GOAL-ORIENTED BUSINESS PROCESS MONITORING

AN APPROACH BASED ON USER REQUIREMENT NOTATION COMBINED

WITH BUSINESS INTELLIGENCE AND WEB SERVICES

By

Pengfei Chen

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Abstract

The monitoring of business processes plays an important role in the field of Business Process Management (BPM). However, helping decision makers understand how their business currently stands in relation to their business goals is an important and unresolved issue in BPM. Related questions include how to determine what problems there may be and where they are in the goal hierarchy, along with the alignment between processes and goals. These issues should be considered in a systematic and integrated manner to help achieve and evolve business process goals.

This thesis proposes an approach utilizing User Requirements Notation to model goals and processes, to build Key Performance Indicator models, and combining with a Business Intelligence tool to monitor and measure business processes for the purpose of iteratively improving both business goals and processes. The work is illustrated through a healthcare industry case study of the hospital discharge process.

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List of Acronyms

Acronym	Definition
2NF	Second normal form
3NF	Third normal form
AD	Activity Diagram
API	Application Programming Interface
ARIS	Architecture of Integrated Information Systems
BAM	Business Activity Monitoring
BI	Business Intelligence
BPEL	Business Process Execution Language
BPM	Business Process Management
BPMN	Business Process Modeling Notation
BPMS	Business Process Management System
BPR	Business Process Reengineering
CRM	Customer Relationship Management
DOM	Document Object Model
EEML	Extended Enterprise Modeling Language
EJB	Enterprise Java Bean
EMF	Eclipse Modeling Framework
ERPs	Enterprise Resource Planning systems
ETL	Extract-Transform-Load
FR	Functional Requirements
GEF	Graphical Editing Framework
GRL	Goal-oriented Requirement Language
IT	Information Technology
ITU	International Telecommunications Union
JavaEE	Java Platform, Enterprise Edition
JBI	Java Business Integration
jPDL	jBPM Process Definition Language
jUCMNav	Java Use Case Maps Navigator
KPI	Key Performance Indicator
NFR	Non-Functional Requirements
OLAP	Online Analytic Processing
Open ESB	Open Enterprise Service Bus
RMI	Remote Method Invocation
SCM	Supply Chain Management
SOA	Service Oriented Architecture
TQM	Total Quality Management
UCM	Use Case Map
UML	Unified Modeling Language
URN	User Requirement Notation
WS-BPEL	Web Services Business Process Execution Language

WSDL	Web Service Definition Language
XML	Extensible Markup Language
XPDL	XML Process Definition Language
XSD	XML Schema Definition
YAWL	Yet Another Workflow Language

Chapter 1 Introduction

This thesis illustrates an approach to goal-oriented business process monitoring. The approach introduces KPI modeling and evaluation into an URN based business process modeling tool and combines them with business information providers and business monitoring services.

1.1. MOTIVATION

Nowadays, more and more businesses and organizations realize that to survive and become more competitive in this fast changing world, they must be able to easily adapt and respond to opportunities and risks. A business process is defined as a set of sequences of business activities that fulfill business goals (Debevoise 2005, 3). Since a business' major objectives need to be designed, executed, and managed to cope with a changing environment, making core business processes agile and flexible has become one of the most important strategies for modern businesses. In order to easily meet the needs of business changes and enable appropriate response time in today's event driven business environment, finding a method of effectively managing and evaluating the performance of business processes is critical for business success (Thomas, et al. 2005, 1).

Business process management was developed to be a useful environment for business stakeholders (Debevoise 2005, 3). Business process management is usually categorized into three groups, i.e. business process design, process execution and process monitoring. However, currently neither process nor process monitoring adequately takes into account the relationship between processes and goals. The alignment between processes and goals is missing from most of the current business process management systems (BPMS). However, these links between business processes and goals are important to BPM since they can be used to identify goals and thus naturally lead to the consideration of questions such as "why", "how" and "how else" (Yu and Mylopoulos 1998, 1). As a key component of BPMS, business process activity monitoring (BAM), a term coined by the Gartner Group, quoted in (Dresner 2003), usually sets up target values for each performance indicator. However, even though target values can be treated as the goals of performance indicators, they are actually not the goals of the business processes. More likely, they are just values to be reached but lack meaning or purpose. Those target values exist separately without relationships and hence it is hard to share a united vision of the monitored business processes. BPM needs to align the business processes with strategic goal architecture, and requires a change in emphasis from process to goal-oriented monitoring.

On the other hand, BI technology now is widely used in business analysis. Knowledge of past business processes can be elicited by extracting from an operational data source, transforming into an intermediate result, and loading into a data warehouse. Then the data can be analyzed with BI technology (Grigoria, et al. 2004, 2). Current data warehousing (DW) and business intelligence approaches are usually used in mid- to long- term process measurement and for process monitoring in which the metrics may change frequently. There are also some efforts and approaches that enhance business intelligence to support real-time business analytics and BAM. Such approaches include the architecture suggested in (Seufert and Schiefer 2005) and the SeeWhy Real Time Business Intelligence (SeeWhy 2006). However, these usages of BI in BPMS are only loosely connected to the business processes and do not provide sufficient support in dealing with the goal models. It should be noted that metrics and performance indicators themselves are not goals but rather ways to evaluate the actual values of the business processes or activities in relation to their target values.

1.2. THESIS GOALS AND SUGGESTED APPROACH

The main objective in building a goal-oriented monitoring system is to improve the alignment between business processes and goals and to provide an overall performance view of a company's core processes and goals. This thesis proposes an approach based on User Requirement Notation (URN), which enables links between business processes and business goals, and combining it with business intelligence tools in a Service Oriented Architecture (SOA) to build an interactive and automated system where a business' decision makers, analysts, process designers, data providers, and information technology (IT) people can collaborate in the iterative business process management life cycle, and design, build, monitor and improve business processes with the aim of achieving business goals.

In particular, this approach will focus on the following areas:

- *Integrating KPI models into URN to fill the gap between business processes and goals.* URN is comprised of two complementary notations, Use Case Maps (UCM), which depicts business scenarios; and Goal-oriented Requirement Language (GRL), which describes business objectives (Weiss and Amyot 2005d, 3-4). Although various traceable links can be created between GRL elements, such as tasks and goals, and specific UCM elements, such as responsibilities, components and even entire plug-in maps (Weiss and Amyot 2005c, 3), the URN link (Roy, Kealey and Amyot 2006, 14) can be used more effectively by specifying the relationships among KPI models, business processes and business goals.

- *Using a KPI model and KPI strategies to help business information providers design data models and generate KPI values.* Since the evaluation of business processes and goals relies on the measurement of KPIs whose values can be retrieved from back-end business information providers, providers may need necessary information from KPI models to help understand the needs of business process designers and decision makers in effectively designing resources. Currently, BI tools and data warehouse are widely used to offer business analysis to end users. When creating OLAP cubes in the BI framework or designing data marts in a data warehouse, related knowledge from KPI models, such as which dimensions business analysts are interested in when monitoring performance, or what the grain of the business process is (Kimball and Ross 2002, 31), may help the BI or data warehouse designers to find, build, generate and optimize proper data models.

- *Designing KPI evaluation strategy to set different contexts for indicators and KPI information elements so as to precisely describe the requirements of evaluation.* Business analysts and decision makers need to evaluate business process performance in different contexts. The context definition should answer two questions: from which point of view business users want to evaluate the specific performance issues; and what the evaluation standards of those performance issues are. To meet these requirements, the approach in this thesis will extend GRL strategy to set context for indicators and KPI information elements, such that under different strategies users can specify different context values for the KPI information elements, i.e. dimensions, as well as different sets of KPI measurement settings such as target values, threshold values, etc. Next, the specific context information along with KPI model information will be provided to business information providers preparing data reports or queries. The presence of a knowledge discovery process can therefore aid business information providers, such as BI systems, in finding, selecting, organizing, distilling and presenting information (Ou and Peng 2006).

- *Combining business information providers to provide initial values for the KPI model to evaluate performance of the business processes in achieving their goals.* As a complete URN modeling tool, jUCMNav can analyze GRL models and, by providing GRL evaluation strategy, find the best trade-off between various alternatives to reaching desired goals (Roy, Kealey and Amyot 2006, 10). Applied to business process modeling, GRL evaluation strategy can be used to evaluate to what degree the business goals have been reached. In the goal model hierarchy, the satisfaction levels of the lower level goals or tasks are initialized and then propagated to evaluate the performance of higher level goals. On the other hand, by drilling down into the lower level goals or tasks, users can obtain more specific information. In our approach, KPI models will contribute to the initialization of the linked goals or tasks by retrieving indicator values from external resources called business information providers, such as BI tools, data warehouse, operational database, XML and various other sources.

1.3. THESIS CONTRIBUTIONS

This thesis is based on the research work in the ORNEC e-Health project as well as previous published literature about business process monitoring and alignment. The main contributions of this thesis focus on an approach to implementing goal-oriented business process monitoring based on URN combined with business intelligence and Web services. They are listed as follows:

- *A proposed extension to URN that supports integrated KPI-Goal-Process modeling.* By adopting URN, the links between business processes and goals enables traceability of the performance evaluation on both sides. By integrating KPI modeling with URN, the existence of URN links becomes more reasonable and useful for practical purposes.

- *An extension to jUCMNav that allows KPI evaluation to be integrated with Goal Evaluation.* KPI evaluation strategies are defined to set different contexts for KPIs and KPI information elements to precisely describe the requirements of evaluation.
- *A framework for data model and KPI report generation.* This approach aims to facilitate the data modeling process in a systematic manner with aid of the business knowledge from business users.
- *A framework for integrating business process monitoring with goal-based evaluation and design of business process models.* KPI values can be automatically retrieved from business information providers, such as BI tools, and then can be used to initialize and propagate the evaluation levels of higher level goal models.

1.4. THESIS OUTLINE

This thesis is structured as follows:

Chapter 1: gives background information about the general concepts, notations and tools used in this thesis including URN and jUCMNav, Data Warehouse, BI technology, SOA and BPM.

Chapter 1: related research into business process management and business process monitoring, including: research on the fundamental business process management methodologies; research on business process modeling using URN; and a survey and comparison of BPM features and functionalities, esp. the goal related features, among the leading major business process management systems in the industry currently.

Chapter 1: introduces and describes the methodology used in the goal-oriented business process monitoring approach.

Chapter 1: illustrates in detail the implementation of the three modules of the proposed system including the business process monitoring tool, the business process information providers and the business process monitoring services.

Chapter 1: demonstrates and analyzes a case study of the discharge process in the health care industry.

Chapter 1: evaluates the goal-oriented business process system in comparison with other tools; and discusses its benefits as well as concerns, limitations and insufficiencies, according to the results of the implementation, the case study and feedback from conferences and seminars.

Chapter 1: concludes the thesis by discussing the contributions achieved throughout this research and presents future work related to this thesis.

Chapter 2 Background

This chapter introduces background knowledge related to this thesis in the areas of URN and URN modeling tools, data warehousing, BI technology, SOA, BPM, and BPMS.

2.1. USER REQUIREMENT NOTATION

In 2003, the standardization sector of the International Telecommunications Union (ITU) published the initial Z.150 series of Recommendations (ITU-T 2003) for User Requirements Notation in describing the needs of modeling and analyzing functional requirements (FR) and non-functional requirements (NFR) in the form of goals and scenarios prior to the detailed design (Weiss and Amyot 2005b, 1). As described in the ITU standard (ITU-T 2003, 5), URN is originally designed to a) "Specify or discover requirements for a proposed system or an evolving system" and b) "review such requirements for correctness and completeness". A later article (Weiss and Amyot 2005b) demonstrates an URN-based approach plus a supply chain management case study to argue that URN-based tools can be useful and usable for business process modeling since the concepts in URN, such as behavior, structure, goals, and non-functional requirements, are all relevant for business process modeling. Furthermore, based on these efforts, recent research by (Mussbacher 2007) further assesses the applicability of UCMs for workflow description and compares them with other languages and standards, such as BPMN, UML Activity Diagrams and BPEL4WS. This research illustrates that applying URN has great potential in business process management, not only for business process modeling but for the whole BPM life-cycle. With this in mind, this thesis will focus on how URN helps business process modeling and monitoring.

URN combines two complementary notations: Use Case Maps (UCM), used to describe the functional requirements as causal scenarios, and Goal-oriented Requirement Language (GRL), which enables the description of business goals, non-functional requirements, alternatives and rationales (Amyot 2003, 1-2).

2.1.1 Use Case Maps

As an integral part of URN, Use Case Maps (UCM) is a scenario notation that suits the description of functional requirements and high level design (Mussbacher 2007, 2).

Figure 1 below illustrates a simple example of using UCM to describe a library check-out process. The most frequently used UCM concepts and notation elements, such as responsibility, component, start/end points, stub and plug-in, are expressed in this map. Responsibilities are taken by specific components or roles; for example, the library assistant has two responsibilities: "checkStudentID" and "checkOutItems". The start and end points specify the possible entrances and end results of processes, such as "startCheckOut", "checkedOut" and "rejected". This example also shows that a sub-process "CheckoutOnSelfServeMachine" is embedded as a plug-in of the stub in the main process.

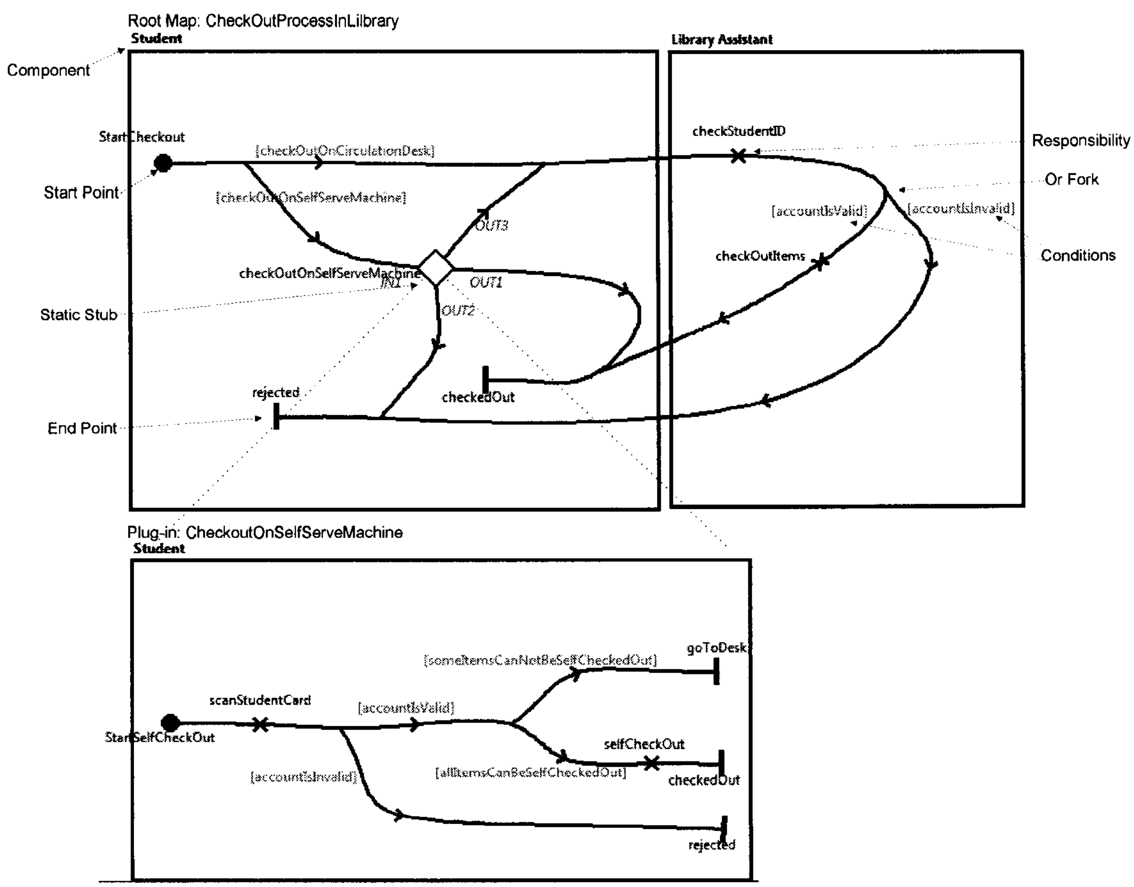

Figure 1: UCM model of a library check-out process

The basic elements included in UCM notation are shown in Figure 2 (Amyot 2003, 18).

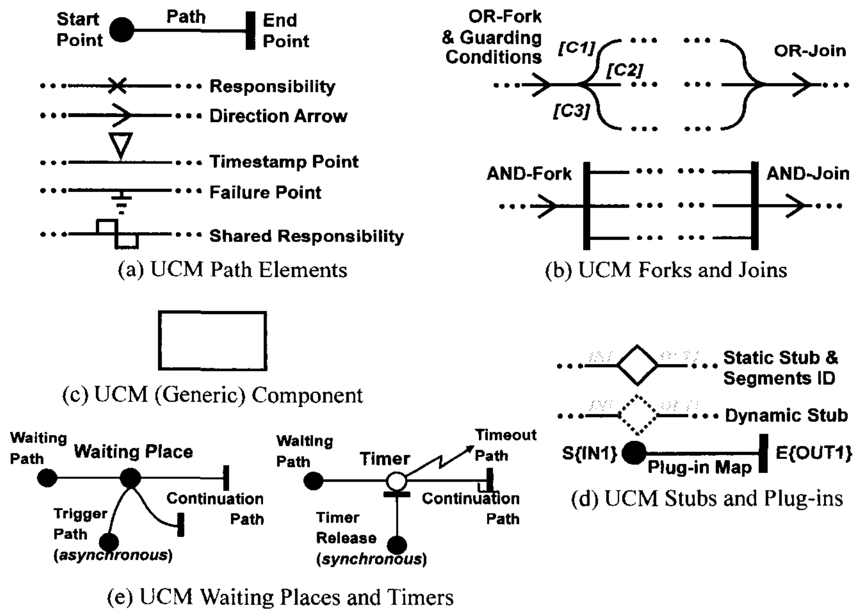

Figure 2: Basic elements of the UCM notation

The elements in UCM notation can be categorized into UCM path elements, forks and joins, components, stubs and plug-ins and waiting places and timers. In a UCM model, the causal flows of responsibilities, such as sequence, alternative and concurrent, describe how behaviors of a system, such as operations, actions, tasks, functions, etc., are performed by the components or roles involved in that system. Forks and joins are used to depict alternatives and concurrency on the path, while waiting places and timers represent the conditional stops on the path. By using the UCM stubs and plug-ins, a business process can be described and organized in multi-level hierarchies of UCM maps, each of which may contain any number of path elements, sequences and other kinds of elements. Moreover, the stubs and plug-ins can be reused to describe the reusable units of business behaviors and structures. These features make UCM a useful notation for easily and clearly describing complex business processes, scenarios and behaviors. As will be elaborated upon later in this thesis, the decomposition feature can also be useful in locating interesting areas or problems in business processes by enabling users to drill both up and down the process hierarchy.

While UCMs are used to describe multiple scenarios in an abstract and integrated view and contribute to the understanding and explanation of the whole system, by extracting and defining individual scenarios from the whole view on the other hand, people can better understand particular functionalities in complex processes (Amyot, Cho, et al. 2003, 1). As an example, the solid black path in Figure 3 shows a scenario where library users choose to check-out by using self-serve machines but later find that some library materials must be checked out at the circulation desk.

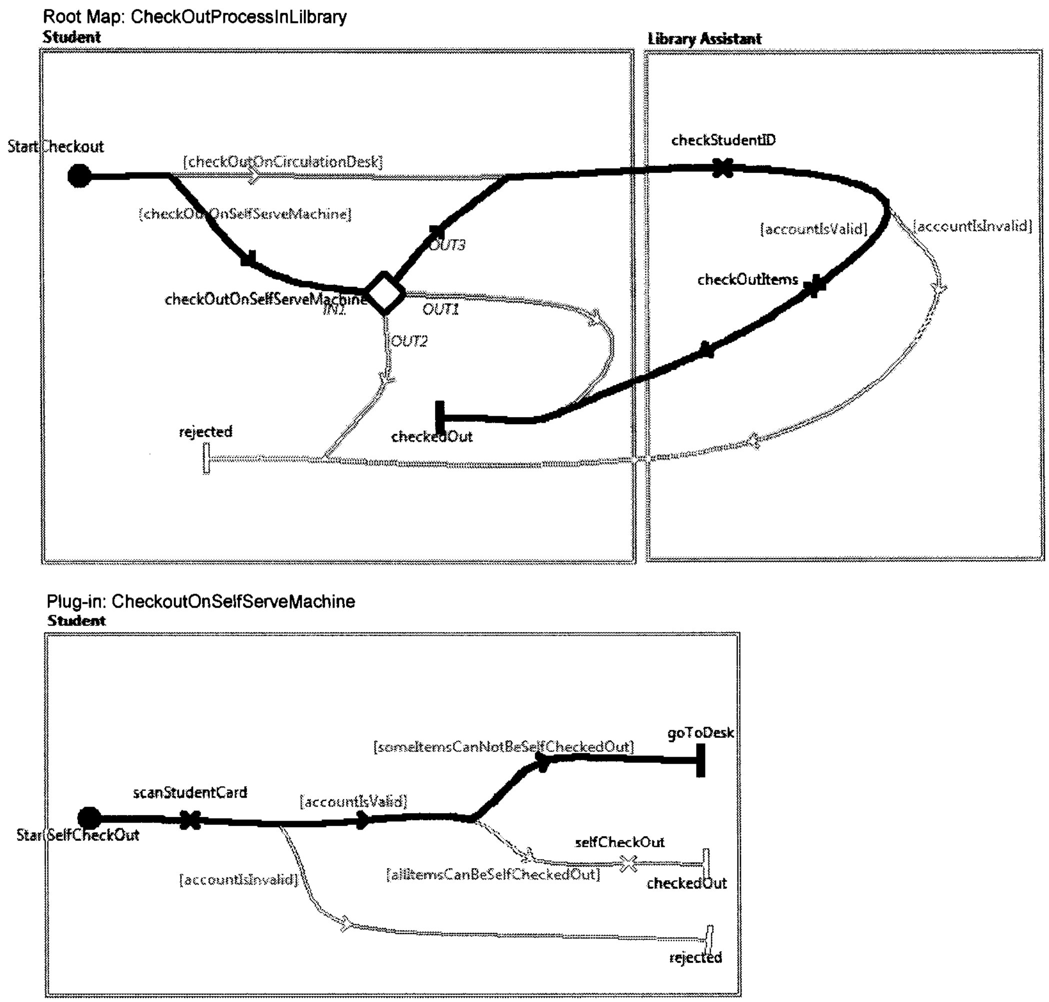

Figure 3: A scenario definition in the check-out process

2.1.2 Goal-Oriented Requirement Language

As an important sub-notation in the complete coverage of URN, Goal-Oriented Requirement Language (GRL) captures business goals, stakeholders' concerns, alternative means of achieving goals, and the rationale for goals and alternatives (Amyot 2003). The basic elements of GRL notation are shown in Figure 4 (Amyot 2003, 18).

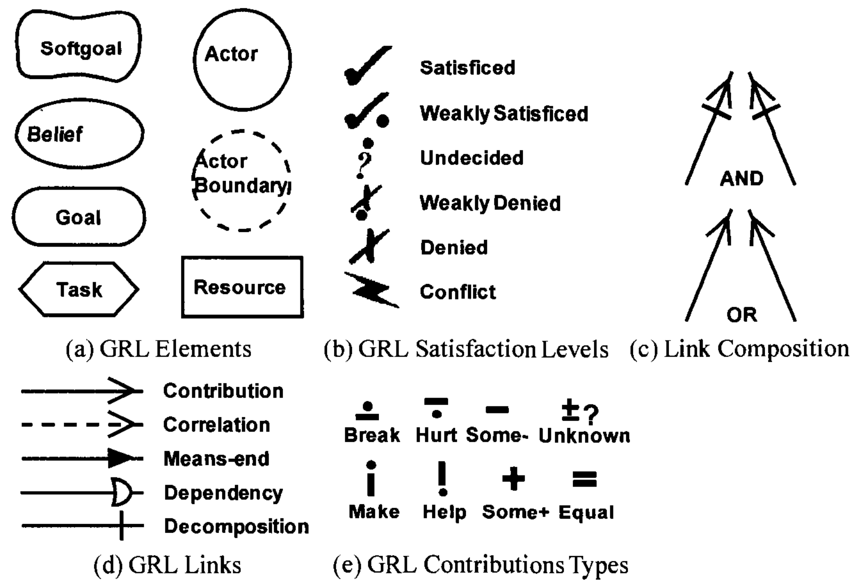

Figure 4: Basic elements of GRL notation

The notation elements in GRL can be categorized into five groups: the GRL elements, the GRL satisfaction levels, the link composition types, the GRL links, and the GRL contribution types. The major GRL elements are intentional elements, i.e. Softgoal, Goal, Task and Resource. While Goals are used to denote functional requirements, Softgoals can be used to depict non-functional concerns, and Tasks represents specific solutions contributing to the achievement of Goals or Softgoals. Actors are used to represent stakeholders and can set boundaries to include intentional elements representing the interests of stakeholders. Intentional elements can be connected by GRL links with either AND or OR compositions. Different weightings can be applied to GRL links to represent the various degrees of relationships between two intentional elements, which can then be used later by the propagation algorithm in the GRL strategy to calculate the satisfaction levels of each intentional element. The weightings assigned to contributions can be set as either pre-defined values, such as Make, Help, Some Positive, Some Negative, Hurt and Break, or simply as numeric values from -100 to 100.

As an example, Figure 5 shows a goal model of a library check-out process which shows the top goal of the process as being to provide satisfactory check out service, which can be broken down into three sub-goals: 1) it should be easy for users to check out; 2) users should have less waiting time; 3) the availability should be considered; and 4) the process should be effectively managed to avoid losses. To meet these goals, several tasks, such as making library assistants available to help users checking out, installing self serve machines to improve availability as well as reduce waiting time, and using an account management system to check account actions against the library regulations. These tasks can be further broken down into sub-tasks for more detail.

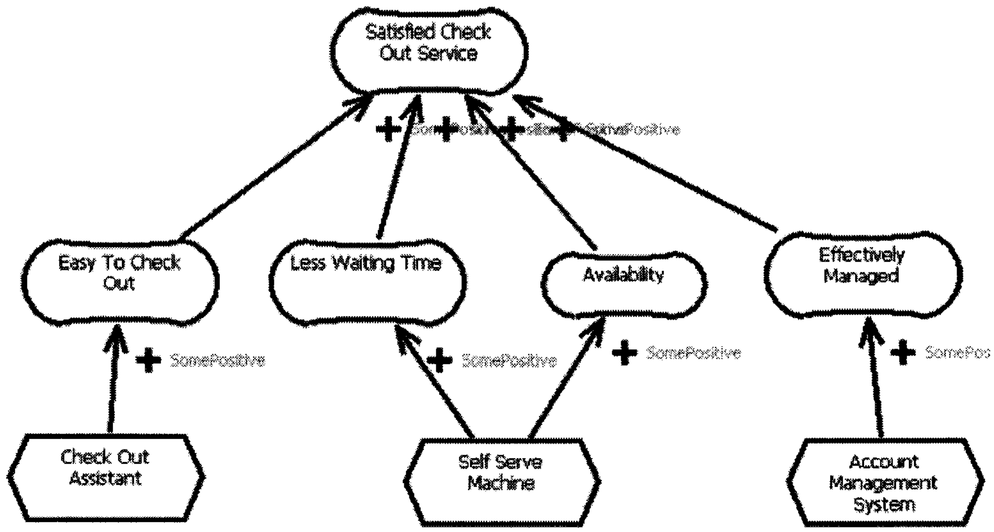

Figure 5: A goal model of the library check-out process

2.1.3 Links between GRL and UCM

Since the original purpose of URN is to capture and describe user requirements prior to any design, by combining and integrating UCM with GRL in URN, it is natural that the refinement of the goal model may provide guidance for eliciting requirements (ITU-T 2003, 22). On the other hand, the elicitation process may also give pointers for further goal refinement. The links between GRL and UCM allow the ability to ask "why" for user requirement scenarios.

Furthermore, by mapping UCM to GRL, the synergy between GRL and UCM assists in evaluating how the business goals are covered by the requirement scenarios and to what degree these goals have been met. This ability can be helpful when applied to business process modeling and monitoring and will be discussed in more detail in the chapter on business process modeling. Apart from "why", URN links also allow people to ask "how" and "how much" when examining the meeting of business goals.

2.1.4 jUCMNav: a graphical URN modeling tool

jUCMNav is an Eclipse-based open-source tool for editing and analyzing URN models. It supports URN links between UCM and GRL so that the two sub-notations are implemented in an integrated manner (Roy, Kealey and Amyot 2006, 1).

Before jUCMNav, tools for each sub-notation in URN modeling existed in isolation. The UCMNav tool, which supports UCM notation via an X11-based graphical editor, supported neither GRL nor linking to external GRL models, while OpenOME, the best GRL modeling tool at the time (Yu 2005), did not cover anything in the UCM side. However, to "provide facilities to express the relationship between goals and system requirements (ITU-T 2003, 2)" is one of the capabilities defined in the URN standard. The integration of both notations was therefore required to implement a whole view of URN, which lead to the development of jUCMNav as the first tool to support the entirety of URN.

The jUCMNav tool implements the concept of GRL strategy, which is used to evaluate to what degree business goals are achieved in a given context (Roy, Kealey and Amyot 2006, 10). Users define sets of initial evaluations of chosen intentional elements (usually leaves of the graph) in a GRL model, and then those initialized values will be propagated to higher intentional elements via links between them, up to the highest level goals in the model. However, currently jUCMNav only supports bottom-up evaluation (Kealey, et al. 2006) (J.-F. Roy 2007), whereas OpenOME also supports top-down evaluation (Yu 2005).

A GRL strategy defined using the library check-out goal model and its evaluation results are shown in Figure 6. The evaluation levels of intentional elements are represented using numerical values between -100 to 100 and the elements are color-coded, varying from red (-100) to green (100).

jUCMNav is an Eclipse plug-in developed based on Eclipse Modeling Framework (EMF) and Graphical Editing Framework (GEF). Since jUCMNav is an open source URN tool and the implementation of the business process modeling and monitoring tool in this thesis is based on jUCMNav, the monitoring tool too is available under an open source license and as part of the current release of jUCMNav.

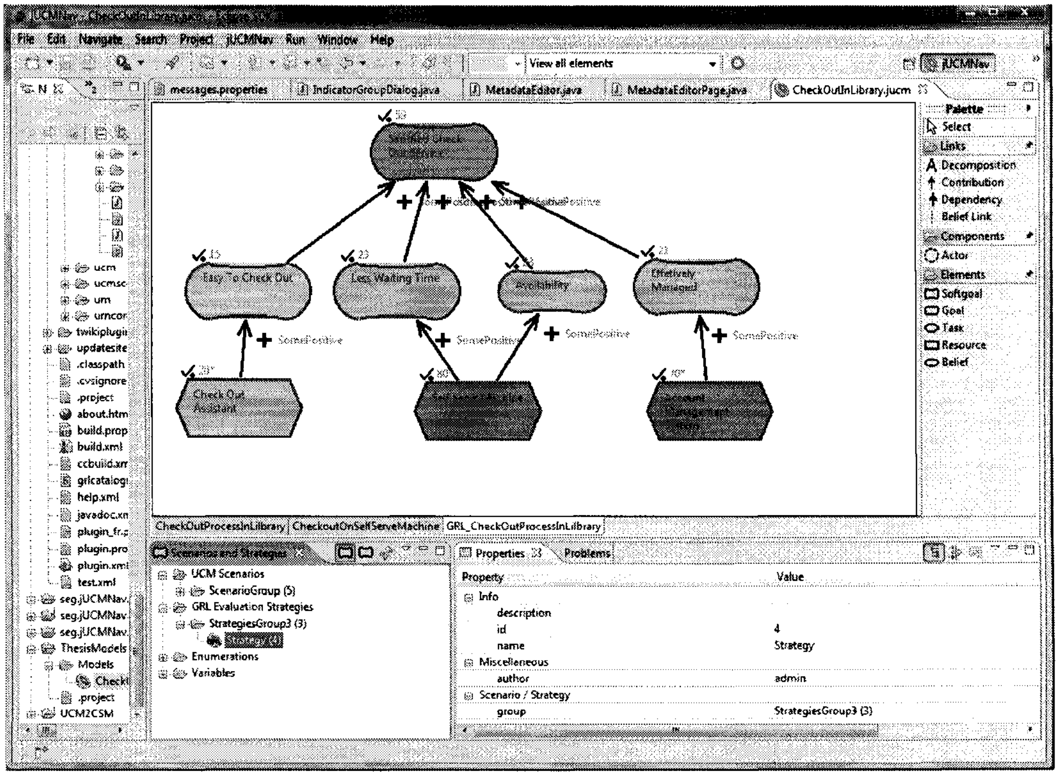

Figure 6: An example of GRL strategy and evaluation results in jUCMNav

2.2. DATA WAREHOUSE

A data warehouse is described as a "subject-oriented, integrated, time varying, non-volatile collection of data that is used primarily in organizational decision making" (Inmon 2005). A data warehouse plays an important role in process measurement, which typically provides statistical process data which combines with business data to determine the performance of business processes (Küng, et al. 2005, 5). In the project for this thesis, the data warehouse is mainly used as a query-able source of business information, to either provide data directly to monitoring services or feed data to a BI engine for further refinement. The dimensional modeling, which is mainly a data mart design, is one of the main concerns in preparing business information providers in this approach.

As a logical subset (view) or a physical subset (extract) of the complete data warehouse (Inmon 2005), a data mart is built to meet a specific, predefined need for a certain grouping and configuration of select data. A star schema or a dimensional model is a popular way to design data marts, but a snowflake schema is also used for some particular considerations. As a special case of the snowflake schema, the star schema allows a single level of dimension tables (Star Schema 2006), while the snowflake schema may contain "a set of constituent dimension tables which can be further broken up into sub-dimension tables" (Mark Levene 2003) and thus is better normalized but more complex for query (Star Schema 2006). For dimension tables, it is common to consolidate redundant data and be in second normal form (2NF), while fact tables are usually in third normal form (3NF) which doesn't contain redundancy data. A dimensional model designed using a star schema to show sales transactions is in Figure 7, in which the dimension tables, i.e. time, product, customer, promotion and representative, are connected to the sale transaction fact table through the foreign keys.

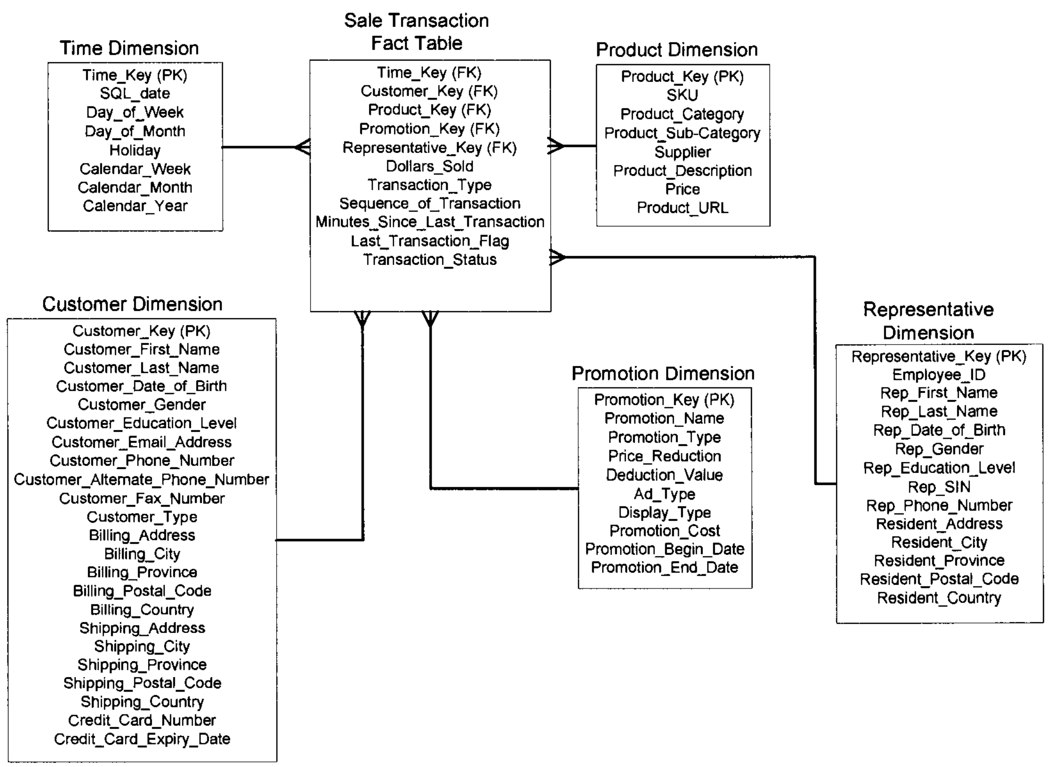

Figure 7: A dimensional model of a sales transaction

2.3. BUSINESS INTELLIGENCE

Business Intelligence (BI) can be defined as an integrated solution in which a collection of applications and databases work together to provide business users easy access to business data (Moss and Atre 2003, 4). The collaborative applications include both operational and decision support applications working directly with either an operational database or data warehouse.

Nowadays, companies are more process oriented than they were in the past (Baïna, Tata and Benali 2003, 1). In order to keep pace with the fast changing business environment and to be successful in the competitive market, companies are urged to synchronize their business activities right through from customers to suppliers and they need a way to keep achieving the business goals defined by their strategies. Thus, to align business processes to business goals, business decision makers need to continuously measure business performance using key performance indicators (KPIs) to ensure their business is effective and efficient. BI technology by design can act as a bridge between operational data and business performance information in order to efficiently and effectively generate KPI values (Kruppke and Bauer 2006, 77).

In the project for this thesis, Cognos 8 BI, which is a well known and most used platform in BI market, is chosen to act as business information providers working with the monitoring services and the monitoring tools. Cognos 8 BI is a comprehensive BI platform consisting of the Cognos Framework Manager used for building data models, the Cognos Report Studio used for generating business reports, and the Cognos Analysis Studio providing complete BI analysis capabilities, as well as the Cognos scorecarding and dashboard tools (Cognos 2007). Two steps are required to generate business performance information using the Cognos tools. First, with the help of KPI information provided by the KPI model, business data models will be created in the Cognos Framework Manager. Then, according to different contexts defined in KPI strategies, KPI reports from multiple points of view will be generated in the Cognos Report Studio ready to be executed by the monitoring services through the Cognos SDK.

2.4. SERVICE ORIENTED ARCHITECTURE

A Web service is "an interface that describes a collection of operations that are network-accessible through standardized XML messaging" (Gottschalk, et al. 2002). To enable communication between different technologies and platforms, or to work in a dynamic environment where information providers or requesters may be variable and unpredictable, a capacity loosely coupling a requester and the service to be used is required (Weerawarana, et al. 2005, 9). The more Web services available through SOA, the more flexibility and adaptability BPM system components have (Hill, Sinur and Flint, et al. 2006).

The overall architectural model of SOA consists of the three types of participants shown in Figure 8 (Singh and Huhns 2005, 20), in which the service providers create Web services and publish them by registering with service brokers; the service brokers maintain the registries of published services and make them available for searching and visiting; and the service requesters search the registries from service brokers for required services as well as the providers, and then bind with the providers and send requests to the services.

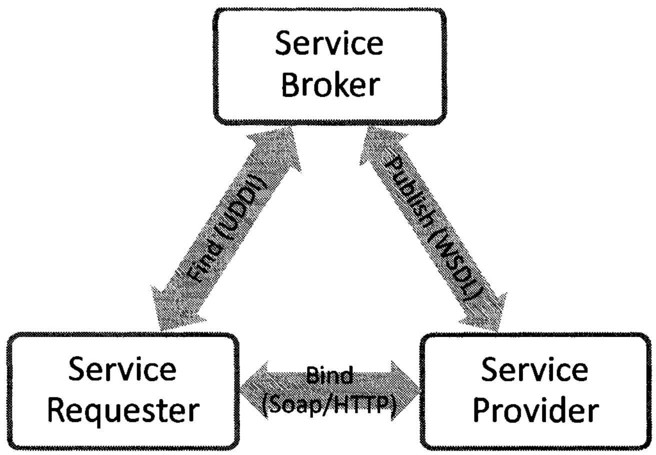

Figure 8: The general architectural model of SOA

2.5. BUSINESS PROCESS MANAGEMENT

Business process management (BPM) is the understanding and management of the diverse and cross-organizational processes which link humans and automated systems together. It integrates methods, techniques and tools to support the design, execution, management, and analysis of operational business processes. A business process management system (BPMS), on the other hand, can be defined as "a generic software system that is driven by explicit process designs to enact and manage operational business processes" (Aalst, Hofstede and Weske 2003, 1). Adoption of BPMS and SOA technologies greatly reduces technical work when handling business management issues (Hill, Sinur and Flint, et al. 2006).

As the central object of BPM and BPMS, a business process is not simply a coordinated chain of activities, those activities should also work together to carry out a complete business goal (Debevoise 2005, 3). Without keeping business goals in mind, a BPM is not a complete solution. Recent studies and surveys show that the most CIOs consider BPM as the most important technology in helping them achieve their business goals (Appian Software October, 2006)(Rudden January, 2007, 1). BPM thus needs to align business processes with business goal architecture and requires a change in the emphasis of monitoring from process to goal-oriented.

2.5.1 Business process management life cycle

Business process management activities can be considered as an iterative and continuous process of improving business processes and achieving business goals. As depicted in Figure 9, a complete BPM solution should contain an iterative life cycle which includes the following steps: business process modeling, execution, monitoring and optimization.

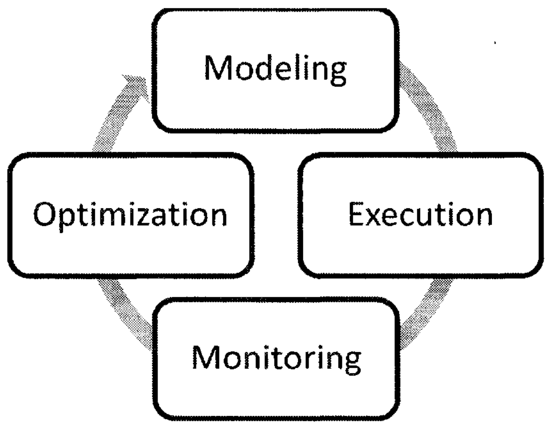

Figure 9: Business process management life cycle

In these steps in business process modeling, the main tasks include the capture and analysis of business process requirements, the design and generation of business models, simulations, and the defining of business metrics and KPIs. There are many languages and notations that can be used for business process modeling and each of them has its own specific features and advantages as well as shortcomings; these will be discussed later in this thesis.

Next, business processes will be assembled, deployed, carried out and managed by integrated applications. A process execution engine should be used to support the execution of operational processes.

The business activity information generated from the process execution will then be fed into the monitoring applications for either long term analysis and/or real-time business activity monitoring (BAM) and event handling to gain insight into the business and IT performance. What combination of solutions should be used is decided by business requirements and decision makers' needs.

The purpose of monitoring is to find problems and make improvements. For some real-time events or errors, the problems can be fixed or the events handled without touching process design. But for others, especially the performance issues due to process deficiency, improper design, changes of environment, adjustment of goals, etc., business process optimization and redesign will be needed.

2.5.2 Integration of business process management system

The series of applications and technologies from process modeling, execution, monitoring and optimization work together in improving the performance of business processes (Lee and Dale 1998, 3). Web services based on service oriented architecture provide a loose coupling between those co-operators, which might be based on different technologies and platforms and be from different companies. Since the notion of SOA precludes differences of knowledge or assumptions among the specific platforms that the participants run on (Weerawarana, et al. 2005, 9), it provides a standard interface to remove the communication difficulties inherent with different BPM applications and resources. Also, according to Gartner (Hill, Sinur and Flint, et al. 2006), adoption of BPMS and SOA technologies greatly reduces the amount of technical work of integrating miscellaneous applications and systems to work as a whole when handling business management issues.

However, apart from considering the method of communication, the question of what formats should be used for transfers between providers and requesters to ensure the contents are understandable and useful should also be handled carefully. Thus, defining standard formats for knowledge transfer is necessary for smooth interoperability between the BPM components.

2.6. CHAPTER SUMMARY

This chapter first introduced URN, which is the notation used for business process modeling in this thesis, together with the graphic editor for URN, i.e. jUCMNav. Then the background information regarding data warehouses, business intelligence and Web services was presented in sections 2.2, 2.3 and 2.4. Finally, BPM and BPMS, the BPM life cycle and the integration of BPM components were discussed.

Chapter 3 Related Work

This thesis proposes an approach based on the User Requirements Notation (URN) to model goals and processes, build Key Performance Indicators (KPI) models, and monitor business processes for the purpose of iteratively improving both business goals and processes. Business process monitoring is an essential step in the BPM life cycle, thus the theories and methodologies of BPM should be a guide line for the implementation of such a business process monitoring system. The methodology of this approach is based on modern process management theories, such as Total Quality Management (TQM), Six Sigma and Business Process Re-engineering (BPR), which will be discussed in this chapter.

To better understand the current situation of business process modeling and why the approach chosen in this thesis was a URN-based solution, this chapter examines and presents the major issues in business process modeling and the related research on URN. This chapter also surveys the current status of BPMS and evaluates the leading BPM tools in industry today.

3.1. METHODOLOGIES FOR BUSINESS PROCESS MANAGEMENT

Under the process management framework, re-engineering is combined with other quality and process-focused business improvement approaches, such as Six Sigma, Total Quality Management (TQM) and Business Process Re-engineering (BPR), in an integrated approach to business process management (Chang 2006, 29). To analyze, improve, control, and manage processes, business process monitoring plays an indispensable role in determining appropriate process improvement tools to implement a project.

3.1.1 Total quality management

TQM is a structured system that aims at continual improvements in customer satisfaction and quality in all organizational processes: Total means every person and all processes organization-wide; Quality means improving customer satisfaction, and Management means the management system with steps (Vonderheide-Liem and Pate 2004, 3). Hence, TQM focuses on quality and works on the basis that all persons and roles involved in an organization's processes should also be involved in the quality improvement life cycle. Figure

10 shows the Shewhart cycle (Vonderheide-Liem and Pate 2004, 4), of continuous process improvement. The TQM practices discussed in (Chang 2006, 10) emphasize the importance of identifying customer requirements and using scientific methods for monitoring quality and discovering any problems to be dealt with.

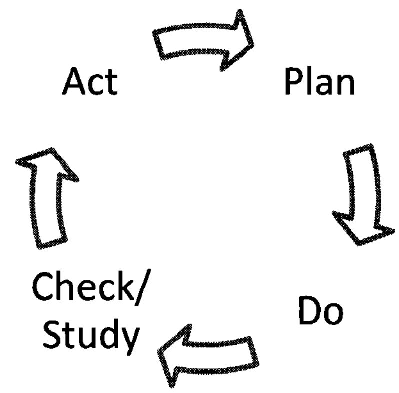

Figure 10: The Shewhart cycle

3.1.2 Six Sigma

The Six Sigma system was originally developed with the aim of systematically improving processes by eliminating defects. Six Sigma has since been widely adopted for business performance improvement and has become a management fad in many industries (Chang 2006, 16). The implementation methodology of Six Sigma seeks by means of large amounts of data analysis to identify the source of defects that contribute to process variation. It thus requires having a precise understanding of business requirements in order to identify and eliminate defects in business processes (Vidovic and Vuksic 2003, 27). Two methodologies utilized in Six Sigma are DMAIC, which stands for Define, Measure, Analysis, Improve and Control; and DMADV, which stands for Define, Measure, Analyze, Design and Verify. DMAIC is usually applied to improving an existing process while DMADV aims to create and design new processes.

When applied to the business process management life cycle; to "Define" is to identify the business requirements and goals; "Measure" is to monitor the business processes and collect relevant data toward achieving these goals; then to "Analyze" and "Improve" are to identify and improve processes based on the monitoring results; and finally, "Control" should be performed throughout the life cycle to ensure the continuous measurement and instituted control.

3.1.3 Business process re-engineering

Business Process Re-engineering (BPR) is a business improvement approach that aims at improving the efficiency and effectiveness of business processes both within and between organizations. The degree of BPR change is determined by the level of change occurring in seven aspects of re-engineering, which are process work flows, roles and responsibilities, performance measurements and incentives, organizational structure, IT culture and skill requirements (Chang 2006).

Within the field of industry management, although a significant number of BPR methodologies have been developed they all share some basic principles which will be adopted in the approach of this thesis. These shared principles include setting business process objectives or goals, identifying existing processes and envisioning new processes, process monitoring which involves performance measurement, and process redesign.

3.2. BUSINESS PROCESS MODELING

Business process modeling can be defined as "a structured method for describing and analyzing opportunities to improve the business objectives of stakeholders, including providers and customers" (Weiss and Amyot 2005b, 1). According to this definition, a complete business process modeling solution should have ability to depict two aspects of business processes: the process modeling and the goal modeling, as well as the relationships between processes and goals. A business process model thus should be able to specify the following information: the roles involved in the processes, the work-flows and activities, the contributions of processes to goals, and also to answer the well known "W5" questions: "Why do this activity", "When and Where should this activity be performed", "What are the responsibilities of this activity" and "Who should be involved in this activity" (Weiss and Amyot 2005b, 1).

In recent years, a variety of modeling languages and techniques, such as BPMN, XPDL, BPEL, EPC, i*, UML 2.0 AD, YAWL, EEML, NFR, JPDL and URN, have been suggested for business process modeling, each of which has its own benefits and strengths depending on one's different points of view. Based on the features and functionalities of business process modeling discussed above and the principles argued in (Mayr, Kop and Esberger 2007), by comparing the process modeling capabilities, such as the ability to support roles, sequence flow, message flow, event handling, activities and process hierarchies, and the goal modeling capabilities; or to support goals, roles, contributions and evaluation as well as the links between processes and goals; URN is the only notation which fully covers business process modeling and goal modeling abilities as well as the traceability between them that allows the application of design experts' know-how to information systems by adopting one's specific business and technology experience and situation (Liu and Yu 2004, 1). Hence, as discussed in the review of the literature on URN in section 2.1, the nature of URN makes it a perfect candidate for business process modeling, in which UCM can perform process modeling (Weiss and Amyot 2005b) (Mussbacher 2007, 10) and GRL can depict business goal models. The links between UCM and GRL can then represent and describe the relationships between business processes and goals. URN provides a combined view of goals and processes that is unique, together with ways of annotating additional information that enable various extensions. Accordingly, it is an excellent candidate to be used as a basic notation in the approach to business process monitoring utilised in this thesis.

3.3. BUSINESS PROCESS MANAGEMENT SYSTEMS

As discussed in the section 2.5, BPMS allows organizations to integrate people, data and IT technologies into a process-centric solution (Chang 2006, 50). The monitoring and measurement of business processes, which is a key step in the BPM life cycle (see the Figure 9), enables BPMS to monitor, control, and improve business processes in real time (Chang 2006, 50). On the one hand, BPMS provides the ability to effectively and efficiently measure business process activities in real time for the further business process monitoring; while on the other hand, the business process monitoring provides information to help determine which processes will contribute the most value in the business process improvement.

In this section, the leading BPMS products in the industry are evaluated and compared based on their features and functionalities.

3.3.1 Evaluation

According to Gartner (Hill and Sinur 2006), there are over 150 products that could be categorized as business process management software. Based on our research into the BPM industry, Gartner's Business Process Management Suite report of 2006 (Hill and Sinur 2006) and Forrester Research's reports on Business Process Management (Clair and Teubner Q3 2007)(Moore Q1 2006)(Vollmer and Peyret Q4 2006), this thesis chooses the BPM companies and products that have leading or strong positions in the industry and then does further research and comparison based on the features and functionalities that show their coverage of the BPM life cycle, especially in regard to goal related capabilities. Each of those products has its own strengths and has a leading or challenging position within different areas and perspectives, such as human-centric, integration-centric, or document process points of view. The evaluated features and functionalities include: business process modeling, business goal modeling, business goal evaluation, links between goals and processes, KPI modeling, KPI evaluation/monitoring, business events handling, process simulation, process execution, contribution to data modeling, contribution to process redesign, and system assembling and integration. It should be noted that the features and functionalities are chosen for evaluation according to the objectives of this thesis so it is not an overall evaluation on those products.

(1) IBM WebSphere process integration products

As one of the leading BPM solution providers in the industry, IBM produces IBM WebSphere process integration software, a comprehensive BPM solution enabled by SOA for process modeling, simulation and implementation and execution (Wahli, et al. 2007, 15). The product also allows users to monitor and analyze the implemented business processes. To provide these features and functionalities, the following IBM WebSphere process integration products are necessary: WebSphere Business Modeler, WebSphere Integration Developer, WebSphere Process Server, and WebSphere Business Monitor.

The following features and functionalities evaluated in this thesis are found the IBM products:

- Business process modeling: the IBM solution provides WebSphere Business Modeler, a BPEL based process modeling tool, for modeling process flows, business items and resources. By using this tool various elements and sequences can be defined to construct a complex business process.
- KPI modeling: WebSphere Business Modeler allows users to define business performance indicators including KPI and metrics for the processes. Two KPIs, i.e. number and duration, can be measured and calculated from defined metrics. Dimensions can be created and assigned to KPIs. However, due to the lack of

business goal models and links between processes and goals, KPIs are organized in a process based manner and simply linked to processes without illustrating the relationships between business performance, business objectives and business processes. Furthermore in the business modeler, KPIs can only be associated with processes, not with business activities or responsibilities.

- KPI evaluation/monitoring: WebSphere Business Monitor can be used to analyze the process execution data for measuring business metrics and KPIs defined on processes. The KPI evaluation values can be used for continuous process improvement.
- Business events handling: using WebSphere Business Modeler business event objects can be created and then monitored in WebSphere Business Monitor.
- Process simulation: After modeling a business process, WebSphere Business Modeler can simulate the running of the process to assess its performance, generate statistics about its execution, and pinpoint potential improvements.
- Process execution: Business process models can be exported to WebSphere Integration Developer to implement processes and generate EAR files to be deployed on the WebSphere Process Server for execution.
- Contribution to data modeling: monitor models generated in WebSphere Business Monitor can be installed on a Monitor Server to generate data schema and script files. These schema and scripts can be then executed in IBM DB2 to create an OLAP cube.
- Contribution to process redesign: measurement results generated from WebSphere Business Monitor can be used to improve the business process. However, a systematic strategy to link the performance evaluation results and the process redesign is still missing from the solution.
- System assembling and integration: IBM WebSphere process integration products are built with IBM SOA foundation, which has benefits in flexibility, adaptability, scalability and efficiency (Keen, et al. 2007, 15).

However, the IBM solution doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes.

(2) Intalio business process management system

Intalio BPMS Community Edition is a business process management product with an Open-Source-Like License. It includes: Intalio BPMS Designer, which is an Eclipse-based integrated development environment for designing business processes with BPMN and deploying them by transforming BPMN to BPEL; and Intalio BPMS Server, which is a native BPEL 2.0 process server based on Java Business Integration (JBI).

The following features and functionalities evaluated in this thesis are found in the Intalio BPMS:

- Business process modeling: Intalio BPMS Designer includes a complete BPMN modeler to allow users to design business processes based on BPMN. The tool includes a Data Mapper view, a graphical tool that allows users to define data transformation between variables defined in different process elements. Finally, when a process is designed and ready for deployment, the tool can generate BPEL and WSDL files, compile required code and then deploy the process to Intalio BPMS Server.
- Business events handling: Intalio BPMS designer includes event and message elements in BPMN to provide event handling capability in business processes.
- Process execution: Intalio BPMS Server follows the BPEL 2.0 standards based on J2EE. The server includes a native BPEL 2.0 runtime, so can execute deployed processes in online. It can also generate statistics presenting the status of running or finished processes. However, there is no monitoring against business process and business activities.
- System assembling and integration: as Intalio BPMS Server is designed based on Service Oriented Architecture (SOA), all external systems are transparent Web services while deployed processes can register their WSDL interfaces onto a UDDI registry.

However, the Intalio BPMS solution doesn't support the features of business goal modeling, business goal evaluation, links between goals and processes, KPI modeling, and KPI evaluation and monitoring. In addition, there is no process simulation function in the current version, although it is an open source product based on SOA which enables a good extendibility. However, it doesn't directly provide information to help data modeling and process redesign.

(3) Appian enterprise BPM suite

Appian enterprise is a comprehensive BPM suite. Compared with other BPM tools, it includes a large scope process, knowledge, analytics and access.

The following features and functionalities evaluated in this thesis are found in the Appian BPM suite:

- Business process modeling: in the Appian BPM suite, the Appian Process Modeler is a browser based process modeler that allows users to analyze and build process models that conform to BPMN.
- KPI modeling, KPI evaluation/monitoring: Appian enterprise BPM suite provides functionalities on business operation and process execution analytics that include: Appian Process Analytics and Business Analytics, which enable process execution measurement and business monitoring; and Appian Dashboard Reporter, which offers a business and process performance monitoring dashboard with various charts and views. However, the performance measurement behaviors are not goal-oriented and are not well linked to business processes and business goals.
- Business events handling: Appian Business Activity Monitor generates event triggers and alerts to control process flows based on rules defined on the processes.
- Process simulation: Appian Simulation provides capabilities to identify potential bottlenecks and errors by exploring "what if" scenarios on the process level.
- Process execution: Appian Process Engine and Appian Rules Engine in the suite provide the capabilities to automate processes and centrally-managed business rules.
- Contribution to process redesign: with Appian Process Manager and Appian Analytics, process performance reports can be generated to help optimize work-flows. However, there is no systematic strategy to help the optimization; it still heavily relies on users' business experience and knowledge.
- System assembling and integration: by adopting the J2EE-compliant architecture and building on a service-oriented architecture, the Appian enterprise BPM products are well integrated and worked in a scalable, secure and extendable way.

However, due to the limitations of BPMN and the lack of a goal-oriented vision, the Appian BPM solution doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes, and nor does it directly provide information to help data modeling.

(4) Global 360 enterprise BPM suite

G360 enterprise is a business process management platform that combines process modeling, design, execution, control, and analytics components to manage a complete process life cycle.

The following features and functionalities evaluated in this thesis are found in the Global 360 BPM suite:

- Business process modeling: the G360 BPM suite includes G360 Process Designer, which is used to define business processes and rules with BPMN and XPDL support.
- KPI modeling: through G360 Process Designer and G360 Goal Manager, KPIs can be defined for processes. The process designer says that it has the capability of defining business goals, but in fact it is to define KPIs and their target values against processes.
- KPI evaluation/monitoring: the Analytics Engine provides users the ability to generate statistics about goal (KPI) attainment, and also productivity and work-load information. However, the historical analytics in G360 rely on Excel which means there is no awareness of the process being analyzed (Moore Q1 2006).
- Business events handling: with G360 Process Designer, the system can respond to business and transaction events.
- Process simulation: G360 Process Simulator can be used to help determine how processes will behave in various scenarios by test driving business processes and alternate models.
- Process execution: the BPM suite supports process execution and management.
- System assembling and integration: the BPM applications in the suite as well as their external application are orchestrated using a SOA infrastructure.

However, the Global 360 enterprise BPM solution doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes. Although the product supposedly has the ability to define goals, it is actually to define KPIs and set their target values to evaluate processes. In addition, it doesn't directly provide information for data modeling and nor does it implement a systematic strategy for process redesign.

(5) Tibco iProcess Suite

As a leading company in the BPM field, Tibco provides the iProcess Suite, which is a comprehensive business process management solution covering business process modeling, execution, rules and analysis.

The following features and functionalities evaluated in this thesis are found in the Tibco BPM solution:

- Business process modeling: the iProcess suite includes Business Studio, which is an Eclipse-based process modeling tool with support for the full BPMN and XPDL.
- Business goal modeling and links between goals and processes: iProcess Conductor addresses some goal-oriented concepts, but, it is more like a BPMS for on-the-fly processes (DiToro and Schaffhauser 2006). The tool allows users to specify goals for processes and to categorize processes against their overall goals. However, without an integrated goal architecture, without matching and linking goals, processes and performance models in different hierarchies, and without a goal-oriented evaluation strategy, this solution cannot be addressed as a complete systematic goal-oriented solution.
- KPI modeling and KPI evaluation/monitoring: iProcess Analytics enables the establishment and continuous measurement of KPIs for ongoing processes.
- Business events handling: through iProcess Rules based on the BPMN modeling, events can be defined in processes to identify critical issues.
- Process simulation: iProcess Analytics allows taking a specified process definition and simulating the running of user cases in the process.
- Process execution: the iProcess Engine integrated in the suite supports process transactions across multi-servers.
- Contribution to process redesign: iProcess Analytics and Rules can provide some information for process improvement. However, there is no systematic methodology

to be used in the process optimization and redesign, but rather a reliance on users' business experience and knowledge.

- System assembling and integration: the applications in the iProcess suites are well integrated through a service-oriented architecture.

However, the Tibco BPM solution doesn't provide a complete solution to handle goal related features since it lacks a goal architecture, links between goals, processes and performance models in different hierarchies and a goal-oriented evaluation strategy. In addition, it doesn't directly provide information for data modeling and nor does it implement a systematic strategy for process redesign.

(6) EMC BPM Suite

EMC has the leading position in document-centric BPMS with "strong design, image repository, monitoring and management and product architecture", according to the Forrester's BPM reports in 2007 (Clair and Teubner Q3 2007). The EMC BPM suite provides capabilities across process modeling, execution, business activity monitoring and analysis.

The following features and functionalities evaluated in this thesis are found in the EMC BPM suite:

- Business process modeling: in the suite, EMC Documentum Process Builder allows users to build and deploy process models fully supported by BPMN and XPDL.

- KPI modeling and KPI evaluation/monitoring: EMC Business Activity Monitor can be used to create and track aggregate KPIs, and then the graphical metrics can be displayed in the management dashboards.

- Business events handling: the EMC BPM Suite is able to listen for and respond to external events, which are generated by external systems and received by Business Process Services; content events, which represent changes in the state of a content object; and any events generated by Process Engine and that can trigger other actions.

- Process simulation: EMC Documentum Business Process Simulator allows the analyst to trial, compare and examine processes, determine required resources and estimate process cost and time.

- Process execution: EMC Documentum Process Engine has the capability to execute and manage business processes. It also provides interfaces that allow users to view and control the execution context.
- System assembling and integration: EMC Documentum Process Engine uses Business Process Services, which adopts a service-oriented architecture, as the integration layer to connect the business processes with external systems, applications and data sources.

However, the EMC BPM suite doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes; it doesn't directly provide information for data modeling, and it doesn't implement a systematic strategy for process redesign.

(7) Pegasystems SmartBPM Suite

According to (Moore Q1 2006), Pegasystems has a leading position in the human-centric BPMS market with its strength in business rules/process engines. The components of the Pegasystems SmartBPM Suite cover the whole BPM life-cycle from modeling through improvements.

The following features and functionalities evaluated in this thesis are found in the Pegasystems SmartBPM Suite:

- Business process modeling: the PegaRULES Process Commander in the suite integrates Microsoft Visio through a web browser to build processes and rules with support for XPDL. Processes can also be directly built in Microsoft Visio and then imported into the Process Commander.
- KPI modeling and KPI evaluation/monitoring: with Process Analyzer and PegaRULES Process Commander, users can monitor and manage business activities via the pre-formatted reports and supports for metrics and KPI analysis.
- Business events handling: through PegaRULES Process Commander, alerts and triggers can be created to automatically respond to events via e-mails, faxes, letters, and wireless messages as part of work-flow.

- Process simulation: through the wizards provided by a Process Simulator, analysts can simulate business processes so as to quantify and compare service levels, time, errors, and cost reductions.
- Process execution: PegaRULES Process Commander combines a business rule engine and a process engine and can run on main J2EE-compliant application servers, including IBM WebSphere, BEA WebLogic, and Apache Tomcat. It supports industry standards such as BPEL.
- Contribution to process redesign: Process Analyzer can provide online analysis and recommendations for continuous process improvement.
- System assembling and integration: Pegasystems SmartBPM Suite has a J2EE and XML standardized architecture built with SOA.

However, the Pegasystems SmartBPM Suite doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes; it doesn't directly provide information for data modeling, and doesn't implement a systematic strategy for process redesign.

(8) Lombardi Teamworks BPMS

Gartner's research (Hill and Sinur 2006) and Forrester's report (Moore Q1 2006) show that Lombardi has a leading position in the BPM industry. The Lombardi Teamworks BPMS provides features and capabilities in process design, control and improvement.

The following features and functionalities evaluated in this thesis are found in the Lombardi Teamworks BPMS:

- Business process modeling: the Eclipse-based Teamworks Authoring Environment provides Process Modeler which uses BPMN as its standard and can import processes from BPEL.
- KPI modeling and KPI evaluation/monitoring: Teamworks Authoring Environment provides the capability to define and evaluate KPIs for processes.
- Business events handling: based on BPMN, events can be defined in processes in Process Modeler.

- Process simulation: through Process Optimizer in Teamworks Authoring Environment, users can create what-if scenarios for processes to simulate and compare the performance of process models.
- Process execution: working with application servers including BEA WebLogic, IBM WebSphere and JBOSS, users can view and execute business processes through Lombardi Teamworks Portal.
- Contribution to process redesign: Process Optimizer provides information for business process analysis and continuous improvement. The Playback component allows users to go through processes step by step to find any problems. Teamworks also can recommend solutions to process problems and thus can help business analysts make changes.
- System assembling and integration: Lombardi Teamworks BPMS is based on the J2EE architecture built with SOA and the enterprise service buses (ESB), while Connector Framework provides many connectors and an integration wizard to integrate process applications directly to existing ERP, ECM, EAI and legacy applications.

However, Lombardi Teamworks BPMS doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes, and nor does it directly provide information for data modeling.

(9) Savvion BusinessManager Platform

As one of the leaders in the human-centric BPMS (Moore Q1 2006)(Hill and Sinur 2006), Savvion's BusinessManager platform allows users to design, test, simulate, analyze and optimize business processes.

The following features and functionalities evaluated in this thesis are found in the Savvion:

- Business process modeling: Savvion Process Modeler in the platform provides a friendly visual environment that allows users build business processes based on BPMN.
- KPI modeling and KPI evaluation/monitoring: users can create business rules and metrics in Savvion BPM Studio, and then Savvion BPM Portal provides the dashboard view and reports so users can monitor and view achievement against KPIs.

- Business events handling: based on BPMN, Savvion Process Modeler allows users to create rules, events and exceptions in business processes. The Savvion BPM server in the BusinessManager platform contains a business rules/event management engine, which can handle procedures, policies, events and exceptions. Savvion BPM Portal can also provide real time alerts which are generated based upon particular process conditions.
- Process simulation: the simulation environment built in Savvion Process Modeler enables users to test processes and compare different scenarios.
- Process execution: a process engine is included in the Savvion BPM server to execute processes and enables Web-based work-flow by assigning and tracking tasks.
- Contribution to process redesign: the simulation environment included in Savvion Process Modeler can provide deficiency information about the designed processes to help improvement. In addition, the Savvion BPM Portal provides a dashboard view along with reports and real time process alert information which can be used to analyze and improve business processes. However, a systematic strategy for process redesign is not implemented in this platform.
- System assembling and integration: the Savvion BusinessManager platform is built on J2EE and XML in service oriented architecture. Savvion BPM Studio in the platform presents a visual design environment allowing users to manage and integrate Web services. The Savvion BPM server includes an integration engine that can be used to connect different enterprise applications via a standard interface and over 200 adapters.

However, the Savvion BusinessManager platform doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes. Furthermore, it doesn't directly provide information for data modeling or implement a systematic strategy for process redesign.

(10) FileNet Business Process Manager

FileNet is evaluated as a strong performer and challenger in BPMS, especially in the human-centric and enterprise content management areas, according to Gartner (Hill and Sinur 2006) and Forrester (Moore Q1 2006). FileNet Business Process Manager combines various products for business process modeling, monitoring, analysis, simulation and automation.

The following features and functionalities evaluated in this thesis are found in the webMethods BPM platform:

- Business process modeling: FileNet Business Process Manager provides a Microsoft Visio based Process Designer to define BPMN and XPDL based business processes.
- KPI modeling and KPI evaluation/monitoring: KPIs can be defined in FileNet Business Process Manager and be monitored in real time through a web-based dashboard in FileNet Business Activity Monitor and Process Analyzer. However, the lack of capability in a process-aware analysis environment makes the FileNet solution weak in process analysis and optimization (Moore Q1 2006).
- Business events handling: threshold values can be defined for KPIs so that KPI threshold violations will trigger active alerts and send notifications to users.
- Process simulation: with FileNet Process Simulator, the simulation scenarios, in which resources, business calendar, working shifts, cost, time and roles can be configured, can be defined and then be used to perform "what-if" analysis.
- Process execution: the defined business processes can be executed in FileNet Process Engine with FileNet Rules Engine. Rich automation features, such as automatic routing, resource pools, work prioritization, exception processing, task reassignment and process voting, are well implemented in FileNet Business Process Manager.
- System assembling and integration: FileNet Business Process Manager supports both J2EE and .Net architectures.

However, FileNet Business Process Manager doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes. Furthermore, it doesn't directly provide information for data modeling, or implement a systematic strategy for process redesign.

(11) Fujitsu Interstage BPM Suite

Fujitsu is a strong performer in human-centric BPMS. The Fujitsu Interstage BPM suite contains Interstage Business Process Manager, which aims to cover the full process life cycle, and CentraSite, which is an SOA repository acting as a Web services and SOA asset management platform.

The following features and functionalities evaluated in this thesis are found in the webMethods BPM platform:

- Business process modeling: in the suite, Interstage Business Process Manager Studio provides a visual Eclipse-based modeling environment, closely following to BPMS standards including BPMN, BPEL, XPDL and WfXML, which is seen as one of the strengths of the Fujitsu BPM suite.
- KPI modeling: Interstage Business Process Manager provides a business activity monitoring dashboard to allow users to define KPIs, their threshold values and the form of notification.
- KPI evaluation/monitoring: Interstage Business Process Manager Analytics enables users to view business process analysis and reporting with the ability to slice and dice metrics.
- Business events handling: based on BPMN, events can be defined in processes.
- Process simulation: a simulation environment is built into Interstage Business Process Manager Studio, which allows users to do "what-if" analysis by defining and running business process scenarios. It provides a simulation results view that helps users compare scenarios and identify potential process bottlenecks.
- Process execution: Interstage Business Process Manager offers the ability to automate business processes and rules.
- Contribution to process redesign: the simulation function and the BAM dashboard can provide information to help users identify process bottlenecks and optimize and redesign processes. However, the solution lacks a systematic strategy for process redesign.
- System assembling and integration: by being strongly committed to BPMS standards and supporting leading J2EE application servers in the industry, the Fujitsu Interstage BPM suite is built upon an open standard architecture. Also, the integration with

CentraSite, which provides a SOA registry and repository, makes the solution easily sharable and integrated with existing applications.

However, the Fujitsu Interstage BPM suite doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes. Furthermore, it doesn't directly provide information for data modeling and doesn't implement a systematic strategy for process redesign.

(12) BEA AquaLogic BPM Suite (Fuego)

The BEA system became a solid leader in the BPMS industry after Fuego joined BEA's AquaLogic product family in 2006. The BEA AquaLogic BPM suite now includes components for modeling, simulating, developing, deploying, executing and managing business processes.

The following features and functionalities evaluated in this thesis are found in the webMethods BPM platform:

- Business process modeling: BEA AquaLogic BPM Studio contains an Eclipse-based BPM Designer with the full support for BPMN and UML modeling standards.
- KPI modeling and KPI evaluation/monitoring: the BEA AquaLogic BPM suite allows users to directly define KPIs and other business metrics in the process models and then continuously track them through the BEA AquaLogic BPM Dashboard to enable real performance analysis against the processes.
- Business events handling: events and exceptions can be defined in the processes and notifications can be created directly in the processes.
- Process simulation: BEA AquaLogic BPM Studio includes a simulator that allows users to define scenarios for simulation. The results can be shown in the simulation view.
- Process execution: facilitated by BEA's strength in enterprise application servers, BEA AquaLogic BPM Enterprise Server executes processes designed in BEA AquaLogic BPM Designer and any BPEL processes. It can be deployed on major application servers like BES WebLogic or open source wares like Tomcat. In addition, BEA AquaLogic BPM Manager provides a console that allows users to view real time process information and manipulate the running processes.

- Contribution to process redesign: the results of simulations and the performance measurement during execution can be used for further optimization and continuous process improvement. However, a systematic strategy for process redesign is still missing from the solution.
- System assembling and integration: the BEA AquaLogic BPM suite adopts a service infrastructure to provide business service interactions. Also, it provides a simple wizard to enable connecting processes to a variety of IT systems in non-SOA environments.

However, the BEA AquaLogic BPM suite doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes. It doesn't however, directly provide information for data modeling and or implement a systematic strategy for process redesign.

(13) webMethods Fabric business process integration platform

webMethods is a leading vendor of integration-centric BPMS (Vollmer and Peyret Q4 2006), which has strong BPM features in process modeling, process monitoring along with good SOA capability. The webMethods platform combines components of business process modeling, execution, monitoring and optimization into a comprehensive BPMS.

The following features and functionalities evaluated in this thesis are found in the webMethods BPM platform:

- Business process modeling: the webMethods Designer combined in the platform is an Eclipse-based process modeler with the support for BPMN.
- KPI modeling and KPI evaluation/monitoring: webMethods Designer also allows users to define KPIs, which can then be measured in run time and displayed in webMethods Dashboard.
- Business events handling: webMethods Optimize for Process has capabilities including event management and alerts. Alerts also can be generated by webMethods Dashboard to send notifications of abnormal KPI performance.
- Process execution: webMethods Process Engine hosted on a webMethods Integration Server can execute the processes defined in webMethods Designer.

- Contribution to process redesign: webMethods Optimize for Process can provide information about the process activities, KPIs, events and alerts to guide further business process improvement. However, a systematic strategy for process redesign is still missing from the solution.
- System assembling and integration: webMethods Fabric business process integration platform integrates a good SOA capability by providing a registry/repository solution to incorporate BPM and SOA.

However, webMethods BPMS platform lacks a full-fledged business-oriented simulation solution (Vollmer and Peyret 2006). The platform doesn't support the features of business goal modeling, business goal evaluation, and links between goals and processes. It also does not directly provide information for data modeling or implement a systematic strategy for process redesign.

(14) SeeWhy real time BI platform

The SeeWhy Real Time Business Intelligence community edition is a real time business intelligence solution. Its main features include: defining and handling real time metrics, alerts and actions, business intelligence under SOA and event driven architectures, automatically testing every metric against multiple dimensions, rich built-in BI analytics, tracking sliding and periodic time windows. SeeWhy Real Time Business Intelligence includes the following components: SeeWhy Server, SeeWhy Navigator and SeeWhy Desktop.

The following features and functionalities evaluated in this thesis are found in the SeeWhy BI platform:

- KPI modeling: SeeWhy Desktop allows users to manage and deploy metrics and then monitor and analyze them in SeeWhy Server and SeeWhy Navigator. A complete set of attributes and configurations can be defined with metrics, including: values, aggregation period, aggregation filter, thresholds, triggers, filters and dimensions.
- KPI evaluation/monitoring: the metrics deployed on the SeeWhy server can be monitored through SeeWhy Navigator, which is an online web tool. With SeeWhy Navigator, users can monitor defined metrics in real time. Moreover, metrics can be monitored at both the aggregate level and the dimension level. Another useful option is to be able to look across the dimension instances and see their latest values.

- Business events handling: SeeWhy Navigator includes an alert function by showing two statuses for the monitored metrics. It uses a green globe to indicate that, as far as these metrics are concerned, all is well or as expected, and a red globe to indicate that an event has just caused the metric to alert users to a problem or exception of some kind.
- Process simulation: SeeWhy includes an event simulation to feed events into the server to test changes. However, since there are no processes modeled, the simulation is not based on business processes.
- System assembling and integration: The components, including SeeWhy Server, SeeWhy Navigator and SeeWhy Desktop, are integrated to work together as a whole and are designed for SOA.

However, SeeWhy provides a solution only in real time business intelligence, so there is no process modeling, goal modeling and evaluation, links between goals and processes, or process execution included. It also doesn't directly provide information to help data modeling and process redesign.

(15) JBoss jBPM

JBoss jBPM is a JBoss Enterprise Framework that delivers work-flow, BPM, and process orchestration. The following tools are provided in jBPM: JBoss jBPM Process Designer, which is an Eclipse plug-in for process design based on jPDL; JBoss jBPM jPDL, which includes the core execution engine, jPDL Runtime and identity component (JBoss.com 2007); JBoss jBPM BPEL, which provides an alternative to jPDL by providing WS-BPEL Runtime to execute BPEL based processes.

The following features and functionalities evaluated in this thesis are found in the JBoss BPM framework:

- Business process modeling: by using JBoss jBPM Process Designer, users can design business processes based on jPDL. Processes are modeled in the jPDL standard in terms of tasks, wait states for asynchronous communication, timers, automated actions, etc.

- Business events handling: by implementing jPDL, events can be described and handled by defining state nodes, signals and actions.
- Process execution: jPDL processes can be deployed on the JBoss jBPM jPDL server from the designer tool. Once deployed, processes can be started and assigned to specified users, who can then take further action (by filling in forms or making decisions) to proceed the processes.
- System assembling and integration: JBoss jBPM provides the following tools and process execution engine to integrate services deployed in a SOA and automate workflows in Java and Web applications.

However, JBoss jBPM doesn't support the features of business goal modeling, business goal evaluation, links between goals and processes, KPI modeling, and KPI evaluation and monitoring. The JBoss jBPM jPDL server has a management tool for managing process and task instances. However there are no features available for monitoring and analyze process performance from business point of view, nor are there functions for process simulation, data modeling and process redesign.

(16) SUN JavaEE Open ESB platform

SUN JavaEE Open Enterprise Service Bus (Open ESB) uses a Java Business Integration (JBI) runtime that incorporates the JSR 208 specification for Java Business Integration and other open standards. It includes: Open ESB 2.0, which includes an Enterprise Service Bus (ESB) runtime using Java Business Integration (JBI) as the foundation; GlassFish V2 application server, which is a free, open source application server which uses the newest features in the JavaEE 5 platform; Java Platform Enterprise Edition (JavaEE), which provides Web services, component model, management, and communications APIs for developing server-side Java applications; NetBeans IDE 5.5 with the NetBeans Enterprise Pack, which provides visual design tools for XML schema creation and visualizing BPEL based web service orchestration.

The following features and functionalities evaluated in this thesis are found in the JavaEE Open ESB platform:

- Business process modeling: The NetBeans IDE with Enterprise pack provides visual design tools for BPEL based web service orchestration. The visual design tool allows users to directly work on BPEL files to create or modify BPEL processes. It can also integrate Web services components into the BPEL processes and connect available Web services to the processes.

- Business events handling: by implementing BPEL 2.0, messages and events can be defined in business processes in the visual design tool in NetBeans.
- Process execution: The defined BPEL processes can be then combined with other components such as Web services and EJB to be deployed on GlassFish, the open source JavaEE application server. The application server integrates a BPEL runtime engine to execute processes.
- System assembling and integration: Open ESB allows you to integrate Web services and enterprise applications as loosely coupled composite applications, realizing the benefits of an SOA.

However, the Open ESB platform doesn't support the features of business goal modeling, business goal evaluation, links between goals and processes, KPI modeling, and KPI evaluation and monitoring. It also does not provide a process simulation feature, although it is open source and its architecture, by adopting SOA, enables a good extendibility. However, it doesn't directly provide information to help data modeling and process redesign.

3.3.2 Comparison

Table 1 compares the major leading and challenging BPMS products in the industry. The results of the comparison indicate that almost all the BPMS products implemented business process modeling through different modeling languages and notations. Most of those products cover KPI definitions and evaluation, although to different degrees. The process simulation and execution too are covered by most of them to fulfill the BPM life cycle. The results also conclude that most of these BPMS products don't cover business goal modeling, goal evaluation and links between business goals and processes. The Tibco iProcess suite allows users to specify goals for processes and trace the processes against the goals. However, since its process modeling is based on BPMN, the Tibco suite doesn't provide an integrated goal architecture and cannot define links among goal hierarchies, process hierarchies and performance models. It also lacks a goal-oriented evaluation strategy. For these reasons, the Tibco BPMS still cannot be called a goal-oriented solution.

Secondly, the KPI monitoring in all those products is relatively simplistic and don't include a strategy to support building the data models for retrieving KPI values. Only IBM has the full data warehouse support for complete performance management.

After description and discussion of the method, implementation and case study, the URN based approach in this thesis will be compared with these BPMS products in section 7.1.

Table 1: A comparison of the leading BPMS products in the industry

Part I						
	Business process modeling	**Business goal modeling**	**Business goal evaluation**	**Links between goals and processes**	**KPI modeling**	**KPI evaluation/ monitoring**
IBM WebSphere process integration products	√	×	×	×	–	√
Intalio BPMS	√	×	×	×	×	×
Appian Enterprise BPM Suite	√	×	×	×	–	–
G360 Enterprise BPM Suite	√	×	×	×	–	–
Tibco iProcess Suite	√	–	×	–	–	–
EMC BPM Suite	√	×	×	×	–	–
Pegasystems SmartBPM Suite	√	×	×	×	–	–
Lombardi Teamworks BPMS	√	×	×	×	–	–
Savvion BusinessManager Platform	√	×	×	×	–	–
FileNet BP Manager	√	×	×	×	–	–
Fujitsu Interstage BPM Suite	√	×	×	×	–	–
BEA AquaLogic BPM Suite (Fuego)	√	×	×	×	–	–
webMethods Fabric BP integration platform	√	×	×	×	–	–
SeeWhy real time BI platform	×	×	×	×	–	–
JBoss jBPM	√	×	×	×	×	×
SUN JavaEE Open ESB platform	√	×	×	×	×	×
Part II						
	Business events handling	**Process simulation**	**Process execution**	**Contribution to data modeling**	**Contribution to process redesign**	**System assembling and integration**
IBM WebSphere process integration products	–	√	√	–	–	√
Intalio BPMS	–	×	√	×	×	–
Appian Enterprise BPM Suite	–	√	√	×	–	–
G360 Enterprise BPM Suite	–	√	√	×	–	–
Tibco iProcess Suite	–	√	√	×	–	–
EMC BPM Suite	–	√	√	×	×	–
Pegasystems SmartBPM Suite	–	√	√	×	–	–
Lombardi Teamworks BPMS	–	√	√	×	–	–
Savvion BusinessManager Platform	–	√	√	×	–	–
FileNet BP Manager	–	√	√	×	–	–
Fujitsu Interstage BPM Suite	–	√	√	×	–	–
BEA AquaLogic BPM Suite (Fuego)	–	√	√	×	–	–
webMethods Fabric BP integration platform	–	×	√	×	–	–
SeeWhy real time BI platform	–	–	×	×	×	–
JBoss jBPM	–	×	√	×	×	–
SUN JavaEE Open ESB platform	–	×	√	×	×	–

√: Supported
–: Partial supported
×: Not supported

Covered: ▒
Uncovered: □

3.4. CHAPTER SUMMARY

This chapter discussed the methodologies adopted in business process management, including Six Sigma, TQM and BPR. It also illustrated the strength of URN in business process and goal modeling. The comparison among the BPMS products which have leading or challenging positions in the industry gives a clear idea of the current situation and the strong need for the goal-oriented solution.

More details about the URN based solution and the implementation as well as some case studies will be illustrated in the following chapters.

Chapter 4 Toward Goal-Oriented Business Process Monitoring

This chapter introduces the approach of goal-oriented business process monitoring. The conceptual view of the methodology, the steps of the methodology, the key concepts of KPI model and KPI evaluation strategy, and the method combining BI technology and Web services will be presented in the following sections.

4.1. AN APPROACH TO A GOAL-ORIENTED MONITORING TOOL

Since the goal-oriented business process monitoring tool aims to align business goals and business processes, it requires a mechanism to trace business goals to find linked business processes and drill into details, and on the other hand to investigate what contribution and satisfaction level a business process is making toward its goals. This capability is important since it enables business analysts to not only locate problems, but also know where the causes of the problems may have arisen.

For this purpose, the following requirements should be satisfied in this approach:

(1) *Business processes and goals should be linked together and the links be usable effectively;*

(2) *The monitoring process needs to be continuous, and it needs to flexibly adapt to changes in definitions of KPIs.*

(3) *The reports/data generated from the monitoring process should be available to each of goal, KPI and process modeling so that goals, KPIs and processes can be aligned and improved in an iterative and tri-directional manner;*

(4) *Moreover, the monitoring results should be able to provide information for business process redesign and performance improvement.*

The methodology of this approach was first introduced in a previous publication (Pourshahid, Chen, et al. 2007) and later improved in a paper (Pourshahid, et al. 2008. (accepted, to appear)) and a thesis (A. Pourshahid 2007. (in progress)).

The following sections discuss the methodology implemented in this thesis.

4.2. OVERVIEW OF THE METHODOLOGY

4.2.1 Conceptual view

The methodology of this approach is based on quality and process-focused business improvement approaches, including Six Sigma, Total Quality Management (TQM) and Business Process Re-engineering (BPR) (Vonderheide-Liem and Pate 2004)(Chang 2006), which have been discussed in section 3.1. Figure 11 shows the conceptual view of the methodology, in which business processes and business goals are effectively linked through business process monitoring and evaluation and thus both can affect each other and be improved in the bidirectional iteration.

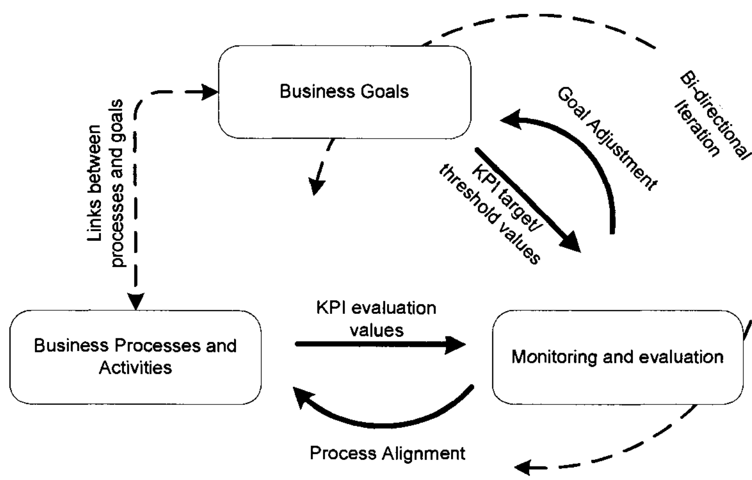

Figure 11: A conceptual view of the goal-oriented business process monitoring methodology

There are two improvement cycles in this iterative process. On the one hand, business processes and activities provide operational data for performance analysis and evaluation. The evaluation results can be then organized and customized to provide valid information specifically for business process redesign and optimization. On the other hand, business decision makers set target and threshold values for business goals and the information will then be used in evaluating the status of performance indicators. The evaluation results reflect to which degree the specific goals are satisfied by the linked business processes. Thus this information can help decide whether it is time to revise and adjust business goals to keep the business growing appropriately. This adoption of this methodology demonstrates that the main motivation of business process monitoring is not only business process improvement but also business goal improvement.

To achieve this objective, the KPI model, which is one of the key concepts in this approach, is integrated to work with the business process model and goal model to enable quantitative evaluation of the efficiency and effectiveness of business processes.

4.2.2 Steps of the methodology

Based on the conceptual design of the methodology, Figure 12 depicts the detailed steps of the methodology constructed to complete the business process improvement iteration.

The first step, which is fundamental to the whole process, is to build business process models and business goal models. As discussed in section 3.2, the nature of URN makes it an excellent notation for business process modeling, in which UCM can perform process modeling and GRL can depict goal models. UCM enables users to model not only dispersed and sole functional use cases but also present the business process as whole. GRL, on the other hand, enables users to build whole multi-level goal hierarchies with contributions assigned among intentional elements. URN links between UCM and GRL enhance the ability to trace the links between processes and goals and thus can be used to link KPI model evaluation to related business processes. Due to these features, URN is adopted to do business process and goal modeling in the implementation of this approach.

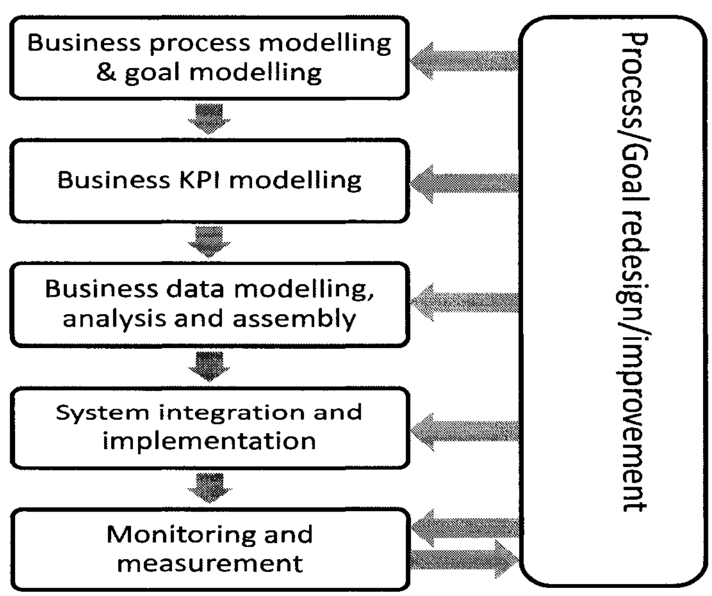

Figure 12: The steps of the methodology

After modeling business processes and goals, a KPI model will be built to be the performance model between the process model and the goal model. In this approach, the KPI model is integrated with the GRL model and connected to UCM maps through URN links. KPI evaluation strategies are developed to set contexts for evaluation of KPI values, and thus to meet the different evaluation needs and to answer various performance related questions. Then, the evaluated KPI values will contribute to the linked parent tasks or goals in the GRL model and propagate through the GRL links until the highest level goals. Since intentional elements are linked to processes or process elements (roles or responsibilities), KPIs are then connected to corresponding processes to show their performance. Users can either trace the KPIs or goals which have performance issues to determine which processes contribute to the results, or choose a particular process or activity to see what KPIs are defined on it and what the performance in a specific context is. The details of the KPI model will be depicted in the following section 4.3.

After the KPI model is ready, in order to do KPI evaluation, KPI values under different strategies should be retrieved from the back-end data sources. The data sources could be various types, such as BI tools, a data warehouse, an operational database, or even flat files. The KPI definitions and the context information defined in strategies can be provided to build the data model and generate KPI values. Since BI tools provide business users easy access to business data (Moss and Atre 2003, 4), they can act as a bridge between business data and business performance information to generate KPI values efficiently and effectively.

After all required tools and components, such as the business process monitoring tool with the business models, the data warehouse and the BI tools, are ready, it is the time to assemble and integrate them to co-operate and work on the process as whole. This step usually requires detailed engineering and technical work due to the diversity of systems and heterogeneous infrastructures that are involved in the execution of end-to-end processes (Küng, et al. 2005). Therefore, due to its advantages in enhancing communication between different technologies and platforms in a dynamic environment, SOA becomes a useful architecture to meet the requirements of this approach, in which Web services can be designed to accept requests from the process monitoring tool, communicate with BI services to retrieve KPI evaluation values, and then send the values back to the monitoring tool. The SOA design enables the solution to be flexible in handling communications with different business information providers.

Finally, the progress enters into the continuous iteration of business process monitoring and business process redesign and goal improvement. The KPIs are evaluated and the evaluation values are propagated to calculate the satisfaction level of each business goal and to present the performance status of each business process toward achieving its goals. The evaluation information can then be organized and categorized to serve the purpose of business process redesign as well as re-alignment and improvement of goals.

It should be noted that this kind of quality improvement approach is not undertaken lightly and usually leads to some difficulties in practice (Vonderheide-Liem and Pate 2004, xiii). A lot of corporate effort, executive commitment and corporate will are required for the successful implementation of this approach (Teubner, Leaver and Barnett 2007).

4.3. INTEGRATING KPI MODELS WITH URN

4.3.1 KPI model design

The KPI model is a key concept in this approach as it works with the goal model and process model to fill the gap between them. Figure 13 depicts the KPI model integrated with URN to evaluate business goals by monitoring business processes.

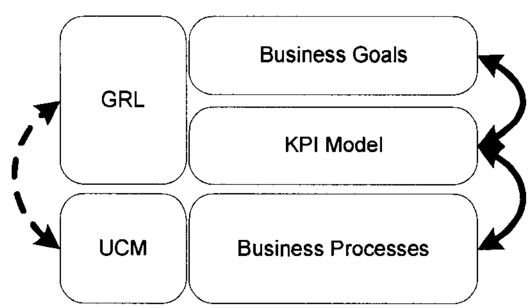

Figure 13: KPI model with GRL and UCM

The KPI model is designed to be an extension of the GRL model to contribute to the connected tasks in the goal model. Through the contribution links between the KPI and goal models, the evaluation value of KPIs initialize the evaluation level of intentional elements of the goal model at the lowest level and propagate to the highest level of goals. Various degrees of impact, such as some positive, some negative, help, make, hurt and break, can be assigned to the contribution links to define how KPI evaluation results affect satisfaction of goals as well as how lower level goals contribute to the higher level goals.

A KPI model is defined by two kinds of elements: key performance indicators (KPIs) and KPI information elements.

KPIs are the main objects in a business performance model that enables business users to specify the performance management aspects of business processes against business goals (Wahli, et al. 2007, 192). From this definition, KPIs are based on business goals on the one side and associated with business processes on the other side. Also, the KPIs defined in a KPI model should be able to draw conclusions regarding the effectiveness and efficiency of business processes (Kronz 2006, 3). Since KPIs are the detailed specifications required to trace business goals, they should be "quantifiable, measurable and results-oriented" (Wahli, et al. 2007, 193). KPIs are quantifiable measures so usually they are numeric based and should not be expressed in a vaguely, like "some" and "most". "Measurable" requires that the KPIs can be measured from the data of business process activities. Usually, metrics, which are unit measurements of a process or a process activity, are used to calculate KPIs. KPIs are results-oriented since the performance of a KPI is evaluated based on the measurement results retrieved from back-end business information providers and by comparing it with the target and threshold values set on that KPI.

The design of KPI is quite flexible for users. They can define any kind of KPI that may contribute to the evaluation of goal models, such as average, maximum, trend, duration, etc. Multiple KPIs can have different contributions to their goals or tasks. This is implemented by setting the contribution weightings on the contribution links. Figure 14 shows an example of defining multiple KPIs for one task.

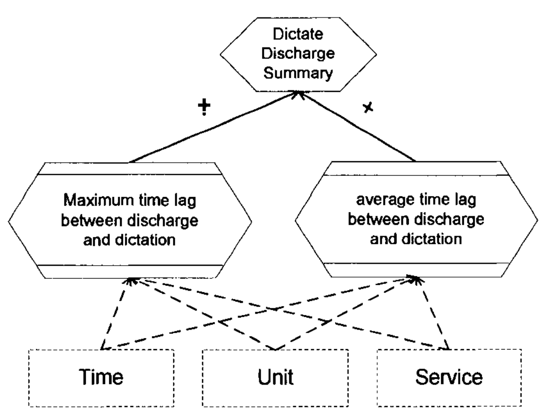

Figure 14: A KPI model with multiple KPIs defined for one task

KPI information elements, on the other hand, setup contexts for KPIs by adapting categories and architectures on raw data to select instances for KPI reporting and analysis (Wahli, et al. 2007, 194). In the approach used in this thesis, dimensions are used as information elements to convert data to business information that can be later used to generate KPI evaluation values.

Figure 15 shows the KPI model evaluation process. Evaluation context information of the KPI, including the linked process and dimensions, can be provided to business information providers for the building of data models and generation of KPI reports. Next, the KPI values generated in the reports will be retrieved and transferred to the KPI model. Then, through the contribution links and the links between goals and processes, the satisfaction levels of goals and the performance status of the processes can be calculated and presented to users.

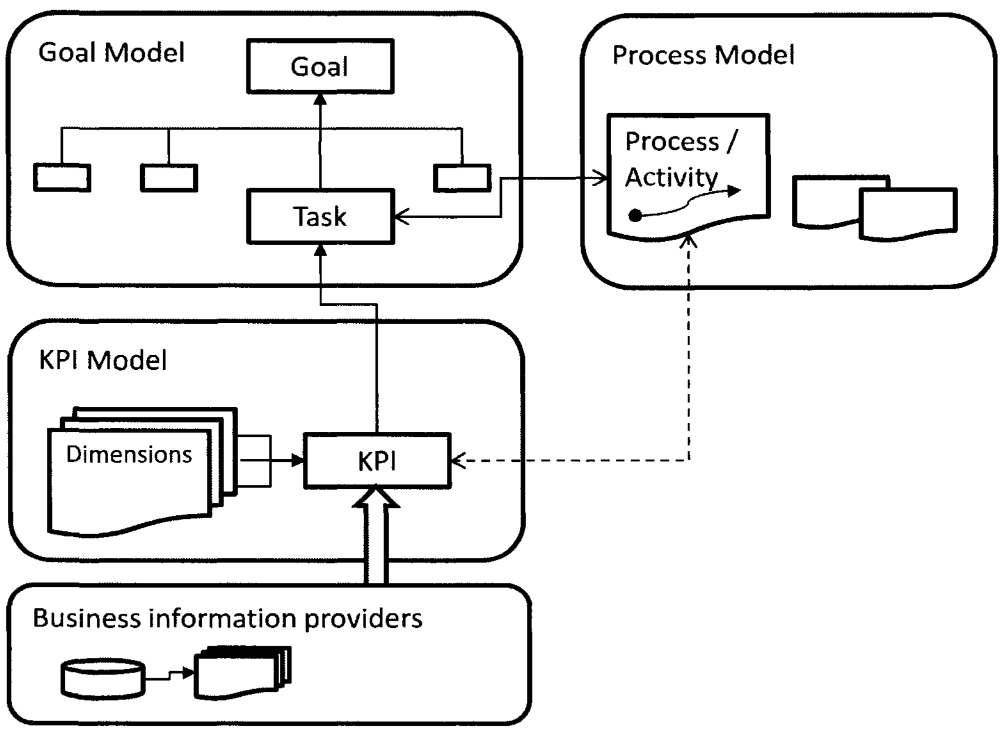

Figure 15: The KPI model evaluation process

4.3.2 Consideration of business process redesign

According to the research into process design and redesign in (Reijers 2005, 209), performance indicators can be placed into four main performance dimensions: time, cost, quality and flexibility, along which the effects of redesign can be measured. The conceptual framework of these four dimensions is called the devil's quadrangle (Reijers 2005, 210) and is shown in Figure 16.

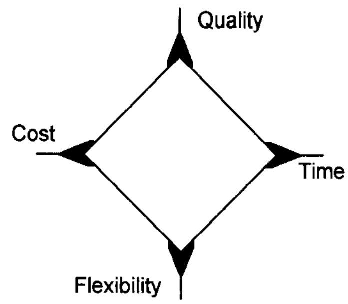

Figure 16: The devil's quadrangle

Thus, KPIs are categorized in the four dimensions and one KPI can be dropped into one or multiple dimensions. For example, the KPI "average time lag between discharge and dictation" can be specified as the time and quality related issue, the KPI "total cost of labour per product" is a cost indicator, and the KPIs "proportion of transferred patients to different locations" can be kind of flexibility issue.

The KPIs' evaluation results can provide evidence for choosing redesign patterns by prioritizing performance aspects of the business processes to be improved. This thesis organizes the impacts of the redesign patterns on the four performance dimensions (see Table 2), which are well analyzed in (Reijers 2003) and (Reijers 2005).

Table 2: The impacts of the redesign patterns on the four performance dimensions

Redesign Patterns	**Time**	**Cost**	**Quality**	**Flexibility**
Task Patterns				
Task Elimination	↑	↑	⇣	N/A
Task Composition	↑	N/A	⇡	⇣
Task Automation	↑	↑	↑	↓
Routing Patterns				
Re-sequencing	↑	↑	N/A	N/A
Knockout	⇣	↑	N/A	⇣
Control Relocation	N/A	N/A	↑	N/A
Parallelism	↑	⇣	⇣	⇣
Triage	↑	↑	↑	↓
Allocation Patterns				
Case Manager	N/A	⇣	↑	N/A
Case Assignment	↑	N/A	↑	↓
Customer Teams	↑	N/A	↑	↓
Flexible Assignment	↑	N/A	↑	N/A
Resource Centralization	⇡	↓	N/A	↑
Split Responsibilities	⇣	N/A	↑	N/A

Redesign Patterns	**Time**	**Cost**	**Quality**	**Flexibility**
Resource Patterns				
Numerical Involvement	↑	⇡	⇣	N/A
Extra Resource	↑	↓	N/A	⇡
Specialist-Generalist	↑	⇣	↑	↓
Generalist-Specialist	N/A	⇡	N/A	↑
Empower	⇡	⇡	⇣	N/A
External Party Patterns				
Integration	↑	↑	N/A	⇣
Outsourcing	N/A	↑	⇣	N/A
Interfacing	⇡	⇡	⇡	⇣
Contact Reduction	⇡	⇣	⇡	N/A
Buffering	↑	⇣	N/A	N/A
Trusted Party	↑	↑	N/A	N/A
Integral Business Process Patterns				
Case Types	⇡	⇡	⇣	⇣
Technology	⇡	⇡	⇡	⇡
Exception	↑	⇣	N/A	⇣
Case-based Work	↑	⇡	N/A	N/A

↑ : Positive Impact ↓: Negative Impact
⇡: May positive ⇣: May negative Impact

It should be noted that choosing redesign patterns only gives a general idea as to the redesign solution, however more study into how those patterns can be applied and specific business knowledge and experience are also essential for a successful business process redesign approach.

4.3.3 KPI evaluation

Figure 15 also demonstrates that a KPI model extends the GRL evaluation strategy to propagate the KPIs' impacts on intentional elements in the goal model. However, the evaluation of the KPI model itself needs more work done on it, including setting KPI target and threshold values and setting levels of details on dimensions. For this purpose, KPI strategy is defined to setup context information for KPI evaluation.

For each KPI strategy, specific properties are specified for the KPIs and KPI information elements. With the KPIs, the following properties are defined:

- *The target value* is the quantifiable goal of performance setting on the business processes.
- *The threshold value* is used to set a threshold line for warnings. Any value between the threshold value and the target value is acceptable and indicates a healthy situation.
- *The worst value* is the bottom line, the most serious condition that can be expected. Any value between the worst value and the threshold value is treated as unhealthy and unacceptable, and in that case, a warning should be given that action is required to handle the problem.
- *The unit* is the basic unit of a quantifiable KPI and used to describe the unit of the number.

A KPI's target value, threshold value and worst value should be reviewed and thus may be changed during the BPM life cycle according to the evaluation results so as to fit with certain business statuses and needs and hence keep the business growing.

On KPI information elements, the following strategy properties are defined:

- *The level of detail* points out the level in a dimension so that the specific information in this level will be extracted and aggregated.
- *The value* is the chosen object on the selected level in the dimension. The KPI value will be extracted and aggregated on the selected level and the selected object.

After KPI strategies are defined in the KPI model, the strategy information can be provided to business information providers to build a data model and generate corresponding KPI values. Then, when the monitoring tool asks for evaluation values of KPIs meeting some specific strategy, the strategy information can be used to match the values in the business information providers.

GRL strategies use an evaluation level, expressed as a percentage value from -100 to +100, to measure the satisfaction status of a goal or a task (Amyot 2003, 5). To contribute to the goal model, the evaluation value of a KPI should be compared with its target value, threshold value and worst value to calculate its evaluation level for propagation. For this purpose, as Figure 17, shows, the target value is mapped to +100, the worst value is mapped to -100 and the threshold value is mapped to 0. Then, KPI values can be transformed to GRL evaluation levels by using particular algorithms. The way to characterize KPIs in this thesis is not a standard but typical way used among BPMS products. However, the GRL evaluation level values can be translated to other methods and presented with different points of view, such as the "traffic lights" used in Cognos tools.

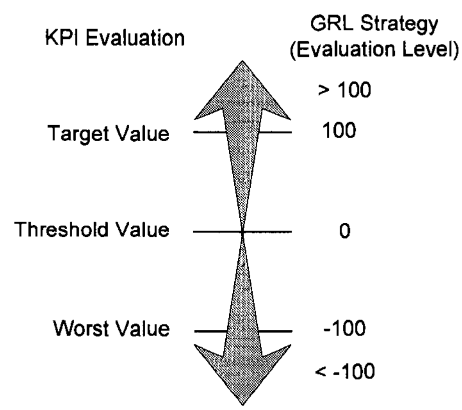

Figure 17: The mapping between KPI evaluation and GRL evaluation level

4.4. CHAPTER SUMMARY

This chapter explained the concepts and methodology used in the approach of the goal-oriented business process monitoring. URN is used as the basis of process and goal modeling, while the KPI model, as an extension of GRL, contains KPIs and dimension elements used for KPI evaluation. UCM, GRL and KPIs are linked together to evaluate the performance of business processes toward achieving business goals.

The following chapter explains the implementation of a whole business process monitoring system that adopts the methodology introduced in this chapter.

Chapter 5 Implementation of Goal-Oriented Business Process Monitoring

This chapter first gives an overview of the implementation of the goal-oriented business process monitoring system. Then, section 5.2 illustrates the architecture of the system. After the architecture is clarified, the implementation of the three main components of the monitoring system will be depicted in the next three sections. Finally, the last section discusses the integration of the whole system.

5.1. OVERVIEW

Since the goal-oriented business process monitoring system consists of three main components: the business process monitoring tool, the business information provider and the monitoring services, the implementation of the system includes three corresponding development parts integrated together in a service oriented architecture.

The business process monitoring tool developed is based on jUCMNav, which is an Eclipse-based open source URN modeling tool. A KPI model is integrated as part of a GRL graph with URN links connected to UCM maps and elements. KPI strategy is implemented as an extension of GRL strategy and the propagation algorithm in GRL is also used to calculate the impacts of KPIs on the connected intentional elements. Several specific strategy properties are defined for the KPIs and dimension elements to set up the context for KPI evaluation. There are two KPI related views implemented: the KPI list view, which is used to show and manage KPIs in a tree view, and the KPI view, which shows the KPIs' evaluation status on selected intentional elements, GRL graphs, UCM maps and elements.

In this implementation, Cognos 8 BI is used as the business information provider to build data models and generate KPI reports for KPI evaluation under the various contexts since it is now the most used tool in BI market. Data models are designed and built in the Cognos Framework Manager according to the KPI information provided by KPI models from the monitoring tool side. Then KPI reports which will be executed in the run time for generating

KPI values are designed and built in Cognos Report Studio according to the KPI strategy information defined for the KPI models.

Next, the monitoring tool and the business information providers are combined through the monitoring Web services. The monitoring Web services receive requests from the monitoring tool, communicate with the Cognos services to retrieve KPI values and send final results to the monitoring tool. In this implementation, the monitoring services are developed on the latest JavaEE platform and deployed on the open source version of the JavaEE application server GlassFish.

Finally, the components and modules are integrated together to form the business process monitoring system as whole.

5.2. SYSTEM ARCHITECTURE

The system architecture of the goal-oriented business process monitoring system consists of three main components: the business process monitoring tool, the business information providers and the monitoring services; illustrated in Figure 18.

The business process monitoring tool, which implements the modeling and evaluation process throughout UCM, GRL and KPI depicted in Figure 15, is a URN based tool with integrated UCM, GRL and KPI modules. The KPI module, which includes the KPI modeling and KPI evaluation functionalities, requests KPI values from the monitoring services and then evaluates goal models in GRL as well as the linked process models in UCM.

The monitoring services layer, where information from the miscellaneous business information providers is extracted, formatted and organized, offers an agile and adaptable interface to facilitate the monitoring tool's generation of KPI values. The monitoring services can be provided through Web services, remote method invocation (RMI), external plug-ins, or other possible service providers.

There are miscellaneous business information providers including operational databases, data warehouses, BI servers, and other business applications, such as the online system corresponding to business process execution, e.g. BPEL engine for fully automated online business processes, ERPs, CRMs and SCMs, or even XML files and flat files, which provide data for the evaluation process illustrated in Figure 15. Multiple information providers can coexist in the same system and provide information from different sources and perspectives for KPI evaluation. Those information providers should have some mechanism designed, such as a query interface, service gateway, downloadable files etc., so the monitoring services work with them to retrieve required information.

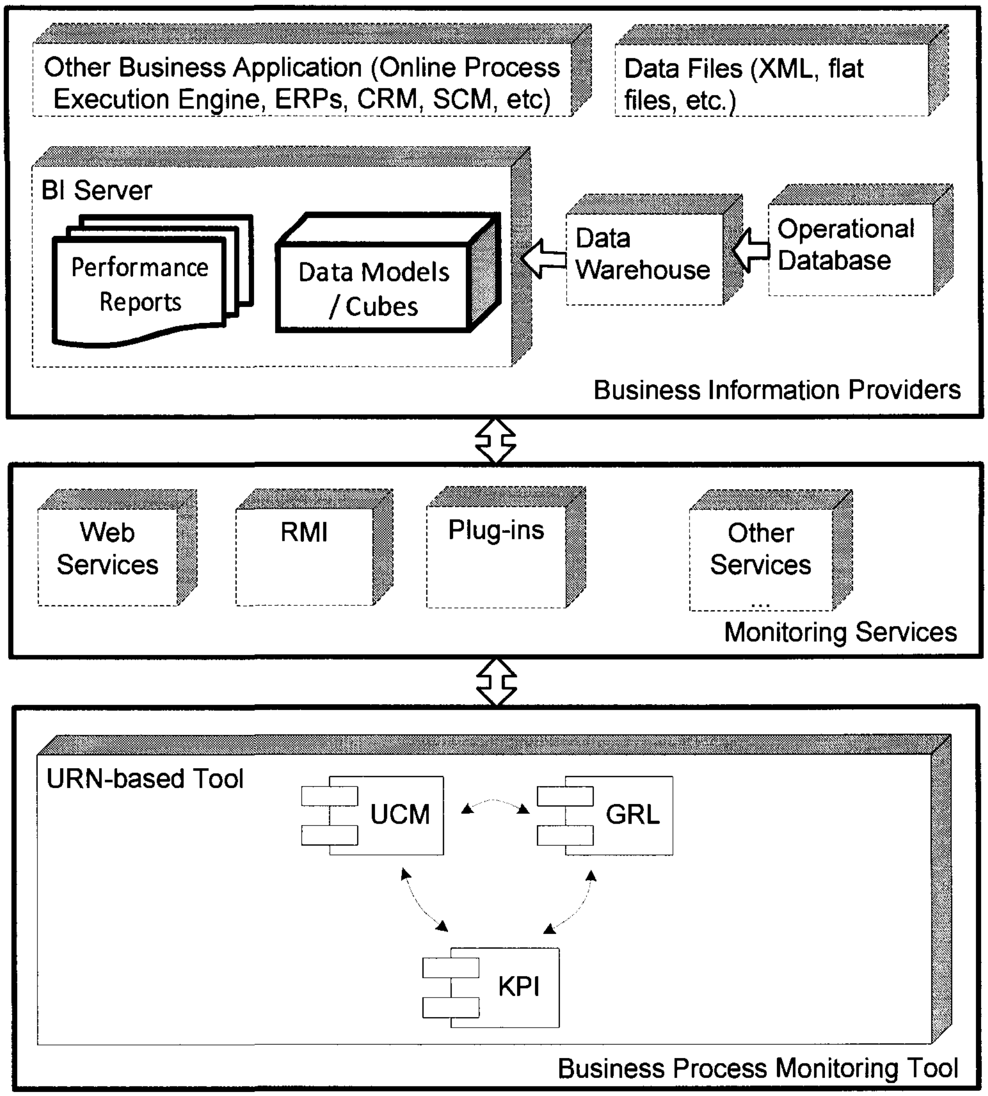

Figure 18: Architecture of the goal-oriented business process monitoring system

5.3. BUSINESS PROCESS MONITORING TOOL

5.3.1 Overview

The business process monitoring tool implemented is based on jUCMNav, which is an open source URN modeling tool introduced in the section 2.1.4. jUCMNav is an Eclipse plug-in that is used to build URN models, including GRL and UCM models. It also includes a scenario traversal mechanism which highlights traversed paths in UCM diagrams, and a GRL strategy mechanism to analyze GRL models using a set of user-defined evaluations (Roy, Kealey and Amyot 2006, 10).

Figure 19 illustrates the relationships among the components of the monitoring tool (the highlighted parts are new KPI components proposed in this approach, while the white parts are existing components adopted by this implementation). The implementation of jUCMNav is based on the Eclipse Modeling Framework (EMF) and Graphical Editing Framework (GEF). EMF, which is a "modeling framework and code generation facility for building tools and other applications based on a structured data model" (Eclipse.org 2007a), can import Rational Rose class models and generate model code from the UML models. By using GEF the model code generated can be used to create a rich graphical editor (Eclipse.org 2007b). In implementing this approach, the KPI meta-models were defined based on the original URN meta-model and then the model code was regenerated through EMF. The functionalities of KPI modeling and evaluation are developed based on the generated model code with the facilitation of GEF.

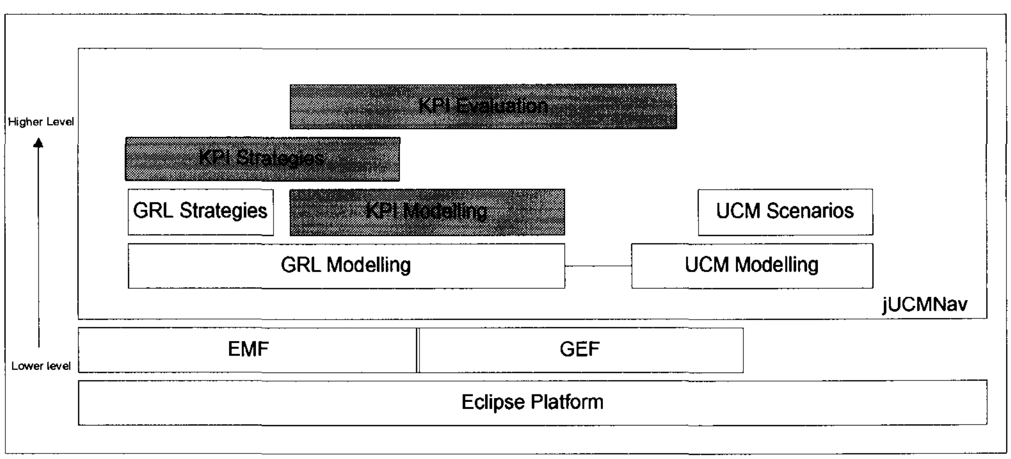

Figure 19: The monitoring tool component relationships

In the original version of jUCMNav, when triggering GRL strategies, the initial values of evaluation on GRL models are set manually without proper justification. As an extension of functionalities in jUCMNav, KPI modeling is implemented to define KPIs linked to GRL models to help monitor how well business processes contribute to their business goals by retrieving KPI values from BI tools. KPI strategies, which are an extension of GRL strategies, define sets of evaluation settings on KPIs and dimension elements to give contexts for KPI evaluation. The KPI evaluation module sends requests with the KPI strategy settings to the monitoring services and gets the KPI values back.

In addition, a KPI list view and a KPI view are implemented to provide users visual views for the purposes of managing KPIs and presenting the performance of KPIs defined on goals and processes.

5.3.2 Design of the KPI metamodel

(1) KPI modeling

KPI model elements are designed as an extension of GRL in URN since KPIs should be involved in GRL evaluation strategies. First of all, a specific package named KPIModel is added into the URN meta-model to contain all KPI model elements, KPI model links and KPI strategy elements, as shown in Figure 20, Figure 21 and Figure 22. Within these class diagrams, the white components are original URN elements while the highlighted components are new added KPI model elements.

As depicted in Figure 20, "Indicator" is defined as a special type of intentional element in GRL intended to represent KPIs in KPI models, thus KPIs can be involved in GRL strategies to evaluate other kinds of intentional elements, usually tasks, in goal models. Indicators can be assigned to multiple Indicator Groups, which include the four default performance dimensions used in process redesign, i.e. cost, time, quality and flexibility. However, users can add any customized groups to categorize and distinguish their KPIs for any other purposes.

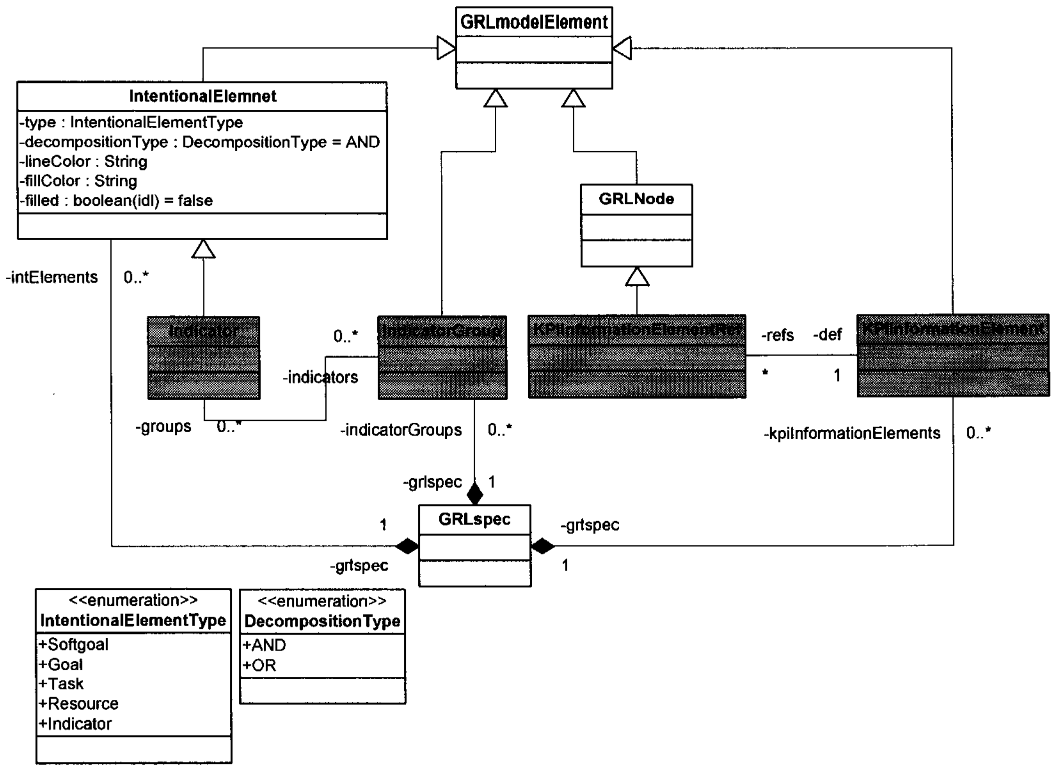

Figure 20: KPI model elements

KPIInformationElements, as illustrated in Figure 21, are connected to Indicators through KPIModelLinks to specify in what perspectives users want to evaluate the KPIs. In this implementation, Dimension is the default KPI information element used as data categories to organize and select instances for KPI evaluation. There is a restriction upon the KPI model links, as they can only connect KPI information elements to indicators. Since KPIs, KPI information elements and KPI model links could be reused in multiple diagrams and thus multiple instances could exist at the same time and share a same definition, their reference classes including IntentionalElementRef, KPIInformationElementRef and KPIModelLinkRef are defined in Figure 20 and Figure 21 to represent instances of those element definitions.

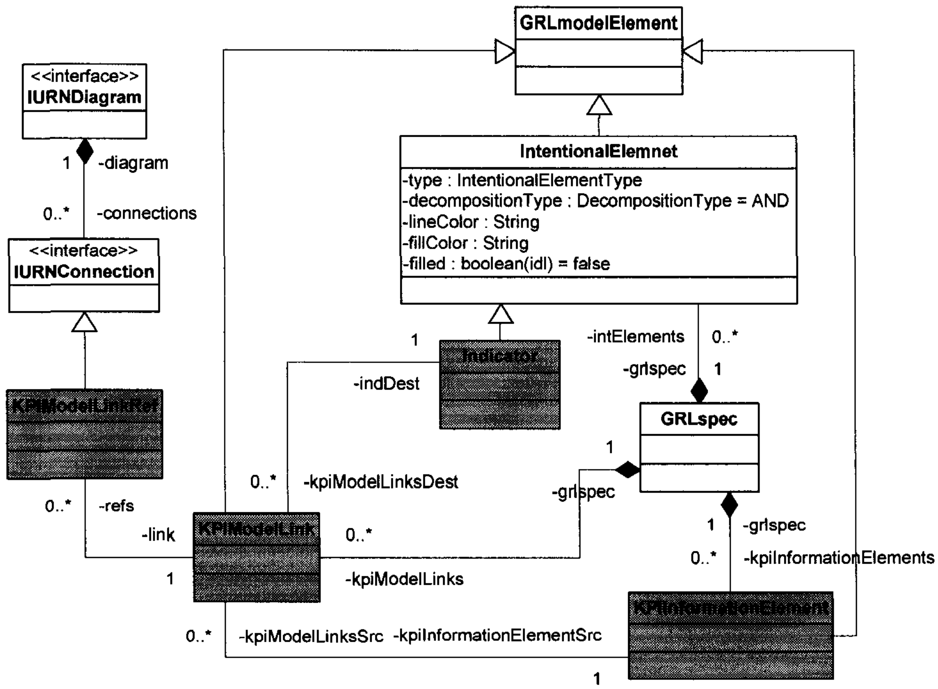

Figure 21: KPI model links

(2) KPI evaluation

As shown in Figure 22, the KPI evaluation strategy model is designed as an extension of GRL strategy. Specific strategy information is defined for Indicators and KPIInformationElements. For Indicator, since it is a special type of intentional element, there is already an evaluation defined for it under each strategy. Thus, by associating a KPIEvalValueSet class, which contains the target value, the threshold value, the worst value, the evaluation value and the unit of the indicator, to the evaluation, each indicator can have a set of specific KPI evaluation values defined under each strategy. The KPIInformationElement, on the other hand, needs its own evaluation class, i.e. KPIInformationConfig, to contain a set of specific dimension settings including the level of dimension and the value of dimension under each strategy. The dimension settings include the level of dimension, which specifies the category of data in the dimension hierarchy, and the value of dimension, which specifies the exact value of that level of details. The dimension settings define a specific context for KPI evaluation and the setting information will be used to build data models and KPI reports on the BI server, in addition to being transferred as parameters of the KPI value requests to the monitoring services for the retrieval of specific KPI values under a particular strategy.

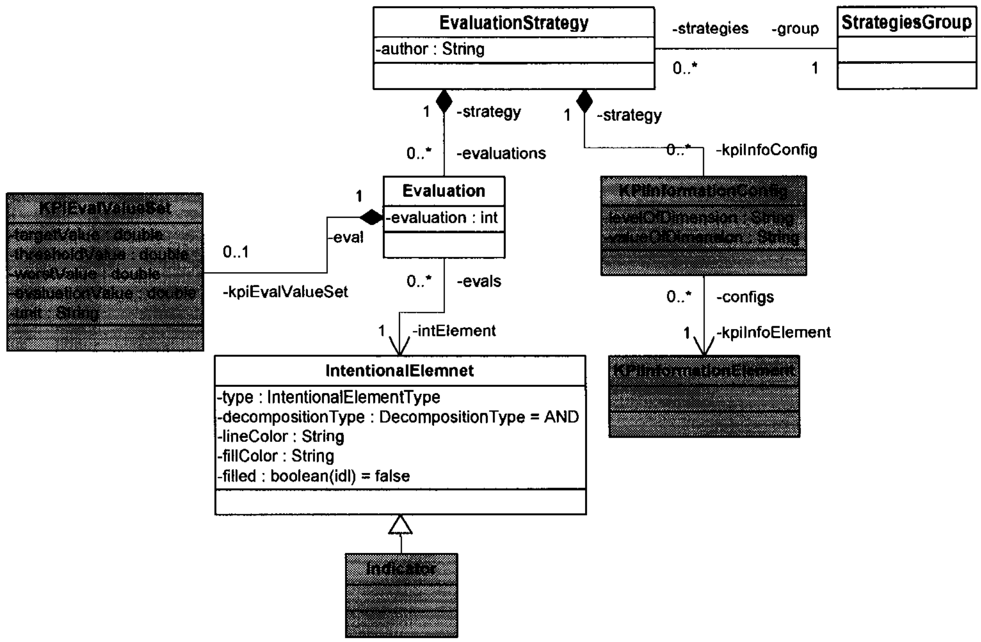

Figure 22: KPI strategy

5.3.3 Implementation

As introduced in sections 2.1.4 and 5.3.1, the monitoring tool is developed based on the open source URN modeling tool: jUCMNav which adopts EMF and GEF frameworks to generate code and build the tool. After the KPI meta-models are created, they are ready to be imported through EMF to generate the model code. Figure 23 demonstrates the KPI model elements and links imported from the KPI class models defined in Rational Rose.

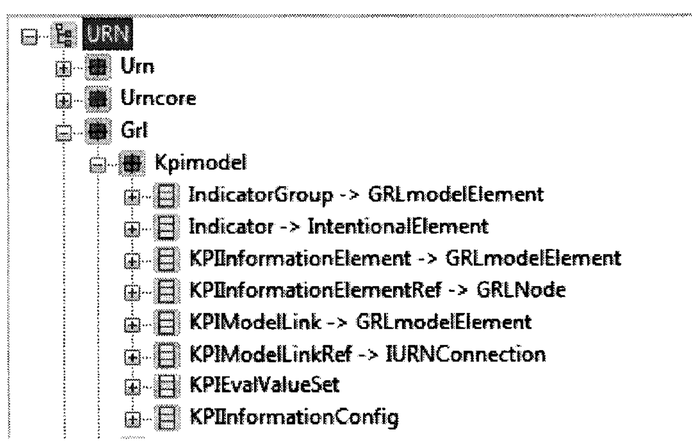

Figure 23: The imported KPI model

In the KPI modeling section, facilitated by GEF, a KPI palette is created on the GRL editor so users can create KPIs, and dimension elements as well as the KPI model links. Figure 24 shows the KPI palette, which includes three elements: Indicator, Dimension and KPI Model Link. Figure 24 also gives an example of a KPI model, which defines a task associated with three KPIs with each of them having some dimensions linked to it.

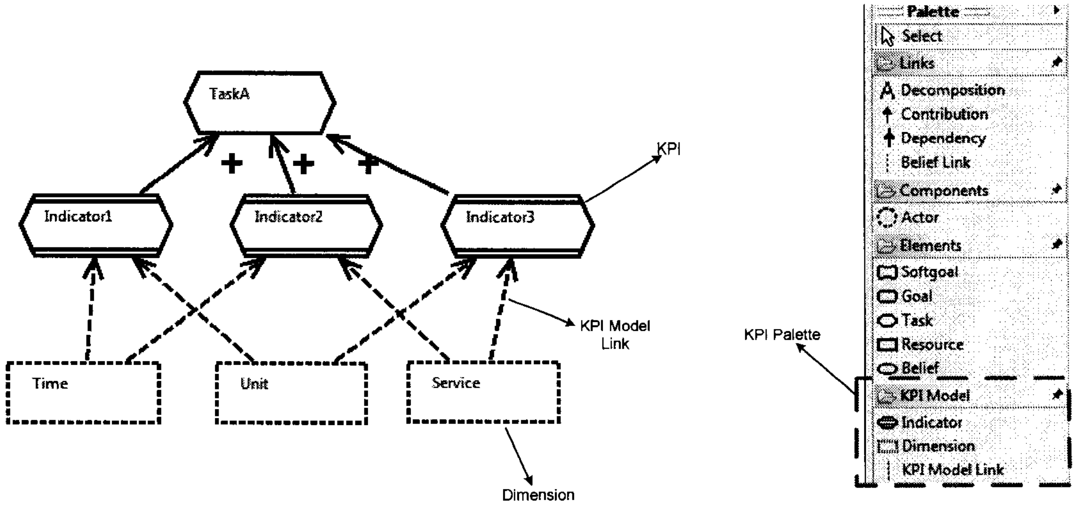

Figure 24: The KPI palette and the sample KPI model

To manage KPIs and KPI groups, a KPI list view, shown in Figure 25, is created to present users an overview of categorized KPIs. Users can also create their own groups in the KPI list view. In the KPI list view, four groups of performance dimensions, i.e. cost, time, quality and flexibility, are created by default.

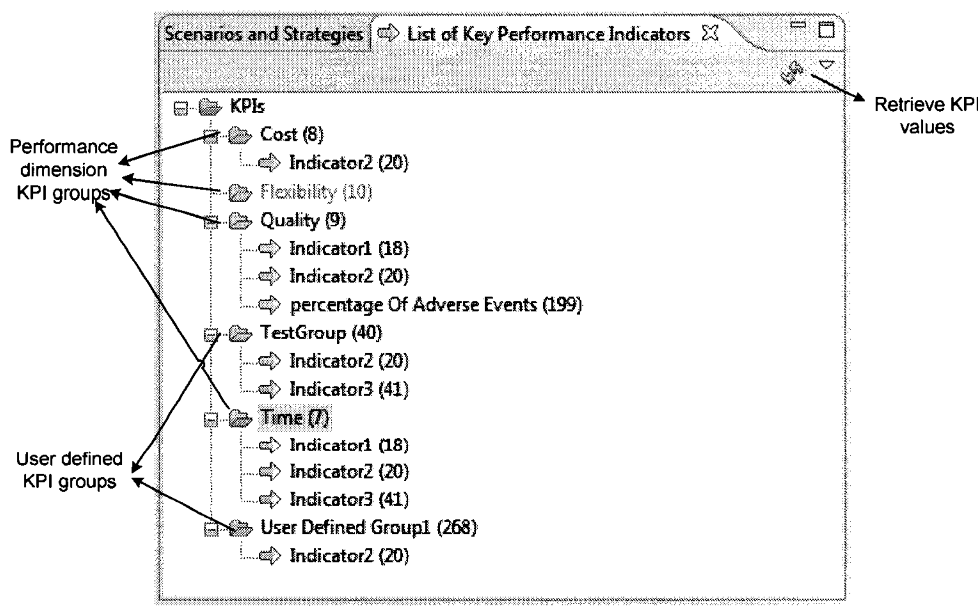

Figure 25: The KPI list view

To assign or remove KPI groups on a selected KPI, users can open the pop-up dialog window shown in Figure 26, from the KPI's context menu either through the KPI list view or the GRL editor.

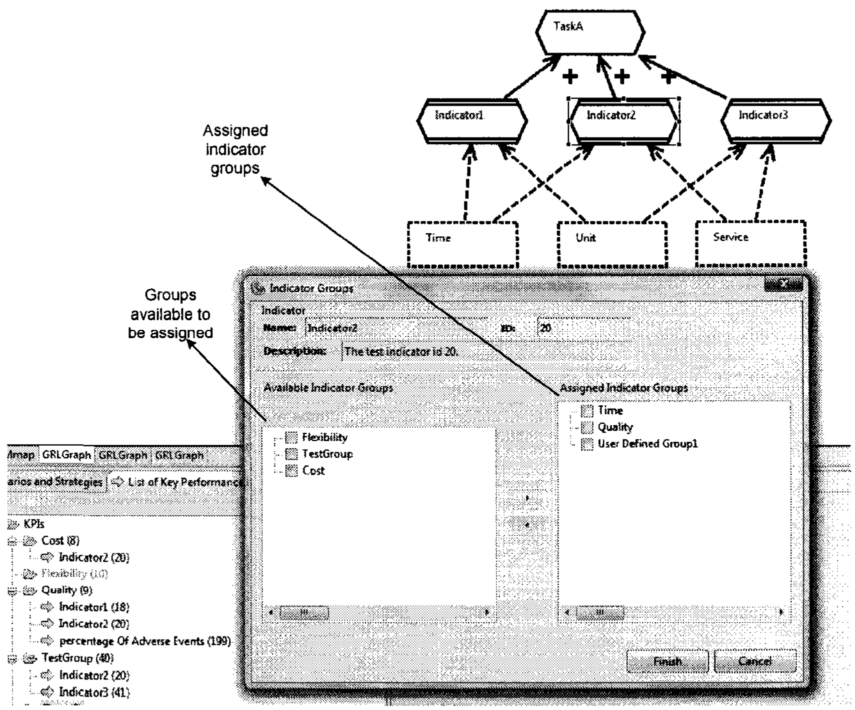

Figure 26: Assigning or removing KPI groups on a selected KPI

In the KPI evaluation section, shown in Figure 27, in the *Tool Properties* view, each evaluation strategy can define for each indicator the target value, the threshold value, the worst value, the evaluation value and the unit of the indicator, and also define the level and value of dimension for each KPI information element.

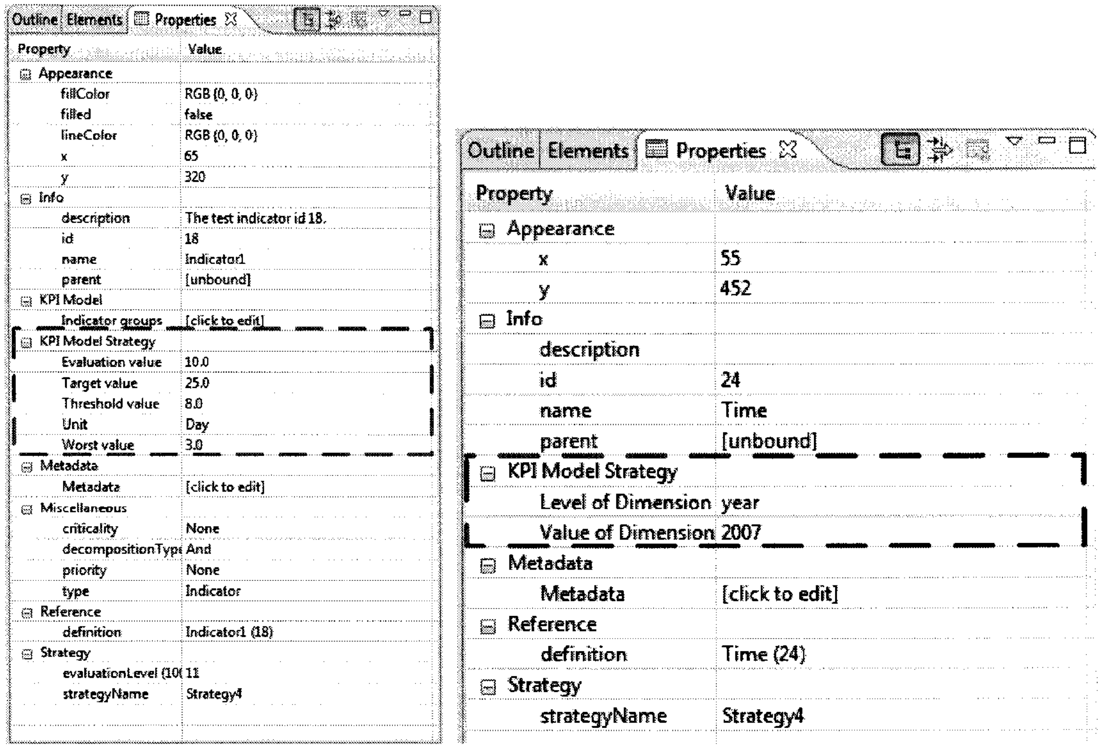

Figure 27: The KPI strategy attributes of Indicators (left) and KPI Information Elements (right)

KPI strategies are managed the same way as the normal GRL evaluation strategies in the GRL strategy view in jUCMNav. (See Figure 28 below).

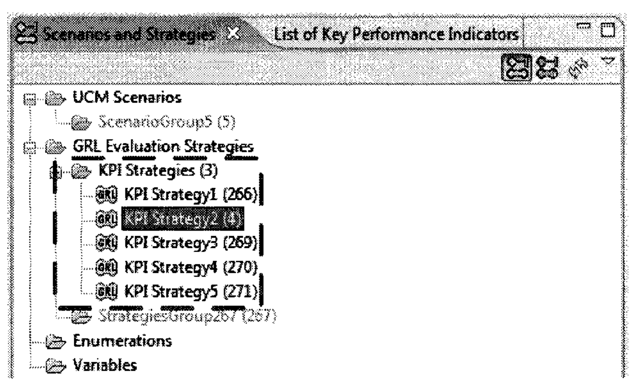

Figure 28: KPI strategies in the GRL strategy view

After KPI models are defined and KPI strategies are created, KPI values then can be retrieved through the monitoring services by clicking on the menu button "Retrieve KPI values", shown in Figure 25. The KPI evaluation module includes an interface defined for requesting KPI values so that the interface can be implemented in different ways to obtain KPI values. In this implementation, a Web services client serves as the interface to facilitate the communication with the external monitoring services. To connect to the monitoring services, the URL of the monitoring services is set in jUCMNav's KPI monitoring preferences page in the Eclipse tool, as shown in Figure 29.

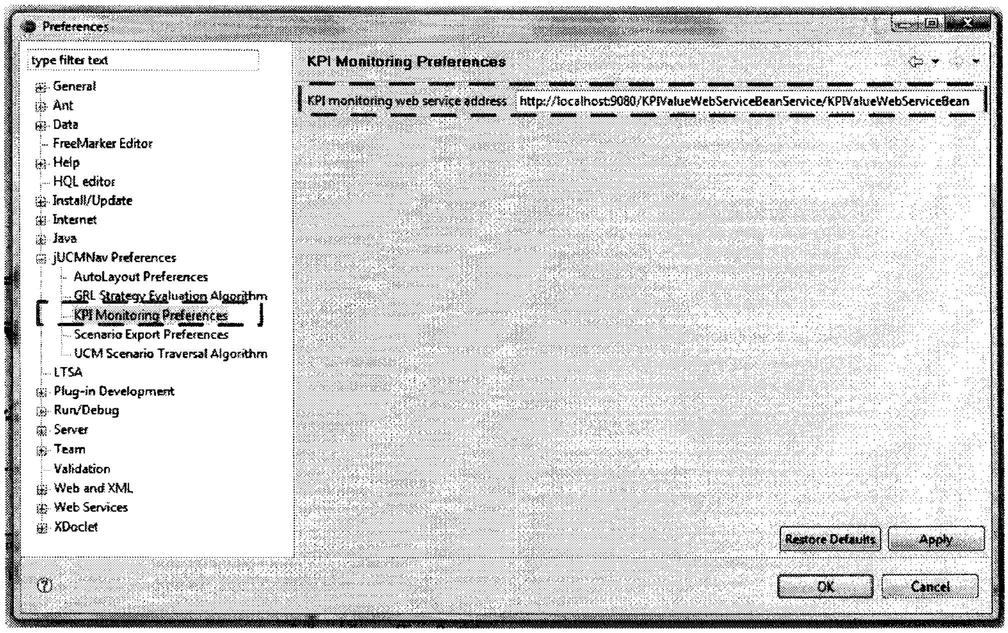

Figure 29: The KPI monitoring preferences page

After the KPI values are retrieved and applied to each KPI in each strategy, the KPIs' evaluation values can be transformed to GRL evaluation levels according to the algorithm defined in Table 3 and are then used for propagation to generate evaluation levels on higher level goals at the time when users trigger any evaluation strategy.

Table 3: The algorithm for transforming KPI values to GRL evaluation levels

Conditions		Evaluation Level
target value < worst value	**evaluation value ≤ target value**	+100
	evaluation value ≥ worst value	-100
	target value < evaluation value ≤ threshold value	$\left(\frac{\textit{threshold value} - \textit{evaluation value}}{\textit{threshold value} - \textit{target value}}\right) \times 100$
	threshold value < evaluation value < worst value	$\left(\frac{\textit{evaluation value} - \textit{threshold value}}{\textit{worst value} - \textit{threshold value}}\right) \times -100$
target value ≥ worst value	**evaluation value ≥ target value**	+100
	evaluation value ≤ worst value	-100
	threshold value ≤ evaluation value < target value	$\left(\frac{\textit{evaluation value} - \textit{threshold value}}{\textit{target value} - \textit{threshold value}}\right) \times 100$
	worst value < evaluation value < threshold value	$\left(\frac{\textit{threshold value} - \textit{evaluation value}}{\textit{threshold value} - \textit{worst value}}\right) \times -100$

After a specific evaluation strategy is triggered, the KPI evaluation status is shown in the KPI list view as icons with different colors, in which the red-down arrow means poor performance, the green-up arrow means acceptable or satisfied performance and the yellow arrow means the performance just meets the threshold value. The KPI view is designed to present the details of

KPI evaluation status visually so that when a user selects any GRL/UCM element or map that has KPIs defined or linked either directly or indirectly, the KPIs' evaluation status will be displayed in the KPI view to present a general performance view of that process or goal. In the design of this implementation, the URN editors, the GRL strategy view, the KPI list view and the KPI view are synchronized to present an overview of process and goal evaluation from different perspectives. Figure 30 shows the KPI list view and the KPI view in the triggered evaluation mode.

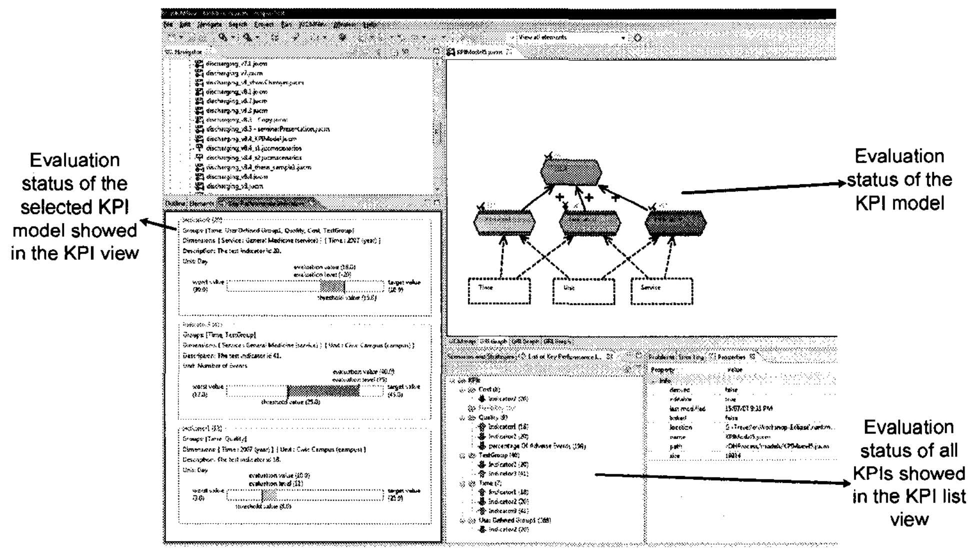

Figure 30: KPI evaluation views

Business processes and goals can be linked by URN links, thus KPIs defined for goal models can also be linked to processes. In this case, when users trigger a strategy and choose a process element, the linked KPIs are shown in the KPI view and the satisfaction level of the connected goal element will be displayed on the target process element. Figure 31 shows the evaluation status of a selected process which has been linked to its goal models through URN.

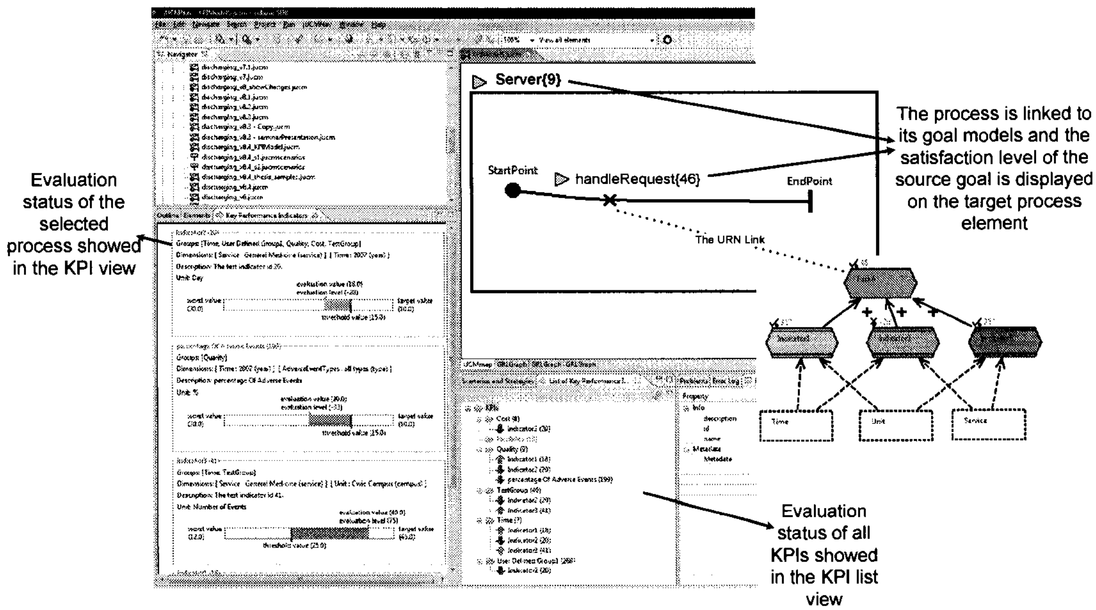

Figure 31: The evaluation status of a selected process

A detailed KPI evaluation status figure is shown in Figure 32, in which the KPI information, such as its name and the description, the groups and the evaluated tasks are presented to users, along with the strategy information, such as the dimensions, the unit, the target, threshold, worst and evaluation values.

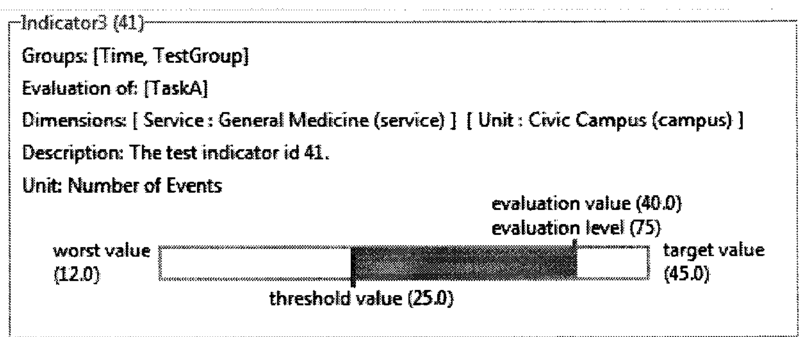

Figure 32: A KPI evaluation status figure

5.4. BUSINESS PROCESS INFORMATION PROVIDERS

5.4.1 Overview

As shown in Figure 18, business process information providers are responsible for providing KPI values by analyzing business data from either operational databases or data warehouses. Cognos 8 BI, which is a comprehensive business intelligence tool, is used as the business information provider in this implementation. As discussed in the section 2.3, by providing business performance information which can be used to generate KPI values, BI tools serve efficiently and effectively.

There are two steps to generating KPI values by using the BI tools. First, it is necessary to build data models based on the definition information from KPI models. The following information can be provided to build data models:

- The business process evaluated by a KPI and the measurement of the KPI can be used to define the facts in the fact table of the data model, since a fact table consists of the measurements, metrics or facts associated with the target business process (Adamson 2006, 10).
- The dimensions that users are interested in evaluating on this KPI state what dimension tables should be used in the data model and what dimensions should be associated with the fact table.

In the next step, after data models are built, KPI reports, which generate KPI values in the run time, will be created in the BI tools to be ready for execution. The levels of detail and the values set on dimensions under each KPI strategy give the specific context information to build KPI reports for each KPI strategy.

Figure 33 presents the architecture of KPI data modeling using Cognos BI tools. The Cognos 8 BI framework manager can be used to build the data models from a data warehouse or databases. In the Cognos 8 BI framework manager, we first need to create data marts based on the existing data source, either the operational databases or the data warehouse, and these data marts are then used to build OLAP cubes. Next, Cognos 8 BI report studio is used to create KPI reports based on the OLAP cubes built in the framework manager. The KPI reports will be organized in such a way that the monitoring services can easily follow the path of a KPI report according to the KPI and strategy information.

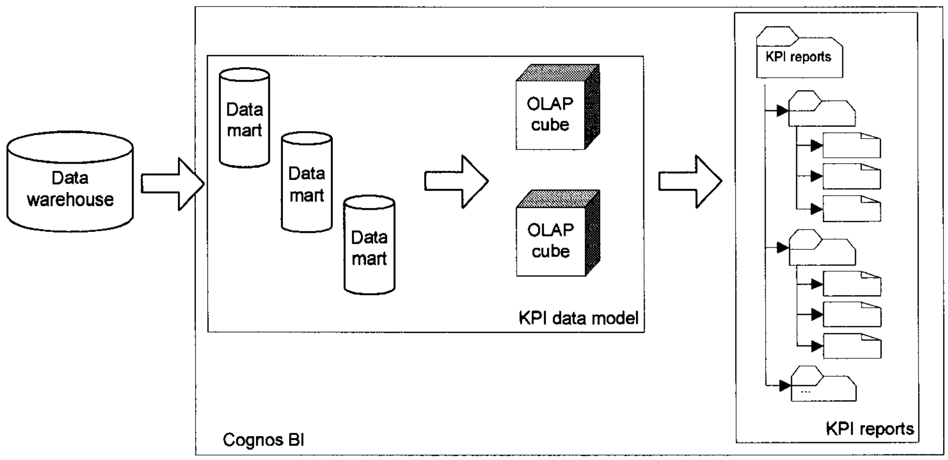

Figure 33: The architecture of KPI data modeling

5.4.2 Building data models

(1) Building data marts

The first step for building data models is to build data marts for KPI models. It is not necessary to have one data mart for each KPI since some KPIs may share the same fact but have different grains on the fact or may need to be evaluated from different dimensions.

A data mart schema, usually a star schema, consists of a fact table, which contains the foreign keys of dimensions and the facts associated with a process, and dimension tables, which contain groups of dimensions that provide all contexts for facts (Adamson 2006, 7-10). Thus, to design a data mart, the following questions need to be answered: 1). what dimensions should be used in this data mart; 2). what process is associated with the facts; 3). what the grain of the data mart schema should be; and 4). what facts should be included in the fact table.

The information from KPI models can help answer those questions and build the data marts. Table 4 depicts the mappings between the data mart designs and the KPI model information.

Table 4: The mappings between KPI model information and data mart designs

Data mart designs	Information in KPI model
Dimensions	The dimensions connected to KPIs
The associated process	The tasks and processes linked to KPIs
Grain of the data mart schema	The lowest level of detail in all strategies defined on all related KPIs; Or, the lowest possible level of detail
Facts	The essential metrics used to calculate all related KPIs

Some information in KPI models can be directly used in the data mart designs, as the dimensions connected to the KPIs are usually the necessary dimensions to be defined in the data mart. Other kinds of information, however, can support data mart modelers in making decisions. The tasks and process linked to the KPIs can be used to find the proper level of process that can cover all facts and thus is a suitable process to be associated with the data mart schema. To find out the grain of the data mart schema, it is first necessary to find all KPIs associated with this data mart and then compare all strategy settings on each dimension to find the lowest level of detail of each dimension. It should be noted that the lowest level among those strategy settings gives an idea of the mandatory level that has to be reached but not the necessary level to define the grain, since usually the grain of a data mart schema should record data at the lowest possible level of detail (Adamson 2006, 12). Finally, according to the definitions of KPIs and the knowledge of databases, the data mart modeler needs to determine which metrics can be used to calculate those KPIs and those metrics then can be added as facts into the fact table. Figure 34 shows the typical structure of a data mart star schema used for KPI evaluation.

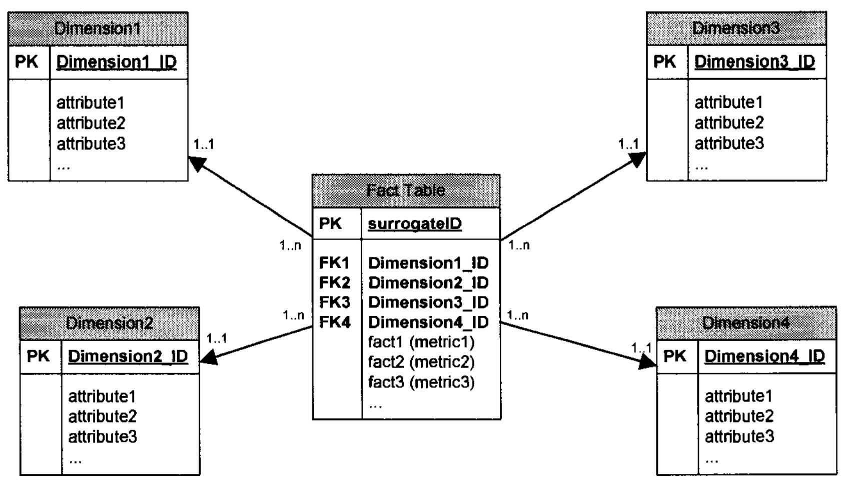

Figure 34: The typical star schema of a data mart used for KPI evaluation

Because business processes are complex and gaps exist between data and business information, human experience and knowledge is still important in building data marts, although the information from KPI models can help make quick and proper decisions.

(2) Building OLAP cubes

In this step, OLAP cube metadata is created from data marts and is typically modeled multi-dimensionally to support further complex analysis and visualization (Chaudhuri and Dayal 1997, 1). An OLAP cube contains dimension tables and a measure dimension table. The dimensions in the OLAP cube are hierarchical and thus provide the ability to drill both up and down through multiple levels. The measure dimension contains a logical collection of facts that evaluate the business performance. Thus, the measures in the measure dimension can actually represent KPIs and the dimensions define the context for those KPIs in the measure dimension.

Table 5 depicts the mappings between the OLAP cube architecture and the KPI model or strategy. Due to its role in business analysis, OLAP cube elements can easily map to KPI model and strategy information and settings. The dimensions in an OLAP cube are the dimensions connected to KPIs and the measurements in a measure dimension can represent KPIs. The dimension strategy settings, i.e. the level of dimension, defined in each strategy, can be used to help design the dimension hierarchies, and even though the strategy information may not cover all levels in that dimension it can provide information about which levels in the dimension hierarchies are necessary for KPI monitoring. Figure 35 shows the typical architecture of an OLAP cube used for KPI evaluation.

Table 5: The mappings between OLAP cube architecture and KPI model/strategy

OLAP cube architecture	KPI model/strategy
Dimensions	The dimensions connected to KPIs
Dimension hierarchies	The strategy settings of dimensions
Measurements in the measure dimension	KPIs

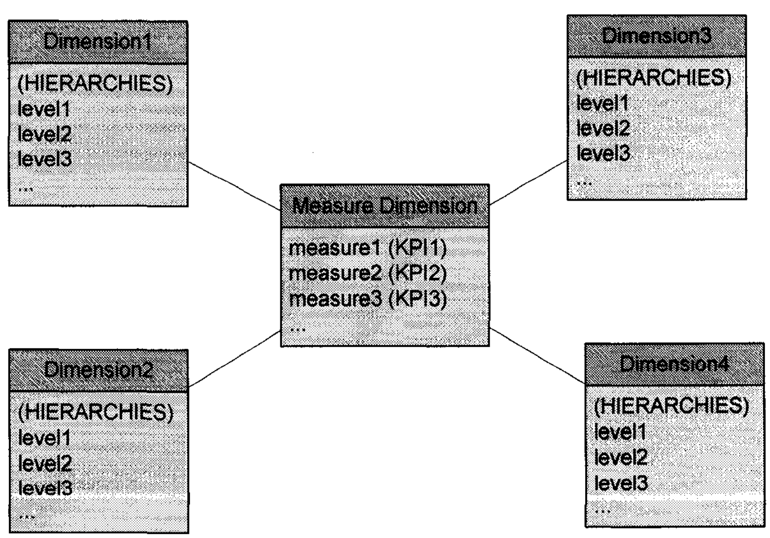

Figure 35: The typical architecture of an OLAP cube used for KPI evaluation

After OLAP cubes are created, they can be used in the next step, the creation of KPI reports.

5.4.3 Creating KPI reports

In this step, KPI reports are created, based on OLAP cubes, to generate KPI values within various contexts, i.e. KPI strategies. In this implementation, Cognos 8 BI report studio is used as the tool to create the KPI reports. The KPI reports will be triggered remotely by the client application through Cognos connections and executed in the Cognos server, and the results are then sent back to the client side to analyze and to obtain KPI values.

KPI reports are designed and organized in such a way that the client side, i.e. the monitoring services, can easily match the paths of the reports, find and execute them and then retrieve the KPI values from the KPI reports. Since each KPI has an evaluation value under each strategy, KPI reports are categorized and named in the tree hierarchies shown in Figure 36.

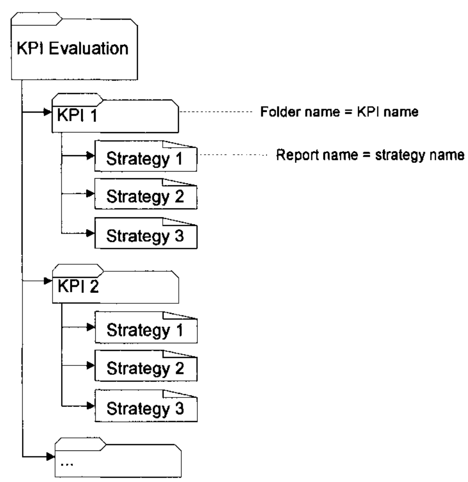

Figure 36: The tree hierarchies of KPI reports

In this design, each KPI has a folder named with the KPI name, each of which is under the "KPI Evaluation" folder. Since each KPI has multiple KPI reports corresponding to KPI strategies and the report names match the strategy names, when a client application looks for a KPI report from the Cognos repository, the complete search path of the KPI report looks like:

"/content/package[@name='kpiPackageName']/folder[@name='kpiFolderName']/folder[@name='kpi Name ']/report[@name=' kpiStrategyName']"

Finally, KPI reports are created based on the OLAP cubes and the context information defined in KPI strategies. For a KPI report, a specific KPI's evaluation value will be the only measure generated in the report.

5.5. BUSINESS PROCESS MONITORING SERVICES

5.5.1 Overview

When both the KPI model and the KPI reports are ready, the monitoring tool and the business information provider need a way to combine and work together. In a loose coupling design, Web services is a suitable technology platform for undertaking this work. As illustrated in Figure 18, the monitoring services take tasks, including accepting requests from the monitoring tool, communicating with BI services to retrieve KPI reports, extracting KPI values from the KPI reports, and matching, packaging and sending KPI values back to the monitoring tool. By adopting a Service Oriented Architecture (SOA), the integration between different BPM components in the architecture shown in Figure 18 will have more flexibility, along with faster development and deployment cycle times, lower cost and greater effectiveness, and are thus an adaptable and scalable solution (Wahli, et al. 2007, 9)(ENIX Consulting 2006, 2). Hence, in this implementation, Web services work with enterprise Java beans (EJBs) to handle the monitoring services in the service oriented architecture.

Figure 37 depicts the architecture and work-flow between the layers in the monitoring services.

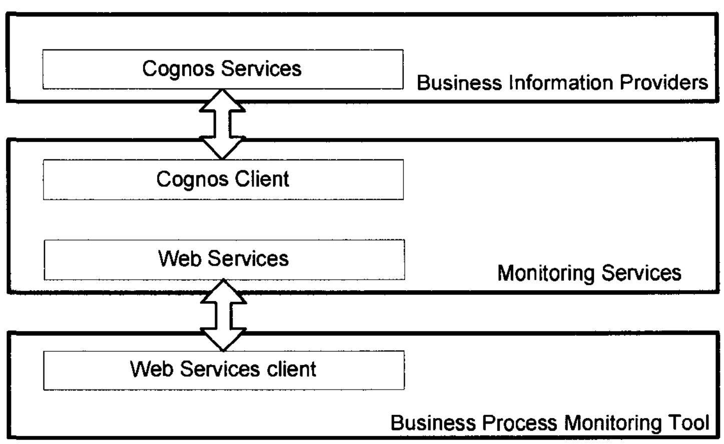

Figure 37: The architecture and work-flow of the monitoring services

In this architecture, the Web services provides a remote interface to receive requests from the monitoring tool and return KPI values to it. Behind the Web services, the enterprise session bean is used to handle real business logic by requesting KPI reports from the Cognos client module, analyzing the returned KPI reports to obtain KPI values, and returning organized KPI values to the Web services. The Cognos client module is responsible for communicating with the back-end Cognos services to execute and retrieve KPI reports, and then return the

KPI reports to the session bean. Finally, the KPI values extracted from the KPI reports are entered into their corresponding KPI entities and returned to the monitoring tool.

5.5.2 Web services, Enterprise Session Bean and Cognos client

The Web services are deployed on the open source version of the JavaEE application server Glassfish. The services provide a web method for the client application to retrieve KPI values by providing information about KPIs and KPI strategies in an array of KPI entities. The web method then invokes the business logic method in the enterprise session bean and returns the results to the client application.

The enterprise session bean is also deployed on the JavaEE application server. It implements the business logic of the monitoring services and provides a local business interface to the Web services. In the business logic method, it first creates the Cognos client, and then invokes the method in the Cognos client to retrieve KPI values. After the KPI values are returned, it puts all KPI values into corresponding KPI entities and returns them to the Web services.

The Cognos client communicates with the Cognos server by using Cognos SDK. It constructs the path of KPI reports, (depicted in section 5.4.3, based on the KPI and KPI strategies information passed from the session bean, finds and executes the KPI reports in the Cognos server and then receives the generated reports back. The generated reports are in XML format so that they can be parsed using XML Document Object Model (XML DOM) to extract KPI values.

5.6. SYSTEM INTEGRATION

Building with the service oriented architecture, the monitoring tool, monitoring services and business information provider are integrated together in a loose coupling. Figure 37 illustrates the interfaces connecting the three system components together that allow the business process monitoring system to work as whole. Instead of let the business process monitoring tool call the Cognos services directly, the communication between the monitoring tool and the monitoring services is through Web services and the communication between the monitoring services and the business information providers is through HTTP services. Accordingly, the business information providers and the monitoring services can be deployed and located in different environments without needs for compliance between them, and the monitoring tool can run on any client machine that has a connection to the Web services.

5.7. CHAPTER SUMMARY

This chapter separately described in detail the implementation of the business process monitoring tool, the monitoring services and the business information providers as well as the integration of the whole system. The implementation combines the URN notation, Eclipse based modeling and graphic editing frameworks, the Web services, and the BI technologies to build the goal-oriented business process monitoring system.

The next chapter presents a case study by applying this goal-oriented business process monitoring approach to the discharge process in the health care industry.

Chapter 6 Case Study

This chapter will review a real world case study in the health-care industry. The goal-oriented business process monitoring approach will be applied to the case study by modeling the processes and goals, creating KPI models, building data models and KPI reports, deploying monitoring services and evaluating the processes and goals.

To begin with, background information of the case study will be introduced in section 6.1. Then, the process and goal models of the discharge process and the KPI models will be presented and described in the following sections, 6.2 and 6.3. Next, sections 6.4 and 6.5 depict how the data model, KPI reports and KPI values are generated through BI tools and the monitoring services. Finally, in the last section, the whole monitoring process and results are presented and discussed.

6.1. BACKGROUND

6.1.1 Performance management in the health care sector

Information technologies have been widely used in the complex sector of health care to help improve efficacy, safety and traceability, which are essential requirements for current health care services (Staccini, et al. 2001, 1). Traceability requires the ability to continuously monitor all health care activities to detect, measure, and prevent adverse events occurring during or after health care delivery and to enable performance management, which is a key issue in the continuous process of delivering high-quality health-care services. However, neither BPM tools nor DW/BI tools are widely used in hospitals. Currently, there are still lots of painful manual, paper-based processes in place trying to do the continuous monitoring that is required. Even though in a few places, KPIs and metrics have already been used in health care systems (Berler, Pavlopoulos and Koutsouris 2005, 1,8), the usage of the KPIs remains at the simple level of using the balanced scorecard (BSC) facilitated by data warehouse and BI technologies. In that usage, KPIs are isolated from the processes and goals, and are not well managed or presented in a whole business view. This case study tries to use the goal-oriented business process monitoring system implemented in this thesis to integrate the health care performance models with the health care processes and goals.

6.1.2 The hospital discharge process

This case study focuses on the discharge process in a Canadian hospital. However, due to the confidentiality and privacy constraints, the name of the hospital cannot be announced in this thesis. The discharge process is a key process in the health care sector, which starts from the time when a patient enters the hospital and ends at the time when the patient is discharged. To cover the whole life cycle of the discharge process the readmission of patients due to post discharge adverse events is also modeled in the discharge process examined for this case study.

6.1.3 Adverse events

It has been found that a substantial number of patients experience adverse events caused by medical care before or during hospitalization, or after hospital discharge (Forster, Clark, et al. 2004, 1). Many systemic problems could contribute to all of the preventable and ameliorable adverse events. However, according to the survey and research of (Forster, Murff, et al. 2003, 5), "poor communication between the hospital caregivers and either the patient or the primary care physician" is the most common reason for 59% of preventable and ameliorable adverse events that occur in the provision of discharge care. Hence, in this case study, we tried to find and monitor possible problems causing poor communication in the discharge process, build KPI models, data models and KPI reports, and then make a performance evaluation against the problems.

6.1.4 Hospital data warehouse

In this case study, a real data schema from the Canadian hospital we worked with is used to build the data warehouse. We simulated the hospital data warehouse and environment by using the real data schema, however, due to the confidentiality and privacy constraints, we generated the simulated data for the research and testing by using the data generator application provided in (Zhan 2007). The simulated data was generated randomly within proper ranges that were validated with the hospital. Although all names and facts appearing in the case studies are fictitious, everything else is the same as it would be if accessing the real hospital data warehouse, i.e. no modifications to the system will be required to connect it to a real data feed.

6.2. DISCHARGE PROCESS MODELING

6.2.1 Overview

The first step is to model the discharge processes and goals by URN in the jUCMNav tool introduced in section 2.1. Since the discharge process is the main process in the hospital it therefore contains many sub processes. Furthermore, because the discharge process contributes to the top goals of the hospital, those top goals too can be broken down into many sub goals at different levels. We tried to build both the process models and goal models in a hierarchical architecture to describe the processes and goals on the different detail levels and enable users to drill both up and down between higher and lower processes and goals in the hierarchy.

6.2.2 Business process modeling

The discharge process starts from the point where patients enter the hospital and ends at the point where patients are fully discharged without further readmission. Table 6 lists all actors identified in the discharge process. They will be involved in the support of the various functionalities in all processes.

Table 6: The teams/agents/actors involved in the discharge process

Main Actors	Sub-actors
Hospital	
	Administration Department
	Emergency Department
	General Medicine
	Waiting Place
External Entities	
	Clinic
	Other Hospitals
	Post-discharge External Entities
	Home Care Services
	Home
Physician	
Patient	

Figure 38 presents an overview of the top level of the discharge process. A patient could either directly enter the emergency department in the hospital, or be referred to the hospital by external entities, such as clinics or other hospitals. Next, in the administration department or the emergency department, it will be decided if the patient should be sent to general medicine as an inpatient. After the patient is discharged from general medicine, they could be sent either directly to the external entities, or to the waiting place to wait for the approval from the external entities. After being discharged from the hospital, if adverse events occur, the patient could go back to the hospital for readmission.

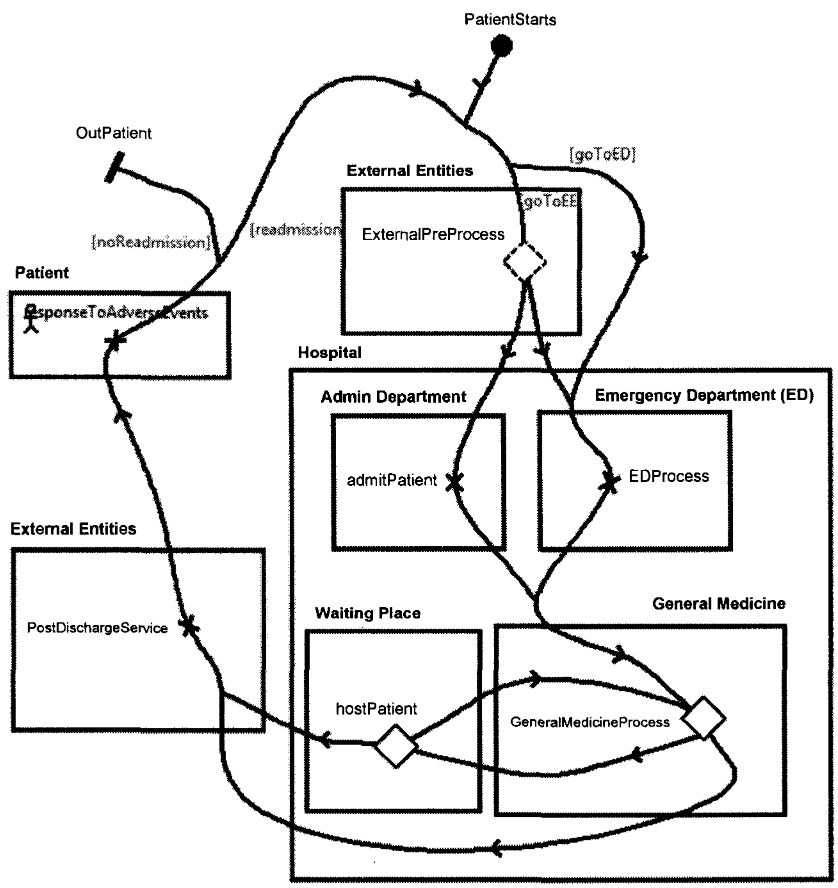

Figure 38: The discharge process

In this case study, we focus on the general medicine process, which contains the main part of the hospital's discharge process. Thus, Figure 39 drills down into the next level of the process, in general medicine. In UCM hierarchy, a sub-map has to include at least inputs and outputs from enclosing map, but it can include more output that may or may not be showed in the enclosing map, e.g. the end points "toNotAdmitted" and "out" in Figure 39 are not showed in its enclosing map Figure 38.

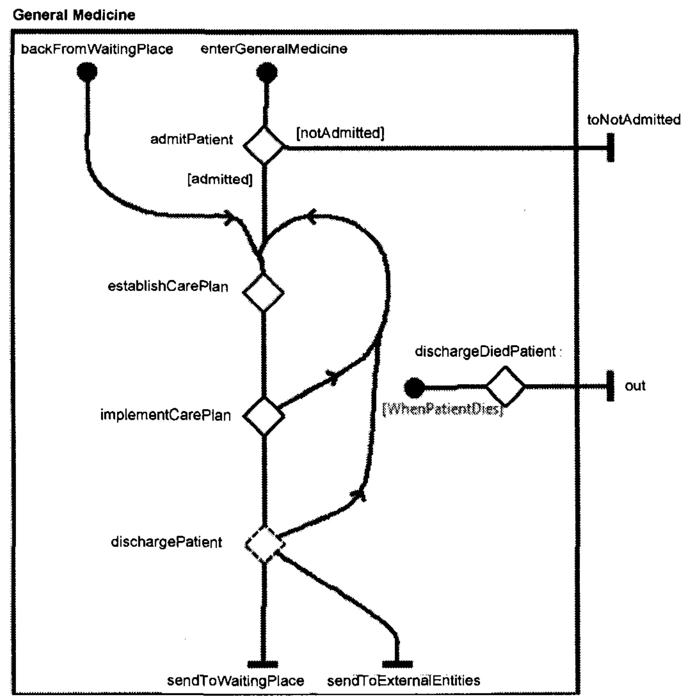

Figure 39: The discharge process in General Medicine

This level of detail, illustrates that after the patient gets admitted to general medicine, a care plan and a discharge plan will be established for them as per the sub-process shown in Figure 40.

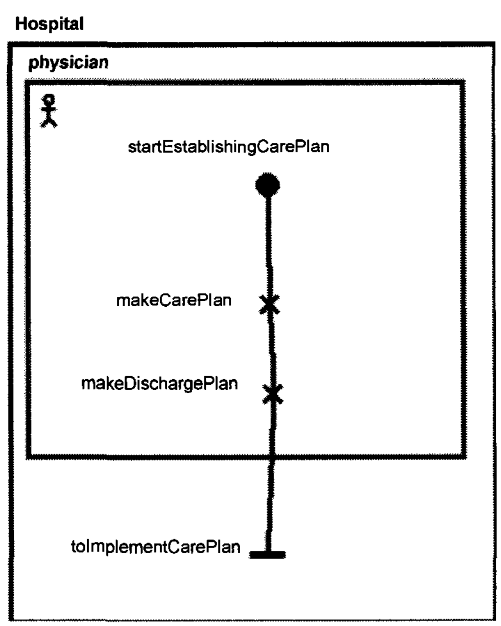

Figure 40: The process of establishing a care plan

The established care plan will then be implemented as per the process shown in Figure 41. In this process, the treatment and test steps will be implemented in a dynamic sequence defined in the care plan. After implementation, the patient's medical condition will be evaluated to decide if the patient can be discharged or whether the original care plan needs to be changed. Then, back to the higher level in Figure 39, there are two exits from the implementation process, one goes back to the establishing a care plan process to change the care plan, and the other goes to the patient discharge process. According to the discharge plan, the patient will be either discharged directly to home with or without home care services, as shown in Figure 42, or discharged to an external entity for post-discharge care, as shown in Figure 43.

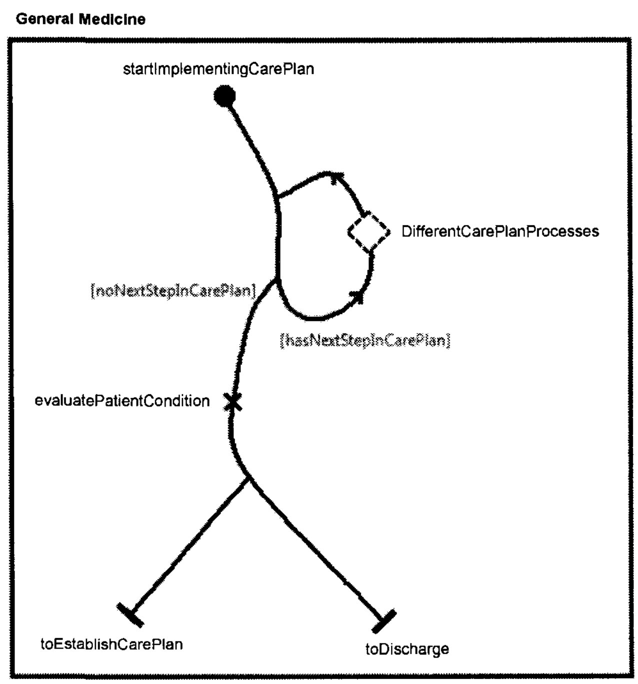

Figure 41: The process of implementing a care plan

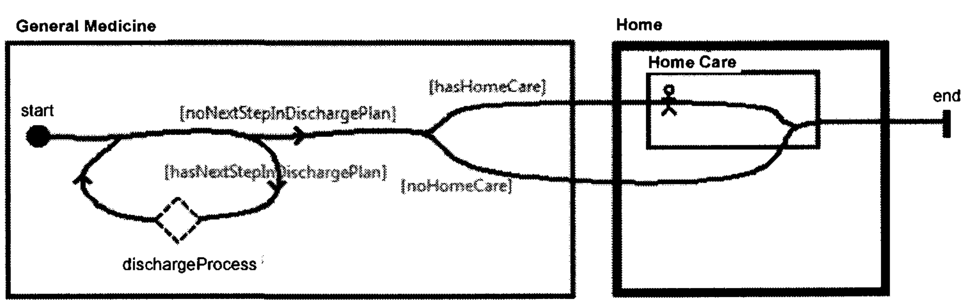

Figure 42: The process of discharging to home

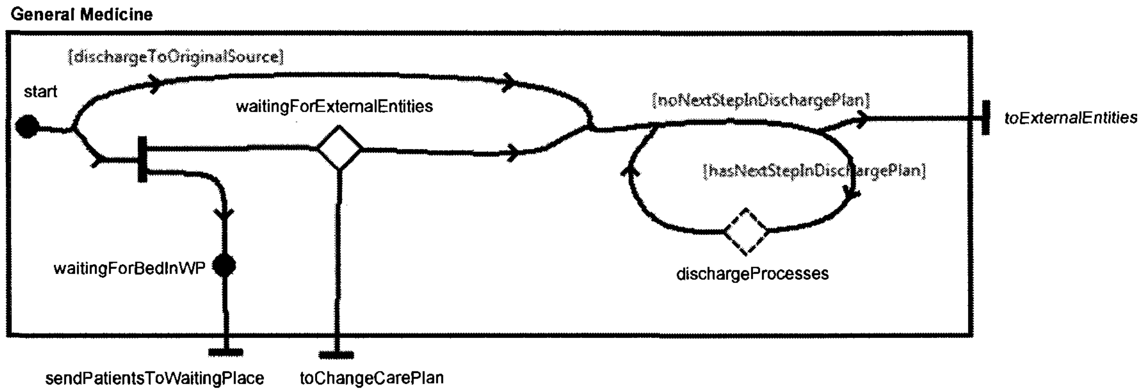

Figure 43: The process of discharging to external entities

In the process of discharging to external entities, there are several conditions to be considered. If the patient entered from an external entity and they are going to be discharged to the same place, no admission approval from that entity is needed and the patient can be discharged directly to the original entity. In another case though, if the patient has to be discharged to an external entity which they did not originally come from, the patient needs to wait for approval and a vacancy from that entity, as shown in Figure 44. At the same time, if there is a vacancy in the waiting place in the hospital, the patient will be sent to there, as shown in Figure 45. If there is no available bed in the waiting place, the patient has to stay in general medicine.

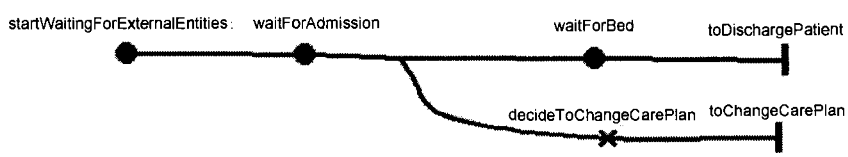

Figure 44: The process of waiting for approval from external entities

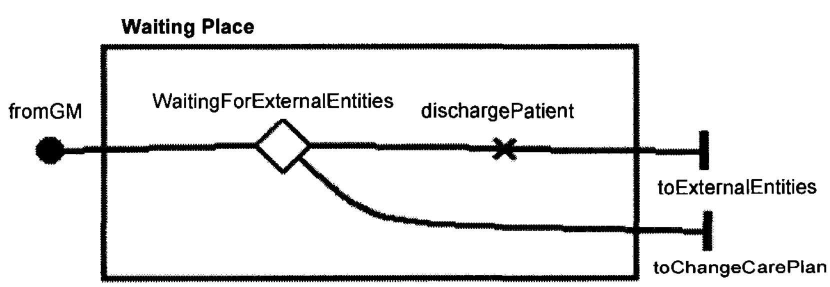

Figure 45: The process of waiting in the waiting place

Next, depending upon the patient's discharge plan, the process goes to handle several discharge procedures including "Educate Patient", "Book Follow-up Visits", "Write Discharge Prescription", "Write Discharge Letter", "Call Care Provider", "Book Follow-up Laboratory

Tests", "Enter Patient Into Follow-up Phone System", "Activate Home Care", "Final Assessment", "Enlist Family Care Giver", "Dictation Process" and "Book Follow-up Radiology Tests".

Finally, returning to the top level process in Figure 38, the patient exits the hospital from either the waiting place or general medicine and goes either to their home or to an external entity for post-discharge care. If adverse events occur, if necessary the patient will be sent back to the hospital for readmission.

6.2.3 Business goal modeling

The discharge process and each of the sub-processes in the hospital should all have their objectives and thus contribute to the hospital's goals on different levels. On the top level, which is displayed in Figure 46, the goal of the discharge process contributes to improving health care outcomes, which is the top goal of the hospital. It can be divided into three sub-goals including "Reducing the Readmission Rate", "Reducing Length of Stay" and "Improving Patient Safety". These three goals can then be reached by "Reducing Post-Discharge Adverse Events" and "Reducing During-Stay Adverse Events".

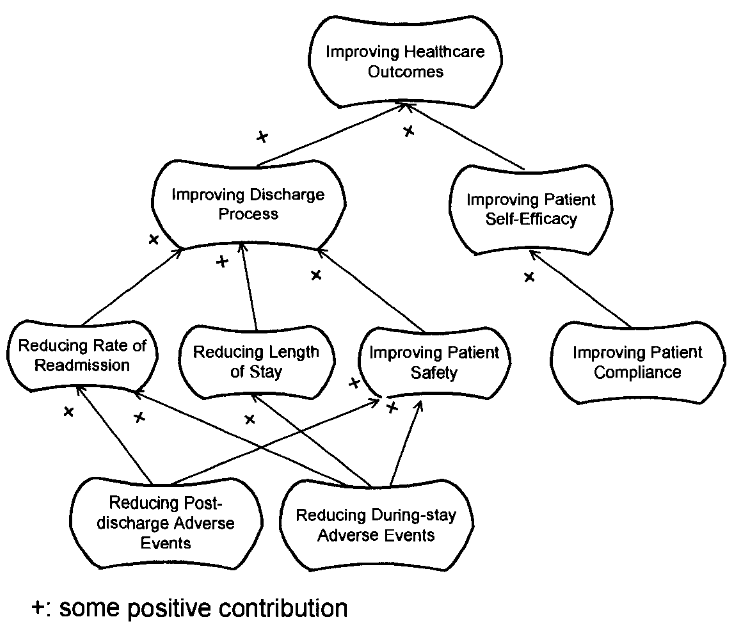

Figure 46: The hospital's top level goals

Drilling down into the second layer of the goal model in Figure 47, there are several sub-goals making their contributions to "reduce post-discharge adverse events" and "reduce during-stay adverse events". Some of them can be then drilled down into more detail like "Correct therapy" and "Decrease over-therapy"; others, which are the leaves in this layer of the goal model, can be divided into tasks in the next layer of goal models and those tasks then performed to achieve the goals. Figure 48 to Figure 52 show the tasks performed to achieve "adequate communication", "adequate follow-up", "adequate monitoring", "correct diagnosis", and "post-discharge services".

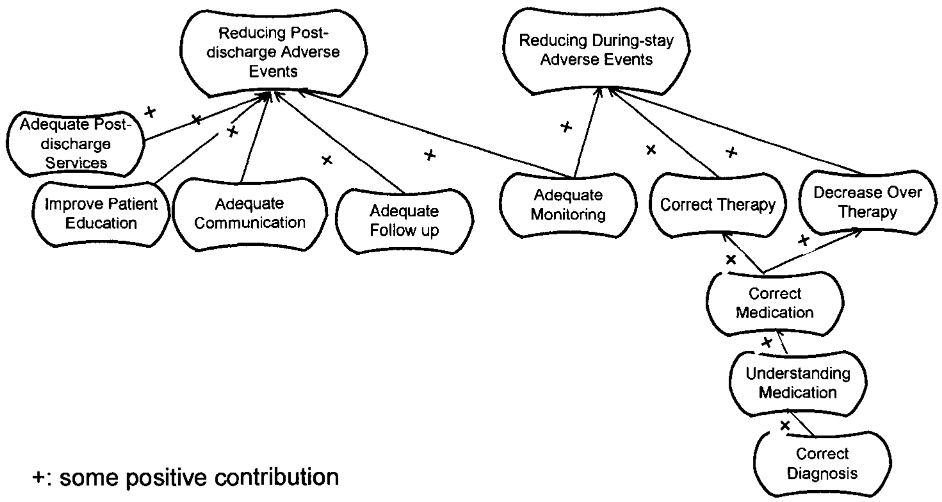

Figure 47: The second layer of the goal models

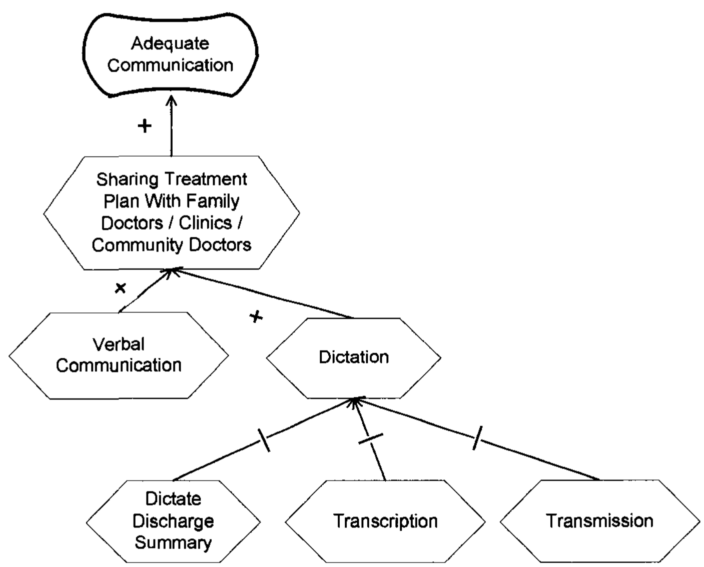

Figure 48: The tasks performed to achieve adequate communication

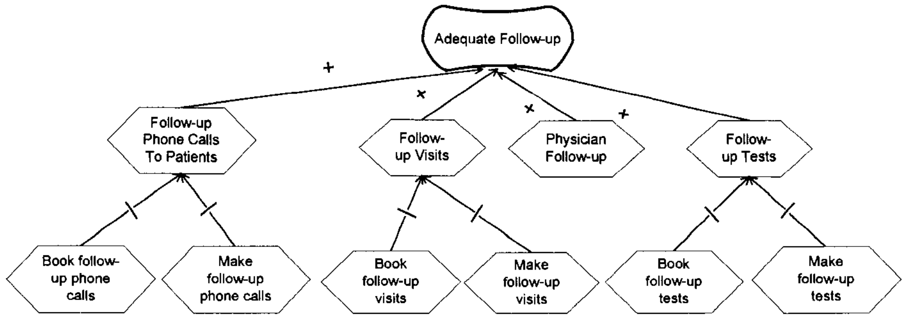

Figure 49: The tasks performed to achieve adequate follow-up

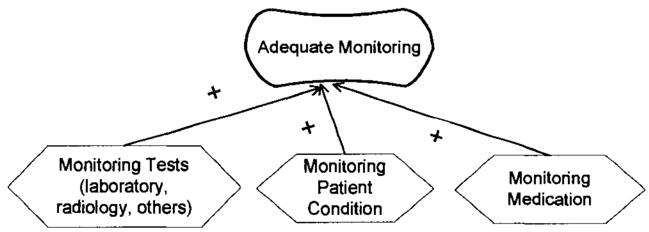

Figure 50: The tasks performed to achieve adequate monitoring

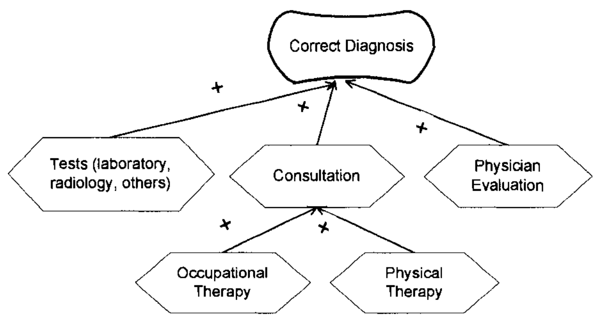

Figure 51: The tasks performed to achieve correct diagnosis

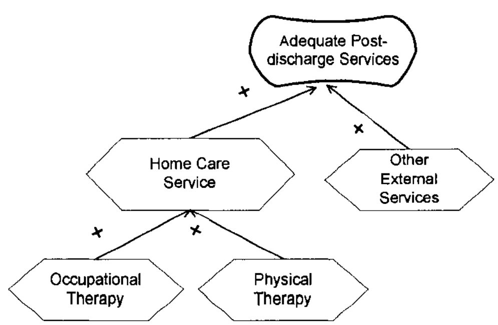

Figure 52: The tasks performed to achieve adequate post-discharge services

6.2.4 Links between business processes and goals

The discharge processes and goals are linked through URN links defined between them. The links enable traceability between the process elements and the goal elements as well as the KPIs.

Table 7 lists the mappings between business processes and goals or tasks through URN links in the discharge process.

Table 7: The mappings between business processes and business goals/tasks through URN links

Business Goals/Tasks	Business Processes
Improving Discharge Process	The discharge process
Home Care Service	Discharge to home
Active Home Care	Activate home care
Other External Services	Discharge to other places
Dictation	Dictation process
Dictate discharge summary	Dictate discharge summary
Transcription	Transcription
Transmission	Transmission
Book Follow-up Phone Calls	Enter patient into follow-up phone system
Make Follow-up Phone Calls	Monitor phone system
Book Follow-up Visits	Book follow-up visits
Make Follow-up Visits	Perform follow-up visits
Book Follow-up Tests	Book follow-up laboratory tests
	Book follow-up radiology tests
Make Follow-up Tests	Follow-up laboratory tests
	Follow-up radiology tests
Tests	Laboratory tests
	Radiology tests
Physician Evaluation	Evaluate patient condition
Correct Medication	Medication
Consultation	Consultation plan service
Occupational Therapy	Occupational therapy
Physical Therapy	Physical therapy

6.3. KPI MODELS

6.3.1 Overview

Based on the business process models, goal models and URN links, we built KPI models to quantitatively evaluate efficiency and effectiveness on processes and goals.

According to the survey and research in (Forster, Murff, et al. 2003, 5), "poor communication between the hospital caregivers and either the patient or the primary care physician" is the common cause of 59% of preventable and ameliorable adverse events in the provision of discharge care.

Since adverse events have become a significant performance issue in regard to hospitalization and "poor communication between the hospital caregivers and either the patient or the primary care physician" (Forster, Murff, et al. 2003, 5) is the most common reason for this in the "provision of discharge care" based on the research into adverse events discussed in section 6.1.3, KPI models, shown in Figure 53, can be built upon the dictation process against the dictation tasks in the goal model "Adequate Communication", shown in Figure 48.

6.3.2 Key performance indicators

As shown in Figure 48, the dictation task can be divided into three sub-tasks, which are the "dictating discharge summary", "transcription" and "transmission" tasks. Hence the dictation process shown in Figure 53 consists of the three sub-processes.

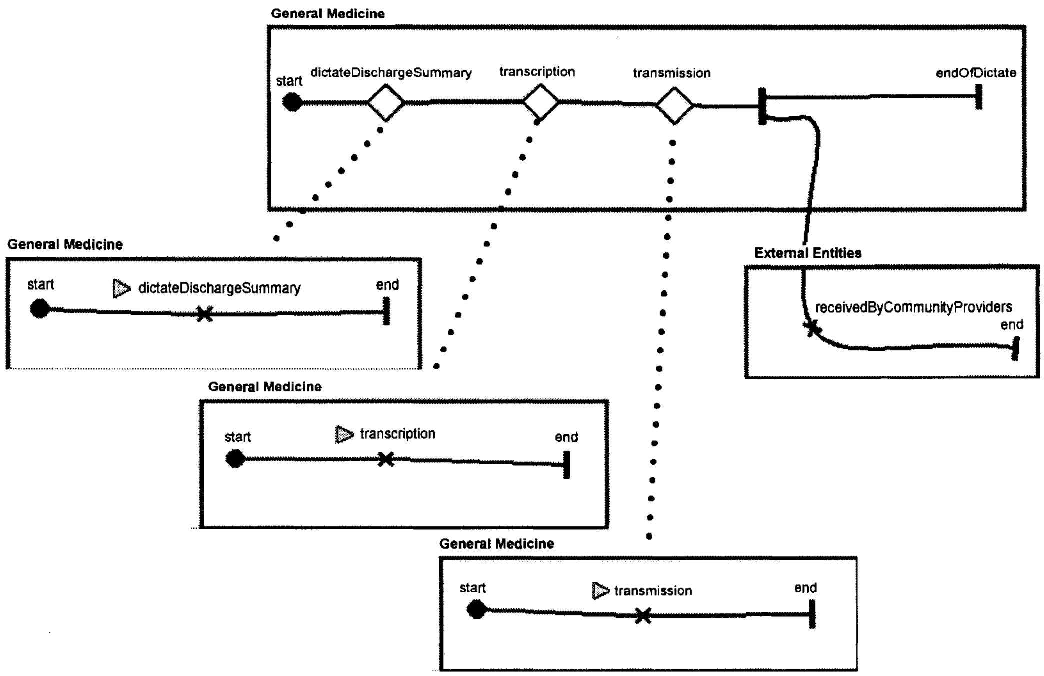

Figure 53: The dictation process and its sub-processes

As showed in Figure 54, there are three KPIs defined for the sub-tasks of the dictation task: the "average time lag between discharge and dictation", which is defined for the "dictate discharge summary" task, the "average time lag between dictation and transcription", which is defined for the "transcription" task, and the "average time lag between transcription and transmission", which is defined for the "transmission task". It is easy to conclude that all the three KPIs are the time measures. However, they should also belong to the quality group, since in the discharge process in a hospital, the time issue of the communication do have significant impacts on causing preventable and ameliorable adverse events.

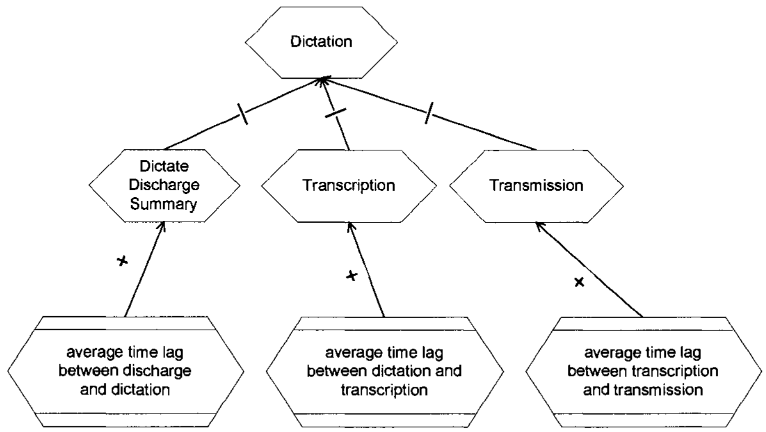

Figure 54: The KPIs defined for the dictation process

6.3.3 KPI information elements

After the KPIs are defined on the KPI models, in order to evaluate those KPIs, users need to specify dimensions to each KPI in the KPI models. From the business users' point of view, by defining dimensions, they can point out from which perspective or which kinds of hierarchy, such as time (year, month, day, etc.) and organization (campus, department, etc.), they want to evaluate KPIs. Based on this understanding, users can easily create dimensions and attach them to KPIs. Different KPIs can share the same dimensions, in other words, dimensions can be reused.

Figure 55, Figure 56 and Figure 57 present the KPI models defined for the dictation sub-tasks. Three dimensions are defined for the KPIs to illustrate that the KPIs should be evaluated from the three perspectives of time, unit and service.

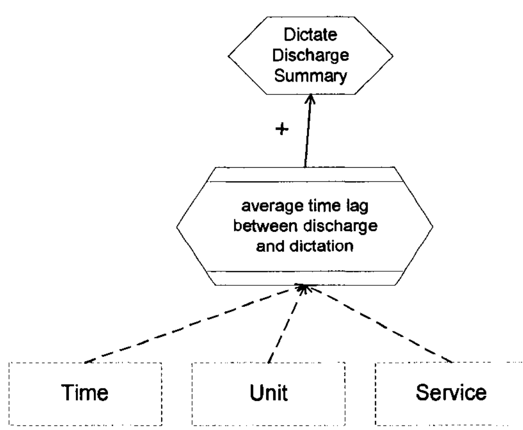

Figure 55: The KPI model of the "dictate discharge summary" task

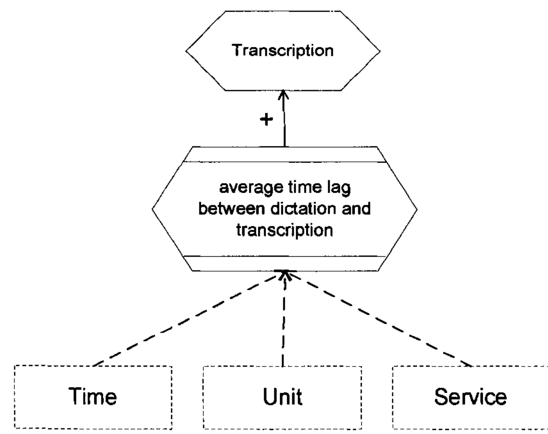

Figure 56: The KPI model of the "transcription" task

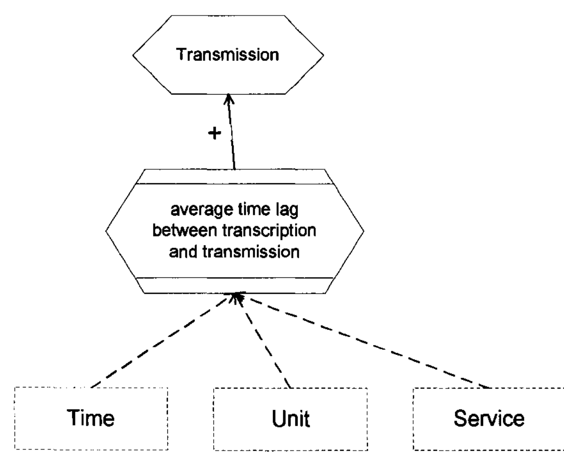

Figure 57: The KPI model of the "transmission" task

6.3.4 KPI strategies

As illustrated in Figure 22 in section 5.3.2, KPI strategies are defined for the KPIs and dimension elements to set contexts for evaluation. For a KPI, the target value, the threshold value, the worst value and the unit are defined as the criteria for the KPI evaluation, and the evaluation value in the context will be retrieved from the monitoring services at the run-time. For a dimension, the level of dimension can be used to describe the fact of this KPI evaluation, while the value of dimension specifies what KPI value should be generated in a KPI report.

The hierarchies of the three dimensions defined in the dictation process are depicted in Table 8. In each strategy, each dimension will be given a specific level for the level of dimension property and a specific value for the value of dimension property, e.g. for the unit dimension, set the level of dimension to "Campus" and the value of dimension to "Civic".

Table 8: The hierarchies of the dimensions defined in the dictation process

	Time	Unit	Service
Level 1	Year	Campus	Service
Level 2	Month	Unit	Physician
Level 3	Day		

Figure 58 shows the KPI strategies that are defined for the dictation process in the strategies view. Each strategy set a specific context for evaluation, e.g. for the strategy 1, the context is that the KPI evaluation of the General Medicine department in the Civic campus for the year 2005.

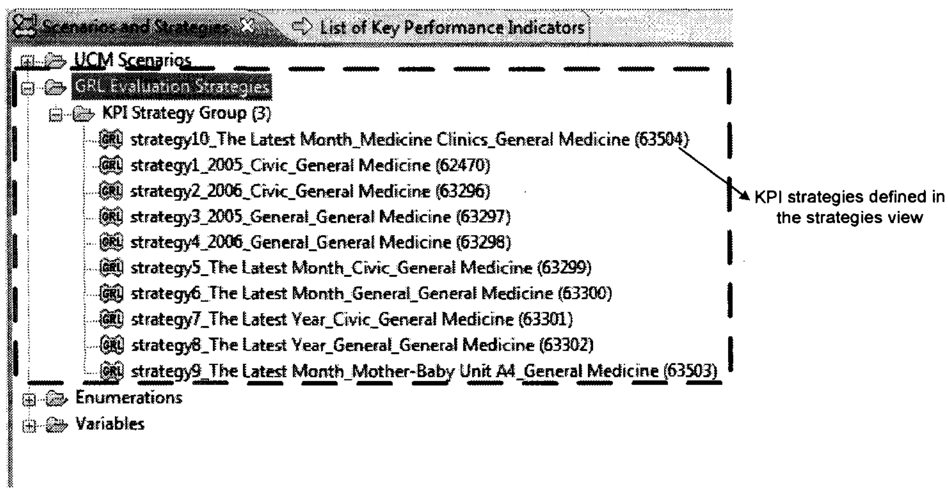

Figure 58: KPI strategies defined in the strategies view of jUCMNav

Table 9 shows the settings of KPIs and dimensions for each strategy. Each strategy defines levels and values on dimensions. The values of dimensions are chosen based on the levels of the dimensions shown in Table 8, such as, for the Unit dimension, if the level is Campus, there are two values to be chosen in this level: the civic campus and the general campus. More details about ranges of dimension values are listed in Appendix B. The levels and values of dimensions defined in each strategy depict a fact against each KPI. For example, strategy 1 defines such a fact on KPI 1 that shows "yearly average time lag between discharge and dictation per campus per service", and for the same KPI on the strategy 10, it shows "monthly average time lag between discharge and dictation per unit per service". Another example is for the KPI 2, the strategy 5 defines "monthly average time lag between dictation and transcription per campus per service".

Table 9: The strategy settings of KPIs and dimensions

Strategies	Time	Unit	Service	KPI 1	KPI 2	KPI 3
1	Level: Year Value: 2005	Level: Campus Value: Civic	Level: Service Value: General Medicine	Target: 5 Threshold: 12 Worst: 18 Unit: Day	Target: 9 Threshold: 18 Worst: 30 Unit: Day	Target: 5 Threshold: 10 Worst: 20 Unit: Day
2	Level: Year Value: 2006	Level: Campus Value: Civic	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
3	Level: Year Value: 2005	Level: Campus Value: General	Level: Service Value: General Medicine	Target: 5 Threshold: 12 Worst: 18 Unit: Day	Target: 9 Threshold: 18 Worst: 30 Unit: Day	Target: 5 Threshold: 10 Worst: 20 Unit: Day
4	Level: Year Value: 2006	Level: Campus Value: General	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
5	Level: Month Value: The Latest Month	Level: Campus Value: Civic	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
6	Level: Month Value: The Latest Month	Level: Campus Value: General	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
7	Level: Year Value: The Latest Year	Level: Campus Value: Civic	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
8	Level: Year Value: The Latest Year	Level: Campus Value: General	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
9	Level: Month Value: The Latest Month	Level: Unit Value: Mother-Baby Unit A4	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day
10	Level: Month Value: The Latest Month	Level: Unit Value: Medicine Clinics	Level: Service Value: General Medicine	Target: 3 Threshold: 10 Worst: 15 Unit: Day	Target: 7 Threshold: 18 Worst: 30 Unit: Day	Target: 3 Threshold: 7 Worst: 15 Unit: Day

KPI 1: average time lag between discharge and dictation
KPI 2: average time lag between dictation and transcription
KPI 3: average time lag between transcription and transmission

6.4. GENERATING KPI VALUES

6.4.1 Overview

As shown in Figure 33, three steps are required to generate KPI values for the discharge process. First, according to the strategy settings in Table 9, we found the required facts and dimensions and then created necessary data marts for the discharge process in the Cognos framework manager. Next, based on the data marts and the KPI definitions, we built OLAP cubes to be analyzed for creating KPI reports. Finally, in the Cognos report studio, we created KPI reports for generating KPI values of the discharge process.

6.4.2 Data Marts

Cognos framework manager provides a convenient environment to extract, organize and transform a data source to create the star schema of data marts. The data source of the discharge process includes tables extracted from the original data warehouse, which is shown in Figure 59 and the simulation data that was generated by the data generation tool developed in (Zhan 2007).

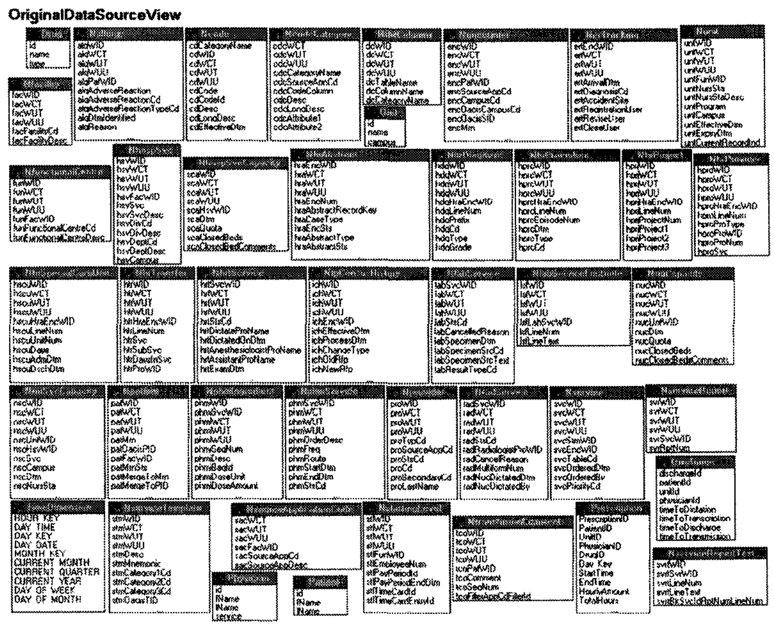

Figure 59: The original data source view

According to the mapping strategy defined in Table 4, we designed data marts for each KPI, as shown in Table 10, and then integrated them to one or multiple final data marts, as shown in Table 11.

Table 10: The data mart design for each KPI model

Data mart design	KPI 1	KPI 2	KPI 3
Dimensions	Time, Unit, Service	Time, Unit, Service	Time, Unit, Service
The associated process	The dictation process	The dictation process	The dictation process
Grain of the data mart schema	Time: month Unit: unit Service: service		
Facts (metrics)	The time to discharge The time to dictation	The time to dictation The time to transcription	The time to transcription The time to transmission

Table 11: The final data mart design

Data mart design	
Dimensions	Time, Unit, Service
The associated process	The dictation process
Grain of the data mart schema	Time: day Unit: unit Service: physician Patient: patient
Facts	The time to discharge The time to dictation The time to transcription The time to transmission

It should be noted that, usually, the grain of the data mart should be as low as possible so that the final data marts can be reused for KPIs that have smaller grain in future. Also the dimensions' hierarchy should reach as low a level as possible for re-usability. Moreover, some reasonable information could be also added as dimensions to make the data mart more meaningful and useful, such as the patient information for the discharge data mart. Based on the design, the final data mart is generated in Cognos framework manager, as shown in Figure 60.

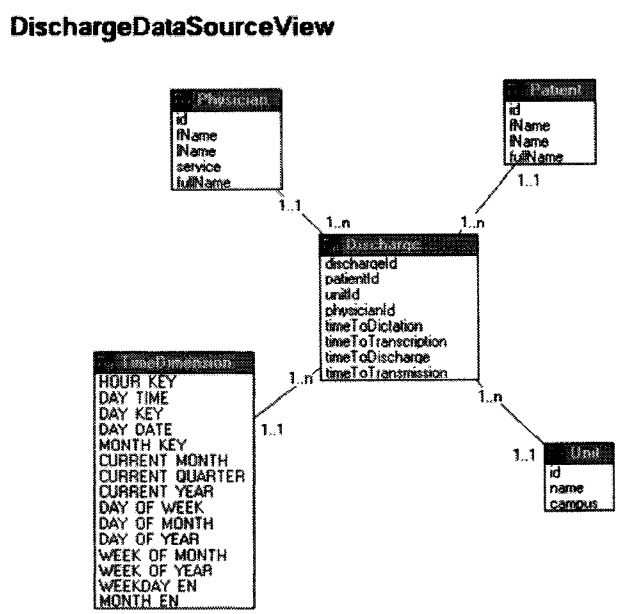

Figure 60: The discharge data mart

6.4.3 OLAP cubes

According to the mapping strategy defined in Table 5, we generated the mapping information showed in Table 12 and then built the OLAP cubes for the discharge process based on the data marts.

Table 12: The mappings between OLAP cube architecture and KPI model/strategy

OLAP cube design	
Dimensions	Time, Unit, Service
Dimension hierarchies	Time: year, month, day Unit: campus, unit Service: service physician Patient: patient
Measurements in the measure dimension	average time lag between discharge and dictation = The time to discharge - The time to dictation
	average time lag between dictation and transcription = The time to dictation - The time to transcription
	average time lag between transcription and transmission = The time to transcription - The time to transmission

Based on the design, we built the OLAP cube in Cognos framework manager, as shown in Figure 61.

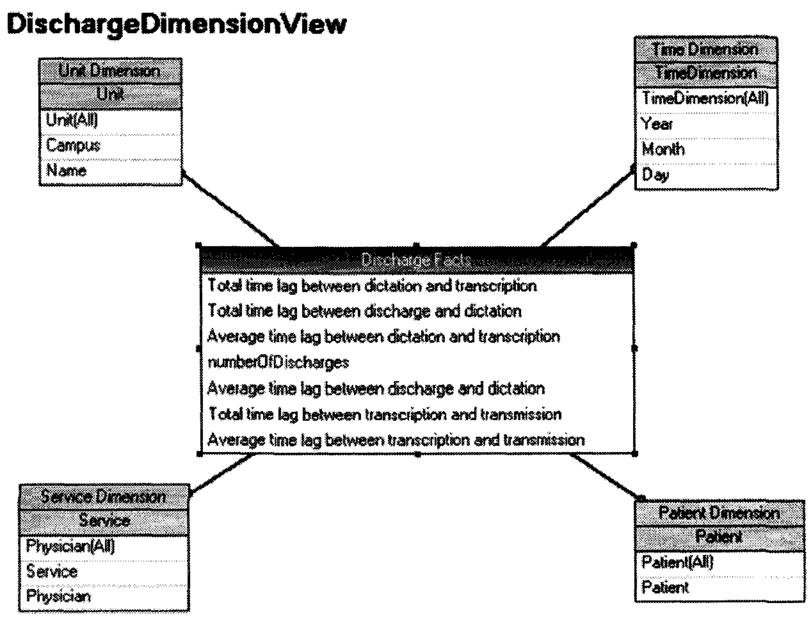

Figure 61: The discharge OLAP cube

6.4.4 KPI reports

After the discharge data model is constructed, the data model can be published and can then be used in the discharge process package. Inside the discharge process package, KPI reports are created, organized and named according to the rules discussed in section 5.4.3. Each KPI has a KPI folder and all KPI folders are put under a KPI evaluation folder, as shown in Figure 62.

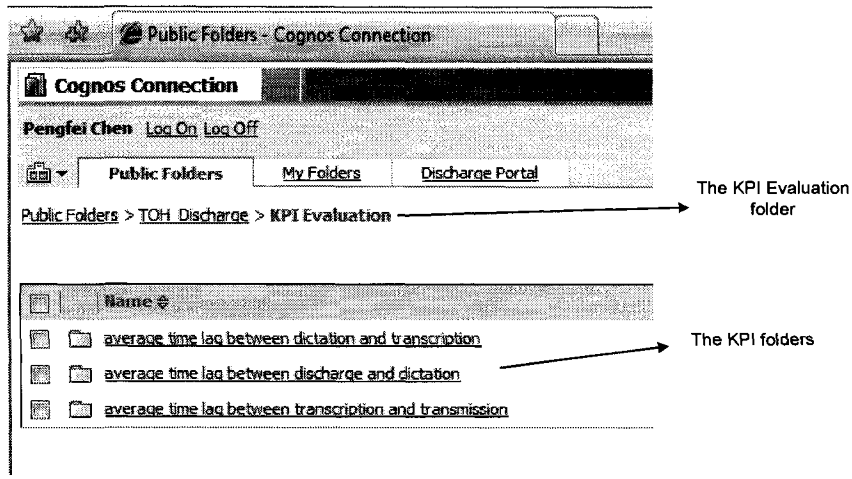

Figure 62: The KPI Evaluation folder contains KPI folder

In each KPI folder, each strategy has a KPI report created for each KPI, as shown in Figure 63.

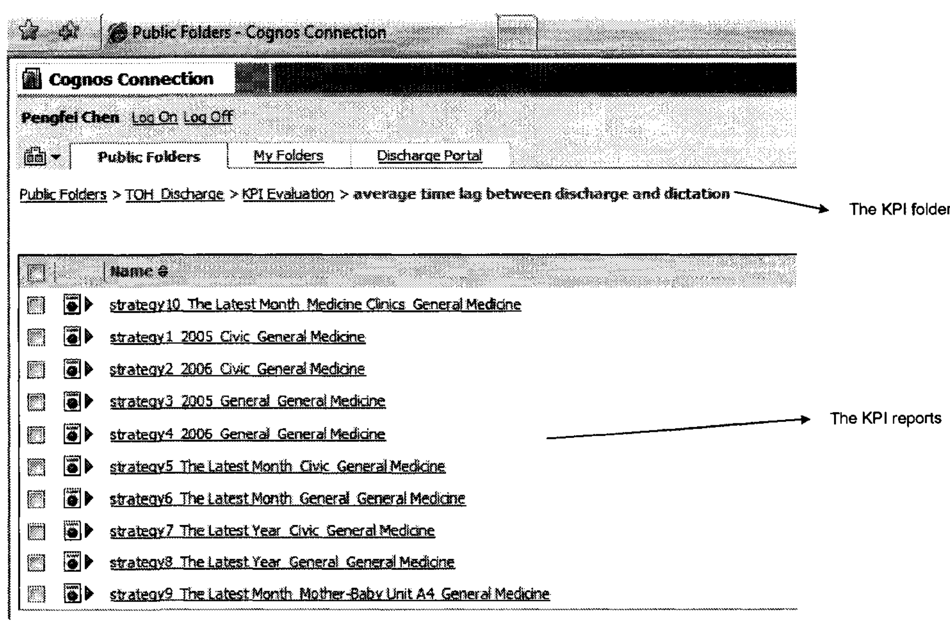

Figure 63: The KPI folder contains KPI reports

The KPI reports are created in Cognos report studio to generate KPI values under particular strategies by using the data model objects, as shown in Figure 64.

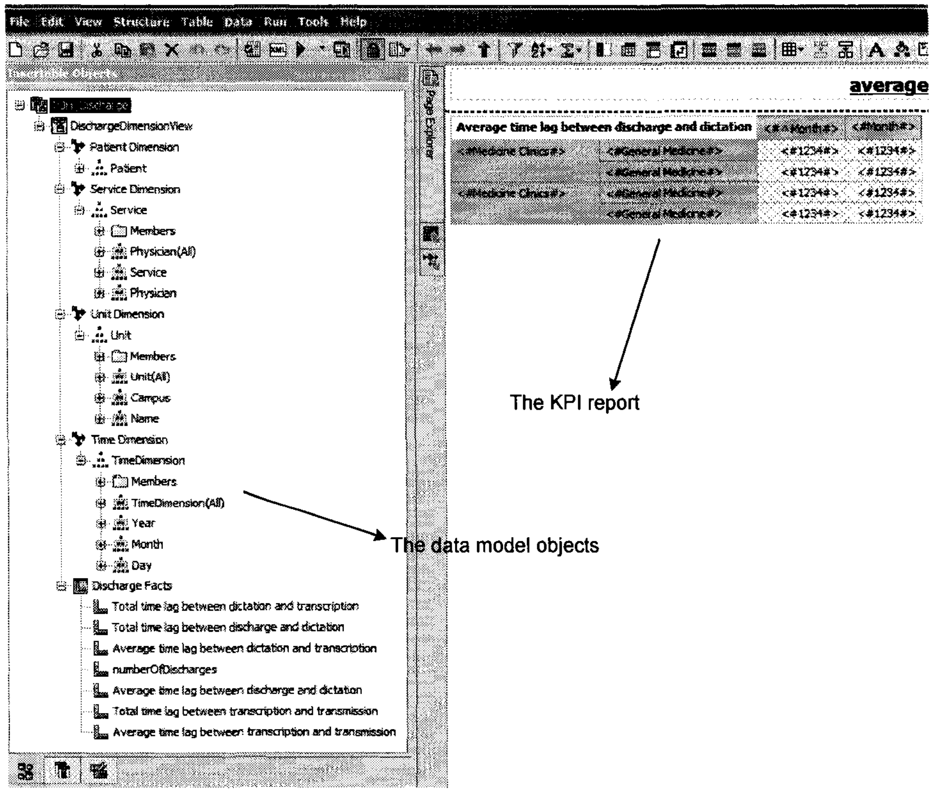

Figure 64: The KPI report in Cognos report studio

Finally, to test the created KPI reports, they can be executed from the Cognos report studio or the Cognos connection interface. Figure 65 shows the execution result of a KPI report. In the KPI evaluation process, the KPI reports will be executed at the run-time when users trigger the refresh button in the KPI list view to retrieve KPI values.

Average time lag between discharge and dictation		2005
Civic	General Medicine	25.7

Figure 65: The result of the executed KPI report

6.5. MONITORING SERVICES

Once the monitoring services have been implemented and deployed on the application server, there is no specific work to do for the case study, because the path of the KPI reports can be generated automatically according to the rules defined in section 5.4.3 and 5.5.2. For example, at the run-time, the path of the KPI report of KPI 1 under strategy 1 should look like:

"/content/package[@name=TOH_Discharge']/folder[@name='KPI Evaluation']/folder[@name='average time lag between discharge and dictation']/report[@name='strategy1_2005_Civic_General Medicine']"

6.6. KPI PERFORMANCE MONITORING AND EVALUATION OF GOALS

6.6.1 Evaluation

Once all the components, including the process, goal and KPI models, monitoring services, monitoring data models and KPI reports are ready, we started to monitor and evaluate the dictation process in the monitoring tool at run-time.

There is no specific order to doing the monitoring and evaluation. However, the following steps are required to obtain the results of the monitoring and evaluation:

- *The KPI list view, the KPI view and the strategies view should be opened;*
- *The KPI values should have been retrieved by pressing the refresh button in the KPI list view*
- *A strategy should be selected and triggered in the strategies view;*
- *All KPIs and their status are shown in the KPI list view. However, if users want to see the results for specific business objects, such as a goal or goal model, a process, a responsibility, a KPI, an intentional element, or a KPI group etc., they need to open or click on that object and the related KPIs will be appear in the KPI view.*

Figure 66 shows the evaluation result of the dictation task by triggering strategy 1, which means the dictation KPIs in the civic campus in the general medicine service in the year of 2005. The result shows that the evaluation levels of the transcription task and the transmission task are under their threshold values and thus have poor performance that needs to be improved.

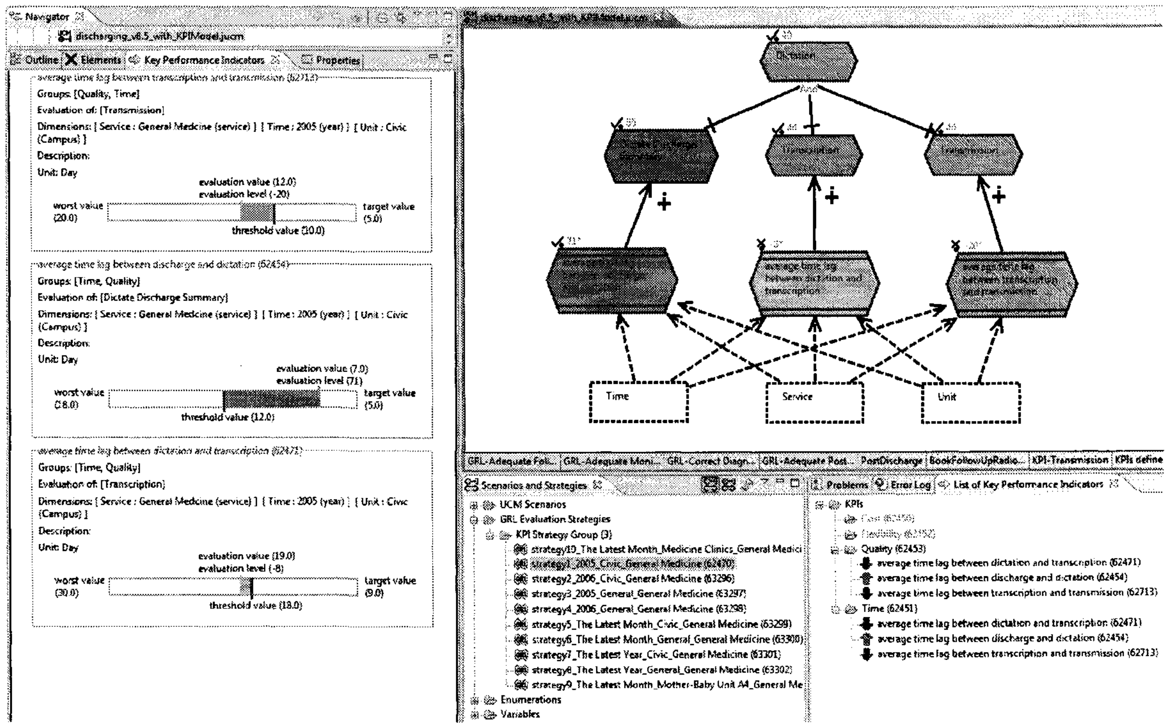

Figure 66: The evaluation results of the dictation task under the strategy 1

Figure 67 gives another evaluation result of the dictation process by triggering strategy 5, which means the dictation KPIs in the civic campus in the general medicine in the latest month. The result shows that in the dictation process, there is a serious problem with the time lag between the transcription and the transmission sub-processes. Then, by drilling into the transmission process in the process editor, the specific performance view of the transmission process is shown as Figure 68.

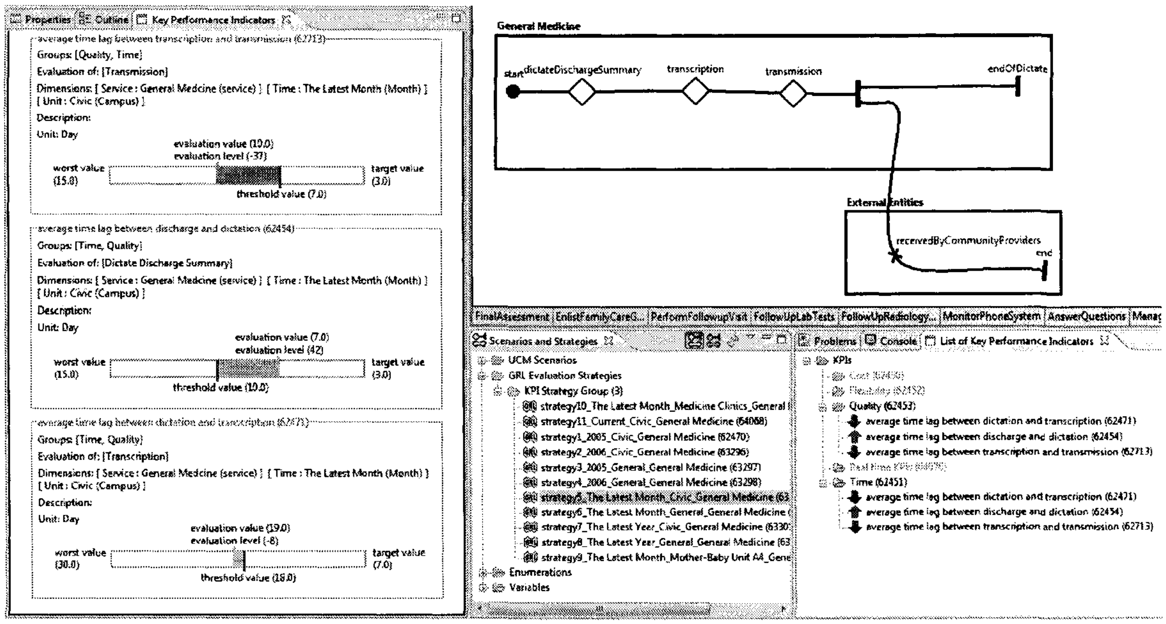

Figure 67: The evaluation results of the dictation process under the strategy 5

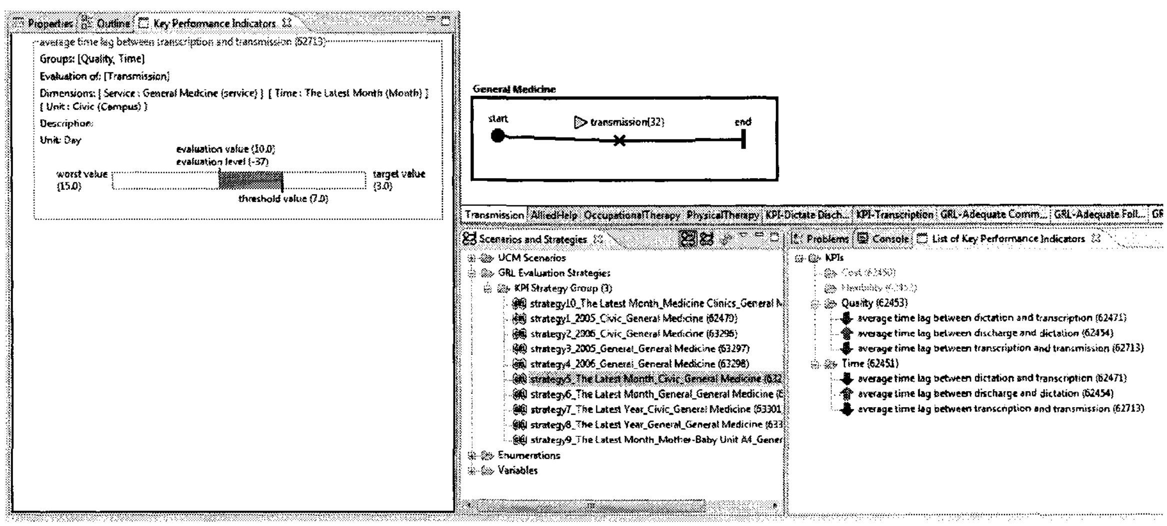

Figure 68: Drilling into the transmission process

6.6.2 An example of real time KPIs

We have illustrated how KPI models are built, how KPI strategies are defined, and the overall evaluation procedure. The KPIs defined for the dictation process are measured by analyzing the historical data in the BI tools. However, not only can historical performance be measured by KPIs, but real time KPIs can also be defined for monitoring. Figure 69 shows a KPI model that contains three real time KPIs: the number of dictations delayed over 10 days, the number of transcriptions delayed over 18 days and the number of transmissions delayed over 7 days. A strategy is also created specifically for the evaluation of these three KPIs, in which the time dimension is set to be always the current time, and the service dimension is set to be general medicine, and the unit dimension is set to be the civic campus. Thus, under that strategy, evaluation of the KPIs answers questions about current situations: such as how many cases have been delayed for over 18 days in general medicine on the civic campus.

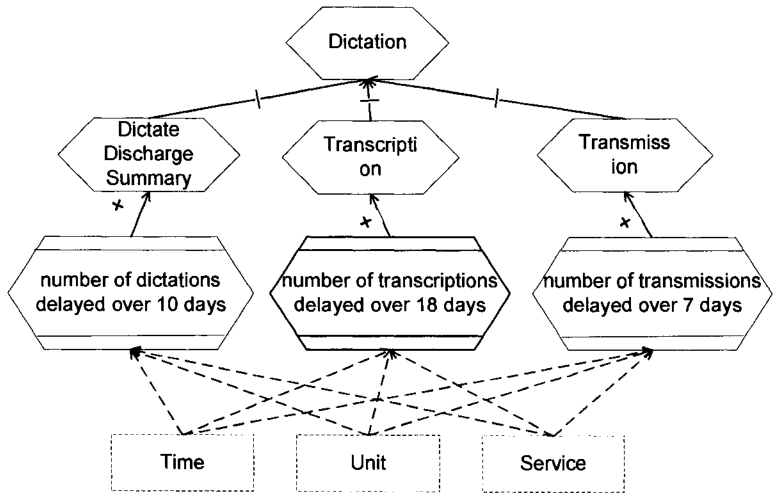

Figure 69: Real time KPIs defined for the dictation process

Figure 70 shows the evaluation result, that currently there are 19 cases that have been delayed for over 18 days in general medicine on the civic campus, with an evaluation level of -26, which indicates poor performance.

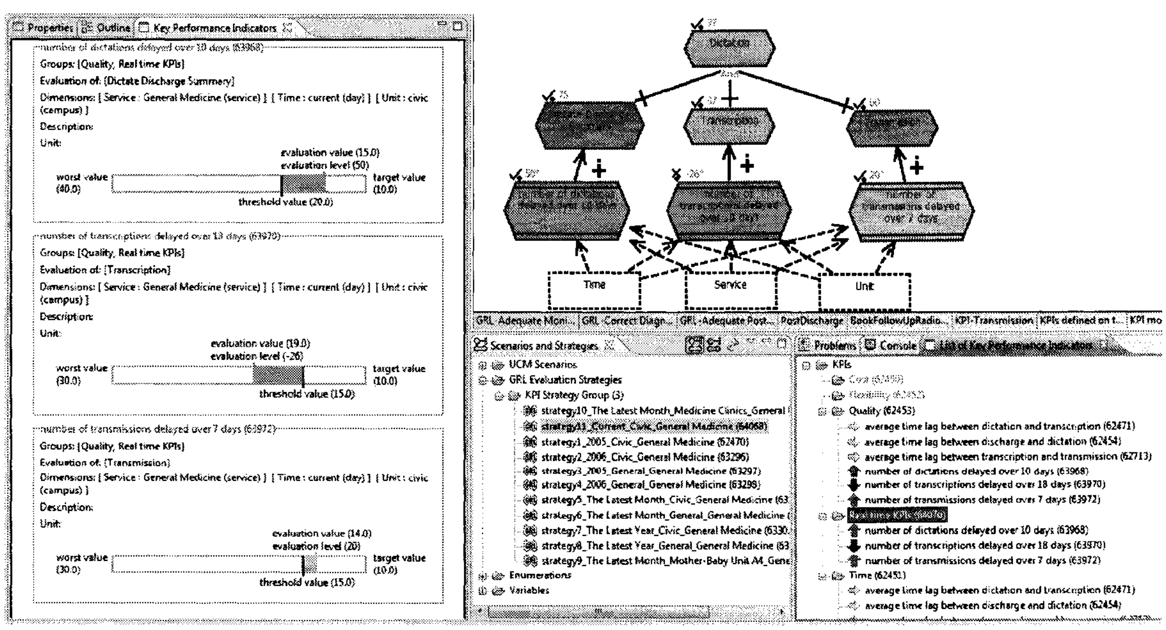

Figure 70: Evaluation of real time KPIs defined for the dictation process

6.7. CHAPTER SUMMARY

This chapter presented a case study of the discharge process in the health care industry. The case study includes building process models, goal models, KPI models and defining KPI strategies in the monitoring tool jUCMNav, building data marts and OLAP cubes from the original data warehouse, creating KPI reports, and making the monitoring services work as a whole with the other two components to form a goal-oriented business process monitoring system. Finally, the chapter presented the evaluation results of the dictation process.

Chapter 7 Discussion

The previous chapters describe the methodology, design, implementation and case study of the URN based goal-oriented business process monitoring solution. In this chapter, the URN based solution will be discussed and compared with the other BPMS products evaluated in section 3.3. This chapter will also discuss the benefits and limitations of this approach according to the results and feedback.

7.1. COMPARISON WITH OTHER PRODUCTS

According to results of the implementation and the case study, the following features and functionalities are designed and implemented in this goal-oriented business process monitoring solution:

- Business process modeling and business goal modeling: the process modeling tool in this solution is implemented based on jUCMNav, which is an Eclipse-based URN modeling tool, to provide both business process and goal modeling capabilities. Process models can have multiple hierarchies to depict different levels in detail. Goal models can also be built in an architecture that can define contribution and/or decomposition relationships between sub-goals/tasks and higher level goals. The tool also allows the user to import /export process and goal models from external sources, such as: Telelogic Doors, Use Case Editor (UCEd) and Core Scenario Model (CSM).
- Links between goals and processes: in URN, business processes and business goals are connected by URN links in different hierarchies and these links can be used to trace and allocate business processes to goals. Moreover, since KPI models are connected to goal models and contribute to goal evaluation, URN links enable traceability among business processes, business goals and performance models.
- Business goal evaluation: KPI strategies can be defined in KPI models and integrated with GRL strategies defined in goal models to build an overall evaluation strategy

covering KPI measurement and performance evaluation measured against goals as well as processes.

- KPI modeling: KPI models contains KPIs, allowing users to specify what should be measured, and dimensions, so users can specify from which perspectives or within which categories of data the KPIs should be measured.
- KPI evaluation/monitoring: by taking advantage of BI and data warehouse tools, the KPIs evaluation reports used to generate KPI values can be defined by designers quickly and easily, and KPIs can be evaluated in run time.
- Business events handling: based on URN, events can be defined in processes with pre- and post-conditions defined.
- Process simulation: the current system implemented only provides the simulation capability in data level. However, the powerful and comprehensive scenario defining capability of URN provides a solid basis for implementing a process-based simulation.
- Contribution to data modeling: the information from KPI models and KPI strategies can be used to build data marts, OLAP cubes and KPI reports to meet the requirements of KPI evaluation. Sections 5.4.2 and 5.4.3 describe how to facilitate building data models and KPI models by using information from KPI models and strategies.
- Contribution to process redesign: the approach in this thesis makes some initial effort on process redesign by using the KPI dimensions defined in the devil's quadrangle (Figure 16), i.e. cost, time, quality and flexibility, for grouping KPIs. Thus, the impacts of redesign patterns in the four KPI dimensions are organized in Table 2 and can be used to match and find proper redesign patterns for process redesign and improvement.
- System assembling and integration: the system is built with SOA and implements a monitoring service layer to make it flexible, extendable, and easily integrated with external systems, applications and data sources.

However, an execution engine and a process-based simulation need to be integrated with the current system to cover the full BPM life cycle.

Compared with the leading and challenging BPMS products in the industry listed in Table 1, the URN based goal-oriented business process monitoring system combined with Cognos BI tools implements most of the important features and functionalities that are covered by those BPM tools, such as business process modeling, KPI definitions, KPI evaluation and process simulation, with exception of a process execution engine. The URN solution also contributes to data modeling and assists in process redesign. And more importantly, the results clearly show that the URN-based approach provides the only solution that covers all goal-oriented features and integrates business goal modeling, goal evaluation and the links between goals, processes and KPI models. Thus, to provide a comprehensive BPMS solution, the approach of business process monitoring combined with Cognos BI tools in this thesis can be added as complementary to those existing products in the industry.

7.2. BENEFITS AND LIMITATIONS

The case study presented in the last chapter illustrates that the approach described in this thesis brings the following benefits to business process management:

- *Introducing URN into BPM:* the User Requirement Notation can describe both business processes and business goals and also build links between them. This capability promotes the understanding and reasoning of business process design and evaluation. It also helps business users trace and locate performance issues in connection with business processes and goals.
- *Integrating a KPI model to work with a URN model: integrating a KPI model with a URN model enables performance evaluation of both business processes and business goals.* Firstly, KPIs are defined and contribute to the evaluation of goal models to specify which performance issues should be monitored for the tasks or goals; secondly, dimensions are defined and assigned to KPIs to declare from what perspective users are interested in those performance issues.
- *Using information from a KPI model and KPI strategies to help build data models and create KPI reports to generate KPI values:* each KPI strategy defined in the KPI model has a specific evaluation context and is triggered to answer users' specific performance concerns. KPI strategies specify what categories of data should be used for evaluation by

defining levels and values on dimensions, and how measurement results can be transformed to evaluation results by defining the target value, threshold value and worst values of the KPIs. The KPI model and strategy information can be used to build data models and KPI reports as described in sections 5.4.2 and 5.4.3.

- *Implementation of the goal-oriented business process monitoring system:* finally, the approach in this thesis integrates the modeling tool, the monitoring services and the BI tools together to build a goal-oriented business process monitoring system with a service oriented architecture. Based on URN and integrated with a KPI model, the system allows users to trace performance issues between business processes and goals. In combination with BI tools, it enables the fast and easy retrieval of KPI values. Being built with SOA, the system provides an open and extendable platform for further goal-oriented process analysis and management, such as process prioritization and scenario performance evaluation.

The research work and ideas of the approach were previously published in (Pourshahid, Chen, et al. 2007) and (Pourshahid, et al. 2008. (accepted, to appear)). According to the results of the implementation, the case study, the evaluation and comparison with the leading and challenging BPM tools in the industry, the comments and feedback from the WER 2007 conference and the seminars with hospital stakeholders, research groups and colleagues, the following concerns, limitations and insufficiencies in the current approach should be stated, clarified and/or improved:

- *What kinds of performance issues can be defined and monitored?* Basically, there is no limitation to defining KPIs, no matter for real time analysis or for historical reports. In this implementation, since the BI tool is used as the business information provider, it relies on the BI tool to decide what kinds of business performance measurement can be created in KPI reports, such as average values, total values, variations, and trends, etc. However, since this approach is built with SOA, any kind of data sources or external business applications could act as the business information providers in this architecture (see Figure 18), for example as a process execution engine can be integrated to feed instance data for activity monitoring, or the transaction data from an operational database can be used for business analysis, or KPI reports can be generated from periodically updated xml data sheets or flat files. Hence, generally, it is possible to define KPIs to monitor any measurable performance issues.

- *Performance issue:* actually, performance is an important concern in data analysis related areas, such as BI or data warehouses. It always takes time to retrieve KPI values from any back-end data sources so if there are hundreds or more KPIs defined for various processes, how we do deal with that? One possible solution, which benefits from the architecture of this approach, is to periodically pre-retrieve and store KPI values from the BI server to a buffer in the monitoring services layer, so whenever requests for KPI values are sent from the monitoring tool, the latest KPI values stored in the buffer can be immediately returned to the client side. The interval time for refreshing the buffer can be set according to business needs.
- *Dynamic process concern:* the question is how we deal with dynamic processes that are created on the fly. The dynamic process concern is raised because it is possible that in the modeling phase people either don't know what will happen or know what will happen but are not sure when and/or where it is going to happen. In the latter situation, it is an issue of dynamic work-flow or events. In this case, usually each step in the dynamic process can be chosen according to set conditions so that the URN can be used to define pre- and post-conditions for process scenarios and the business logic can be chosen in the run time. For the former situation, alternative processes should be able to be created in the run time and either share the same goal with the original process or have some new goal defined. The dynamic process concern is out of the scope of this thesis, but it could be an interesting topic for further research.
- *The weight of contributions should be numerical:* currently in the GRL modeling, there are several contribution levels defined for the contribution links, such as some positive, some negative, help, make, etc. However, to precisely describe the contribution between higher level goals and lower level goals or tasks, a range of numerical contribution values, such as from -100 to 100, should be used for this purpose.
- *The propagation algorithm should be modified to be better suited to business process evaluation:* the current approach reuses the propagation algorithm originally designed for goal evaluation in requirement engineering. Since we usually define KPIs having positive contribution to the evaluation of connected goal models, it leads to a problem where

the range of the evaluation level on goal models is only from 0 to 100 while the range of evaluation level on KPI models can be between -100 and 100. To be consistent and reasonable, a redesign of the propagation algorithm should be considered.

- *Automatic generation of data model and KPI reports:* the current approach provides a strategy and method to use the information from KPI models and KPI strategies to facilitate building data models and KPI reports. However, this has not been an automated process. To make this solution more usable and to reduce the level of human intervention, this step should be automated and integrated into the system.

- *Execution engine and simulation:* as we discussed in section 7.1, an execution engine and a process-based simulation need to be integrated and implemented with the current system to cover the full BPM life cycle.

Chapter 8 Conclusions

This chapter summarizes the approach of the thesis, reviews the contributions and discusses future work and further research possibilities.

8.1. SUMMARY OF CONTRIBUTIONS

This thesis introduced an approach for implementing a goal-oriented business process monitoring system consisting of a business process modeling and monitoring tool, monitoring services and an information provider. Through the implementation of the approach, the following contributions are made in this thesis:

- *A proposed extension to URN that supports integrated KPI-Goal-Process modeling.* Integrating a KPI model with a URN model enables performance evaluation of both business processes and business goals. In addition, URN links provide traceability among business process models, goal models and the KPI models.
- *An extension to jUCMNav that allows KPI evaluation to be integrated with Goal Evaluation.* The KPI evaluation strategy can be used to set different contexts for KPIs and KPI information elements to precisely describe the different requirements of KPI evaluation.
- *A framework for data model and KPI report generation.* The approach in this thesis developed a strategy to use information from KPI model and KPI evaluation strategies to help build data models and create KPI reports for generating KPI values.
- *A framework for integrating business process monitoring with goal-based evaluation and design of business process models.* By integrating a KPI model and combining it with BI and Web services, KPI values can be automatically retrieved and used to propagate the evaluation of goal models.

8.2. WAY FORWARD

The implementation of the approach in this thesis is an initial step in introducing URN into business process management. As discussed previously in this thesis, there are several issues remaining to be studied and resolved. Furthermore the integration of a KPI model with business process and goal models opens new research possibilities into the alignment of business goals and processes.

8.2.1 Cover a full BPM life cycle

To complete the full BPM life cycle shown in Figure 9, the business process monitoring system implemented in this thesis needs to be further integrated with an execution engine in addition to implementing a process-based simulation.

Simulation allows users to explore "what if" scenarios, the results of which can help users to evaluate the performance of processes under different scenarios and to identify potential process bottlenecks.

By integrating an execution engine, the modeled business processes thus can be executed and managed. As a result, the generated business activity information from the execution process can be fed into the monitoring applications either for long term analysis and/or for real-time business activity monitoring (BAM) and event handling.

8.2.2 Limitations and improvements

There are some issues discussed in section 7.2 that need to be complemented or improved.

Firstly, since the current propagation algorithm is designed for goal evaluation in requirement engineering, it could be better to redesign the algorithm to meet the needs of business process evaluation. Therefore, extra research effort will be required to determine the specific needs of business process evaluation and how the propagation algorithm should be customized to meet those needs.

Secondly, it could be better to set the weightings of the contributions applied to the contribution links between KPIs and tasks/goals as numerical values, so users can define more precise weightings and have more choices in selecting the weightings placed upon the contributions. However, by giving meanings to the weightings of the contributions, such as some positive, help, hurt, etc., the current method has benefits of its own in making it easier for users to understand, and sometimes, easier to choose. Both benefits and disadvantages should be considered in developing a proper method of assigning the weighting placed upon a particular contribution.

Next, a strategy can be implemented to automatically generate data model and KPI reports by taking advantage of the information from KPI models and KPI strategies. At the very least, some initial work can be done automatically based on the current information we can obtain, such as facts, dimensions, level and value of dimensions, etc.

Finally, in considering the performance issue, a buffer storing KPI values can be added to the monitoring services layer and a mechanism can be designed to automatically refresh the buffer at user defined intervals.

8.2.3 Future research

The current approach in this thesis provides a basic platform that is open to extensions. More effort can be made in regard to the alignment of business goals and processes based on the integration of KPIs and URN throughout the BPM life cycle. Currently, the following on-going study is being done by the team:

- *Process portfolio:* a process portfolio prioritizes business processes in a hierarchical quadrant based on their importance and performance; their values can be calculated or retrieved from goal models and KPI models. It gives users an overall understanding of the current business process status in each level and allows users to drill-down and drill-up.
- *Scenario-based evaluation:* this approach aims to allow users to determine the performance and impact of a scenario or a particular part of the process in relation to the goal model.

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Appendix A: Design of the monitoring services

The monitoring services are designed to receiving requests from the monitoring client application and returning KPI values. The services are described in Web Service Definition Language (WSDL) with its XML Schema Definition (XSD) defined.

At first, the monitoring services XSD file defines the elements and types used for constructing the WSDL file.

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<xs:schema version="1.0" targetNamespace="http://service.bpm.com/" xmlns:tns="http://service.bpm.com/"
xmlns:xs="http://www.w3.org/2001/XMLSchema">
```

> Comments: defining the elements used to store KPI information transferred between the server and the client.

```
<xs:element name="retrieveKPIValues" type="tns:retrieveKPIValues"/>
<xs:element name="retrieveKPIValuesResponse" type="tns:retrieveKPIValuesResponse"/>
```

> Comments: defining the types of elements. An array of KPI entities can be handled in one operation.

```
<xs:complexType name="retrieveKPIValues">
  <xs:sequence>
    <xs:element name="kpiEntities" type="tns:kpiEntity" maxOccurs="unbounded" minOccurs="0"/>
  </xs:sequence>
</xs:complexType>
<xs:complexType name="retrieveKPIValuesResponse">
  <xs:sequence>
    <xs:element name="return" type="tns:kpiEntity" maxOccurs="unbounded" minOccurs="0"/>
  </xs:sequence>
</xs:complexType>
```

> Comments: defining the basic unit containing KPI information.

```
<xs:complexType name="kpiEntity">
  <xs:sequence>
    <xs:element name="indicatorName" type="xs:string" minOccurs="0"/>
    <xs:element name="kpiValue" type="xs:string" minOccurs="0"/>
```

```xml
      <xs:element name="strategyName" type="xs:string" minOccurs="0"/>
    </xs:sequence>
  </xs:complexType>
</xs:schema>
```

Next, based on the elements and types defined in the XSD file, the monitoring services are defined in the WSDL file.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<definitions xmlns="http://schemas.xmlsoap.org/wsdl/" xmlns:tns="http://service.bpm.com/"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
targetNamespace="http://service.bpm.com/" name="KPIValueWebServiceBeanService">
  <types>
    <xsd:schema>
      <xsd:import namespace="http://service.bpm.com/" schemaLocation="http://mcr-s4010-
w02.site.uottawa.ca:9080/KPIValueWebServiceBeanService/KPIValueWebServiceBean/__container$publishing$
subctx/META-INF/wsdl/KPIValueWebServiceBeanService_schema1.xsd"
xmlns:wsdl="http://schemas.xmlsoap.org/wsdl/"
xmlns:soap12="http://schemas.xmlsoap.org/wsdl/soap12/"/>
    </xsd:schema>
  </types>
```

Comments: defining the messages carrying parameters and returned values.

```xml
  <message name="retrieveKPIValues">
    <part name="parameters" element="tns:retrieveKPIValues"/>
  </message>
  <message name="retrieveKPIValuesResponse">
    <part name="parameters" element="tns:retrieveKPIValuesResponse"/>
  </message>
```

Comments: defining the port method used to retrieve KPI values.

```xml
  <portType name="KPIValueWebServiceBean">
    <operation name="retrieveKPIValues">
      <input message="tns:retrieveKPIValues"/>
      <output message="tns:retrieveKPIValuesResponse"/>
    </operation>
  </portType>
```

Comments: binding the port method and the service operation.

```xml
  <binding name="KPIValueWebServiceBeanPortBinding" type="tns:KPIValueWebServiceBean">
    <soap:binding transport="http://schemas.xmlsoap.org/soap/http" style="document"/>
```

```
  <operation name="retrieveKPIValues">
   <soap:operation soapAction=""/>
   <input>
    <soap:body use="literal"/>
   </input>
   <output>
    <soap:body use="literal"/>
   </output>
  </operation>
 </binding>
```

Comments: defining the service.

```
 <service name="KPIValueWebServiceBeanService">
  <port name="KPIValueWebServiceBeanPort" binding="tns:KPIValueWebServiceBeanPortBinding">
   <soap:address location="http://mcr-s4010-
w02.site.uottawa.ca:9080/KPIValueWebServiceBeanService/KPIValueWebServiceBean"
xmlns:wsdl="http://schemas.xmlsoap.org/wsdl/"
xmlns:soap12="http://schemas.xmlsoap.org/wsdl/soap12/"/>
  </port>
 </service>
</definitions>
```

Appendix B: Dimensions in the discharge processes

In the case study, a real data schema from the Canadian hospital we worked with is used to build the data warehouse. All names and facts appearing in the case studies are fictitious, but everything else is the same as accessing the real hospital data warehouse, i.e. no modifications to the system would be required to connect it to a real data feed.

The levels and range of values of the Time dimension:

Level 1	Level 2	Level 3
Year	**Month**	**Day**
2005-2006	01-12	01-31

The levels and range of values of the Unit dimension:

Level 1	Level 2
Campus	**Unit**
Civic	Alternate Level of Care (ALC) Units -- 2
	Clinical Teaching Unit (CTU), General Internal Medicine / Family Medicine
	Endoscopy Unit
	General Surgery and Urology - A3
	Hemodialysis - E6
	Medicine Clinics
	Mother-Baby Unit A4
	Obstetrical High Risk Unit
	Ottawa Regional Women's Breast Health Centre (WBHC)
	Post-Anesthetic Care Unit (PACU)
General	Alternate Level Care Unit - E5
	Birthing Unit
	Emergency Department
	General Surgery and Trauma - B2 / D2
	Geriatric Assessment Unit - A1
	Intensive Care Unit
	Mother-Baby / Gynecology - B4
	Neurosurgery and Neurosurgery Observation Area (NOA) - F7
	Orthopedic Surgery - A2
	Pain Management Clinic

The levels and range of values of the Service dimension:

Level 1	**Level 2**
Service	**Physician**
General Medicine	Arnie Baker
	John Arbuthnot
	H. Richard Hornberger
	Oliver Goldsmith
	Michael Cook
	Tobias Smollett
	Patrick Abercromby
	Arthur Johnston
	Georg Büchner
	Ludwig Büchner
	Kurt Schopenhauer
	João Guimarães Rosa
	Silas Weir Mitchel
	Lewis Thomas
	Adeline Yen Mah
	Janet Asimov
	Deepak Chopra
	Alex Comfort
	Erasmus Darwin
	Theodor Drachman
	Georges Duhamel
	Havelock Ellis
	Arnie Baker
	John Arbuthnot
	H. Richard Hornberger
	Oliver Goldsmith
	Michael Cook
	Tobias Smollett
	Patrick Abercromby
	Arthur Johnston
	Georg Büchner
	Ludwig Büchner
	Kurt Schopenhauer
	João Guimarães Rosa
	Silas Weir Mitchel
	Lewis Thomas
	Adeline Yen Mah
	Janet Asimov
	Deepak Chopra
	Alex Comfort
	Erasmus Darwin
	Theodor Drachman
	Georges Duhamel
	Havelock Ellis
	Florence Nightingale
Cardiology	Orvan Hess
	Ashoka Jahnavi-Prasad
	William Harvey

Level 1	**Level 2**
Service	**Physician**
Cardiology	Thomas Addis
	Virginia Apgar
	Hans Asperger
	Jean Astruc
	Frederick Banting
	Christiaan Barnard
	Charles Best
	Norman Bethune
	Theodor Billroth
	Jean-Martin Charcot
	Charles R. Drew
	Garcia de Orta
	Christiaan Eijkman
	Pierre Fauchard
	Girolamo Fracastoro
	Sigmund Freud
	Daniel Carleton Gajdusek
	William Harvey
	Ernst Haeckel
	Orvan Hess
	Ashoka Jahnavi-Prasad
	Thomas Addis
	Virginia Apgar
	Hans Asperger
	Jean Astruc
	Frederick Banting
	Christiaan Barnard
	Charles Best
	Norman Bethune
	Theodor Billroth
	Jean-Martin Charcot
	Charles R. Drew
	Garcia de Orta
	Christiaan Eijkman
	Pierre Fauchard
	Girolamo Fracastoro
	Sigmund Freud
	Daniel Carleton Gajdusek
	Ernst Haeckel
Radeology	Marcello Malpighi
	Otto Fritz Meyerhof
	George Richards Minot
	Charles Horace Mayo
	William James Mayo
	Richard Morton
	Egas Moniz
	William Worrall Mayo
	William McBride

Level 1	**Level 2**
Service	**Physician**
Radeology	Edward Jenner
	Carl Jung
	Leo Kanner
	Robert Koch
	Theodor Kocher
	Rene Theophile
	Janet Lane-Claypon
	Joseph Lister
	Richard Lower
	Amato Lusitano
	Herbert Needleman
Surgery	Charles Jean Henri Nicolle
	William Osler
	Ralph Paffenbarger
	Ambroise Paré
	Wilder Penfield
	Joseph Ransohoff
	Jonas Salk
	Ignaz Semmelweis
	John Snow
	Thomas Sydenham
	James Mourilyan Tanner
	Carlo Urbani
	Andreas Vesalius
	Andrew Wakefield
	Allen Oldfather Whipple
	Carl Wood
	Ole Wormius
	Magdi Yacoub
	Thomas Browne
	Oliver Wendell Holmes, Sr.
	David Livingstone
	Albert Schweitzer
	Mungo Park
	William Gilbert
	Thomas Campion
Cancer	Samuel Garth
	William A. Hammond
	Ronald Laing
	Stanisaw Lem
	Carlo Levinovelist and
	Jean-Paul Marat
	Theodore Isaac Rubin
	Oliver Sacks
	Frank Slaughter
	Benjamin Spock
	Atul Gawande
	Vladislav Vanc
	Paolo Mantegazza