STATUS OF THESIS

Title of thesis	An Object Oriented Approach for Business Process Reengineering

I ABDELMAJID OMER ALHUSSEIN MUSMAR

hereby allow my thesis to be placed at the Information Resource Center (IRC) of Universiti Teknologi PETRONAS (UTP) with the following conditions:

1. The thesis becomes the property of UTP.
2. The IRC of UTP may make copies of the thesis for academic purposes only.
3. This thesis is classified as

☐ Confidential

☑ Non-confidential

If this thesis is confidential, please state the reason:

____

The contents of the thesis will remain confidential for ____________ years.

Remarks on disclosure:

____

Endorsed by

ABDELMAJID OMER ALHUSSEIN MUSMAR

Date: 19-11-08

DHANAPAL DURAI DOMINIC P
AZWEEN ABDULLAH
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, Tronoh, 31750
Perak, Malaysia

Date: 19-11-08

UNIVERSITI TEKNOLOGI PETRONAS

Approval by Supervisor (s)

The undersigned certify that they have read, and recommend to The Postgraduate Studies Programme for acceptance, a thesis entitled "**An Object Oriented Approach for Business Process Reengineering**" submitted by **(Abdelmajid Omer Alhussein Musmar)** for the fulfillment of the requirements for the degree of Master of Science in Information Technology.

____

Date

Signature :

Main Supervisor : Dr. P.D.D. Dominic
Senior Lecturer
Department of Computer & Information Sciences
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750 Tronoh,
Perak Darul Ridzuan, MALAYSIA.

Date : 19-11-08

Signature :

Co-Supervisor : Dr Azween Bin Abdullah
Senior Lecturer
Information Technology/Information Systems
Universiti Teknologi PETRONAS
31750 Tronoh
Perak Darul Ridzuan

Date : 20|11|08

TITLE PAGE

UNIVERSITI TEKNOLOGI PETRONAS

An Object Oriented Approach for Business Process Reengineering

By

Abdelmajid Omer Alhussein Musmar

A THESIS

SUBMITTED TO THE POSTGRADUATE STUDIES PROGRAMME

AS A REQUIREMENT FOR THE

DEGREE OF MASTER OF SCIENCE

INFORMATION TECHNOLOGY

BANDAR SERI ISKANDAR,

PERAK

November, 2008

ABSTRACT

Successful Business Process Reengineering (BPR) projects depend on the appropriate business process modeling techniques. On the other side, Information technology (IT) is considered as a key enabler of BPR. Since the object-oriented technique became the most common approach for implementing information systems, the object oriented approach to business process modeling seems to be the best way for more successful BPR projects.

This work aims to develop a modeling method for BPR. This method should fill the gap between modeling business process and creating a supportive information system for the redesigned processes in BPR. The present work introduces BPR modeling method that links object orientation with business process modeling. The proposed method integrates an object-oriented modeling method (An Extended object-oriented modeling method) with object-oriented modeling language (Unified Modeling language UML).

Design science methodology was used to develop the proposed modeling method. The proposed method was implemented into two types of business process case studies. The implementation showed a promising modeling technique for representing the business process and linking business process modeling with the development of the supportive information system.

ACKNOWLEDGEMENTS

First I want to thank my parents, my brother, and my sister for their spiritual encouragement and support. They influenced me to always pursue higher academic achievement. They have been supportive all the time.

Special thank to my supervisors Dr. Dominic and Dr. Azween for their encouragement, suggestions and guidance. Without their participation and their valuable comments on my thesis, this work could not be completed. I especially express my sincere appreciation to my co-supervisor Dr. Azween, for his understanding and support.

Finally, I would like to thank all my friends for their support and help. I would also like to thank my colleagues in Computer and Information Science department. They have been very friendly.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

The purpose of this research is to develop a BPR modeling method. The aim of this chapter is provide general and basic information about this research. In order to achieve this aim this chapter organized into six sections. More specifically, this chapter starts with a brief background overview of BPR in section one. Section one also provides the main definitions of BPR. This section helps in understanding the rest of the chapter. Then the problem statement of this research is presented in the second section. This section is important because it controls the purpose of all the sections that come after (i.e. objectives, scope of research, and importance of research sections). The third section discusses objectives which this research intends to achieve. This section shows how these objectives are related and derived logically from the problem statement. Section four illustrates the scope of this work. This is followed by a discussion of research importance in section five. Finally, section six presents an outline of the thesis structure.

1.1 Background

The idea of Business Process Reengineering or Redesign (BPR) started from a simple claim made by Hammer (1990). Hammer published an article in which he claimed that the major challenge for managers is to obliterate non-value adding work, rather than using technology for automating it. According to Hammer the managers should focus in using computers and Information Technology (IT) as tools for improving the business processes, and this can be done by using IT to remove the outdated work that does not add any value for customers, not by speeding it up through software and automation.

A similar idea was advocated by Davenport and Short (1990). Davenport and Short suggested that IT can be more than a useful tool in BPR. Thinking about information technology should be in terms of how it supports new or redesigned business processes, rather than business functions or other organizational entities. And business processes and process improvements should be considered in terms of the capabilities information technology can provide.

Different definitions by several researchers can be found for the term "Business Process Reengineering", but the most common definition of BPR was provided by Hammer and Champy (1993) as follows: "*the fundamental re-thinking and radical redesign of business processes to achieve dramatic improvement in critical, contemporary measures of performance, such as cost, quality, service and speed.*" They addressed four key words in the preceding definition: fundamental, radical, dramatic, and process. According to Hammer and Champy fundamental means that an organization or a company must ask fundamental questions about the existing business rules and assumptions in order to determine what they have to do, for example they may ask why we do what we do?, and why do we do it in this way?. The second key word is radical and this in reengineering terms means reevaluating all existing processes and procedures and inventing completely new ways of doing business. BPR is not about improving the existing processes, but it is about business reinvention and redesigning of the processes. The third key word dramatic means to make great quantum leaps in performance. Reengineering is not about making incremental or marginal improvements. The last key word is process. According to Hammer and Champy, a 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*".

Davenport and Short (1990) defined business process redesign as "*the analysis and design of work flows and processes within and between organizations*". Davenport and Short also defined a business process as a "set of logically related tasks performed to achieve a defined business outcome". According to Davenport and Short the processes have two important characteristics: the first one is that they have customers (either internal or external to the firm), and the second one is that they cross organizational boundaries.

Kettinger, Guha and Teng (1995) defined "business process reengineering as an organizational initiative to accomplish strategy-driven (re)design of business processes to achieve competitive breakthroughs in quality, responsiveness, cost, flexibility, and satisfaction. These initiatives may differ in scope from process improvement to radical new process design". According to Kettinger, Guha and Teng (1995) BPR employs a combination of management theory, system analysis, industrial engineering, operations research, quality measurement, communication analysis and information system techniques and tools.

1.2 Problem Statement

The BPR literature review showed that there is a high rate of failure in companies that have tried to reengineer their business process (Hammer & Champy, 1993). Many research works have been conducted to study and address the reasons for BPR failures. Many reasons have been addressed for BPR failure but human resistance, lack of open commitment by senior management to a BPR effort and lack of corporate Information System are considered as the most common reasons for BPR failure.

BPR effort is not an easy project and involves dramatic change in how business process can be done. For the organizations that want to reengineer their business process, accurate and complete representation and analysis of business processes are crucial to the success of BPR (Luo & Tung, 1999). The techniques for characterizing and analyzing business processes are referred to as business process modeling. Several modeling methods have been proposed to model business process and help BPR practitioners to conduct successful BPR projects. Most of the methods that have been proposed have been designed to work in specific area such as system analysis and design, database design, software engineering, software development and other different fields. Therefore each of these methods uses a different set of notations and models business processes from different perspectives. More details about business process modeling methods and their strength and weakness are discussed in the literature review in chapter two.

BPR projects are usually huge because they contain number of phases and different kinds of people are involved in each phase. Generally BPR effort starts by a clear representation of the existing business process. After the representation analysis for the existing process is required in order to identify and evaluate the opportunities for modifying the business processes. Lastly the creation of information system to support and implement the reengineered process is required. An appropriate modeling method is required to help BPR practitioners complete the previous steps smoothly. Some researchers like (Luo and Tung 1999; Gunasekaran and Kobu 2002) have proposed frameworks that help the BPR practitioners to select the appropriate modeling methods for each phase in a BPR project.

In this work it is argued that there is still lack of good BPR modeling methods that support BPR effort, despite all the modeling methods and techniques that have been proposed for BPR. This argument based on the following points:

- Most of the modeling methods that have been used in BPR are originally developed to be used in other fields which makes their notations difficult to be understood by BPR team members that they do not have good background in field that the methods belong to.
- Using different modeling methods from phase to phase in BPR project increases the time and cost of BPR effort, for example using modeling method for analysis phase and using another for the design or implementation phase.

The development and implementation of successful business information systems require an integration of the seamless design of both the business processes and the information systems supporting the business processes (Loos & Allweyer, 1998; Okawa, Hirabayashi, Kaminishi, Koizumi, & Sawamoto, 2007). Therefore, an effective business process modeling method is needed for that integration. The problem addressed in this research is the lack of BPR modeling methods that link between business processes modeling phase and the information system design and development phase in BPR projects.

1.3 Research Objectives

BPR effort is more complicated than simple automation issues. Companies that want to reengineer their business process should have a BPR team which consists of experts in different fields like (IT, management, system analysis, etc). BPR team begin by analyzing the business process and setting the goals, then looking for reengineering opportunity, reengineer the business process and using IT to create business information system for the reengineered process.

This research aims to develop a BPR modeling method that could help the BPR practitioners in modeling business process and fill the gap between business process analysis and the design of business information system.

1.4 Scope of Research

This research focused on linking the gap between business process modeling phase and information system design and development phase in BPR projects. This research also aims to introduce simple process modeling notations which could help BPR participants in understanding the existing business processes.

1.5 Importance of Research

Since BPR was introduced to the world most of the researchers linked the success of the BPR effort with the success of the IS that support the reengineered business process as the literature review in chapter two illustrates. Some projects died off even before implementation of IS because of the high cost and lengthy time spent in analysis (Dennis, Carte & Kelly, 2003)

Modeling has always been at the core of both organizational design and Information Systems development (Irani, Hlupic & Giaglis, 2001). Therefore the importance of this research comes from the fact that the proposed method could reduce the time and cost of the analysis phase in BPR project. Also the method could link between the analysis phase, design phase, and the implementation of supporting IS.

1.6 Structure of Thesis

This thesis is organized into six chapters. Chapter one provides a background overview of the research, problem statement, research objective, scope of research, importance of research, and presents the structure of the thesis. Chapter two is literature review which discusses the role of IT in BPR, business process modeling, object orientation and business process modeling, and modeling methods used in BPR. Chapter three addresses the details of the research methodology used in the research. In Chapter four, the proposed BPR modeling method is presented. Chapter five discusses the implementation of the proposed method via case studies. Finally, Chapter six concludes this thesis by presenting the contributions, limitations of the research, and highlights some future works.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews a wide range of BPR literature. The purpose of this literature review is to attempt to identify previous work that could provide a good basis to establish the requirements for developing the proposed BPR modeling method. The first section discusses the importance of business process modeling in BPR. Then section two discusses the implementation of object orientation in business process modeling to achieve better BPR outcomes. Section three shows a brief literature on the methodologies that have been proposed to conduct BPR effort. This section shows the steps that should be followed to conduct BPR project. This review is important and required to develop modeling method that can support all the BPR effort activities. Finally section four discusses the modeling methods that have been used in BPR. This review shows the strength those modeling methods have as well as their shortcomings. This is important to identify the desired properties of a BPR modeling method. Section five summarizes this chapter.

2.1 Business Process Modeling

Business process modeling is a technique that visualizes business in the real world (Tsugane & Asakura, 2006); in other word it is a description of the tasks that have to be carried out, and the order in which these tasks have to be carried out Dijkman and Joosten (2002). Business process modeling uses graphical diagrams and textual format to get an abstract representation of business processes (Wei, Hongwei, Jin & Changrui, 2006) in order to identify and evaluate the opportunities for modifying the business processes and to describe how work is accomplished in a business.

Due to the fact that a variety of persons, like managers, users, systems analysts, and developers are involved in BPR projects, each with different tasks and a distinct view on business processes (Rohloff, Danet & Munchen, 1996) business process modeling is acknowledged as an important activity for Business Process Reengineering (Bosilj-Vuksic, Giaglis & Hlupic, 2000). Also it is critical for an organization to have a BPR modeling methods that efficiently support a BPR projects because of the high risks involved in BPR. Therefore most methodologies for BPR include modeling phase to develop a model of business process and analyze it (Nakatani, 1999).

Irani, Hlupic and Giaglis (2001) discussed BPR from modeling perspective and they argued that there is a lack of comprehensive, scientifically established design methodology to structure, guide, and improve business process modeling efforts. According to Irani et al. the dynamic models of business processes can help overcome the inherent complexities of studying and analyzing businesses and, therefore, contribute to a higher level of understanding and improvement.

A business process model captures the relationships that are meaningful to the business between different organizational concepts, such as activities, the resources used by activities and the human or automated actors who perform these activities. Identifying the properties and relationships of these concepts is fundamental to help understanding and evolving the business since it facilitates the communication between stakeholders, business specialists and support system specialists (Caetano, Silva & Tribolet, 2005).

Many authors argue that a major problem that contributes to the failure of business process change projects is the lack of tools for evaluating the effects of designed solutions before implementation (Irani, Hlupic & Giaglis, 2001). Business process modeling can provide BPR participant the information needed to decide what to change, how to change it, and what the result of change will be.

2.2 Object Orientation and Business Process Modeling

The application of object-orientation in business process modeling is considered to be one of the steps to break a number of limitations of traditional approaches and move towards a more comprehensive modeling framework (Mentzas, 1999). Using object oriented approach for modeling business process has been the subject of numerous research papers by several researchers. The structure as well as the behaviors (dynamics) of a business process can be efficiently modeled with an object oriented approach (Kazuo & Yadav, 1996). Several frameworks and modeling methods have been developed for an integrated modeling of the entire enterprise with respect to both organizational and information systems aspects (Bosilj-Vuksic, Giaglis and Hlupic 2000; Peters and Peters 1997; Cheol-Han, R, A and Kyung-Huy, 2003; Karl, Keith, Aybüke, Steven and June 2004; Loos and Allweyer 1998; Mentzas 1999; Badica et al. 2005).

Nakatani (1999) addressed six reasons that make Object Orientation very useful in modeling business process:

1. Object oriented concept can represent tangible and intangible entities, so resources and work products can be represented as either tangible or intangible objects.

2. A whole-to-part relationship can be explicitly supported by the object oriented concept.

3. Specifying the relationships among objects can be easily done using object oriented concept.

4. Encapsulation property in object oriented concept allows the elimination of non fundamental processes without affecting the fundamental one.

5. Attributes of objects can be used to capture and represent information about business process.

6. Methods can be used to specify user defined control logic performed on the information captured as attributes.

Mentzas (1999) developed BROOM (Business Reengineering with Object-Oriented Modelling) process modeling approach, which integrates an object-oriented method (Object Modeling Technique, OMT) with a business process modeling method (Action Workflow Analysis, AWA). Mentzas developed this modeling framework to be used in BPR and Information Process Reengineering (IPR) fields. OMT is applied in both static and dynamic aspects. The event trace diagram is expanded by the workflow analysis carried out with the Action Workflow Analysis methodology to represent the dynamic side of the model

As illustrated in Figure 2-1 BROOM consist of several steps: conceptual modeling of current processes, Process mapping, Definition of metrics, Process Measurement and Benchmarking, Process Redesign, Process Simulation and Evaluation, and Information Process Development;

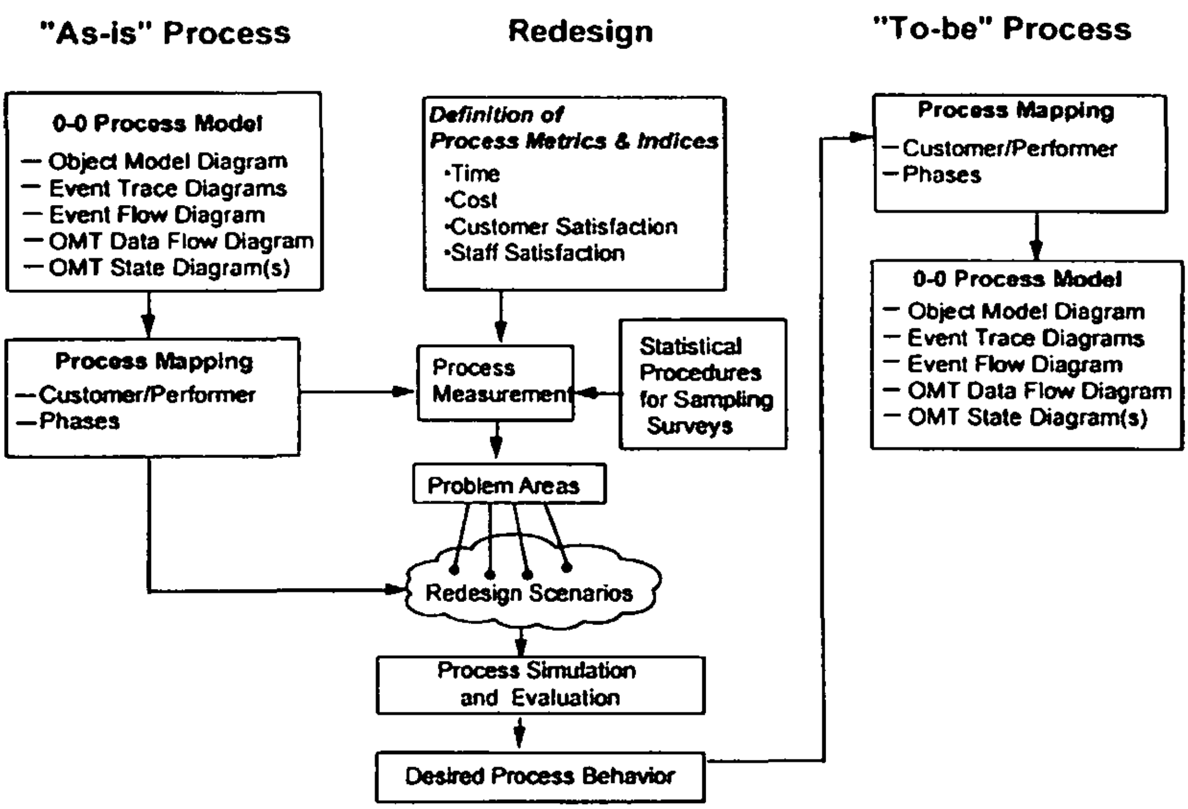

Figure 2-1: The BROOM Redesign Steps. (Mentzas, 1999).

This section explains the work that should be done in each step. Conceptual modeling of current processes refers to the development of the object-oriented models for each of the processes in the "as-is" situation. Process mapping refers to the development of the business workflow models for the "as-is" situation. Definition of metrics used as benchmarking guidelines for a quantitative simulation of the selected processes. Process Measurement and Benchmarking refers to the derivation of the values of metrics for the "as-is" version of processes and related comparisons and the determination of target metrics. Process Redesign is carried out by developing the "to-be" workflow model. Process Simulation and Evaluation refers to re-evaluating the associated metric values for alternative "to-be" models and the selection of most appropriate ones. Information Process Development refers to the development of object-oriented models for the selected "to-be" processes. OMT is applied in modeling static and dynamic aspects. The event trace diagram is expanded by the workflow analysis to represent the dynamic side of the model.

Mentzas summarized benefits of the BROOM approach under two main categories: benefits from using the object-oriented paradigm within a business context, and benefits from a coupled two stage approach in modeling both business and information processes. Because this section concentrates on the integration between object-orientation and business process modeling, only the benefits from using the object-oriented paradigm within the business context are addressed. These benefits were summarized as follow:

- **Communication:** Business object-oriented models provide common terms and ideas at a level of detail which can be shared among business and technical people to articulate and understand the business in business terms.
- **Modeling:** Business object-oriented models have certain characteristics and behavior which enables them to be used naturally in modeling business processes, and the relationships and interactions between business concepts.
- **Design:** Business object-oriented models represent real world things and concepts which enable design effort to be concentrated in manageable chunks.
- **Implementation:** Business object-oriented models have late and flexible binding and well defined interfaces so that they can be implemented independently, i.e. information process implementation can be "seamlessly" derived from the corresponding business process models.
- **Distribution:** Business object-oriented models are independent so that they can be distributed as self-contained units to platforms with suitable installed infrastructure.

- **Evolution:** Business object-oriented models can be used in a variety of roles and evolve with the needs of the business. They provide a means for integrating, migrating and evolving existing applications.

Snoeck, Poelmans and Dedene (2000) also proposed an architecture that integrates the concepts of object-oriented modeling with those of business process modeling. According to Snoeck, Poelmans and Dedene (2000) such integration can lead to several advantages for both fields of interest. The main advantages for object-oriented development are a better organizational fit and a better separation of concerns in the design of systems. The main advantages for workflow systems are a better adaptability for the functional part and the general advantages of the object-oriented approach such as e.g. portability across platforms.

2.3 BPR Methodologies

The PBR literature shows a large number of BPR methodologies that have appeared during recent years. These methodologies have been proposed to help researchers and organizations to conduct BPR effort successfully. Nakatani (1999) claimed that BPR researchers have derived their structured methodologies by examining successfully completed BPR projects and finding common attributes among them.

Davenport and Short (1999) proposed the first step-by-step methodology. Those steps are:

1. Develop the business vision and process objectives.
2. Identify the process to be redesigned.
3. Understand and measure the existing process.
4. Identify IT levers.
5. Design and build a prototype of the new process.

Davenport and Short (1999) stated that rationalization is insufficient as a process redesign objective and instead of task rationalization, redesign of entire processes should be undertaken with a specific business vision and related objectives in mind. To identify the processes for redesign Davenport and Short suggested two major approaches. These approaches are the exhaustive approach, which attempts to identify all processes within an organization and then prioritize them in order of redesign urgency and the high-impact approach, which attempts to identify only the most important processes or those most in conflict with the business vision and process objectives. Davenport and Short addressed two primary reasons for understanding and measuring processes before redesigning them. The first one is that understanding problems is important so that they are not repeated. Second, accurate measurement is necessary to be used for future improvements. Davenport and Short also considered IT as powerful tool and can create options for new process design, rather than simply support them.

Kettinger, Guha and Teng (1995) studied many BPR methodologies and they found that methodologies for BPR have some practiced approaches that are common among all those methodologies. Kettinger et al. developed Process Reengineering Life Cycle (PRLC) methodology for BPR, this methodology was developed based on the study which they had conducted.

Valiris and Glykas (1999) classified BPR methodologies into two main categories: the management accounting and the information system development categories. Valiris and Glykas (1999) made this classification depending on the perspective that methodologies take in BPR. In the management accounting perspective the analysts focus in reengineering business processes and use IT as an enabler in the reengineering effort. In the Information System (IS) development perspective IS developers have to understand business processes in way that make the use of IT has the highest possible impact on the reengineered business process. Valiris and Glykas (1999) stated that most BPR methodologies follow similar steps in BPR effort:

1. Establishment of the business vision and objectives.
2. Identification and focus on the core business processes that support them.
3. Modeling and analysis of the business environment.
4. Streamlining.
5. Continuous control and improvement of previous steps.

From BPR methodologies literature it is clear that most of the BPR methodologies share at least the following steps:

1. All methods define the project before beginning (selection of business process).
2. All methods have analysis step (analysis of the selected business process).
3. All methods have a redesign step or reengineering business process step.
4. All methods plan and implement a solution (implementation of the reengineered process).

2.4 Modeling Methods Used in BPR

Successful BPR project depends on the appropriate business process modeling techniques so there are many techniques and methods used in this field. In this section the main techniques and most frequently used are listed as well as their characteristics.

2.4.1 Flowcharts

A flowchart is graphical representation in which symbols are used to represent such things as operations, data, flow direction, and equipment, in order to define and analyze a problem and find the solution (Aguilar-Saven, 2004). Flowcharting is one of the first graphical modeling techniques and it is very useful as a simple, graphic means of communication, intended to support understandable descriptions of processes (Stemberger, Jaklic & Popovic, 2004). A set of standard flowchart symbols most commonly used to model business processes illustrated in (Figure 2-2). This method has several advantages and here are some of them addressed by Damij (2007):

1. Flowchart diagram is very simple and this enables the analyst to develop a process model by transforming his/her knowledge into series of connected activities.
2. The flowchart technique is flexible as it allows each modeler to unite various pieces of the process together to gain the whole picture as he/she feels they fit best.
3. The visibility of a flowchart, which contains several tens of activities, is pretty good.
4. There are several widely used software packages which enable the analyst to model a business process by drawing a flowchart, such as iGrafx, Visio and others.

According to Nakatani (1999) flowcharts have several shortcomings as a BPR modeling methods

1. Flowcharts have difficulty in representing a complex structure of a process.
2. Inputs and outputs of activities are not specified in flowcharts.
3. Flowcharts do not specify where and by whom the processes are performed.
4. Neither process measurement variables nor strategic aspects of a process are captured in flowcharts.

Also, flowcharts do not include a timeline and duration for tasks. Therefore, it is difficult to show parallel tasks and the relationships between them. In addition, it is not easy to modify flowchart diagrams; small alterations in a flowchart may require re-drawing the whole diagram.

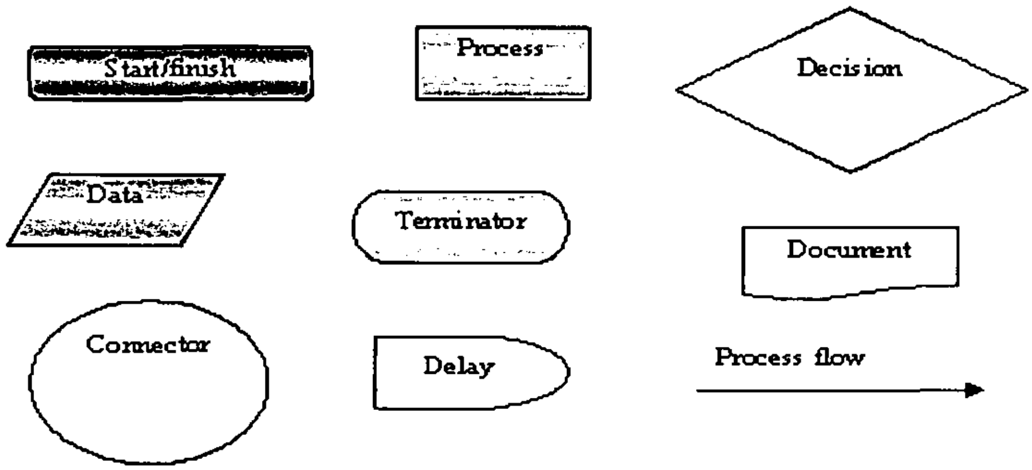

Figure 2-2: Flowchart Symbols

2.4.2 Data Flow Diagrams – DFD

A data flow diagram (DFD) is a graphical technique that depicts information flow and transformation as data move from input to output (Zhi-Yu, Shi-Quan & Jin-Pei, 2005). There are four components to a DFD: processes, data flows, data stores, and external entities (Figure 2-3). Together, these elements create a map of the processes within a business (Turetken & Schuff, 2002). DFDs describe the processes showing how these processes link together through data stores and how the processes relate to the users and the outside world (Aguilar-Saven, 2004). DFDs are simple, easy to comprehend and easy to improve, as they are intended for communication between the modeler and the users. Such documents show the relationships among all components of the system specification (or detailed user requirements), including system outputs, data definitions, system inputs (or transactions), and process specifications (or business rules) (Damij, 2007).

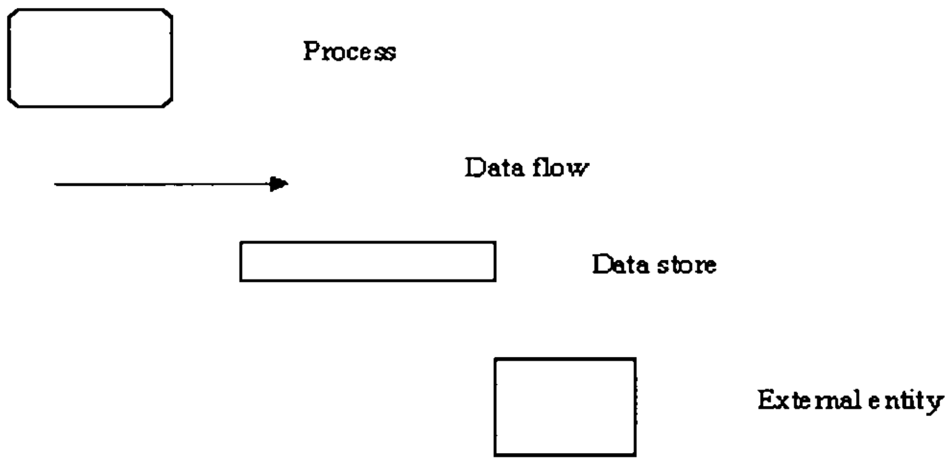

Figure 2-3: Data Flow Diagrams Symbols

DFD models have several shortcomings as BPR modeling method. The important shortcomings of the DFD models can be summarized into two main points:

1. DFD is poor at modeling business process form behavioral perspective. DFD does not specify the order in which the different tasks are executed. Considering the time dimension in modeling business process is very important for BPR.
2. DFD has a lack in representing organizational perspective. DFD does not specify who performed the business processes and how. Also The DFD does not show roles and responsibilities.

2.4.3 Role Activity Diagrams – RAD

RAD is a visual notation for business process modeling (Badica, Teodorescu, Spahiu, Badica, & Fox, 2005). RAD is composed of essential concepts, such as role, state, process, goal, activity, and interaction as shown in Figure 2-4 (Lin, Yang & Pai, 2002). Roles can be humans as well as software and hardware systems (Karl, Keith, Aybüke, Steven & June, 2004). RADs provide a different perspective of the process and are particularly useful in supporting communication and they are easy and intuitive to read and understand presenting a detailed view of the process and permitting activities in parallel (Aguilar-Saven, 2004). The RAD provides an excellent means of describing dependencies between roles in organizations that work discretely and in unison to achieve a goal (Karl et al., 2004).

In short RAD strongly represents the behavioral and organizational perspectives but it does not support hierarchical decomposition (Nakatani, 1999). RAD does not capture information and detailed description of activities and objects that interact with a business process. The notations used in RAD are not as formal and rigid as those used in DFD. As a result, it is difficult to model large-scale processes using RAD (Luo & Tung, 1999).

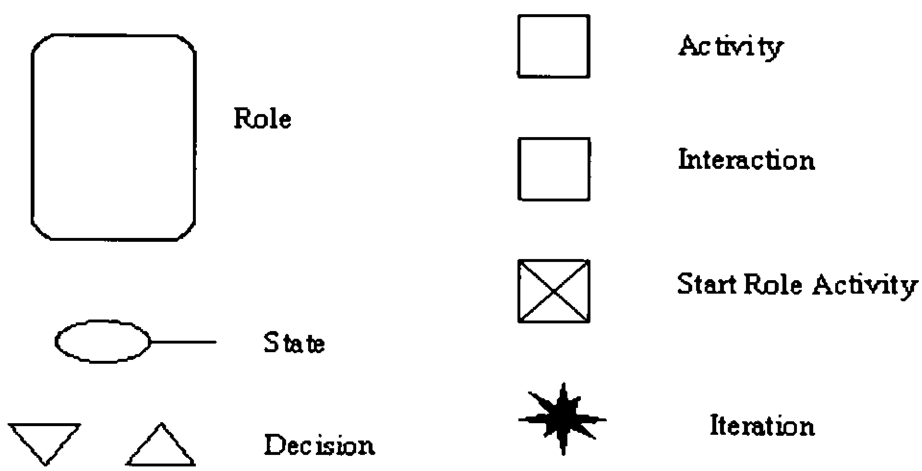

Figure 2-4: Role Activity Diagrams Symbols

2.4.4 IDEF

IDEF, an abbreviation of ICAM (Integrated Computer Aided Manufacturing) DEFinition, was first used for the analysis and design of the computer aided manufacturing system by the United States air force in 1981 (Yan-Ling, Fu-Yuan & Wen-Bo, 2004). It is made of a series of modeling methods comprising IDEF0 for functional modeling, IDEF1x/ EXPRESS for information modeling, IDEF3 for business process modeling, IDEF4 for object modeling and IDEF5 for ontology modeling (Mertins & Jochem, 2005).

The IDEF series methods are relatively independent to each other, so each of these models uses different perspective for modeling the business processes. Several researchers suggest that IDEF is a suitable method for BPR (Bosilj-Vuksic, Giaglis and Hlupic 2000; Peters and Peters 1997; Badica et al. 2005; Cheol-Han and Kyung-Huy 2003). IDEF0 is mainly concerned with what activities the organization performs so the basic building block of the IDEFO model is the Activity Cell (Figure 2-5). Peters and Peters (1997) developed a process modeling tool for BPR by integrating IDEF0 with Petri nets. Badica (2005) proposed a business process modeling approach that integrates Role Activity Diagrams with Hybrid IDEF (integrates IDEF0 and IDEF3)

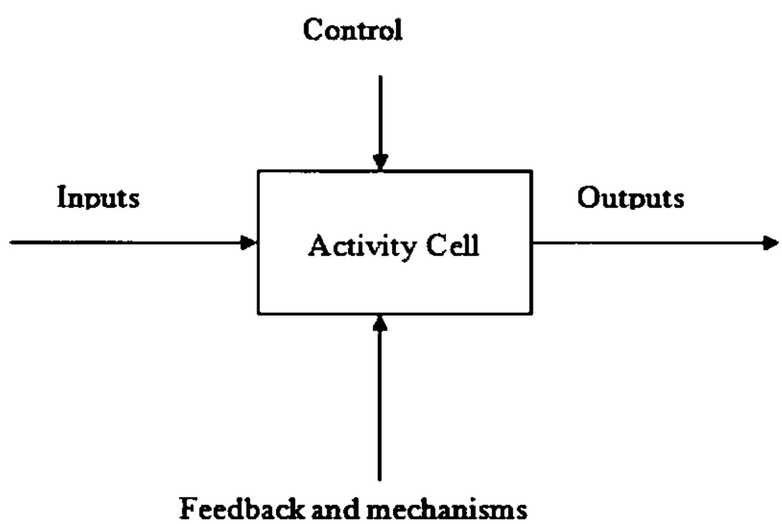

Figure 2-5: The Activity Cell

This section describes the syntax and notations of IDEF diagram as in Figure 2-6 and the description is adopted from Waltman and Presley (1993). Functions are represented by boxes and interfaces are represented by arrows, the boxes represent functions such as activities, actions, processes or operations. Arrows indicate data. In IDEF, data can be information or physical objects. The position of the arrow indicates the type of information being conveyed. The arrows entering and leaving the boxes on the left and right represent "Inputs" and "Outputs", respectively. Inputs represent data needed to perform the function. Outputs show the data that is produced as a result of the function. The function transforms the inputs into the outputs. Arrows which enter from the top indicate "Controls", or things which constrain or govern the function. Arrows entering the bottom of the boxes are "Mechanisms". Mechanisms can be thought of as the person or device which performs the function. An IDEF model is made up of several diagrams. Each diagram describes in more detail a box from a more general diagram. The process of describing a box in more detail is known as decomposing a function. The more general diagram is called the parent of the detailed diagram. IDEF models are read in a "Top-Down" fashion. The top level diagram, also called the Context or A-0 Diagram, summarizes the overall function of the system which is represented by a single box. The A0 diagram represents the first decomposition of the system.

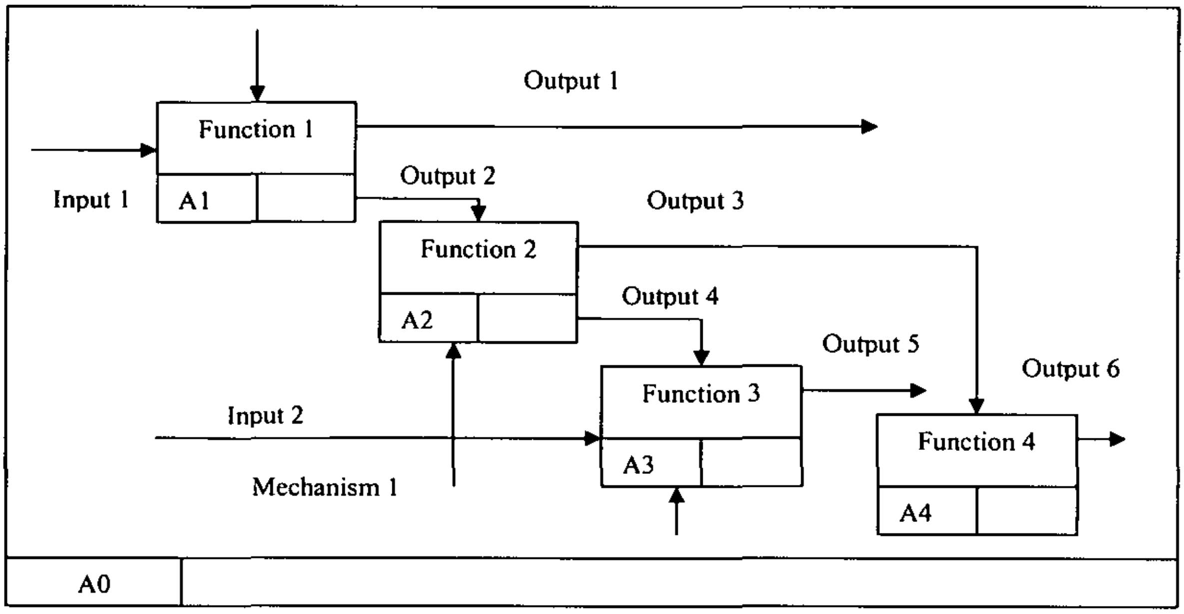

Figure 2-6: An Example of an IDEF Diagram

IDEF is a good technique for business process modeling but it has some limitations. First, IDEF does not specify resources and represent user and strategic perspectives. Second, IDEF diagrams are complex and can get more complicated which make it difficult for many people to understand the diagrams. Since the BPR effort involve different kinds of people, the IDEF diagram need improvement to be understood by people in the BPR team. Finally, IDEF is not a very good system development method. Therefore, IDEF need to be integrated with other method for BPR because as mentioned earlier the development of the support information system is important in reengineering effort.

2.4.5 Petri Net

A Petri net is a graphical and mathematical modeling tool that is able to model concurrent, asynchronous, distributed, and parallel systems (Gunasekaran and Kobu, 2002). Petri net is an example of a business process modeling technique that combines visual representation using standard notation with an underlying mathematical representation (Vergidis, Tiwari & Majeed, 2008). Petri net consists of places, transitions, and arcs. Places are drown as circles and represent possible states or conditions of the system, transitions are drown bars or boxes and describe events that may modify system states, and the arcs represent relationships between places and transitions. The dynamic behavior of a system can be represented using tokens, which graphically appear as black dots in places (Salimifard & Wright, 2001).

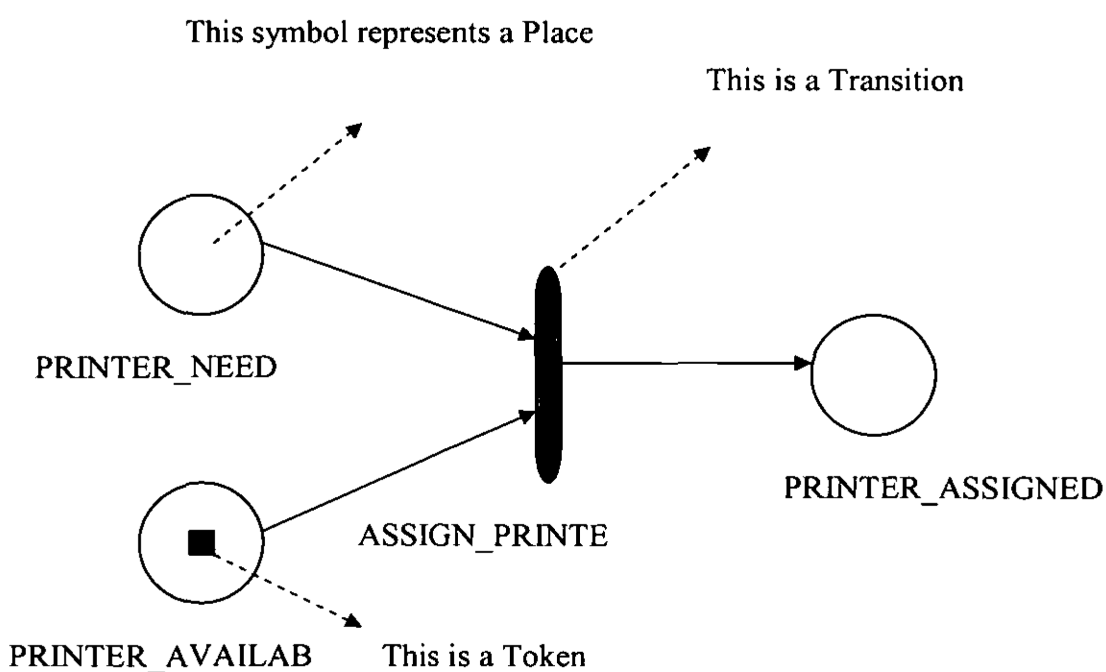

Figure 2-7: Basic Elements of a Petri Net.

Figure 2-7 shows a simple Petri net with its basic components: transition, place and token. Since 60s, Petri net and its extended forms have been widely used in many fields. In the latest years, some research started to focus on the application of Petri net in BPR (Fei, Junwei & Qidi, 2003). Petri nets are one of the most widely used methods in modeling of parallel dynamic systems because of their characteristics: simplicity, representation power comprising concurrency, synchronization and resource sharing, strong ability of their mathematical analysis and application of software tools (Bosilj-Vuksic, Giaglis & Hlupic, 2000).

Although Petri nets have many good points it has some limitations. Petri net describes the dynamic of the business process, but does not represent the data and operations on data. Petri net is only used to analyze the validity of the process, to make sure that the process going well without any dead lock, but fails to analyze the performance and optimization of the process. Petri nets Like IDEF, are not easily understandable for non-experts members in BPR team

2.4.6 Unified Modeling Language

Unified Modeling Language (UML) is a collection of languages that primarily support object-oriented modeling of software systems in terms of flows, objects, and messages (Rittgen, 2006). There are three main modeling viewpoints in UML: ''functional'' models which describe system requirements from user viewpoints, ''static'' models which are essentially class diagrams that describe system elements and their relationships (including generalization, aggregation and association relationships), and ''dynamic'' models which describe system behavior over time (Cheol-Han & Kyung-Huy, 2003).

UML has nine predefined diagrams to capture the three important aspects of systems: structure, behavior, and functionality (Eriksson & Penker, 2002). Although UML in its first years has been used mainly for modeling software systems, it is also a very suitable for business modeling. It has the ability to describe both the structural and behavioral aspects of a business process.

Dijkman and Joosten (2002) introduced a procedure to transform business process models into UML Use Case diagrams. According to Dijkman and Joosten (2002) business processes can be described by use case models because a use case diagram can describe the behavior of the system under development. Since the proposed modeling method in research uses UML notations, more discussion and details about UML will be provided in chapter five which discusses the proposed method.

2.5 Summary

In summary, several modeling methods have been used for BPR. However, all of those modeling methods have two common problems. First those methods do not provide notations or diagrams that can work as common vocabulary between the BPR team members. All BPR team members must work together on a plan to come to agreement on the best plan. A BPR modeling method should support the display of plans in a format that can be created, edited, and understood by non technical people. Second and more importantly, each of those modeling methods by itself does not have mechanisms to efficiently and effectively analyze and redesign the business process and also develop and implement the supportive information system for BPR project. Chapter four presents the proposed modeling method to resolves the shortcomings of these existing modeling methods used in BPR.

CHAPTER THREE: RESEARCH METHODOLOGY

The objective of this research work is to develop a BPR modeling method. To achieve this objective Design Science Research methodology proposed by Hevner et al. (2004) was used. Design Science is an IS research methodology, which offers specific guidelines for a research. Design Science focuses on the development and performance of (designed) artifacts with the explicit intention of improving the functional performance of the artifact. Design research is applied to categories of artifact including algorithms, human computer interfaces, design methodologies (including process models) and languages. Its application is most notable in systems development, design of human-computer interfaces and architectural designs for computing and communication (Ram & Raghav, 2005).

Hevner et al. (2004) presented a conceptual framework for understanding, executing, and evaluating IT artifacts (Figure 3-1). According to Hevner et al. and as the Figure 3-1 illustrates the environment for IS research, is composed of people, (business) organizations, and their existing or planned technologies. Business needs are assessed and evaluated within the context of organizational strategies, structure, culture, and existing business processes. They are positioned relative to existing technology infrastructure, applications, communication architectures, and development capabilities. Together these define the business need or "problem" as perceived by the researcher. The knowledge base provides the raw materials from and through which IS research is accomplished. The knowledge base is composed of Foundations and Methodologies.

The authors of methodology also proposed seven guidelines that help researchers in conducting and evaluating good design science research (Table 3-1). The authors of the proposed framework claim that each of the guidelines should be addressed in some manner for IS design science research to be complete, but researchers can use their creative skills and judgment to determine when, where, and how to apply each of the guidelines in a specific research project.

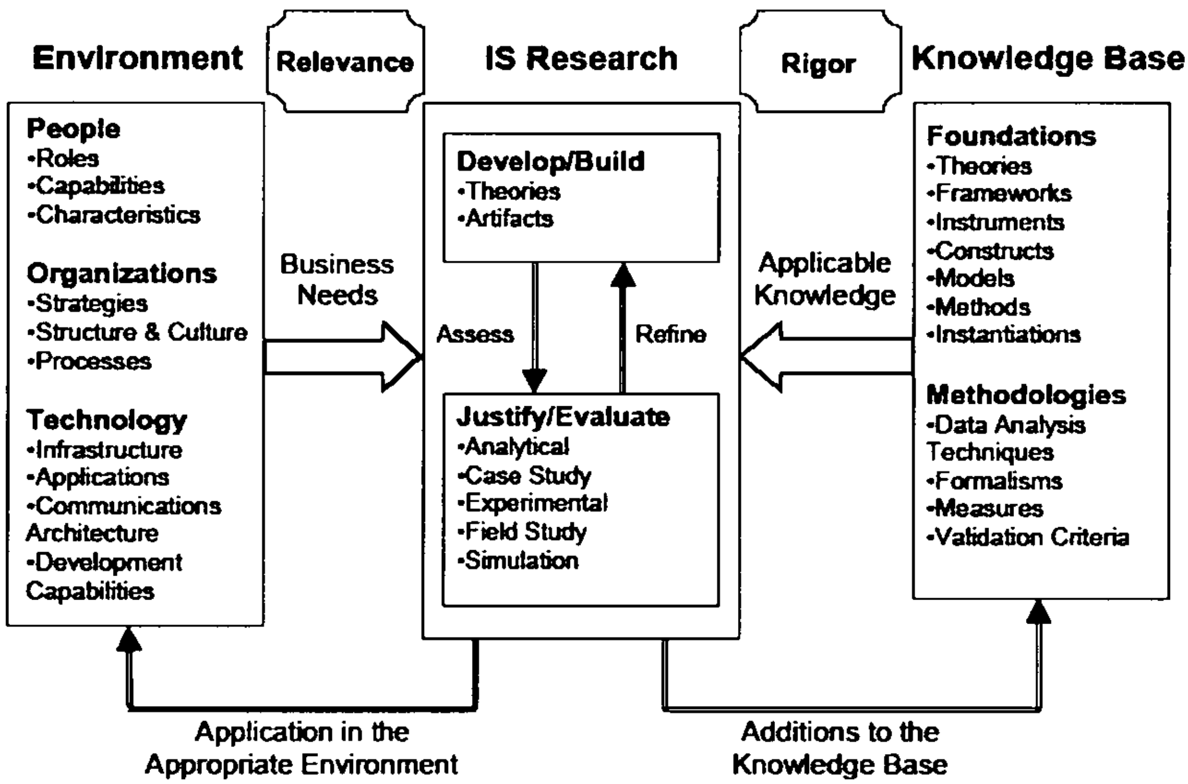

Figure 3-1: IS Research Framework. (Hevner et al., 2004).

There are two reasons for using this methodology:

1. The objective of this work is to develop a BPR modeling method and design science research is fundamentally a problem-solving paradigm methodology. According to Hevner et al. (2004) the main objective of design science research is to develop technology based solutions to important and relevant business problems.
2. Design science methodology assist researchers to understand the requirements for effective design research by providing a conceptual framework and clear guidelines for understanding, executing, and evaluating the research.

Table 3-1: Design-Science Research Guidelines. (Hevner et al., 2004)

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

3.1 Design as an Artifact

The first guideline in design science methodology aims to create a purposeful IT artifact which can address an important organizational problem. There are many definitions of the term IT artifact but this work considered the definition that provided by Hevner et al. (2004) to IT artifact term as "Our definition of IT artifacts is both broader and narrower than those articulated above. It is broader in the sense that we include not only instantiations in our definition of the IT artifact but also the constructs, models, and methods applied in the development and use of information systems".

This research proposes a business process modeling method for BPR effort. This method will be used to support BPR from selecting and representing the business process till the implementation of business information system. Therefore there is a clearly identifiable artifact produced in this research and this artifact is the proposed modeling method.

3.2 Problem Relevance

The design science objective is to develop and implement innovative IT artifacts that can provide solutions to unsolved and important business problems. The authors of this methodology explain that the relevance problem for a design-science research effort is with respect to a constituent community. For BPR researchers that constituent community is the practitioners involved in BPR project i.e. (managers, users, systems analysts, and developers). To be relevant to this community, research must address the problems faced and the opportunities afforded by the interaction of people, organizations, and information technology.

Adopting BPR effort by different type of organizations is growing rapidly, several modeling methods to support organizations in reengineering their work have been proposed and used, and there is still lack in modeling methods which can support all BPR phased in effective manner. The problem which this research is addressing and trying to solved is the lack of modeling methods that support BPR effort in effective and efficient manner which is a relevance problem to BPR community. This is the very relevant problem addressed by this research

3.3 Design Evaluation

In general, evaluation is an important and crucial process in any research work because it is the way that researchers can provide evidences to prove the efficiency of their work. According to the authors of design science methodology the IT artifact can be evaluated in terms of functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes. Design science methodology has addressed a number of evaluation methods that researchers can use to test and evaluate if the new artifact satisfies the requirements and constraints of the problem it was meant to solve. These evaluation methods are summarized in Table 3-2. In this work, the first method was chosen and the proposed modeling method was applied to two business processes case studies.

Table 3-2: Design Evaluation Methods. (Hevner et al., 2004)

1. Observational	Case Study – Study artifact in depth in business environment
	Field Study – Monitor use of artifact in multiple projects
2. Analytical	Static Analysis – Examine structure of artifact for static qualities (e.g., complexity)
	Architecture Analysis – Study fit of artifact into technical IS architecture
	Optimization – Demonstrate inherent optimal properties of artifact or provide optimality bounds on artifact behavior
	Dynamic Analysis – Study artifact in use for dynamic qualities (e.g., performance)
3. Experimental	Controlled Experiment – Study artifact in controlled environment for qualities (e.g., usability)
	Simulation – Execute artifact with artificial data
4. Testing	Functional (Black Box) Testing – Execute artifact interfaces to discover failures and identify defects
	Structural (White Box) Testing – Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation
5. Descriptive	Informed Argument – Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility
	Scenarios – Construct detailed scenarios around the artifact to demonstrate its utility

3.4 Research Contributions

The overall assessment for any research work depends on the contribution that work gave to the world (area of study). According to Hevner et al. "the contributions of behavioral-science and design-science in IS research are assessed as they are applied to the business needs in an appropriate environment and as they add to the contents of the knowledge base for further research and practice". Therefore Design science methodology specified three types of contributions (Design artifact, foundations, and methodologies) and at least one of them must be found in a given research work. Most often, the contribution of design-science research is the artifact itself (Hevner et al., 2004). Since this research aims to introduce modeling method to be used in BPR effort, the contribution of this work belongs to the first type (the design artifact). In this work the contribution is the proposed modeling method.

3.5 Research Rigor

In design science research rigor addresses the way in which research is conducted. The authors of this methodology argued that the application of rigorous methods in both the construction and evaluation of the designed artifact is required in design science research. Rigor must be assessed with respect to the applicability and generality of the artifact. According to Hevner et al. (2004) rigor is derived from the effective use of the knowledge base (theoretical foundations and research methodologies). They also claimed that the success of research is depending on the researcher's skilled selection of appropriate techniques to develop or construct an artifact and the selection of appropriate ways to evaluate the artifact.

The presented work has theoretical foundations in both business process modeling and IS design theory. The previous research in modeling business process and developing information systems for BPR provided good foundation for this research. This research uses UML notations which have been used in IS development. Also the Extended Object-Oriented Modeling for BPR was created mainly for modeling business process in BPR effort. Therefore this research is based on a clearly defined and tested BPR literature and knowledge

3.6 Design as a Search Process

Design science is essentially a search process to discover an effective solution to a problem. According to Hevner et al. (2004) effective design requires knowledge of both the application domain (e.g., requirements and constraints) and the solution domain (e.g., technical and organizational). Therefore this research starts by identifying what is BPR. After the definition a brief discussion on the role of IT in BPR project and the need of business process modeling was provided. After that the advantages of using object orientation with business process modeling for BPR is discussed. Then a discussion on the techniques and the modeling methods in BPR presented. The design science process employed by this research is to develop an effective modeling method for BPR, so based on the previous works this research has proposed modeling method for BPR and the proposed method is implemented in business process case studies.

3.7 Communication of Research

Design science research must be presented both to technology-oriented as well as management-oriented audiences (Hevner et al., 2004), so the research must provide sufficient detail about the artifact to technology-oriented audiences and management-oriented to be able to implement and use it within an appropriate organizational context. Since this work aims at the people involved in BPR project and those often are variety of persons from different background like managers, users, systems analysts, and developers. This research provides clear information to both technical and managerial audiences.

CHAPTER FOUR: THE PROPOSED APPROACH

This research proposes a modeling method that integrates the Extended Object-Oriented modeling method with UML for BPR effort. With the proposed method it is possible for BPR practitioners to model the business processes and its information systems without the need for switching between different modeling paradigms or translating between different modeling languages. This chapter discusses the proposed approach.

According to Curtis et al. (1992), a good process model should capture information about a process using four perspectives: functional, behavioral, organizational, and informational. In view of the fact that UML diagrams have been used to model business process from structural, behavioral, and functional point of view (Eriksson & Penker, 2002), this chapter discusses and explains the properties of the proposed approach based on these three modeling perspectives.

4.1 Structural Modeling

Generally structural model shows the static structure of the system being modeled, focusing on the elements of a system, without considering the time. The structural model describes the structure of the data that support the business process in an organization.

UML considers structure diagrams as a classification; therefore it provides a number of diagrams for structure modeling. However UML Class diagrams are the mainstay of the structures diagrams and provide the initial set of notation elements that all other structure diagrams used (Bell 2004; Ambler 2004). And because the class diagram is so foundational, it was used for the integration in the proposed modeling method. In class diagram classes are depicted as boxes. The class box always contains the class name. Class attributes and operations may be depicted. In this case the top compartment of the class box contains the class name, the middle compartment contains the class attribute and the bottom compartment contains the operations as illustrated in Figure 4-1. Relationships are depicted as lines between classes which participated in those relationships.

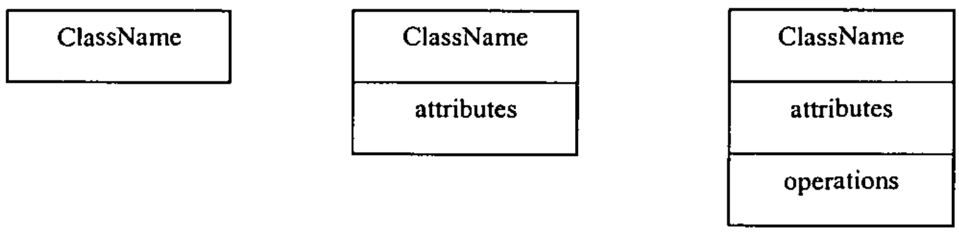

Figure 4-1: UML Notations for Classes

There are three main types of relationships between classes: generalization, aggregation, and association. These relationships are summarized in the following points:

Generalization: sometimes there are classes that share some attributes and/or operations. With generalization mechanism analysts are able to create classes that inherit attributes and operations of other classes. In UML a generalization relationship is depicted as a solid-line path from the more specific class (child or subclass) to the more general class (parent or superclass), with a large hollow triangle at the end of the path connected to the more general class (parent) (Alhir, 2002). As shown in Figure 4-2 Process1 represents the parent class and Process2, Process3, and Process4 represent the children classes.

Aggregation: sometimes there is a process made up of other processes. This kind of relationship in UML is called Aggregation or Composition Association or whole-part relationship or has-a relationship. UML Composition Association relationship is depicted as a solid-line path from the element which represent a whole to the element that represent a part, with filled diamond at the end of the path connected to the element that represent a whole. As shown in Figure 4-3 Process1 represents the whole class and

Process2, Process3, and Process4 represent the parts.

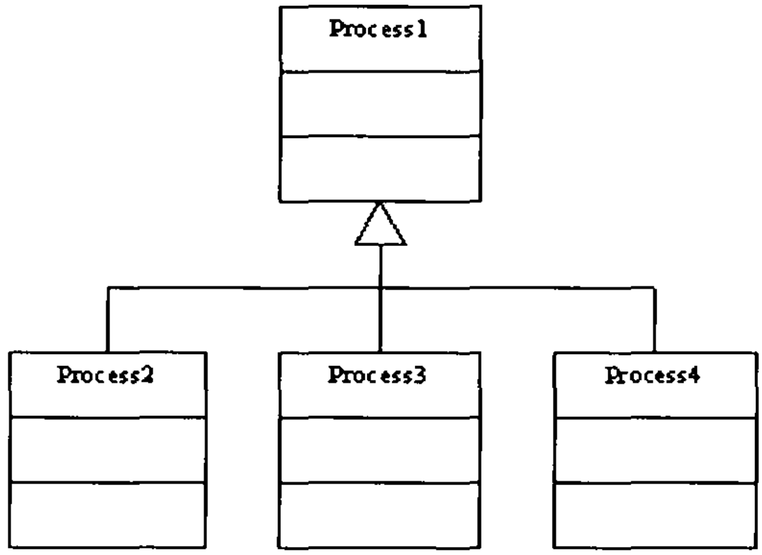

Figure 4-2: A UML Class Diagram with Generalization

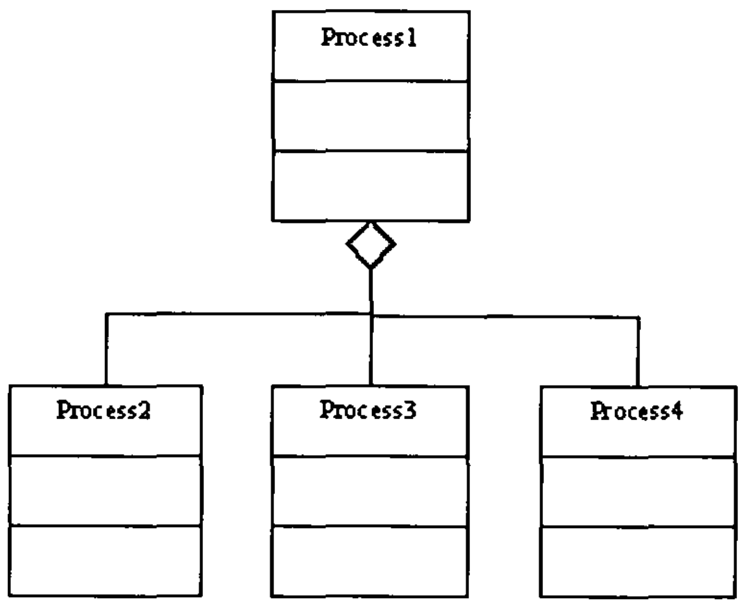

Figure 4-3: A UML Class Diagram with Aggregation

Association: an association is a relationship between two classes, which describes the reasons for the relationship and the rules that govern the relationship. An association is depicted as a line joining the two class boxes. An association has a name and optionally a small arrowhead to depict the direction in which the association name should be read. The name of an association describes the nature of the relationship between two classifiers and should be a verb or phrase. On each end of association line is the multiplicity of the association, which indicates how many instance of one class are related to an instance of the other class. Each end of a relationship has properties that specify the role of the association end, its multiplicity, visibility, navigability, and constraints. Figure 4-4 illustrates the way that association is depicted in UML class diagram. Table 4-1 summarizes the potential multiplicity indicators for association relationships.

Table 4-1: Multiplicity Indicators

0..1	Zero or one
1	One only
0..*	Zero or more
1..*	One or more
N	Only *n* (where *n* > 1)
0..n	Zero to *n* (where *n* > 1)
1..n	One to *n* (where *n* > 1)

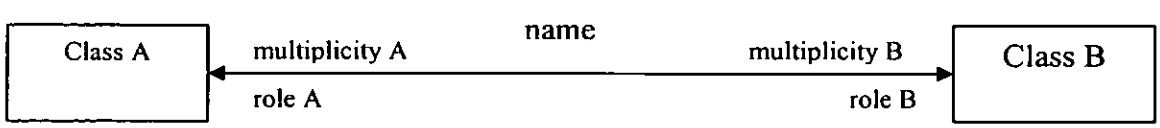

Figure 4-4: A UML Class Diagram with Association

An Extended object-oriented modeling methods for BPR has been developed by Nakatani (1999) based on a previous work done by Kazuo and Yadav (1996). The Extended object-oriented modeling methods framework uses two types of objects to capture the information about business process. They are process object and resource object. These two types of objects have been extended from the traditional objects by adding new component to their structure. A process object is used to describe business process and process steps. The structure of process object is shown in Figure 4-5.

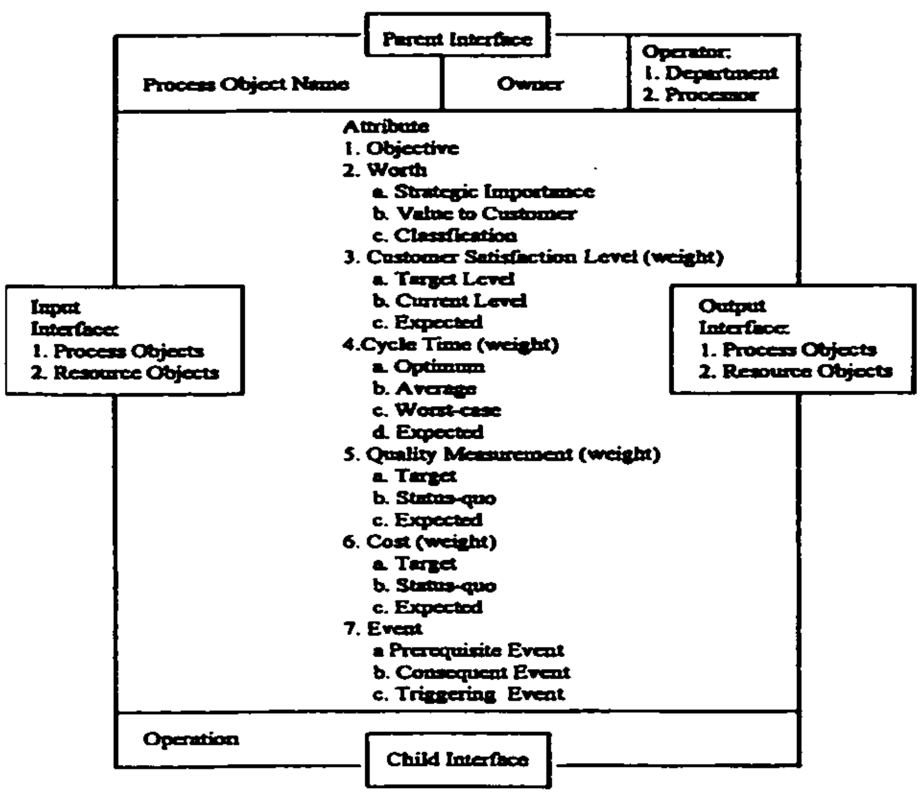

Figure 4-5: A Structure of Process Object. (Nakatani, 1999)

A resource object describes work product and resources. The structure of resource object is shown in Figure 4-6.

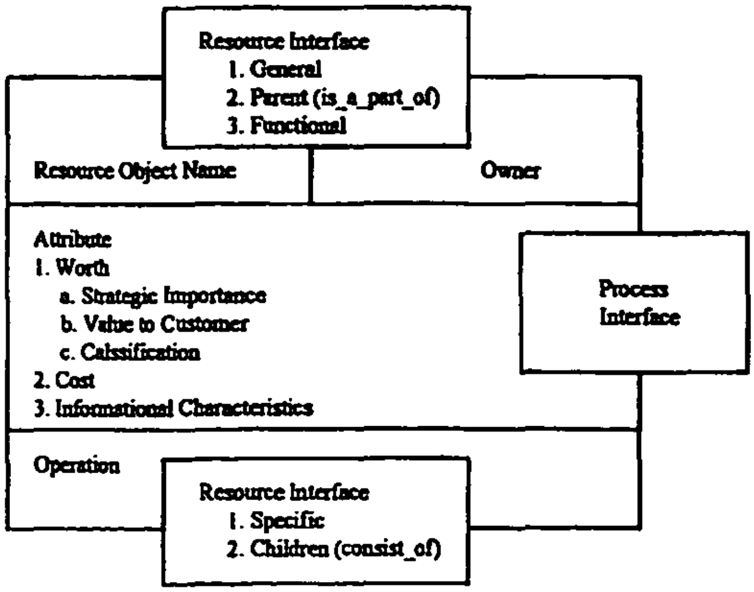

Figure 4-6: A Structure of Resource Object. (Nakatani, 1999)

Extended Object-Oriented modeling method uses the process object diagram to represent the structure of business process in an organization. The interface component in process object is used to illustrate relationships between the process objects. Figure 4-7 shows how generalization and aggregation is depicted using the parent-children interface.

The parent and children interfaces are used to specify a Whole-to-Part and General-to-Specific relationships among process objects. The parent part specifies the next higher level of a process object and the children part specifies the next lower process objects. A whole-to-part relationship among process objects is represented as shown in Figure 4-7. In short the parent and children interfaces work as interface pointers. The children interface of a parent process object contains information about which process objects are its children. The parent interface of a child process object contains information about which process object is its parent (Nakatani, 1999). Therefore, parent-children interfaces are replaced by "parent-children" when they are connected as shown in Figure 4-7.

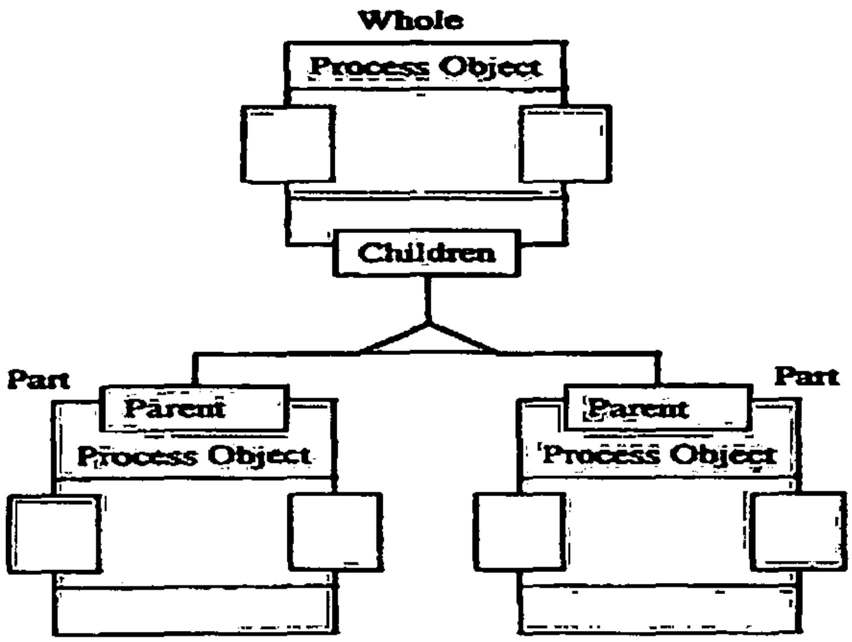

Figure 4-7: A Whole-to-Part, General-to-Specific of Process Object Diagram

The proposed modeling methods introduces business process diagram which integrates UML class diagram with process object diagram for structural modeling. Since both of UML class diagram and process object diagram uses similar format to represent business process, the business process also is represented by the same rectangular shape. To illustrate the relationship between business processes both of UML class diagram and process object diagram are used. For example as shown in Figure 4-8 to represent the generalization between Process1, Process2, and Process3, the parent and children interface as well as the hollow triangle were used. The parent and children interface beside the filled diamond also were used to illustrate the Aggregation (whole-to-part) relationship as shown in Figure 4-8.

There is no standard way to depict the association relationship in the process object diagram. Therefore the UML class diagram notations to depict the association are chosen in the proposed diagram. There are two associations relationships depicted in Figure 4-8. The name1 association links between Process3 and Process6. The multiplicity of name1 indicates that only one instance of Process3 can be related to 1 to 5 instances of Process6. The second one is name2 which links between Process9 and Process10. The multiplicity of name2 indicates that zero or one instance of Process9 can be related to any number of instances of Process10. The stick arrow at the end of association indicated the navigability of name1 is form Process3 to Process6 and the navigability in both directions

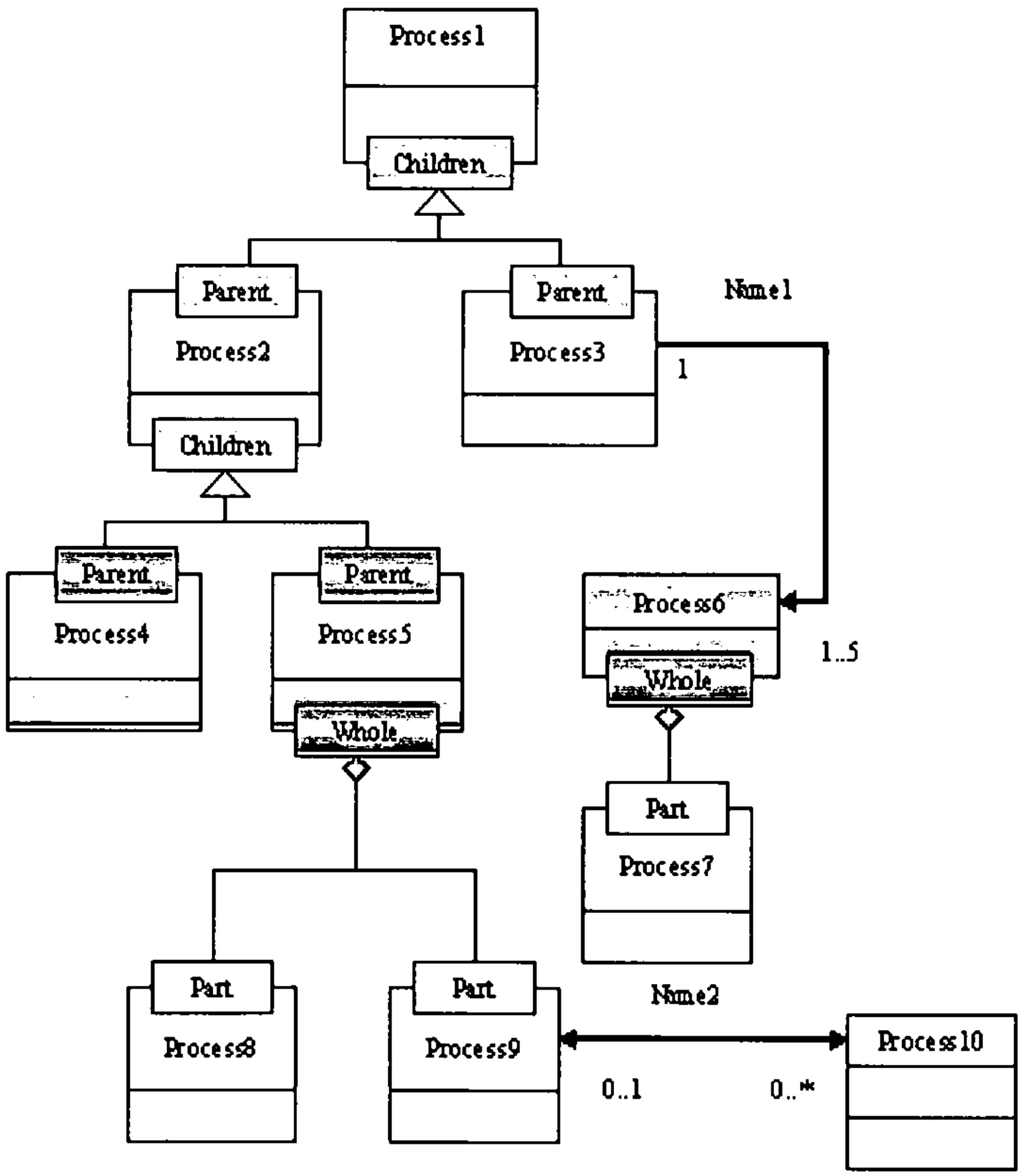

Figure 4-8: A Business Process Diagram

4.2 Behavioral Modeling

Behavior model describes the internal dynamic aspects of an information system that support the business process in an organization (Dennis, Wixom & Tegarden, 2004). The behavioral perspective is used to represent when business processes are performed and the sequential relationships among them.

UML Sequence diagrams are the most popular UML artifact for dynamic modeling and they are used in both analysis and design phase of the project. The sequence diagram shows the explicit sequence of activities among set of business objects over time. The sequence diagrams usually are used to depict the sequence of a single scenario of business process as in Figure 4-9. In sequence diagram the process objects that participate in the sequence are placed horizontally a cross the top of diagram in some logical way like the order in which they participate in the sequence. The object symbols form object diagram is used to represent the process objects. The lifeline of object is depicted as dotted line runs vertically below the object. Thin rectangular box, called execution occurrence, shows when process object send or receive messages. The order of messages between objects goes from the top to bottom of the diagram.

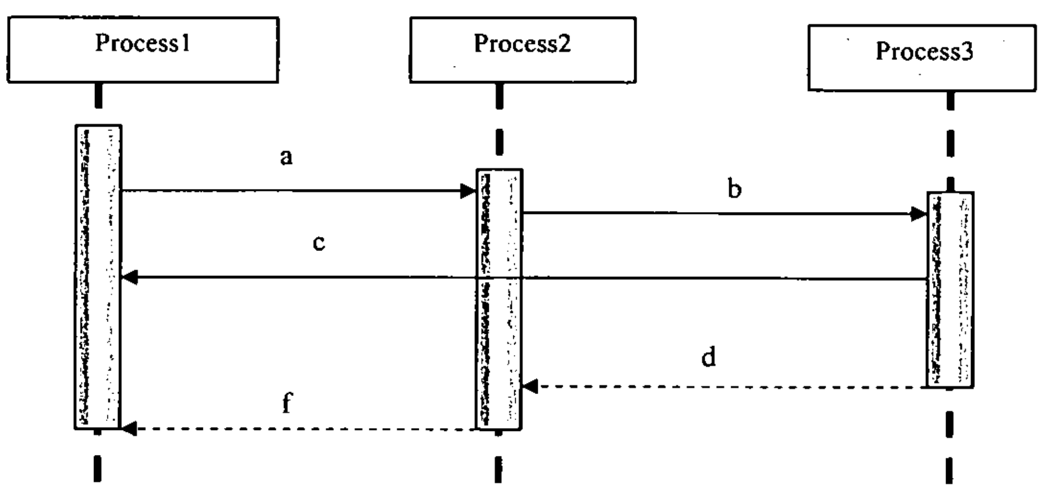

Figure 4-9: A UML Sequence Diagram

Extended Object-Oriented modeling method uses two types of diagrams to describe the behavior of business processes. These diagrams are: process object diagram with the process sequence and process object diagram with cycle time information. In the first type the process sequence is specified by tracing the consequent and prerequisite events of the process objects. As Figure 4-10 shows the process object diagram with the process sequence uses solid or dashed lines end with arrow to connect the process objects, the solid line means a higher level sequence and the dashed line means detailed level sequence.

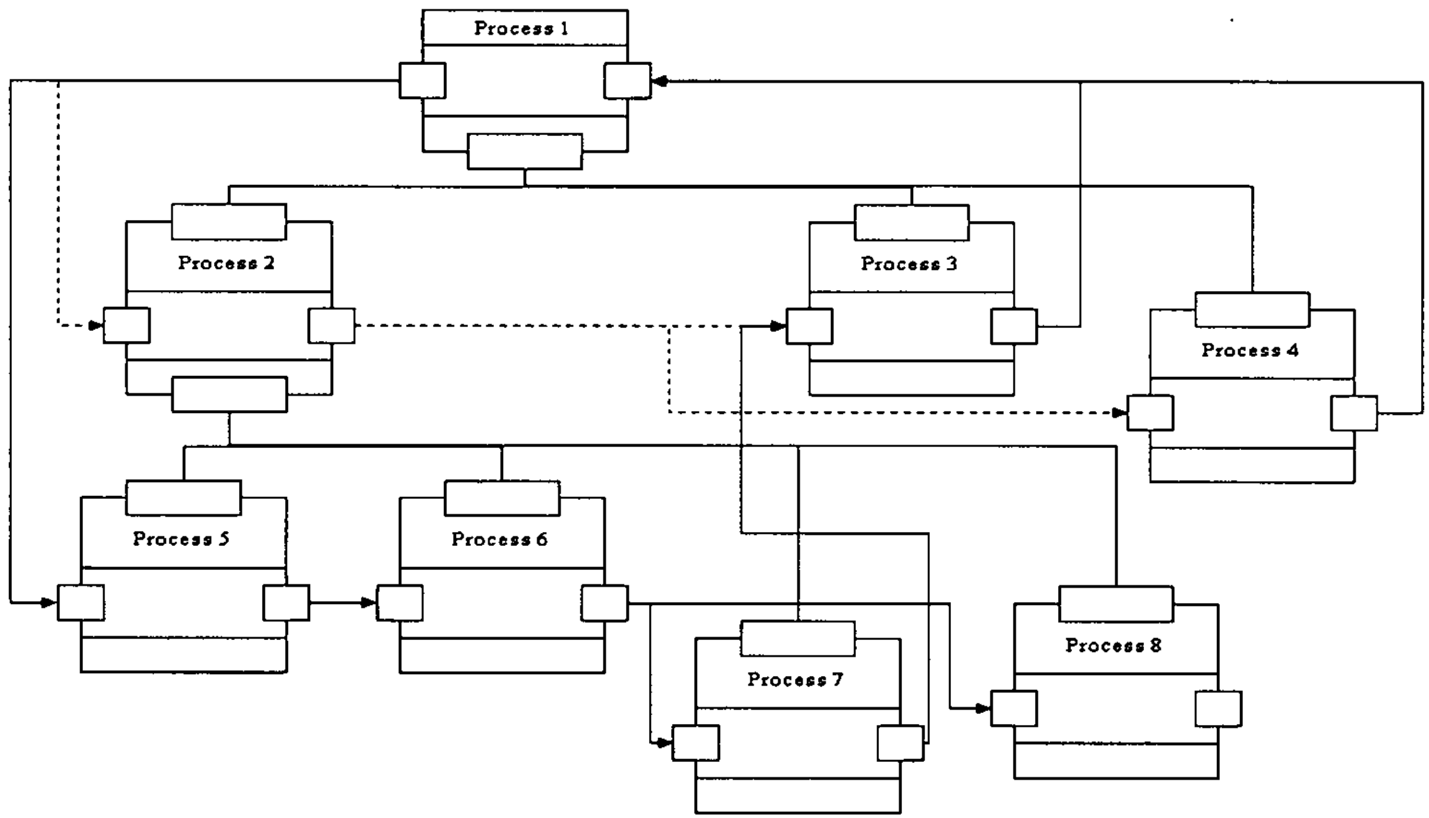

Figure 4-10: A Process Object Diagram with Process Sequence. (Nakatani, 1999)

The reason for build process object diagram with cycle time information is to analyze the process from time view and specify the business process with long cycle time to be considered for reengineering process. For example if the worst-case cycle time is seriously longer than the average or target cycle time the business process needs to be redesigned. Automation is on of the way to reengineer business process. The expected cycle time of a parent process object is calculated by adding its children's average cycle times. Figure 4-11 illustrates a process object diagram with cycle time information for four business processes.

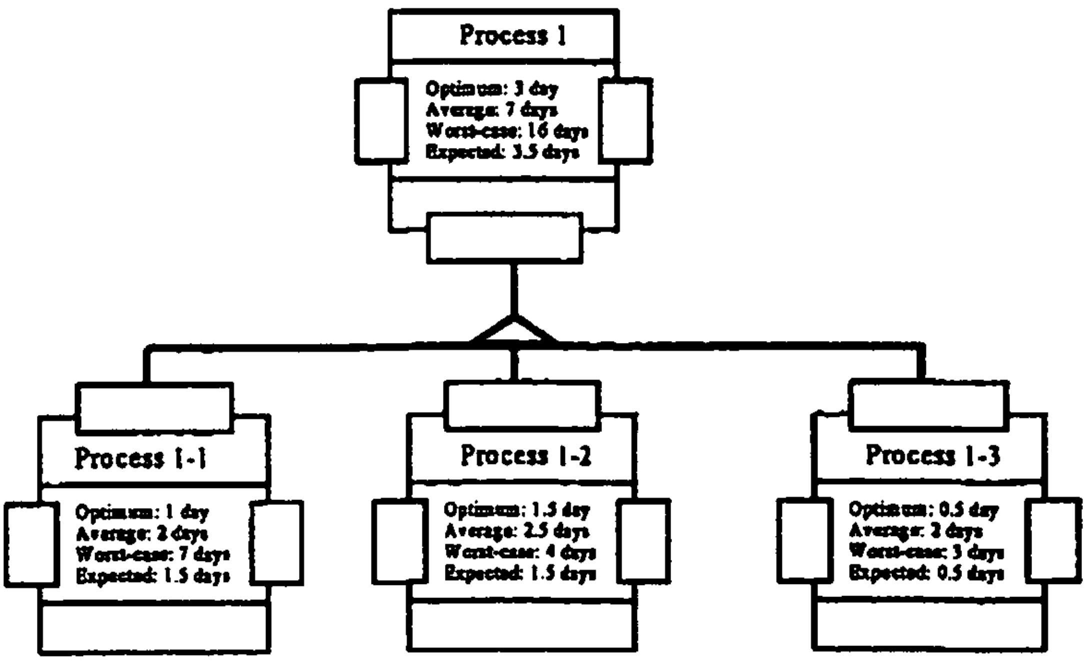

Figure 4-11: A Process Object Diagram with Cycle Time Information.

The process object diagram with cycle time information is good at showing the time duration for business process and that because of the cycle time attribute which illustrates all the possible time durations that the business process may take. Knowing the exact time duration of business process is important to BPR analysts because it gives the analysts a clear idea about which business processes they should consider for reengineering. However there are some problems that process object diagram suffers from, these problems are summarized in the following two points:

1. Process object diagram does not clearly specify the order in which the business processes do activates or send messages and events to other business process especially in large diagrams.
2. Illustrating both of the sequences of business processes and relations between them in only one diagram make the diagram complicated and difficult to understand.

UML sequence diagram is good at showing sequential logic of business processes but not that good at giving a clear idea about the time duration of those business processes because the execution occurrence which represent the time duration of the business process does not precisely specify how long does the business process take.

The proposed method developed a Business Process Sequence Diagram to model the behavior of business processes. This diagram integrates the behavioral diagrams of the Extended Object-Oriented modeling method with UML sequence diagram. This diagram gets the advantages of both of process object diagram with cycle time information and UML sequence diagram. As a result, the BPR practitioners can have good reengineering opportunity for business process.

Figure 4-12 shows the business process sequence diagram of the proposed method. As the figures show the business process diagram has similar general format of UML sequence diagram. The business process sequence diagram uses the same technique that UML sequence diagram uses to illustrate the order of the business processes that participate in the sequence. However the proposed diagram uses the process object symbol to represent the business process instead of object symbols form UML object diagram. In business process sequence diagram the time duration as well as the order of the business process in the sequence is illustrated in a clear way.

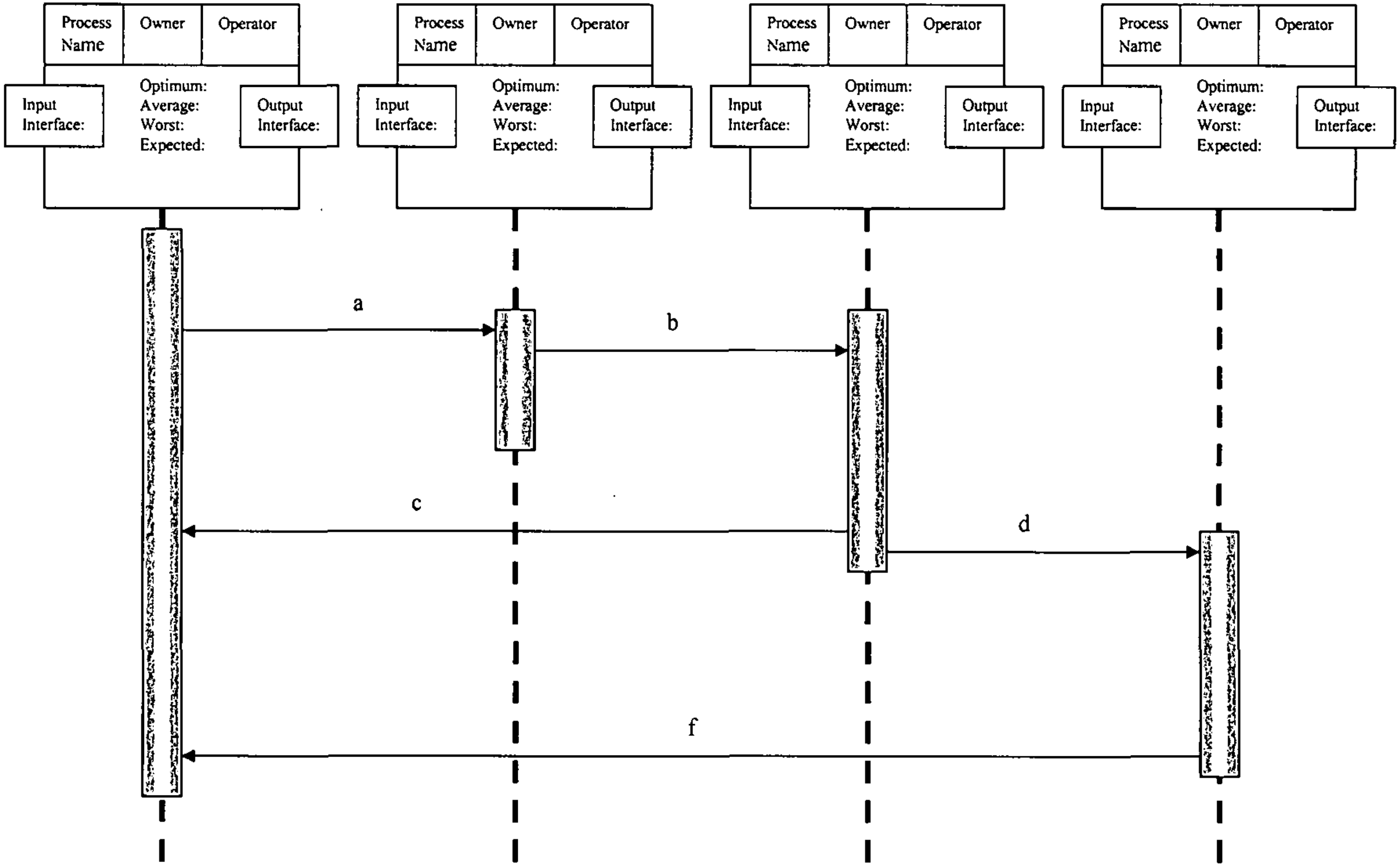

Figure 4-12: A Business Process Sequence Diagram.

4.3 Functional Modeling

Functional models describe business processes and the interaction of an information system with its environment (Dennis, Wixom & Tegarden, 2004). The functional modeling is used to represent what business processes are performed and flows of entities (inputs and outputs) that are relevant to them.

UML has two types of diagrams to represent the functionality of information system: activity diagram and use case diagram. Activity diagrams support the logical modeling of business process and workflows. Use case diagrams are used to describe the basic function of information system (Dennis et al., 2004). An activity diagram depicts the primary activities in a business process and the relationships among these activities. Figure 4-13 shows the elements of activity diagram.

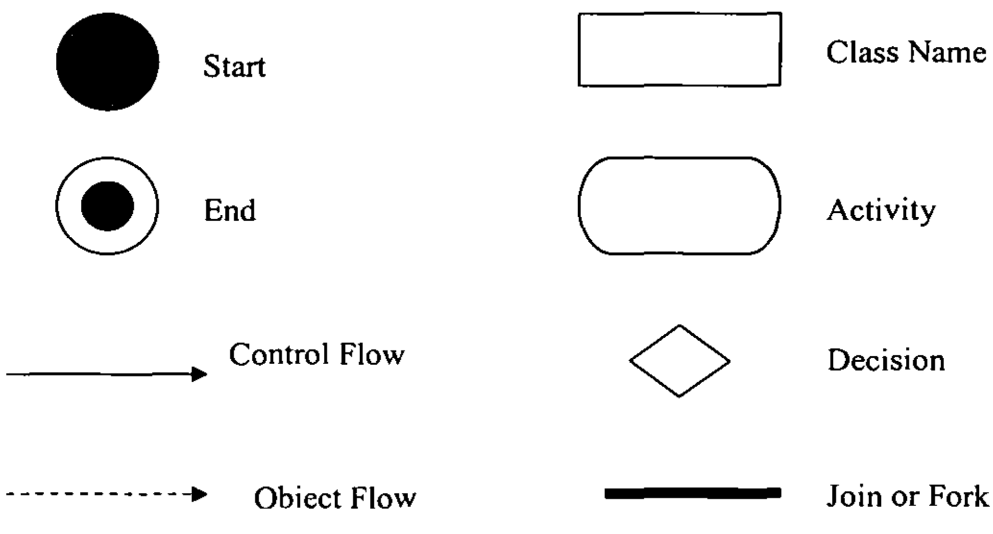

Figure 4-13: Elements of UML Activity Diagram.

Figure 4-14 shows a simple activity diagram that incorporates four activities and two objects. The black circle at the top shows the starting point of the process. It leads to the first activity. Once Activityl is completed, decision must be taken. If the decision is yes Activity2 starts and modifies Objectl. If the decision is No Activity3 modifies Object2 and triggers Activity4. This final activity ends the process, which is shown by the concentric circles at the bottom of the diagram.

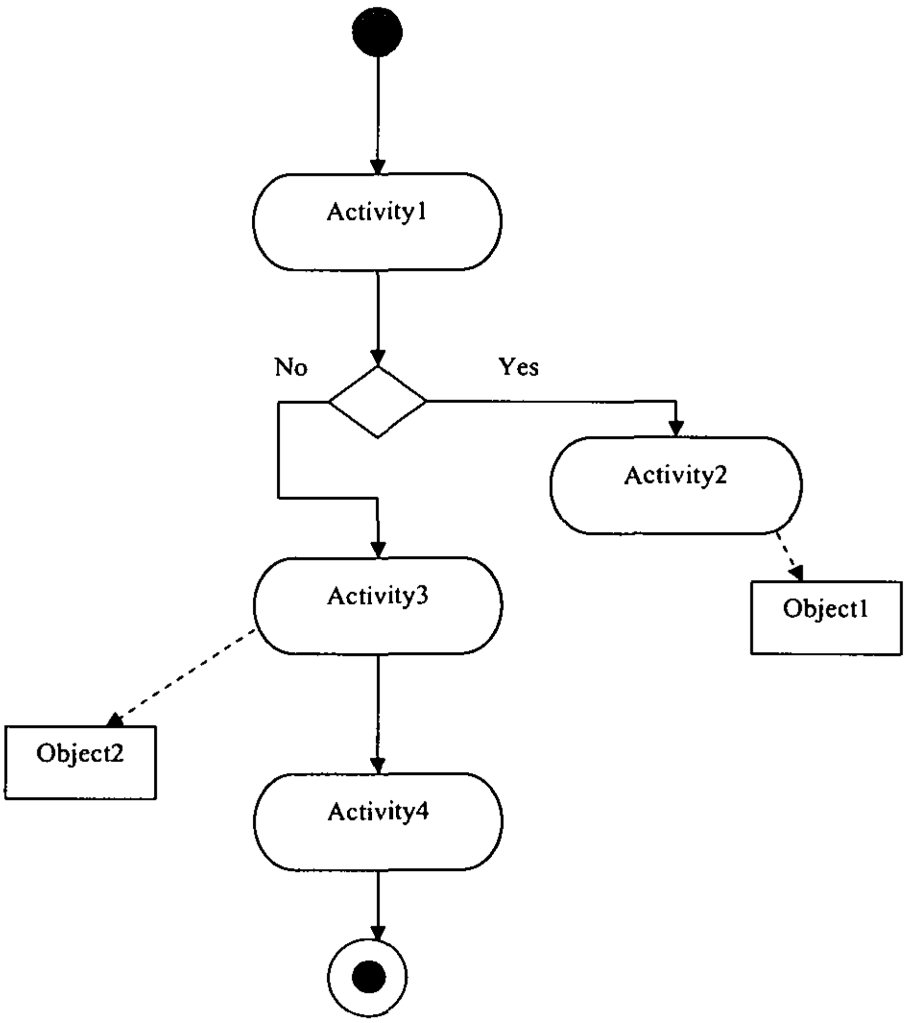

Figure 4-14: Example of UML Activity Diagram

Extended Object-Oriented modeling method does not provide special diagrams to represent each modeling perspective like UML does. It has two basic diagrams to represent all the business process modeling perspectives: process object diagram and recourse object diagram. These two basic diagrams are used to describe business process form structural point of view. To represent the behavioral aspect of business process the process object diagram with the process sequence and process object diagram with cycle time information are used. To represent the business process form functional view the same two diagrams are used with more focus on the owner of process objects and resource objects. Redefining the owner of process objects and resource objects facilitates a cross functional perspective to analyze and redesign a business process.

Since Activity diagrams are useful for business modeling and their notations are simple the proposed method uses them for detailing the processes involved in business activities.

The strength of a good BPR modeling method depends on its ability to represent the business processes in structural way. A good modeling method should enable managers, systems analysts, developers and business users to collaborate to ensure that the necessary understanding of the business context is available to the IS developers. Also it should provide a unique means for specialist from different areas of expertise to exchange information easily and clearly, so that any changes to business process can be tested on models before the implementation.

Despite the fact that UML can be used in modeling business process, it was created to be used mainly for modeling software systems, so BPR practitioner needs some knowledge and background in software developing field to understand the UML diagrams and notations. The Extended Object-Oriented Modeling for BPR has the ability to capture the information necessary to support the BPR. However it concerns only capturing sufficient information to develop business process models and not information systems development activities (Nakatani, 1999). Therefore, information systems analysts must construct models for information systems development from the business process models.

This work proposed BPR modeling method that integrates the Extended Object-Oriented modeling methods for BPR with UML. The extended object-oriented modeling method is mainly business process modeling method. UML is mainly object-oriented software systems development method. As a result the proposed modeling method has the advantages of the both integrated methods.

CHAPTER FIVE: CASE STUDIES

This chapter describes the implementation of the proposed modeling method into business process case studies. The proposed method was implemented into two kind of business process. The first case study represents an organizational business. The second represents non-organizational business process. This chapter has two main sections. Each section starts with brief description of the case study. Then the rest of the section discusses how the proposed method was used to reengineer the case study business processes.

5.1 The First Case Study

The proposed approach has been implemented within a case-study in UNIVERSTI TEKNOLOGI PETRONAS (UTP). UTP is one of the well known private universities in Malaysia. Registration office is the department that is responsible for registration processes in UTP. For examples registration for fresh students' process, courses registration process, exemptions process, deferment process, and other processes. Some of these processes are being done manually and the others through computerized software systems like UTP website.

5.1.1 Selection of Business Process

Selection of business process in BPR project required modeling method that has the ability to represent the work as a collection of business process. The selection also require preliminary analysis and evaluation of business processes, so the modeling method should show only the overview level characteristic of business process and hiding unnecessary details. To carry out BPR in an enterprise BPR analysts first have to identify its goals and objectives at strategic, business and operational levels and also to understand the structure of the enterprise (Damij, 2003). To achieve that BPR analysts usually start by organizing interviews with the top management to identify the organizations strategic plan, goals, structural scheme. Identifying these objectives and goals in most methods depend on the experience of the analysts.

In the proposed modeling method all the required information is collected by using process object and resource object templates (Figure 5-1).

	Information	Sources
OBJECT NAME:	object name (verb + object)	
OWNER :	process owner name (proper noun)	
OPERATOR :	processor name (proper noun)	
	functional department (proper noun)	
ATTRIBUTE:		
OBJECTIVE :	objective of the process (infinitive + object)	
WORTH:	strategic importance (likert-scale/numeric)	
	value to customer (likert-scale/numeric)	
	classification (fundamental/nonfundamental)	
CUSTOMER SATISFACTION LEVEL:	target level (likert-scale/numeric)	
	current level (likert-scale/numeric)	
	expected level (likert-scale/numeric)	
CYCLE TIME:	optimum cycle time (numeric)	
	average cycle time (numeric)	
	worst-case cycle time (numeric)	
	expected cycle time (numeric)	
QUALITY MEASUREMENT:	target (numeric)	
	status-quo (numeric)	
	expected (numeric)	
COST:	target (numeric)	
	status-quo (numeric)	
	expected (numeric)	
EVENT:	prerequisite event 1, 2, 3 ,.... (noun clause)	
	consequent event 1, 2, 3,.... (noun clause)	
	triggering event 1, 2, 3,.... (noun clause)	
OPERATION:	operation logic 1, 2, 3,...	
INTERFACE:		
INPUT:	previous process object name. resource 1, 2, 3,....	
	resource object name, (optional: attributes 1, 2, 3,....)	
OUTPUT:	next process object name. resource 1, 2, 3,...	
	resource object name, (optional: attributes 1, 2, 3,....)	
PARENT:	parent process object name 1, 2, 3,...	
CHILDREN:	child process object name 1, 2, 3,...	

Figure 5-1: Process Object Template. (Nakatani, 1999)

The Extended Object-Oriented Modeling for BPR has customized information collection formats and information presentation formats. These formats are customized for each BPR activity. These customized formats contain only relevant information for each of the BPR activities they support. Figure 5-1 illustrates process object template which is one of the information collection format. This format is used to collect the necessary information of business process objects. The process object -see Figure 4-5 in chapter four- has six components: name, owner, operator, attribute, interface, and operation. The name represents the overall characteristics of process. The owner defines the person who is responsible for the process. The operator defines who is to perform the process step and the functional department to which the operator belongs (the operator can be human or programmable machine).

The attribute component has seven parts: objective, worth, customer satisfaction level, cycle time, quality measurement, cost, and event. The objective is used to evaluate whether or not the process is fundamental and value-adding. The worth is used to store the importance of the process object. The customer satisfaction level is used to evaluate the health of the process object. The cycle time is used to determine whether or not the process object needs to be reengineered. The quality measurement is used to specify how the quality of the process measured. The cost is used to specify the cost of carrying the process object. The event is divided into the prerequisite event, consequence event, and triggering event. The prerequisite event must have occurred before the process start, the consequence event is created at the completion of the process, and the triggering event is used to trigger the process. The operation defines the operations performed on the attribute of process object. The interface has four parts: input specifies the inputs resource objects and the inputs from the previous process object in the process sequence; output specifies the resource objects that the process object passes to the next process object in the process sequence, parent specifies the next higher level of process object, and children specifies the next lower process objects.

In this phase BPR practitioners should construct process level model i.e. representing the work as a collection of business processes and identifying its goals and objectives. Also the relationship between business processes should be specified. In order to do this in the case study each business process in the registration unit was represented by a process object and the required information was collected by using the customized information collection format i.e. process object template. The objectives were defined as to what is currently being done and the process object diagram was constructed. Figures 5-2, 5-3, and 5-4 represent three different ways to illustrate the business processes in the registration office.

In Figure 5-2 UML class diagram was used to represent the business process of the registration unit. The problem with this diagram is that in BPR team only system developer and other practitioners with software development background can understand the relation between the processes in the diagram. Figure 5-2 illustrates that the processes represented by classes RegForFreshStd (Registration for Fresh Students), CreditTransfer, Exemption, AddDropCourses, Deferment, and PreRegForSenior (Pre Registeraation for Senior Students)which are parts from the whole process represented by class Registration.

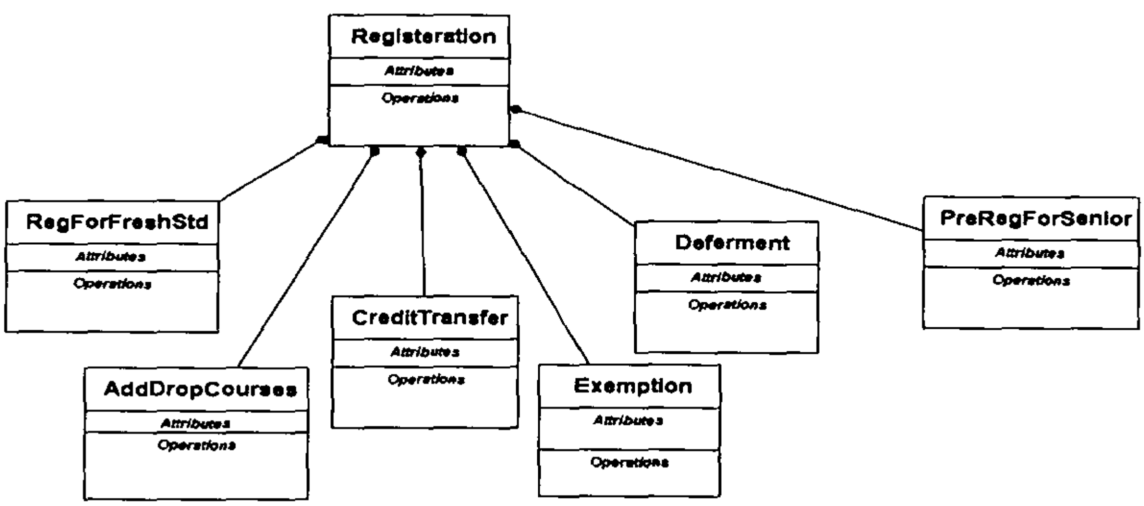

Figure 5-2: UML Class Diagram of the Registration Unit Processes

Figure 5-3 illustrates the same business process in Figure 5-2 but here the process object diagram from extended object-oriented modeling method was used. In this diagram all the BPR practitioners can easily understand the relations between the processes in the diagrams. The Whole-to-Part Relationship clearly is specified through the interface component. In Figure 5-3 it is clear that the processes represented by classes RegForFreshStd, CreditTransfer, Exemption, AddDropCourses, Deferment, and PreRegForSenior are parts from the whole process represented by class Registration.

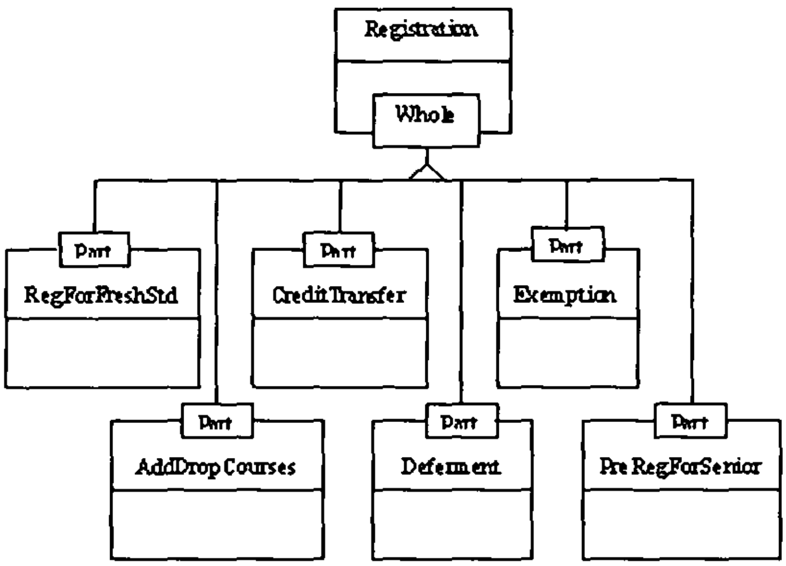

Figure 5-3: Process Object Diagram of the Registration Unit Processes

Figure 5-4 represents the business process in a diagram that used mixed notations from both UML and extended object-oriented modeling method. This diagram illustrates the idea of this research. This diagram makes it very clear to all the BPR practitioners to understand the kind of relation exist between the business process. Combining notations form UML and extended object-oriented modeling method gives the business information system developers the ability to use the same diagrams that had been used to analyze the business process again to create the software.

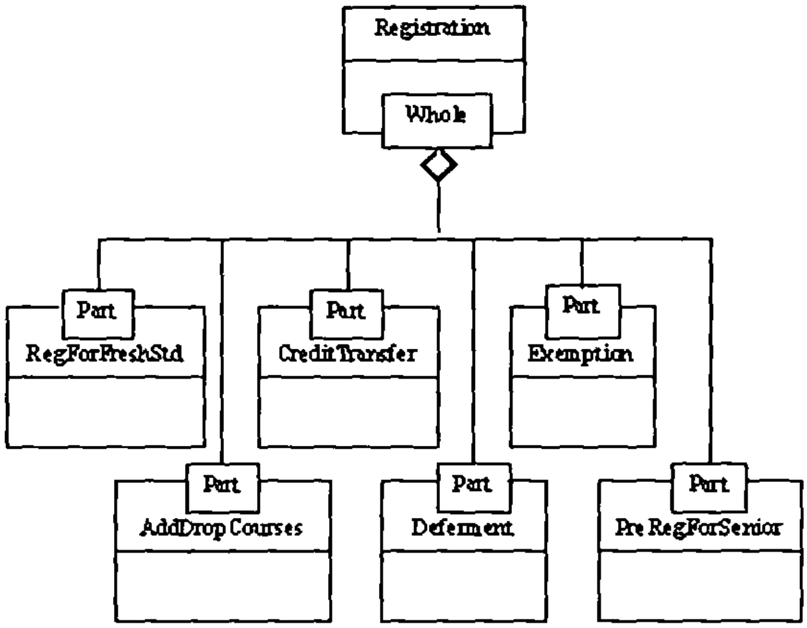

Figure 5-4: Business Process Diagram of the Registration Unit Processes

5.1.2 Development of a Model for the Existing Process

At this phase the business process was decomposed into process steps and the process steps were defined as process objects. A process object template was used to collect information about those process steps. Figure 5-5 shows a template of process object for Submit Course Registration Form (CRF) process but this template does not include all the attributes of process object. The attributes which have not been included in this case study are worth, customer satisfaction level, quality measurement, and cost. Calculating the values of these attributes is the responsibility of the BPR practitioners that they have management and business administration background because BPR analysts can use a complicated formula to measure these attributes. Actually there are many methods to measure customer satisfaction level, quality, and cost for business process, considering such process exceed the scope of this research. The next paragraph will be description of the components and the attributes in the template in Figure 5-5.

In Figure 5-5 submit CRF represents the name of the process which is a sub-process from whole students' registration process. A student represents the owner of this process because he or she is the one who is responsible for this process. The student also represents the processor of the process in operator component and that is because the student is the one who must choose and fill in the CRF with courses and after that submit the form to the registration executive and the registration unit represents the functional department which the processor belongs to. The objective of the process at this phase should be defined as to what is currently being done; it was defined as filling in and submits a complete CRF. The optimum, average, and worst cycle times for the submit CRF process specified as 1, 4, 7 hours respectively. Registration unit must organize meeting with fresh students for orientation and during this meeting students get the CRF and course registration guideline. Planning for meeting was considered as prerequisite event for submit CRF process, distributing the CRF and CR guidelines was considered as consequent event, and collecting the CRF from students was considered as triggering event. In the interface component the previous process object name was not specified in the input part and that is because the previous process does not belong to the registration unit process but the resource object name was specified as CRF and CR guidelines. In the output part the Verification process specified as next process object name because the registration unit must verify the CRFs after the submission and the CRF considered as resource object. The parent and children interfaces are used to specify a whole-to-part relationship among process objects, registration for fresh students was specified as parent process due to the fact that Submitting CRF is part from whole fresh students' registration process.

	Information	Source
Object name:	Submit CRF	
Owner:	Student	
Operator:	Processor name: Student	
	Functional department: Registration Unit	
Attribute:		
Objective:	Objective of process: fill in and submit a complete CRF	
Cycle time:	Optimum cycle time: 1 hour	
	Average cycle time: 4 hours	
	Worst-case cycle time: 7 hours	
	Expected cycle time: 4 hours	
Event:	Prerequisite event: plan for meeting with fresh students	
	Consequent event: distribute the CRF and CR guidelines	
	Triggering event: collecting the CRF from students	
Interface:		
Input:	Previous process object name.	
	Resource object name: CRF, CR guidelines	
Output:	Next process object name: Verification	
	Resource object name: CRF	
Parent:	Parent process object name: Registration For Fresh Students	
Children:	Child object name: none	

Figure 5-5: Template of a Process Object for Submit CRF Process

After the information collection format had been used to collect the necessary information about the business processes, a business process diagram was developed for the business process. Figure 5-6 shows only the part of the business process diagram that is related to submit CRF and Add or Drop Course processes. The next paragraph describes of how the business process diagram of the proposed method in Figure 5-6 depicted the business processes and the relations between them.

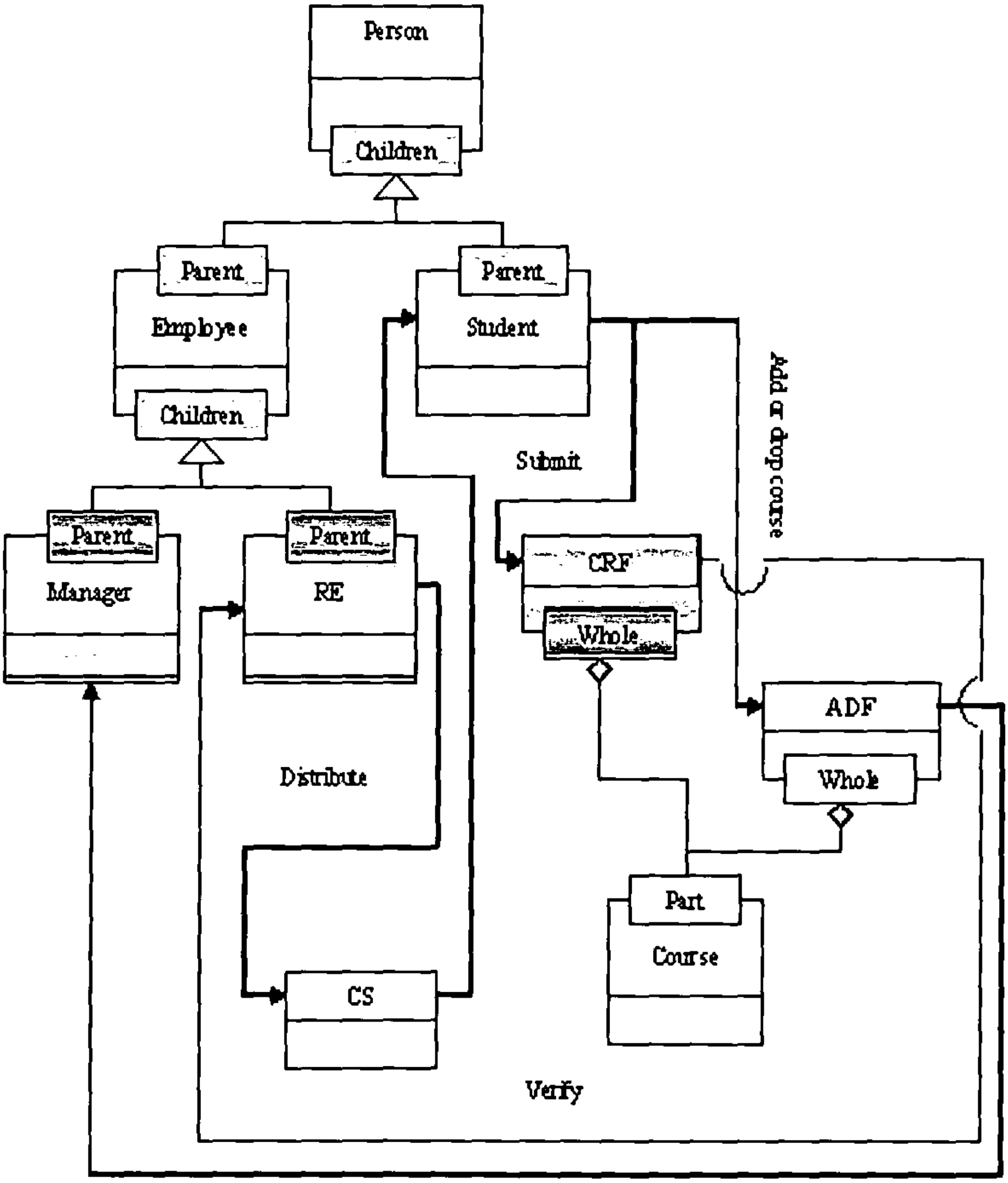

Figure 5-6: Business Process Diagram of Submit CRF and Add/Drop Course Processes

The business process diagram in Figure 5-6 was developed to analyze the business process and to reengineer them. BPR practitioners from different backgrounds should get involve in this analysis process. The business process and their relations should be depicted in a way that is clear to all those practitioners. Figure 5-6 shows inheritance relationship existing between Person, Employee, and Student and also the inheritance relationship existing between Employee, Manager, and Registration Executive (RE). To illustrate these relations both of the UML notation for inheritance and the parent and children interfaces from extended object-oriented modeling method were used. Standard UML class template was used for all business process included in inheritance relationships. Children interface compartment with a triangular arrowhead was attached at the end of class template that represents the parent process (for example Person). And solid line was drawn from that arrowhead to the parent interface which had been added to the upper part for class template for the business process that represents child process (for example Student) (see Figure 5-6). The relation between CRF and Course and between Add or Drop Form (ADF) and Course is a whole-to-part (composition) relationship because both of CRF and ADF contain number of courses. To denote the whole-to-part relationship standard UML class template was used for all business process included in this relation. Children interface compartment with a filled diamond was placed at the end of class template that represents the whole process (CRF and ADF). And solid line was drawn from that diamond to the parent interface which had been added to upper part for class template for the business process that represent a part process (Course) (see Figure 5-6).

5.1.3 Analysis of Existing Business Process

In this phase a model should contain information about a business process sufficient enough for BPR analysts to be able to discover a reengineering opportunity.

The reason for reengineering business process is to reduce the time and cost of the business process. While filling out the process object templates, cycle time was specified for each process object independently of other process objects to be used in analysis and reengineer the business process.

Time analysis is one of the most important processes in BPR effort. Good BPR modeling method should have an effective time analysis technique. The proposed method integrates the process object diagram with cycle time information from the extended object-oriented modeling method with UML sequence diagram. To show the strength of the new integration the next two sections will discuss on using process object diagram with cycle time and UML sequence diagram respectively to represent some of the registration business processes from behavioral view. Other sections will discuss the using of the proposed method for the same purpose in the same business processes.

This section discusses the use of process object diagram with cycle time information in two of registration processes. The reason for building such diagrams is to analyze the process from time view and specify the business process with long cycle time to be considered for reengineering process. For example, if the worst-case cycle time is seriously longer than the average or target cycle time, the business process needs to be redesigned. Automation is one of the ways to reengineer business process. Figure 5-7 shows process object diagram with cycle time information. Registration for fresh students is one of the processes that Figure 5-7 shows, this process has four process steps or sub processes that must be done for whole process to be completed. The first process step is that the student must fill in the CRF and submit it to the RE in registration unit. The second process step is verification of CRFs by the RE and after that the third process step comes which is returning CSs to students. The last process step is record keeping and updating database. The cycle time for the Registration for fresh students is about five weeks but each process step has its own cycle time as illustrated in Figure 5-7. The expected cycle time of a parent process object is calculated by adding its children's average cycle times.

Beside the cycle time analysis for business process there is another important issue that BPR analyst should consider, that is the business process sequence. There are many different techniques to illustrate business process sequence these techniques were provided by different business process modeling methods. In extended object-oriented modeling method the business process sequence is added to the process object diagram and this is achieved by connecting the process objects according to their prerequisite events and consequent events. Solid or dashed lines end with arrow were used to connect the process objects, the solid line means a higher level sequence and the dashed line means detailed level sequence.

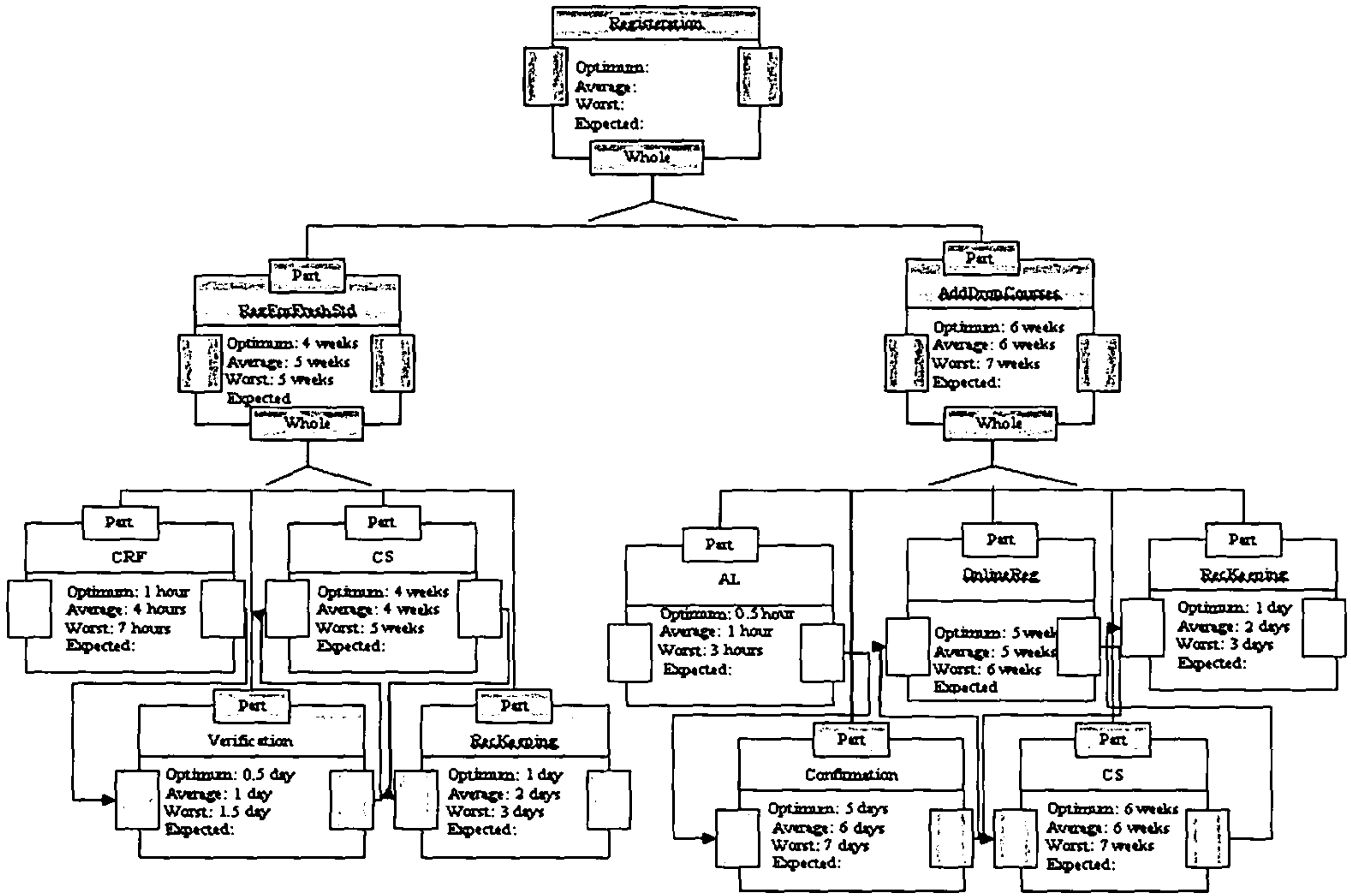

Figure 5-7: Process Object Diagram with Cycle Time Information

UML Sequence diagrams are the most popular UML artifact for dynamic modeling and they are used in both analysis and design phase of the project. The sequence diagram shows the explicit sequence of activities among set of business objects over time. The sequence diagram usually is used to depict the sequence of a single scenario of business process like in Figure 5-8 which illustrates the business process sequence for the submit CRF process and Figure 5-9 which illustrates the business process sequence for the add and drop courses process.

In sequence diagram the process objects that participate in the sequence are placed horizontally a cross the top of diagram in some logical way like the order in which they participate in the sequence. The object symbols form object diagram is used to represent the process objects. The lifeline of object is depicted as dotted line runs vertically below the object. Thin rectangular box, called execution occurrence, show when process object send or receive messages. The order of messages between objects goes from the top to bottom of the diagram.

Figure 5-8 shows the following scenario:

1. Student selects some courses and adds them to CRF.
2. Student submit CRF to RE
3. The RE verify the CRF and create CS
4. The RE distributes the CSs to students.

Figure 5-9 shows the following scenario:

1. Student selects some courses and adds them to ADF.
2. Student submit Application Letter (AL) and ADF to Manager and RE
3. The manager verify the AL and ADF for confirmation and approval
4. The RE registers the courses online and create CSs
5. The RE distributes the CSs to students.

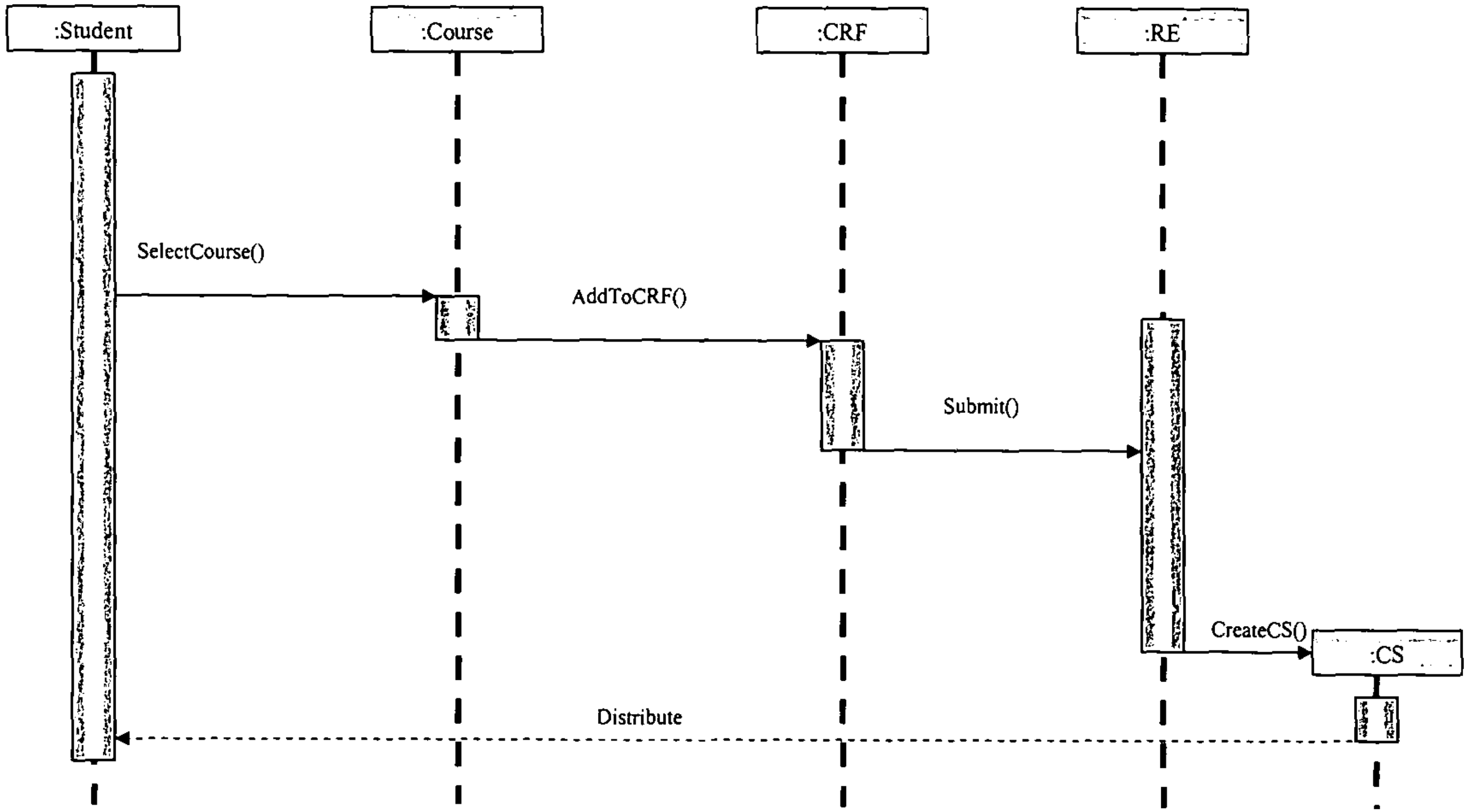

Figure 5-8: UML Sequence Diagram of Submit CRF

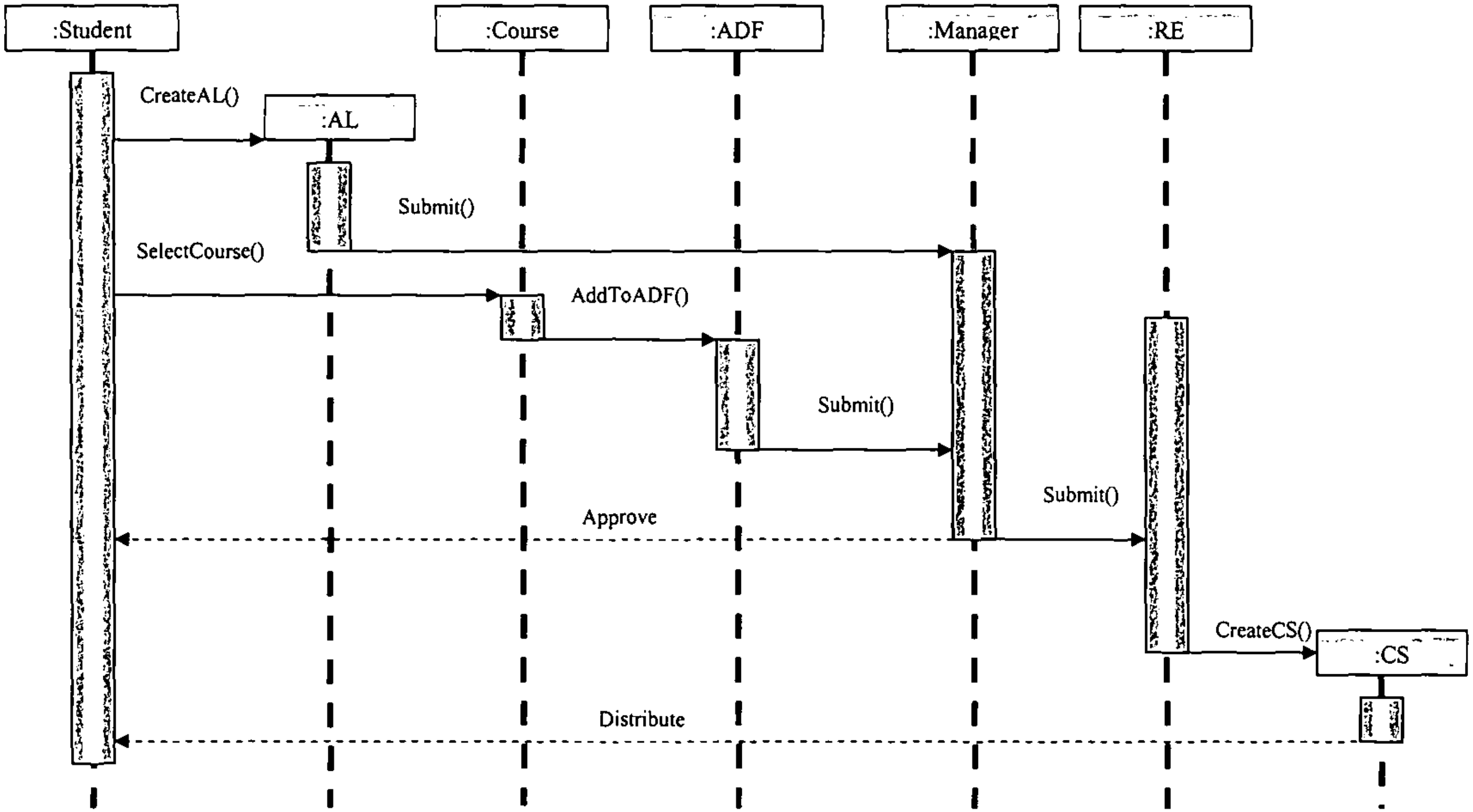

Figure 5-9: UML Sequence Diagram of Add and Drop Courses

The process object diagram with cycle time information is good at showing the time duration for business process and that because of the cycle time attribute which illustrates all the possible time durations that the business process may take. Knowing the exact time duration of business process is important to BPR analysts because it gives the analysts a clear idea about which business processes they should consider for reengineering. However there are some problems that process object diagram suffers from, these problems are summarized in following two points:

1. Process object diagram does not clearly specify the order in which the business processes do activates or send messages and events to other business process especially in large diagrams.
2. Illustrating both of the sequences of business processes and relations between them in only one diagram make the diagram complicated and difficult to understand.

UML sequence diagram is good at showing sequential logic of business processes but not that good at giving a clear idea about the time duration of those business processes because the execution occurrence which represent the time duration of the business process does not precisely specify how long does the business process take.

To get the advantages of both of process object diagram with cycle time information and UML sequence diagram and avoiding their shortcoming the proposed method presented a business process sequence diagram to model the behavior of business processes. This diagram integrates the process object diagram with cycle time information from the extended object-oriented modeling method with UML sequence diagram. As a result the BPR practitioners can have good reengineering opportunity for business process.

Figure 5-10 and Figure 5-11 shows the business process sequence diagram for the CRF submission process and add and drop courses process respectively. As the figures show the business process diagram has similar general format of UML sequence diagram. The business process sequence diagram uses the same technique that UML sequence diagram uses to illustrate the order of the business processes that participate in the sequence. However the proposed diagram uses the process object symbol to represent the business process instead of object symbols from UML object diagram. In business process sequence diagram the time duration as well as the order of the business process in the sequence is illustrated in a clear way. For example in Figure 5-10 it is clear that the verification is the second business process in the process sequence and the time it takes around 1 day.

In addition to cycle time information the process object provides BPR analysts other important information which can play critical role in the reengineering process. For example the process object that represents the verification process in Figure 5-10 illustrates the following information: (a) the input interface illustrates that the filled CRF is the input resource from the previous process; (b) student is the owner of this business process; (c) student is the operator of this process and registration unit is the department which the student belong to; (d) the output interface illustrate that the verification should pass a verified CRF to next business process in sequence; and (e) the output interface also illustrate that the next business process is Return CS. These kinds of information give BPR team a deep understanding of the business process. As a result BPR practitioners will be able to decide which business process should be removed and which one should be considered for reengineering. For example some business processes may take long time but they are fundamental or produce output to other fundamental process. This kind of business processes should be removed but they can be redesigned instead.

BPR team should also conduct customer satisfaction level analysis, quality analysis, and cost analysis. These kinds of analysis were ignored in this work because of the BPR team did not include practitioners with related background.

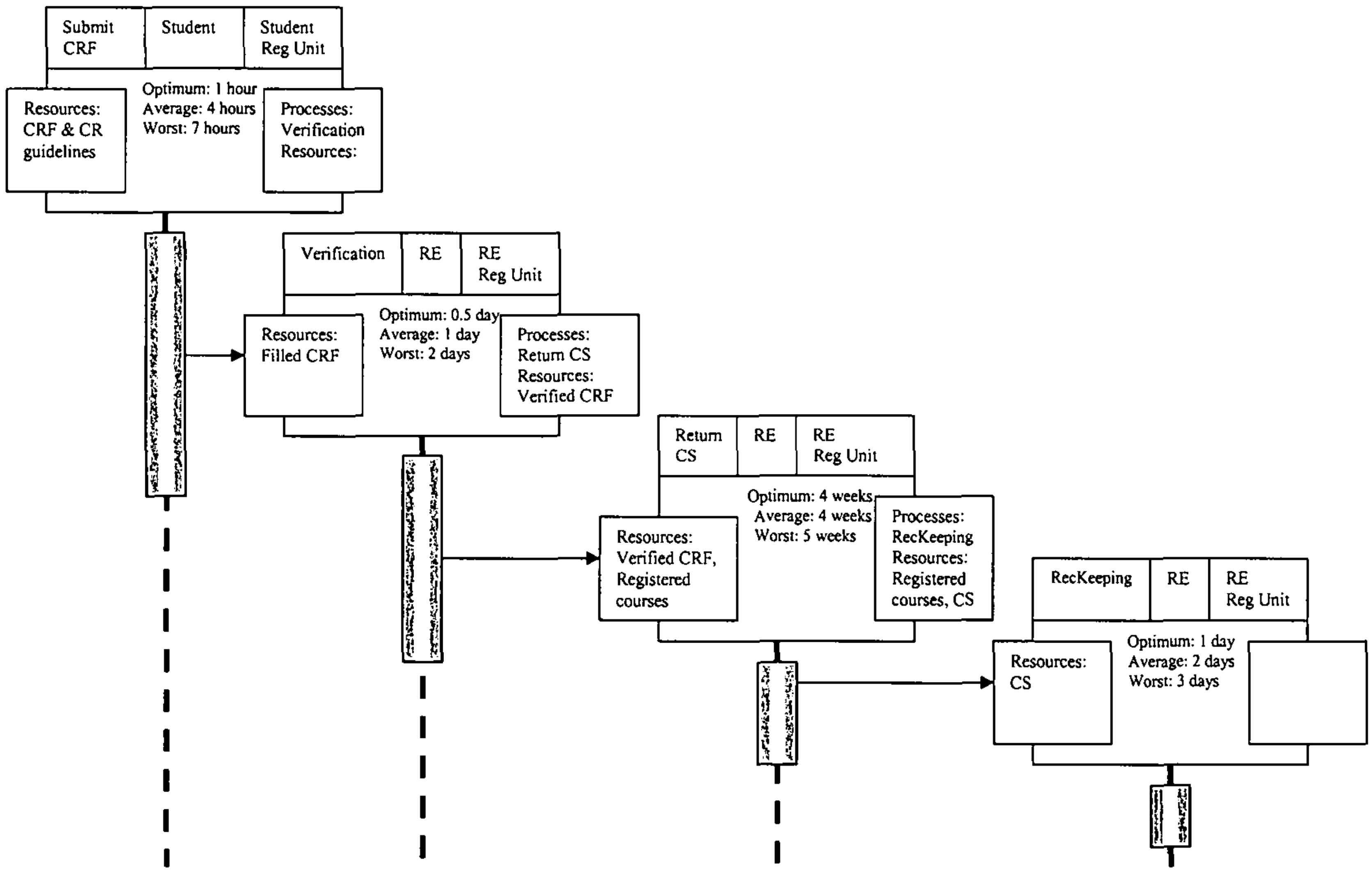

Figure 5-10: Business Process Sequence Diagram of Submit CRF

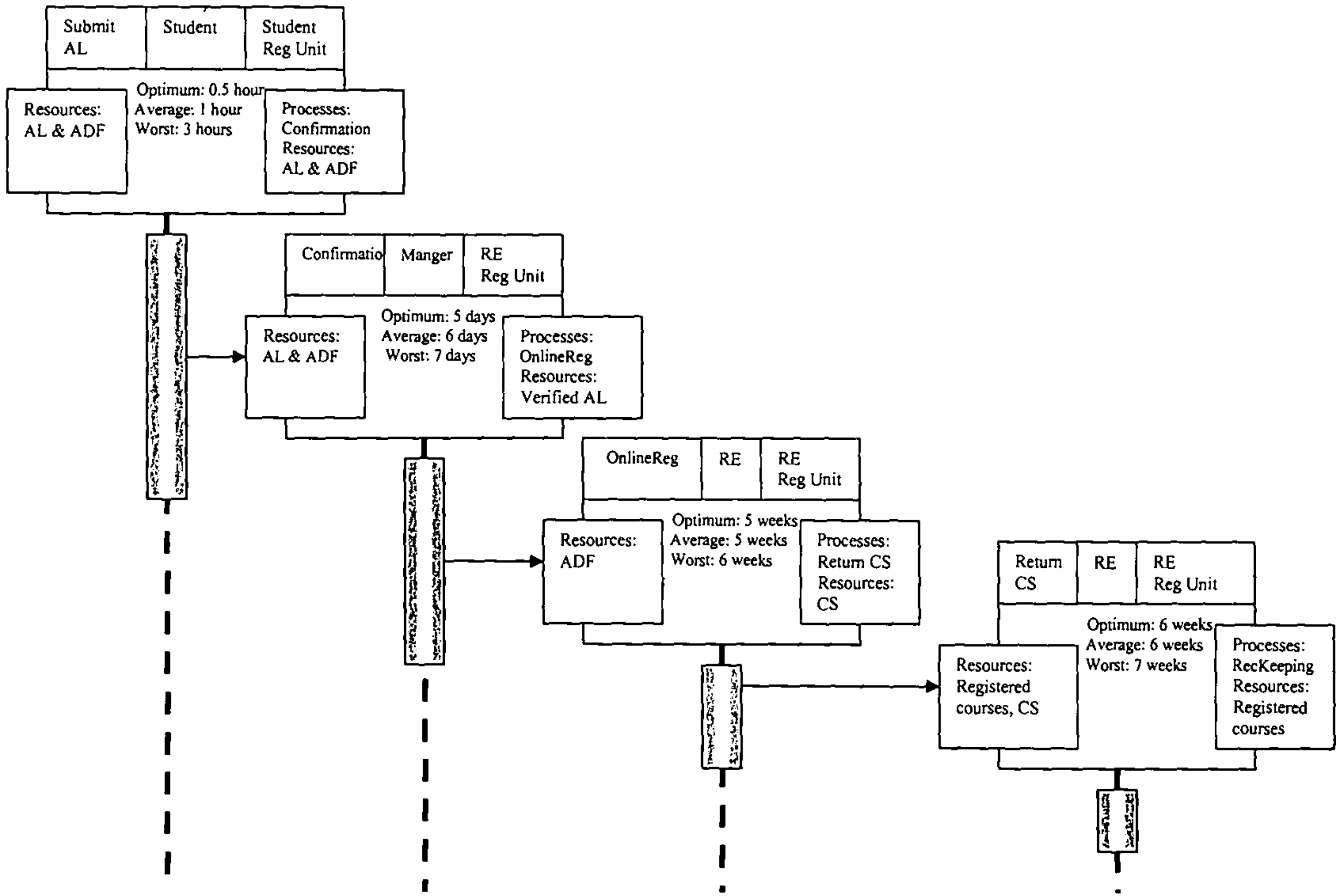

Figure 5-11: Business Process Sequence Diagram of Add and Drop Courses

5.1.4 Reengineering the Business Process

In this phase the analysts should find new ways to do the business. In the current approach BPR analysts can use the information in the existing model to delete non-fundamental process or reduce the cycle time and cost of the process. Reengineering business processes required deep understanding of their activities. Activity diagrams were used to model the business process and describe their primary activities. Figure 5-12 shows the activity of Add and Drop courses business process. These process starts by submitting Application letter (Submit AL) by students (Student) to the registration unit (Manager and RE). The manager checks the AL for approval (Approve AL). If the letter is rejected the student should correct the letter and try again (Correct AL). In case that the letter is accepted the student should register the courses they want to add or delete online (Register online). After the online registration the registration executive (RE) distributes the conformation slips (Distribute CS). The last activity is the record keeping and updating the database (Keep record).

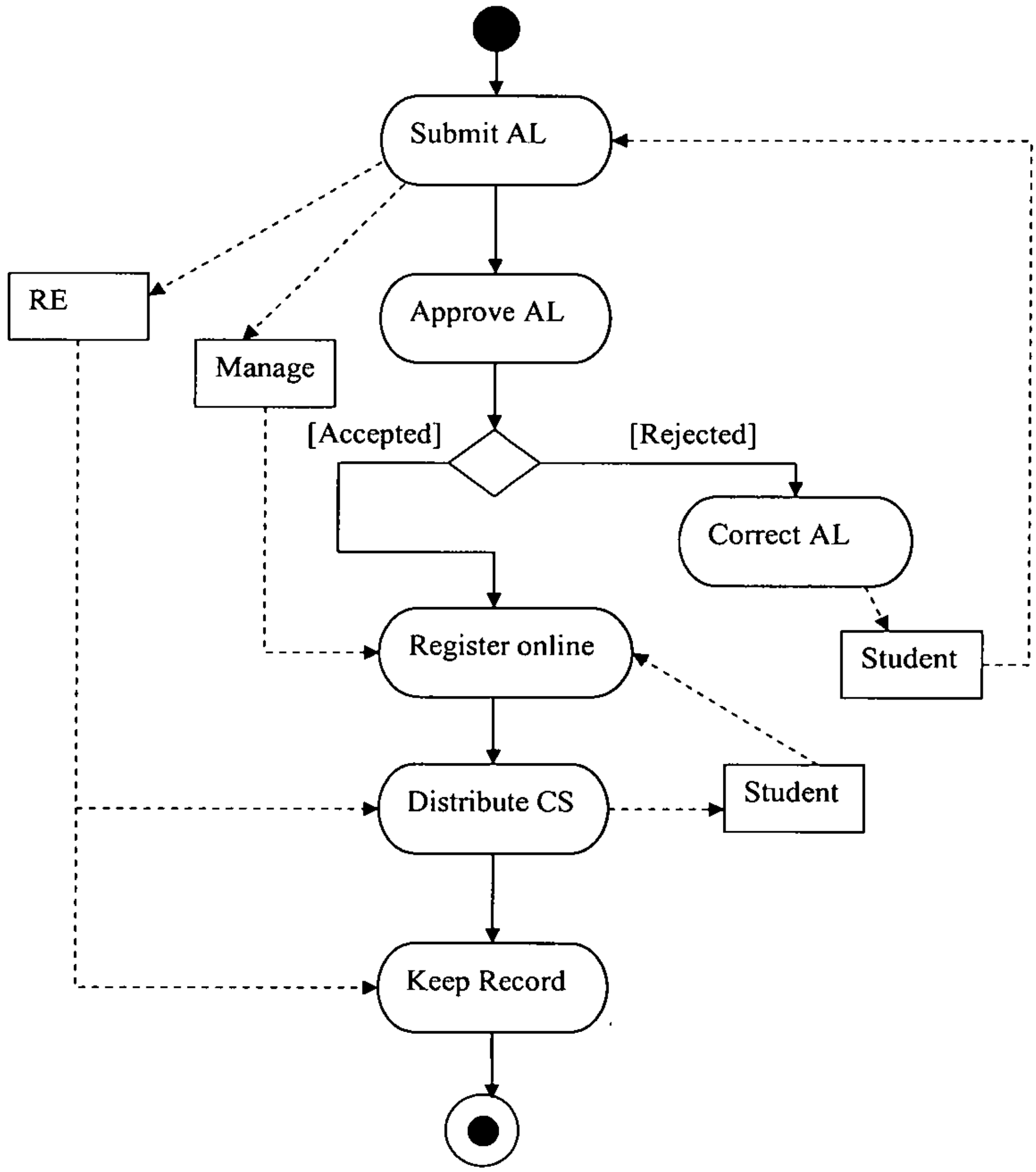

Figure 5-12: Add and Drop Courses Activity Diagram

5.1.5 Implementation of the Reengineered Business Process

A modeling method for BPR should support the implementation of reengineered process. Using IT to automate and create information system for the reengineered process is one of the main steps in BPR effort. Since requirements for information system implementation are derived from business analysis, using the proposed method the developers are able to create the information system for the reengineered process by translating the diagrams and model that were created in the analysis phase to software code. This can be done without creating a new model because developer can use the same UML notations that were used in analysis phase into the implementation phase.

5.2 The Second Case Study

The proposed method was implemented to model the process of self-healing system (Elhadi & Abdullah, 2008). Elhadi and Abdullah used biological wound-healing process to develop self-healing software system architecture.

5.2.1 Selection of Business Process

As what have been done in the first case study the selection of the processes is required to construct a process-level model. The proposed self-healing system architecture has five phases:

- Monitoring phase: Failure Detection
- Fault Control Phase: Stop losing other components
- Repair Phase: Isolating and repairing the faulty component
- Validation Phase: Test the healed component

- Integration Phase: Returning the healed component to the system

Each phase was considered as a process. Each process in the self-healing system was represented by a process object. The required information was collected by using a process object template for the selection phase. Figure 5-13 represents a general diagram of self-healing system process. This diagram was developed based on the information was collected. The business process diagram was used to represent these processes.

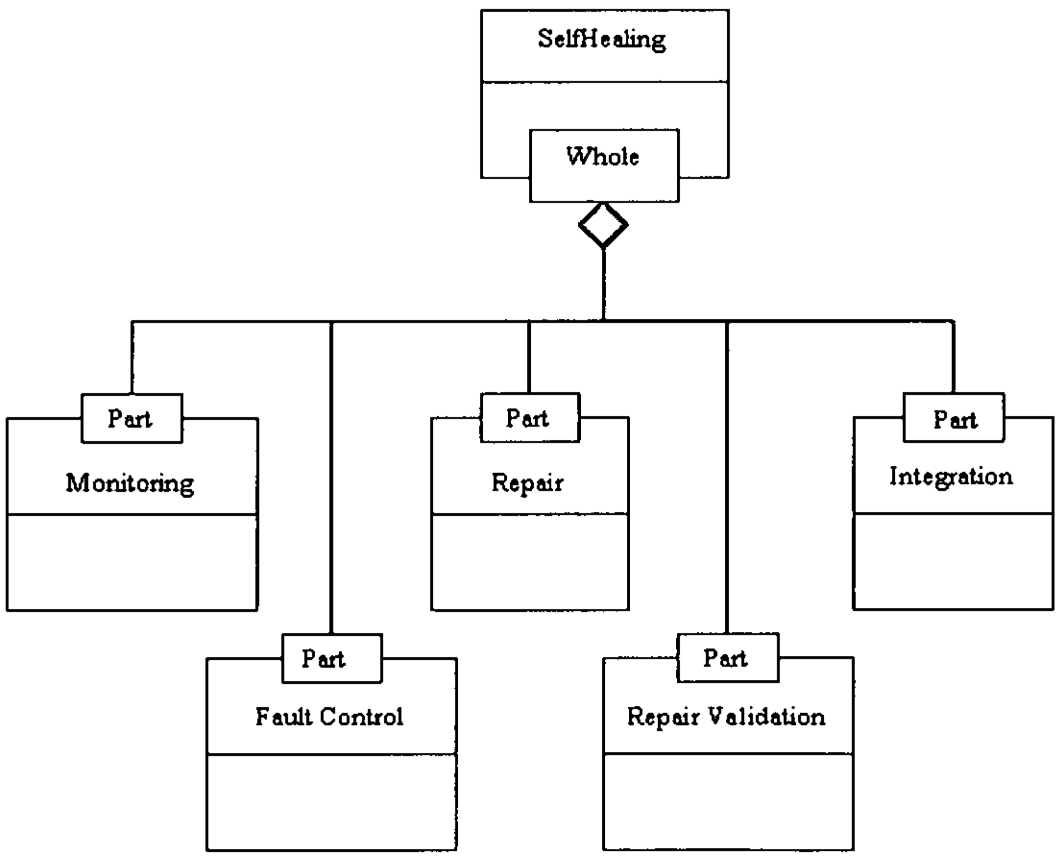

Figure 5-13: General Business Process Diagram for Self-healing Process

5.2.2 Development of a Model for the Existing Process

At this phase more details are needed. The business process was decomposed into process steps and the process steps were defined as process objects. A process object template was used to collect information about those process steps. Figure 5-14 and Figure 5-15 shows the information collection formats that were used for monitor and control processes respectively.

In Figure 5-14 Monitoring represents the name of the process which is sub-process from whole self-healing processes. A Self-healing system represents the owner of this process because it is responsible for this process. The Fault Detector represents the processors of the process in operator component. The objective of the process is observing the component's behavior. When a fault occurred the fault must be detected. Therefore fault occurring was considered as prerequisite event. Collecting the fault information was considered as consequent event. Triggering event in this process is sending the fault information to Control Fault process. In the interface component there are no previous processes and resources. Next process objects are Control and Repair. The parent and children interfaces are used to specify a whole-to-part relationship among process objects, Self-healing was specified as parent process. Children processes are Fault Detector, Fault Analyzer.

	Information	Source
Object name:	Monitoring	
Owner:	Self-healing system	
Operator:	Fault Detector	
	Monitoring phase	
Attribute:		
Objective:	Observing the component's behavior	
Event:	Prerequisite event: fault occurring	
	Consequent event: collecting the fault information	
	Triggering event: sending fault information	
Interface:		
Input:	Previous process object name: none	
	Resource object name: none	
Output:	Next process object name: Control, Repair	
	Resource object name: fault information	
Parent:	Parent process object name: Self-healing	
Children:	Child object name: Fault Detector, Fault Analyzer	

Figure 5-14: Template of a Process Object for Monitoring Process

In Figure 5-15 Control Fault represents the name of the process which is sub-process from whole self-healing processes. A Self-healing system represents the owner of this process because it is responsible for this process. The Fault Expansion Detector and Fault Expansion Resistor represent the processors of the process in operator component. The objective of the process is stopping the expansion of the fault. When a fault is detecting in monitoring phase the Control Fault process must starts working to stop the expansion of the fault. Therefore fault detecting was considered as prerequisite event for Control Fault process. If one of the components of the system fails, this fault may affect the other components that are related to the faulty component. As a result blocking the components that related to the faulty component was considered as consequent event. In the interface component the previous process object is Monitoring. The Resource object is the fault information which is sent by the monitoring process. The parent and children interfaces are used to specify a whole-to-part relationship among process objects, Self-healing was specified as parent process. Children objects are Fault Expansion Detector and Fault Expansion Resistor.

	Information	Source
Object name:	Control Fault	
Owner:	Self-healing system	
Operator:	Fault Expansion Detector, Fault Expansion Resistor	
	Fault control phase	
Attribute:		
Objective:	Stop the expansion of the fault	
Event:	Prerequisite event: fault detecting	
	Consequent event: blocking the components that related to the faulty component	
	Triggering event: none	
Interface:		
Input:	Previous process object name: Monitor	
	Resource object name: fault information	
Output:	Next process object name: none	
	Resource object name: none	
Parent:	Parent process object name: Self-healing	
Children:	Child object name: Fault Expansion Detector, Fault Expansion Resistor	

Figure 5-15: Template of a Process Object for Control process

The authors of the proposed self-healing system did not consider the processes cycle time. They focused on their sequence more than the duration. Therefore the cycle time information was not collected. Based on the previous information a more details diagram was created Figure 5-16.

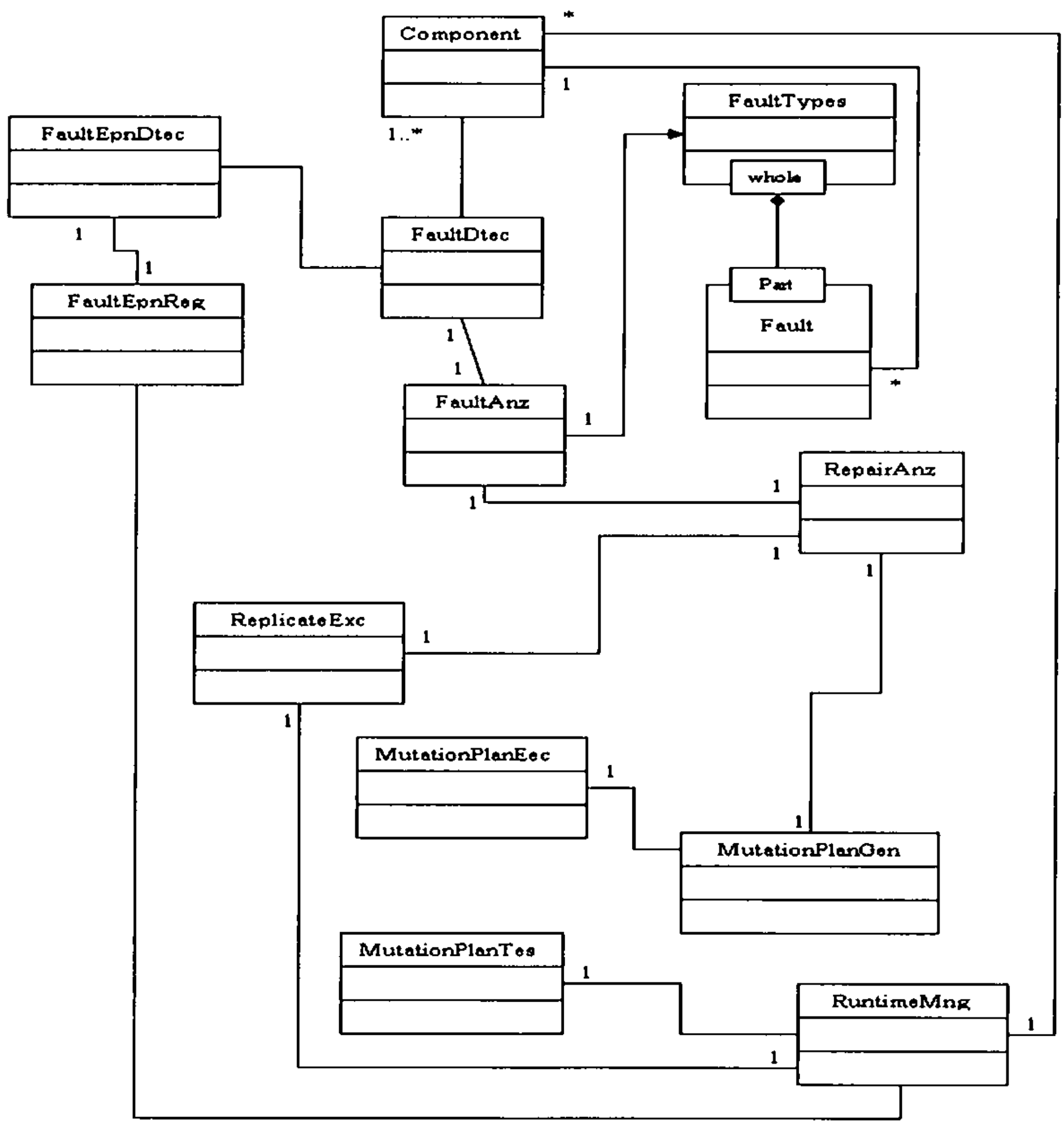

Figure 5-16: Business Process Diagram for Self-healing process

5.2.3 Analysis of Existing Business Process

Since the process time duration was not consider in this case study, the process sequence diagram in Figure 5-17 shows only the sequence of the process without the cycle time information.

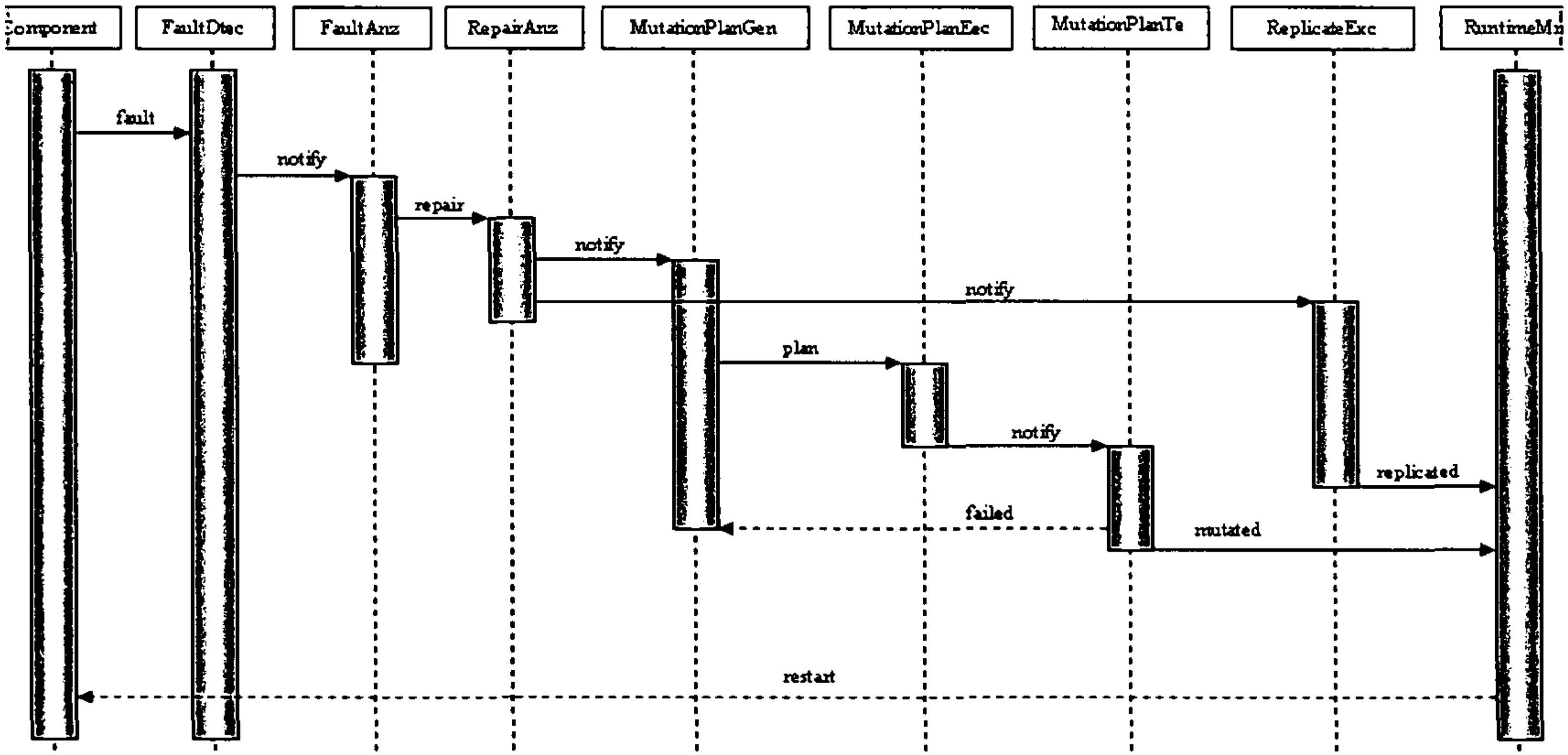

Figure 5-17: Business Process Sequence Diagram for Self-healing Process

5.2.4 Reengineering the Business Process

As what have been done in the first case study the Activity diagrams were used to model the business process and describe their primary activities in Figure 5-18.

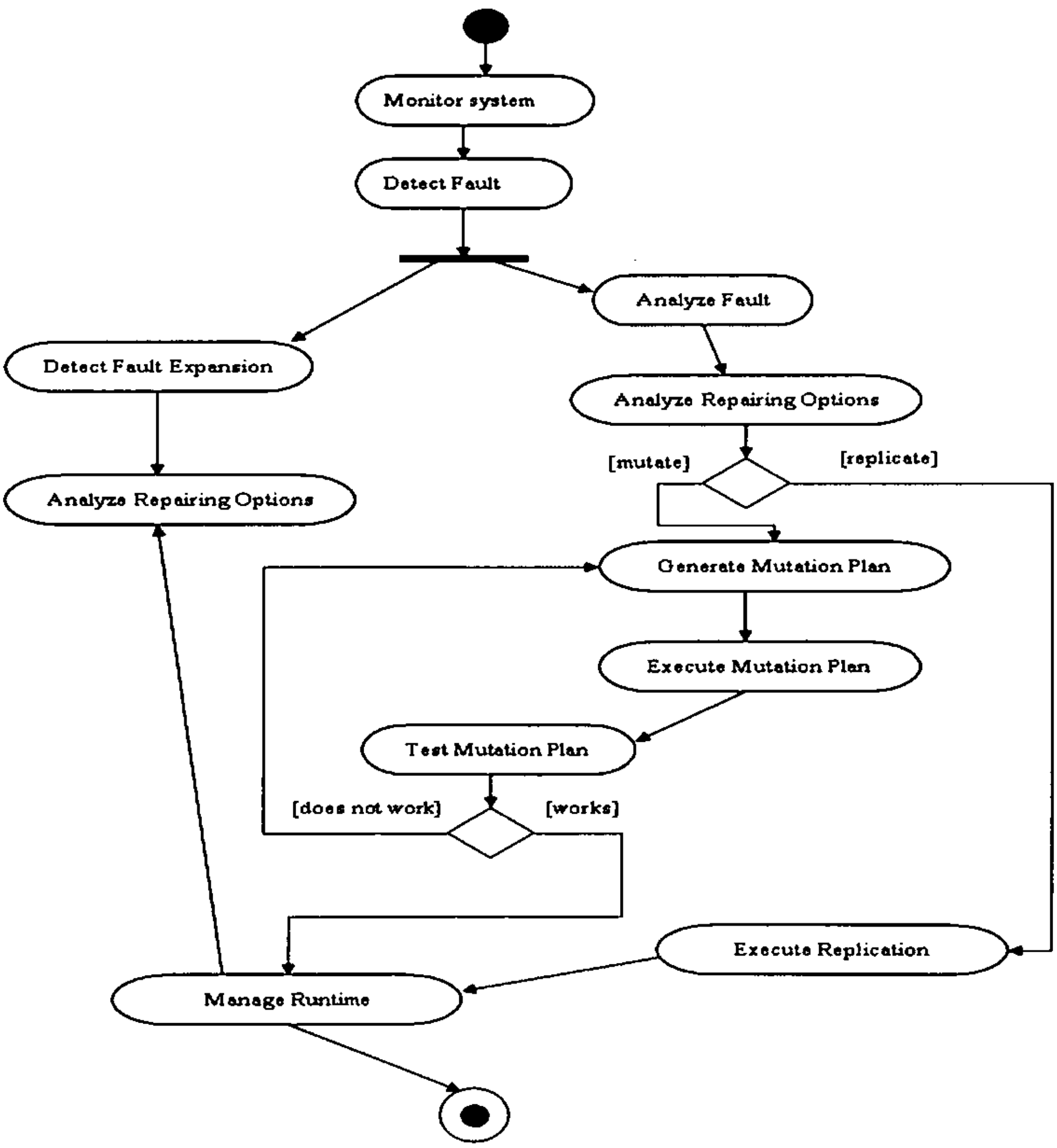

Figure 5-18: Activity Diagram for Self-healing Process

5.2.5 Implementation of the Reengineered Business Process

The diagrams which have been created in this case study are quite similar to the original UML diagrams. Because of nature of processes which is non-organizational process. As a result the creation and implementation of the support software system will be easy.

In this chapter discussion on the implementation of the proposed method was provided. The result from this chapter is that the propose method is more applicable and gives more scene when it is applied to organizational business process. It is also good in modeling non-organizational process specially in collecting information about processes. In other words, in modeling organizational business processes the features of the proposed modeling method will be more notable compared to other modeling methods.

CHAPTER SIX: CONCLUSIONS

This chapter highlights the contribution, limitation, and the future works for this research. The first section discusses the contribution of the research. The second section discusses the limitations of this work. And the last section addresses the future issues.

6.1 Contributions

This work proposed BPR modeling method that integrates the Extended Object-Oriented modeling methods for BPR with UML. The extended object-oriented modeling method is mainly business process modeling method. The contribution of this research can be summarized in two main points as follow:

- The proposed method uses introduced notations namely the Business Process Diagram, Business Process Sequence Diagram, and Activity Diagram to enable all BPR practitioners to understand the models that represent the business process. These notations could lead to a better information exchange between BPR practitioners. As a result, effective reengineering ideas can be produced.
- Extended Object-Oriented modeling is mainly business process modeling methods. UML is mainly object-oriented software systems development method. Accordingly, the proposed method could help on bridging the gap between the analysis of business process and the creation and implementation of IS for the reengineered business processes.

6.2 Limitations

BPR is a large effort that should be conducted by a team. Experts from different fields should join the BPR team and participate in BPR phases. The IT experts cannot handle all BPR processes without the help of other BPR practitioners. During the implementation of the proposed method to the case study a number of analysis process which needs specific background knowledge were ignored. For example the customer satisfaction level analysis, quality analysis, and cost analysis were ignored. To conduct such kind of analysis BPR practitioner needs some background of knowledge like management or business administration. Therefore, the main limitation of this work comes from the partial implementation of the proposed modeling method into the case studies.

6.3 Future works

The future works for this research can be divided into three issues:

- The first issue is the implementation of the proposed modeling method to a large BPR project which is conducted by a BPR team.
- The second issue could be comparative study between the proposed modeling method and one of the well known business process modeling methods for BPR such as IDEF, Petri Net, and DFD.
- Finally, the proposed modeling method could be implemented as an automated tool.

PUBLICATIONS

1. Abdelmajed Omer Musmar, Azween B Abdullah, and Dhanapal Durai Dominic P, "Object Oriented Modeling Method for successful Business Process Reengineering", National Postgraduate Conference, Universiti Teknologi PETRONAS, Tronoh, Malaysia, March 2008.

2. Abdelmajed Omer Musmar, Azween B Abdullah, and Dhanapal Durai Dominic P, "Object Orientation with Business Process Modeling for Successful Business Process Reengineering", Third International Symposium on Information Technology 2008 (ITSim'08), Universiti Kebangsaan Malaysia, Malaysia, August 2008. (accepted for presentation)

REFERENCES

Aguilar-Saven, R. (2004). Business process modeling: Review and framework. *International Journal of Production Economics, 90*(2), 129-149.

Alhir, S. S. (2002). *Guide to applying the UML.* New York: Springer-Verlang.

Ambler, S. W. (2004). *The Object Primer: Agile Model-Driven Development with UML 2.0.* New York: Cambridge University Press.

Badica, C. Teodorescu, M. Spahiu, C. Badica, A. Fox, C. (2005). Integrating Role Activity Diagrams and Hybrid IDEF for Business Process Modeling Using MDA. *Symbolic and Numeric Algorithms for Scientific Computing, SYNASC. 2005* (p. 4).

Bell, D. (2004, September 15). *UML basics: The class diagram.* Retrieved June 21, 2008, from http://www.ibm.com/developerworks/rational/library/content/RationalEdge/sep04/bell/.

Bosilj-Vuksic, V., Giaglis, G. M., & Hlupic, V. (2000). IDEF diagrams and petri nets for business process modelling: Suitability, efficacy, and complementary use. *ICEIS 2000, Proceedings of the Second International Conference on Enterprise Information Systems* (pp. 242-247).

Caetano, A., Silva, A. R., & Tribolet, J. (2005). Using roles and business objects to model and understand business processes. *Proceedings of the 2005 ACM symposium on applied computing.* (pp. 1308–1313).

Cheol-Han, K., Weston,R. H., Hodgson, A., & Kyung-Huy, L. (2003). The complementary use of IDEF and UML modelling approaches. *Computers in Industry, 50*(1), 35-56.

Curtis, B., Kellner, M. I., & Over, J. (1992). Special issue on analysis and modeling in software development. *Process Modeling. Communications of the ACM, 35*(9).

Damij, N. (2007). Business process modeling using diagrammatic and tabular techniques. *Business Process Management Journal, 13*(1), 70-90.

Damij, T. (2003). Using an object-oriented methodology called TAD in business process reengineering. *Journal of Object Technology, 2*(2), 151-168.

Davenport, T. K., & Short, J. E. (1999). The new industrial engineering: Information technology and business process redesign. *Sloan Management Review, 31*(3).

Dennis, A. R., Carte, T. A., & Kelly, G. G. (2003). Breaking the rules: Success and failure in groupware-supported business process reengineering. *Decision Support Systems, 36*(1), 31-47.

Dennis, A., Wixom, B. H., & Tegarden, D. (2004). *Systems Analysis and Design with UML Version 2.0: An Object-Oriented Approach.* New York: John Wiley & Sons.

Dijkman, R. M., & Joosten, S. M. M. (2002). Deriving use case diagrams from business process models. *Proceedings of the 6th International Conference on Software Engineering and Applications (SEA).*

Elhadi, M., & Abdullah, A. (2008). Layered biologically inspired self-Healing software system architecture, *International symposium on information technology 2008 (ITSim'08),* Vol. 4, pp. 1 – 9.

Eriksson, H.-E., & Penker, M. (2002). *Business modeling with UML.* New York: John Wiley & Sons.

Fei, Q., Junwei, Y., & Qidi, W. (2003). BPR oriented process modeling and optimization based on high level petri net *The Fourth International Conference on Control and Automation (ICCA'03)* (pp. 238- 241).

Gunasekaran, A., & Kobu, B. (2002). Modelling and analysis of business process reengineering. *International Journal of Production Research, 40*(11), 2521-2546.

Hammer, M. (1990). Re-engineering work: Don't automate, obliterate. *Harvard Business Review, 68*(4), 104-112.

Hammer, M., & Champy, J. (1993). *Reengineering the corporation.* New York.

Hevner, A., March, S., Park, J. and Ram, S. (*2004*). Design science in information systems research. *MIS Quarterly, 28*(1), 75-105.

Irani, Z., Hlupic, V., & Giaglis, G. (2001). Editorial: Business process reengineering: A modeling perspective. *The International Journal of Flexible Manufacturing Systems, 13,* 99-104.

Karl, C., Keith, P., Aybüke, A., Steven, J. B., & June, V. (2004). Connecting role activity diagrams to the problem frames approach. *AWRE'04 9th Australian Workshop on Requirements Engineering.*

Kazuo, N., & Yadav, S. B. (1996). An extended object-Oriented modeling method for business process reengineering, *Proceedings of the Americas Conference on Information Systems* (pp. 167-169).

Lin, F-R., Yang, M-C., Pai, Y-H. (2002). Generic structure for business process modeling. *Business Process Management Journal, 8*(1), 19-41.

Loos, P., & Allweyer, T. (1998). Object-orientation in business process modeling through applying event driven process chains (EPC) in UML*EDOC '98, Proceedings. Second International* (pp. 102-112). La Jolla, CA, USA.

Luo, W. & Tung, Y.A. (1999). A framework for selecting business process modeling methods. *Industrial Management & Data Systems, 99*(7), 312-319.

Mentzas, G. N. (1999). Coupling object-Oriented and workflow modeling in business and information process reengineering. *Information Knowledge Systems Management, 1*(1), 63–87.

Mertins, K., & Jochem, R. (2005). Architectures, methods and tools for enterprise engineering. *International Journal of Production Economics, 98,* 179–188.

Nakatani, K. (1999). *An extended object-oriented modeling method for business process reengineering.* Unpublished doctoral dissertation, Texas Tech University (p. 324).

Okawa, T., Hirabayashi, S., Kaminishi, T., Koizumi, H., & Sawamoto, J. (2007). A Method of Linking Business Process Modeling with Information System Design Using UML and its Evaluation by Prototyping, *Proceedings of the 2nd IEEE Asia-Pacific Service Computing Conference*, 458-465

Olalla, M. F. (2000). Information technology in business process reengineering. *International Advances in Economic Research,* 6(3), 581–589.

Peters, L., & Peters, J. (1997). Using IDEFO for dynamic process analysis Robotics and Automation,. *Proceedings., 1997 IEEE International Conference* Vol. 4, pp. 3203-3208.

Ram, R., & Raghav, R. (2005). Foreword design science and information systems. *Information Systems Frontiers.* 7(3), 215-215.

Rittgen, P. (2006). *Enterprise modeling and computing with UML.* Hershey, Pa.: Idea Group Pub.

Rohloff, M., Danet, G., & Munchen. (1996). Reference model and object oriented approach for business process design and workflow management *Information Systems Conference of New Zealand, 1996. Proceedings,* pp. 43-52.

Salimifard, K., & Wright, M. (2001). Petri net-based modelling of workflow systems: An overview. *European Journal of Operational Research, 134*(3), 664-676.

Snoeck, M., Poelmans, S., & Dedene, G. (2000). An Architecture for Bridging OO and Business Process Modeling *Proceedings of the technology of object-oriented languages and systems (TOOLS 33)* (pp. 132-143).

Stemberger, M. I., Jaklic, J., & Popovic, A. (2004). Suitability of process maps for business process simulation in business process renovation projects *Proceedings 16th European Simulation Symposium György Lipovszki.*

Tsugane, N., & Asakura, T. (2006). Use of business modeling in requirements definition phase. *Fujitsu Scientific and Technical Journal, 42*(3), 316-322.

Turetken, O., & Schuff, D. (2002). The use of fisheye view visualizations in understanding business process. *ECIS 2002 The Xth European Conference on Information Systems.*

Valiris, G., & Glykas, M. (1999). Critical review of existing BPR methodologies. *Business Process Management, 5*(1), pp. 65-86.

Vergidis, K., Tiwari, A., & Majeed, B. (2008). Business process analysis and optimization: Beyond reengineering, *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE* (Vol. 38, pp. 69-82).

Wei, W., Hongwei, D., Jin, D., & Changrui, R. (2006). A comparison of business process modeling methods, *Service Operations and Logistics, and Informatics, 2006. SOLI '06. IEEE International Conference* (pp. 1136-1141).

Yan-Ling, X., Fu-Yuan, X., & Wen-Bo, H. (2004). Business process reengineering based on IDEF methods *Information Reuse and Integration, 2004. IRI 2004. Proceedings of the 2004 IEEE International Conference* (pp. 265- 270).

Zhi-Yu, C., Shi-Quan, C., & Jin-Pei, W. (2005). An intelligent management system for evaluating science research projects. *Industrial Engineering & Management Systems IEMS, 4*(1), 109-116.