, this technique is not widely used because it is difficult to access data via an enterprise-wide corporate portal as most organisations only have a small group of data miners. (Tsui 2002 a & b). The technique is also very useful for finding out the hidden relationships between data and hence helps in creating new knowledge. Notes: Data = structured data Text = unstructured data	Text Mining: SemioMap by Entrieva: Searches relationships within unstructured data. This software provides a graphical interface to view text collections. It allows discovering relevant information and knowledge from seemingly impenetrable mountains of text. It is used primarily by researchers and intelligence analysts to display how phrases interact across documents and to uncover meaning that is not readily apparent. www.semio.com Intelligent Miner for Text by IBM: Turns unstructured information into business knowledge for organisations. The knowledge-discovery "toolkit", within the software, includes components for building advanced text mining and text search applications. It consists of a wide range of text analysis tools for feature extraction, clustering, categorization and summarization. It contains Web-access tools, such as NetQuestion Solution and IBM Web Crawler. It also unlocks the business information that is trapped in emails, insurance claims, news feeds and Lotus Notes, as well as analysing patent portfolios, customer complaint letters, and even competitors' Web pages. http://www-3.ibm.com/software/data/iminer/fortext Megapture Intelligence: Provides solutions based on semantic network analysis, a method that uses Artificial Neural Networks to extract semantic ("meaning") information from the text. This information may then be used to create summarizations, concept-based searches, or even semantic text based navigations. http://www.megaputer.com
	Knowledge Mapping (KMpp) – Concept Mapping: A graphical representation of procedures and processes to enable free flow of information and sharing of knowledge. Knowledge maps are of various types namely Cognitive Maps, Concept Maps, Logic Flow Maps, Mission Maps, Sociometric Maps, Decision Trees, and Influence Diagrams. Among these, the Concept Maps, Decision Trees and Influence Diagrams are the most frequently used ones. http://www.kmindia.org/asci/km_zine/_zine_kno_map.htm 16/09/2002	Knowledge Service by Kanisa: Composed of two key components, Kanisa Knowledge Map Generator and Auto Classification Engine (ACE). The Knowledge Map Generator creates a Knowledge Map out of a set of overlapping taxonomies that describe the way the products, services and business processes relate to one another. ACE uses the Knowledge Map as an electronic blueprint to automatically organize and index all contents regardless of location. http://www.kanisa.com IHMC Concept Map The IHMC Concept Mapping Software empowers users to construct, navigate, share, and criticize knowledge models represented as Concept Maps. The toolkit is platform independent and network enabled, allowing users to build, and collaborate during the construction of concept maps with colleagues anywhere on the network, as well as, share and navigate through others' models distributed on servers throughout Internet. http://cmap.coginst.uwf.edu

Creating New Knowledge	Mind Mapping Applications (MMA) – Brainstorming: A process of focussing on a problem, and then deliberately coming up with as many deliberately unusual solutions as possible and by pushing the ideas as far as possible. Several tools help in structuring these ideas by providing visual environments for the ideas to be captured and shared, both at the individual and group levels (Tsui 2002a & b). They also provide a method for developing creative solutions to problems.	Mind Manager by Mindjet LLC.: This is a two dimensional graphical display of linked concepts. It supports the generation of concept maps (mind maps) as well as automatically generating documents, presentations, and web pages from these maps (Tsui 2002a). This product is described as the best mind mapping tool (Tiwana 2000). http://www.mindjet.com The Brain: A visualisation system that supports three-dimensional views of linked concepts. The Brain can be web-deployed and is adopted in many organisations as a front end to the organisations' products (Tsui 2002a). http://www.natraficial.com
	Data Warehouses (DW): A logical collection of information –gathered from many different operational databases- that support business analysis activities and decision-making tasks (Haag, Cummings, and Dawkins 1998).	Syncsort: Syncsort Incorporated is a leading developer of high-performance business intelligence and data warehousing software for mainframe, UNIX, and Windows environments. SyncSort for Windows minimizes the sorting time for large volumes of data and significantly improves the performance of enterprise applications. Whether administering a very large database or data warehouse, or managing data from web sites and e-commerce, SyncSort provides high enterprise performance for data applications. The Visual SyncSort brings graphical ease of use to the applications of sorting/merging/copying/joining and recording the processing features. http://www.syncsort.com

Appendix A7

KM Dimensions and supporting Technology Categories

Appendix A7: KM Dimensions and supporting Technology Categories

KM Sub-process	Technology Category	KM Dimensions											
		Conversion Types				Ownership Forms				Transfer Domains			
		Tacit to Tacit	Tacit to Explicit	Explicit to Tacit	Explicit to Explicit	Individual to Individual	Individua l to Group	Group to Individual	Group to Group	Internal to Internal	Internal to External	External to Internal	External to External
Locating & Accessing Existing Knowledge	ED	✓	✓			✓	✓	✓	✓	✓			
	DW				✓				✓	✓			
	WC				✓			✓	✓			✓	
	D/T M		✓		✓			✓	✓	✓		✓	
	KMpp		✓		✓	✓	✓	✓	✓	✓	✓	✓	
	KDP				✓			✓	✓	✓			
	INRA/EXRA				✓				✓	✓	✓	✓	
	SE				✓	✓	✓	✓	✓			✓	
	T/O T				✓			✓	✓	✓		✓	
	WMT				✓			✓	✓			✓	
	EDMS				✓	✓	✓	✓	✓	✓			
	E-Mail				✓	✓	✓			✓	✓	✓	
Capturing Existing Knowledge	WP		✓		✓	✓	✓	✓	✓	✓	✓	✓	
	CBR		✓				✓		✓	✓			
	KB		✓		✓		✓		✓	✓	✓		
	KMpp		✓		✓	✓	✓	✓	✓	✓		✓	
Representing Knowledge	MMA		✓				✓		✓	✓			
	WPb		✓		✓		✓		✓		✓	✓	
	VR		✓		✓	✓	✓	✓	✓	✓	✓	✓	
	WP		✓		✓	✓	✓	✓	✓	✓	✓	✓	
	CAD		✓		✓	✓	✓	✓	✓	✓	✓	✓	
	SS				✓	✓	✓	✓	✓	✓	✓	✓	
	KMpp		✓		✓	✓	✓	✓	✓	✓	✓	✓	
Sharing Knowledge	WPb				✓		✓		✓	✓	✓	✓	
	CoPs	✓	✓						✓	✓			
	INRA/EXRA				✓				✓	✓	✓	✓	
	WBFS				✓				✓	✓	✓	✓	
	IM		✓		✓	✓	✓		✓	✓	✓	✓	
	IGWS	✓	✓		✓	✓	✓		✓	✓	✓	✓	
	MtMd	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
	Email		✓		✓	✓	✓		✓	✓	✓	✓	
Creating New Knowledge	D/T M		✓		✓			✓	✓	✓			
	MMA		✓				✓		✓	✓			
	KMpp		✓		✓				✓	✓	✓	✓	
	DW				✓				✓	✓			

See Appendix A5 for meanings of abbreviations

Appendix A8

Relating Technology Categories to Combinations of KM Dimensions

Appendix A8: Relating Technology Categories to Combinations of KM Dimensions

KM Dimensions				Required							
Transfer Domain				Internal				External			
Ownership Form				Individual		Group		Individual		Group	
Knowledge Typ				Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit
			KM Sub-process	Technology Categories for KM sub-processes							
Current	Internal	Individual	Tacit								
			Locate	ED	ED, KMpp	ED	ED, KMpp		KMpp		KMpp
			Capture		KMpp, WP		CBR, KB, KMpp, WP		WP		KB, WB
			Represent		CAD, KMpp, VR, WP		CAD, KMpp, WP MMA, VR, WPb		CAD, KMpp, VR, WP		CAD, KMpp, VR, WPb, WP
			Share	IGWS, MtMd	Email, IM, IGWS, MtMd	IGWS, MtMd	Email, IM, IGWS, MtMd,	IGWS, MtMd	Email, IM, WP, MtMd	IGWS, MtMd	Email, IM, IGWS, MtMd
			Create				MMA				
			Explicit								
			Locate		EDMS, Email, KMpp		EDMS, Email, KMpp		Email, KMpp		Email, KMpp,
			Capture		KMpp, WP		KB, KMpp, WP		WP		KB, WP
			Represent		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WPb, WP
			Share		Email, IM, IGWS, MtMd		Email, IM, IGWS, MtMd, WPb		Email, IM, IGWS, MtMd		Email, IM,IGWS, MtMd, WPb
			Create								
		Group	Tacit								
			Locate	ED	D/T M, ED, KMpp	ED	D/T M, ED, KMpp		KMpp		KMpp
			Capture		KMpp, WP		CBR, KB, KMpp, WP		WP		KB, WP
			Represent		CAD, KMpp, VR, WP		CAD, KMpp, MMA, VR, WP		CAD, KMpp, VR, WP		CAD, KMpp, VR, WPb, WP
			Share	MtMd	MtMd	CoPs, IGWS, MtMd	CoPs, Email, IM, IGWS, MtMd	MtMd	MtMd	IGWS, MtMd	Email, IM, IGWS, MtMd
			Create		D/T M		MMA, D/T M, KMpp				KMpp
			Explicit								
			Locate		D/T M, EDMS, KDP, KMpp, T/O T		DW, D/T M, EDMS, INRA/EXRA, KDP, KMpp, T/O T		KMpp		INRA/EXRA, KMpp
			Capture		Kmpp, WP		KB, KMpp, WP		WP		KB, WP
			Represent		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WPb, WP
			Share		MtMd		Email, IM, IGWS, INRA/EXRA, MtMd, WBFS, WPb		MtMd		Email, IM, IGWS, WPb INRA/EXRA, MtMd, WBFS,
			Create		D/T M		D/T M, KMpp, DW				KMpp

Appendix A8: Relating Technology Categories to Combinations of KM Dimensions

KM Dimensions				Required							
Transfer Domain				Internal				External			
Ownership Form				Individual		Group		Individual		Group	
Knowledge Typ				Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit
KM Sub-process				Technology Categories for KM sub-processes							
External	Individual	Tacit	Locate		KMpp		KMpp	ILLOGICAL COMBINATIONS			
			Capture		KMpp, WP		KMpp, WP				
			Represent		CAD, KMpp, VR, WP		CAD, KMpp, VR, WPb, WB				
			Share	IGWS, MtMd	Email, IM, IGWS, MtMd	IGWS, MtMd	Email, IM, IGWS, MtMd				
			Create								
		Explicit	Locate		Email, KMpp, SE		Email, KMpp, SE				
			Capture		KMpp, WP		KMpp, WP				
			Represent		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WPb, WP				
			Share		Email, IM, IGWS, MtMd		Email, IM, IGWS, MtMd, WPb				
			Create								
	Group	Tacit	Locate		D/T M, KMpp		D/T M, KMpp				
			Capture		KMpp, WP		KMpp, WP				
			Represent		CAD, KMpp, VR, WP		CAD, KMpp, VR, WPb, WP				
			Share	MtMd	MtMd	IGWS, MtMd	Email, IM, IGWS, MtMd				
			Create				KMpp				
		Explicit	Locate		D/T M, KMpp, SE, T/O T, WC, WMT		D/T M, INRA/EXRA, KMpp, SE, T/O T, WC, WMT				
			Capture		KMpp, WP		KMpp, WP				
			Represent		CAD, KMpp, SS, VR, WP		CAD, KMpp, SS, VR, WPb, WP				
			Share		MtMd		Email, IM, IGWS, INRA/EXRA, MtMd, WBFS, WPb				
			Create				KMpp				

See Appendix A5 for meanings of abbreviation

Appendix A9

KM Processes and Supporting Techniques

Appendix A9: KM Processes and supporting Techniques

KM Sub-process	KM Technique	Description of Technique
Locating & Accessing Existing Knowledge	Face to Face Interaction (F-F)	Face-to-Face Interaction is a traditional approach for sharing the tacit knowledge (socialisation) owned by an organisation's employees. It usually takes an informal approach and is very powerful. Face-to-face interactions also help in increasing the organisation's memory, developing trust and encouraging effective learning. Lang (2001) considers it to provide strong social ties and tacit shared understandings that give rise to collective sense-making. This can also lead to an emergent consensus as to what is valid knowledge and to the serendipitous creation of new knowledge and, therefore, new value. This provides an environment within an organisation where participants see the firm as a human community capable of providing diverse meanings to information (i.e. knowledge).
	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 others respond. This is a very useful technique for capturing and sharing knowledge. Discussions forums can be very general where any question type can be posed or they can be very specific for particular users having similar interests e.g. a discussion forum for users of a specific software program. Although these are web-based, they are usually described as techniques rather than technologies.
Capturing Existing Knowledge	Post-Project Review (PPR)	Post-Project Reviews are debriefing sessions used to highlight lessons learnt during the course of a project. These reviews are important to capture knowledge about, causes of failures, how they were addressed, and the best practices identified in a project. This increases the effectiveness of learning as knowledge can be transferred to subsequent projects. However, if this technique is to be effectively utilised, adequate time should be allocated for those who were involved in a project to participate. It is also crucial for post-project review meetings to take place immediately after a project is completed as project participants may move or be transferred to other projects or organisations.
	Recruitment (Rt)	Recruitment is an easy way for knowledge buy-in. This is a tool for acquiring external tacit knowledge especially of experts. This approach adds new knowledge and expands the organisational knowledge base. Another benefit is that other members within the organisation can learn from the recruited member formally and informally so that some knowledge will be transferred and retained if the individual leaves the organisation. Some organisations also try to codify the recruited person's knowledge that is of critical importance to their business.
	Discussion Forums (DF)	As above
	Apprenticeship (Ap)	Apprenticeship is a form of training in a particular trade carried out mainly by practical experience or learning by doing (not through formal instruction). Apprentices often work with their masters and learn craftsmanship through observation, imitation, and practice. They focus on improving the skills of the individuals so that they can later perform tasks on their own. This process of skill building requires continuous practice by the apprentices until they reach the required level.
	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. The mentor provides a coaching role to facilitate the development of the trainee by identifying training needs and other development aspirations. This type of training usually consists of career objectives given to the trainee where the mentor checks if the objectives are achieved and provides feedback.
	Training (Tr)	Training helps in improving staff skills and therefore increasing their knowledge. Its implementation depends on plans and strategies developed by the organisation to ensure that employees' knowledge is continuously updated. Training usually takes a formal format and can be internal where seniors train juniors within the organisation or external where employees attend courses managed by professional organisations.

KM Sub-process	*KM Technique*	*Description of Technique*
Representing Knowledge	N/A	
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 (Ruggles, 1997). These groups are different from teams and task forces. People in CoPs can perform the same job or collaborate on a shared task (software developers) or work together on a product (engineers, marketers, and manufacturing specialists). They are peers in the execution of "real work." What holds them together is a common sense of purpose and a real need to know what each other knows. Usually, there are many communities of practice within a single company and most people normally belong to more than one.
	Face to Face Interaction (F-F)	As above
	Seminars (Sr)	Seminars are meetings for the exchange of ideas. These are discussion-based sessions in which presenters lead a small group of participants in a discussion about a defined topic. Usually, learners prepare before coming to the seminar by reading about the seminar topic. This preparation is solitary, and it may include active reading and text marking, preparing questions, etc.
	Discussion Forums (DF)	As above
	Apprenticeship (Ap)	As above
	Mentoring (Mn)	As above
	Training (Tr)	As above

KM Sub-process	*KM Technique*	*Description of Technique*
Creating New Knowledge	Brainstorming	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. The participants shout out ideas as they occur to them and then build on the ideas raised by others. All the ideas are noted down and are not criticized. Only when the brainstorming session is over are the ideas evaluated. Brainstorming helps in problem solving and in creating new knowledge from existing knowledge (Tsui 2002a & b). The following rules are important to brainstorm successfully: • A leader should take control of the session and keep it on course. Initially the problem to be solved is defined with any criteria that must be met. He or she should encourage an enthusiastic, uncritical attitude among brainstormers and encourage participation by all members of the team. The session should be announced as lasting a fixed length of time, and the leader should ensure that no train of thought is followed for too long. The leader should try to keep the brainstorming on subject, and should try to steer it towards the development of some practical solutions. • Participants in the brainstorming process should come from as wide a range of disciplines with as broad a range of experience as possible. This brings many more creative ideas to the session. • Brainstormers should be encouraged to have fun brainstorming, coming up with as many ideas as possible, from solidly practical ones to wildly impractical ones in an environment where creativity is welcomed. • Ideas must not be criticised or evaluated during the brainstorming session. Criticism introduces an element of risk for a group member in putting forward an idea. This stifles creativity and cripples the free running nature of a good brainstorming session. • Brainstormers should not only come up with new ideas in a brainstorming session, but also should 'spark off' from associations with other people's ideas and develop other people's ideas. • A record should be kept of the session either as comprehensive notes or a tape recording. This should be studied subsequently for evaluation. It can also be helpful to write down and explore the ideas on a board, which can be seen by all brainstormers.

Appendix A10

KM Dimensions and Supporting Techniques

Appendix A10: KM Dimensions and supporting Techniques

KM Sub-process	KM Technique	KM Dimensions											
		Conversion Types				Ownership Forms				Transfer Domains			
		Tacit to Tacit	Tacit to Explicit	Explicit to Tacit	Explicit to Explicit	Individual to Individual	Individual to Group	Group to Individual	Group to Group	Internal to Internal	Internal to External	External to Internal	External to External
Locating & Accessing Existing Knowledge	Face to Face Interaction	✓				✓				✓			
	Discussion Forums	✓							✓	✓	✓		
Capturing Existing Knowledge	Post-project review		✓				✓			✓			
	Recruitment	✓					✓					✓	
	Discussion Forums	✓							✓	✓	✓	✓	
	Apprenticeship	✓				✓				✓			
	Mentoring	✓				✓				✓			
	Training	✓				✓	✓			✓		✓	
Representing Knowledge	N/A												
Sharing Knowledge	Communities of Practice	✓							✓	✓			
	Face to Face Interaction	✓				✓				✓			
	Seminars	✓					✓		✓	✓	✓	✓	
	Discussion Forums	✓				✓				✓	✓	✓	
	Apprenticeship												
	Mentoring												
	Training												
Creating New Knowledge	Brainstorming		✓						✓	✓			

Appendix A11

Relating KM Techniques to Combinations of KM Dimensions

Appendix A11: Relating KM Techniques to Combinations of KM Dimensions

KM Dimensions				Required							
Transfer Domain				Internal				External			
Ownership Form				Individual		Group		Individual		Group	
Knowledge Typ				Tacit	Explicit	Tacit	Explicit	Tacit	Explicit	Tacit	Explicit
			KM Sub-process	KM Technique for KM Sub-processes							
Current	Internal	Individual	Tacit: Locate	F-F							
			Capture	Ap, Mn, Tr		Tr	PPR				
			Represent								
			Share	F-F, DF		Sr		DF		Sr	
			Create								
			Explicit: Locate								
			Capture								
			Represent								
			Share								
			Create								
		Group	Tacit: Locate			DF				DF	
			Capture			DF				DF	
			Represent								
			Share			CoPs, Sr				Sr	
			Create				Br				
			Explicit: Locate								
			Capture								
			Represent								
			Share								
			Create								
	External	Individual	Tacit: Locate								
			Capture	Tr		Rt, Tr					
			Represent								
			Share	Df		Sr					
			Create								
			Explicit: Locate								
			Capture								
			Represent								
			Share								
			Create								
		Group	Tacit: Locate								
			Capture			DF					
			Represent								
			Share			Sr					
			Create								
			Explicit: Locate								
			Capture								
			Represent								
			Share								
			Create								

ILLOGICAL COMBINATIONS

See Appendix A9 for meanings of abbreviation

Appendix A12

Questionnaire for Refining the IMPaKT Methodology and Prototype

Appendix A12: Questionnaire for Refining the IMPaKT Methodology and Prototype

A Prototype System for Knowledge Management Impact Assessment

The completion of this questionnaire should follow a demonstration on the prototype system.

Information about Participant

Date ________________
Company Name ____
Role carried out/position held (e.g. project manager, design consultant, engineer) ____________________
Area of experience (e.g. civil engineering, building, design, etc) ____________________
Experience in/with construction industry (years) ____________________

A: BUSINESS IMPROVEMENT STRATEGY SUB-SYSTEM

Please tick the box that best represents your response to a question.

(Larger scores reflect more positive response)

		Ranking				
		1	2	3	4	5
1	How easily does the system facilitate the formulation of a business improvement strategy?					
2	How well does the system facilitate the understanding of terminologies used?					
3	How easily does the system facilitate the determination of performance gaps?					
	a. Quantitative approach					
	b. Qualitative approach					

B: KM STRATEGIC PLAN SUB-SYSTEM

Please tick the box that best represents your response to a question.

KM PROBLEM CLARIFICATION AND RESPONSE

		Ranking				
		1	2	3	4	5
4	How easily does the system facilitate the identification of the KM sub-processes involved in a business problem?					
5	How well does the system help in identifying the most suitable KM tools for a KM sub-process?					
6	How helpful was the information obtained about the selected KM tools?					

KM ACTION PLAN

7	How well does the system help in developing a KM action plan?					
8	How useful were the sliders (in the action plan check list) in capturing the response from users?					
9	How clearly does the system state the actions to be taken?					
10	How helpful were the colours (traffic light system) in illustrating the importance of the actions to be taken?					

CAUSE-AND-EFFECT MAP

11	How well does the system support linking the KM initiatives to strategic objectives and performance measures?					
12	How simple was it to create a link or remove a link?					

C: KM EVALUATION STRATEGY SUB-SYSTEM

Please tick the box that best represents your response to a question.

		Ranking				
		1	2	3	4	5
	EFFECTIVENESS OF KM INITIATIVES					
13	How easily does the system enable identifying the likely contribution of a KM initiative to a performance measure?					
14	How easily does the system help in identifying the probability of success of a KM initiative?					

15 How can the system for determining the effectiveness be improved? (please answer below)

____

____

____

	EFFICIENCY OF THE KM INITIATIVES	1	2	3	4	5
16	How useful was the 'dynamic' guide for selecting an evaluation method?					
17	How well does the system present the Cost Checklist and Benefit/Utility Checklist?					

18 How can the system for determining the efficiency be improved? (please answer below)

____

____

____

	PRIORITISING KM INITIATIVES	1	2	3	4	5
19	How useful was the drag-and-drop method for prioritising the KM initiatives?					
20	How useful was the effectiveness-efficiency matrix?					

21 How can the system for prioritising the KM initiatives be improved? (please answer below)

____

____

____

D: GENERAL QUESTIONS ON THE SYSTEM

Please tick the box that best represents your response to a question.

		Ranking				
		1	2	3	4	5
	MANAGEMENT OF SYSTEM INTERACTION					
22	How attractive is the graphical user interface of the system?					
23	How easily can a user edit input?					
24	How useful were the dynamic links between the user inputs?					
25	How easy is it to navigate between the different stages within the system?					
26	How clear are the instructions for using the system?					
	EFFICIENCY					
27	How effective is the system in reducing duplication of input?					
28	How effective is the on-screen help in facilitating the use the system?					
29	How convinced are you that the system can be used by organisations?					
	OUTCOME					
30	How easily can the system's output be understood?					
31	How accurate was the system's output compared to what was expected?					
	GENERAL					
32	How useful was the approach used in the system?					
33	How confident are you with computers (generally)					
34	What is your overall rating of the system?					

In what ways can the **Business Improvement Strategy Sub-system** be improved?

In what ways can the **KM Strategic Plan Sub-system** be improved?

In what ways can the **KM Evaluation Strategy Sub-system** be improved?

Appendix A13

Evaluation Questionnaire

Appendix A13: Evaluation Questionnaire

A Prototype System Developing and Implementing Knowledge Management Strategies

Using CLEVER and IMPaKT Prototype Systems for Structural Design Knowledge

The completion of this questionnaire should follow a demonstration on the prototype system.

A. Information about Participant

Date ______________

Company Name ____

Role carried out/position held ____________________

Experience in structural design (years) ________________

B. The CLEVER Prototype

Please tick the box that best represents your response to a question.

(Larger scores reflect more positive response)

KM PROBLEM AND GOALS IDENTIFICATION

		Rating Poor 1	2	3	4	Excellent 5
1	How well does the system clarify problems of structural design knowledge?					
2	How relevant to structural design are the knowledge characteristics used in the system?					
3	How well does the system relate structural design knowledge to organisational business drivers?					
4	How well does the system help in identifying the organisational goals for managing structural design knowledge?					

KM STRATEGY DEVELOPMENT

		1	2	3	4	5
5	How well does the system help in developing a KM strategy for sharing structural design knowledge?					
6	How well does the system help in identifying the sources of knowledge?					
7	How well does the system help in identifying the users of knowledge?					

GENERAL

		1	2	3	4	5
8	How appropriate is the system for structural design departments/divisions?					
9	What is your overall rating of the system?					

C. The IMPaKT Prototype

KM STRATEGY DEVELOPMENT

		1	2	3	4	5
10	How well does the system help in developing a KM strategy for sharing structural design knowledge?					
11	How well does the system identify the tools required for managing structural design knowledge?					
12	How well does the system help in developing an action plan for implementation?					
13	How well does the system relate the KM initiatives to strategic objectives and performance measures (cause-and-effect map)?					

KM STRATEGY EVALUATION

		1	2	3	4	5
14	How useful do you think the system will be in evaluating a KM strategy before implementation?					
15	How useful do you think the system will be in evaluating a KM initiative after implementation?					
16	How well does the system help in prioritising KM initiatives?					

GENERAL

		1	2	3	4	5
17	How appropriate is the system for structural design firms/departments/divisions?					
18	What is your overall rating of the system?					

In what ways can the CLEVER prototype be improved?

In what ways can the IMPaKT prototype be improved?

Further comments (please use back of sheet if required)