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Knowledge-based Customization of Enterprise Systems for Business Process Improvement

by

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

The rapid change of the business environment has had a dramatic effect on the organization and the information infrastructure of enterprises. Many companies are attempting to implement business process improvement (BPI) projects and streamline the business processes to realize cost reduction, quality improvement, and the ability to respond faster to business problems and opportunities. Many managers recognize the advantages of the adoption of new business processes but they may worry about the influences, benefits and drawbacks after the implementation of the new processes or systems in their company. Moreover, it requires a long and tedious implementation that usually involves many people, considerable time, and it is trial-and-error in nature. In addition, the selection and customization of the new applications and technologies is often not easy because there are many software packages available in the market. However, most of them are too complicated and only a small part of the functions in the software package is suitable for direct adoption. Therefore, the new system may not integrate well with the existing system or it may not fit into the current practice of the company.

In this thesis, the knowledge-based approach is proposed for managing, storing, retrieving and distributing the valuable experience of past BPI projects in the consultancy companies. The knowledge involves planning, integrating and configuring different components of an enterprise system. Such knowledge needs to be continuously updated and made readily accessible to other users. Based on the knowledge-based approach, the consultancy companies tend to adopt the strategy of "Sharing existing knowledge better". A knowledge-based customization system (KBCS) is proposed to enhance the business process in an enterprise. The KBCS is built based on knowledge-based system architecture and incorporates various artificial intelligence (AI) technologies such as a rule-based expert system and case-based reasoning (CBR). Three modules are included in the KBCS: the Business Analysis Module (BAM), the Process Improvement Module (PIM) and the Customization Module (CM). The system allows the capture of the valuable experience and tacit knowledge involved in planning, integrating and configuring different components of an enterprise system. Therefore, the companies can generically and rapidly develop the new business processes and customize the enterprise systems which best fit the current practice and business flow of the company.

In order to verify the suggested methodology, a case study was done in Kaz (Far East) Limited (formerly Honeywell Consumer Products (HK) Ltd.) so as to validate the performance of KBCS. The results show that the KBCS can generate a BPI solution as well as the detailed configuration of the components for the implementation of the scan-based warehouse management system for the company. It significantly reduces the time for the design and implementation of the whole project as compared with the traditional BPI method. With the successful development of the platform, it is believed that the time, the cost and the risk for developing a complex enterprise system can be significantly reduced. As a result, a total solution can be determined for the company based on their strategic objectives and existing resources. All potential problems and conflicts can also be predicted without the need for conducting an expensive trial implementation.

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1.1 Background of Study

Today's business environment involves rapid changes in the organization and the information infrastructure of the company. Changes are being driven by technology, by globalization of business activities, by rapidly changing markets, and by intense competition, as well as by re-organization such as consolidations, divestitures, and mergers (Cummins, 2002). For example, the business environment is becoming more complex with the rapid development of technology and the increasing importance of the World Wide Web (WWW) as well as the increase in electronic commerce (Fitzgerald & Siddiqui, 2002). Therefore, many companies attempt to apply new management strategies, redesign their business processes or adopt the new technologies to obtain the huge performance payoffs of operating better, faster and more efficiently (Drago and Geisler, 1997).

Most small and medium sized enterprises (SMEs) lack a fully integrated enterprise system to handle complex business processes from ordering management, manufacturing, down to logistics management. Many manufacturing enterprises are still not familiar with the use of IT techniques to improve their business (Lee, Lau, Cheung & Choy, 2003). They usually operate under various constraints of technical, financial and human resources. The adoption of new technology or new workflow is paramount to improvement in the organization. It is not only necessary to streamline processes and to integrate separate business functions into seamless processes, but also to keep these processes so flexible that they can be swiftly adapted to the changing situations.

Many managers recognize the advantages of adoption of new business processes but they don’t fully understand how to employ the new workflow or new technology effectively. On the other hand, many technical workers understand the details of various technologies but they don’t have the management perspective to provide the solutions which are aligned with the company’s business objectives. They may seek external help from some experts or consultant companies with the necessary IT experience (Jarrar & Aspinwall, 1999).

Business Process Improvement (BPI) is critical to many organizations because the existing processes of some firms were never formally designed, but evolved with time. Therefore, the critical administrative business processes need to be analyzed in order to improve the performance of the organization in areas such as cost, quality, service and performance. In addition, the business processes can cut across the functional sectors of an organization, and the information processing is organized along these functional sectors. Supporting and automating various business information processes within an organization requires the integration of various enterprise applications (Daum & Scheller, 2000).

However, many organizations fail in the BPI or can’t obtain the expected benefits (Sarkis & Talluri, 2002; Launonen & Kess, 2002; Jarrar & Aspinwall, 1999; Drago & Geisler, 1997). The change of the existing processes is painful, risky and not easy to justify using the traditional cost/benefit analysis (Paper, 1998). In most cases, business processes are tightly coupled to computer applications. Although humans manage much of the work, computer systems are designed to support the existing processes and organization structure. When the business processes are changed, associated changes are usually required for the computer systems. These changes are often more complex and difficult to implement then they appear on the surface (Cummins, 2002).

Many organizations found that the selection of the suitable technology, hardware and software is a very critical, challenging and time-consuming task. Although excessive numbers of hardware and software packages for particular enterprises are available in the market, such as various Enterprise Resource Planning (ERP) systems and Product Data Management (PDM), most of them involve expensive investment and maintenance costs. This is particularly true for large and complex systems that are developed for multi-national and large corporations (such as Winchill, Oracle, SAP, etc). The structure of the system and syntax of the programming language are usually too complex to use. A series of training courses have to be held for training the staff in the organization.

Therefore, it is not easy for an organization to adopt the most suitable technology and components at the minimum investment cost without the external help from experts or consultant companies. The result is that changes in business processes require a long and tedious implementation that involves many people, considerable time, and usually trial-and-error solutions.

It is necessary to develop a new business modeling tool that can help the experts in the consultancy companies to accumulate and reuse the successful experience of the past BPI projects. The enterprises will benefit from the tool with better knowledge on previous cases. In general, changes to systems and processes should not need to start from scratch. The previous experience can be applied in a similar BPI project to reduce the life cycle of the projects and increase the success rate of the projects. By referring to similar successful projects and the simulation of a proposed solution can help both the client company and consultancy firm to discuss and formulate the most suitable BPI solution for the client company. In this way, the error and risks can be minimized before the implementation of the BPI project. The objectives of this project are to combine the management and technical perspectives on the improvement of business processes. An integrated system is proposed for the retention and reuse of the knowledge in the previous BPI projects so as to rapidly and generically select and customize the enterprise systems based on the business objectives and the business process flow of an organization.

1.2 Research Objectives

The knowledge-based methodology applied to improve the business process has attracted a lot of research attention in recent years. For example, Ku *et al.* (1996) have suggested the adoption of a case-based reasoning (CBR) approach to extract reusable knowledge for the new project in business process improvement. However, most of the previous research work focuses on the recommendation of the redesigned process modeling without the detailed configurations of the hardware and software for the implementation of the proposed new model. For example, the CAPMOSS proposed by Kim *et al*. (2000). Relatively little research work has been found for the development of an integrated system for the customization of enterprise applications based on the reuse of existing knowledge.

As a result, the objectives of the project are:

(i) To study business process improvement, artificial intelligence and enterprise systems development.

(ii) Hence, to develop a knowledge-based customization system (KBCS) for the customization of enterprise systems,

(iii) To verify the performance of the KBCS through a trial implementation in a selected reference site.

The key contribution of this thesis is to establish a knowledge-based approach for reusing and distributing the valuable experience in the consultancy companies. Based on this approach, the consultancy companies can adopt the strategy of “Sharing existing knowledge better”. A prototype KBCS is developed to prove the concept of the proposed approach.

1.3 Research Methodology

The research methodology covers the design of a knowledge-based system (KBS) for dealing with the selection and customization of the enterprise systems. In the first phase of this research, a literature review is done in order to understand the existing problems during the business process improvement and the customization of the enterprise systems. Different BPI approaches and various AI techniques are reviewed in this stage. Then, the concept of the knowledge-based approach is developed for the BPI project. A prototype knowledge-based customization system (KBCS) is developed based on the proposed framework. It integrates the knowledge management, simulation and different AI techniques for capturing the valuable experience and tacit knowledge of the BPI projects. The planning, integrating and configuring of different components of an enterprise application are included. This system allows the consultancy companies and experts to accumulate and reuse the organizational knowledge to generically and rapidly customize the enterprise applications for the client companies.

A case repository is built with previous industrial projects conducted in The Hong Kong Polytechnic University Microsoft Enterprise Systems Center (MESC). The center has the most advanced facilities for supporting projects and interaction with many communities. A number of successful research and industrial projects have been conducted with the collaboration of various enterprises. Some cases are codified and the knowledge repository is built for providing solutions for the industries. An Industrial case study was carried out in the Kaz (Far East) Limited (formerly Honeywell Consumer Products (HK) Ltd.) to evaluate the performance and reliability of the system. The results are then discussed.

1.4 Thesis Layout

Chapter 1 is the introduction of the background to the research, followed by defining the research objectives and methodology of the study. In the second chapter of this thesis, a literature review of the existing problems and current practices of the BPI is carried out. The knowledge management (KM) and various AI technologies, such as the knowledge-based system, expert system and CBR are introduced. Chapter 3 addresses the proposed knowledge-based approach for the BPI. A comparison between the traditional and knowledge-based approach for BPI is explained. Chapter 4 explains the system design and the implementation of the knowledge-based customization system (KBCS). The architecture of the system and various modules are explained. An industrial case study and the findings are discussed in Chapter 5. Finally, the conclusion and suggestions for further work are presented in Chapter 6 and 7 respectively.

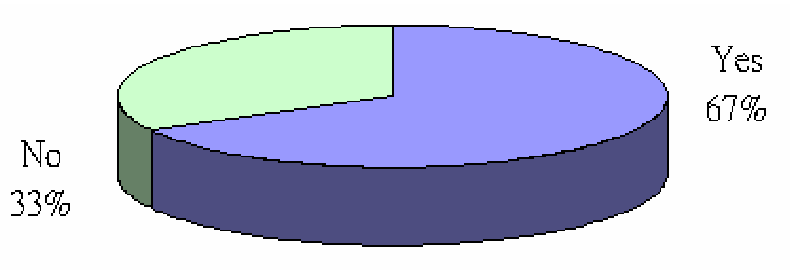
Chapter 2 Literature Review

2.1 Introduction

The business environment becomes more complex with the rapid development of technology and the increase in importance of the World Wide Web (WWW) as well as in electronic commerce (Fitzgerald & Siddiqui, 2002). In order to align with and collaborate with business partners and customers, many organizations invest in the new system, hardware and business process.

For example, with the standard web browsers nowadays, the Internet brings ubiquitous connectivity, real-time access, and a simple universal interface to interact with their customers and business partners. Many traditional enterprises are transforming themselves into e-businesses by the way they carry out their business processes to take full advantage of the capabilities of the Internet. Figure 2.1 shows two-third of the 230 companies that engaged in BPI or redesign efforts in 2001 believe that their efforts are being driven by e-business projects (Harmon, 2003). The Internet allows an enterprise to communicate instantly with customers, suppliers and partners. It changes the way information can move across enterprises, the way business transactions are carried out, and the way relationships are nurtured and maintained.

In recently years, BPI has introduced in order to provide an effective and comprehensive means to improve a company's performance (Lee & Chuah, 2001; Flanigan & Scott, 1995; Zairi, 1997; Tenner & DeToro, 1997). BPI is a structured approach to analyze and continually improve fundamental activities of a company's operation by simplifying and streamlining business processes (Lee & Chuah, 2001). It leads to the efficient and effective use of resources such as facilities, people, equipment, time and capital (Zairi, 1997). It also increases the competitive power of the organization such as the higher customer expectations, new technologies, increased marketing dynamics and rapidly growing competition at the international level (Marjanovic, 2000; Drago & Geisler, 1997).



Sample:
230 companies

Figure 2.1 Companies that indicated that their business process change efforts were being largely driven by the Internet and the need to implement e-business systems. (Harmon, 2003)

In this chapter, the importance and challenges of the traditional approach to BPI are reviewed. The recent research work in BPI is also highlighted and the impact of the new approaches such as the knowledge-based approach and various artificial intelligence (AI) technologies for supporting the decision making is discussed. Finally, the challenges in the supply chain management (SCM) and various problems are discussed.

2.2 Evolution of Business Process Improvement

Hammer and Champy (1993) stated that the business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. In recent research, Launonen and Kess (2002) defined the business process as a structured measured set of activities and flows that use necessary resources to provide specified product or services for a particular customer. Pankowska and Sroka (2002) defined a process as a flow of activities that produces an output of value to the recipient. Each process can be viewed as an exchange of services embedded in a recipient-supplier relationship. The recipient (customer, client, patient, etc.) requests the desired output whereas the supplier performs the process. The process activities are the means to transform the process input (material, information, etc.) into the desired output. During its performance the process changes states, which are triggered by events. The process flow is determined by business rules (conditions).

For the improvement of the business processes, there is a large amount of literature and empirical research from both academics and business consultants. From the earlier literature, Hammer and Champy (1993) define business process re-engineering (BPR) as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service and speed". As Caudle (1995) explained, process improvement can include:

(i) continuous business process improvement that incrementally improves the operation, efficiency, or

(ii) total re-engineering from a clean sheet to achieve maximum effectiveness during a short timeframe.

Some processes may only need incremental improvement in critical areas while others may require a sudden change or total revamp through process re-engineering, or some may even need a combination of both.

In recent literature, there are many theories about the improving, redesigning and automating of the business process, such as business process re-engineering (BPR), business process improvement (BPI) (Flanigan & Scott, 1995), continuous process improvement (CPI), business process change (Harmon, 2003), etc.

According to Lee and Chuah (2001), there are three aspects of BPI strategies and activities commonly being adopted by today's organizations. They are CPI, BPR and business process benchmarking (BPB). According to Harmon (2003), the business process improvement / re-engineering projects can be distinguished by the following descriptions. Figure 2.2 shows an overview of the three major terms to describe the business process change projects. If the process is relatively stable and the goal is to introduce incremental improvements, then the preferred term is **process improvement**. If the process is very large and redesigning of the process is sought in a comprehensive manner, then the term **process re-engineering** will be used. The key distinction is between improvement, which essentially relies on a problem-solving approach, and re-engineering, which relies on re-conceptualizing how a business process should work.

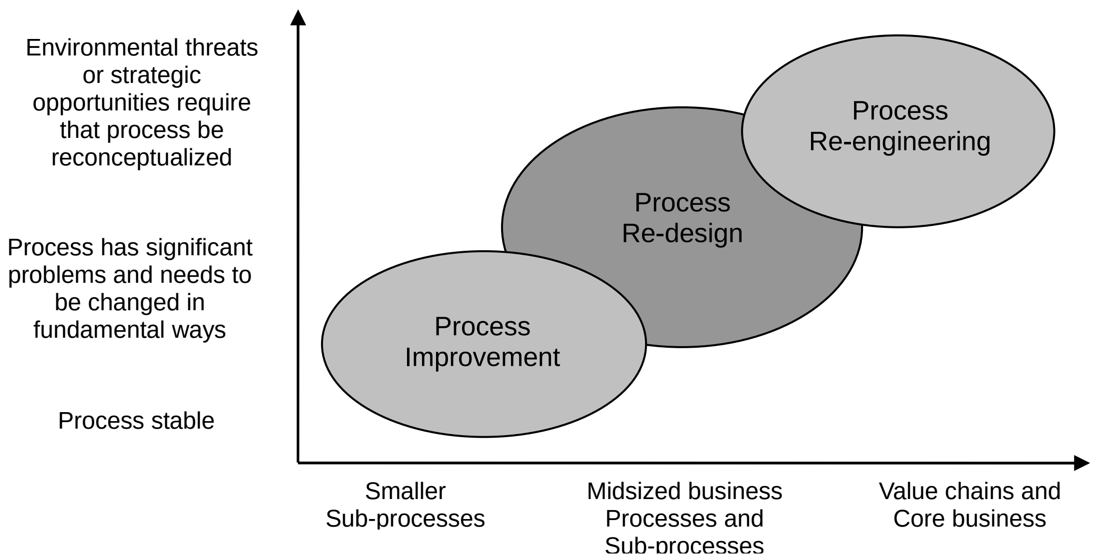


Figure 2.2 Process improvement, process redesign and process reengineering (Harmon, 2003)

2.2.1 Importance of Business Process Improvement

Several organizations in the 1990s faced ever-increasing uncertainty and unprecedented volatility in their external environment. For example, the rapid development of Information technology (IT) can allow the organization to enjoy the benefits of centralization of information and the information is available to individuals throughout the organization so these individuals can make the right decisions (Drago & Geisler, 1997). Moreover, the existing processes in some organizations were never formally designed, but evolved through time. Improvement or redesigning of the business processes is necessary for improving the organization’s performance in such areas as cost, quality, and service. These systems are frequently in urgent need of replacement to adapt to the changing environment of the new business model (Bevington, 2000). The reasons are listed as follows:

(i) The systems are inflexible and severely limit the ability of the business to enter new markets, develop new products and transform themselves in various ways that are appropriate to the environment in which they now find themselves.

(ii) The systems are difficult to maintain and the maintenance cost is too high.

(iii) The systems are based on obsolete technology and can not easily exploit new technology, such as graphical user interfaces and the Internet.

To cope with these environmental changes and uncertainties, organizational changes have been incorporated effectively. The emergence of BPI has enhanced the organizational effectiveness in a competitive environment (Kim *et al.,* 2000). BPI is important within any organization (Wiig, 1995). It is critical to an organization’s long term survival and well being. BPI is simply a method of improving the way a discrete set of business activities is organized and managed. It is a structured approach to analyze and continually improve fundamental activities of a company's operation by simplifying and streamlining business processes (Lee & Chuah, 2001).

Since the early 1990s, there has been an organizational race to implement business process re-engineering. In 2001, a survey was carried out of 230 organizations located throughout the world to determine what they were doing about changes in their business processes (Harmon, 2003). Figure 2.3 shows 49% of the companies, in the mid-1990s, indicated that they had been active in business process redesign. Figure 2.4 shows 83% of the companies said that they had business process projects underway in 2001. In response to another question, they indicated that they expected they would be more active in the next few years.

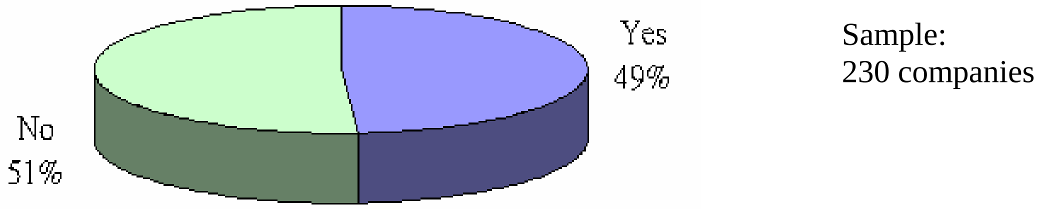


Figure 2.3 Companies active in BPR in the mid-1990s (Harmon, 2003)

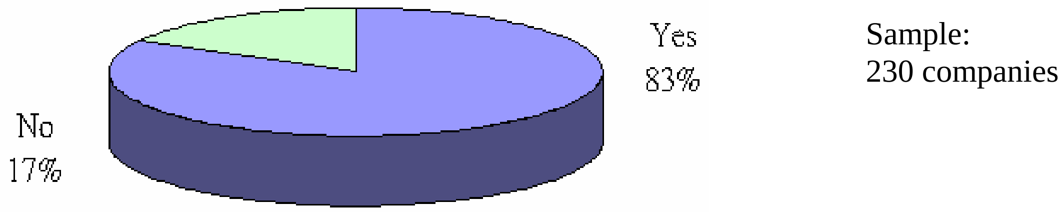


Figure 2.4 Companies engaged in business process improvement or redesign in 2001 (Harmon, 2003)

The goals of BPI are to achieve extensive improvements – in cost, service, quality, use of resources, creation of new capabilities (such as new expertise), constancy, and other factors. Goals can be identified as:

(i) *Short-term improvements* that may be obtained quickly and relatively easily without radical or comprehensive redesign of the business process; or

(ii) *Longer-term improvements* that require substantial and potentially comprehensive and innovative redesign to provide substantial benefits that serve the organization for the foreseeable future.

According to Harrington (1991), the three main purposes of BPI are considered to make business processes effective, efficient, and flexible:

- *making processes effective* – producing the desired results.
- *making processes efficient* – minimizing the resources used.
- *making processes adaptable* – being able to meet changing customer and business needs

2.2.2 Traditional Approaches for Business Process Improvement

In the traditional way, most companies use an experienced facilitator to actually manage the BPI project. The facilitator might come from a BPI group inside the company, or he/she could be an outside consultant. In either case, the facilitator probably has his or her own specific approach to the BPI projects.

Consultancy companies or universities are one of the modern professional service organizations for providing solutions for the BPI. They are knowledge-intensive companies which provide professional knowledge, experience and know-how so as to offer expert advice to their customers. Their large amounts of experience, information and knowledge are their most important assets.

One of the challenges of the consultancy companies is to provide the most suitable BPI solution and to deliver this solution to the customer in a timely manner. In most cases, the efficiency and effectiveness of new solutions have become the benchmark for consulting performance.

Another challenge for these expert consultancy organizations is that they hold very complicated knowledge and this knowledge resides in the heads of their highly-trained, experienced and knowledgeable experts. The high turnover rate of these professionals makes it difficult for companies to maintain and reuse such knowledge if they leave the company. There are many BPI approaches stated by different research outputs (Harmon, 2003; Lee & Chuah, 2001; Lientz & Rea, 1999; Yu & Wright, 1997; Earl *et al*., 1995; Edwards & Peppard, 1994; Davenport, 1993). Figure 2.5 shows the SUPER methodology which is a simple and logical improvement guideline based on 15 key steps. There are 5 main phases which are commonly used in most traditional BPI approaches.

(i) Stage one: Selection of critical process to be changed

The purpose of this stage is to investigate and select the problematic processes that are critical to and essential for the company. The selection of the right process or processes to be changed acts as a target to pinpoint the direction of the improvement program. This stage includes:

- Identifying goals
- Defining scope
- Identifying personnel
- Developing plan and schedule

(ii) Stage two: Understanding and analyzing the process

In this stage, the process architecture/flow is analyzed by the consultancy team. The main activity in this stage is to identify and clearly map out the process tasks and sub-tasks and their important inter-relationships. Problems or process weaknesses may be found in specific processes or sub-processes. Process mapping (Lee and Chuah, 2001) is an effective way to chart the process sequence of each task (AS-IS model).

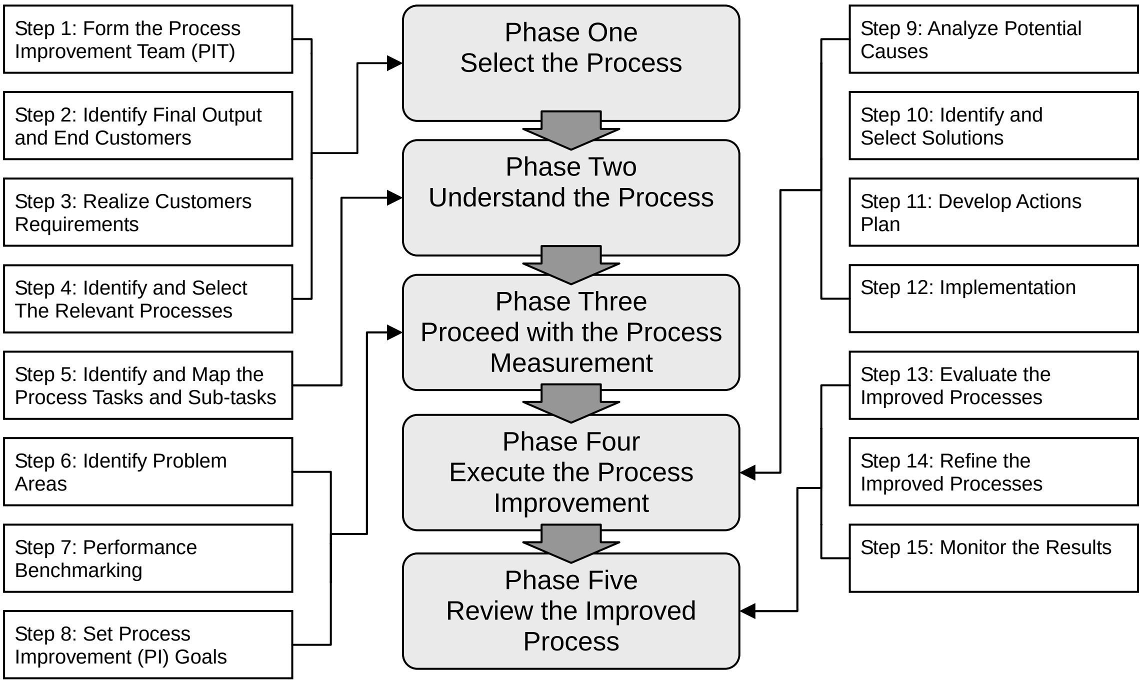


Figure 2.5 A SUPER Methodology for BPI (Lee & Chuah, 2001)

(iii) Stage three: Redesigning the business process

Once the analysis is completed, the experts consider various redesign options and select the most appropriated one. After the redesign is approved, a development plan is created that requires efforts from everyone involved in creating products necessary for the process change. They next:

- Explore alternatives and choose best redesign that achieves the goals
- Define requirements for the development phase

(iv) Stage four: Execute the process improvement

Actually, there is more than one possible solution for the process improvement. The cause and effect diagram (also known as the fishbone diagram) is one of the tools used to identify all potential causes that are contributing to the problem. The selection of the suitable solution depends on the assessment of the company's capacity as well as the estimated return due to the changes. After that, a comprehensive action plan should be developed that shows clearly the key implementation steps, dates, costs, and staff prior to the change of the processes.

(v) Stage five: Review and follow up after the implementation

The purpose of this stage is to monitor and evaluate the improvement results and ascertain whether the operation performance of the problematic processes have achieved the desired state. This is post implementation work that supports measurement and often identifies where the effort should be directed next.

2.2.3 Recent Research on Business Process-improvement

Many business process re-engineering (BPR) methodologies and variations have been proposed by both academics and practitioners, but a close look at the concept of BPR emerged from observing the practices of highly successful organizations in the 1980s and early 1990s (Jarrar & Aspinwall, 1999).

In the recent research (Ku *et al.*, 1996), the knowledge-based methodology applied in the BPI to provide decision support is developed. Redesigning the business process or developing a new process from the previous one can use heuristic knowledge that has been learned from similar projects. Therefore, Ku *et al.* (1996) has suggested the adoption of a case-based reasoning (CBR) approach to retrieve similar BPR projects that can bear upon the current process. For example, when the BPR team develops a redesigned process model for a target business process, they often find a similar business process and apply the best practices in the BPR project to it, and then repair it appropriately to meet the objectives of the target process.

A case-based process modeling support system, CAPMOSS (Kim *et al*., 2000), is developed for enhancing the methodology for process modeling, and to facilitate the BPR process using CBR as a reasoning mechanism. It consists of five main modules and a case base for storing prior BPR cases. Compared with other traditional supports for BPR, this system focuses on the development of process models, the AS-IS model (the current processes) and the TO-BE model (the redesigned processes) in using an event process chain (EPC) diagram. The EPC diagram represents the organization's critical business processes over both geographical as well as dynamic time dimensions and exclusively from the customer's perspective.

The aim of the system is to reuse the past experience of the BPI project cases by adopting the best-fit case that is similar to the current situation. Then, the redesigned business process model is developed by the system even if the user has little experience of process modeling. It is also possible to use a part of the best-fit case of a problem instead of using the entire case. By this approach, the project costs and risks can be reduced.

However, there are some limitations for the CAPMOSS approach and they have to be solved. Firstly, it is necessary to gather many real BPI cases in order to have a powerful application system. Secondly, the scoring method for retrieving the best cases in this approach is simple. It can be improved by using other similarity algorithms such as the weighted sum.

2.2.4 Challenges for the Design and Implementation of BPI

Many organizations fail in the BPI projects or can't obtain the expected benefits (Sarkis & Talluri, 2002; Launonen & Kess, 2002; Drago & Geisler, 1997; Jarrar & Aspinwall, 1999). The success rate of the development of the system for the BPI project is very low. By the estimates, between a quarter to half of all application development projects in the construction industry end in failure (Davenport & Stoddard, 1994; Pena-Mora, Vadhavkar & Dirisala, 2001). Many executive reports show that the system can not be used operationally after the investment of the money and time. Also, the process improvement projects usually have unintended side effects, creating new problems instead of solving the old ones (Marjanovic, 2000).

One of the major reasons for the failure of the BPI is because the project is designed by considering the components first. From the recent research (Pohthong & Budgen, 2001), the BPI can be designed based on two approaches, an internally driven approach (framework first strategy) or the externally driven approach (element first strategy).

(i) *Internally driven approach*: The BPI project is designed based on the remedy for the business challenges or development of the competitive advantages of the organization. The planning is produced and then the technologies and components are sought for fitting the proposed project.

(ii) *Externally driven approach*: The designer begins by identifying likely technologies and components from the commercial market that are candidates for reuse in solving their problem, and then the project is constructed as the solution around these.

The BPI project that is based on the external driven approach leads to the unsuitable adoption of the commercial software. Nowadays, many enterprise commercial software are packaged into different modules which cover different business functions. However, in most situations, these modules are too bulky for the organization. The software package is purchased and implemented in the organization by inexperienced engineers, but only part of the functions is actually used for their daily business operation. The complexities of the commercial software not only increase the investment cost of the BPI project, but also complicate the business operations. Mostly, the simple but customizable software are suitable for the small and medium enterprises (SMEs).

Another reason for the failure of BPI is the development of a process improvement plan without relating it to the strategic issues being faced by the business. BPI projects should be linked to strategic goals and objectives of the organization (Sarkis & Talluri, 2002). Also, employees in the organization should have opportunities to participate in the design of the process improvement project. They are the people who best understand the problems of the existing processes and may have some suggestions for their improvement. Furthermore, their involvement is likely to reduce their resistance to change (Marjanovic, 2000).

Different skills of the staffs in the organization are pre-requested in the development stage of the process improvement project. Business skills are required to understand the target and objectives of the project. Technology skills are needed to perform the tasks. Function skills are needed in the implementation of BPI. They are problem solving, initiative, communication and interpersonal skills in the teamwork (Launonen & Kess, 2002). The project generally requires more highly skilled employees and greater empowerment to those employees. Unfortunately, managers are not always willing or able to change their attitudes towards employees and their overall management styles to fulfill the paradigm shift (Drago & Geisler, 1997).

Many organizations also found that choosing the suitable technology, hardware and software proved to be a very critical and time-consuming task. The selection of the hardware and software not only depended on the investment cost, but also has to consider the difficulties of the integration of the new technology and components with the existing business flow. Many BPI projects are postponed or canceled during the actual implementation stages because of the difficulties of the adoption of the new system. Therefore, they may seek external help from some experts with the information technology (IT) and BPI experience (Jarrar & Aspinwall, 1999).

The knowledge and the experience of the BPI projects are not managed by systematic methods. The information and knowledge for the BPI projects exist in the form of context knowledge or experience of the expert. The development experience and decision making of system design are stored in forms such as design notebooks, minutes of design reviews or inside the software engineering’s memory. Without a systematic knowledge management approach, the knowledge becomes implicit and is often forgotten until time of reuse. Consequently, it is difficult to recover and reuse this vital knowledge.

2.2.5 Business Process Modeling

Business process modeling (BPM) approaches (Kueng *et al.*, 1996) were emphasized from various perspectives by researchers and practitioners during the last few years. This is essential with a business process reengineering life cycle. The BPM plays mainly two important roles:

(i) To capture of the existing processes by structurally representing their activities and related elements; and

(ii) To represent new processes in order to evaluate their performance.

In addition to the above two functions, a BPM method can possess the analysis capability in facilitating process evaluation and alternative selection. Due to the progress of information technology, computer simulation is applicable to serve these purposes.

There are also many BPM approaches (Kueng *et al.*, 1996) which can be divided into four categories as shown in the following:

(i) *Activity-oriented approaches* tend to define a business process as a specific ordering of activities (sometimes referred to as tasks). They generally offer good support in refining process models. However, this mechanistic view may fail to represent the true complexity of work and, in turn, fail to implement new business processes.

(ii) *Object-oriented approaches* are associated with object orientation, such as encapsulation, inheritance, and specialization. The principles of object orientation are applicable to business process modeling. However, practitioners, such as process owners and team members, tend to describe their work by activities rather than by objects.

(iii) *Role-oriented approaches* suggest that a role be involved in a set of activities, and carry out particular responsibilities (Ould, 1995). A group of primitive activities can be assigned to a particular role (i.e. actor or agent). However, they are not suitable to express an intricate sequencing logic.

(iv) *Speech-act oriented approaches*, based on speech act theory under language/action perspective, view the communication process as four-phased loop: proposal, agreement, performance, and satisfaction (Medina-Mora *et al*., 1992). Although business cases can be viewed as a communication between customers and performers, this modeling approach does not provide much help in analyzing existing processes or creating new processes.

2.2.6 Business Process Analysis and Modeling (BPA/M) Tools

Many BPR software tools are available on the market (Wright and Burns, 1996). The BPR software is a category of business software that captures the key elements of real-world business processes by representing them through software objects that allow us to model the process, analyze it, redesign it and structure it for workflow implementation and information systems design.

Each type of process element, such as process, task, input/output, is represented by a software object that has different attributes and a particular graphical shape when it appears on the computer screen. The software allows the users to draw and redraw complex processes easily. It also allows users to link resources that perform work (people, machines, software) with various tasks in a business process where they are used. BPR software does process performance calculations under different conditions and enables users to see the effects of many what-if questions as they rethink and change the design of a process.

The tools can be classified by the facilitating BPR project life-cycle, and by purpose. Project life cycle tools include strategic initialization with direction identification and opportunity searching; implementation with "as-to-be" model building, and exploitation with further improvement. The purpose of the tools includes (Klein, 1994): project management; co-ordination; modeling; business process analysis; human resource analysis; and systems development. (Yu & Wright, 1997)

There are six categories of BPR tools which are described by Klein (1994)

(i) Project management, e.g. Microsoft Project

(ii) Co-ordination, e.g. Microsoft Excel, Lotus and e-mail

(iii) Modeling, e.g. Computer Aided Software Engineering (CASE) tools such as Popkin System Architect

(iv) Analysis, e.g. the same tools as used for modeling

(v) Human resource allocation and design, e.g. assessment, teambuilding and organization charting (CorelDRAW)

(vi) Systems development, e.g. Visual C ++, and Borland Delphi

Packaged application vendors are also providing tools to assist their customers in BPI projects. For example, ProcessModel (www.processmodel.com) is one of the process analysis and modeling tools on the market. By using the software, the companies can document their existing business processes by creating a process map, typically in the form of a flowchart. Data about how the process operates will be added and it allows a more rigorous analysis of potential problem. Then, it combines the process map and data to create a 'model' that is used to identify problems within the process. The model has two diagnostic tools – an animation of the processes in action and a statistical report.

Figure 2.6 shows the process map of the final assembly line in a bicycle manufacturing plant. The flowchart shows the assembly processes of the combination of the bicycle frame with the wheels, pedals, seat, etc. Then, the data of the process is added to the process map, such as the processing time of each station, transportation between the stations, etc. Finally, the bottleneck of the process can be found by the analysis of the production cycle time, production cost, line balancing, resource usage, etc.

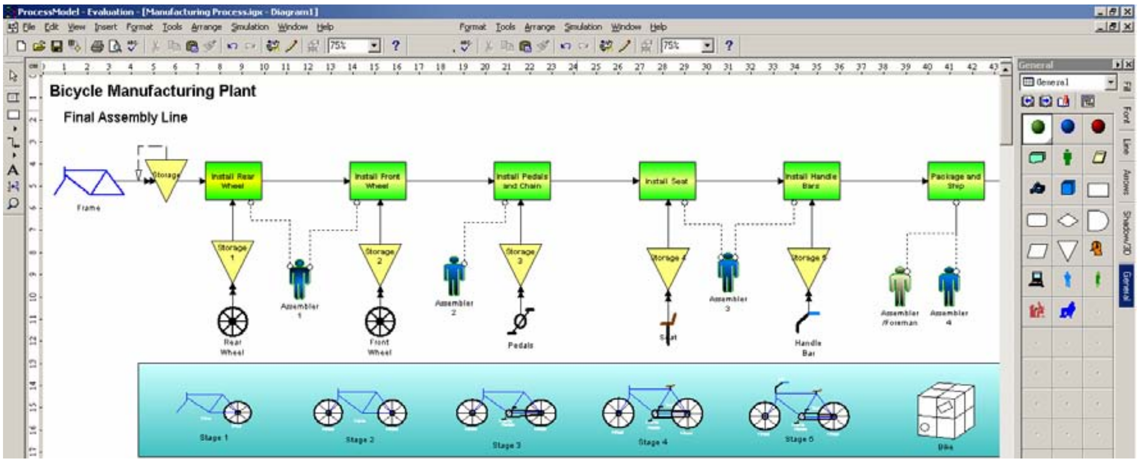


Figure 2.6 Process map of the final assembly line in a bicycle manufacturing plant in ProcessModel

2.3 Overviews of Knowledge Management

Knowledge management (KM) has been practiced since ancient times. Oral traditions were passed from generation to generation. When writing was invented, oral traditions were written down and codified into histories, stories, rules and laws. Libraries stored tablets, then scrolls, and then books, which contained the important knowledge of the times.

Nowadays, KM is a process that helps organizations identify, select, organize, disseminate and transfer important information and expertise that are part of the organizational memory that typically resides within the organization in an unstructured manner. This enables effective and efficient problem solving, dynamic learning, strategic planning and decision making. It focuses on identifying knowledge, explicating it in a way so that it can be shared in a formal manner and then reusing it.

Knowledge management is multi-disciplinary and draws on aspects of science, interpersonal communication, organizational learning, cognitive science, motivation, training and business process analysis. It is more a methodology applied to business practices than a technology or product. KM has been considered as a discipline that encompasses processes and techniques for the creation, collection, indexing, organization, distribution, access to and evaluation of institutional knowledge for improvement of performance, and more generally, for the exploitation of intellectual capital, including reuse opportunities (Tsui, Garner & Stabb, 2000).

Obviously, it is important to examine what knowledge can be managed in the organization. According to the knowledge cycle (Beijerse, 2000), as shown in Figure 2.7, within the organization, one first looks from a strategically driven viewpoint to determine which the necessary knowledge is, then one looks to see what knowledge is available and based on this, the knowledge gap is determined. One closes this gap by developing knowledge and, if that is not possible, by acquiring knowledge, after which the developed and acquired knowledge are locked within the organization. These three processes are mainly linked to the structure and the systems. The knowledge is then shared and utilized; processes that are largely dependent on the company culture. Finally, the (utilized) knowledge is evaluated – often with a certain strategic vision – with which the process can be started again from the beginning.

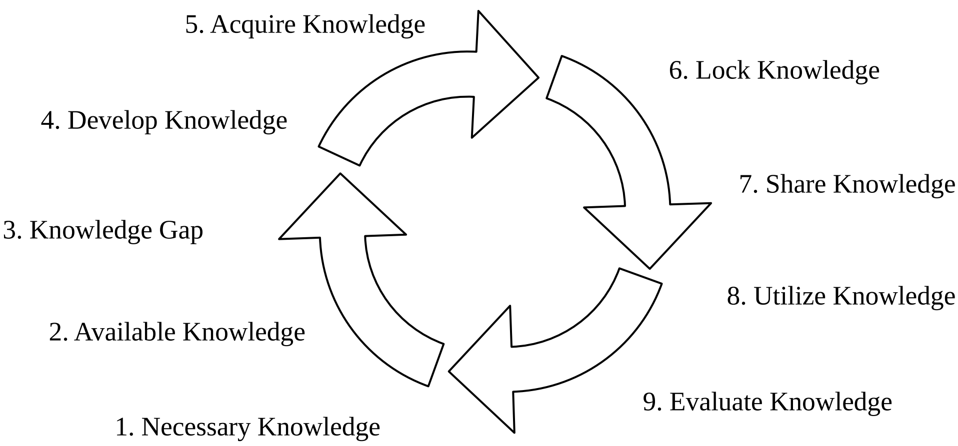


Figure 2.7 The Knowledge Cycle within Knowledge Management (Beijerse, 2000)

2.3.1 Codification and Personalization Approaches

There are two predominant and high level approaches to designing and deploying KM application: the Codification and Personalization approaches. The codification approach consolidates reusable assets into one or more designated repositories. This approach favors greater emphasis on the use of technology, especially search engines. The Personalization approach focuses specifically on the people and cultural issues in the establishment of virtual groups or knowledge communities. Technologies are also used to support the sharing of knowledge in such groups and communities but it is deemed to play a secondary role compared to connecting and locating people of common interest.

In a very general sense, the codification approach is more suitable to situations where work tasks are similar and existing assets can be adapted for reuse. In contrast, the personalization approach is appropriate for situations where the bulk of the critical knowledge in an organization is tacit, work tasks are fairly unique, and it is difficult to reuse knowledge assets from task to task without significant modifications. The two approaches are complimentary; it is not unusual for organizations to adopt a combination of the two approaches in deploying KM application(s).

Codification and personalization are two expansive knowledge management approaches. There is no right or wrong approach – both are required in the right balance. The right balance is determined by the company's objectives in pursuing KM. For any KM initiative to be successful, both approaches must be present in the knowledge orientation of the firm, but not with equal weighting. If a company decides to use codification as its primary strategy, it should direct, for example, 80 percent of its efforts toward codification and the remaining 20 percent toward personalization.

2.3.2 Type of Knowledge: Explicit and Implicit knowledge

With regard to KM, people must take into consideration the more system-bound side of knowledge (explicit knowledge) and more people-bound side of knowledge (tacit knowledge). Polanyi (1958) first conceptualized and distinguished between an organization's tacit knowledge and explicit knowledge.

Explicit knowledge is that component of knowledge that can be codified and expressed in a systematic and formal language: documents, databases, scientific formulas, standardized procedures, webs, e-mails, charts, etc. It can be easily transferred and spread. Tacit knowledge is personal, context-specific knowledge that is difficult to formalize, record, or articulate; it is stored in the heads of people. The tacit component is mainly developed through a process of trial and error encountered in practice.

From a study of the success of Japanese entrepreneurs, it has become apparent that their success is mainly due to their ability to transform implicit knowledge into explicit knowledge (Polanyi, 1966). It is attempted to grasp people's creative ideas (implicit knowledge) as information and knowledge systems (explicit knowledge), so that they become reproducible and useable.

2.3.3 Modes of Knowledge Conversion

The Nonaka and Takeuchi (1995) knowledge spiral/conversion model is basically a two-dimensional matrix depicting four possible scenarios of tacit and explicit knowledge interaction or "conversion". As shown in Figure 2.8, Nonaka's models consist of four processes which are externalization, internalization, socialization and combination. The knowledge transfer as a spiral process in which existing knowledge can be in either form i.e. tacit or explicit. Each type of knowledge can be converted. The objective of knowledge transfer can be to convey either tacit or explicit knowledge and each mode of transfer operates differently. When viewed as a continuous learning process, the model becomes a clockwise spiral. Organizational learning depends on initiating and sustaining the learning spiral. The model is a spiral but not a cycle. This is because as one "Learns" around the spiral, understanding moves to deeper and deeper levels:

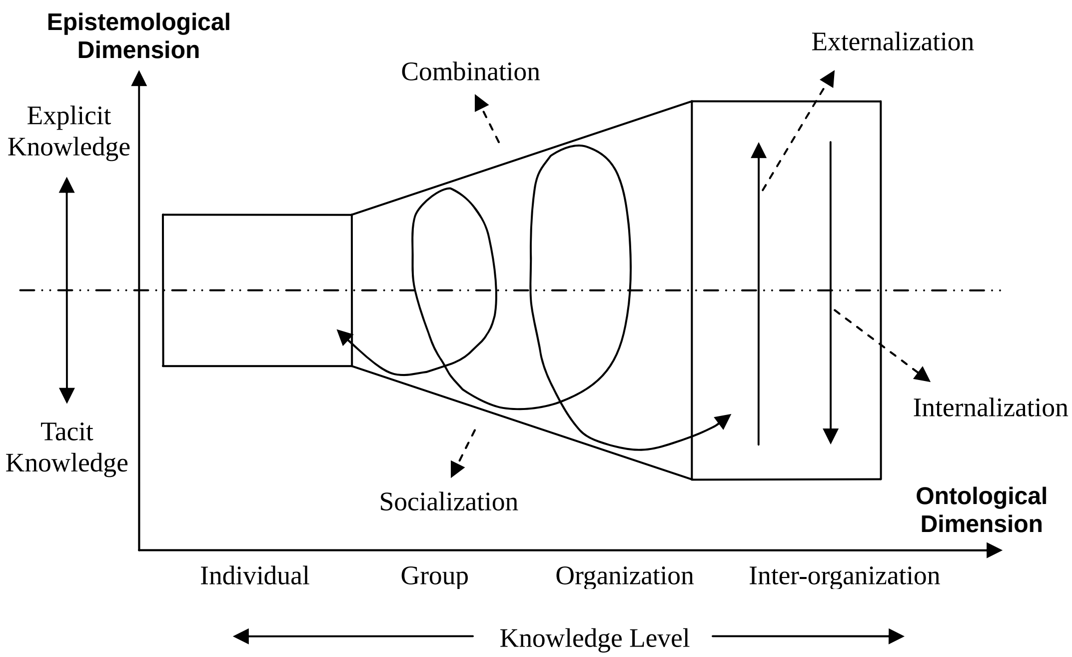


Figure 2.8 Spiral of organizational knowledge creation (Nonaka & Takeuchi, 1995)

2.3.4 A Scale for Measuring Knowledge about a Process

A company's knowledge about its processes may range from "total ignorance about how they work" to "very formal and accurate mathematical models". Bohn (1997) has identified eight stages of technological knowledge which is shown in Table 2.1. In the final stage, the complete functional form and parameter values are known to determine the result. Process and environment are so well understood that people can head off any problems in advance by feed-forward control.

Table 2.1 Stages of Knowledge

Stage	Name	Comment	Typical Form of Knowledge
1	Complete Ignorance		Nowhere
2	Awareness	Pure art	Tacit
3	Measure	Pre-technological	Written
4	Control of the mean	Scientific method feasible	Written and embodied in hardware
5	Process capability	Local Recipe	Hardware and operating manual
6	Process characterization	Tradeoffs to reduce costs	Empirical Equations (Numerical)
7	Know why	Science	Scientific Formulas and Algorithms
8	Complete Knowledge	Nirvana	

2.3.5 Knowledge Management in the Corporate World

Over the past few years, there has been an explosion of interest in the field of knowledge management (KM). The power of knowledge is a very important resource for preserving valuable heritage, learning new things, reusing and sharing information and knowledge, solving problems, creating core competences, and initiating new situations for both individual and organizations now and in the future (Liao, 2003; O'Leary, 2001; Becerra-Fernandez & Aha, 1999). The goal of KM is to capture, store, maintain and deliver useful knowledge in a meaningful format to anyone who needs it anyplace and anytime within an organization (Turban & Aronson, 2001). Basically, KM is collaboration at the organization level. Loss of knowledge is a problem that companies must address, even when they are not faced with the threat of downsizing. It is up to the organization to adopt the methodologies and software tools that best address their demands for storage and reusability of past project experiences. The majority of KM projects currently in place attempt to create some kind of a knowledge repository to store explicit knowledge of organizational information. Explicit knowledge should be carefully organized and its access should be intuitive.

In the corporate world, a 1998 Delphi Group survey found that over half of the respondents report active KM efforts in their firms and nearly half of the companies treat KM as a strategy issue, and 80% of the companies treat KM as making an important contribution to business practice (Holsapple, 2001).

Knowledge management can be defined as the achievement of the organization's goals by making the factor knowledge productive. This is done primarily by facilitating and motivating people to tap into and develop their core competencies. Besides this, knowledge management includes the entirety of systems with which the information within an organization can be managed and opened up.

2.3.6 Classification of KM researches and technologies

Tsui, Garner and Stabb (2000) summarized three dominant streams of research / applications of KM:

(i) The first stream focuses primarily on research into the theory of knowledge, the knowledge of the firm, organizational culture, measurement of intellectual capital and learning organizations. These researchers tackle the theoretical aspects of KM and some are even challenging Nonaka and Takeuchi's (1995) framework for the socialization and externalization of knowledge.

(ii) The second stream is represented by the work on corporate memories (also known as organizational memory or organizational memory information systems (OMIS)) for enhanced decision making. A corporate memory embraces all forms of institutional knowledge, whether formally encoded within the current information systems, or tacit (informal) knowledge used by individuals in professional practice. (Verbal instructions by supervisors, for example, are not usually captured at source!)

This group has a strong focus on knowledge sharing and on practical applications of KM.

(iii) The third stream, with a strong contribution from computer scientists and AI researchers in particular, tackles the areas of intelligent agents, ontologies (taxonomies), data mining, knowledge modeling and computer-mediated collaborations.

According to Beiferse (2000), there are nine possible knowledge streams within the organization that are important for the management or the entrepreneur to think about in order to structurally manages these processes. The nine knowledge streams are mentioned here.

(i) **Determine the knowledge necessary –** before the knowledge stream can be started, it is important that people look at what knowledge is necessary for the organization and its goals. This is mainly a strategically driven activity.

(ii) **Determine the knowledge available –** it is obviously important that people look at what knowledge is already available in the organization. The knowledge available can be determined by baring successful acquisitions or projects or best practices, by maintaining a CV file of the personnel or by organizing experience swapping sessions.

(iii) **Determine the knowledge gap –** the difference between the necessary and available knowledge is called the knowledge gap. It is important to have a good insight into this knowledge gap in order to close it in the correct places.

(iv) **Knowledge development –** developing knowledge can be done via research and development, through education and training or by means of customer satisfaction studies.

(v) **Knowledge acquisition –** this is possible by employing specifically qualified personnel or by purchasing market research or strategic reconnaissance.

(vi) **Knowledge lock –** knowledge is changed into structural and systematic form and that this is ensured, whereby the knowledge is determined and is available to everyone.

(vii) **Knowledge sharing –** a crucial aspect within KM is sharing the available knowledge between employees mutually, between employees and managers, between departments, etc. It is important that the correct knowledge gets to the right person at the right time.

(viii) **Knowledge utilization –** it should be clear that the actual utilization of the knowledge forms a central element within the KM process. It is difficult to name examples of KM systems that are specially targeted at the utilization of knowledge.

(ix) **Evaluate knowledge –** obviously the knowledge should be evaluated within the organization. Evaluation of knowledge can be done through project evaluations, internal and external audits, executing customer satisfaction studies or benchmarking.

Based on the scope of 234 articles on KM application, Liao (2003) classified KM technologies using seven categories:

(i) KM framework,

(ii) knowledge-based systems (KBS),

(iii) data mining (DM),

(iv) information and communication technology (ICT),

(v) artificial intelligence (AI) / expert systems (ES),

(vi) database technology (DT) and

(vii) modeling, together with their applications on different research and problem domains.

2.3.7 Knowledge-based Approaches for Business Process Improvement

The knowledge-based methodology applied in the BPI to provide decision support is developed in the recent research. Ku *et al.* (1996) have suggested the adoption of a case-based reasoning (CBR) approach to retrieve similar BPI projects for the current process. Even though they did not provide a specific methodology in the adaptation process, their research tries to apply knowledge-based techniques to BPR (Kim *et al.*, 2000).

The major difficult tasks in the customization of enterprise applications are creating an alternative business process to redesign the current business process and the customization of the hardware and software components for the new process. There are typically no preferred answers and there are often many potential solutions. There are sometimes no precise rules for computing the best solution (Harman & Jones, 2001). Generally, for representing the concepts in social science and business, the knowledge represented by the empirical modeling seems better suited than precise mathematical modeling (Beynon, Rasmequan & Russ, 2002).

However, the good solutions can be recognized and repeatedly used in the similar problem situations. Based on the experientially based modeling principles, experience is the primary and primitive ingredient in the empirical modeling (EM) (Beynon, Rasmequan & Russ, 2002). In keeping with the philosophical principles developed by James (1912), experiences are to be interpreted through their relation to other experiences.

The case-based reasoning (CBR) is especially useful when a domain knowledge lacks of a strong set of heuristics but consists of a set of successfully and unsuccessfully solved cases (Bradley & Gupta, 1995; Ketler, 1993). It assumes that the solution in previous cases can inform and improve solutions that appear in the present situation. A case base is the accumulated knowledge of the problem solving experience. As the number of cases increases and quantity and in diversity, the case base becomes more useful (Grupe *et al*., 1998). Therefore, the CBR approach is used as a knowledge-based methodology for business process reengineering to provide decision support to its users in the modeling of the current problems and in the redesigning of critical business processes.

2.4 Decision Support Systems, Expert Systems and Knowledge-based Systems

2.4.1 Decision Support Systems

Decision support systems (DSS) are computer technology solutions that can be used to support complex decision making and problem solving. The original DSS concept was most clearly defined by Gorry and Morton (1971) who integrated Anthony's (1965) categories of management activity and Simon's (1960) description of decision types. They combined the two theories with the terms structured, unstructured and semi-structured, rather than programmed and non-programmed.

(i) In a **structured problem**, the procedures for obtaining the best solution are known. Whether the problem involves finding an appropriate inventory level or choosing an optimal investment strategy, the objectives are clearly defined. Common objectives are cost minimization and profit maximization.

(ii) In an **unstructured problem**, human intuition is often the basis for decision making. Typical unstructured problems include planning new services or choosing a set of new projects for the next year. Only part of the unstructured problem can be supported by advanced decision support tools such as expert systems (ES) and knowledge management systems (KMS).

(iii) The **semi-structured problems** fall between structured and unstructured problems, having some structured elements and some unstructured elements. Solving them involves a combination of both standard solution procedures and human judgment.

A DSS was defined as a computer system that dealt with the problem where at least some stage was semi-structured or un-structured. The “Human-machine” problem-solving system (Shim *et al.*, 2002) consists of the computer system and decision maker. The computer system could be developed to deal with the structured portion of the problem and the judgment of the decision maker was brought to bear on the unstructured part.

2.4.1.1 General stages for Problem Solving

The problem solving can consist of two general stages: Problem formulation and problem solving (Courtney & Paradice, 1993). Problem formulation contains three phases:

(i) “Problem identification” occurs when the problem solver perceives the need for a decision to be made.

(ii) “Problem definition” concerns the cognitive conceptualization of the problem situation. During definition, the problem solver determines the relevant properties of the problem situation.

(iii) “Problem structuring” examines the relevant components of the problem situation in order to determine a strategy for addressing the problem.

On the other hand, the problem solving stage contains two phases:

(i) “Diagnosis” occurs when the problem solver identifies a problem’s causes.

(ii) “Alternative generation” occurs next and concerns the design of the alternative courses of action.

Figure 2.9 shows the traditional decision-making paradigm for DSS (Courtney, 2001). Once the problem is recognized, it is defined in terms that facilitate the creation of mathematical models. Alternative solutions are created, and models are then developed to analyze the various alternatives. The choice is then made and implemented.

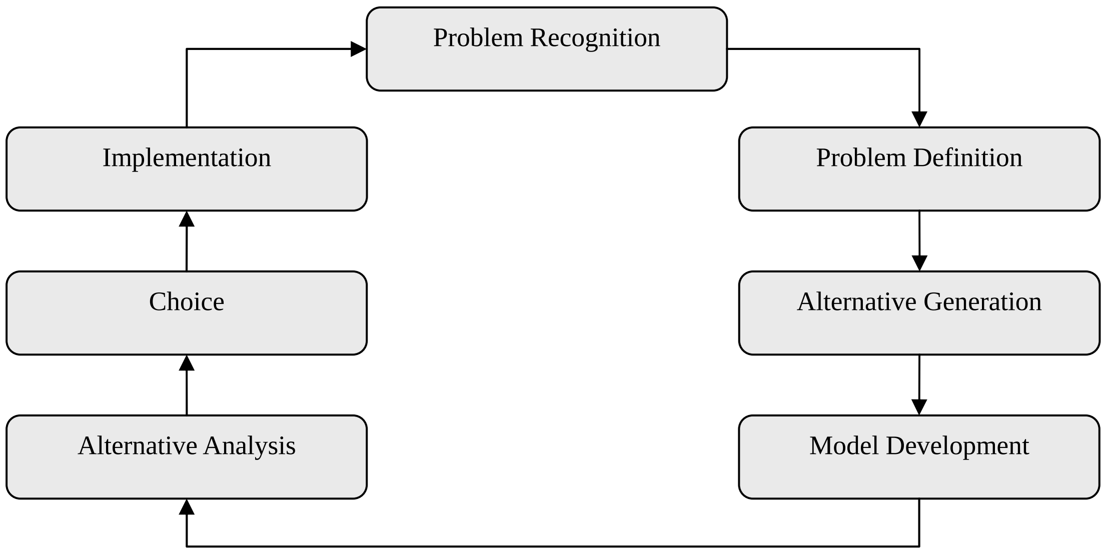


Figure 2.9 The traditional decision-making paradigm for DSS (Courtney, 2001)

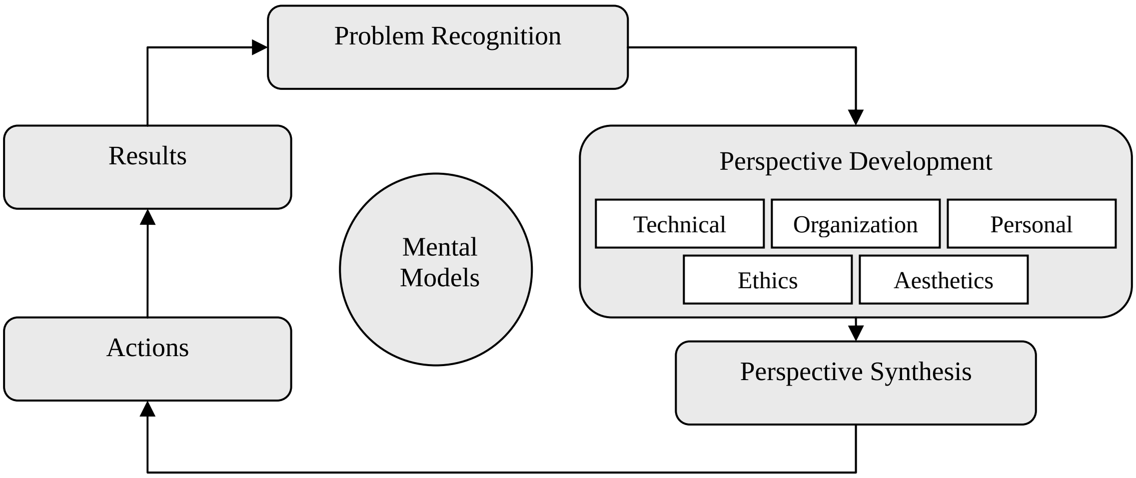


Figure 2.10 The new decision-making paradigm for DSS (Courtney, 2001)

By comparison with the conventional DSS, the main difference with the new approach (as shown in Figure 2.10) is the development of multiple and varied perspectives during the problem formulation phase. The decision process begins with the recognition that a problem exists; that is, a decision needs to be made. But rather than jumping simply into analysis, the process consists of developing multi perspectives which provide much greater insight into the nature of the problem and its possible solutions than the heavy reliance on the technical perspective that DSS has advocated in the past.

2.4.1.2 Classification of DSS

There are several ways to classify the decision support systems. Turban and Aronson (2001) summarized that there are nine types of DSS which are

(i) Alter's (1980) output classification,

(ii) Holsapple and Whinston's (1996) classification,

(iii) Text-oriented DSS,

(iv) Database-oriented DSS,

(v) Spreadsheet-oriented DSS,

(vi) Solver-oriented DSS,

(vii) Rule-oriented DSS,

(viii) Compound DSS and

(ix) Intelligent DSS.

Some types of DSS are discussed as following:

(i) Rule-oriented DSS – The knowledge component of DSS described earlier includes both procedural and inferential (reasoning) rules, often in an expert system format. These rules can be qualitative or quantitative, and such a component can replace quantitative models or can be integrated with them.

(ii) Intelligent DSS – The so-called intelligent or knowledge-based DSS has attracted a lot of attention. The rule-oriented DSS which we described above can be divided into six types: descriptive, procedural, reasoning, linguistic, presentation and assimilative. Mirchandani and Pakath (1999) divided and identified four intelligent DSS models: symbiotic, expert-systems-based, adaptive and holistic.

Beginning in about 1985, group decision support system (GDSS), or just group support systems (GSS), evolved to provide brainstorming, idea evaluation, and communications facilities to support team problem solving. Executive information systems (EIS) have extended the scope of DSS from personal or small group use to the corporate level. Model management systems and knowledge-based decision support system have used techniques from artificial intelligence and expert systems to provide smarter support for the decision maker. (Bonczek *et al.*,1981; Courtney & Paradice, 1993)

2.4.2 Expert Systems

Expert Systems (ESs) are one of the most commercially successful branches of artificial intelligence. Welbank (1983) defines an expert system as follows:

> *"An expert system is a program which has a wide base of knowledge in a restricted domain, and uses complex inferential reasoning to perform tasks which a human expert could do."*

During the 1980s, many universities and companies turned their attention to expert system (Leondes, 2002). Most universities rapidly developed and offered expert system courses. Companies initiated expert system projects and formed internal AI groups. The majority of expert systems developed are rule-based. A survey of systems built since the 1970s shows that approximately 80% of them are rule-based (Durkin, 1993). The comparison of the conventional systems and the expert systems are shown in Table 2.2.

An expert system (ES) is a system that uses human knowledge captured in a computer to solve problems that ordinarily require human expertise (Turban & Aronson, 2001). Well designed systems imitate the reasoning processes experts use to solve specific problems. Such systems can be used by experts as knowledgeable assistants.

Expert systems can be viewed as having two environments: the development environment and the consultation (runtime) environment. The structure of an expert system (Turban & Aronson, 2001) is shown in Figure 2.11. The development environment is used by an ES builder to build the components and put knowledge into the knowledge base. The consultation environment is used by a non expert to obtain expert knowledge and advice. This environment can be separated once a system is completed.

Table 2.2 The comparison of the conventional systems and the expert systems (Durkin, 1993)

Conventional Systems	Expert Systems
Information and its processing are usually combined in one sequential program.	Knowledge base is clearly separated from the processing (inference) mechanism.
Program does not make mistakes	Program may make mistakes
Do not explain why input data are needed or how conclusions are drawn	Explanation is a part of most expert system.
Require all input data. May not function properly with missing data unless planned for.	Do not require all initial facts. Typically can arrive at reasonable conclusion with missing facts.
Effective manipulation of large databases.	Effective manipulation of large knowledge bases.
Easily deal with quantitative data.	Easily deal with qualitative data.
Use numerical data representations.	Use symbolic and numerical knowledge representations.

Expert systems, an artificial intelligence method for capturing knowledge, are knowledge-intensive computer programs that capture the human expertise in limited domains of knowledge (Laudon & Laudon, 2002). For this, human knowledge must be modeled or presented in a way that a computer can process. Usually, expert systems capture the human knowledge in the form of a set of rules. The set of rules in the expert systems adds to the organizational memory, or stored learning of the organization. An expert system can assist decision making by asking relevant questions and explaining the reasons for adopting certain actions. Wong *et al.* (1994) implemented a study in 1993 examining the current utilization of ESs and their benefits in manufacturing among the 500 largest industrial companies in the USA. Table 2.3 shows the summary of applications of expert systems in different areas.

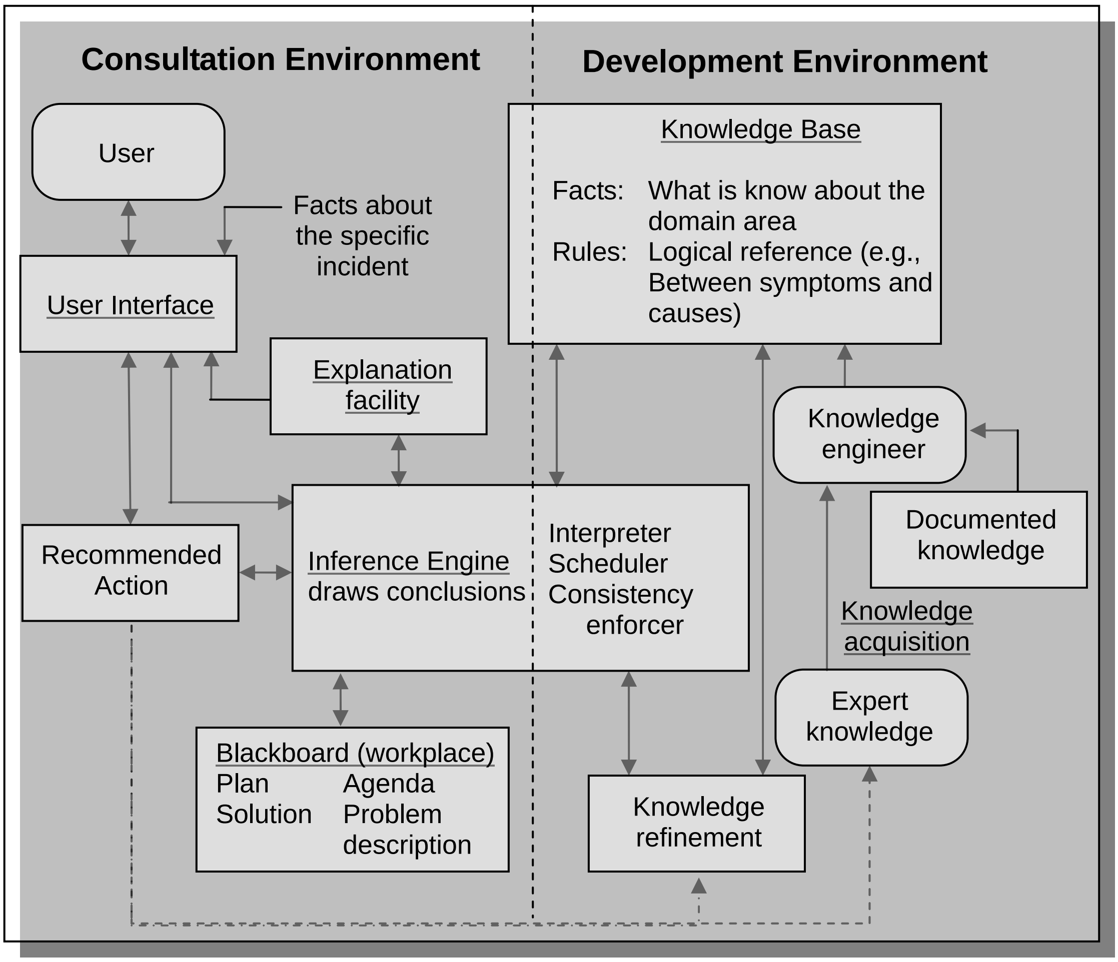


Figure 2.11 Structure of an expert system (Turban & Aronson, 2001)

Table 2.3 Areas of Expert System Applications – Survey of Wong *et al.* (1994)

System Domain	Frequency	Percentage
Scheduling	18	35.3
Process Design	16	31.4
Maintenance and Repair	15	29.4
Process Selection	13	25.5
Facility Layout	11	21.6
Material Selection	6	11.8
Production Planning and Control	4	7.8
Capacity Planning	4	7.8
Facility Location	3	5.9
Project Management	3	5.9
Tool Selection	2	3.9
Data Selection	2	3.9
Quality Control	2	3.9
Forecasting	2	3.9
Storeroom Design	1	2.0
Vendor Selection	1	2.0

Leondes (2002) summarized six common tools for developing expert systems. They are (i) rule-based tools, (ii) frame-based tools, (iii) fuzzy logic tools, (iv) induction tools, (v) case-based reasoning tools and (vi) neural network tools.

2.4.2.1 Rule-based Expert System

Rule-based reasoning (RBR) includes database updating rules, process control rules, and data deletion rules for logical reference (Knight & Ma, 1997). In the RBR systems, the specialized domain declarative knowledge is represented as a set of

IF < precondition(s) > THEN < conclusion(s) > rule format.

A typical rule has two parts: the precondition and the conclusion. The precondition contains information on which facts or situations must be true for the rule to be used. If these match exactly to the facts of the current applications, the rule fires, and the conclusion then presents information on the consequences on the match.

In RBR systems, knowledge is represented as facts about the world (i.e. relationships between entities, e.g. A->B) and mechanisms (known as inference engine) for manipulating the facts.

2.4.2.2 Inference Engine

The “brain” of the rule-based expert system is the inference engine, as known as control structure or the rule interpreter (in rule-based expert system). This component is essentially a computer program that provides a methodology for reasoning about information in the knowledge base and for formulating conclusions.

The basic reasoning procedure is the manipulation of the logical expressions to create a new expression. The most important method is called “modus ponens”. It is processed by the inference engine and the functions of the inference engine are listed as following:

- Fire the rules
- Present the user with the questions
- Add the answer to the ES blackboard (or assertion base)
- Infer a new fact from a rule

The rules are interpreted and ranked by the inference engine in a logical order. A series of questions are generated from the inference engine to collect the user's answers for firing the rules or realizing the premises. This process can be done in one of two directions, which is forward chaining (or data-driven approach) and/or backward chaining (or goal-driven approach). It will be continued until no more rules can be fired or until a goal is achieved.

Forward chaining is a data-driven approach. It starts from available information as it becomes available or from a basic idea, and then it tries to draw conclusion. The inference engine analyzes the problem by looking for the facts that match the IF part of its IF-THEN rules. As each rule is tested, the program works its way toward one or more conclusions.

On the other hand, backward chaining is a goal-driven approach in which you start from an expectation of what is going to happen (hypothesis) and then seek evidence that supports your expectation. The inference engine starts with a goal to be verified as either true or false. Then it looks for a rule that has this goal in its conclusion part of the IF-THEN rules. It then checks the premise of the rule in an attempt to satisfy the rule. If the goal is proven, then the next goal is tried.

2.4.3 Knowledge-based systems (KBS)

Knowledge management is variously defined, but tends to involve the "preparation" or "formal management" of knowledge for "distribution" or "re-use"

(Abbott, 1999; O'Leary, 1998). In discussing the relationship between KBS and knowledge management, Hendriks and Vriens (1999) notes that KBS are the outcomes of a knowledge engineering process that may provide some of the "building blocks" of knowledge management. Central to this knowledge engineering process is the means by which knowledge can be acquired, which is evidently important for KM too. Techniques for knowledge acquisition have been developed by the KBS community discussed.

The acquisition and representation of knowledge and the development of strategies for reasoning over this knowledge has been a focus of the work of the artificial intelligence (AI) community throughout the latter half on the 20th century. Work on KBS has contributed to the development of more complex hybrid DSS which represent the melding of Holsapple and Whinston's (1996) solver-oriented, database-oriented and rule-based DSS into a single system. Four main components of KBS (Dhaliwal & Benbasat, 1996) are usually distinguished:

(i) a knowledge base,

(ii) an inference engine,

(iii) a knowledge engineering tool and

(iv) a specific user interface.

The lessons learnt in developing KBS are increasing to be applied more generally: to allow for the explicit representation of knowledge, to develop strategies to search this knowledge, and to allow for explanation to be given to the users. The experience of the KBS community throughout the last few decades makes an invaluable contribution to the discipline of KM.

According to a survey for KPMG conducted by the Harris Research Center (Turban & Aronson, 2001), the top five reasons that firms initiate knowledge management systems are:

(i) Better decision making

(ii) Reduced costs

(iii) Faster response time to key issues

(iv) Improved productivity

(v) Shared best practices

In a very broad sense, knowledge based systems (KBS) are programs that use human-like reasoning processes, which rely on experimental human knowledge (expertise) represented in a knowledge base for a specific problem. When KBS approach the performance levels of a human expert, they are called ES. Essentially, an expert system is a computer program that attempts to encapsulate some of the problem-solving expertise of a human expert within a narrow application domain (Ranky, 1990).

2.5 Case-based Reasoning

Case-based reasoning (CBR) is a method for developing conceptual design and military decision support systems (Lee & Lee, 1999). The root of case-based reasoning in AI is found in the works of Schank (1982) on dynamic memory and the central role that a reminding of earlier situations and situation patterns have in problem solving and learning. It is an intelligent systems methodology that enables information managers to increase efficiency and reduce cost by substantially automating processes. By identifying and ranking the relevance between a new case and previously encountered cases, CBR systems can capture and share all of an organization related knowledge capital for future use, and knowledge recycling can optimize resources spent on research and development. (Becerra-Fernandez & Aha, 1999). Figure 2.12 shows the basic flowchart of case-based reasoning.

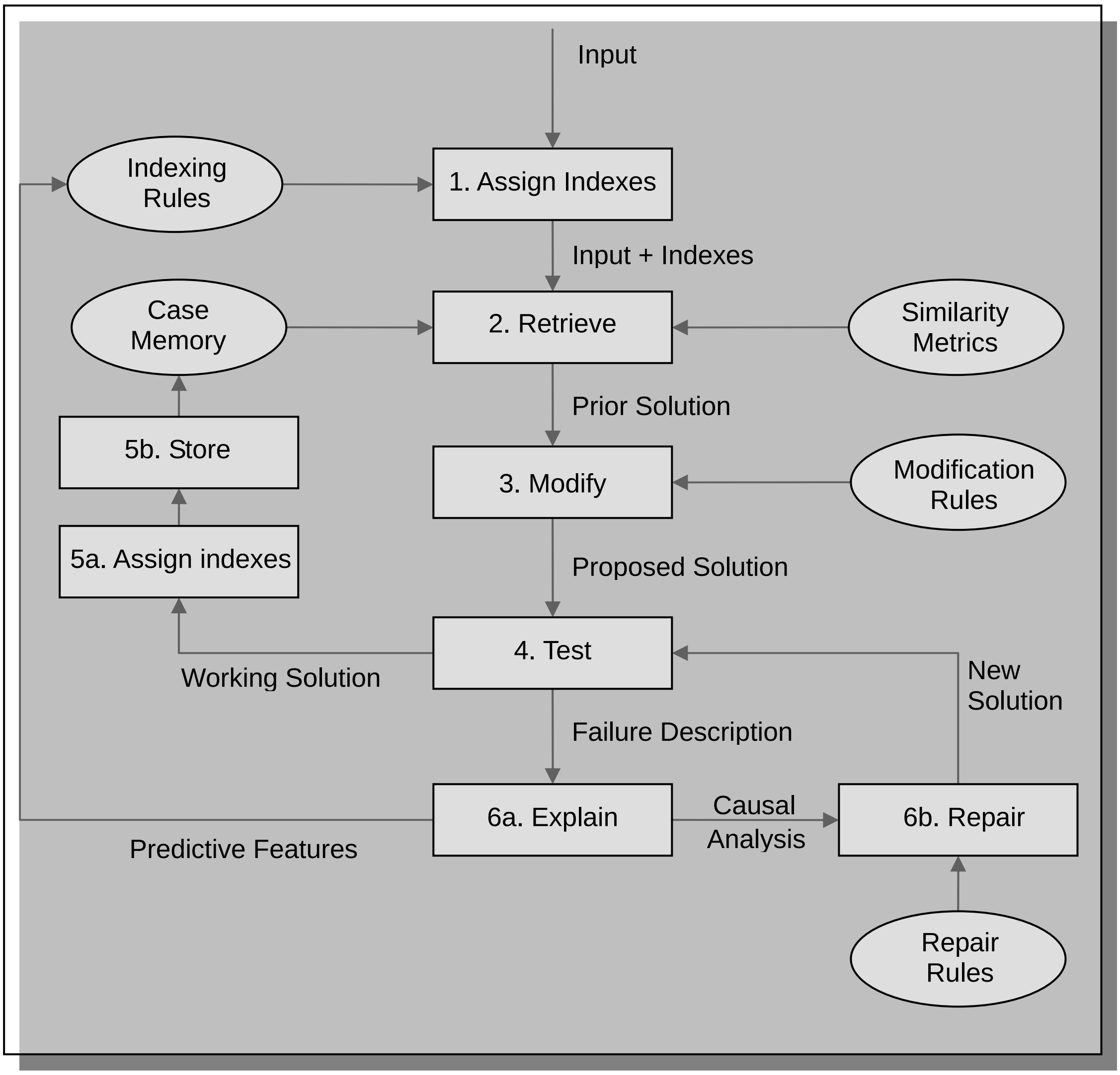


Figure 2.12 Case-based Reasoning Flowchart (Becerra-Fernandez & Aha, 1999)

The collection of knowledge related to a problem used in an AI system is organized and it is called a knowledge base. Most knowledge bases are limited in that they typically focus on some specific, usually narrow, subject area or domain. A very important feature of case-based reasoning is its coupling to learning. CBR favors learning from experience, since it is usually easier to learn by retaining a concrete problem solving experience than to generalize from it. Still, effective learning in CBR requires a well worked out set of methods in order to extract relevant knowledge from the experience, integrate a case into an existing knowledge structure, and index the case for later matching (Aamodt & Plaza, 1994).

2.5.1 CBR Cycle

Generally speaking, CBR solves problem with a cycle in four steps as shown in Figure 2.13. Firstly, by matching the similarity of cases against the cases in the knowledge repository, similar cases are retrieved. Secondly, the retrieved cases are used to suggest a solution which is tested and reused for success. The solution is then revised if necessary. Finally, the current problem and the final solution are retained as part of a new case which is stored in the knowledge repository for future use.

(i) **Retrieving** a case starts with a problem description and ends when a best matching case has been found. Some systems retrieve cases based largely on superficial syntactic similarities among problem descriptors, while advanced systems use semantic similarities.

(ii) **Reusing** the retrieved case solution in the context of the new case focuses on: identifying the differences between the retrieved and the current case; and identifying the part of a retrieved case which can be transferred to the new case. Generally the solution of the retrieved case is transferred to the new case directly as its solution case.

(iii) **Retaining** the case is the process of incorporating whatever is useful from the new case into the knowledge repository. This involves deciding what information to retain and in what form to retain it; how to index the case for future retrieval; and integrating the new case into the case library.

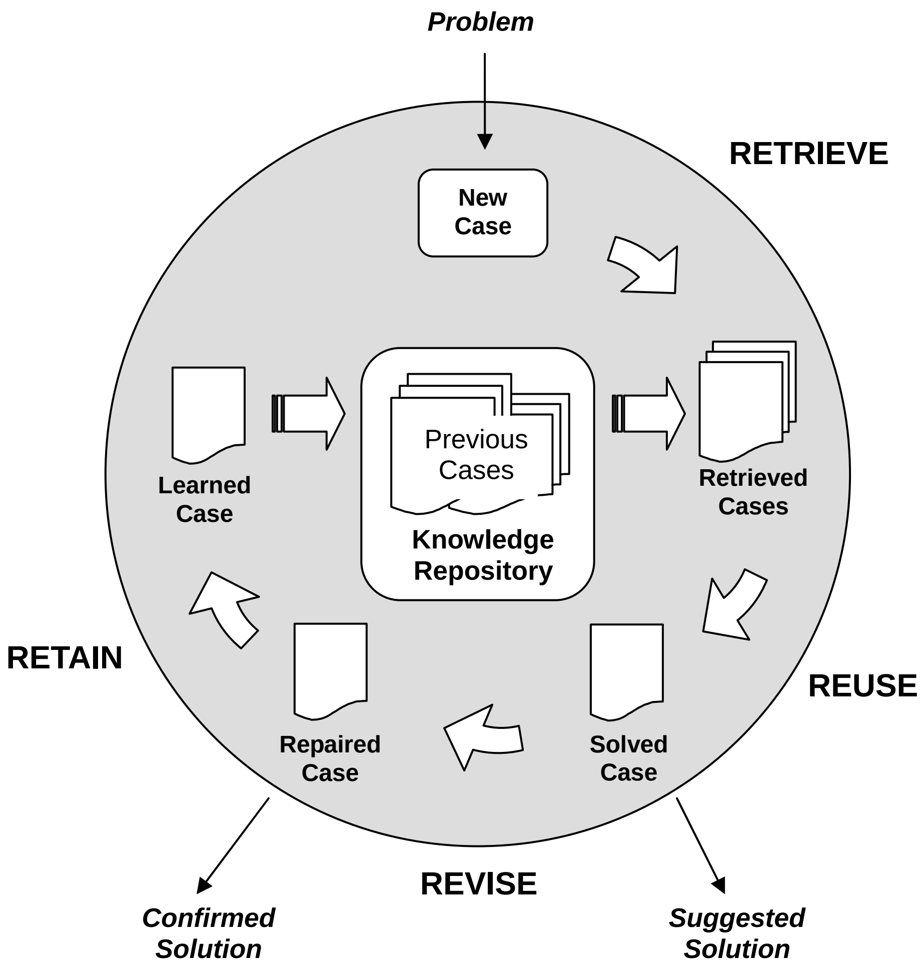


Figure 2.13 Case-based Reasoning Cycle

2.5.2 Advantages and Disadvantages of CBR

There are a number of advantages to use CBR. Firstly, case base captures knowledge easily. The structure of cases is much less constrained than rules are. There is no need for discovering complex interrelations between cases or the relationship between the case attributes and the solution is not understood well enough to represent it in rules. Moreover, the solutions of CBR are understandable. It is easy in explaining and justifying a solution from CBR.

There are also disadvantages of using CBR. If the knowledge repository does not have a sufficiently similar case, the retrieved cases may be inappropriate for the new problem. The case-based system may exhibit the bias associated with the availability heuristic, just as an inexperienced decision maker may do. When the case base lacks of sufficiently relevant case, CBR may not be able to recognize a new problem type when a new case is distinguished form prior cases by a feature.

2.5.3 Recent research on CBR

CBR becomes the hot topic in many investigations. For example, it has been applied to the decision support for product configuration (Inakoshi *et al.*, 2001) and business software development process (Grup *et al.*, 1998).

The first CBR system that might be called a case-based reasoner was the CYRUS system, developed by Janet Kolodner (Aamodt & Plaza, 1994; Kolodner, 1983a & 1983b), at Yale University. CYRUS was based on Schank's (1982) dynamic memory model and MOP theory (Kolodner, 1983a; Kolodner, 1983b) of problem solving and learning. It was basically a question-answering system with knowledge of the various travels and meetings of former US Secretary of State Cyrus Vance.

Another basis model of CBR was developed by Porter and Bareiss (1986) at the University of Texas, Austin. They initially addressed the machine learning problem of concept learning for classification tasks. This led to the development of the PROTOS (Porter & Bareiss, 1986; Bareiss, 1989) system, which emphasized integrating general domain knowledge and specific case knowledge into a unified representation structure.

A tool "Navy Conversational Decision Aids Environment (NACoDAE)", was designed by Navy Center for Applied Research in Artificial Intelligence (NCARAI), to minimize the loss of organizational knowledge, efficiently use lessons learned databases (Becerra-Fernandez & Aha, 1999). NCARAI has been involved in both basic and applied research in artificial intelligence since its inception in 1982. Several NCARAI projects have focused on designing, implementing, and evaluating practical extensions of NaCoDAE. This software is based on conversational CBR (CCBR) technology. The CCBR tools enhance decision making by identifying similar scenarios previously encountered and by adapting the previous experiences to the current problem scenario, in order to provide a new solution. A CCBR system can combine cases if they have similar patterns to that of the current case. In additional, this technology can serve as a learning tool that makes use of all documented experience from past projects and applies it to a present project application.

The CAPMOSS (Kim *et al.*, 2000) is proposed and used efficiency, effectiveness and transformation as the objectives for BPR projects. It focuses on the development of process models, the AS-IS model (the current processes) and the TO-BE model (the redesigned processes) in using an event process chain (EPC) diagram. The EPC diagram represents the organization's critical business processes over both geographical as well as dynamic time dimensions and exclusively form the customer's perspective.

However, there are some limitations for the CAPMOSS approach and have to be solved. Firstly, it is necessary to gather many real BPI cases in order to be a powerful application system. Secondly, the scoring method for retrieving the best cases in this approach can be improved by other similarity algorithms.

Several research studies have given empirical evidence for the dominating role of specific, previously experienced situations, or cases, in human problem solving (Ross, 1989). Schank (1982) developed a theory of learning and reminding based on retaining of experience in a dynamic, evolving memory structure. Rouse & Hurt (1982) indicated the use of past cases is a predominant problem solving method among experts as well. Anderson (1983) has shown that people use past cases as models when learning to solve problems, particularly in early learning. Veerakamolmal & Gupta (2002) presented the procedures to initialize a case memory for different product platforms, and to operate a CBR system, which can be used to plan disassembly processes.

2.6 Summary of Literature Review

After the review of the literature, it is found that business process improvement (BPI) is important for the organization in that it can help it to deal with the rapid change of the competitive business environment and with the adoption of the new technologies. The expert consultancy companies or the universities are professional services organizations for providing solutions for business process improvement. They are knowledge-intensive companies which provide professional knowledge and experience, and offer expert advice to their customers.

The most difficult tasks in the business process improvement projects are creating an alternative business process, to redesign the current business process, and the customization of the hardware and software components for the new process. There are typically no preferred answers or precise rules for computing the best solution. There are often many potential solutions and they are highly dependent on the experience of the consultants. The complicated knowledge is existing in the brains of the experts and it is difficult for the company to maintain and reuse this knowledge.

The knowledge-based methodology applied to improve the business process has attracted a lot of research attention in recent years. Successful solutions can be recognized and repeatedly used in similar problem situations. For example, Ku *et al.*, (1996) have suggested the adoption of a case-based reasoning (CBR) approach to extract reusable knowledge for new projects in business process improvement. However, most of the previous research work focusses on the recommendation of the redesigned process modeling but the framework can not provide the detailed configurations of the hardware and software for the implementation of the proposed new model.

Relatively little research work has been found for the development of an integrated platform for the selection and customization of enterprise applications and for using simulation for facilitating the development and validation of the business process improvement projects within the consultant company.

Therefore, a new and intelligent approach is need to dealing with the formulation of the business process as well as the selection and customization of various enterprise applications. Various artificial intelligence (AI) techniques such as a rule-based expert system, case based reasoning (CBR), etc. are suitable to support the decision making during the business process improvement project.

Chapter 3 Traditional VS Knowledge-based Approaches for the Customization of Enterprise Systems

3.1 Introduction

In this chapter, the traditional and proposed knowledge-based approaches for the customization of enterprise systems are discussed. A comparison is made and the advantages of the proposed approach are highlighted.

The improvement of the business process and adoption of the new technologies are significantly important for enabling organizations to cope with the rapid changes in the competitive business environment. To cope with these environmental changes and uncertainties, organizational changes have been incorporated effectively. The emergence of business process improvement has enhanced the organizational effectiveness in a competitive environment (Kim *et al*., 2000). Moreover, the existing processes in some organizations were never formally designed, but evolved through time (Drago & Geisler, 1997). The improvement of the business processes is necessary for improving the organization's performances, in such areas as cost, quality, service and performance.

Many organizations may want to improve their existing workflow and system. However, it is a critical, time consuming and risky task. Most companies may lack the experience and technological knowledge to enable them to improve the process. It is challenging for them to redesign the business process as well as select the suitable technologies, hardware and software components. They always postpone the decision to improve strategy in order to avoid risks.

They may seek external help from consultancy companies. The consultants are knowledge-intensive experts with valuable experience in the BPI projects. However, only little research work has been found on the management of knowledge to facilitate the development and validation of the BPI projects in the consultancy companies. Also, most of the research work focuses on the recommendation of the process modeling for the process improvement. But it is not detailed enough for the implementation of the proposed new solution as well as the customization of the hardware and software.

As shown in Figure 3.1, the present study focuses on the business process improvement domain. The target business processes are the middle or small sized business processes or sub-processes. These processes have to be improved or changed because of the change in the business environment nowadays or they will have significant problems in the existing operations.

(i) Process Improvement – focuses on the incremental improvement of an existing process in order to solve the existing problems or increase the performance of the business processes.

(ii) Change of current business environment – some business processes have to be changed to align with the changing business environment. For example,

- The popularization of e-business forces the company to interact with their customers directly through the Internet. Therefore, much information, such as the product information and inventory data, have to be automatically acquired by the new hardware devices and then digitized for real-time online access.
- The implementation of new technologies may be enforced by the business partners. For example, Wal-Mart (News of Wal-Mart, 2004) has set its top 100 suppliers to be placing Radio Frequency Identification (RFID) tags on cases and pallets destined for Wal-Mart stores. Therefore, the manufacturers should invest in the RFID technology.

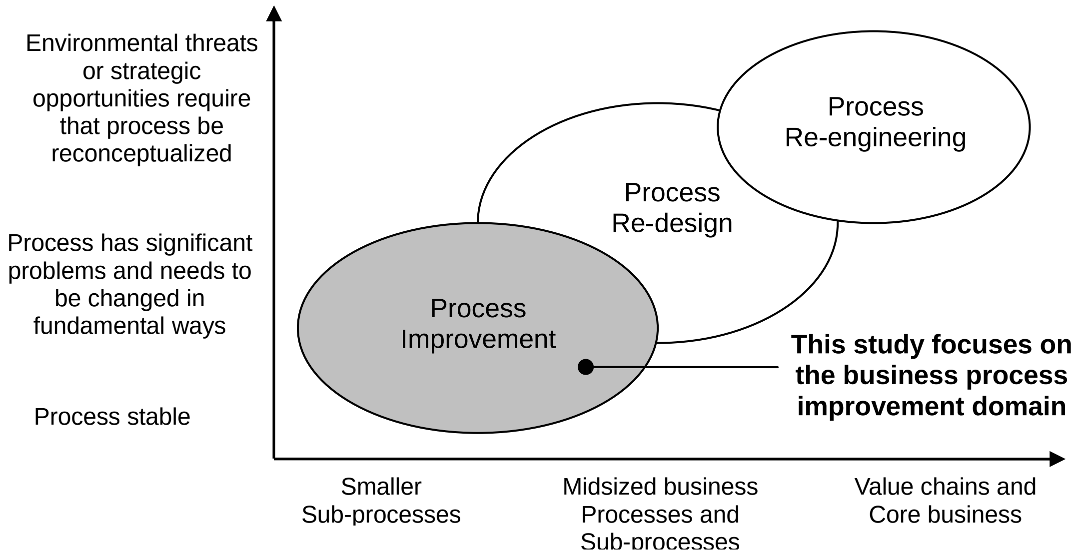


Figure 3.1 Target domain focused in this study (after Harmon, 2003)

3.2 The traditional approach for customization of enterprise systems

The generic workflow of the BPI process is shown in Figure 3.2. Once the managers of the client company want to improve their business processes because of the changing environment or the existing problems in their company, they may ask for help from the consultancy company. The consultants help the managers (or any others from the client company) to analyze the existing problem and objectives of the BPI project. Hence, the proposed solutions are generated for improving the existing problems. The suitable technologies, hardware and software components for the implementation of the proposed solution are recommended by the consultants. Finally, the solution is implemented in the client company and the solution may be revised if necessary.

In the traditional approach of the BPI process, the formulation of the new business process and the customization of the hardware and software components are heavily relied on the know-how and experience of the individual consultant. Since the business environment change from time to time and the available hardware and software on the market are developed rapidly. The conventional approach based on the individual human judgment and experience is inefficient and suffers from business risk. Moreover, the valuable knowledge involved in the decision making of consultancy work is difficult to acquire, share and diffuse among the consultants in the company.

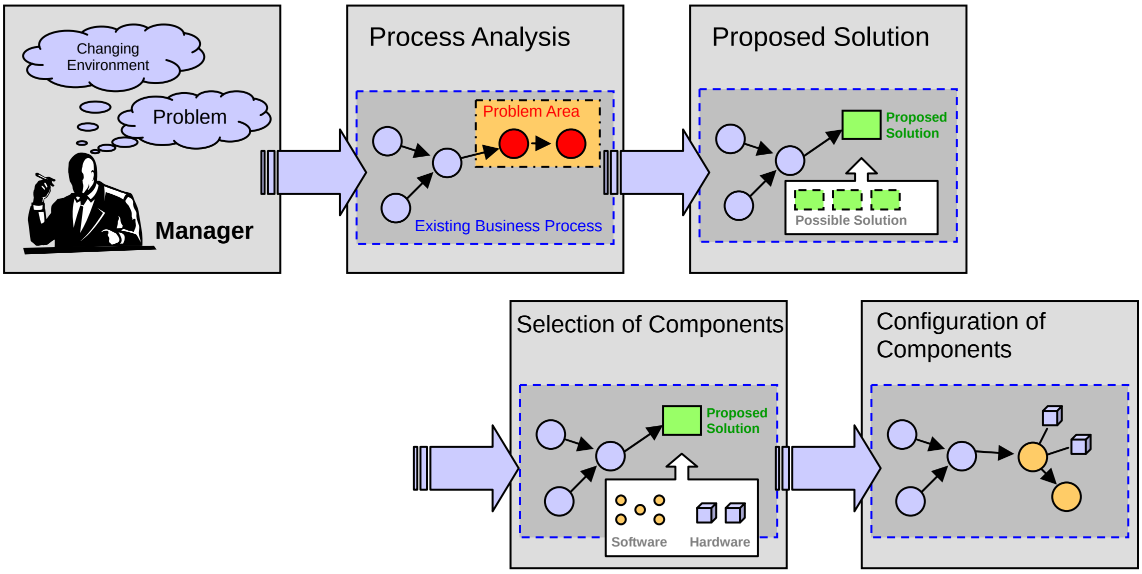


Figure 3.2 Generic workflow of the BPI process

3.3 The knowledge-based approach for the customization of enterprise systems

The knowledge-based approach for the customization of enterprise systems enhances the business process improvement project as well as the selection and customization of the software and hardware for the proposed solution. Figure 3.3 shows that relationship diagram between the client company, the consultancy company and the knowledge repository. When the client company wants to improve their business process due to different reasons, most of them are lack of knowledge about the BPI. The "missing knowledge" can be supplied by the experts in the consultancy company. In the proposed knowledge-based approach, the individual knowledge of the expert can be accumulated in the knowledge repository. Then, the knowledge can support the consultants to formulate the new BPI solution and customization of the systems by reusing the past experience and the decision making is supported by various AI technologies.

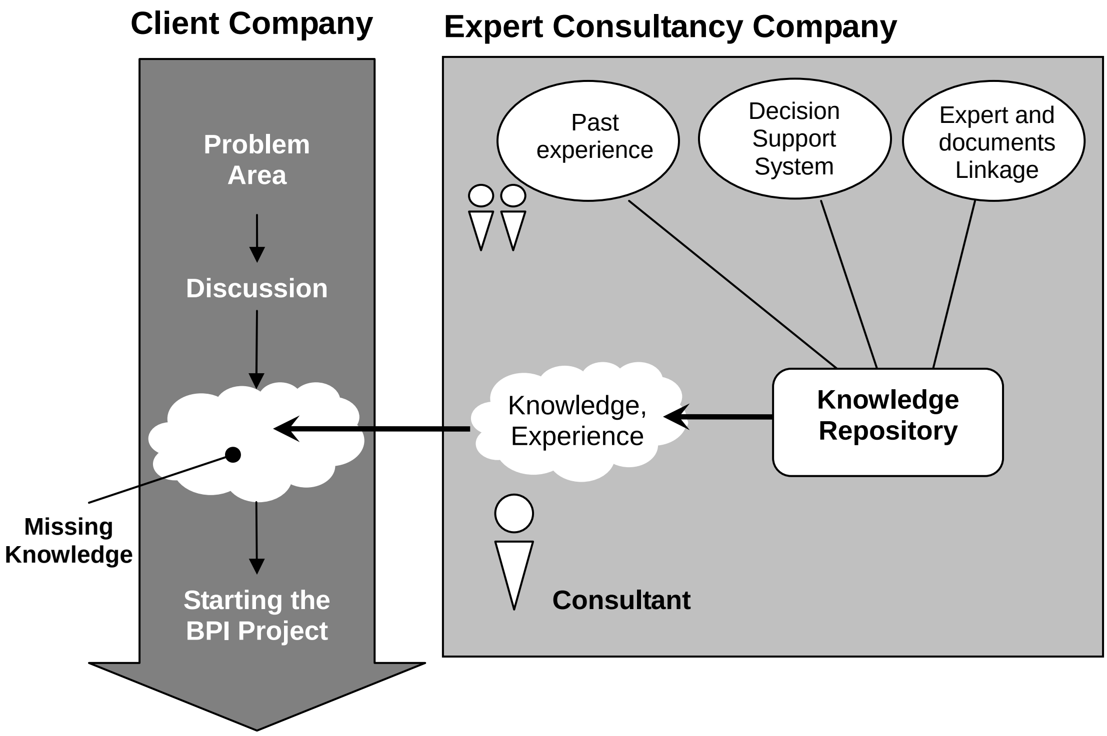


Figure 3.3 The relationship between the client company, consultancy company and the knowledge repository

Figure 3.4 shows the proposed knowledge-based approach for the customization of enterprise systems. The knowledge in the past BPI projects is stored in the knowledge repository. The rule based expert system and CBR help the consultants to evaluate and analyze the existing business process and then reuse the past experience so as to solve the current BPI problem. Finally, the selection and customization of the most suitable technologies, hardware and software is enhanced by reusing the past experience in knowledge repository. Generally, the components can be reused in similar industry and situation as well as how to configure the hardware and software components.

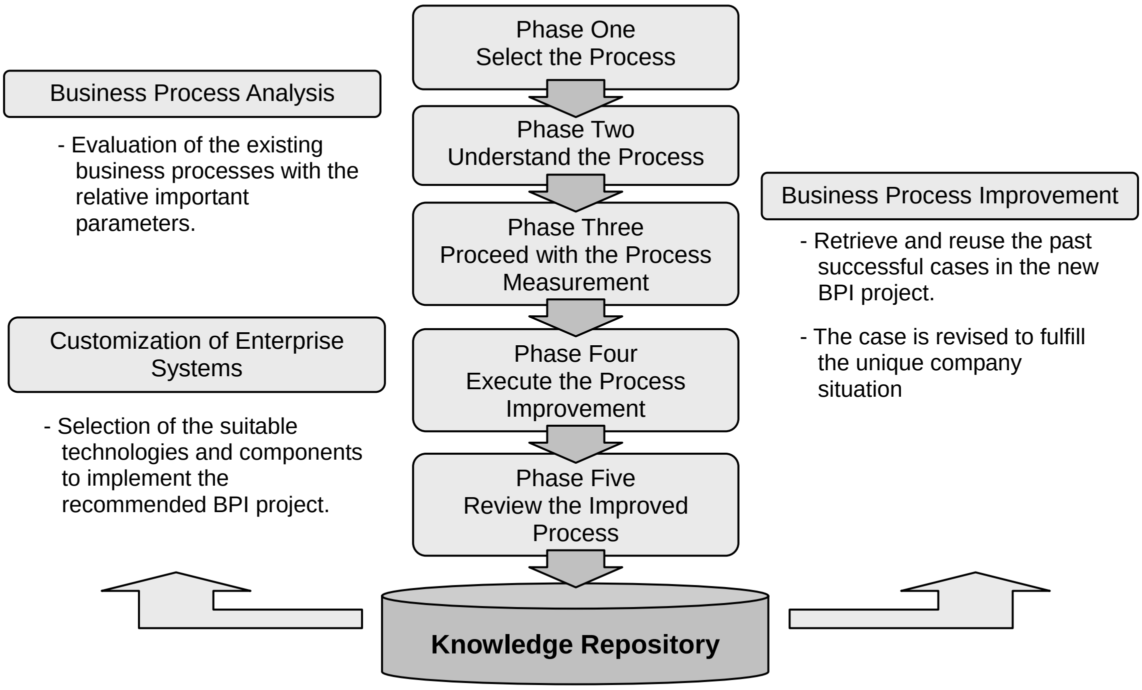


Figure 3.4 The proposed knowledge based approach for BPI

3.3.1 Knowledge pyramid for proposed knowledge based approach

The knowledge domains for supporting the knowledge-based approach in the BPI project can be represented by the knowledge pyramid which is shown in Figure 3.5. It is divided into three levels which are:

(i) the strategy planning tier (executive decisions regarding overall mission and goals)

(ii) the operational control tier (middle managers to achieve the company goals)

(iii) the software and hardware customization and integration tier (first line supervisors directing specific tasks)

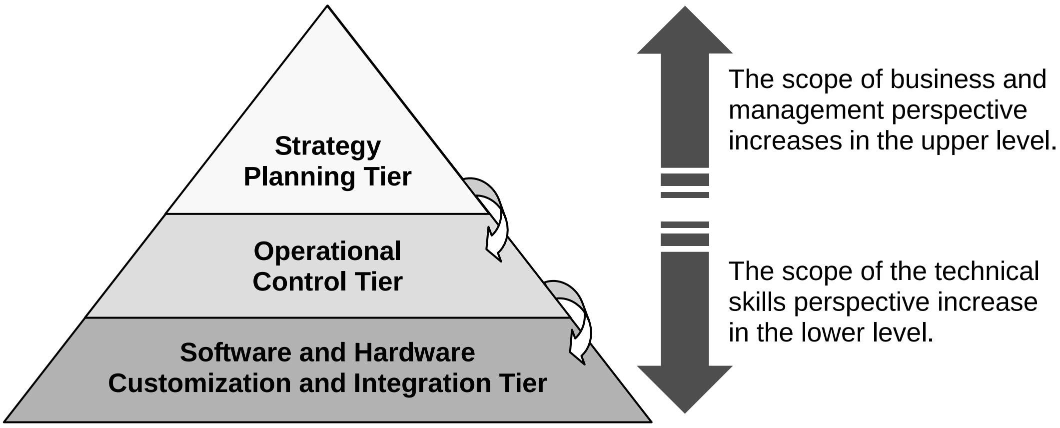


Figure 3.5 Knowledge pyramid for the knowledge-based approach

In the first tier, the organization’s strategy and the existing functional activities are analyzed. The top management people are involved in the formulation of the organization’s overall strategy, mission and goals. Then, the new business process as well as the detailed operations of the solution is formulated at the operational control tier. The middle managers with the operational perspective are involved in providing the detailed operation of the current workflow and in the achievement of the company goals. Finally, the selection of the suitable software and hardware as well as the detail configuration and setting of them are supported by the last tier. The staff with the technical perspective can carry out the business process improvement project with the help of this tier.

3.3.2 The strategy planning tier

This is the uppermost tier of the knowledge pyramid. In this tier, the user with the strategy and management perspective is preferred. They should have the ability to formulate the organization’s strategy and policy rather than the hands-on technical skills. The whole BPI project is conducted with the top-down approach. It is driven by the corporate strategies, goals and managerial objectives, but not driven by the existing technologies or software on the market. Therefore, the most fundamental stage is the formulation of the strategies of the organization. A good BPI project should match the organization's strategy and be considered together with the chances and risks of changing the existing business operations. It can either effectively exploit, build upon or develop the enterprise resource base, capability, synergy, value generation and competitive advantage of the organization or remedy the corporate weaknesses. Then, the scope and objectives of the BPI project can be defined.

3.3.3 The operational control tier

This is the middle level of the pyramid. The approach for best fit process improvement is recommended in this tier so as to carry out the confirmed business strategy. First of all, the parameters of the current business processes and the problems encountered are analyzed in order to propose the best recommendation. The expert system is used to acquire and analyze all critical parameters. Then, the heuristic approach is used to propose the most feasible solution from the past successful experiences in the knowledge repository. Past cases of a similar business nature, business process and problem statements, can be reused as the proposed project for the organization. Empirical modeling is better than precise mathematical modeling for selecting the most suitable approach because no preferred answer and no explicit mathematical modeling is developed to formulate the project.

The CBR technology is used to retrieve some similar business process improvement projects from the knowledge repository and a best-fit approach is proposed for the current situation. The retrieved cases include all the relevant information for the user to adopt the most suitable one. This is the critical information included in the retrieved cases:

(i) the innovated technology in the retrieved case.

(ii) the hardware and software used in the retrieved case.

(iii) the implementation period and the total investment cost of the retrieved case.

(iv) the estimated profit margin, turnover and return on investment (ROI) for their company.

3.3.4 The software and hardware customization and integration tier

The redesign of the current information system, innovation of new techniques and development of the e-commerce application are all commonly involved in the latest BPI project. In the lower tier of the pyramid, the knowledge for carrying out the IT related part in the project is provided. The selection of suitable hardware and software to carry out the confirmed project is supported. From the adopted case, the applied hardware and software are proposed for reuse in the current situation. The components can be substituted with others to customize the organization. Then, the detailed configuration and setting of each component are provided to shorten the implementation time of the project. The users with the technical perspective can be involved in this stage to customize the setting of the components. Finally, the simulated operation of the new workflow can be shown to ensure that the redesigned workflow is suitable and can be adopted easily by the staff.

3.4 Benefits of the knowledge-based approach

Many chief executive officers stated that “Knowledge” can separate their company from their competitors. Many leading organizations are now discovering that they need to do a better job of capturing, distributing, sharing, preserving, securing and valuing the precious knowledge in order to stay ahead of their competitors. The process of managing knowledge in organizations is referred to as “Knowledge Management” (KM). The objectives of KM are acquisition of new knowledge from external sources, generation of new knowledge inside the organization, standardization of existing knowledge in the form of procedure/protocols, transforming individual (worker’s) knowledge into collective knowledge, and facilitation of the “reuse” and consolidation of knowledge about operations. Figure 3.6 shows the flow chart of organizational learning through maintaining a corporate memory (Borghoff & Pareschi, 1998). The lessons learned in the organization are stored in the knowledge repository so that they can be retrieved and used when needed.

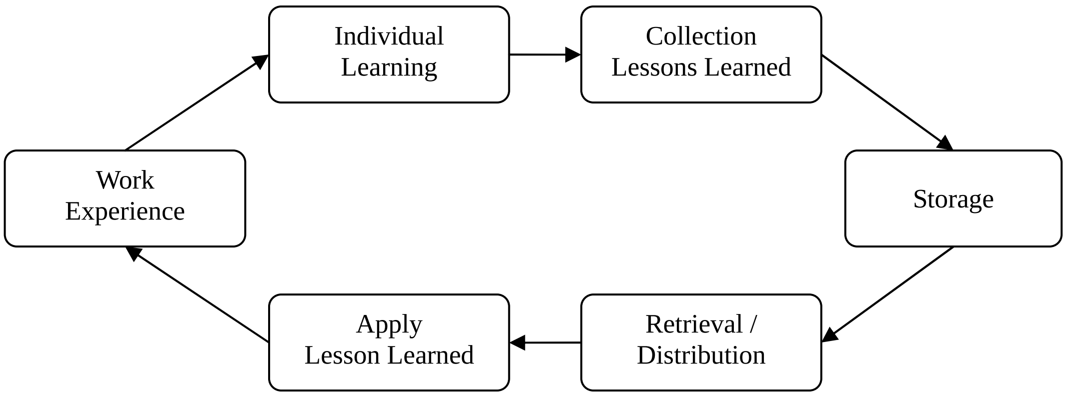


Figure 3.6 Organizational learning through maintaining a corporate memory

The success and failure projects can be managed in the knowledge repository. Knowledge repositories are widely recognized as the key components of the knowledge based system. The structure of the repository is entirely dependent on the kinds of knowledge stored. The repository can range from simply a list of frequently asked questions and solutions, to a listing of individuals with their expertise and contact information, to detailed best practices for a large organization.

By using different AI technologies such as case-based reasoning, the accumulated experience can be retrieved and reused easily to support the decision making of the consultant. Therefore, the proposed BPI solution becomes more reliable and suitable for their clients. It is a continuous learning process for the consultancy company to retrieve, revise and retain the knowledge for the BPI project.

Finally, the selection of the most suitable hardware and software to carry out the proposed BPI project is one of the major challenges for many consultants. It is time consuming for sourcing suitable hardware and software because there are many available applications on the market. The specifications and advantages of the hardware and software are not the same. Also, it is high risk of investment in new technology because they may not be suitable for the proposed business process and integrated with the existing systems. Therefore, knowledge-based approach can help the consultancy company to select and configure the most suitable hardware and software for the proposed new BPI solution with the past experience in the knowledge repository.

Chapter 4 Design and Implementation of the Knowledge-based Customization System

4.1 Introduction

In this chapter, the system design of the knowledge-based customization system (KBCS) is proposed by the author (Tsoi *et al.,* 2003). There are three main modules which are the **business analysis module** (BAM), **process improvement module** (PIM) and the **customization module** (CM). A hybrid decision-support system is used to support these modules. It relies on two reasoning methods, rule-based reasoning (RBR) and case-based reasoning (CBR) for assisting the selection of alternative BPI solutions and the decision-making during the selection of suitable technology and applications for the company.

4.2 Architecture of the knowledge-based customization system

KBCS is used by the consultancy company to enhance its core competence by shortening the project cycle and providing a reliable solution by the reuse of the successful past cases. The architecture of the KBCS is shown in Figure 4.1. It is implemented as a client-server system which is divided into a front-end tier and a back-end tier. The front-end tier provides the user interface for several modules in KBCS. The back-end of KBCS consists of the application tier and the knowledge repository tier for the storage of knowledge and for supporting decision making. The detailed descriptions of the tiers are shown below:

(i) The *user interface tier* - users can interact with the system through this tier to formulate the suitable technology and application for their organization. Three core modules are involved in the KBCS, which are: the business analysis module (BAM), process improvement module (PIM) and the customization module (CM), respectively.

(ii) The integrated application tier - several artificial intelligence technologies, such as case-based reasoning engine, rule-based expert system and simulation are used to facilitate the recommendation and decision making in the whole of the business process improvement project.

(iii) The knowledge repository tier - the accumulated organizational knowledge is stored and represented in different formals such as cases, rules and documents.

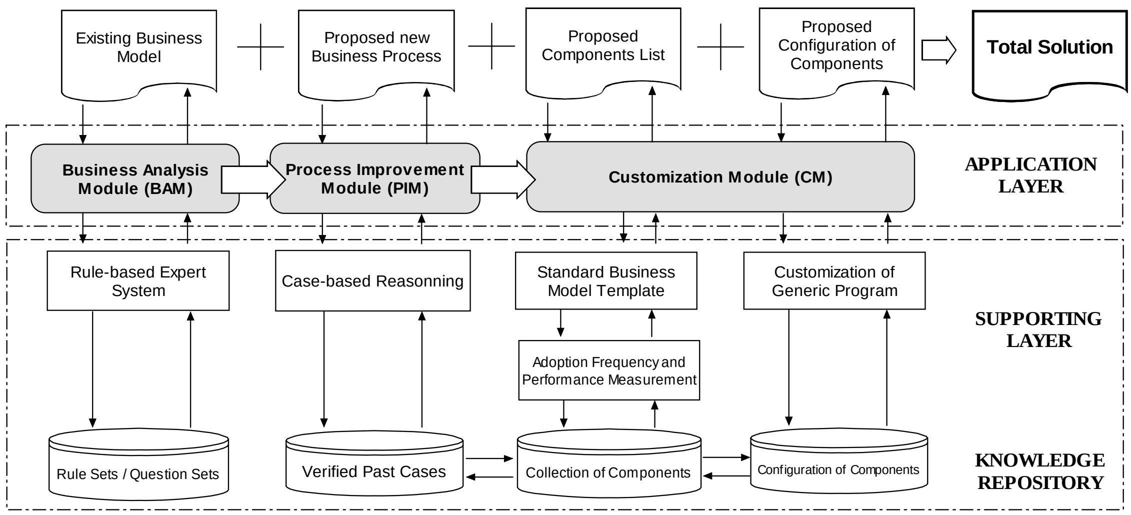


Figure 4.1 Architecture of the knowledge-based customization system (KBCS)

The performance and the reliability of the KBCS depend on the accumulation of the experience of the experts in the past projects. The knowledge repository can be built up by assimilation of the knowledge of the BPI projects in the organization. The system design, implemented technologies, customer feedbacks and the problems (such as the conflicts between the components) are appended to the knowledge repository for future reuse.

The expected outputs of the KBCS are listed as follows:

(i) The benefits and risks after the implementation of the process improvement project, with the proposed technology.

(ii) Part of the new workflow or the operation of the components can be simulated.

(iii) The list of components, such as hardware and software, for the implementation stage of the project.

(iv) The detailed configurations and settings of each component for the proposed project.

4.3 Business Analysis Module (BAM)

The business analysis module (BAM) relies on the initial evaluation of the existing business processes with the related important features as well as the strategic goals of the enterprise. This is accomplished by the use of an expert system which is associated with rich repositories of domain knowledge. The existing business processes are represented by a set of attributes which include the business workflow, the business rules as well as the basic information on the targeted business process. The information is analyzed by the expert system and the set of parameters is rearranged to formulate a proposed solution in the next module.

When the organization wants to improve their business process and then carry out the new business process with some hardware and software components, they can design the new process with two strategies:

(i) *Component-oriented* – the consultants begin by identifying the technology, hardware and software components that the candidates are using in solving their problem. Then, a new workflow is constructed to co-operate with the components.

(ii) *Objective-oriented* – the consultants propose a BPI plan for solving the problem, and then they look for components that fit within the resulting solution.

In this thesis, the proposed framework is based on the "objective-oriented" strategy which customized the enterprise systems by the formulation of strategies and objectives in the organization before the selection of the suitable technologies, hardware and software. A successful BPI project should match the organization's mission as well as the consider the chances and risks of the changing of the existing business operations. Failure to understand and respond to these factors is likely to be correlated with a disproportionate degree of risk and the potential for organization failure.

The analysis of the existing business process is a very complicated process and there are no straightforward procedures for doing this, which is a critical aspect of the whole business process improvement project. If the objectives and the existing business process are formulated incorrectly, then the solution provided can not be a good solution for the organization.

Traditionally, it is done by the experts or the consultants from the consultancy company. The analysis of the objectives and the current business processes can be done by conducting interviews with the managers, knowledge workers and technical workers. Some possible topics within the interview are given below:

(i) Current practice of the business processes (as well as the past practice if possible).

(ii) Improvements tried before and the report of the results.

(iii) The business challenges and the objectives of the company.

(iv) The details of the infrastructure of the company.

(v) Identification of related experts, documents and resources for further review.

The rule-based expert system is used to enhance the process of business analysis. The business analysis module (BAM) in the KBCS relies on the initial evaluation of the existing business processes with the relative important features as well as the strategic goals of the customer company. With the help of BAM, the customer can determine which business process has the greatest potential for change or improvement.

This is accomplished through the use of a rule-based expert system which is associated with rich repositories of domain knowledge. A series of questions is generated from the inference engine and then the user's responses are analyzed by the engine. The existing business processes are formulated and represented by a set of attributes which include the business workflow, the business rules as well as the basic information on the targeted business process. Finally, a diagnostic situation can be formulated to represent the current situation. In the next module, the past experience is extracted by finding the similar cases in the knowledge repository.

4.3.1 Analysis of Existing Business Model by Rule-based Expert System

The analyzed parameters are composed of explicit information and tacit expressions respectively. For example, there is some well-defined and explicit information such as the inventory size or number of workers, etc. in the consultant project about the warehouse management system. This information can be obtained directly from the managers or other employee. However, there is some information, such as the workflow and operations of the warehouse, which can not be obtained directly.

In the traditional approach, this process can be done by interview with the managers, knowledge workers and technical workers. In the KBCS, this process is replaced by the rule-based expert system. A series of questions are generated by the rule-based reasoning engine within the expert system to obtain the tacit information. The tacit expressions are inferred by firing the rules in the knowledge repository.

As shown in Figure 4.2, the rule-based expert system consists of the knowledge base and the inference engine. The knowledge base consists of a network of rules that interconnect to form a repository of knowledge. The inference engine interprets the rules and ranks them in a logical order. By generating a series of questions from the inference engine, the user's responses are analyzed by the IF-THEN rules. Hence, the user requirements and the attributes of the existing business processes can be obtained and used to formulate the solution set based on the Case-based Reasoning (CBR).

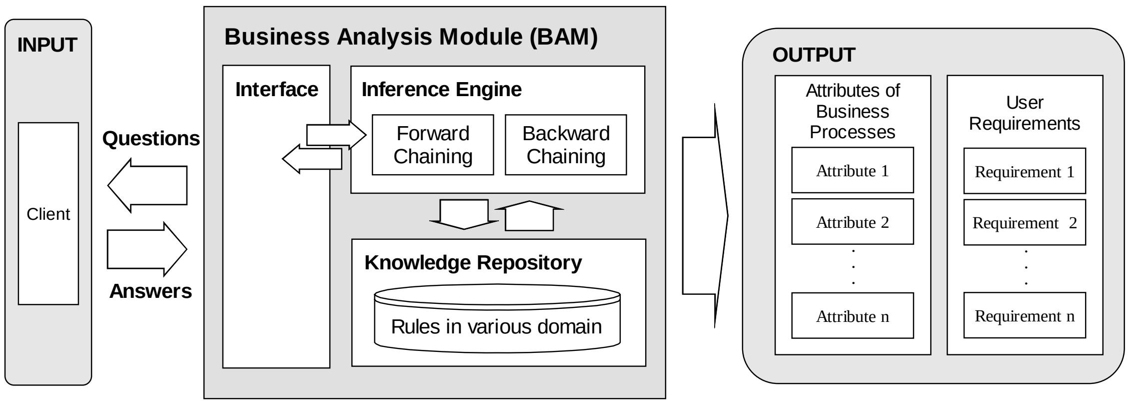


Figure 4.2 Analysis of the existing business model by the BAM

Table 4.1 shows ten sample attributes to represent the objectives of the organization and the information of finished goods store. The attributes not only consist of quantitative value but also consist of linguistic expressions or fuzzy sets. So, the type of attribute can be classified as crisp number (CN), crisp symbolic (CS), fuzzy linguistic (FL), fuzzy numbers (FN) and fuzzy intervals (FI) (Liao, Zhang & Mount, 1998).

Table 4.1 Sample attributes to represent the situation of finished goods store

Attribute	Type	Example	Attribute	Type	Example
Budget	FI	\$500k - \$650k	Product Nature	CS	Household Electrical
Development Time	FI	1 – 1.5 years	Average Product Size	FI	0.028 CBM
Inventory Size	CN	15,000 m^2	Average Product Cost	FI	\$400
Number of Workers	CN	30	Existing Software	CS	In-house software
Technical skill of workers	FL	0.10	Existing Network	CS	Simple intranet

4.3.2 Design of Rules in the Knowledge Repository

The basic idea of this module is that specialized domain knowledge of the consultants is presented as a network of interconnected "condition-action" pairs: IF-THEN rules. Each rule has two parts which is formulated in the form of:

IF < premise 1, premise 2 … > THEN < consequence >

The IF statement contains the information on which the premises must be true for firing the rules. The premises are deduced by matching the user input from the questions. The THEN statement describes the action taken in response or the consequence. A sample set of rules for the production logistic is shown in Table 4.2 and these rules determine the efficiency and reliability of the operations in production logistic.

4.3.3 Design of Inference Engine

The basic reasoning procedure is the manipulation of the logical expressions to create a new expression. The most important method is called "modus ponens". It is processed by the inference engine and the functions of the inference engine are listed as follows:

(i) Fire the rules

(ii) Present the user with the questions

(iii) Add the answer to the ES blackboard (or assertion base)

(iv) Infer a new fact from a rule

For example, the rule "IF distribution of products are recorded on PAPER AND human error = ALWAYS THEN reliability of product distribution = LOW". The inference engine will generate some questions such as "Do you have a systematic warehouse system to record the distribution of items, or it is recorded on paper work only?". If the answer "Paper" is given by the warehouse manager, then the inference engine knows that the fact of the first premise is "true". If the manager said that they always have human error on the handwriting, then the expert system can conclude that "the reliability of the product distribution is not accurate enough". This rule is "fired". Firing a rule occurs only when all the rule's hypotheses (conditions in the IF part) are satisfied (evaluated to be true). Then, the conclusion drawn is stored in the "assertion base". This is a database which stores "Low reliability of product distribution" and it can be used to satisfy the premise of other rules. For example, the system may recommend that using a bar-code system to identify the items and locations can reduce the human input error and also increase the reliability of the product distribution.

The rules are interpreted and ranked by the inference engine in a logical order. A series of questions will be generated from the inference engine to collect the customer's answers for firing the rules or realizing the premises. This process can be done in one of two directions, which is forward chaining (or data-driven approach) and/or backward chaining (or goal-driven approach). It will be continued until no more rules can be fired or until a goal is achieved.

Forward chaining is a data-driven approach. It starts from available information as it becomes available or from a basic idea, and then a conclusion is attempted to draw (as shown in Figure 4.3). In the figure, the A, B, C … G are the "premise" or "consequence" parts in the IF-THEN rules. The R1, R2 … R4 are the rules in the inference engine. The inference engine analyzes the problem by looking for the facts that match the IF part of its IF-THEN rules. As each rule is tested, the program works its way toward one or more conclusions.

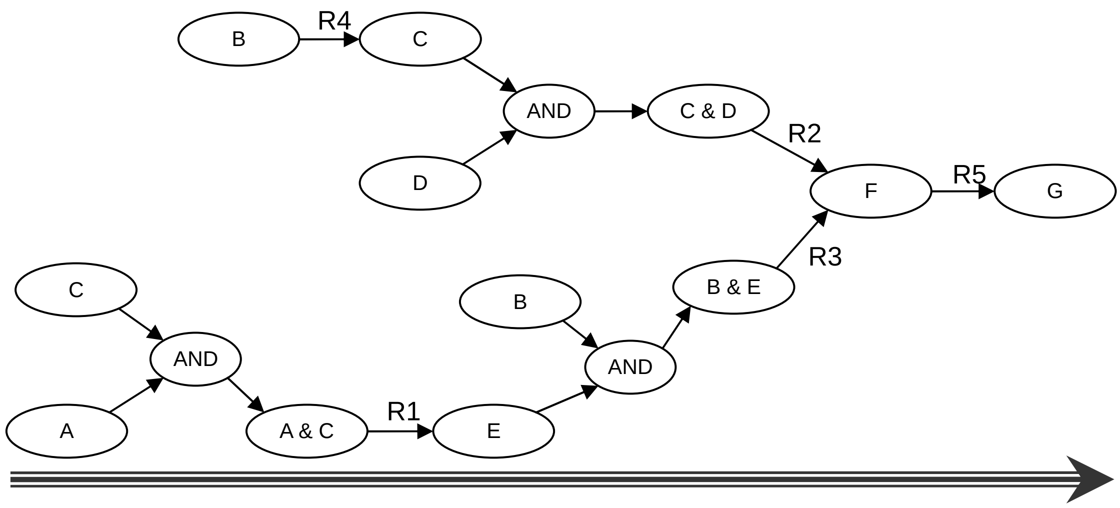


Figure 4.3　Forward chaining in an inference engine

On the other hand, backward chaining is a goal-driven approach in which an expectation of what is going to happen (hypothesis) is started and then seeks evidence that supports your expectation (as shown in Figure 4.4). The inference engine starts with a goal to be verified as either true or false. Then it looks for a rule that has this goal in its conclusion part of the IF-THEN rules. It then checks the premise of the rule in an attempt to satisfy the rule. If the goal is proven, then the next goal is tried.

Here is an example involving an investment in hardware and software for the warehouse management system. The sample premises used in the KBCS are shown in Table 4.2. In the inference engine, there are many rules for inferring and generating the conclusion. Table 4.3 shows some sample rules (simplified) being used in the system:

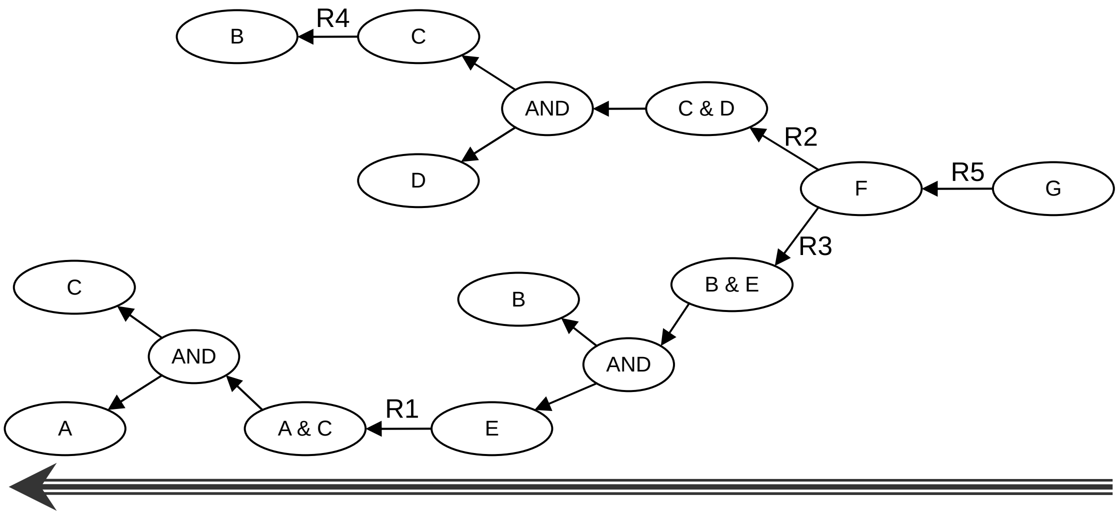


Figure 4.4 Backward chaining in an inference engine

Table 4.2 Sample premises to be used in KBCS

Premise	**Description**
A	The budget is over $20,000.
B	The logistic workers are well enough educated.
C	Training will be provided within the coming three months.
D	Have sufficient network sockets in the inventory workspace
E	Bar code is printed on the package
F	RFID is embedded in the package
G	Invest in bar code scan-based warehouse management system
H	Invest in RFID warehouse management system

In the KBCS, both the forward chaining and backward chaining are used. Firstly, the basic information for the BPI is collected by forward chaining, such as the budget of the project, the existing equipment of the warehouse, etc. It attempts to derive as much information as possible and places it in the working memory. It acts as a catalyst for the system by causing the firing of rules that add further information to the working memory.

Table 4.3 Sample rules to be used in KBCS

	IF	**THEN**	**Rule**
R1	IF the logistic workers are NOT well enough educated	THEN training is required	IF B is *true* THEN C is *true*
R2	IF the budget is over $20,000 AND bar-code is printed on the package	THEN investment on bar code scan-based warehouse management system is recommended	IF A is *true* AND E is *true* THEN H is *true*
R3	IF the budget is over $20,000 AND RFID is embedded in the package AND the workers are educated enough	THEN investment on RFID warehouse management system are recommended	IF A is *true* AND F is *true* AND B is *true* THEN H is *true*

Then, the feasibility of the investment of the warehouse management system is analyzed by backward chaining. For example, if the company wants to invest in the RFID technology, the RFID tag must be embedded in the components or finished goods package. Also, the investments of the RFID readers, computers / handheld devices or network sockets in the production line are also under consideration. Questions about the feasibility of the premises are generated. Then, the feasibility of the investment on the RFID technology can be obtained.

4.3.4 Formulation of the diagnostic situation

The rule-based expert system can help the consultants to analyze the objectives and existing situation of the client company. A diagnostic situation can be formulated to codify the company situation as different parameters. In the next module, the successful past experience is extracted by finding the similar cases in the knowledge repository. Therefore, a succinct representation of the current situation and filtration of the feasibility of alternative solutions can increase the accuracy and performance of the reuse of existing organizational experience when it is applied to the new problem.

4.4 Process Improvement Module (PIM)

Traditionally, the solution of the BPI project is proposed by the experts or the consultants from the consultancy company. However, it is highly dependent upon the exposure of the experts to similar projects and on their experience. The traditional knowledge sharing approach in most consultancy companies is called "people networking", which means that the process of knowledge transfer only happens to a limited extent between groups of knowledge workers. There are two problems of "people networking" in practice. Firstly, it is hard to retain the knowledge in the company if experienced staff leaves the company. Secondly, the learning process is very slow for the new staff.

A better approach "the codifying of experience" (Kepczyk, 1999) can accumulate a person's knowledge in one or more knowledge repositories and shares it probably through IT. In the present study, the valuable empirical experiences of the consultants are accumulated and stored in the knowledge repository in different formats such as rules, cases or documents. By capturing best practices and especially solutions to problems, similar situations can be dealt with efficiently and effectively. Also, the system is used to enhance the knowledge sharing between the consultants, to reuse the knowledge in the similar BPI projects, and to deliver the knowledge to the right people to prevent repeating the errors of the past.

In the KBCS, after the formulation of the diagnostic situation, some appropriate technologies or enterprise applications are proposed by the process improvement module (PIM) with the reuse of the valuable empirical knowledge of the previous business process improvement projects. Cases are retrieved from the knowledge repository with the following critical information:

(i) the innovated technology in the retrieved case.

(ii) the hardware and software used in the retrieved case.

(iii) the implementation period and the total investment cost of the retrieved case.

(iv) the estimated profit margin, turnover and ROI for their company.

By comparing the technology, redesigned workflow, opportunities and the risks of the proposed technology, the most suitable case (or part of the case) can be reused by the organization. A schematic diagram of the PIM is depicted in Figure 4.5. After the formulation of the user requirements and business attributes, appropriate cases of previous implementation of enterprise applications are recommended based on a case-based reasoning (CBR) algorithm (Aamodt & Plaza, 1994). They are listed and ranked in descending order according to the similarity value. The detailed information of the projects and the profit margin and ROI are estimated by the system to support the decision making of the user.

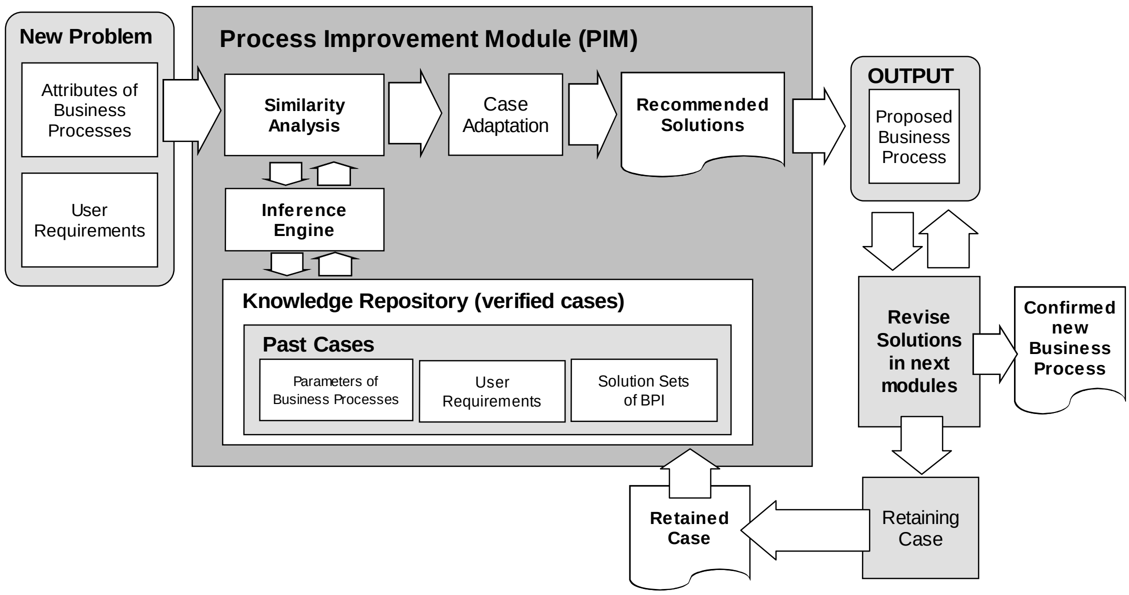


Figure 4.5 A schematic diagram of the PIM

The most suitable case can be adopted by the user after considering the opportunities and risks of the new technology or business model. The recommended case can either be adopted or revised to fulfill the unique company situation in the next module. The confirmed case is implemented in the enterprise. After the implementation of the project, the case is verified and retained in the knowledge repository for future reuse.

4.4.1 Deriving solutions by Case-based Reasoning (CBR)

The improvement of the business processes or development of a new process are retrieved in the knowledge repository by CBR. That it is used for problem solving and learning has attracted a lot of research interest over the last decade (Aamodt & Plaza, 1994; Kolodner, 1992; Simoudis, 1992). It is able to utilize the specific knowledge of previously experienced, concrete problem situations (cases). At the highest level of generality, as shown in inter-layer of the Figure 4.6, a general CBR cycle may be described by the following four processes:

(i) RETRIEVE the most similar cases or cases.

(ii) REUSE the information and knowledge in that case to solve the problem.

(iii) REVISE the proposed solution.

(iv) RETAIN the parts of this experience likely to be useful for future problem solving.

It is a knowledge management and problem solving paradigm that in many respects is fundamentally different from other major AI approaches. CBR is able to utilize the specific knowledge of previously experienced, concrete problem situations (cases). It is used to adapt the solutions that have been used to solve old problems, for use in solving new problems. A new problem is solved by finding a similar past case, and reusing it in the new problem situation.

In the outer layer of the Figure 4.6, the CBR cycle starts with the knowledge needs of a new business process improvement project. Some similar past BPI projects are retrieved which are similar to the diagnostic situation of the new project. With various decision support and AI technology, the client company can revise the retrieved case and customize the most suitable process and components for their company. The new case, as well as the related documents, is retained in the knowledge repository for future reuse.

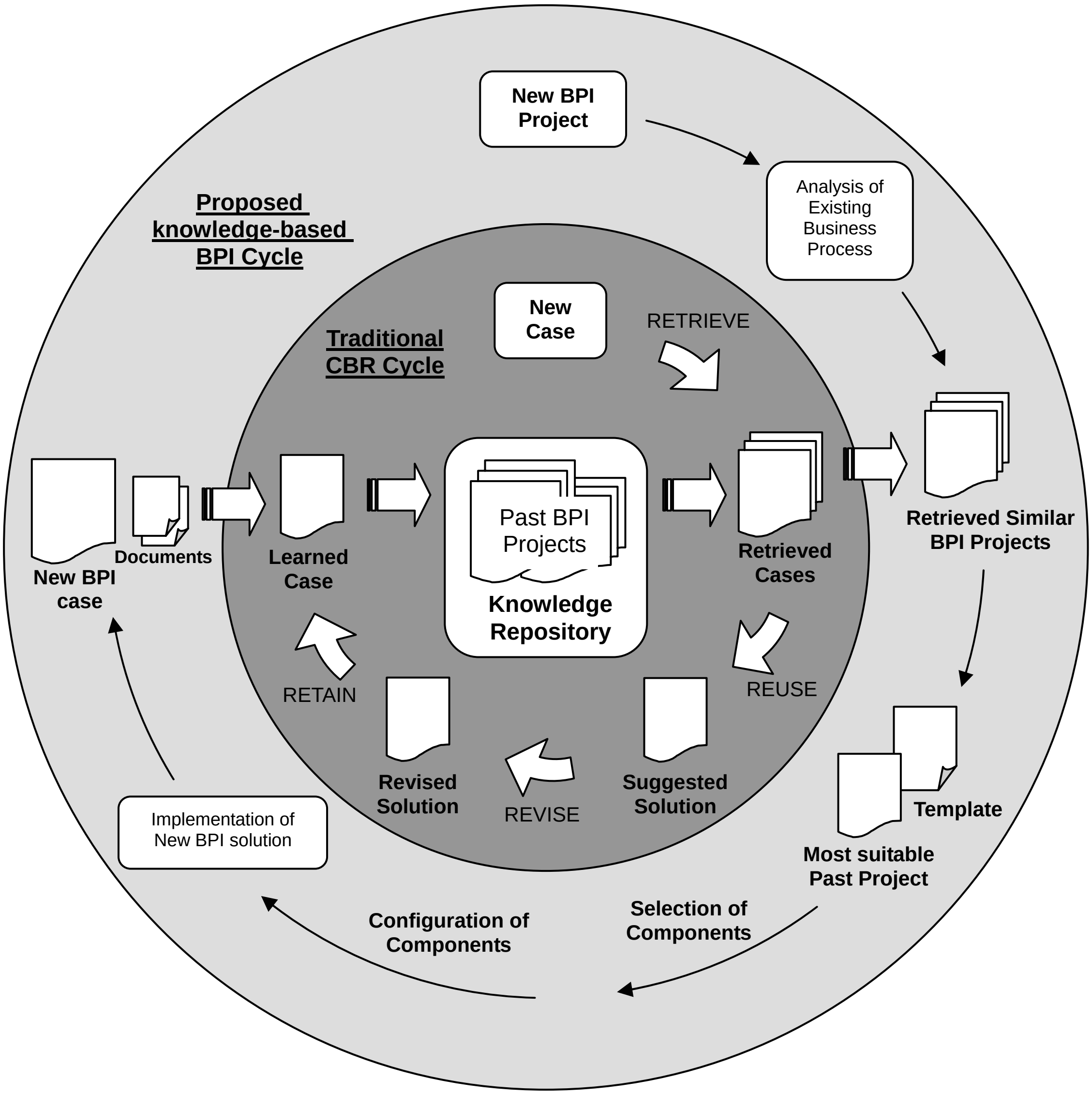


Figure 4.6 The CBR cycle of the proposed knowledge-based BPI cycle

Case-based reasoning has proved to be an extremely effective approach in complex cases (Kolonder, 1993). According to Riesbeck and Schank (1989), the basic justification for the use of this approach is that human thinking does not use logic or reasoning from first principles.

The user inputs a new problem description to the CBR system. Then, one or more previously similar cases are retrieved from the case library so that they can be adopted and reused to solve new problems (Aamodt & Plaza, 1994; Becerra-Fernandez & Aha, 1999).

4.4.2 Design of Cases

The case-based reasoner is heavily depended on the structure and content of its collection of cases (Aamodt & Plaza, 1994). A case is the primary knowledge-base element in a case-based reasoning application. It defines a situation or problem. The cases in the case library are designed for storing the information of each past successful business process improvement projects in various business domain areas. In CBR terminology, a 'case' usually denotes the situation of a problem. All cases in the knowledge repository are codified and made up of three parts, which are the **case number**, the **case symptoms** and the **solution sets**. The structure of each case can be represented as follows:

Case (case number, case symptom, solution set)

The case number is a unique number which is assigned by the system sequentially for the identification of the each verified case. The case symptom consists of the problem description and the parameters of business processes for calculating the similarity with the current situation. Some major parameters for the cases of product logistics in warehouse management are shown in Table 4.4. The solution set consists of the detailed design and implementation information of the BPI project. The solution is also linked to the related documents, resource and the experts involved in that project. Table 4.5 shows a sample case of the inventory management system for a logistics center.

Table 4.4 The content of cases for product logistics of an inventory store

<table>
<tr><th colspan="2">Field Type</th><th>Field Name</th></tr>
<tr><td colspan="2">Case Index</td><td>Case Number</td></tr>
<tr><td rowspan="13">Case Symptom</td><td rowspan="10">Parameters of Inventory Status</td><td>Inventory Size</td></tr>
<tr><td>Product Nature</td></tr>
<tr><td>Average Product Size</td></tr>
<tr><td>Average Product Cost</td></tr>
<tr><td>Workflow of Current Workflow</td></tr>
<tr><td>Challenge of Current Workflow</td></tr>
<tr><td>Existing Software</td></tr>
<tr><td>Existing Network</td></tr>
<tr><td>Number of Workers</td></tr>
<tr><td>Technical skill of workers</td></tr>
<tr><td rowspan="3">Objectives of BPI Project</td><td>Budget</td></tr>
<tr><td>Development Time</td></tr>
<tr><td>Objectives of BPI Project</td></tr>
<tr><td colspan="2" rowspan="2">Solution Set</td><td>Past Success BPI Project</td></tr>
<tr><td>Template of Components Integration</td></tr>
</table>

For the calculation of the similarity function, all cases are represented in a vector form. For the Equation (4.1) and (4.2), let X be case indexes whose feature values are x_i. The verified cases in the knowledge repository be the Y whose feature values are y_i. The number of feature is m for both the diagnostic situation and the case.

$$X = [x_1, x_2, x_3, ..., x_m] \tag{4.1}$$

$$Y = [y_1, y_2, y_3, ..., y_m] \tag{4.2}$$

Table 4.5 A sample case of the inventory management system for a logistics center

Index	WM-016
Project Title	Scan-based Trading based on Palm Technology for Finished Goods Store
Company Name	Company ABC.
BPI Area	Inventory Management System for Logistic Center
Development period	3 months
Trial run period	6 months
Project budget	HK$ 100,000
Business Challenge	1. Stock in and stock out transactions are recorded by paper. 2. The inventory information is not computerized. 3. They can't search for the goods in a systematic way.
Inventory Information	1. Inventory Size = 57,600 m^2 2. Number of workers = 20 workers
BPI Solution	Using scan-based Palm Technology for managing warehouse information - Hardware: Symbol handheld devices, bar-code printer, etc. - Software: self-developed software to converter the PDF database to XML file - Others: assign the unique location bar-code system.

4.4.3 Retrieval of similar cases

Retrieval of similar cases is a primary step in CBR and the similarity measure plays a very important role in case retrieval. If many past cases are suitable for the current situation, the appropriateness of proposed solutions is determined by the similarity calculation. The retrieve task starts with a (or partial) problem description, and ends when a best matching previous case has been found.

There are two major case retrieval approaches:

(i) One is the distance-based or computational approach, which calculates the distance between cases from a number of objects constituting the cases. The most similar case is determined by the evaluation of a similarity measure.

(ii) The second is the indexing or representational approach. The similar case is coded into the structure of the case base itself. The cases are connected by indexing structures. The indexing structure can be traversed to search for the similar case. Another situation is based on the graphical appearance of the cases, which compares abstracted bitmaps of design pictures.

In the present research, the similarity measure is focused on the distance-based approach. The PIM makes use of the inverse of weighted normalized Euclidian distance or Hamming distance (Liao, Zhang & Mount, 1998) as the similarity measure.

The retrieval of cases is based on the similarity function, $SIM(X,Y)$, of the feature of the case selected. The similarity function can be calculated in various ways. Equation (4.3) shows the most common equation for finding the similarity of two cases (Pal & Palmer, 2000).

$$Similarity = SIM(X,Y) = 1 - DIST(X,Y) = 1 - \sqrt{\sum_{i=1}^{n} w_i^{\,2} dist^2(x_i, y_i)} \tag{4.3}$$

where n is the number of attributes, w_i is the normalized weighting of the i-th attributes.

The distance, $DIST(X,Y)$, between X and Y can be calculated by using the Euclidian distance, where weight w_i is normalized for denoting the importance of the i-th attributes and $i = 1, 2, \ldots n$, being the number of the attributes in the cases. The normalized $dist(x_t, y_i)$ is often represented as Equation (4.4).

$$dist(x_i, y_i) = \frac{|x_i - y_i|}{|\max_i - \min_i|} \tag{4.4}$$

For numerical attributes, $\max_i$ and $\min_i$ are the maximum and minimum values of the i-th attributes. By calculating the similarity, the retrieved cases are ranked in descending order according to the similarity. Detailed descriptions and related documents for each case can be selected by the /users.

The consultants can retrieve and adapt the case as a recommendation of the BPI project. The proposed solution can be revised in the Customization Modules until it satisfies the customer's needs. The new solved case is then retained into the knowledge repository. The consultant has to select the case that should be retained and determine how to index the new case into suitable case catalogue. Moreover, a regular review of the knowledge repository is needed to maintain the size of the repository. Some outdated cases can be archived in an offline repository and some very similar cases can be merged or removed to reduce the size of the repository.

4.5 Customization Module (CM)

According to Lientz and Rea (1999), in most BPI projects, much time is spent on the implementation of the project. The majority of books and articles don't cover the implementation problem during the project. However, in most BPI projects, the implementation of the hardware and software components under a well designed system architecture is the end product of the projects.

In the implementation period of the proposed project, most organizations can not carry out the project due to the following reasons:

(i) They found that choosing the suitable technology and hardware is a very critical and time-consuming task. External help from the expert or consultant company is sought for the selection of technology (Jarrar & Aspinwall, 1999)

(ii) Integration of the new technology and components with the existing business flow is a difficult task.

(iii) Lack of experience to implement the large-size enterprise applications (e.g. ERP system) is a problem.

(iv) Highly-skilled employees are required to setup and initiate the system to fit the organization's best practice.

(v) Some software can not be customized to handle the unique business operations and information.

In this section, the customization module (CM) is introduced. The selection and the customization of suitable technology, hardware and software are undertaken by the CM. In the present study, the components are encapsulated within the object-oriented technology with the standard protocol, input and output interface that allows efficient communication with other objects (Sutherland, 1995). Also, the components can be exchanged with other objects since they have well defined and common interfaces. Then, standard template is retrieved. This is a set of components with a well-defined interactive relationship with each other. The user can redesign the templates or substitute the components to fit their unique situation and requirements. The recommendation of the suitable substituted components is dependent on the adoption frequency and the performance index of the component. Moreover, the general configurations and settings of the adopted components are recommended. Their retrieval is based on their similarity to past situations that are stored in the knowledge repositories. Also, some generic programs are provided to fit the unique operation of the organization. They can be customized to provide different functions according to the customer's requirements. Therefore, the enterprise application can be customized using the proposed design and the unique workflow of the enterprise. The enterprises can also customize their own applications according to their business needs with a minimized investment that minimizes the time and the risk of the implementation.

4.5.1 Representation of Hardware and Software by Object Components

Each object component is incorporates the object-oriented design knowledge with the standard protocol, input and output interface that allows efficient communication with other objects. Objects can be exchanged and aggregated to fit different business operations.

Business objects are defined as aggregates of domain objects which are the fundamental components in the system. They are objects representing the data and behavior of the business entities that the application is intended to manage. Individual, persistent shared business objects are specified in terms of their parents, their properties, and their methods.

For the hardware and software components, business objects can be defined as the components with one or more business functions. They can be integrated together to provide a complex business model with rigorous constraints and relationships between the components.

4.5.2 Template for the Process Improvement Project

After the adoption of the reused case, the hardware and software applied in that case are retrieved with the case. The components are recommended to the organization because they are operated successfully in another company with a similar business model. However, the list of the components can be totally accepted by the organization or revised by the substitution of part of the components. Normally, the components are revised in the following situations:

(i) new or updated drivers, hardware and software are offered for sale in the commercial market.

(ii) the technical and knowledge requirements of the implementation of individual component are too high for the organization.

(iii) some components in the proposed solution already existed in the organization.

However, the replacement of the components without surveillance will result in the uncoordinated operation of the whole system. In order to provide the capability of substitution of the components in this system, standard templates are provided by the KBCS to assist the replacement of the components.

It is similar to a “model-driven development”. It allows consultants to build an enterprise application more quickly. In addition, it allows consultants to focus on the application functionality, but not the implementation level, in this stage.

A template provides some well-defined constraints of components and the interactive relationships between the components in the specific business model. Since all business objects are encapsulated with the object-oriented (OO) technology, the business objects with the same interface or within the same family can be substituted without any conflict. For example, a scan-based inventory management template (Figure 4.7) is retrieved if an inventory management application is recommended by PIM. It is a list of essential hardware components, business processes, business objects and utilities in this module.

Business objects are encapsulated as generic components for the implementation of a scan-based inventory management system. Some components are essential for the implementation of the scan-based inventory management system such as handheld devices, built-in or plug-in scanning devices, PDA programs, PDA database, etc. However, some of them are optional components such as the wireless device and wireless access point, etc.

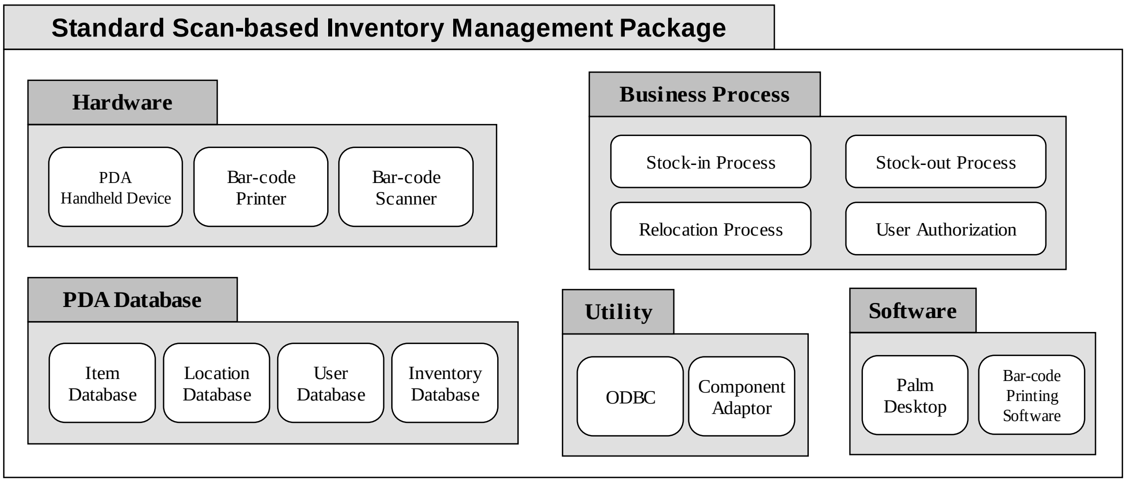


Figure 4.7 Standard Template for Scan-based inventory management

The template provides the interactive relationships and constraints between the components. Once it is requested that the particular component be replaced with other components, a list of components that conform to the constraints of the template is generated. Moreover, an alternative composition of the components is provided in this template. The handheld device and the server can either be connected by a cradle (base option) or by a wireless access point (alternative option).

As shown in Table 4.6, the template is a generic framework of the implementation of the inventory management application. It can be used for various cases with different compositions of hardware and software component. For example, once the Symbol SPT1746 handheld devices are selected in the inventory management applications, different connection methods between the handheld device and the computers are provided by the template. It can be either connected to a local area network (LAN) via the cradle or to the wireless local area network (WLAN) via the wireless access point. Therefore, the user can select the most suitable connection method for their applications.

Table 4.6 Composition of different business objects for various business natures

Business Nature	**Implementation Business Objects (Hardware and Software)**
Inventory Management	1. Symbol SPT1746 (Handheld devices with built-in scanner and wireless)
	2. Symbol Spectum24 11Mpbs Access Point
	3. Stationary PC to collect the transactions from all handheld devices
Retail Store	1. CIPHER Stationary scanning device (connect with PS/2 port)
	2. Star SP2000 (Receipt Printing Device (mid-volume))
Outdoor Petrol Station	1. Symbol SPT1500 (Handheld device with built-in scanner)
	2. Monarch 6015 (Integrated mobile printer)
Hospital	1. Mobile device with build-in scanner and memory
	2. Cradle for data exchange (wireless is not preferable)

4.5.3 Recommendation of Component Substitution

Many organizations may find that only part of the design functions of these large software systems is suitable for their requirements. Some unnecessary functions are included in the commercial systems because they are packaged in the software system. Lack of experience and technological knowledge may lead to difficulties in using a complex system and excessive money is invested for these unnecessary functions in the system. Therefore, due to the expensive investment cost of a large system, the enterprise should look for the customized software that is just right for their objectives and which involves the minimum improvement cost.

Due to the complexities of the software, only a small number of staff can operate them. Many settings and configurations should be carried out on the large software packages before they are implemented. In addition, customization for specific application is often not easy. The workflow of the system may not map into the current practice of the organization. However, the software can not be customized to fit local practice easily. As a result, many BPI projects fail or can’t produce the expected result.

The templates provide guidelines for the integration of the hardware and software components. The latest information of hardware and software are updated and controlled by the consultants. Only qualified and reliable components can be found in the system and other consultants can select and get the detail information about the components for system design. This minimizes the conflicts and allows all consultants to select alternative compositions of the components. However, an excessive number of commercial hardware and software packages are found in the market. The task of finding suitable components based on the user's criteria is introduced in the following section. Decision situations that involve a finite and usually not a large number of alternatives are modeled by an approach called decision analysis, in which the alternatives are listed with their forecasted contributions to the goal(s) or objective(s). They can be evaluated and the best alternative can be selected. Single-goal situations can be modeled with decision tables or decision trees. Multiple goals (criteria) can be solved by using weightings based on decision-making priorities.

The selection of the most suitable substitute components is typically split into two stages. An initial elimination process which retrieves a set of plausible components from the database, and a more elaborate process of selecting the best one from among these. In the first stage, the components that can not meet the requirements of the enterprise application are eliminated. Based on the objectives, requirements, technical knowledge and the existing assets of the enterprise, only the plausible components are shown to the user and the unsuitable components should be eliminated because they can not achieve the requirements of the enterprise. The classification of the suitable and unsuitable objects is done via a decision tree analysis as shown in Figure 4.8. In each decision node, two or more options are provided. A suitable option is selected according to the user requirements. Then, a set of plausible components is selected in the second stage.

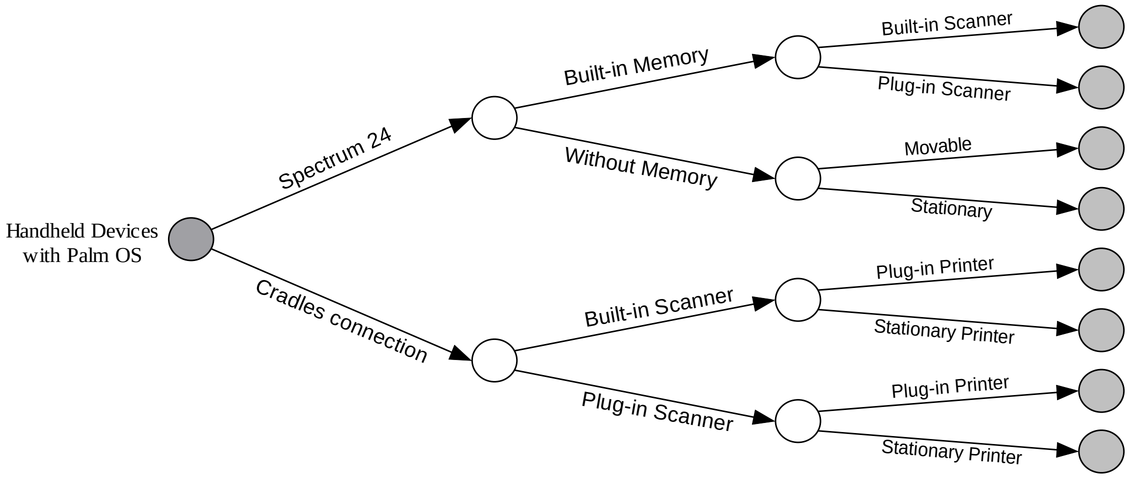


Figure 4.8 To distinguish suitable components of handheld devices

In the second stage, a performance analysis is undertaken in which the performance index of the components is calculated. Each component includes the basic attributes indicating its performance, such as the printing speed, price and development time. They are ranked in decreasing order of a component performance score (S) calculated on the basis of adoption frequency, the performance index and a series of weighted critical factors of the performance of the components (i.e. CPU performance index, size of memory, etc) as follows:

$$S = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \tag{4.5}$$

where n is the number of criteria, w_i is the weighting of the i th criterion, x_i is the normalized value of the i th criterion which should carry value between 0 and 1.

For example, if the company wants to use PDA handheld devices in the new warehouse management system, and the KBCS system proposes PDA handheld device “Symbol SPT-1746” as a suitable and acceptable component. The adoption frequency of each component indicates the popularity of that object. This indicator shows the acceptance of that object in the market. Generally, the business object should be more stable and easy to integrate with other objects.

4.5.4 Recommendation of Configuration and Setting of Components

In the customization module, the components can be customized in two phases. Firstly, the configuration of components can be checked against the information stored in the knowledge repository. For example, the design of the database for storing the inventory information is a time consuming task. However, for similar enterprise applications, most data fields are common and can be shared among various applications. Table 4.7 shows the common database design of the stock-in Personal Digital Assistant (PDA) program for an inventory management application.

After configuration of the components with the common setting, the components have to be customized to fit into the unique requirements of a specific business process. In the second phase, some generic programs are designed to provide special functions for the enterprise applications. For example, the form layout and the data field of the PDA program can be modified by the configure file. Once the user fills in the information of the configure file, a run time stock-in program can be generated and customized with the required form layout and database structure.

Table 4.7 Common database design of a stock-in PDA program for warehouse management

Field Name	Field Type	Input Method	Remark
Item Number	20 Chars	Bar Code Scanning	Retrieving of item description in item table
Location Number	15 Chars	Bar Code Scanning	Retrieving of location description in the location table
Quantity	Integer	Number Pad	

Chapter 5 Case Study and Discussion

5.1 Company background

To demonstrate the capability of the proposed KBCS, a prototype system is built and trial run in a manufacturing company, Kaz (Far East) Limited (formerly Honeywell Consumer Products (HK) Ltd). It is a well established and multi-national company which manufactures a full line of home comfort products such as steam vaporizers, cool moisture, humidifiers, moist and dry heating pads, etc. There are about 45 employees in Hong Kong and around 2,650 in mainland China. Its corporate headquarters, design, sale offices and production plants are widely dispersed in Europe, North America and Asia.

The company possesses a management and support office in Hong Kong and the manufacturing facilities are located in Shajing of Shenzhen in mainland China. The factory in Shajing currently comprises 13 buildings with a total floor space of 720,000 square feet. The newest building contains a training center, showrooms and a "cyber house" as well as serving its purpose as a Distribution Center.

Traditionally, they relied on a paper-based warehouse data acquisition and searching approach. The data entry and product tracking processes in the warehouse relied largely on the warehouse workers. The warehouse data were not recorded accurately and was not detailed enough due to the human error during data entry into the warehouse management system. The warehouse data can not be synchronized with the warehouse management system. A long lead time is found because of the human input of paper-based data to digitized records in the warehouse management system. This affected the efficiency of other production logistics operations and decision making such as the inventory replenishment, production planning and control, etc. They wish to improve their production logistics operations in their production plant (in Mainland China) by a systematic approach and replace the traditional paper-based inventory management approach.

5.1.1 Current workflow of the Finished Goods Inventory Management Policy

In the current practice, majority of the operations inside the logistic center of the company have not been computerized.

Here are the operations of the finished goods warehouse:

(i) After the manufacturing and packaging processes, the finished goods are sent to the finished goods warehouse through the conveyor for storage (Figure 5.1a).

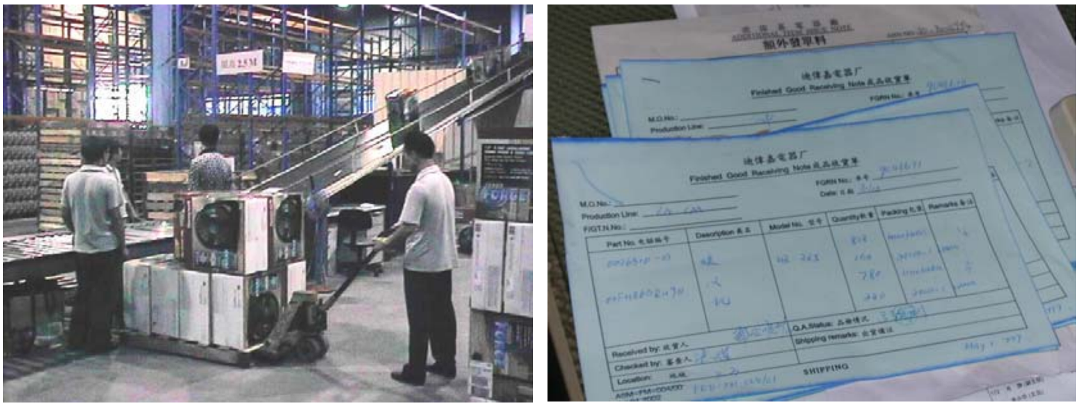
(ii) The Finished goods Receiving Note (FGRN) is sent to the warehouse (Figure 5.1b) and the warehouse workers sign on the FGRN when receiving goods.

(iii) A fixed amount of finished goods is put on a pallet. Then, it is transferred to the shelf by the truck. The selection of location depends on the capacity of each shelf. No fixed location is assigned to the specific items.

(iv) The quantity and stored location of the finished goods are recorded on a paper which is hung on each shelf as shown in Figure 5.2.

(v) The items are kept on the shelf until the pick slip is received.

(vi) As shown in Figure 5.3, the data on the FGRN is entered into the warehouse management system by the warehouse workers. A “Finished Goods Status List” is generated daily to report the current status of the inventory. It includes the stock in, stock out and the balance of the records for each model.



(a) (b)

Figure 5.1 (a) Receiving of finished goods and (b) Finished Goods Receiving Note

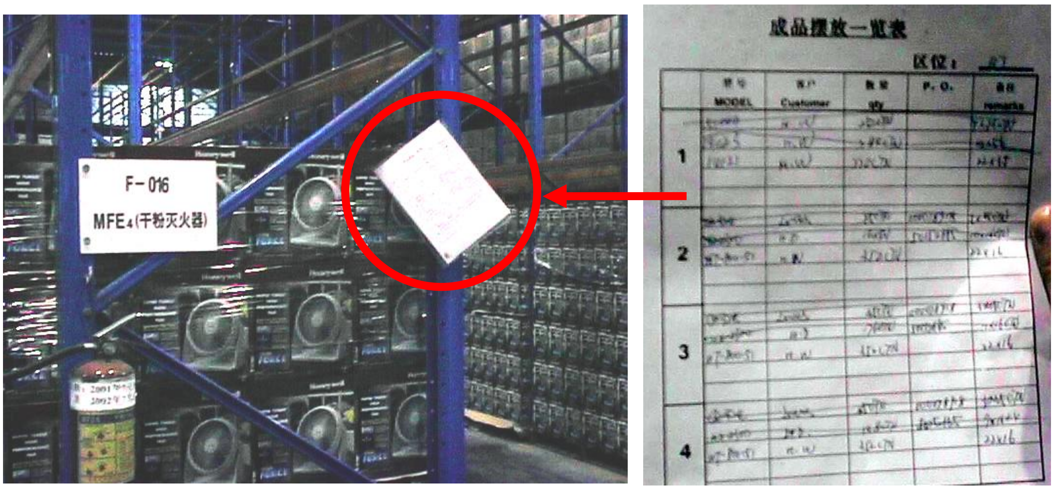


Figure 5.2 A paper for recording the stored items on each shelf

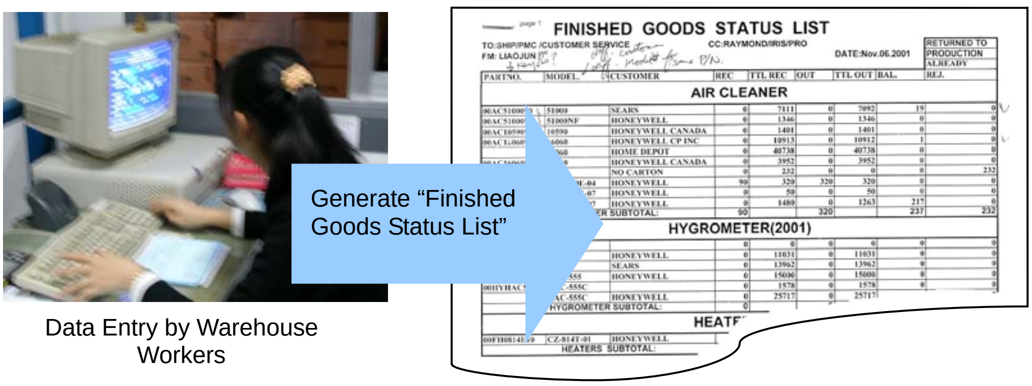


Figure 5.3 Data entry of the warehouse data and report generation of Finished Goods Status List

5.1.2 Business Challenge of the Operation of Production Logistics

The data entry, distribution of the finished goods and product tracking processes still rely on the warehouse workers and the information is recorded mainly on paper. Therefore, the company suffers from inaccurate inventory records, stock tracking problems and warehouse cost controls. The incumbent computers did not record the distribution of the finished goods which severely limited effective management decision making as well as production planning. The major business challenges and problems for the company are outlined as follows:

(i) There are too many standalone systems in each department. The information can not be integrated between different standalone systems. Therefore, redundant data input is required when the product data are transferred from one system to the other.

(ii) With the current approach, the distribution of the goods in the warehouse can not be shown in the warehouse management system and the inventory data are not accurate and detailed enough. This might be due to the human error introduced during the entry of data.

(iii) There is no barcode system to assist the collection of the inventory data for inventory management.

5.1.3 Objectives of the BPI in the warehouse management system

The management was clear in their objectives to put in place a system for recording the precision warehouse data and distribution of goods. Difficulties arose in sourcing new generation technology and software to fulfill the requirement of the stock and production planning. Here are the objectives for the improvement of the business process in the warehouse management system:

(i) To understand the concurrent operation of the logistics center of the finished goods.

(ii) To count the number of workers, trucks and equipment that is involved in the operation.

(iii) To understand the existing bar-code system of the finished goods produced.

(iv) To suggest a suitable bar-code system to identify the storage location.

(v) To suggest the number of items of hardware equipments for the scan-based trading system (SBTM).

5.2 Improving warehouse management operation with the KBCS

In the present study, an enterprise application is customized for the company according to the following four steps:

(i) Analysis of the existing business model and business challenges.

(ii) Recommendation of the enterprise application.

(iii) Proposing of a list of software and hardware components for the implementation of the enterprise application.

(iv) Customization of the components and configuration of the components.

5.2.1 Analysis of the Current Warehouse Operations

The business process improvement project started with the analysis of the current situation and business objectives. A snapshot of the scenario of the analysis process for the current finished goods warehouse management is shown in Figure 5.4. The BAM starts with the selection of the appropriate area for improvement. Only the information of the operations of the finished goods warehouse is collected and analyzed in the case study. Then, the explicit and tacit information is collected in two different ways. The explicit information can be obtained from the users directly. Then, the tacit information may be obtained by asking the users some questions. . The answers are deduced by the inference engine. For example, if the recording of the stock-in and stock-out operations are recorded on paper and the inaccuracy of the inventory information is found to be due to human error, the reliability of the number of products and the product distribution in the finished goods warehouse would be designated as unreliable. Recommendations are then made for the improvement of the accuracy of the data acquisition and inventory management operation. Table 5.1 and 5.2 show part of the diagnostic situation and part of the values and weightings of the new case created in the system respectively.

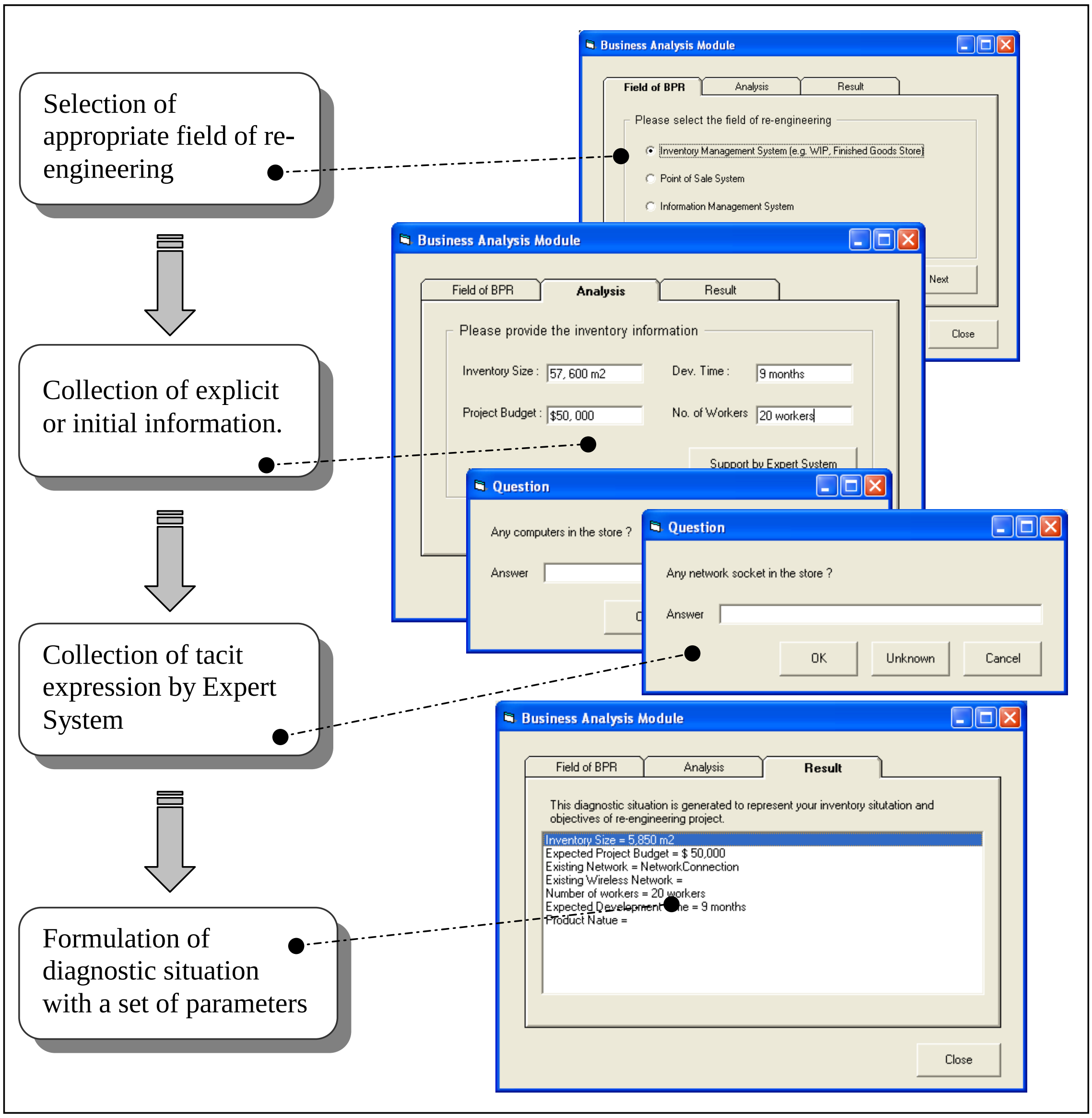


Figure 5.4 A snapshot of the workflow of the BAM in KBCS

Table 5.1 A simple diagnostic situation of finished goods store of Kaz (Far East) Limited

Company Information	
Company Name:	Kaz (Far East) Limited
Nature of Product:	Household Electrical Application (for example Humidifiers, Vaporizers, etc)
Current Status of the Finished Goods Warehouse	
Inventory Size:	5,850 m^2
No. of goods shelves	40 shelves (with unique name for identification). All shelves are divided into four levels.
Types of inventory	Finished goods with package
Barcode System	Have pre-printed unique barcode on the package.
Current warehouse management system	FoxPro and Oracle
No. of workers	8-10 workers
Objectives of the BPI project	
Budget	$50,000
Development Period of BPR project	9 months
Objectives of the project	1. Improve the efficiency for the collection of the inventory data and this allows for quickly generating packing lists, inventory reports, etc. 2. Better integration with existing database systems (FoxPro Application) used in the organization. 3. Computerize the inventory management for finished goods.

Table 5.2 New case in the system (with part of value and weighting)

	Budget	**Dev. Time**	**Inventory Size**	**Product Nature**	**Average Product Size**	**Average Product Cost**	**Existing Network**	**Number of Workers**
Value	50,000	0.75	5,850	Electronic	0.15	300	No	10
Weighting	0.25	0.15	0.05	0.05	0.05	0.05	0.1	0.1

5.2.2 Proposed new technology for the Finished Goods Warehouse

After the identification of the current inventory situation and the recommendation of solution, the similarity function of the past cases in the case library is calculated by using the similarity equation as discussed in section 4.4. The result of similarity calculation is shown in Table 5.3. A case library is composed of the knowledge repository (KR) of prototype tools that stores a number of verified successful cases of implementation. A set of similar past cases is retrieved and ranked as shown in Figure 5.5. As shown in Figure 5.6, the information of each case and the corresponding recommendations derived by the system are provided by the inference engine. The user can select the best-matched case to adapt or revise to resolve the problem.

Table 5.3 Similarity calculation with other cases

Case No.	Similarity	Budget	Dev. Time	Inventory Size	Product Nature	Average Product Size	Average Product Cost	Existing Network
0010	0.86	75,000	0.5	8,000	Electronic	0.03	250	Yes
0002	0.76	120,000	1.5	15,000	Electronic	0.2	400	No
0008	0.72	50,000	2.0	12,000	Toy	0.15	1,000	Yes
0011	0.69	150,000	1.5	12,000	Electronic	0.03	500	No
0006	0.62	200,000	2.5	9,000	Toy	0.05	1,200	Yes

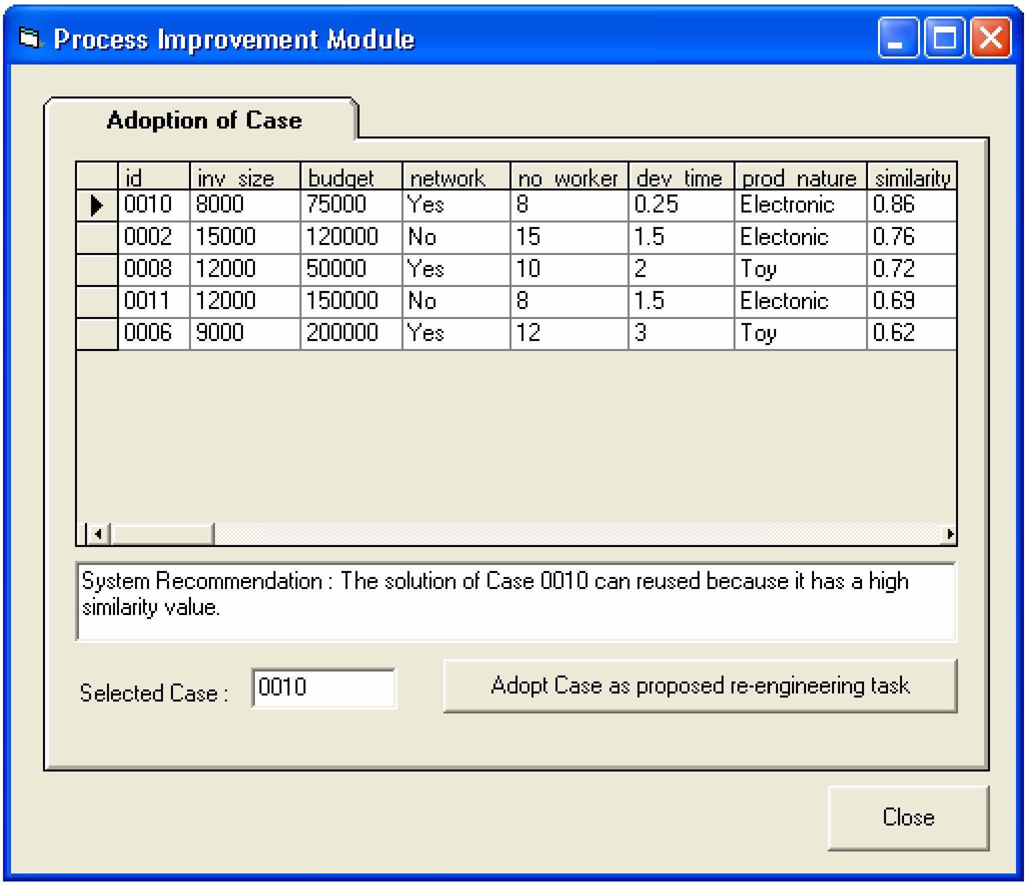


Figure 5.5 Adoption of similar past case

In this case study, the best matched past case is reused and adapted. The daily transactions in the finished goods store are handled with the scan-based Personal Data

Assistant (PDA). Some industrial grade handheld devices equipped with build-in scanner and wireless module are used to improve the performance of production logistics of the finished goods store. As shown in Figure 5.7, all products and locations are encoded with the bar code system and then the information is acquired by the barcode scanner of the handheld device. Nevertheless, the digitized inventory information can be fully integrated with other databases within the enterprise.

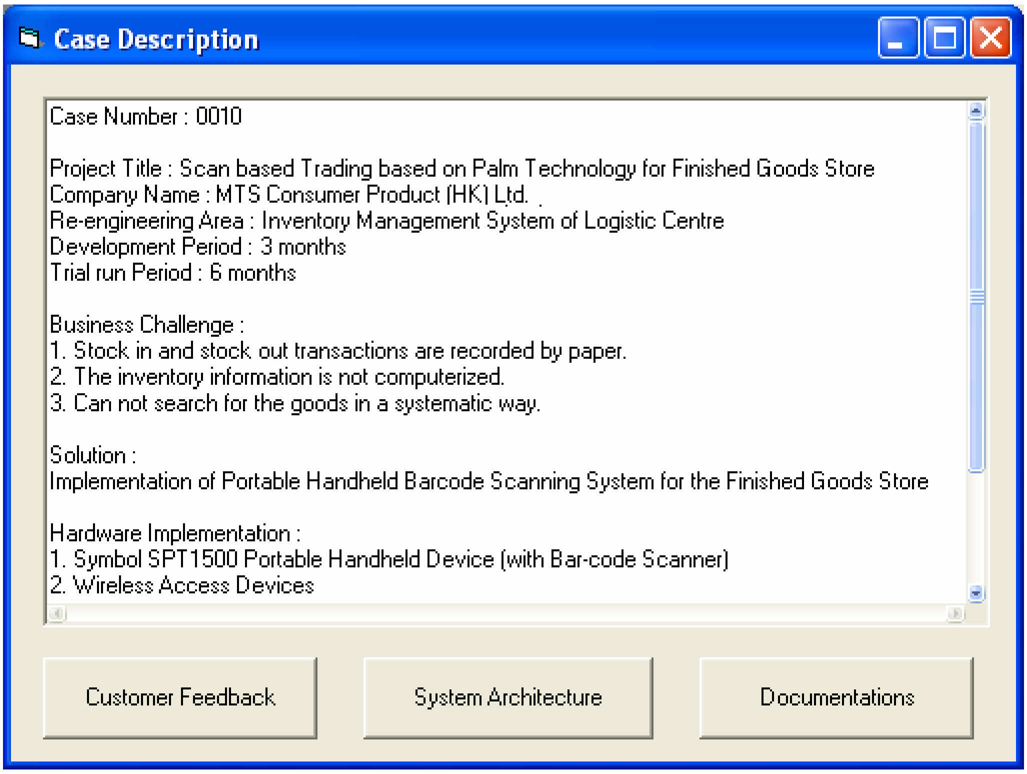


Figure 5.6 Detailed case description of the retrieved case

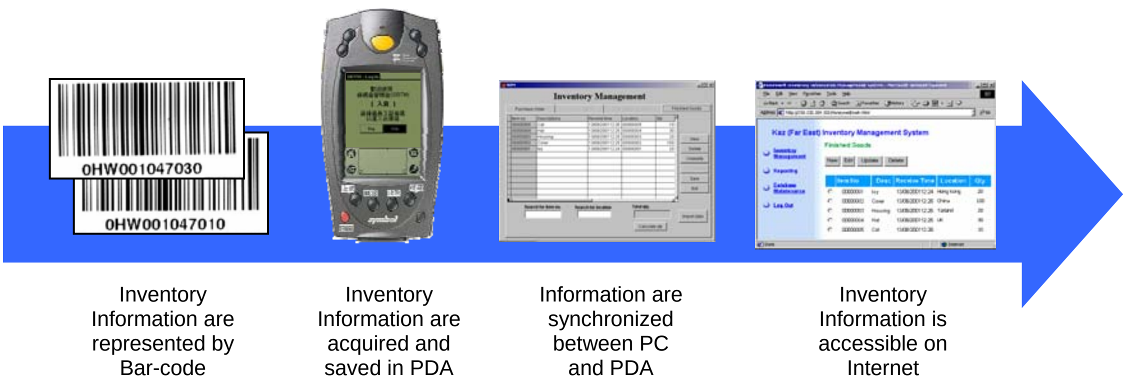


Figure 5.7 Proposed new business process in warehouse management system

5.2.3 Selection and Integration of Portable Handheld Devices

Subsequent to the confirmation of the enterprise application to be used, a template of the scan-based inventory management system and the previously used components are listed as shown in Figure 5.8. The detailed information and the past performance records of each software or hardware can be shown as a reference for the user.

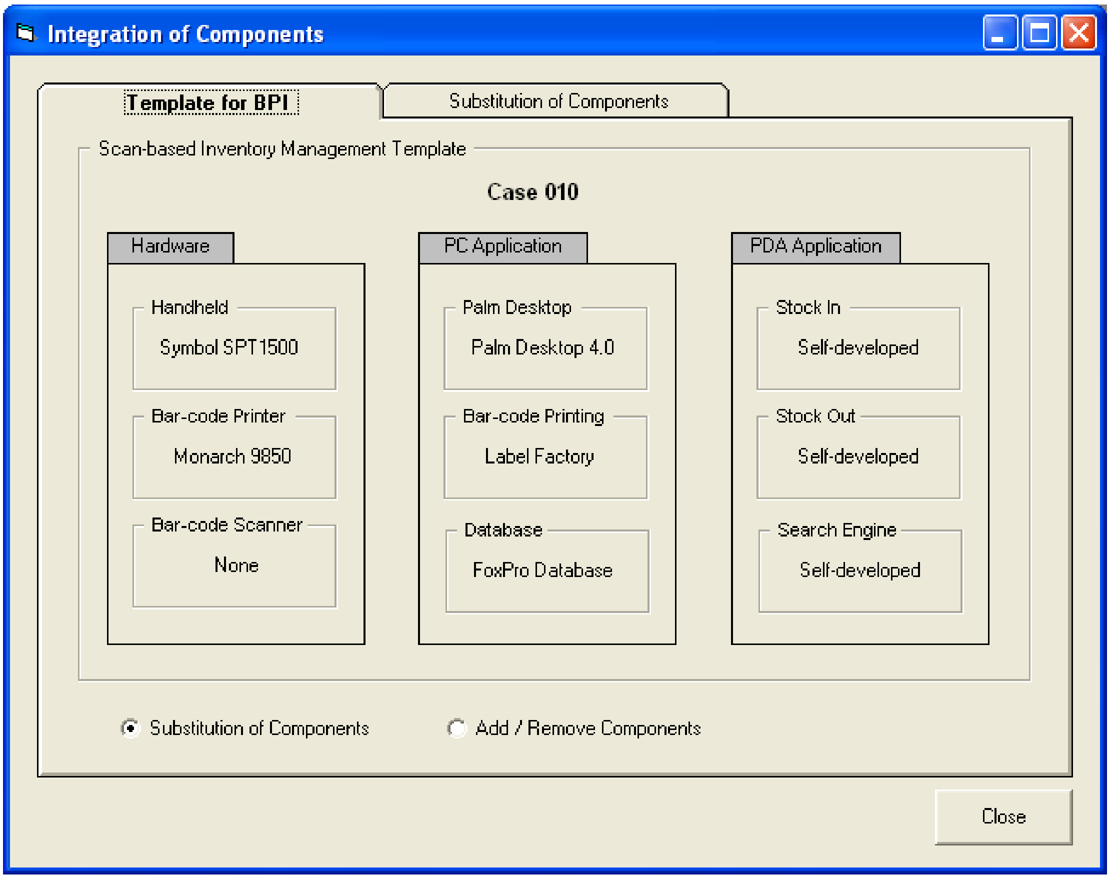


Figure 5.8 Template for scan-based inventory management system

Figure 5.9 shows the template for providing the guidelines for the integration of the hardware and software components. This minimizes the conflicts and allows the users to select an alternative composition of components. In the retrieved case, the handheld device “SPT-1500” is used in the past project. It combines the bar-code scanning technology with the Palm OS Platform which enables users to capture and manage data. However, it is an old model and it exchanges data with the PC-side warehouse applications through the cradle. From the figure, the users can select an alternative data exchange method which is a wireless connection. With the 802.11b technology, the warehouse workers can retrieve and submit the latest information with the PC-side warehouse application.

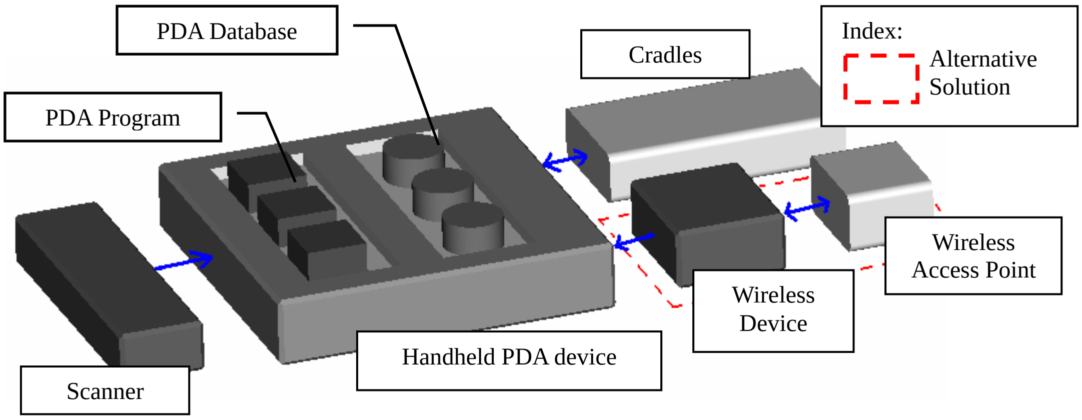


Figure 5.9 Interactive Relationship Diagram of components in the Template

The hardware components recommended in the template provided can be revised by substitution of another component. Searching, using the latest handheld device is expected to replace the outdated model in the template. Figure 5.10 shows the interface for selecting the suitable substitute component to replace the proposed handheld device. There are two stages to filter the most suitable handheld device. In the first stage, the handheld devices without the built-in scanner and wireless abilities are eliminated. In the next stage, only the plausible handheld devices are shown on the system interface.

The system can rank the plausible devices based on the user criteria. Each device has a set of basic attributes included the performance, cost, etc. The overall average performance score can be calculated with the weighted critical factors. For example, component performances score (S) of selecting the handheld devices can be calculated as follows:

S = (0.8)(value of performance index) + (0.2)(value of cost) (5.1)

Finally, the handheld device "SPT-1746" and the wireless access point are selected for this business process improvement project.

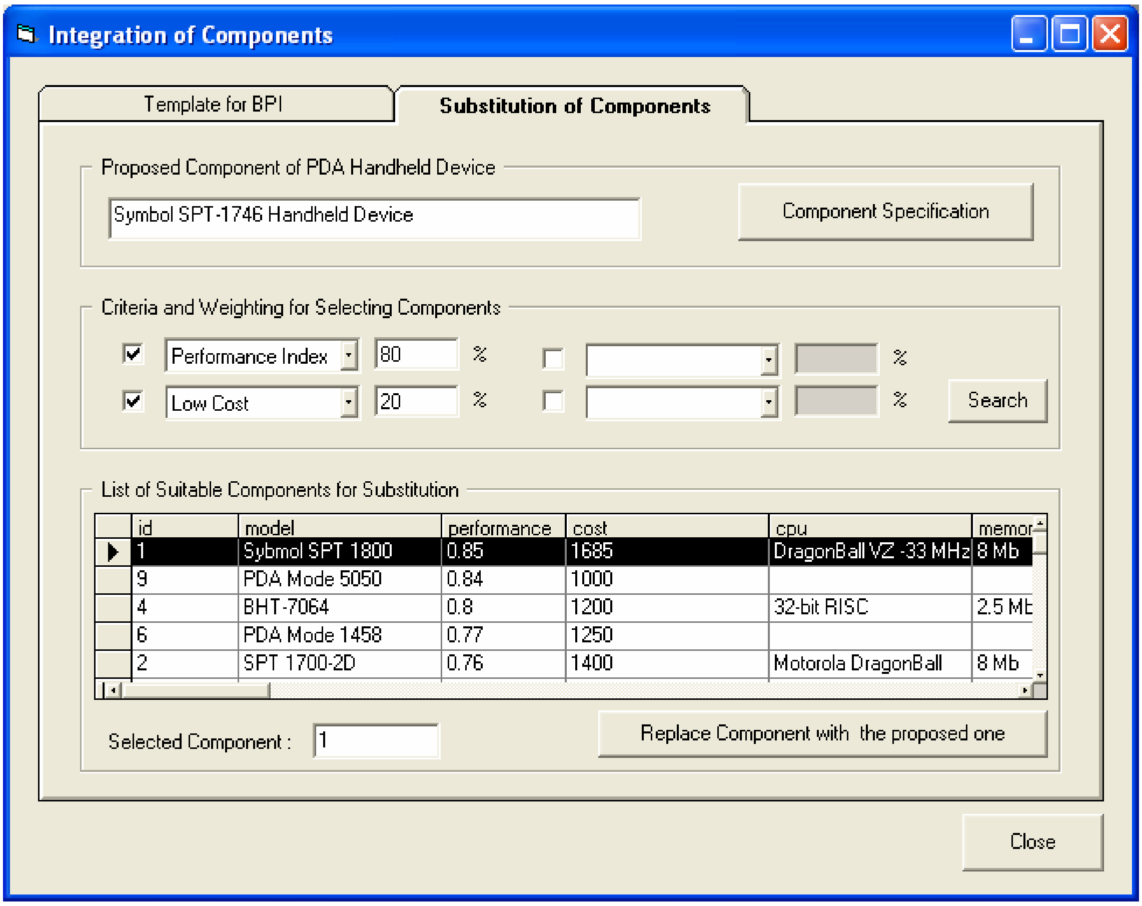


Figure 5.10 Substitution of components in the template

5.2.4 Detailed implementation setting of the scan-based warehouse management system

After the substitution process, the detail technology, software and hardware components for the implementation of the inventory management system are confirmed. Then, the settings of the hardware and software are provided by the system. From the past experience, the knowledge of setting and configuration of the components are stored in the knowledge repository. For example, the generic PDA programs for the inventory management system are provided by the system. The stock-in, stock-out and search functions are provided by the generic program.

5.2.4.1 Using a Bar-code system to represent the warehouse information

The staff number, finished goods part number and location number can be represented by the attached bar-code label to enhance the warehouse data acquisition and reduce the error of human data entry. The finished goods part number can be directly put on the package of the finished goods because it is a registered product ID code as shown in Figure 5.11(a). The staff number can also be obtained from the bar-code on the existing staff card (as shown in Figure 5.11b). The acquisition of the staff number is used for the user identification when they login to the PDA application. Also, in the transaction records of the warehouse operations, the person-in-charge and the time-stamp will be recorded in the system to trace the warehouse operations.

(a) (b)

Figure 5.11 Acquisition of data on (a) the packages of the product and (b) staff cards

In the finished goods warehouse, there are 40 shelves (see Figure 5.12) and each shelf has a unique name for identification. (From AA to AP, and from BA to BX). All shelves are divided into four levels. Therefore, 160 unique bar-codes are used in the location bar-code system. Table 5.4 shows part of the location bar-code system. The standard "Code 39" is used in the location barcode system, which is an alphanumeric bar code and it is for internal used only. Figure 5.13 shows that there is a board, which is hung on the side of each shelf, to display the location bar-code system. When the warehouse workers have to stock in or stock out the finished goods, the location information can be obtained by scanning the bar-code on the board.

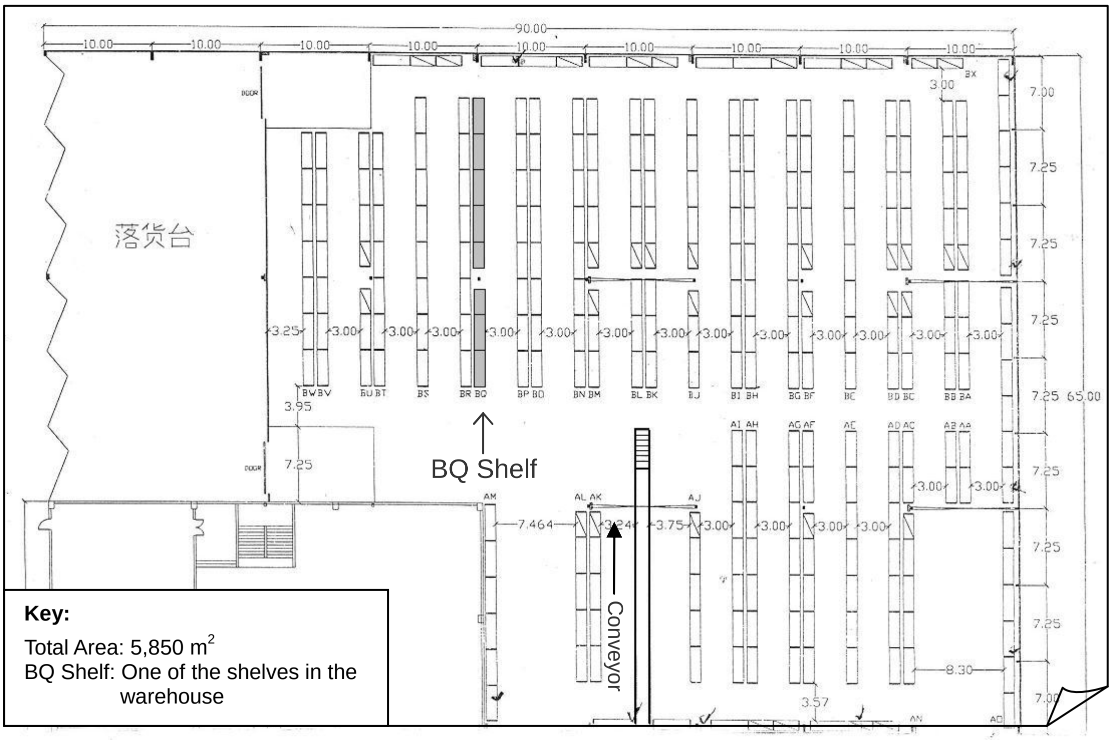


Figure 5.12 The Map of the Finished Goods Warehouse in Kaz (Far East) Limited

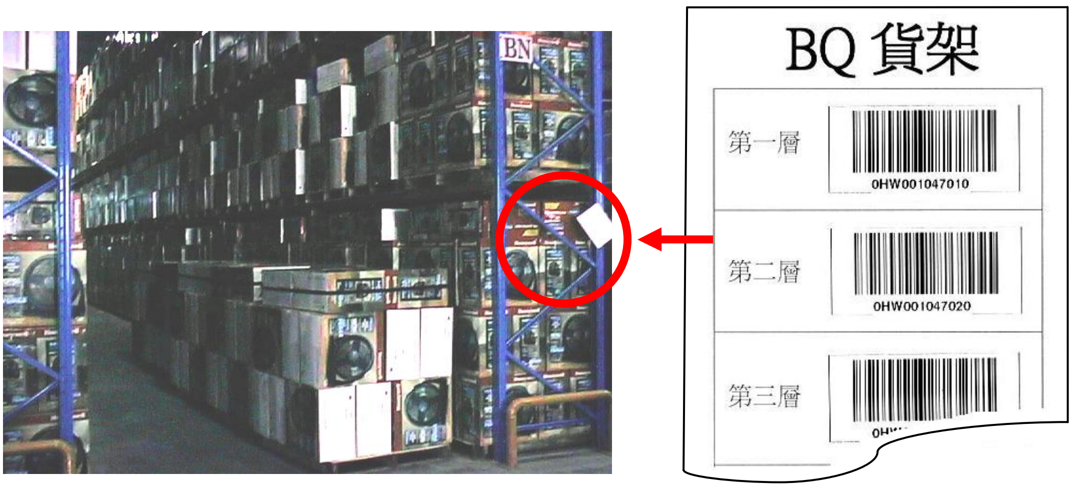


Figure 5.13 The bar-code system for location identification of each finished goods shelf

Table 5.4 Example of the location bar code

Name of the Shelf	Level Number	Location Barcode Number
BQ Shelf	Level 1 (The topmost level)	0HW001047010
BQ Shelf	Level 2	0HW001047020
BQ Shelf	Level 3	0HW001047030
BQ Shelf	Level 4	0HW001047040
BR Shelf	Level 1 (The topmost level)	0HW001048010
BR Shelf	Level 2	0HW001048020
BR Shelf	Level 3	0HW001048030
BR Shelf	Level 4	0HW001048040

5.2.4.2 Using the standard PDA application for warehouse management

Generally, the basic finished goods warehouse management system should handle the user authorization, stock in and stock out of the goods, relocation of goods to optimize the space utilization and handle searching for the storage location of particular items.

Figure 5.14 shows the standard workflow of the PDA application for the stock-in operation. The product and location information are obtained by scanning the attached bar-code to reduce human input error. All transaction records are stored in the PDA device and then exchanged with the PC-side warehouse application through wireless connection.

Figure 5.15 shows the searching ability in the handheld device. After the data synchronization between the handheld PDA devices and the PC-side warehouse application, the latest detail distribution of the finished goods can be searched on the handheld devices at anywhere of the warehouse.

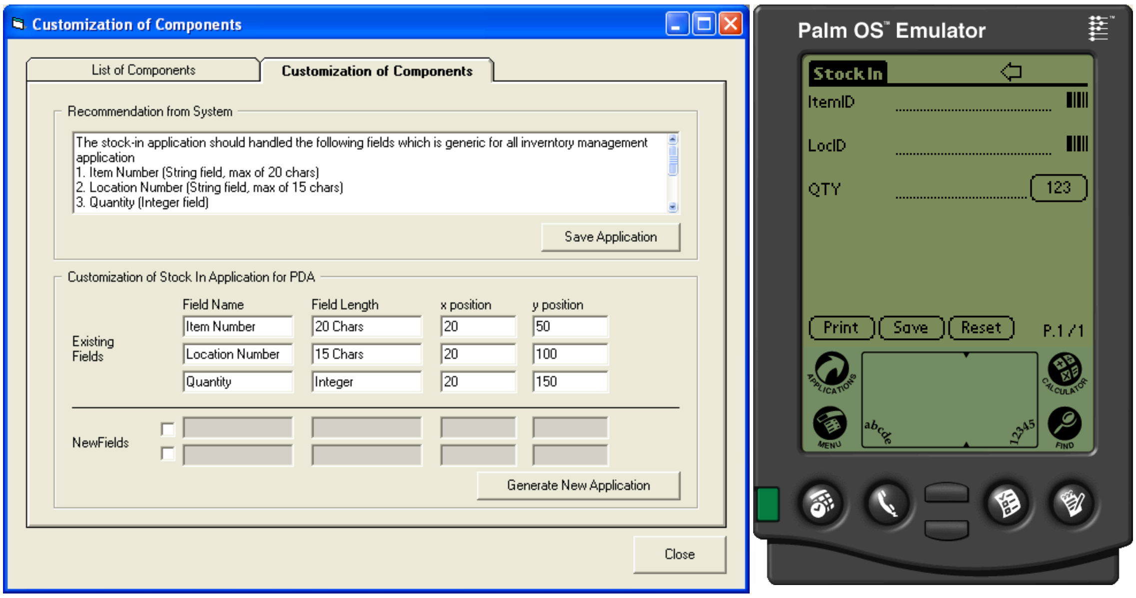
Figure 5.14 Standard workflow of the PDA application for the stock-in operation

Figure 5.15 Searching of finished goods with the PDA handheld device

5.2.4.3 *Customization of PDA application*

Based on the standard PDA application for warehouse management, the customers can customize part of the data fields to fit their unique warehouse operations. For example, they may want to save the FGRN number in each stock-in transaction as a reference document number. Therefore, they have to add an extra data field in both the PDA applications and the PC-side applications. The KBCS provides the user friendly interface for the customers to customize the unique warehouse operations and the new PDA applications can be simulated with the Palm OS Emulator. So they can tailor-make the most suitable applications for their warehouse.

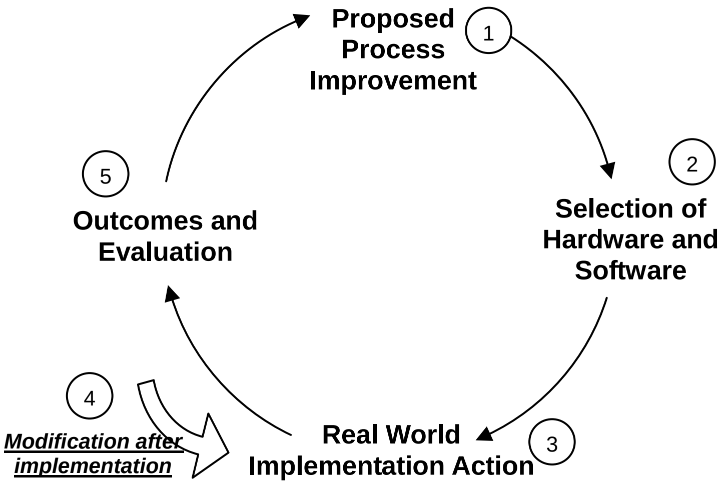
The standard data fields for the stock-in applications are provided by the KBCS. As shown in Figure 5.16(a), several standard data fields (such as the item number, location number and quantity) are shown on the system interface. Those fields are pre-defined in the generic PDA program.



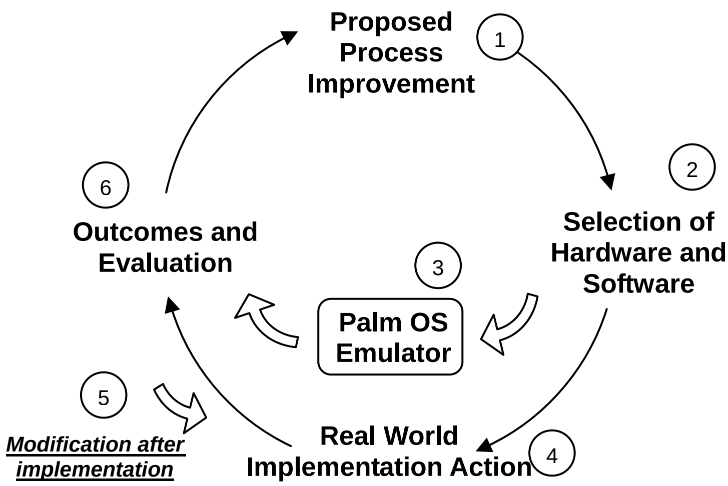
(a) (b)

Figure 5.16 Recommendation of setting of handheld device and the simulator of the PDA program

With the Palm OS Emulator, the expected layout and operation of the PDA application (as shown in Figure 5.16b) can be simulated before the investment of equipments and implementation of the project. Figure 5.17 shows the comparison between the (a) traditional approach and the (b) simulation-based approach for customization of the PDA applications.



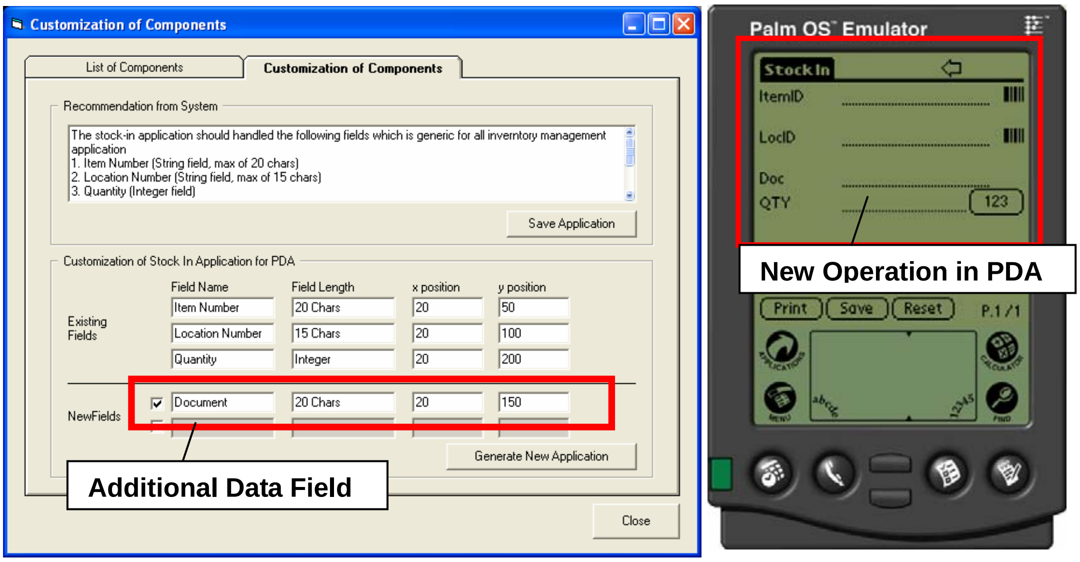
(a)



(b)

Figure 5.17 Comparison between the (a) traditional approach and the (b) simulation-based approach for customization of the PDA applications

In the traditional approach, many changes may occur after the implementation of the system or equipment. Before the implementation in the real world environment, the proposed solution will be simulated in a virtual environment. Therefore, the modification needed after the implementation will be reduced. They are allowed to be edited in the KBCS to tailor-make them for their unique operation. Additional data fields, such as the FGRN document field, can be added through the system interface (as shown in Figure 5.18a) and the simulator will simulate the new operation at once (as shown in Figure 5.18b).



(a) (b)

Figure 5.18 Customization of PDA program to fit unique workflow of the organization

5.2.4.4 Integration with the Warehouse Management System in PC-side

Finally, the warehouse data should be synchronized with the PC-side warehouse management system. Table 5.5 shows that fundamental information, such as the staff and item information, is defined and transferred from the PC-side system to the handheld devices. The transaction records are captured and stored in the handheld devices. Once the wireless data synchronization is completed, the data are transferred to

PC-side and the latest existing stock and the distribution of the finished goods in the warehouse are calculated and updated in the central warehouse management system. Also, this information is transferred to the handheld devices for the searching of finished goods in the devices.

Figure 5.19 shows the integration of the handheld devices and the PC-side warehouse management system. The data synchronization between the handheld devices and the PC terminal can be handled by the HotSync Manager through a wireless connection. It is a standard tool for exchanging the PDA programs and database with the PC terminals. In order to integrate the warehouse data with PC-side warehouse management system, a middle-ware is used to convert the PDA database into XML format which can be readable by the existing warehouse management system. Finally, the latest warehouse information can be shown in the client application. In this project, there are two client applications because they are using the FoxPro-based application now and they are trying to transform the system into a web-based application. Therefore, both client applications are run in parallel during the implementation of this case study.

Table 5.5 Data synchronization between PC-side and Handheld devices

	From PC to Handheld Devices	From Handheld Devices to PC
Staff / Users information and User Permission	√	
Item number and description	√	
Location number and description	√	
Transaction records of the finished goods in warehouse		√
Distribution of goods in the warehouse	√	

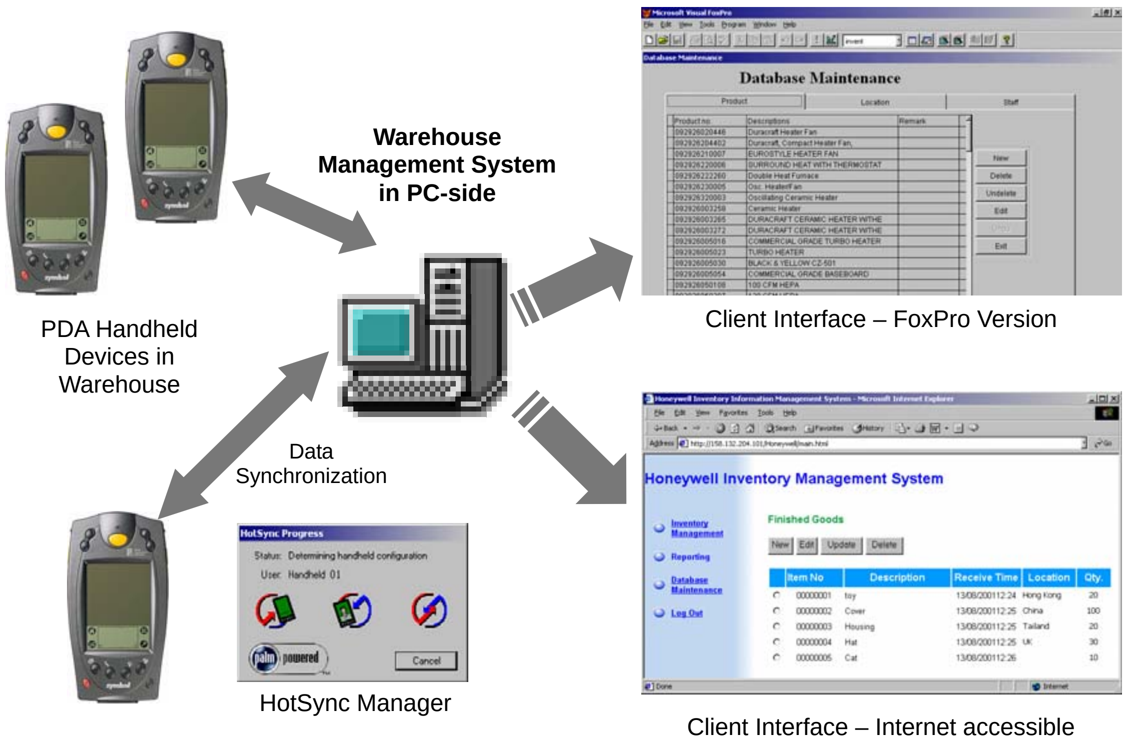


Figure 5.19 Integration of Warehouse Data with WHS and representation of data on Client Interface

5.3 Benefits of the scan-based warehouse management system

With the implementation of the new warehouse management system in Kaz (Far East) Limited, the warehouse information can be computerized, real-time synchronized and integrated with other systems. The new system can prevent the input errors in the transaction records in the warehouse. Therefore, the reliability of the stored finished goods in the warehouse can be improved. Also, it keeps track of the whereabouts of each item. Over 160 unique location barcodes are assigned to identify each of the levels in the goods shelves as well as the re-packaging zone, scrap items zone, etc. The original warehouse operation can not achieve the above benefits. A comparison of the characteristics of the traditional warehouse management approach and the scan-based approach is shown on Table 5.6.

Table 5.6 A comparison of the original and the scan-based warehouse management approaches

	Original Approach	**Scan-based Approach**
Identification of shelves in the finished goods warehouse	The 40 shelves have unique names but storage location will NOT be recorded in the warehouse management system.	Over 160 unique barcode numbers are used to identify the shelves and levels.
Update/synchronize the data with the central warehouse management system	Delay for few hours to one day because the warehouse data has to be re-entered to the central system by the workers.	Data can be updated in real time through the wireless connection with the central system.
Search for the goods in the finished warehouse	Workers have to seek the items with their eyes.	Workers can search for items with the handheld devices.

The main benefits of the scan based system over the conventional warehouse management system are:

(i) Automation of warehouse data acquisition.

(ii) Real-time and efficient synchronization of warehouse transactional data.

(iii) Reduces human errors and hence increases accuracy of the inventory data.

(iv) Allows 24 hours worldwide access of the updated inventory data.

(v) Reduction of paper work.

(vi) Faster response to customer needs.

(vii) Improved data integrity with other systems.

On the other hand, the consultancy team, they can also have the following advantages during the process improvement project:

(i) Knowledge of conducting the BPI projects can be reused in new situation and shared among the staff.

(ii) Knowledge can be captured in terms of verified cases in the knowledge repository for future use.

(iii) Continuous improvement of the BPI solutions is provided because the solution is retrieved and revised based on the successful cases.

(iv) The solution provided from the consultancy team is more understandable and reliable for the client company because they can understand the proposed solution from the retrieved successful cases.

5.4 Performance of the KBCS

Kaz (Far East) Limited decided to improve the warehouse operation a long time ago because of the unreliable inventory record and lack of tracking of the distribution of the finished goods in the warehouse. Most warehouse operations relied on paper work and the managers of company wanted to invest in a systematic approach to acquire the real-time warehouse data and improve the data integrity with the existing warehouse management system. Similar to many other companies, they found that there are many software and hardware solutions available on the market for the warehouse management system but most of them are too complicated and it is not an easy job to implement them in the warehouse. Therefore, they looked for a fast and reliable approach to improve their warehouse operations.

With the use of the KBCS, many successful BPI projects have been stored in the knowledge repository for future reuse. Kaz (Far East) can design their new warehouse operations by referring to the past successful cases of similar situations, in the finished warehouse operation. Using the bar-code to represent the warehouse data is not a new technology but there are various implementation approaches and different hardware and software to match the unique warehouse operations in different companies. Therefore, the reusing of successful cases by the case-base reasoning can reduce the time for formulating the new warehouse operations and sourcing for the suitable hardware and software components. In this section, the advantages and performance of using the KBCS for improving the business process in the finished goods warehouse of Kaz (Far East) is discussed.

5.4.1 Shortening the design period of the BPI project

For the proposed knowledge-based business process improvement approach, the processes of identifying and analysis of customer's needs, company objectives, current problems and existing systems are accomplished by the Business Analysis Module (BAM) in KBCS. Afterward, the similar past cases are retrieved in the knowledge repository (KR) in PIM for adoption for use in the current problem. The system reduces the time spent in the analysis and design stage for formulating the solution for the improvement of the business processes.

The knowledge and tacit practices of experienced consultants can be captured continuously, shared among other consultant members and reused in new BPI projects. It can continuously improve the business process by accumulation and revision of the past successful cases. The codified explicit knowledge can be retrieved when they want to reuse the case. All the documents in the retrieved case, such as the system architecture, implementation guideline, system evaluation reports, etc., can be retrieved and help the company to understand the proposed BPI solution and speed up the formulation of the whole solution for their company.

5.4.2 Staff with various perspectives can be involved in the design stage

One of the major reasons for the success of the business process improvement is the collection of information and ideas from the employees with different perspectives and knowledge. During the analysis and design stage, different staff members, such as the managers and technical staff, can participated to provide the overall situation of the company. The managers can provide the organizational objectives and strategy planning for the consideration of the chances and risks of the changing of the existing business processes. On the other hand, the staff with technical perspective is involved because they are familiar with the existing operations and problems. The involvement of the technical staff not only helps them to solve the existing problems, but also reduces the barriers in the implementation stage. Many cases show that staff is unwilling to change workflows they are used to and this may lead to the extension or failure of the BPI project. In Figure 5.20, the staffs with different perspectives can interact with the KBCS through different computer terminals. The inference engine collects the information from different users for firing the rules and will formulate an overall conclusion.

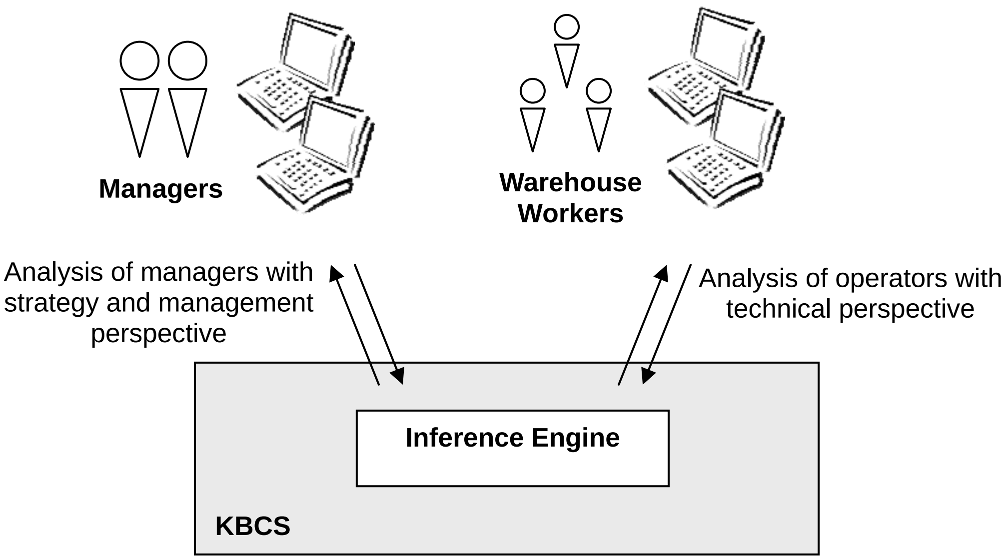


Figure 5.20 Analysis of business process with multi-perspective staffs in BAM

Moreover, the knowledge is codified and represented in different formats so that it can be easily understood by different staff from different sectors. The knowledge repository is composed of a case library which stores a number of verified cases.

Important parameters are codified as the case indexes and the case are represented as written descriptions. Therefore, the staff can understand the proposed new solution even though they may not be familiar with new technologies. Moreover, with the use of the emulator or simulator, some of the operations in the handheld devices can be demonstrated before the investment in the hardware.

5.4.3 Accumulated experiences for knowledge reuse and reduction of the risk of the implementation of the BPI project

One of the challenges for the consultancy companies is that they hold very complicated knowledge and this knowledge vests in the heads of their highly-trained and knowledgeable consultants. This makes it difficult for the companies to maintain and reuse knowledge if they leave the company. It often takes months or years to train new staff. For the traditional consultancy companies, they share knowledge by using “people networking” which means that the process of knowledge sharing relies on the transfer of knowledge by experienced staff. There are three problems in practice. Firstly, it is hard to retain knowledge in the company if experienced staff leaves the company. Secondly, it is hard to reuse the knowledge in various similar projects among the staff. Lastly, it takes a long time to train new staff.

In order to improve the capacity of the consultancy company, the best practice tends to be the “codifying of experience” approach rather than the “people networking” approach (Kepczyk, 1999). The “codifying of experience” approach accumulates a person’s knowledge in the knowledge repository and shares it, probably through the IT technology. The experience and knowledge of the consultants that can be captured includes methodologies, lessons learnt, documentation, etc.

Since the new BPI solution is revised on the basis of the retrieved successful cases in past projects, the risk of the implementation can be reduced. After the revision and reuse of the cases, a large number of cases can be stored in the knowledge repository. The later r cases are improved by solving the conflict between the components and the solution can be implemented in similar industrial situations. For example, the handheld device, with the bar-code scanner, can be used in warehouses, outdoor petrol stations, hospitals, jewelry shops, etc. These cases not only show the different combination of the hardware and software in various situations, but also confirm the capability and acceptability of the handheld devices for data acquisition, and for data representation in mobile devices.

5.4.4 Shortening the implementation period of the BPI project

The selection of the most suitable components and the configuration of components for the implementation of the BPI projects can be shortened by the KBCS. When the case is retrieved from the knowledge repository, the list of hardware and software for the implementation of the project are also retrieved. Customers can revise the solution by replacing the old technology with the latest and most suitable components which match the unique business operations in their company.

Some middle-ware and documentation can be reused in most similar cases. For example, after the data synchronization between the handheld devices and the PC terminal, a middle-ware is required to convert the database file (used in Palm OS) into the XML file which is readable in the existing warehouse management system. This middle-ware is a generic tool which can be reused in other similar cases. Also, the instructions and guidelines for using the scan-based handheld devices in the warehouse management system can be reused in similar situations. This can shorten the time for preparing the instructions and training of the warehouse workers.

Chapter 6 Conclusions

Business Process Improvement (BPI) is important for many companies because it helps them to solve the existing problems in the business processes and adapt to the changing business environment. Typical process related problems include duplication, bottlenecks, excessive non value-adding processes, staff scheduling issues and so on. They may seek help from professional consultancy companies and from consultants who are knowledge-intensive experts who can offer valuable experience and advice on the BPI projects. The large amount of experience, latest information and knowledge are the most important assets. All working knowledge generated within the consultancy company derives mostly from the experience of its staff. However, if the knowledge can not properly stored, classified or synthesized, it is often lost upon the resignation of the staff. Also, customization for enterprise systems is often not easy, and the new business workflow procedure may not map into the current practice of the company.

In order to rapidly and generically provide suitable BPI solutions and integrate various hardware and software, there is a need to develop a new business process improvement platform for accumulating and reusing the existing knowledge in the consultancy company, shorten the design and implementation period, and reduce the risks inherent in the implementation of the project. In many cases, the efficiency and effectiveness of the new solutions have become the benchmark for the consulting performance.

The knowledge based approach is proposed in this research for managing, codifying, storing, retrieving, and distributing the valuable experience and tacit knowledge of the past BPI projects in a new situation. The knowledge involved is that of planning, integrating and configuring different components of an enterprise system. Such knowledge needs to be continuously updated and made readily accessible to other users. Based on the knowledge management approach, the consultancy companies tend to adopt the strategy which is “Sharing existing knowledge better”. They try to make the implicit knowledge more explicit and put it on the platform for knowledge distribution when it is needed.

A prototype knowledge-based customization system (KBCS) is built to enhance the business process improvement projects in the consultancy company. The system that is built is based on the knowledge-based system architecture and various artificial intelligence techniques such as rule-based expert system and case-based reasoning. The KBCS allows the capturing of the valuable experience in the knowledge repository for future reuse. The business analysis module analyzes the existing problems and the organization’s strategy in the company. Then, the process improvement module provides the suitable solutions which have been applied to cases which are similar to the existing problems. They can retrieve and revise the similar cases and then customize the software and hardware in the customization and integration module. Suitable technologies, hardware and software are recommended. Also the detailed configurations of the hardware and software are provided.

The capability and advantages of the KBCS are demonstrated by a trial implementation of the system in Kaz (Far East) Limited which is a consumer product manufacturer. They wish to improve their production logistics operations in the finished goods warehouse by using a systematic approach and to replace the traditional paper-based inventory management approach. With the successful implementation of KBCS, the detailed problems in the warehouse have been analyzed and the new business process is proposed by the system, which is a scan-based warehouse management approach. The industrial grade handheld devices equipped with build-in scanner and wireless module are used to improve the accuracy of acquisition of warehouse data and to improve the data integrity with other systems. The selection of suitable hardware and customization of the PDA program are undertaken by the KBCS.

With the successful implementation of KBCS in the industrial case, the results of the validation indicate that the time taken for the design and implementation of the new warehouse management system is shortened. Also, the proposed solution is more reliable because it is revised by the accumulated successful experience. The cost needed for developing complex enterprise systems can be significantly reduced. After this project, the new case has been retained in the knowledge repository for future use.

Chapter 7 Suggestions for Further Work

Even the solution of the KBCS is based on reusing the past successful experience, the proposed solution may cause significant changes in the workflows and systems in the company. Managers may worry about the influence and drawbacks after the implementation of the new policy in their company. The KBCS can be enhanced by using simulation technology to forecast the benefits of the new operation and solve some problems in the virtual environment before the actual implementation in the real world. Moreover, the consultants and managers can make a better decision based on the result of the simulation. Therefore, the overall solution proposed by KBCS can be more reliable and suitable for the client company.

On the other hand, the performance and the reliability of the KBCS depend on the number of cases stored in the knowledge repository, more cases are required to enrich the retained knowledge to deal with different situations. In order to enhance the ability of the KBCS, some new technologies and cases are required. The radio frequency identification (RFID) technology used in the production, warehouse management and point-of-sale (POS) applications is becoming more popular nowadays. However, many small and medium sized enterprises (SMEs) do not have the resources and manpower to launch the RFID application in their company. The rapid formulation of business process improvement solutions in the KBCS can help them to reuse the knowledge in the past cases in similar organizations.

7.1 Simulation approach for BPI

Business process improvement always involves risk. Managers want to know the extent of risk of each possible solution. Beside the reuse of the successful experience, simulation is another way to reduce the risk of the business improvement. With the simulated environment, managers may know more about how the new process works, how to set the parameters of the new process or how to use the new hardware and software. Here are some examples to illustrate the importance of the simulation ability in the business process improvement:

(i) If a manager would like to implement vendor managed inventory (VMI) strategy to achieve the collaborative partnership with their retailers or distributors, he may want to know the benefits or risks after the implementation of the VMI. On the other hand, the warehouse manager may want to know how to set up the parameters of the VMI, such as the replenishment quantity and frequency.

(ii) If there are many suppliers involved in the implementation of the VMI, the manager may want to select the most appropriate partners to run the VMI.

(iii) If the company wants to invest in the new hardware and software, they may want to know how it works. For example, if they want to use the scan-based handheld devices to enhance the data entry process, they may want to know how to operate the handheld devices.

In the traditional approach, conceptual frameworks are proposed by the experts or consultants. The managers can just predict the result of the new business process based on the verbal or written description of the consultants and/or the success stories from other companies. However, many problems may be found during and after the implementation stage and they have to spend a lot of time to revise the new business processes and operations.

Therefore, simulation of the new business process in the virtual environment can help the company to predict the problems before the real world implementation (Tsoi *et al.*, 2004). Figure 7.1 shows that the virtual companies are created in the virtual environment to represent the participants in the supply chain. If some of the participants want to formulate a collaborative strategy, they can "trial-run" the new strategy in the virtual environment. The flow of goods, stock level, inventory cost, etc. can be simulated before the real implementation. As a result, the risk of the implementation of new business process can be reduced.

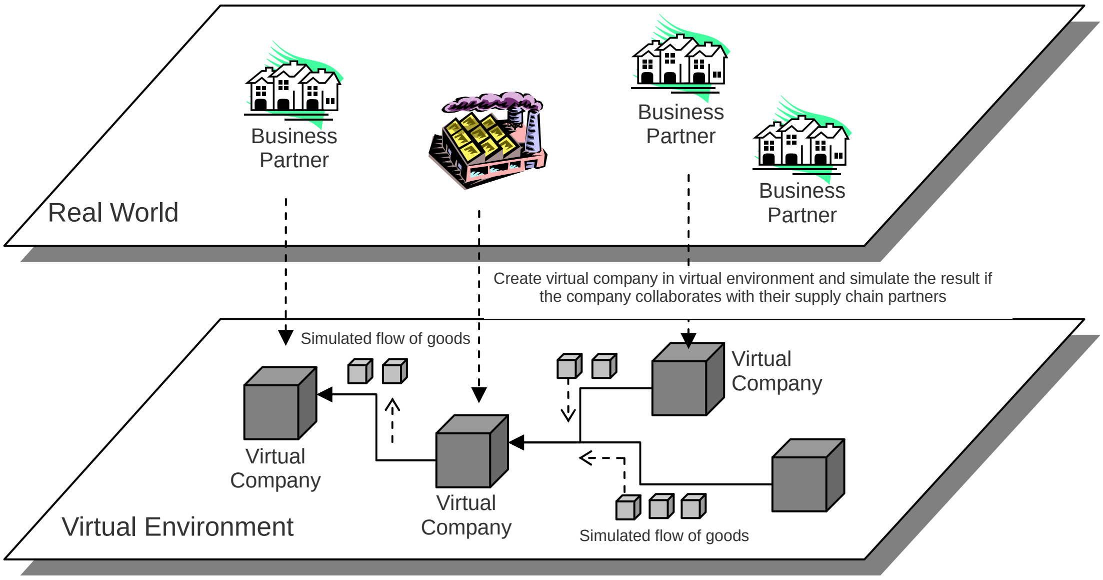


Figure 7.1 Implementation of business process in the Virtual Environment

Moreover, the simulation of the proposed business process and the operation of the components can help them to:

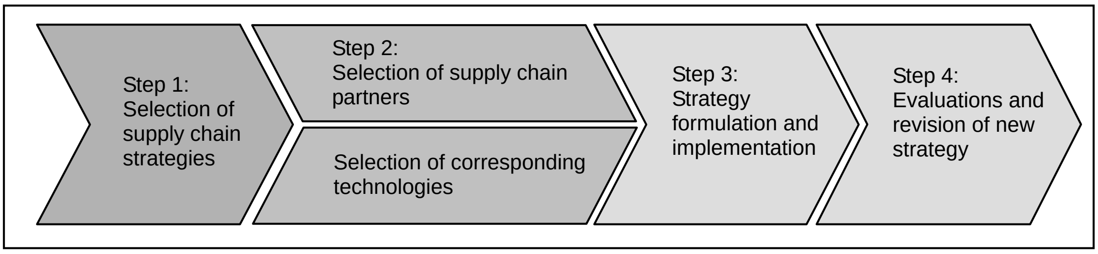
(i) predict the result after the implementation of the new business process

(ii) adjust the parameters appropriately before the real implementation of the policy

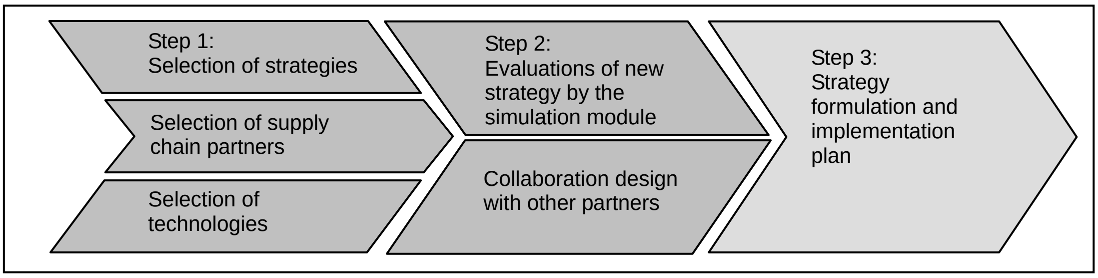
(iii) understand and familiarize themselves with the new hardware and software components.

7.1.1 A comparison between the traditional approach and the simulation approach

The selection of a suitable supply chain strategy and the corresponding technologies are significantly important when the company wants to improve their warehouse performance and collaborate with their supply chain partners. In the traditional approach (as shown in Figure 7.2a), they have to go through several steps in the development project. In most cases, the project may continue for a long time because the proposed new strategy is too abstract and it is difficult for the client company to understand. They may hesitate to carry out the project if the implementation processes and the influence of the solution can not be explained in detail. As a result, many problems can be found after the implementation stage. The strategy has to be revised several times during the evaluation stage. Time and resources may be wasted if the solution can not achieve the company's strategic objectives.



(a)



(b)

Figure 7.2 (a) Traditional and (b) simulation approaches for the development of supply chain strategy

As shown in Figure 7.2(b), the performance of the new strategy will be simulated and evaluated before the implementation stage. It is based on the real demand and inventory data of the company as well as on that of their supply chain partners. Their potential business partners will be invited to join the simulation through the Internet and be involved in the formulation of the new strategy. Therefore, they will make up the strategy that best matches their target objectives, existing assets, the warehouse strategies of their supply chain partners and the company situation. Also, the life cycle of the projects will be shortened and the solutions will better meet the requirements of the company.

7.1.2 Creating the supply chain components in the virtual environment

The components of the supply chain participants (the business partners) are the core element of this module. They will be encapsulated in the standardized input, output and the mathematical model of each component. Each business partner is represented by an object in the virtual environment. Before the simulation, the data and parameters of the objects will be pre-defined with real information. There are four types of objects to represent the supply chain participants:

(i) For the client company, the detailed warehouse information and production capacity of the object will be pre-defined.

(ii) The potential supply chain partners who want to formulate the collaborative strategy with the client company will also provide some important warehouse information for the simulation.

(iii) As for those existing supply chain partners who don’t want to join the collaborative strategy, their performance will be simulated based on the historical record.

(iv) There are some virtual companies available who can be used to generate dynamic transactions if necessary.

In the ideal case, all essential partners in the supply chain will join the system and they will provide the warehouse information for the simulation. Using the information, the system will simulate the most reliable result after the implementation of the VMI strategy. For example, in the retailer outlets of the simplified linear distribution chain, the most up-to-date sales record will be acquired by the POS system from the retailer and the existing EDI interface will allow the supply chain partners to communicate consistently and accurately. In each party, the initial inventory level, order quality and the delay of shipment will be collected and entered into the system. In the whole supply chain, different parties will use different warehouse management strategies. However, the demand and replenishment of each party will be calculated. For each party in the supply chain, the demand depends on its downstream partners. When a downstream party places an order and their inventory is below the safety level, they have to issue a replenishment order and it will be sent to the upstream party. Therefore, the demand and the inventory of each party in the whole supply chain will be simulated.

The system will use the given inventory data, let's say the previous year's one, to simulate the replenishment order and inventory level in the manufacturing firm. By comparing the simulated output with the original inventory data, the firm will judge whether the VMI strategy can help them or not. The figure will show the general inventory status within a long period. However, the reports can be broken down into detail and show all inventory statuses at any specified time. For example, they can check the on-hand inventory at any specified time slot in the simulation. Therefore, the client can know the detailed operation, advantages and limitations of the VMI strategy.

7.2 RFID applications with using KBCS

Wal-Mart (News of Wal-Mart, 2004) has set a January 2005 target for its top 100 suppliers to be place Radio Frequency Identification (RFID) tags on cases and pallets destined for Wal-Mart stores and SAM'S CLUB locations in the Dallas/Fort Worth metroplex area. Along with other retailers, Wal-Mart believes if its incoming inventory was tagged and transmitted it would allow Wal-Mart to keep track of its merchandise and increase efficiency in receiving and handling incoming stock.

RFID technology can be applied in different areas such as supermarkets, bookstores, manufacturing factories, etc. The real time product data or manufacturing data can be captured and revised on the RFID tags. The tags have several advantages compared with the traditional barcode system. They contain the microchips for the storing and modification of dynamic data.

However, many small and medium sized enterprises (SMEs) do not have the resources and manpower to launch the RFID applications. This forms a hurdle for them to cooperate with their logistic partners such as Wal-Mart. They may find difficulties and lack of information for the selection of the appropriate RFID tags and the corresponding application systems.

Therefore, the KBCS can be extended so the SMEs can develop an improved business process with the use of the RFID technology. Since there are many standards of the RFID tags, such as various radio frequencies, data exchange protocols, etc., the KBCS can help the company to select the most suitable tags, readers and middleware for integrating the existing systems.

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APPENDIX A - VB Code for Inference Engine

```
Option Explicit
Dim conn As ADODB.Connection
Dim cmd As ADODB.Command
Dim rs As ADODB.Recordset
Dim SQL As String

Public TargetFieldCount As Integer
Public RulesCount As Integer
Const MAX_TARGET_FIELD = 20
Const MAX_TEMP_FIELD = 20
Const MAX_RULES = 20
Dim TargetField(1 To MAX_TARGET_FIELD, 1 To 2) As String
Dim Rules(1 To MAX_RULES, 1 To 13) As String
Dim TempField(1 To MAX_TEMP_FIELD, 1 To 2) As String
Dim WaitingList(1 To 50, 1 To 2) As String
Dim intWaitingListLast As Integer
Dim intLastTempField As Integer

Public Sub Init()
    Dim Counter, i As Integer

    Set conn = New ADODB.Connection
    ' conn.Provider = "Microsoft.Jet.OLEDB.3.51"
        conn.Provider = "Microsoft.Jet.OLEDB.4.0"
    ' conn.Open App.Path & "\BPR.mdb"
    conn.Open App.Path & "\KevinDB.mdb"

    Set cmd = New ADODB.Command
    cmd.ActiveConnection = conn
    Set rs = New ADODB.Recordset

' Initiation of Variable
    intLastTempField = 1

' Initiation of Target Field of CBR
    SQL = "SELECT name, value FROM CBR_field"

    cmd.CommandTimeout = 15
    cmd.CommandText = SQL
    cmd.CommandType = 1
    rs.Open cmd, , 2, 4

    If rs.EOF Then
        TargetFieldCount = 0
    Else
        Do While Not rs.EOF
            Counter = Counter + 1
            TargetField(Counter, 1) = rs("name")
            TargetField(Counter, 2) = IIf(IsNull(rs("value")), "", rs("value"))
            If Counter = MAX_TARGET_FIELD Then
                Exit Do
            End If
            rs.MoveNext
        Loop
    End If
    TargetFieldCount = Counter
    rs.Close
```

```
' Initiation of Rules
    SQL = "SELECT * FROM Exp_rules"

    Counter = 0
    cmd.CommandText = SQL
    rs.Open cmd, , 2, 4

    If rs.EOF Then
        RulesCount = 0
    Else
        Do While Not rs.EOF
            Counter = Counter + 1
            Rules(Counter, 1) = IIf(IsNull(rs("pre01")), "", rs("pre01"))
            Rules(Counter, 2) = IIf(IsNull(rs("val01")), "", rs("val01"))
            Rules(Counter, 3) = IIf(Rules(Counter, 1) = "", "", "UnKnown")
            Rules(Counter, 4) = IIf(IsNull(rs("pre02")), "", rs("pre02"))
            Rules(Counter, 5) = IIf(IsNull(rs("val02")), "", rs("val02"))
            Rules(Counter, 6) = IIf(Rules(Counter, 5) = "", "", "UnKnown")
            Rules(Counter, 7) = IIf(IsNull(rs("pre03")), "", rs("pre03"))
            Rules(Counter, 8) = IIf(IsNull(rs("val03")), "", rs("val03"))
            Rules(Counter, 9) = IIf(Rules(Counter, 9) = "", "", "UnKnown")
            Rules(Counter, 10) = IIf(IsNull(rs("operation")), "", rs("operation"))
            Rules(Counter, 11) = IIf(IsNull(rs("con01")), "", rs("con01"))
            Rules(Counter, 12) = IIf(IsNull(rs("sol01")), "", rs("sol01"))
            Rules(Counter, 13) = IIf(Rules(Counter, 12) = "", "", "UnKnown")
            If Counter = MAX_RULES Then
                Exit Do
            End If
            rs.MoveNext
        Loop
    End If
    RulesCount = Counter
    rs.Close
End Sub

Public Sub CloseConnection()
    cmd.Cancel
    conn.Close
End Sub

Public Sub Start()
    Dim i As Integer
    Dim j As Integer

        j = 1
    For i = 1 To TargetFieldCount
        CheckPremiseFromConsequent (TargetField(i, 1))

        Do While (intLastTempField > j)
            Call CheckFieldOnTempField(TempField(j, 1))
            j = j + 1
        Loop
    Next i
End Sub

Public Sub CheckPremiseFromConsequent(strConsequent As String)
    Dim i, j As Integer
    For i = 1 To RulesCount
        If Rules(i, 11) = strConsequent And Rules(i, 13) = "True" Then
```

```
        intMessageBoxReply = MsgBox("Error is found !!!", 1, "Error")
    ElseIf (Rules(i, 11) = strConsequent And Rules(i, 13) = "False") Then
        intMessageBoxReply = MsgBox("Error is found !!!", 1, "Error")
    ElseIf (Rules(i, 11) = strConsequent And Rules(i, 13) = "UnKnown") Then
        ' Fire the rules if the premise are True
        If Rules(i, 10) = "" Then    ' only have one premise
            If Rules(i, 3) = "True" Then FireRules (i)
        ElseIf Rules(i, 10) = "AND" Then
            If Rules(i, 3) = "True" And Rules(i, 6) = "True" And (Rules(i, 9) = "True" Or
             Rules(i, 9) = "") Then FireRules (i)
        ElseIf Rules(i, 10) = "OR" Then
            If Rules(i, 3) = "True" Or Rules(i, 6) = "True" Or Rules(i, 9) = "True" Then
             FireRules (i)
        End If

        ' Add the Premise into TempField if they are in "unknown" stage
        Dim booTempFieldHaveIt As Boolean
        booTempFieldHaveIt = False
        If Rules(i, 3) = "UnKnown" Then
            For j = 1 To (intLastTempField - 1)
                If TempField(j, 1) = Rules(i, 1) Then
                    booTempFieldHaveIt = True
                Else
                    booTempFieldHaveIt = False
                End If
            Next j
            If booTempFieldHaveIt = False Then
                TempField(intLastTempField, 1) = Rules(i, 1)
                TempField(intLastTempField, 2) = Rules(i, 2)
                frmDebug.EventList.AddItem ("Rules '" + TempField(intLastTempField, 1)
                 + " = " + TempField(intLastTempField, 2) + "' added to Temp Field")
                intLastTempField = intLastTempField + 1
                frmDebug.EventList.AddItem ("Total records in Temp Field ->" &
                 (intLastTempField - 1))
            End If
        End If
        If Rules(i, 6) = "UnKnown" Then
            For j = 1 To (intLastTempField - 1)
                If TempField(j, 1) = Rules(i, 4) Then
                    booTempFieldHaveIt = True
                Else
                    booTempFieldHaveIt = False
                End If
            Next j
            If booTempFieldHaveIt = False Then
                TempField(intLastTempField, 1) = Rules(i, 4)
                TempField(intLastTempField, 2) = Rules(i, 5)
                frmDebug.EventList.AddItem ("Rules '" + TempField(intLastTempField, 1)
                 + " = " + TempField(intLastTempField, 2) + "' added to Temp Field")
                intLastTempField = intLastTempField + 1
                frmDebug.EventList.AddItem ("Total records in Temp Field ->" &
                 (intLastTempField - 1))
            End If
        End If
        If Rules(i, 9) = "UnKnown" Then
            For j = 1 To (intLastTempField - 1)
                If TempField(j, 1) = Rules(i, 7) Then
                    booTempFieldHaveIt = True
                Else
                    booTempFieldHaveIt = False
```

```
                End If
            Next j
            If booTempFieldHaveIt = False Then
                TempField(intLastTempField, 1) = Rules(i, 7)
                TempField(intLastTempField, 2) = Rules(i, 8)
                frmDebug.EventList.AddItem ("Rules '" + TempField(intLastTempField, 1)
                 + " = " + TempField(intLastTempField, 2) + "' added to Temp Field")
                intLastTempField = intLastTempField + 1
                frmDebug.EventList.AddItem ("Total records in Temp Field ->" &
                 (intLastTempField - 1))
            End If
        End If

    End If
  Next
End Sub

Private Sub CheckPremise(strPremise As String, strValue As String)
Dim i As Integer
  For i = RulesCount To 1 Step -1
    If (Rules(i, 1) = strPremise And Rules(i, 2) = strValue) Then
        Rules(i, 3) = "True"
        frmDebug.EventList.AddItem (strPremise + " = " + strValue + " is True in Rule " & i)
    End If
    If (Rules(i, 4) = strPremise And Rules(i, 5) = strValue) Then
        Rules(i, 6) = "True"
        frmDebug.EventList.AddItem (strPremise + " = " + strValue + " is True in Rule " & i)
    End If
    If (Rules(i, 7) = strPremise And Rules(i, 8) = strValue) Then
        Rules(i, 9) = "True"
        frmDebug.EventList.AddItem (strPremise + " = " + strValue + " is True in Rule " & i)
    End If

    ' Fire the rules if the premise are True
    If Rules(i, 10) = "" Then    ' only have one premise
        If (Rules(i, 3) = "True" And Rules(i, 13) <> "True") Then
            FireRules (i)
            WaitingList(intWaitingListLast, 1) = Rules(i, 11)
            WaitingList(intWaitingListLast, 2) = Rules(i, 12)
            intWaitingListLast = intWaitingListLast + 1
        End If
    ElseIf Rules(i, 10) = "AND" Then
        If ((Rules(i, 3) = "True" And Rules(i, 6) = "True" And (Rules(i, 9) = "True" Or Rules(i,
9) = "")) And Rules(i, 13) <> "True") Then
            FireRules (i)
            WaitingList(intWaitingListLast, 1) = Rules(i, 11)
            WaitingList(intWaitingListLast, 2) = Rules(i, 12)
            intWaitingListLast = intWaitingListLast + 1
        End If
    ElseIf Rules(i, 10) = "OR" Then
        If ((Rules(i, 3) = "True" Or Rules(i, 6) = "True" Or Rules(i, 9) = "True") And Rules(i,
13) <> "True") Then
            FireRules (i)
            WaitingList(intWaitingListLast, 1) = Rules(i, 11)
            WaitingList(intWaitingListLast, 2) = Rules(i, 12)
            intWaitingListLast = intWaitingListLast + 1
        End If
    End If
  Next
End Sub
```

```
Private Sub CheckFieldOnTempField(strLookingField As String)
      Dim i As Integer

' Generate question if available
      SQL = "SELECT * FROM Exp_Q WHERE field = '" & strLookingField & "'"

      cmd.CommandText = SQL
      rs.Open cmd, , 2, 4

      If rs.EOF Then    ' Question not found
            CheckPremiseFromConsequent (strLookingField)
            frmDebug.EventList.AddItem ("Question for asking the premise " + strLookingField + "
not found. Checking other rules.")
      ElseIf rs.RecordCount > 1 Then    ' More than one question is found
            intMessageBoxReply = MsgBox("Error is found !!!", 1, "Error")
      Else    ' One question is found and question generated
            frmDebug.EventList.AddItem ("Question generated -> " & rs("field"))
            frmQuestion.strField = rs("field")
            frmQuestion.lblQuestion = rs("question")
            frmQuestion.Show (1)

      End If

      rs.Close
End Sub

Public Sub CheckReplyAnswer()
      Dim i As Integer
      Dim strLookingValue As String
      For i = 1 To (intLastTempField - 1)
            If TempField(i, 1) = frmQuestion.strField Then
                  strLookingValue = TempField(i, 2)
            End If
      Next
      If frmQuestion.txtAnswer = strLookingValue Then    ' The answer is correct
            Dim j As Integer
            intWaitingListLast = 1
            j = 1
            WaitingList(1, 1) = frmQuestion.strField
            WaitingList(1, 2) = strLookingValue
            intWaitingListLast = intWaitingListLast + 1
            Do While (intWaitingListLast > j)
                  frmDebug.EventList.AddItem (frmQuestion.strField + " = " + strLookingValue + " is
TRUE")
                  Call CheckPremise(WaitingList(j, 1), WaitingList(j, 2))
                  j = j + 1
            Loop
      Else    ' The answer is incorrect
            frmDebug.EventList.AddItem ("Answer of premise " + frmQuestion.strField + " is not
True")
            ' frmDebug.EventList.AddItem ("Checking other rules for premise " +
             frmQuestion.strField)
            ' CheckPremiseFromConsequent (frmQuestion.strField)
      End If
End Sub

Public Sub GetUnknownAnswer()
      frmDebug.EventList.AddItem ("Premise " + frmQuestion.strField + " is not unknown")
      frmDebug.EventList.AddItem ("Checking other rules for premise " + frmQuestion.strField)
```

```
    CheckPremiseFromConsequent (frmQuestion.strField)
End Sub

Public Sub Suspend()
'       me.
End Sub

Private Sub FireRules(n As Integer) ' "n" is the number of the rule
    ' intMessageBoxReply = MsgBox("Error is found !!!", 1, "Error")
    Dim i As Integer
    Rules(n, 13) = "True"
    frmDebug.EventList.AddItem ("The " & n & " th Rule has been fired")
    For i = 1 To TargetFieldCount
        If TargetField(i, 1) = Rules(n, 11) Then
            TargetField(i, 2) = Rules(n, 12)
            frmDebug.EventList.AddItem ("Target field fired")
        End If
    Next
    ' Call CheckPremise(Rules(i, 11), Rules(i, 12))
End Sub

Public Sub ShowRules()
    Dim tempRules As String
    Dim i As Integer

    For i = 1 To RulesCount
        tempRules = "Rule " & i & " : "
        tempRules = tempRules + "IF " + Rules(i, 1) + " = " + Rules(i, 2)
        If Rules(i, 4) <> "" Then
            tempRules = tempRules + " " + Rules(i, 10) + " " + Rules(i, 4) + " = " + Rules(i, 5)
        End If
        If Rules(i, 7) <> "" Then
            tempRules = tempRules + " " + Rules(i, 10) + " " + Rules(i, 7) + " = " + Rules(i, 8)
        End If
        tempRules = tempRules + " THEN " + Rules(i, 11) + " = " + Rules(i, 12)
        frmShowRules.RulesList.AddItem (tempRules)
    Next i
End Sub

Public Sub ShowTargetField()
    Dim tempTargetField As String
    Dim i As Integer

    For i = 1 To TargetFieldCount
        tempTargetField = TargetField(i, 1) + " = " + TargetField(i, 2)
        frmShowTargetField.TargetFieldList.AddItem (tempTargetField)
    Next i
End Sub

Public Sub ShowDiagnostic()
    Dim tempTargetField As String
    Dim i As Integer
        tempTargetField = "Inventory Size = " + TargetField(1, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
        tempTargetField = "Expected Project Budget = " + TargetField(2, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
        tempTargetField = "Existing Network = " + TargetField(3, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
        tempTargetField = "Existing Wireless Network = " + TargetField(4, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
```

```
        tempTargetField = "Number of workers = " + TargetField(5, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
        tempTargetField = "Expected Development Time = " + TargetField(6, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
        tempTargetField = "Product Natue = " + TargetField(7, 2)
    frmAnalysis.lstCurrent.AddItem (tempTargetField)
End Sub


Public Sub setTargetField(xxx As String, yyy As String)
    Dim i As Integer
    For i = 1 To TargetFieldCount
        If TargetField(i, 1) = xxx Then
            TargetField(i, 2) = yyy
        End If
    Next i
End Sub
```

APPENDIX B - VB for Case-based Reasoning

```
Option Explicit
Dim Conn As ADODB.Connection
Dim cmd As ADODB.Command
Dim RS As ADODB.Recordset
Dim SQL As String

Const MAX_CasesNo = 20
Const MAX_FieldOfCase = 10
Dim CaseLib(1 To MAX_CasesNo, 1 To MAX_FieldOfCase) As String
Dim intCaseCount As Integer

Public Sub Init()
    Dim Counter, i As Integer
    Set Conn = New adodb.Connection
    Conn.Provider = "Microsoft.Jet.OLEDB.4.0"
    Conn.Open App.Path & "\KevinDB.mdb"
    Set cmd = New adodb.Command
    cmd.ActiveConnection = Conn
    Set RS = New adodb.Recordset

' Initiation of Variable
    intCaseCount = 0

' Initiation of Case Library
    SQL = "SELECT * FROM CaseLib_Inventory"
    cmd.CommandTimeout = 15
    cmd.CommandText = SQL
    cmd.CommandType = 1
    RS.Open cmd, , 2, 4
    If RS.EOF Then
        intCaseCount = 0
    Else
        Do While Not RS.EOF
            Counter = Counter + 1
            For i = 1 To MAX_FieldOfCase
                CaseLib(Counter, i) = IIf(IsNull(RS(i - 1)), "", RS(i - 1))
            Next i
            If Counter = MAX_FieldOfCase Then
                Exit Do
            End If
            RS.MoveNext
        Loop
    End If
    intCaseCount = Counter
    RS.Close

End Sub

Public Sub Similarity()
     Dim Conn As adodb.Connection, RS As adodb.Recordset, RS2 As adodb.Recordset, SQL
     As String
     Dim SubSim() As Single, i As Integer, Weight() As Single

    Set Conn = New adodb.Connection
    Conn.Provider = "Microsoft.Jet.OLEDB.4.0"
    Conn.Open App.Path & "\KevinDB.mdb"
```

```
    Set RS = New adodb.Recordset
    Set RS2 = New adodb.Recordset

    ReDim Weight(10)
    SQL = "SELECT weight FROM CBR_field ORDER BY id"
    RS.Open SQL, Conn, 1, 3
    For i = 1 To UBound(Weight)
        Weight(i) = RS(0)
    Next
    RS.Close

    SQL = "SELECT * FROM CaseLib_Inventory"
    RS.Open SQL, Conn, 1, 3

    Do Until RS.EOF
      ReDim SubSim(10)
      For i = 1 To 10
        Select Case i
          Case 1, 2, 5, 6 'Numeric
            SQL = "SELECT MIN(" & RS(i).Name & "), MAX(" & RS(i).Name & ")
            FROM CaseLib_Inventory"
            RS2.Open SQL, Conn, 1, 3
            SubSim(i) = SubSimNumber(Int(myInfEng.getTargetField(RS(i).Name)),
             RS(i), RS2(0), RS2(1))
            RS2.Close
          Case 3, 4, 7, 8, 9 'Text
            SubSim(i) = SubSimText(myInfEng.getTargetField(RS(i).Name), RS(i))
          Case 10 'Text
            SubSim(i) = SubSimText(myInfEng.getTargetField(RS(i).Name), RS(i))
        End Select
       Next
       SQL = "UPDATE CaseLib_Inventory SET similarity = " & Round(Sim(SubSim, Weight)
       , 4) & " WHERE id = '" & RS(0) & "'"
       RS2.Open SQL, Conn, 1, 3
       RS.MoveNext
    Loop
    RS.Close
    Conn.Close
End Sub

Private Function SubSimNumber(Val1, Val2, Min, Max)
    SubSimNumber = Abs(Val1 - Val2) / (Max - Min)
End Function

Private Function SubSimText(Val1, Val2)
    If Val1 = Val2 Then
        SubSimText = 0
    Else
        SubSimText = 1
    End If
End Function

Private Function Sim(SubSim() As Single, Weight() As Single)
    Dim i As Byte, Tmp
    For i = 1 To UBound(Weight)
        Tmp = Tmp + (Weight(i) * SubSim(i)) ^ 2
    Next
    Sim = 1 - Tmp ^ 0.5
End Function
```

```
Private Sub cmdRetain_Click()
    SQL = "INSERT INTO CaseLib_Inventory (id, inv_size, budget, network," _
    & " wireless, no_worker, dev_time, prod_nature, no_shelves," _
    & " bar_code, current_system, solution)" _
    & " VALUES('" + Trim(Text31.Text) + "'," & Text41.Text & "," _
    & Trim(Text42.Text) + ",'" + Trim(Text43.Text) + "','" + Trim(Text44.Text) + "'," _
    & Trim(Text45.Text) + "," + Trim(Text46.Text) + ",'" + Trim(Text47.Text) + "'," _
    & Trim(Text48.Text) + ",'" + Trim(Text49.Text) + "','" + Trim(Text50.Text) + "','" _
    & Trim(Text31.Text) + "')"
    cmd.CommandText = SQL
    cmd.Execute
    SQL = "INSERT INTO CBR_Solution" _
    & " VALUES('" + Trim(Text31.Text) + "','Company Name : " & Text32.Text & "','" _
    & Trim(Label2(11).Caption) + "','" + Trim(Label2(12).Caption) + "','" +
     Trim(Label2(13).Caption) + "','" _
    & Trim(Label2(21).Caption) + "','" + Trim(Label2(22).Caption) + "','" +
     Trim(Label2(23).Caption) + "','" _
    & Trim(Label2(31).Caption) + "','" + Trim(Label2(32).Caption) + "','" +
     Trim(Label2(33).Caption) _
    & "')"
    cmd.CommandText = SQL
    cmd.Execute
End Sub
```