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A URN-Based Methodology for Business Process Monitoring

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Thesis submitted to the
Faculty of Graduate and Postdoctoral Studies
in partial fulfillment of the requirements for the degree of

Master of Electronic Business Technologies



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Abstract

Business Process Management Systems (BPMS) are attracting much attention these days as core tools for process management. A BPMS consists of several modules including Business Activity Monitoring (BAM), which evaluates the performance of processes. Although measuring the performance of business processes is based on organizational goals and the impact of processes on such goals is an important aspect of the process evaluation, most of the existing BPMS do not offer appropriate capabilities.

Several process improvements and quality methodologies have also been around for some time. Most of them, however, are based on statistical and management tools that are not integrated with current technologies including BPMS. In other words, the management and quality disciplines have not yet evolved to take full advantage of current technologies that can enhance process improvement efforts. One of the pitfalls here is the failure to use the information generated by different information systems dispersed across the organization to evaluate the impact of processes on their goals.

In this thesis, we use the User Requirements Notation (URN) in a methodology for evaluating business processes against organizational goals. Although URN enables the modeling of processes and goals, its process monitoring capabilities need enhancements and we will address this issue by extending URN. In addition, we propose a methodology that exploits the new capabilities of URN for process analysis and improvement. Unlike other quality methodologies, the methodology and supporting tool proposed are capable of using different sources of information to measure the performance of modeled processes and evaluate their impact on the goal models. The new capabilities and their benefits are illustrated through examples from the healthcare domain.

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List of Acronyms

<u>Acronym</u>	<u>Definition</u>
AD	Activity Diagram
BAM	Business Activity Monitoring
BI	Business Intelligence
BPI	Business Process Intelligence
BPM	Business Process Management
BPMS	Business Process Management System
BPMN	Business Process Modeling Notation
BPR	Business Process Reengineering
CPM	Corporate Performance Management
CPO	Chief Privacy Officer
DW	Data Warehouse
EPC	Event Driven Process Chain
EPM	Enterprise Performance Management
EEML	Extended Enterprise Modeling Language
GRL	Goal-oriented Requirement Language
IDEF	Integrated Definition Language
ITU	International Telecommunication Union
KPI	Key Performance Indicator
NFR	Non-Functional Requirement
OLAP	On-Line Analytical Processing
REB	Research Ethics Board
TOH	The Ottawa Hospital
TOHDW	The Ottawa Hospital Data Warehouse
TQM	Total Quality Management
UCM	Use Case Map
UML	Unified Modeling Language
URN	User Requirements Notation
SOA	Service Oriented Architecture
YAWL	Yet Another Workflow Language

Chapter 1. Introduction

Business processes and their improvement have always represented a challenge in business environments, from the manufacturing and industrialization era to current e-business environments. However, with new technological infrastructure becoming available in recent years, process automation and orchestration is gaining more attention. Furthermore, processes are now more cross-functional than ever in an organization and are even going beyond an organization's boundaries. Gathering the information related to processes from all these different sources, monitoring them, and aligning them with corporate strategies and high-level goals is now a major headache for organizations. In this thesis we address some of these challenges by proposing a goal-oriented process monitoring approach based on the User Requirements Notation (URN). URN is used as the process and goal modeling notation and combined with data warehouses and Business Intelligence tools as sources of information.

In this chapter, we first define some of the concepts to provide a common understanding of the subject matter. Then, we specify some of the problems in current process monitoring and improvement methodologies and tools. The objectives and motivations of this thesis are then illustrated. In addition, we elaborate on the research process used to address the above problems. Finally, we summarize the research contributions.

1.1 Concepts

In this section, some of the concepts required to understand the problem definition are briefly explained. Some of these concepts are further detailed in the literature review and background chapter. The main purpose of this section is to provide a common understanding about the research context.

- **Business Process:** (Silver, 2006b) defines a business process as a “coordinated chain of activities intended to produce a business result.” In another definition, a business process is a “repeating cycle that reaches a business

goal” (Debevoise, 2005). In addition, as indicated in (dictionary.com, 2001), a process is “the sequence of activities, people, and systems involved in carrying out some business or achieving some desired result.” As cited in (Mili, et al., 2003) the definition of business process by the workflow management coalition is “a set of one or more linked procedures or activities, which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships.”

- **Business Process Modeling:** usually involves depicting processes using a specific modeling notation. Process modeling identifies the roles of users involved in processes and the definition of activities that contribute to the satisfaction of business goals (Weiss, et al., 2005).
- **Business Process Modeling Language:** As indicated in (Mili, et al., 2003) we can classify process modeling languages by specific purposes such as describing the process, analysing the process, and executing the process. In addition, one can use them to demonstrate different views of a business. In the context of this thesis, a business process modeling notation is a set of graphical symbols used to describe the process in a way that is understandable and analyzable by human beings. It should be able to answer to the W5 questions about a process (What, When, Where, Who, Why) (Pourshahid, et al., 2007).
- **Business Process Management (BPM):** Business Process Management (BPM) is the understanding and management of diverse and cross-organizational processes, which link humans and automated systems together (Debevoise, 2005 p. 4). In another definition by van der Aalst as cited in (Herk, 2006 p. 3), BPM methodologies, techniques, and software are used to design, execute, and control processes involving humans, organizations, applications, documents, and other sources of information.
- **Business Process Management Systems:** Business Process Management Systems (BPMS), are used to automate processes and to provide process monitoring and improvement capabilities (Appian Corp., 2006). BPMS represent a revolutionary way of using technology in the business environment (Silver, 2006b). BPMS use Service Oriented Architecture (SOA) as the infra-

structure to run the modeled business processes by users using different services across an organization.

- **Key Performance Indicators (KPI):** KPIs are the important quantifiable aspects of a business, calculated based on some defined measurement points and a specified rule for calculation (e.g. patient readmission percentage) (Kronz, 2006).
- **Business Activity Monitoring (BAM):** BAM is usually considered one of the components of a complete BPMS and is gaining more popularity in the industry these days. According to Gartner, “BAM is the real-time reporting, analysis and alerting of significant business events, accomplished by gathering data, key performance indicators and business events from multiple applications” (Dresner, 2003).
- **Quality Methodology:** “Quality methodologies are, in fact, management tools that are used to lead process improvements in organizations.” (Vonderheide-Liem, et al., 2004)
- **Data Warehouse (DW):** “Data warehouse is a collection of decision support technologies, aimed at enabling the knowledge worker (executive, manager, and analyst) to make better and faster decisions” (Chaudhuri, et al., 1997).
- **Data Mart (DM):** “Data Mart is a part of data presentation area where data is organized, stored, and made available for direct querying by users, report writers, and other analytical applications. In its most simplistic form, a data mart presents the data from a single business process.” (Kimball, et al., 2003 p. 10)
- **Business Intelligence (BI):** Business Intelligence is considered “a generic term to describe and leverage the organizations’ internal and external information assets for making better business decisions.” (Kimball, et al., 2003) The idea of Business Intelligence System is first expressed in (Luhn, 1958) as a system that creates “interest profiles for each of the action points in an organization”.
- **Business Process Intelligence (BPI):** Business Process Intelligence (BPI) is usually implemented as a suite of products including Data Warehouses, a BI

tool, and a business process automation and execution engine that supports both business users and information technology users to run and monitor business processes. In addition, BPI can be used to predict unwanted actions, events and exceptions (Grigori, et al., 2001).

1.2 Problem Statement

Businesses are moving toward the use of BPMS to automate their complex and cross-organizational business processes that interact with different information systems and human beings inside and outside the boundaries of organizations. The arising complexity needs to be monitored not only to control the current situation but also to improve and align the business processes and goals. Although both classical process control and quality methodologies (e.g. Six sigma, Lean Thinking, TQM) and new technologies promise to provide such monitoring, each of them has some inadequacies that prevent organizations from having an integrated methodology and tool set for process monitoring and improvement. This issue specifically inhibits alignment of business processes with business goals. The problems associated with current methodologies and technologies are:

- Current performance methodologies and process monitoring tools do not explicitly support goal modeling notations. As a result, they are not capable of providing analysis and visualization of the impact of the performance of processes on the organizational goals (Pourshahid, et al., 2007).
- Some of the classical quality and performance methodologies try to address the objectives and goals of the organization. However, since they are based on statistical and management tools and are not integrated with new technologies, they cannot be a good choice for controlling and monitoring the new BPMS-based environment that businesses are moving toward (Williams, 2007). This new environment includes many complex cross-organizational processes, involving different information systems during the process flow, and generating much data.
- Although classical methodologies like Lean Thinking exist, which are less tied to statistical and managerial tools and, which are bound more closely to a

way of thinking that allows them to be adapted and used in this new era, the provided supporting software for these methodologies were not used widely in enterprises. *One of the main challenges for using this supporting software has been integration with the existing processes supporting software in enterprises* (Masson, et al., 2007).

URN is the only standardization effort that supports modeling of both processes and goals, and as such, it can be considered as key to solving the above problems. The notation, however, its existing semantic and guidelines, and its current available modeling tools do not entirely provide the required capability for process monitoring and alignment. For example:

- The notation cannot define metrics and indicators used for Business Activity Monitoring (Pourshahid, et al., 2007).
- Although there have been some efforts to use URN for process and goal modeling (Weiss, et al., 2006), there is no methodology or guideline to specify how to use URN in the context of process monitoring.
- The available tools do not support the capability of using dispersed data across different information systems as feeds for process performance measurement.

1.3 Motivation

Solving the problems described in section 1.2 would help organizations in using their different sources of information to provide better insight into the impact of their processes on their organizational goals. In addition, the ability of modeling goals, processes, and performance indicators under the umbrella of one methodology and with one modeling language would provide a powerful and consistent way for process improvement that prevents practitioners from losing sight of the organization's goals. According to a recent survey, over 1,400 Chief Information Officers identified business process improvement as one of their companies' top priorities (Rudden, 2007). Business process improvement reduces costs, increases revenues, motivates employees, and satisfies customers.

All this attention and interest from industry motivates the elimination of inadequacies in this area. BAM, as one of the components of BPMS, is a new technology,

which is not well defined and still has room for improvement (Herk, 2006 p. 4). Although there have been many achievements in the industry in this regard, except for some contributions (Heß, 2006)(Ballard, et al., 2006), most tools and methodologies do not allow stakeholders to go through all steps of a BPM project from modeling to performance management (Silver, 2006a) and are representative of the problems described in section 1.2.

1.4 Objective

The objective of this research is to introduce a more adequate methodology for business process monitoring. The main goal of this methodology is to help businesses to evaluate their processes based on the Key Performance Indicators (KPIs) derived from their business goals, and to analyze the impact of business processes on business goals. To provide this capability, we use three fundamental components illustrated in Figure 1.

We have selected URN as the modeling notation in our methodology. URN is the only standardization effort (ITU-T, 2003) that provides the capability of both process and goal modeling. Comparing URN with some of the other process modeling notations, we have observed the advantages and disadvantages of URN in business process monitoring applications and justified it as a good choice. However, since URN needs some improvements and extensions to support the modeling and evaluation of performance models that include KPIs and monitoring dimensions, we propose an extension in this thesis to make URN more suitable for process monitoring.

In addition, we study various existing quality and process performance improvement methodologies and, by observing their common steps, benefits, and drawbacks, adopt and customize the required steps for our methodology.

Furthermore, we use Data Warehouse (DW) and Business Intelligence (BI) respectively to gather all process-related information dispersed across the organization in one place and analyse the gathered data to gain more information and knowledge about processes. This information needs to be passed to the URN toolset through an integration layer for further analysis and visualization of the process performance impact on business goals.

This thesis focuses on the methodology, conceptual meta-models, and requirements. The implementation of the suggested supporting tool and the required integration layers have been completed in a companion thesis (Chen, 2007). Appendix A provides a brief overview of the tool.

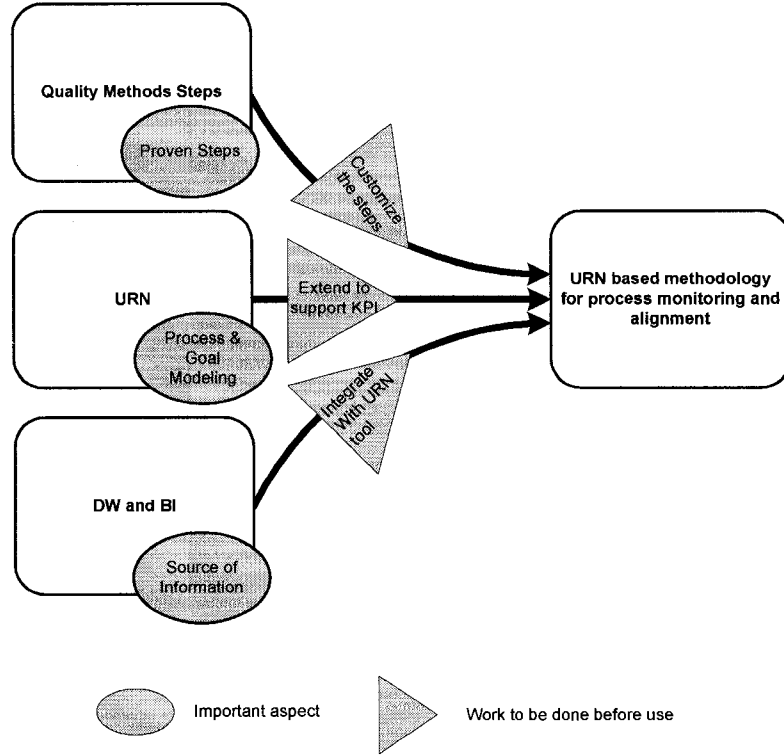


Figure 1: Fundamental components of the suggested methodology

1.5 Research Method

In this section, we elaborate on the process and steps we took to perform this research. The steps are illustrated from a high-level perspective in Figure 2, and in more detail in Figure 3.

We started the research with an initial literature review. After gaining a preliminary understanding about the body of knowledge, the area of research was specified as the draft problem definition. Based on the targeted problems, we designed an exploratory research with test and validation scenarios for formalizing the problem, solving it in iterations, and finally validating the proposed solution. Thereafter, we carried out a more in-

depth literature review and investigation to gain deeper knowledge about the subject matter. Gaining more knowledge, the problem definition and the research design were refined.

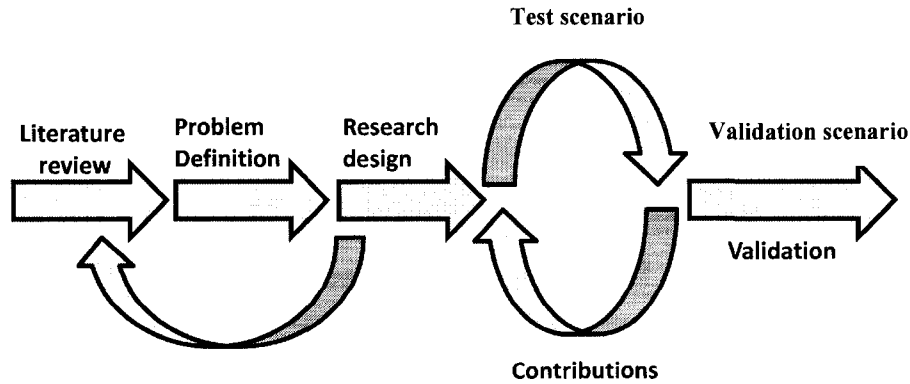


Figure 2: Research method steps – high-level view

In the next step, research started with the modeling of the test scenario. Along the way the opportunities for contributions to solve the defined problem and initial ideas were specified. This step was composed of multiple iterations as the test scenario's process and goal models were evolving. The test scenarios' performance model was also modeled using a prototype of the supporting tool. Initial research results from this test scenario were published in (Pourshahid, et al., 2007). Based on the initial results and feedback on the first paper, the inadequacies of the suggested URN extensions were resolved and the suggested methodology generalized. Using the revised model, a second scenario was completed to validate the steps of the methodology and suggested extensions to URN. To ensure the viability of the suggested methodology, several strategies in the validation scenario were tested to show how changes in process performance impact business goals. The result of this work has also been published (Pourshahid, et al., 2008).

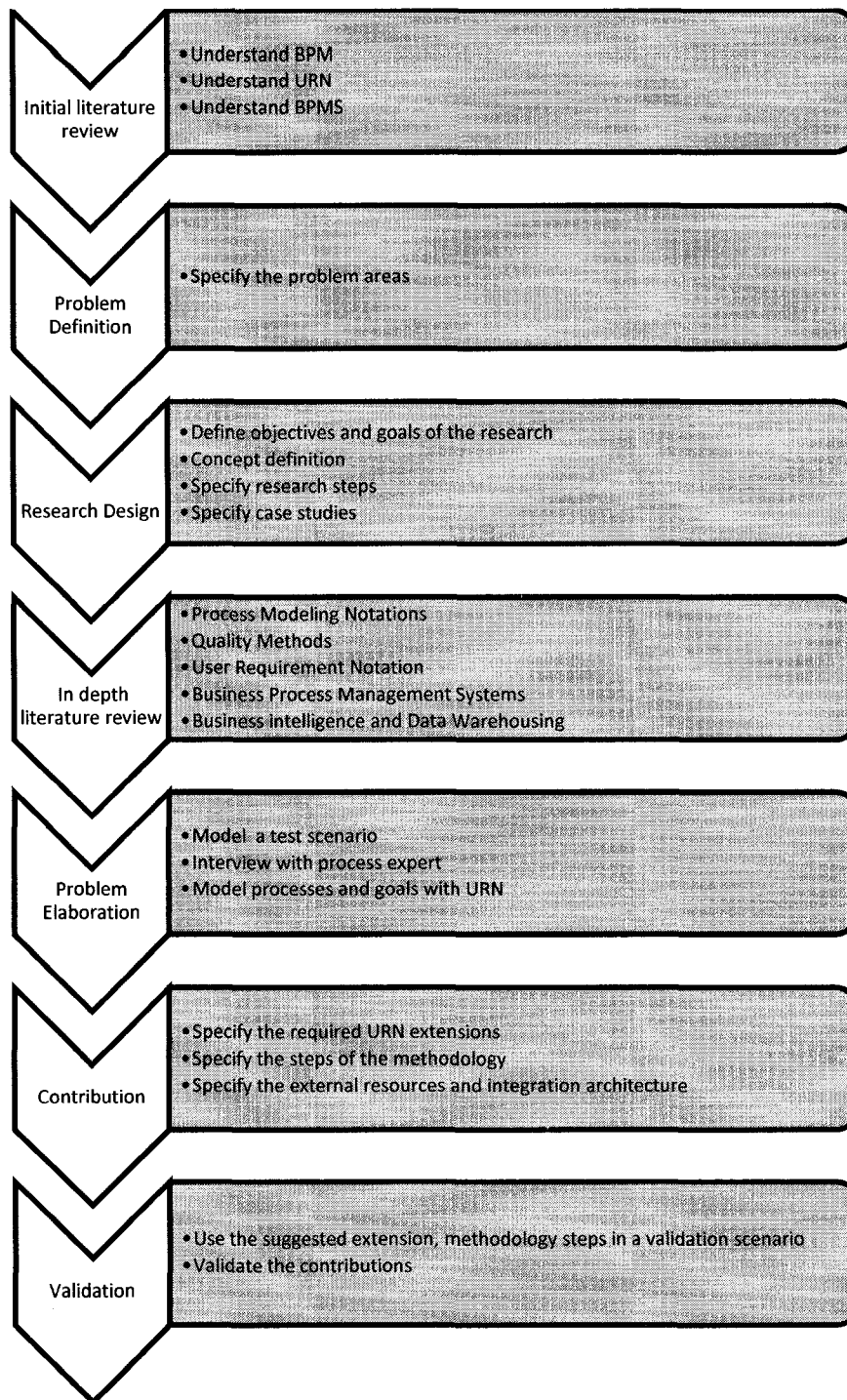


Figure 3: Research method steps – detailed activities and steps

1.6 Thesis Contributions

The five main contributions of this thesis are:

- Enhancement of the User Requirements Notation (URN) to support monitoring and analysis, the impact of business processes performance on business goals, which represents a novel application domain for URN. The extensions to URN introduced in this thesis allow modeling of KPIs.
- A guideline and methodology indicating the steps required for using URN for business process monitoring. In this methodology, new technologies and information sources across the organization are used and the common cycles of quality methodologies are customized to fit into this context.
- Specification of the requirements and high-level architecture for a toolset to support the methodology suggested. This approach uses a DW and a BI tool as the main sources of information, however, since an open web services based architecture has been suggested, other information systems can also be used as sources.
- Suggesting new features required for analysis of processes based on the results of process monitoring. The two suggested features are process portfolio analysis and a partial analysis of processes using UCM scenarios.
- Modeling processes, goal models, and performance models of two realistic validation scenarios that are not only used to validate the methodology but can also be used as a basis for future studies.

1.7 Thesis Organization

This thesis is organized into 7 chapters. Chapter 2 elaborates on the background, related work and findings from other similar methodologies and notations, which motivate the benefits of using URN and justify the steps we propose in our methodology. Chapter 3 elaborates on the problem we address in this thesis using a test scenario— a hospital discharge process. In this chapter, we illustrate the process and goal models of the test scenario and demonstrate why URN needs enhancements to support process performance models, and why URN modeling tools need integration with external sources of informa-

tion. Chapter 4 and Chapter 5 represent the core contributions of this thesis as we specify the URN extensions and the suggested methodology based on URN as a monitoring tool. In Chapter 6, we validate our approach using a validation scenario: the access process for a healthcare data warehouse. Finally, Chapter 7 is dedicated to summary, conclusions, and future work.

1.8 Publications

This thesis has resulted in several publications:

- **Alireza Pourshahid**, Pengfei Chen, Daniel Amyot, Michael Weiss, and Alan J. Forster. "Business Process Monitoring and Alignment: An Approach Based on the User Requirements Notation and Business Intelligence Tools." *10th Workshop on Requirements Engineering (WER 2007)*. Toronto, Canada, May 2007. York University, pp. 80-91.
- **Alireza Pourshahid**, Pengfei Chen, Daniel Amyot, Liam Peyton, Michael Weiss, Sepideh Ghanavati, and Alan J. Forster. "Toward an integrated User Requirements Notation framework and tool for Business Process Management." *3rd International MCE Tech Conference on e-Technologies*. Montréal, Canada, January 2008. IEEE Computer Society, pp. 3-15. (Best Paper Award)
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Chapter 2. Background and Related Work

In this chapter, we investigate some of the existing quality methodologies often used for process monitoring and analysis purposes. The goal of this investigation is to identify their objectives, common steps, and critical success factors, in order to use them in our own methodology after customizing these experiences in our context. In addition, we would like to address some of the drawbacks and inadequacies of these methodologies. Furthermore, we assess some of the existing process modeling notations and investigate their capabilities for goal modeling and performance evaluation. Finally, we will introduce business process management systems and discuss their shortcomings in monitoring, which include demonstrating the impact of process performance on business goals.

2.1 Quality and Process Improvement Methodologies

2.1.1 Total Quality Management (TQM)

TQM is a structured method of improvement that requires the contribution of everyone in the organization, and even the extended organization (supply chain and partners), and focuses on all aspects of an organization's processes to fulfill the requirements of customers and organizational goals.

TQM efforts started before World War II, and Dr. W. Edwards Deming is known to be the pioneer of TQM's philosophy in the 1920s. Later around 1930, Deming worked with Walter A. Shewhart to incorporate statistical methods into TQM. Deming introduced their statistical quality improvement method in Japan where it was very well received. TQM is considered one of the factors that helped the flourishing of Japan's economy in the 1980s. Thereafter, Deming's method gained more interest in U.S manufacturing industry to improve the quality of products in the USA (Hillstrom, et al., 2006).

One of the main principles of TQM is that most of the mistakes by people are due to problems in the systems and processes. As a result, most of these mistakes can be prevented by elimination of process defects. Some of the TQM goals are:

- Focus on customer;
- Involve all people in the organization (Haberer & Webb, 1994);
- Standardize the process;
- Identify process goals and conventions for measurement of goal satisfaction, providing a plan for ongoing measurement of the specified goals;
- Generate step-by-step action plans to solve the observed problems (Vonderheide-Liem, et al., 2004 pp. 3-12). Action plans are documents that specify what is going to be done by whom and by when (Haberer, et al., 1994).

TQM targets both natural process variations and special cause variations. Natural process variations are normal changes in the value of defined indicators caused by natural behaviour of the system. Special cause variations are not normal and need quick response and action plans to be solved.

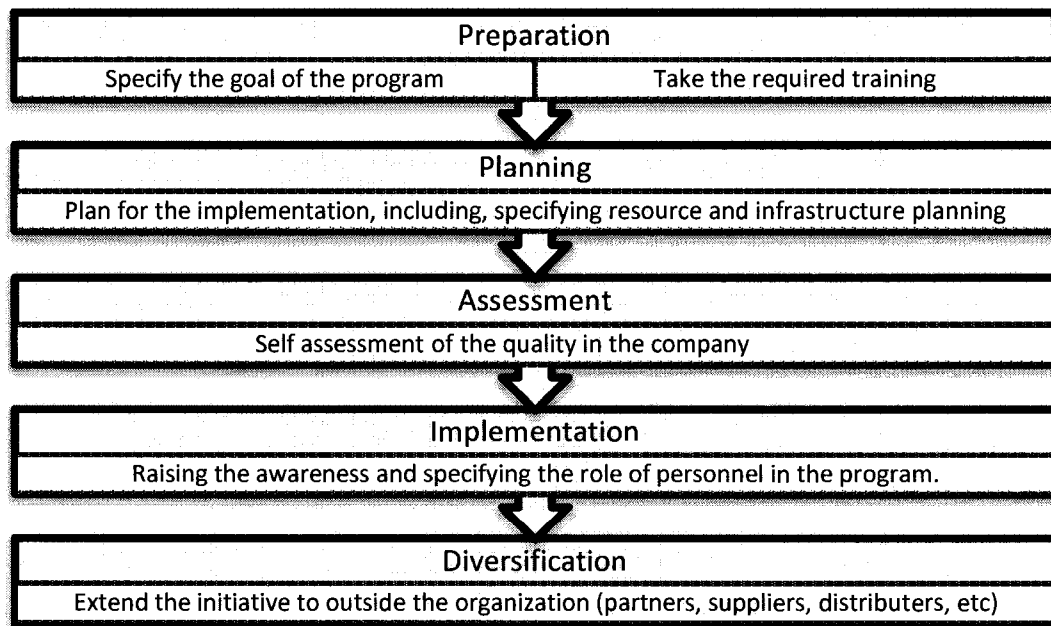


Figure 4: TQM methodology steps.

There are many tools used in the TQM method: Pareto diagrams, control charts, run charts, flow charts, histograms, brainstorming diagrams, and cause and effect diagrams. Even though there are specific modeling notations designed for process modeling, TQM practitioners use flow charts for process modeling.

Jablonski has suggested using five steps for TQM implementation. Although there are many other approaches for implementing TQM, Jablonski's method is known to include the main principles of TQM. (Hillstrom, et al., 2006). We illustrated these steps in Figure 4.

A common factor between all successful TQM practices is using measurement in an ongoing and continuous manner and providing feedback for the next round of improvement (Haberer, et al., 1994 p. introduction). Continuous incremental improvements result in large gains over the long term. In addition, utilization of cross-functional multidisciplinary teams helps workers to appreciate their roles in the overall process and gain a better understanding of the process. Moreover, participative management motivates workers and helps managers to gain a better understanding of the operations (Hillstrom, et al., 2006). The best-known strategy for implementation of TQM is GOAL/QPC, which consists of ten steps. This approach is highly dependent on long-term management support and the first feedback of the project progress is only observable after two years, which is very long for today's agile business environment (GOAL/QPC Research Committee, 1990 p. 12).

2.1.2 Six Sigma

"Six Sigma is a highly structured and disciplined process to eliminate defects, wastes, and quality problems. The resulting improved performance costs less and returns money to the bottom line" (Vonderheide-Liem, et al., 2004 p. 27). This process is based on the principles of TQM and adds more to the quality process. This method is one of the most highly regarded quality methods of recent years. Six Sigma's five main identification factors are (Vonderheide-Liem, et al., 2004 pp. 27-30):

- Structured,
- resource dedication and involvement,
- customer focus,

- error reduction,
- bottom-line enhancement.

Six Sigma starts with identifying processes with improvement requirements and the cost of their defects in organizations. Then, the candidate processes are prioritized and target processes are specified. The main candidates for improvement are those who do not satisfy customers' expectations and needs. Organizations usually bring consultants to help with their improvement processes. These consultants are called Master Black Belts and help with internal resources ranked into three levels: Black Belts, Green Belts, and White Belts. This ranking is based on expertise and the amount of time dedicated to the improvement process.

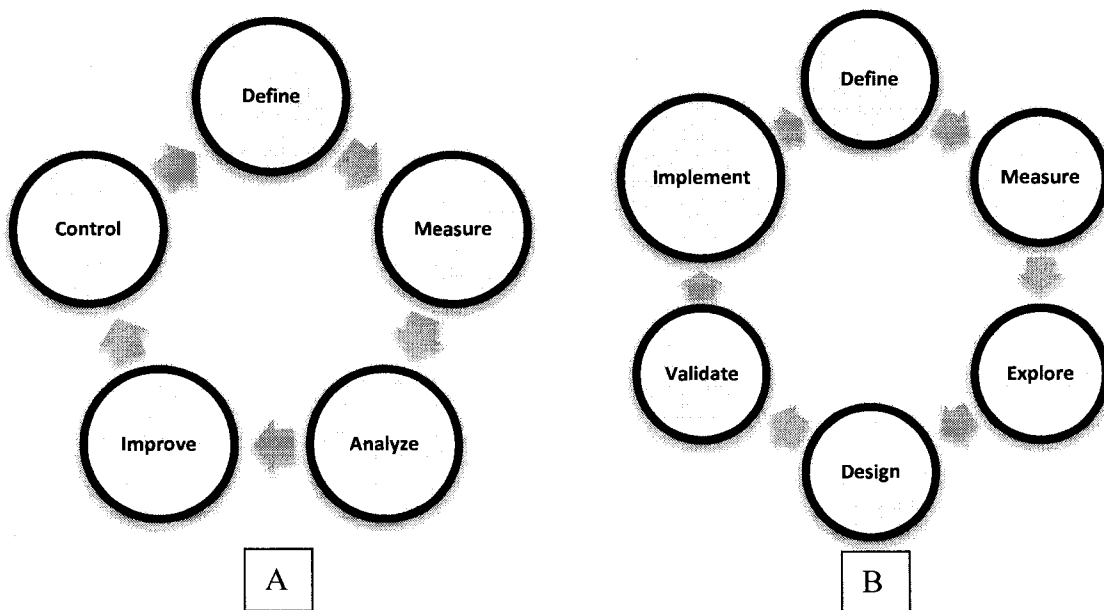


Figure 5: Six Sigma Cycles for existing processes (A) and for new processes (B)

As shown in Figure 5, Six Sigma consists of a specified lifecycle. Figure 5.A. is the lifecycle used for existing processes, and Figure 5.B. is the lifecycle used for new processes. Each step of these lifecycles follows certain objectives and approaches and there are usually some recommended tools. During the *define* phase, the scope, benefits, and plan

of the project are spelled out. In addition, the target processes are specified and mapped. Then, the current state of the process is *measured* and studied. In the next phase, *analysis*, the cause and effect analysis is done to identify the main reasons behind the defects in the processes. The *improvement* phase tries to provide an alternative solution to reduce the defects in the processes. Finally, the *control* phase tends to keep the achieved results by ongoing measurement and monitoring the trend (Trusko, et al., 2007).

Some tools known to be useful in the method are: Kano's model, which helps with capturing customer requirements, SIPOC (Suppliers, Inputs, Process, Outputs, Customers), which is a statistical software for identifying the predominant family of variation or inconsistencies (Trusko, et al., 2007). There are several other tools and charts used with this method like affinity diagrams, benchmarking, brainstorming, flow charts, GANTT charts, cycle time analysis, scatter diagrams, histograms, and failure modes and effects analysis (Vonderheide-Liem, et al., 2004 pp. 34-35). In summary, Six Sigma is highly dependent on statistical methods and tools.

The indicators usually measured during a Six Sigma process are defect opportunities, defect per unit and defect per million opportunities (Vonderheide-Liem, et al., 2004 p. 36) (Trusko, et al., 2007), which make this process somehow closed and limited to what has been dictated in the methodology and not what the real needs of the organization are.

Six Sigma is difficult to use for processes that do not contribute to the bottom line or when their sole objective is not serving the customers. It is very dependent on the availability of the data and it is hard to use in case of complex and interdependent processes as is the case with healthcare clinical processes (Vonderheide-Liem, et al., 2004 p. 39).

2.1.3 Lean Thinking

Lean Thinking, or simply *Lean*, is a quality method pioneered by Toyota (Vonderheide-Liem, et al., 2004 p. 69) to address the challenges of automakers in the early 90's for delivering what customers were looking for – variety in car models at the time. Lean is about shortening the cycle of a process and only doing those activities that provide value

for the customers. All other activities are considered waste and should be eliminated from the process cycle. Lean Thinking uses five steps to improve processes.

- First, the activities providing value are specified,
- Second, the process flow and sequence of activities are illustrated,
- Third, the activities with no value are removed from the cycle,
- Fourth, the services for customers are changed to be ready exactly when they want it and not sooner (pull type services), and
- Finally, the process is improved or remaining wastes are removed in the next iterations.

This cycle is repeated continuously to improve a process (bizmanualz, 2005). In other words, the core of Lean Thinking is value stream, flow, pull, and perfection (Vonderheide-Liem, et al., 2004 p. 70).

The critical success factors of this approach are the support received from top-level management, the authority operational managers have, a detailed implementation plan, teamwork and communication (especially when it comes to cross-functional processes), efficient use of available resources, and, finally, continuous improvement (Keyte, et al., 2004).

Like other classical quality methodologies, Lean Thinking is rather a management approach and, consequently, it uses management and statistical tools. Some of the common tools include simple flow charts and process mapping, time-function mapping, relationship mapping, Pareto charts, control charts, cause-and-effect charts, failure modes and effects analysis, and fault tree analysis (Vonderheide-Liem, et al., 2004 p. 79).

Due to the nature of the approach, however, and its concentration on visualization of the processes and process flow as opposed to statistical measures, there is an opportunity to integrate this method with new BPMS paradigms. Software vendors like Oracle have observed this chance and there have been some efforts to integrate their software with Lean Thinking consulting services. A recent survey, however, revealed that Lean Thinking is still more often used in manufacturing and plant processes and that few adopters use enterprise software to support these practices. One of the main challenges of enterprises in using the supporting software is integration with the existing supporting software for each individual process across the organization (Masson, et al., 2007).

2.1.4 Business Process Reengineering

Business process reengineering (BPR) is one of the well-known improvement methods from the early 1990s. This method has gained more attention after publication of the book called *Reengineering the Corporation: A Manifesto for Business Revolution* by Micheal Hammer and James Champy (Defenselink, 2003). Although BPR does not get the same attention as it used to in the 90s, some of the issues that caused Hammer and Champy to think a business revolution is required still exist and are even more serious in the e-business era. As indicated in (Defenselink, 2003), some of the issues businesses encounter are: unpredictable business environment, customer expectation for customized and high quality products, variety of selection, services, and high responsiveness. Furthermore, since BPR has been used for years in several practices and many different methodologies have been implemented around it, reviewing its proven steps and best practices can be helpful for us.

The classical definition of BPR by Hammer and Champy, which goes back to 1993, is “the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed”. The objective of BPR is a complete reinvention of the business processes and not incremental improvement.

There are several methodologies for implementing BPR. Although most of them use the same principles introduced by Hammer and Champy, finding a guideline to follow might be challenging. To solve this problem, (Muthu, et al., 1999) reviewed existing methodologies and introduced a consolidated framework and coherent methodology. Figure 6 illustrate the common steps suggested in this methodology.

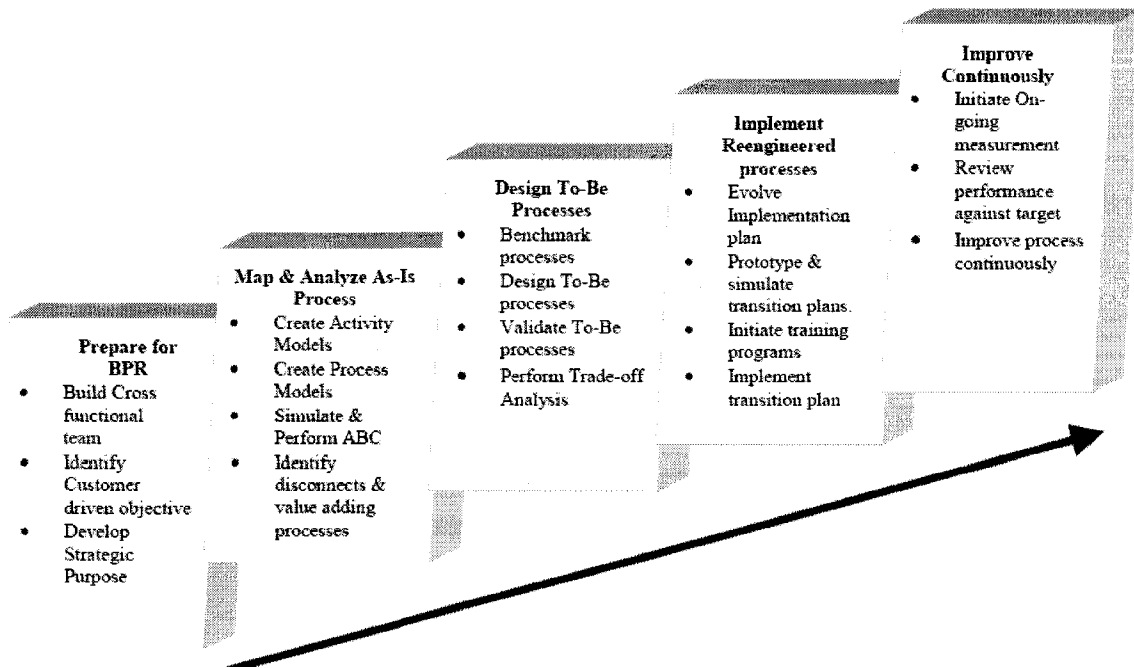


Figure 6: BPR methodology steps (Muthu, et al., 1999)

As suggested in (Defenselink, 2003) and (Prosci, 1999) the critical success factors that should be considered for a BPR project are:

- clear understanding of reengineering,
- strong executive leadership and support,
- appropriate reengineering teams,
- organizational commitment, ownership, and accountability,
- actionable business case,
- clear and measurable objectives, and
- continuous measurement of results.

BPR supporting tools are usually traditional modeling and analysis tools, which can be considered one of the reasons for failed BPR projects. Hence, proper selection of appropriate and more comprehensive modeling tools is an important factor in BPR projects (IEEE Computer Society, 1994). Information related to some of the common tools used for BPR is gathered in (University of Toronto, 2007).

2.1.5 Balanced Scorecard

In early 1990's Robert Kaplan and David Norton developed a management method to address some of the inadequacies of previous methods and to provide a guideline for what needs to be measured in an organization to sustain ongoing growth in the information era (Arveson, 1998).

Balanced scorecard is “a method to organize, communicate, and measure performance on the most important aspects of the organization based on its business plan and strategic goals” (Vonderheide-Liem, et al., 2004 p. 87). The objective of Balanced Scorecard is to measure the high-level goals in a quantitative manner. One of the most important principles of balanced scorecard is concentration on measure-based performance management. In other words, to improve anything in the organization, the appropriate indicators should first be defined and measured (Arveson, 1998).

Balanced scorecard looks at the organization from different perspectives and makes sure all aspects perform as expected based on the organization's objectives. In order to have a balanced scorecard, the four main domains of customers, finances, operations, and employees should perform as expected (Vonderheide-Liem, et al., 2004 p. 89). Operations and employees are also called “Internal business processes”, and “learning and growth” (Arveson, 1998). Figure 7 illustrates a combination of models depicted in both mentioned references to illustrate the four main performance perspectives in balanced scorecard.

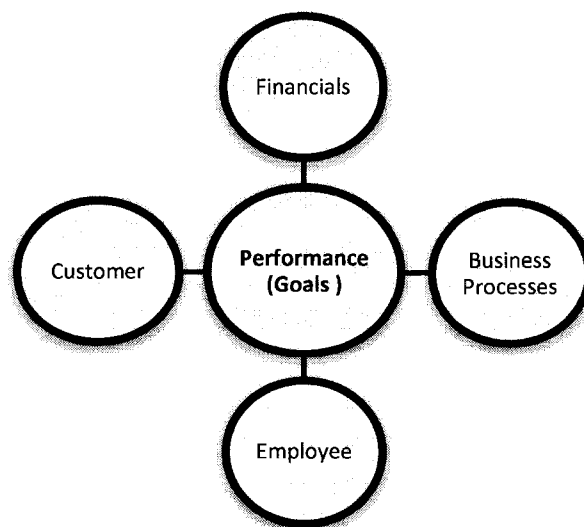


Figure 7: Balanced scorecard's four performance perspectives

Although there are varieties of approaches for implementing balanced scorecard, according to (Vonderheide-Liem, et al., 2004) the most common one is a six step methodology. Figure 8 illustrates these six steps as well as a summary of what needs to be done in each step based on the description provided by (Vonderheide-Liem, et al., 2004).

The critical success factors for balanced scorecard projects are strategic management support of the project and involvement in specifying goals and objectives, cultural change and education in whole organizations to understand measure based management and feedback process, and appropriate selection of the most important indicators with concentration on the outlined objectives (Vonderheide-Liem, et al., 2004).

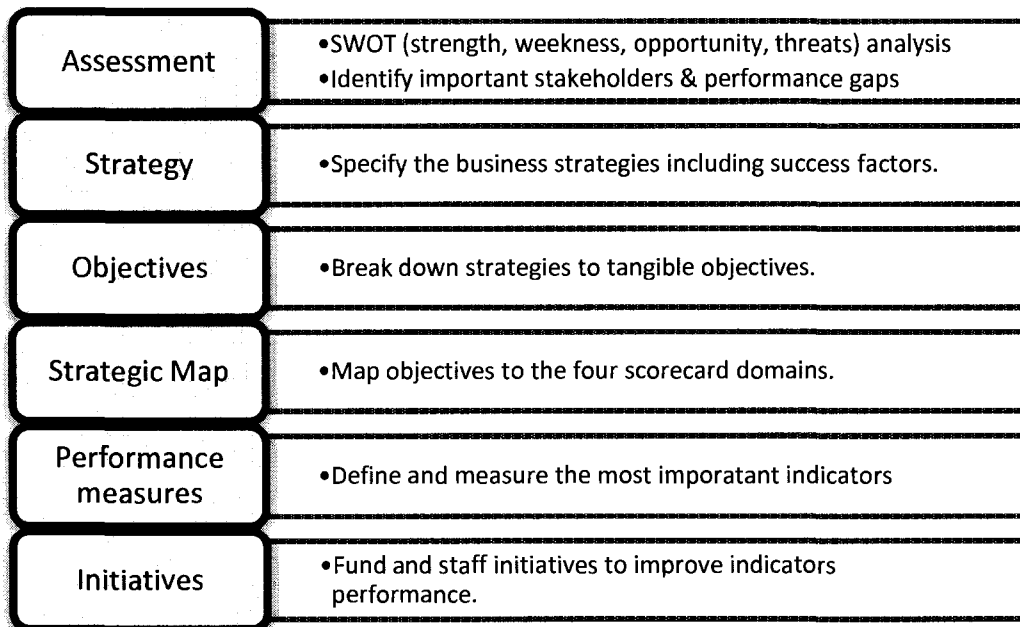


Figure 8: Balanced scorecard project steps

Due to its measurement based nature, balanced scorecard is one of the performance measurement methods in which different information systems and computerized tools can be utilized to move it to the next level. Many organizations now use BI tools and real-time information systems to support their indicator measurements and scorecards generation activities. In addition, different types of charts and report formats are used to show the measured indicators including spider diagram, and color coded report card (Vonderheide-Liem, et al., 2004). While most of the tools are good in demonstrating measures and re-

port to the high-level managers, the utilized methodology to perform the monitoring and improvement in the process level is not specified and practitioners should select the most appropriate methodology in their context (Vonderheide-Liem, et al., 2004 p. 92).

Balanced scorecard and our methodology are complementary in a corporate performance management project. As indicated, one of the four domains of balanced scorecard focuses on business processes, which need to be monitored and improved to address the targets of defined high-level indicators.

2.1.6 Summary of Quality and Process Improvement Methodologies

In this section, we have reviewed several quality and improvement methods. —Table 1 provides a summary of these methodologies including their objectives, steps, tools, and success factors.

Reviewing the literature related to quality and process improvement methodologies, helped us gain a better understanding about existing methods for process improvements and the common steps used in these methodologies. We used this knowledge as a base for the development of our goal oriented process performance monitoring methodology introduced in Chapter 5. In addition, we investigated the tools currently used in these methodologies and their shortcomings in current e-business environments that we addressed in our suggested methodology and its supporting tool.

Table 1 Summary of Reviewed Methodologies

	Six Sigma	TQM	Lean Thinking
Objective	Reduce variation	Elimination of waste	Reduce non-value activities
Steps	Define Measure Analyze Improve Control	Preparation Planning Assessment Implementation Diversification	Identify Value Define Value Streams Determine Flow Define Pull Improve Process
Tools	Statistical management	Statistical management	Statistical Management Modeling and visualization Supporting software exists
Success Factors	Deployment plan Active participation Project review Project selection Project tracking	Participative Management Continuous improvement Teamwork	Leaders support Detail Implementation plan Teamwork & Communication Efficient use of resources Continuous Improvement
	BPR	Balanced Scorecard	The information presented in this table about Six sigma and Lean thinking methodologies is based on: (bizmanualz, 2005)
Objective	Reinvention & Radical change of processes	Quantitative evaluation of high-level goals	
Steps	Prepare for BPR Map & Analyze As-Is Process Design To-Be Process Implement Reengineered processes Improve Continuously	Assessment Strategy Objectives Strategic map Performance measures Initiatives	
Tools	Old fashioned process modeling tools Notations like IDEF	Charts Report Card Supporting software and information systems	
Success Factors	Clear understanding Leaders support Appropriate team Commitment Clear objectives Continuous evaluation	Management Commitment Use of outside consultant Cultural Change Select important measures only	

2.2 Business Process and Goal Modeling Languages

2.2.1 Common Languages

Graphically displaying and documenting business processes is called Business Process Modeling. This is a structural method that tends to help stakeholders analyze the processes and find possible points of improvements. In the course of modeling a process, one usually specifies the defined activities performed by different parties involved in the modeled process (Weiss, et al., 2006). According to (Mili, et al., 2003) a business process and its surrounding area consist of activities, events, resources, roles and actors, functions, organization and hierarchy. In addition, as indicated and modeled in (List, et al., 2005), a business process context includes process goals, enterprise goals, and measures as well as process deliverables. Therefore, business process modeling notations should be able to model the specified factors about the process. A business process modeling language should be able to answer the famous W5 questions - Why, What, Who, Where and When (Weiss, et al., 2005)(Weiss, et al., 2006). While answering the last four questions helps with defining the process itself, answering the first question – why – helps with specifying goals and requirements behind a process. Although goal modeling and traceability between the initial requirements and the implemented process is an important feature for process management, there exists few process modeling notations that support goal modeling (List, et al., 2006).

In order to use a process modeling notation in our process monitoring methodology, this notation should support process modeling, goal modeling, traceability between goal models and processes and goal model evaluation mechanisms, otherwise we would not be able to demonstrate the impact of processes on organizational goals, which is one of the main intentions of our monitoring methodology. Therefore, we have done a survey on well-known process modeling notations to compare their capabilities against URN (User Requirements Notation) - our modeling language of choice. URN is introduced in section 2.2.2.

One of the most famous and widely used process modeling notations is Business Process Modeling Notation (BPMN). The main objective of this new modeling notation is to provide an easy to understand language for all business users with different roles and

levels of expertise. Based on (bpmn.org, 2007), so far 44 implementations of BPMN exist. According to (White, 2004), the four basic categories of elements supported by BPMN are Flow objects, Connecting objects, Swim lanes, and Artifacts. These basic elements provide support for modeling events, sequence flow, message flow, specifying roles, and process hierarchies. Despite its good support for process modeling and user-friendly nature, BPMN does not support any kinds of goal modeling or traceability between goal models and process models.

The Unified Modeling Language (UML) is another widely used modeling language. UML2 is the latest version of the UML and includes 13 notations. According to (Mili, et al., 2003 p. 47) UML2 does not explicitly support process modeling. Practitioners who are familiar with UML use UML activity diagrams (AD) for this purpose. This modeling notation, however, is not as user-friendly as BPMN and has been designed mostly having software engineers as its target audience. Activity diagrams support modeling events, sequence flow, message flow, roles, and hierarchical process modeling. Furthermore, AD do not provide the capability for goal modeling and traceability between goal models and process models (List, et al., 2006).

Event Driven Process Chain (EPC) has been developed by Sheer, Keller and Nuttgens within the framework of Architecture of Integrated Information System (ARIS) (Ferdian, 2001 p. 6) with the same goal as BPMN – to make the process modeling simple for business users (List, et al., 2006). EPC supports events modeling, sequence flow, message flow, and roles. In addition, it provides hierarchical and sub-process modeling using complex function (List, et al., 2006). Again, EPC does not support goal modeling and traceability between goals and processes (List, et al., 2006).

Yet Another Workflow Language (YAWL) is another business process modeling language, which addresses some of the inadequacies of other existing languages for modeling workflow patterns. YAWL supports most of the requirements of a process modeling language through its extensive support for workflow patterns. Unlike some of the discussed workflow languages YAWL also supports process hierarchy modeling through composite tasks. It, however, does not provide goal modeling capabilities. (Aalst, et al., 2002).

Integrated Definition Method 3 (IDEF3) is another process modeling language developed with the goal of being easy to use. In addition, this language is intended to be used by both individuals and teams with large scaling ability. Using process descriptions and the ability to generate multiple view of a process, IDEF3 gives users more flexibility in process documentation and lets them deal with uncertainties during the modeling process. IDEF3 supports sequence flow but does not support events and data flow. In addition, it does not determine roles. It, however, has a decomposition mechanism for illustrating process hierarchies and allows modeling of processes at different levels of abstraction (Mayer, et al., 2005). As the other process modeling notations discussed so far, IDEF3 does not provide goal modeling or traceability between goals and processes (List, et al., 2006).

In contrast with the above languages that offer no support for goal modeling, *i** and the Non-Functional Requirements framework (NFR) are two modeling languages that support goal modeling but have very limited support for process modeling. *i** has been introduced to address organizational context and rationales behind the requirement or answer the why aspects of the requirements. *i** is capable of modeling goals, tasks, and resources and demonstrates their dependencies and mutual contributions using various types of links. Furthermore, it allows users to model roles as organizational actors (Yu, 1997). NFR, on the other hand, deals with *softgoals* or the goals that are hard to express (e.g. flexibility or security). NFR allows user to model softgoals in a graph structure and specifies their levels of mutual contribution. In addition, NFR allows users to specify if root goals are satisfied by the selected goals on the leaf by using an evaluation mechanism (Mylopoulos, et al., 1999).

The Extended Enterprise Modeling Language (EEML) was developed to provide comprehensive process modeling across a number of layers. This modeling language consists of four modeling domains – process modeling, resource modeling, goal modeling, and data modeling. EEML provides all the functionalities required by a process modeling language including modeling events, sequence flow, roles, and process hierarchies (Krogstie, 2005 pp. 10-26). Although it supports goal modeling, it is not as comprehensive as URN (section 2.2.2.1) in this regard. For example, it has only one type of goal unlike URN, which supports hard goals and soft goals. Furthermore, the relationship

provided between goal model components is only a logical decomposition (and, or, xor) and does not provide contribution and dependency relationships. In addition, it does not have a goal propagation mechanism (Krogstie, 2005 pp. 44-49).

To conclude, the process modeling languages investigated each have their own strengths and weaknesses. Most of the process modeling languages do not provide suitable capabilities for goal modeling. On the other hand, goal modeling languages, although they provide goal modeling capabilities, they have very limited support for process modeling. The only modeling language that supports both is EEML, whose goal modeling capabilities are weaker than common goal modeling notations. Furthermore, EEML is not a standardized modeling language.

Based on our investigation none of the existing process and goal modeling languages provides the same capability as the User Requirements Notation (URN). Although URN needs some improvements to support more workflow pattern (Mussbacher, 2007) its overall support for process and goal modeling, and its meta-model extensibility make it a suitable choice for our application. In the next section, we introduce URN in more detail. A more detailed comparison of URN and other workflow languages is available in (Mussbacher, 2007) and (Mussbacher, et al., 2008).

2.2.2 User Requirements Notation

URN is the only standardization effort (ITU-T, 2003) towards a graphical modeling language that supports both process and goal modeling. URN was first developed to address the documentation, discovery, completeness, and correctness of functional and non-functional requirements for new or evolving reactive and distributed systems (Amyot, 2003), but it has been used for other applications since, including business process modeling (Weiss, et al., 2006). URN has been designed with the capabilities required to address the challenges of early stages of requirement gathering for complex systems. URN combines two complementary and integrated notations (Amyot, 2003). The first one is Use Case Map (UCM), which is a workflow or process modeling language with the ability to depict sequence flows, roles, organization units, and process hierarchies. In other words, UCM provides the answer to the what, where, who, and when questions about a process. The second notation is the Goal-oriented Requirement Language (GRL), which

is based on i^* and the NFR framework. GRL can depict complex goal models with different kinds of links between model components and provides the ability to analyze the models, answering the why question about a process (Amyot, 2003). Furthermore, URN provides traceability between UCM and GRL model components through URN links. Consequently, it is possible to show the relationship between process model elements and goal model elements.

2.2.2.1 Goal-oriented Requirement Language

The Goal-oriented Requirement Language is a combination of the core concepts of i^* and the NFR framework. GRL uses i^* model elements and NFR evaluation mechanism to provide a powerful goal modeling and evaluation language. Although GRL is mostly focused on modeling non-functional requirements (high-level goals), it allows one to specify alternative functional requirements (tasks, processes, or solutions) that help with satisfying non-functional requirements. Concisely, GRL can be used to demonstrate which the alternative among several ones has the best global impact on the defined goals based on a set of defined criteria (Amyot, 2003) (Ghanavati, 2007).

GRL models consist of three main types of symbols, intentional elements (goal, task, softgoal, and resource), intentional relationships (decomposition, contribution, correlation, and dependency), and actors. The model elements are called *intentional* because they specify the answer to the why question about the selected requirements and demonstrate alternative options and selection criteria. (Yu, et al., 2006).

Softgoals are cloud shaped symbols used to represent high-level goals with a level of uncertainty that can never be completely satisfied. Softgoals can be connected together using different GRL contribution links (i.e. and/or) with various contribution types (e.g. Break or Make). Softgoals can be decomposed to lower levels of abstraction until they can be illustrated as tangible goals (hard goals) or operational tasks. During this breakdown, decomposition links can be used to specify sub-tasks, and OR decomposition links can be used to demonstrate tasks used for achieving goals. Furthermore, one can use actor and actor boundaries symbols to specify the actors' actions or a part of the model related to an actor. One can use dependency links to show the dependency of actors on each

other for an intentional element. Modelers can also use belief to demonstrate the rationale behind depicted model elements in the goal model (Amyot, 2003)(Yu, et al., 2006).

Finally, GRL supports an evaluation mechanism used to measure the impact of one selected alternative (task, solution, process, or command) on satisfaction levels of high-level goals. The evaluation is done by giving an initial degree of satisfaction to lower level tasks and goals. Thereafter, a propagation algorithm calculates the degree of satisfaction in other goals in the model. The propagation algorithm uses contribution types and satisfaction level of contributors to specify the satisfaction level of a contributee (Amyot, 2003). Recent additions to the GRL evaluation mechanisms include a new quantitative evaluation algorithm and GRL strategies (Roy, 2007 p. 56) giving more power to the user for comparing various alternatives in different situations. For instance, one can define different satisfaction levels in each strategy and compare the results in order to find the best trade-off.

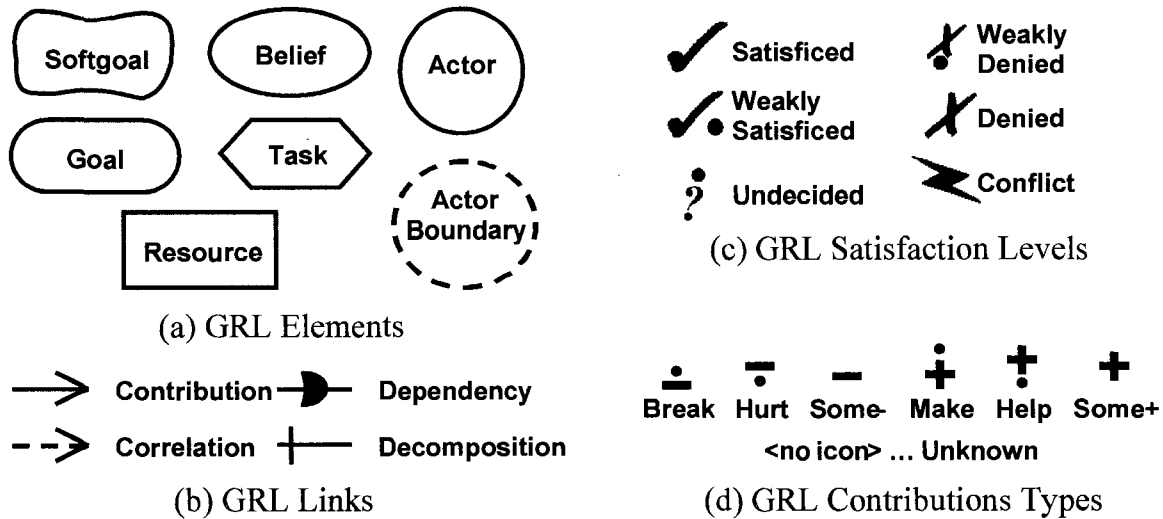


Figure 9: Summary of GRL notation (Amyot, 2003)

Figure 10 illustrates a GRL model with evaluation results. This model consists of four tasks (hexagons) and four softgoals. One of the tasks (Sharing Treatment...) is decomposed into two sub-tasks from one side and connected to a softgoal (Adequate Communication) from the other side. The two sub-tasks are initialized with satisfaction levels (-12 for Dictate Discharge Summary and 50 for Transcription) and the rest of the model is

evaluated based on these values. This goal model is part of the patient discharge process scenario used in Chapter 3.

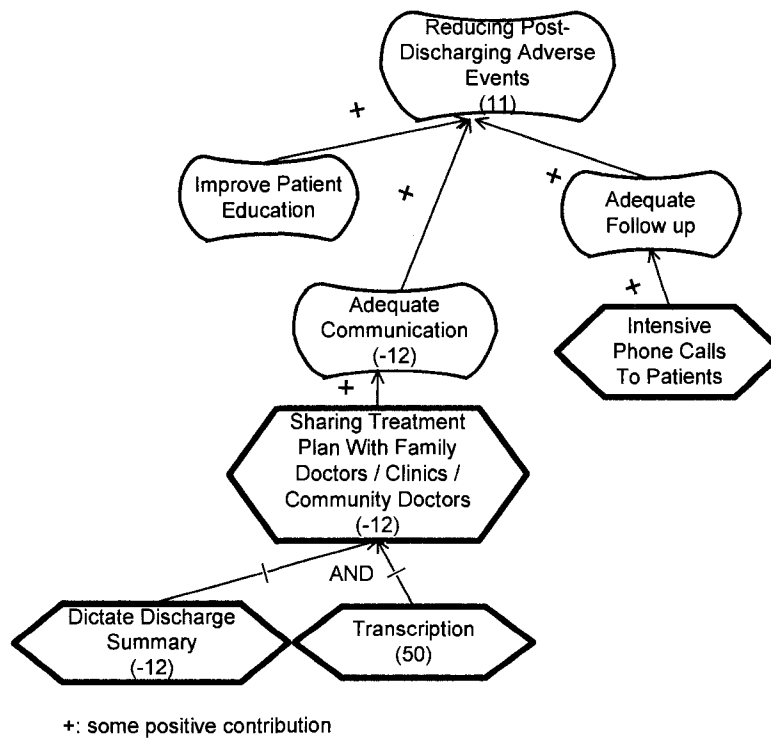


Figure 10: Sample GRL model with evaluation

2.2.2.2 Use Case Map (UCM)

Use Case Map (UCM) is the notation in URN used for modeling operational requirements and high-level design. Figure 11 gives a summary of the UCM notation. Responsibilities are the basic elements of UCM models and represent typically a task or a sub-process performed by an actor or a system. Responsibilities are connected together, using casual paths, to form scenarios starting with Start points and ending with End points. A scenario describes a part of the system's behavior. A Use Case Map model may consist of multiple scenarios that describe possible behaviors in the system. Using forks and joins, one can define alternate or parallel paths in a scenario as well as overlapping and synchronized scenarios. To control scenarios, UCM can be used to define conditions on decisions points (alternate paths). Using stubs – diamond symbols – one can define hierarchical structure in process models. UCM provides two kinds of stubs – static and dynam-

ic. While static stubs can contain one and only one sub-map, dynamic stubs may contain multiple sub-maps, one of which is selected based on the defined conditions. Sub-maps are also called plug-ins. Finally, UCM also supports waiting mechanisms in the form of waiting places and timers.

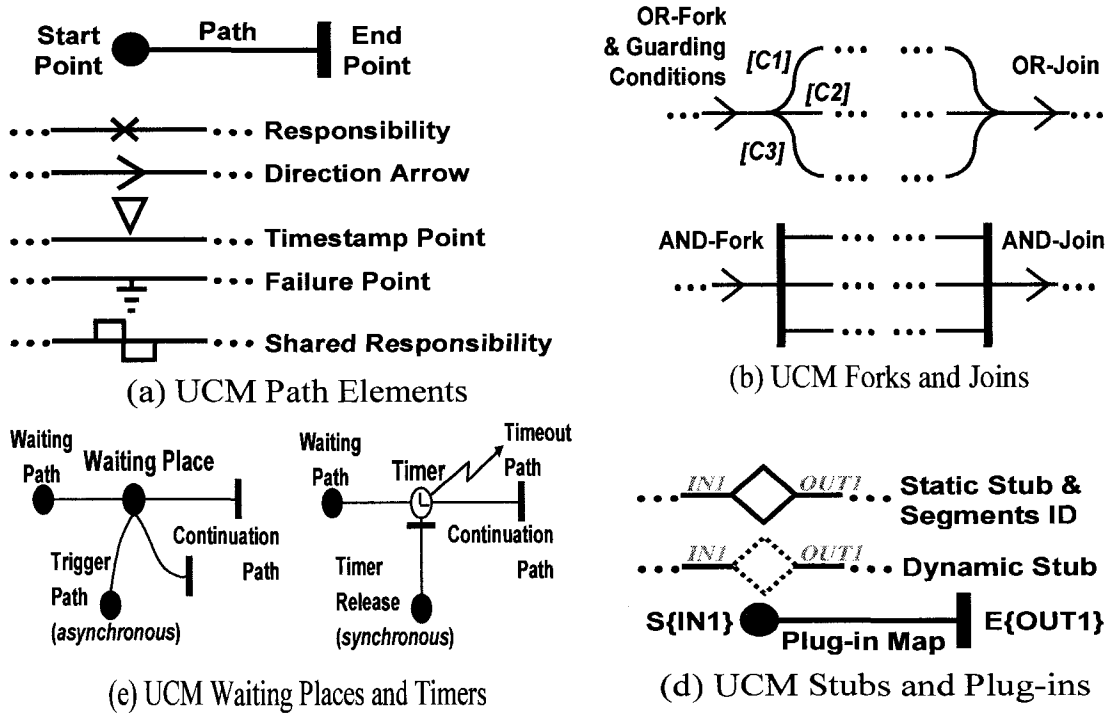


Figure 11: Summary of UCM notation (Amyot, 2003)

Figure 12 illustrates a sample UCM model with one of its plug-ins. The main model has one start point and two end points. In addition, it has three static stubs that are used to encapsulate the underlying behavior. The CPO Review stub has one input and two outputs associated with the start point and two end points of its sub-map in their respective order. The sub-map contains four responsibilities and one Or-Fork controlled by appropriate conditions. This process is elaborated in more detail in Chapter 6.

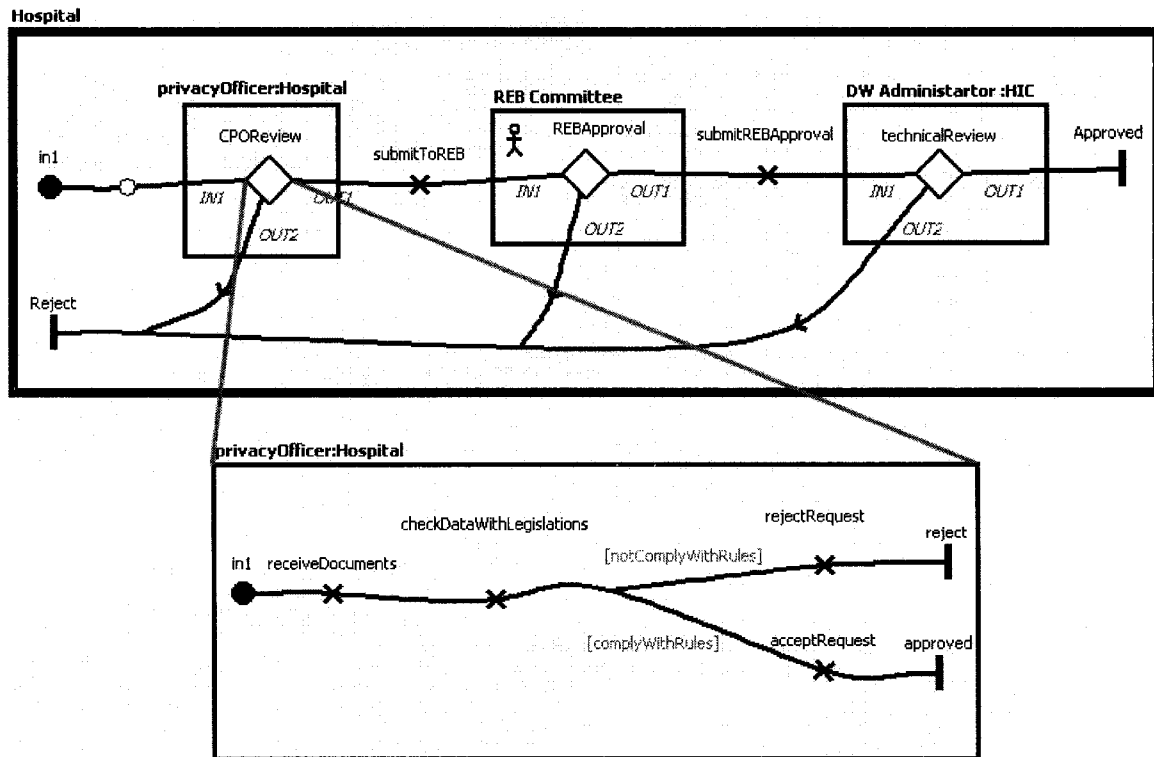


Figure 12: Sample UCM model with a plug-in

2.2.3 URN Applications in the Business Process Domain

Although URN has traditionally been applied to telecommunication systems (Amyot, 2003), it is general enough to support business process modeling in a variety of contexts.

GRL allows users to model business goals. GRL enables us to decompose the goals via its provided links. In addition, lower level goals can be connected to the tasks that need to be performed for achieving the goals.

UCM, on the other hand, can show the same tasks in a chain of activities, a scenario or a business process. Therefore, URN can be used as a whole to connect business goals to operational tasks and study the effect of them on each other.

The research work listed below demonstrated the suitability of URN and its sub-views to model and reason about business processes, goals, and requirements. URN's scenario notation was used to elicit requirements by identifying the different responsibilities and the demands on spatial resolution associated to the actions of each administrative unit in a health information system (Olvingson, 2002). URN's parent goal notations (i* and NFR) were also used to model agent relationships and improvement alternatives to

assist in the analysis and redesign of the patient discharge process in three major Canadian hospitals (Cysneiros, et al., 2004). Early work exploring a more integrated use of both views (GRL and UCM) was done for an information system (Web-based training system) (Liu, et al., 2004). A more integrated view, better supported by tools, was further explored for the modeling, analysis, and evolution of a supply chain management system (Weiss, et al., 2005)(Weiss, et al., 2006).

2.3 Business Process Management Systems

BPMS is used by businesses to design, model, automate, monitor, and finally optimize their processes. It is a revolutionary way of using Information Technology in business. It not only adds value to the business but also provides the ability of using current IT investments. Business analysts and consultants believe that BPMS is one the most recommended investments for process improvement (Rudden, 2007). BPMS helps businesses by automating and managing business rules and processes. Alignment between corporate goals and operational businesses processes is another advantage that recent BPMS try to bring to the table (Heß, 2006). The benefits of using BPMS are summarized in Table 2 based on (Rudden, 2007) (Silver, 2006b)(Appian Corp., 2006).

Table 2 BPMS Advantages

BPMS Values	How and why?
Efficiency	Process automation
Agility	Graphically designed and changeable processes
Compliant and standardization	Using rule repository
Visibility and Manageability	Data gathering, monitoring, and process visibility
Cost Effectiveness	Reusing existing components with little programming
Business Integration	Using web services and XML or “standard-based middleware”

Business Process Management Systems provide their capabilities through a collection of tools and services integrated together using a layered architecture. The core modules of this architecture are:

- BPM Engine,
- Software Integration Engine,
- Process Modeling, and
- Process Monitoring

as illustrated in Figure 13.

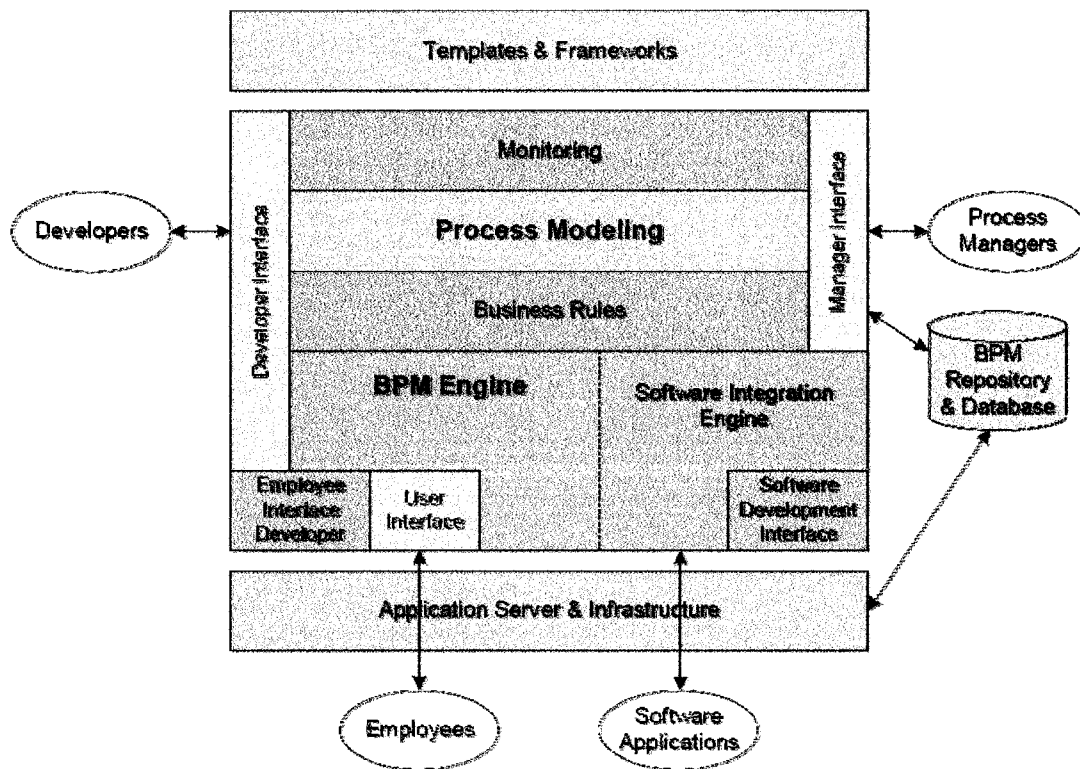


Figure 13: One possible architecture (Miers, et al., 2005)

BPMS address part of the problems indicated in section 1.2 including the integration between process monitoring tools and running processes. Not all BPMS systems, however, are capable of getting connected to other information systems that provide information related to the processes. In addition, most of them do not specify a guideline for using dispersed data across an organization in a coherent data model. In the thesis of (Chen, 2007), a comprehensive study of existing BPMS solutions in the market compares 16 BPMS solutions against 12 criteria. The four main capabilities that most of the leading BPMS solutions in the market do not cover are:

- Business goal modeling,
- Business goal evaluation,
- Traceability between goals and processes, and
- Contribution to data modeling.

2.4 Summary

In this chapter, we have reviewed the related work and background information required for this thesis.

First, we have investigated some of the existing process improvement and quality frameworks to gain more knowledge about their objectives, common steps, tools, and critical success factors. This review provides us with enough background knowledge to be able to specify the required steps for our URN-based process improvement methodology. In addition, we will be able to consider proven success factors in our methodology and address some of the shortcomings of existing improvement methodologies. Table 1 contains a summary of this study.

Furthermore, we have studied several process modeling languages and their capabilities for process modeling, goal modeling, and goal evaluation. Most of the existing process modeling languages have a very limited support for process modeling. On the other hand, the existing goal modeling languages do not support process modeling. Among the investigated modeling languages only two of them (EEML and URN) support both process modeling and goal modeling. Due to its comprehensive goal modeling and evaluation along with process modeling, we have selected URN as our notation and then described it in more detail.

Finally, we have discussed the inadequacies of existing Business Process Management Systems for goal-oriented monitoring of business processes.

Chapter 3. Problem Elaboration

In this chapter, we use an important process from the healthcare sector to achieve the following objectives in the research process:

- Illustrate the capabilities of URN for modeling processes and goals;
- Justify the need for extending URN to support KPI modeling;
- Demonstrate the lack of tool support for process monitoring with existing URN toolsets;
- Introduce some of the methodology steps that will be elaborated in Chapter 5 to provide a process monitoring method with its supporting toolset as we have experienced it in this test scenario.

The selected scenario is the patient discharge process at The Ottawa Hospital (TOH). TOH is an academic health sciences centre with three campuses around the city. TOH has around 11,000 staff and trains around 3,500 health care professionals each year. TOH handles around 120,000 emergency visits and does around 10,000,000 lab tests per year (The Ottawa Hospital, 2007).

In a recent effort, TOH developed a Data Warehouse that integrates hospital records from seven operation systems since 1996. While the developed warehouse does not violate the privacy of patients, it increases the accessibility of data for the purpose of research. Until fall 2006, the TOH Data Warehouse (TOHDW) included “data from more than two million records”. TOHDW is updated on a weekly basis.

Although TOHDW has initially been used by researchers, TOH tries to make it more accessible to all stakeholders and desires to use it for applications (clinical, administrative...) other than just research. One of these applications is improvement of the existing business processes and another one is the reduction of adverse events.

The patient discharge process is a huge process that starts from the moment a patient is admitted into the hospital to the point where the patient is discharged from the

hospital. There are many tasks in this process that can be monitored and improved to make the quality of care better.

3.1 Selecting the Target Process – Patient Discharge Process

In a monitoring and improvement project the target process should be selected based on business priorities, available resources, and available infrastructure. In other words, a combination of priority and feasibility should be considered to select the best target process toward project success. We have considered these factors for selecting the candidate process for our study.

Based on discussions we had with the process expert who participated in this research, we selected the patient discharge process as the target of our study for the following reasons:

- This is a very important process with a direct impact on one of the hospital main goals, i.e., increasing the quality of care – Figure 16 and Figure 17.
- Inadequacies in this process have a direct impact on some of the post-discharge adverse events that are observed (Forster, et al., 2005). As a result, monitoring of this process and consequent improvements will contribute in increasing health care quality and patient satisfaction.
- The current TOHDW schema provides the information required for monitoring this process. This schema was replicated in our lab and with some modifications can be used for this experiment. This not only reduces the feasibility risks for this proof of concept but also makes the results useable in the actual hospital environment.
- We had easy access to the information related to this process due to participation of one of the physicians who was involved in this project as well as in this process.

3.2 Modeling Process and Organizational Goals

After its selection, we modeled the process and its related goals. We interviewed the process expert in several sessions and gathered the required information to be able to model the process more accurately. The process model was first drafted during multiple interview and brainstorming sessions with one process expert and finally it was validated in a meeting with several process experts to make sure it is as close as possible to the reality and reflects the steps that happen in the actual process. The accuracy of the process model is very important to achieve better and more useful results as an artificial model, not rooted in reality, results in a non-effective monitoring effort (Küng, et al., 2005).

The process models and goal models are illustrated in Figure 14 to Figure 23. As shown in Figure 14, this process starts with patients getting into the hospital. This can happen in two ways. Either patients walk in as an emergency patient or they are introduced to the hospital by an external entity. Depending on the previous step, patients are then either admitted to the hospital through the admin department or the emergency department. Subsequently, the patient is transferred to the general medicine department and, after going through several sub-processes, s/he will be either directly discharged or moved to a waiting place (Figure 15).

A waiting place works like a buffer before patients are admitted to external entities. As depicted in Figure 15, if patients require more treatments or any change in their care plan while they are staying in the waiting place, the required action is performed.

Figure 14 to Figure 17 demonstrate the high-level view of the investigated process and the related business goals. URN stubs have been used to encapsulate the details of lower levels of abstraction. The next level of process detail is shown in Figure 18 to Figure 23.

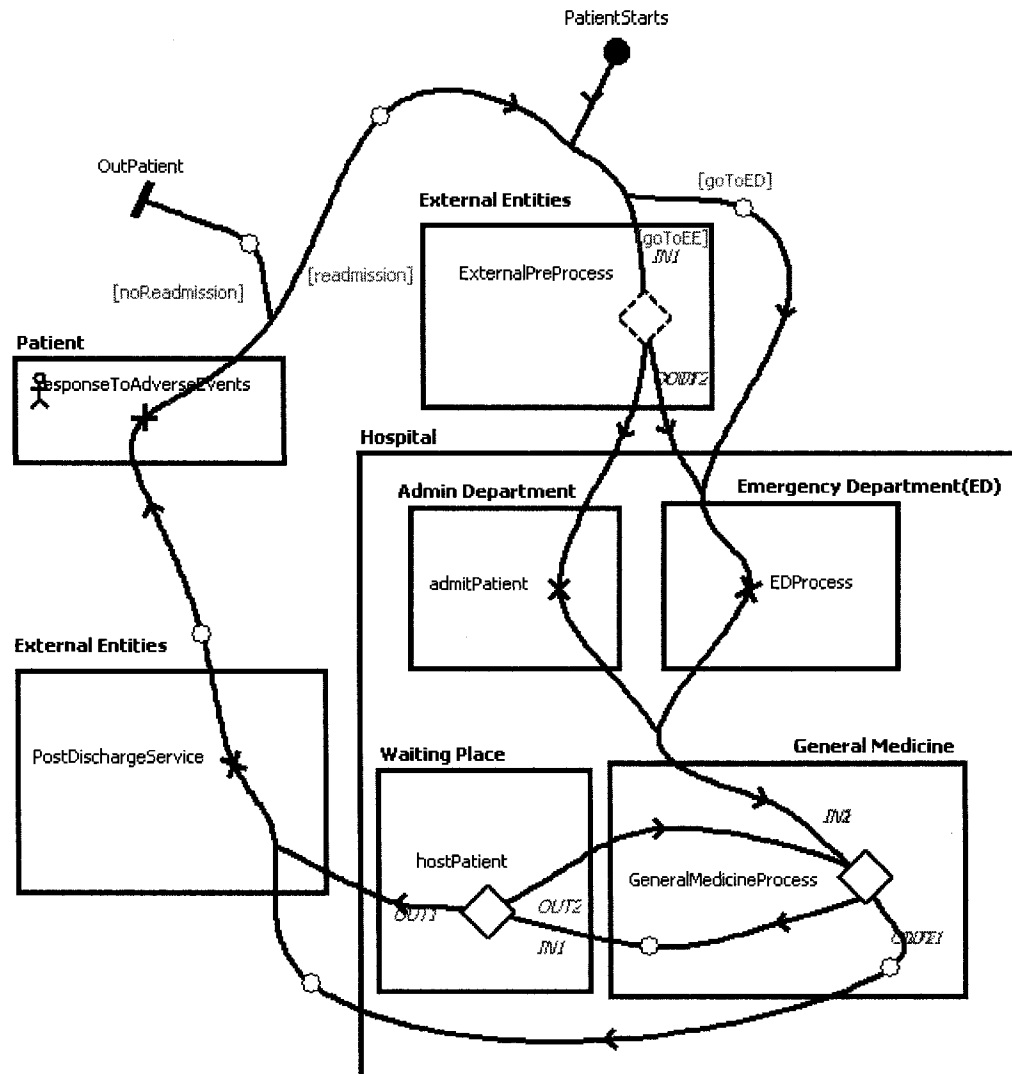


Figure 14: Discharge process – high-level view

After the patient is discharged, there is a risk of post-discharge adverse events occurring. In this case, the patient is readmitted to the hospital. According to (Forster, et al., 2003), 19% of the selected sample group of patients were readmitted to the hospital after discharge due to adverse events. In another study, this was even higher at about 23% (Forster, et al., 2004). As demonstrated in Figure 16, one of the goals of hospital management is to reduce this percentage as much as possible. Post-discharge adverse events introduce risks to the patients' safety. Furthermore, readmission not only is considered a waste for hospital in terms of resources but also has a negative effect on quality of care and reduces the patient satisfaction related to hospital health care services.

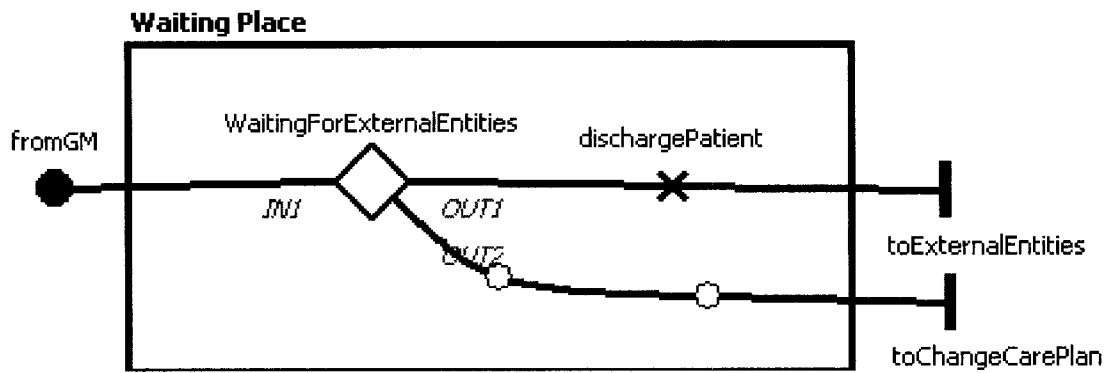


Figure 15: waiting place – hostPatient stub (Figure 14) plug-in

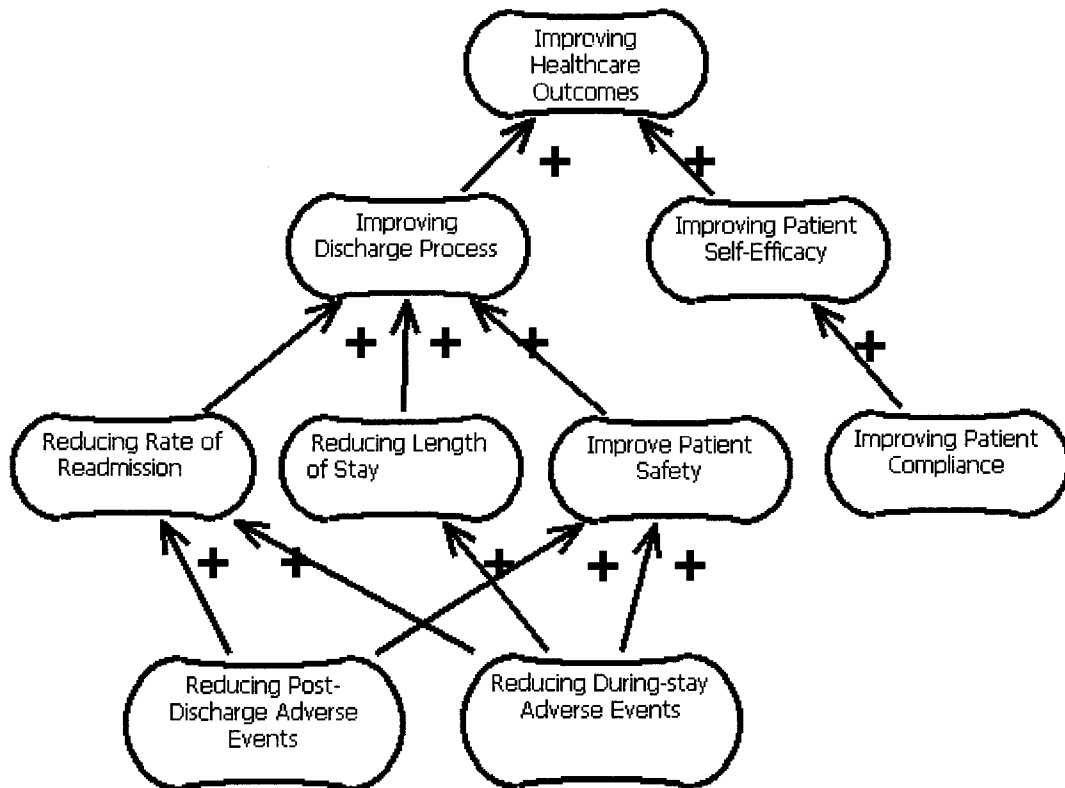


Figure 16: High-level business goals – A

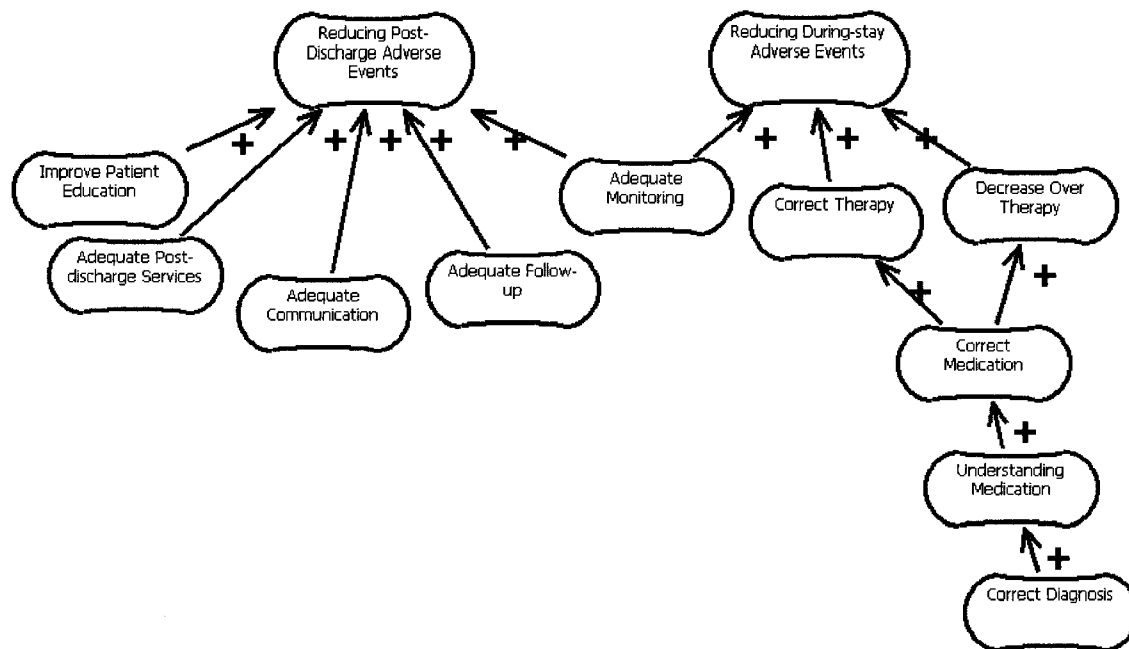


Figure 17: High-level business goals – B (Cont. Figure 16)

Figure 18 illustrates the sequential steps that take place in the General Medicine department. As depicted, this process has two start points (backFromWaitingPlace, enterGeneralMedicine) that refer to two possible ways of transferring a patient to this process. The first way is when a patient is returned from the waiting place because s/he requires a new care plan and the second is when the patient enters the department for the first time. For new patients, the first step clarifies whether the patient can be admitted. Then, based on the symptoms, a care plan is established for the patient as shown in Figure 19. In addition, based on the patient's condition, a discharge plan is also considered. The specified care plan is implemented and then both of the mentioned plans – care and discharge – are revisited and adjusted based on the patient's condition. Consequently, the patient gets to the discharge sub-process. In this step, depending on whether the patient is discharged to home or to an external entity, the sub-process will be different - Figure 20 and Figure 21. We have used a URN dynamic stub in Figure 18 to show that alternative processes may be existing for the dischargePatient stub. Dynamic stubs are very powerful and provide flexibility for process modeling. This sub-process has four exit points to other discharge sub-processes or external processes for patients who are not admitted, discharged, sent to a waiting place, or die.

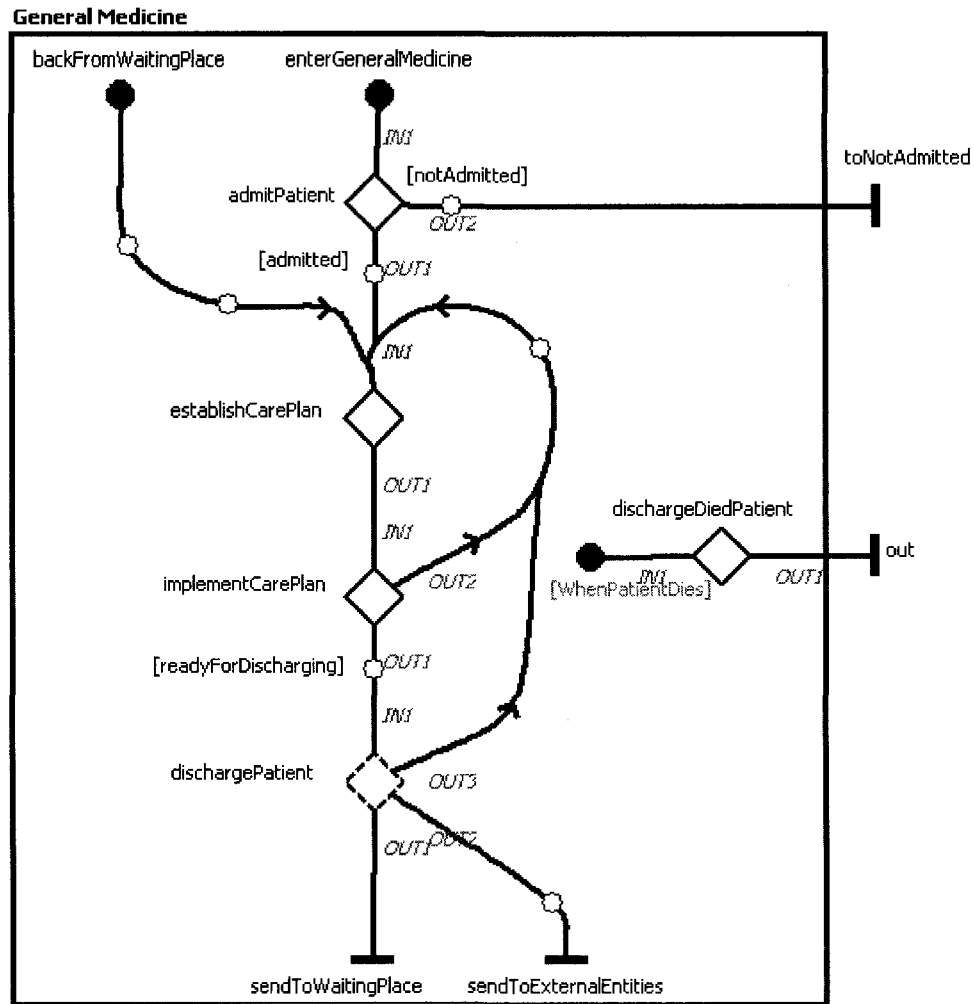


Figure 18: General medicine sub process

Figure 20 illustrates the sub-process for discharging the patient to home. In this case, after performing several tasks and sub-processes that are encapsulated under dischargeProcesses dynamic stub, it is checked to see if the patient's condition requires home care. Then, the patient is discharged to home either with or without homecare. Figure 21 models the same process when the discharge destination is an external entity. In this case the process model is more complicated and we have used AND-Fork and waiting place symbols to depict this process. The AND-Fork shows a patient waiting in parallel for a bed in the hospital's waiting place and admission to external entities. The waiting place demonstrates that the patient should wait until a bed becomes available in the hospital's waiting place. Note that a UCM waiting place (black circle on a path) waits in a process until a condition becomes true, however a hospital's waiting place is a facility that patients are transferred to free up the general medicine resources for other patients in line.

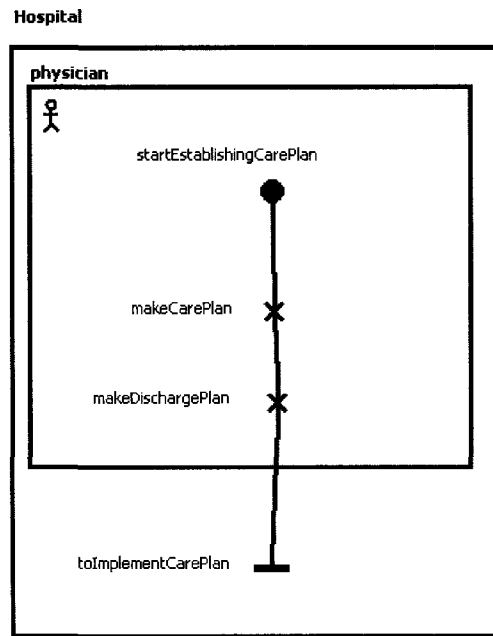


Figure 19: Establishing care plan - plug-in for establishCarePlan (Figure 18)

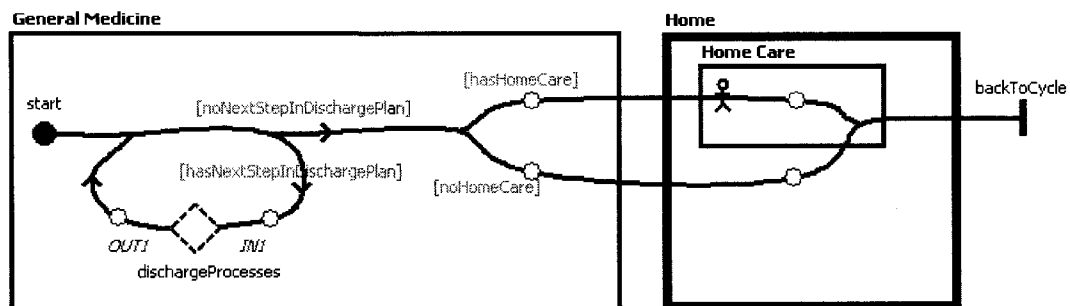


Figure 20: Discharge to home – plug-in for dischargePatient (Figure 20)

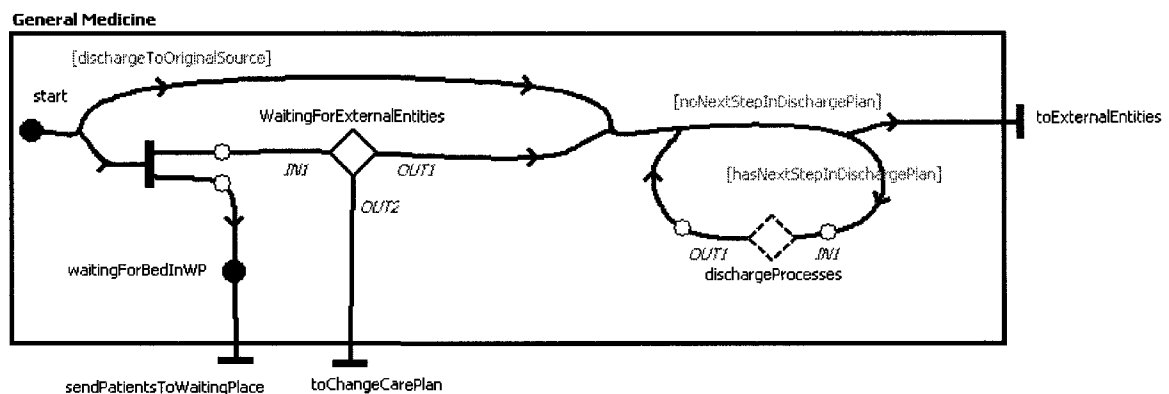


Figure 21: Discharge to external entities – plug-in for dischargePatient (Figure 20)

There are several sub-processes under the dischargeProcesses dynamic stub shown in Figure 20 and Figure 21. Among these sub-processes we elaborate on the *dictation* sub-process (Figure 22), which consists of three steps. First, the condition of the patient, the care plan and other related information useful for patient health record are dictated. Subsequently, transcription is done and, finally, the information is transmitted to community health care providers.

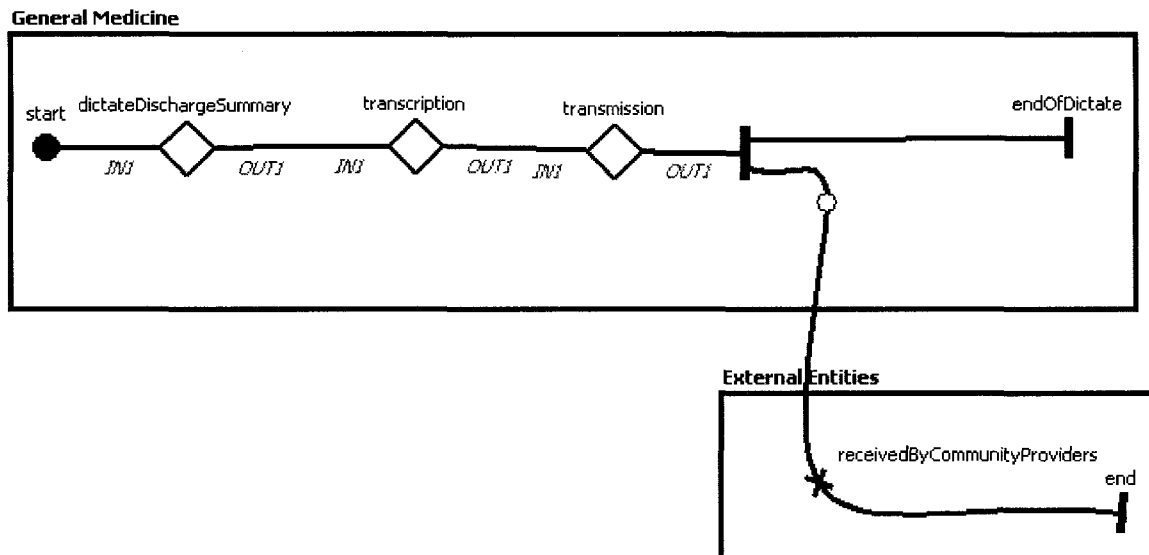


Figure 22: Dictation process – plug-in for dischargeProcesses Figure 20 & Figure 21)

The dictation process in Figure 23 contributes into adequate communication as a sub-task of sharing treatment plan with family doctors clinic and community doctors. Poor communication is known to be one of the main causes for post-discharge adverse events (Forster, et al., 2003). As a result, process stakeholders would like to provide adequate communication and improve this area.

As explained in this section 2.2.2, URN can model processes at different levels of abstraction and in a hierarchical manner using UCM static and dynamic stubs. As illustrated, we have modeled the processes from very high-level processes down to tasks done by different roles. In addition, with GRL, we are able to model the goals of organizations and break them down to reach the tasks used in the process model. Figure 22 (process model) and Figure 23 (goal model) show how URN can be used to model the relationships between process steps (tasks) and the goals and objectives of the organization. In

addition to this visualization, the jUCMNav modeling tool (Roy, et al., 2006) provides a traceability mechanism that allows process authors to link goal models and process models together. Furthermore, GRL's evaluation mechanism allows observing the impact of tasks at the lowest level of the goal model on higher-level goals. These capabilities, if combined with process performance measurement, can provide a powerful monitoring tool that not only evaluates the performance of a process model but also its impact on the goal model.

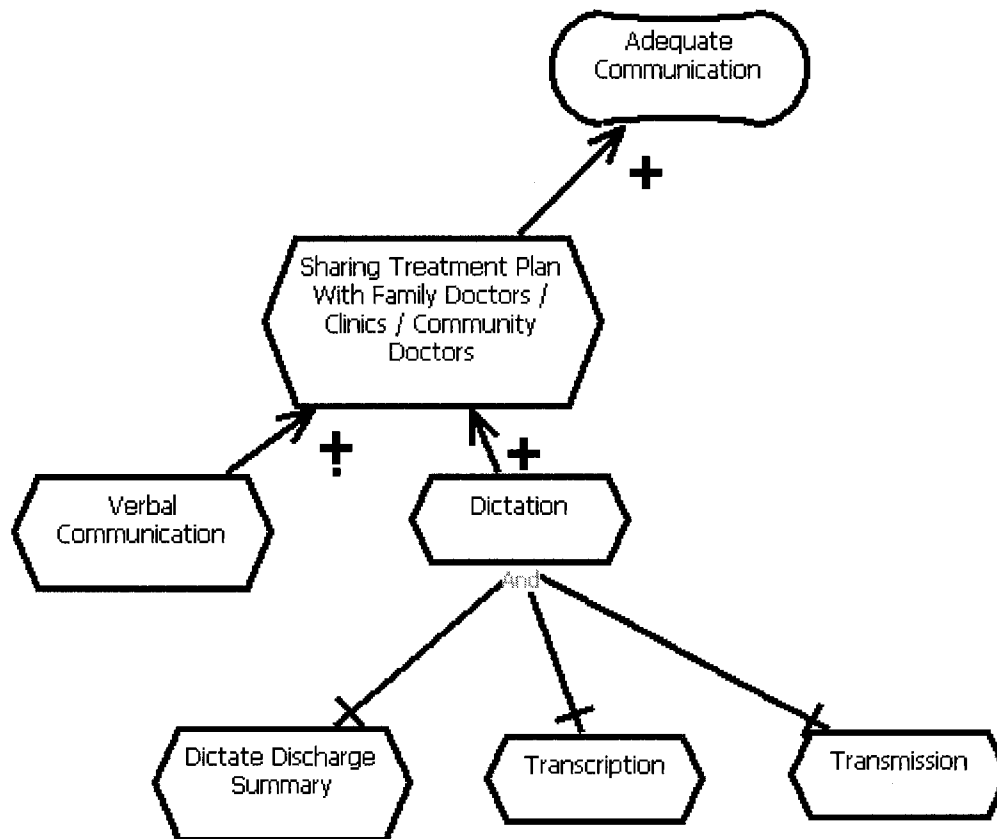


Figure 23: Operational business goals – Includes the process steps in Figure 22

3.3 Defining KPIs and Performance Models

Before any monitoring effort, the points of interest and KPIs on the processes should be specified. According to (Forster, et al., 2004), out of the 76 patients who had post-discharge adverse events, 38 had preventable or ameliorable adverse events. If proper monitoring is done, it can help improve the process by finding the tasks and sub-processes causing preventable adverse events. Based on the interview with the process

professional and the research conducted in (Forster, et al., 2005), one of the main problems in the dictation sub-process (Figure 22) that causes post-discharge adverse events is the existing delay between the time a patient is discharged and the time the required information is transmitted to other healthcare providers (e.g. family doctor). Even though dictation, transcription, and transmission can be done one after another and right away after patients are discharged, due to time limitations by physicians or other high priority tasks, these three steps are done weeks or months after the patients discharge. Therefore, the following KPIs were specified for further investigation of this process:

- The average time lag between discharge and dictation;
- The average time lag between dictation and transcription;
- The average time lag between transcription and transmission;
- Percentage of preventable adverse events.

With current capabilities in URN and jUCMNav, we are unable to model these KPIs and specify appropriate measurement points in the process model. In the next section, we describe the use of DW and BI as sources of information about KPIs.

3.4 Providing Data Sources for Monitoring

The next steps after specifying the points of interest and KPIs is to provide a suitable source of information for business process monitoring. Such a source should enable one to review all the information about the process execution, process steps and possibly process instances states, resources used in the process, and outcomes of the process. In addition, it should be flexible and allow gathering and providing any other required information without limitation. This can be done using several information systems as sources or using a DW that gathers all these information together in a predefined schema with the required semantic and data marts with targeted facts and dimensions for monitoring purposes. Depending on the type of process, the execution method (e.g. electronically or by human being) and how fast we expect the monitoring system to perform, the advantages and disadvantages of different sources of information for monitoring can be discussed. Since the process monitoring expectation in this scenario is not real time and the process is not executed electronically, using TOHDW, which is updated on a weekly

basis, seems reasonable. In general using a DW as a source of information is becoming a proven practice, and BPI systems work based on this approach (Grigori, et al., 2004) (Casati, et al., 2002).

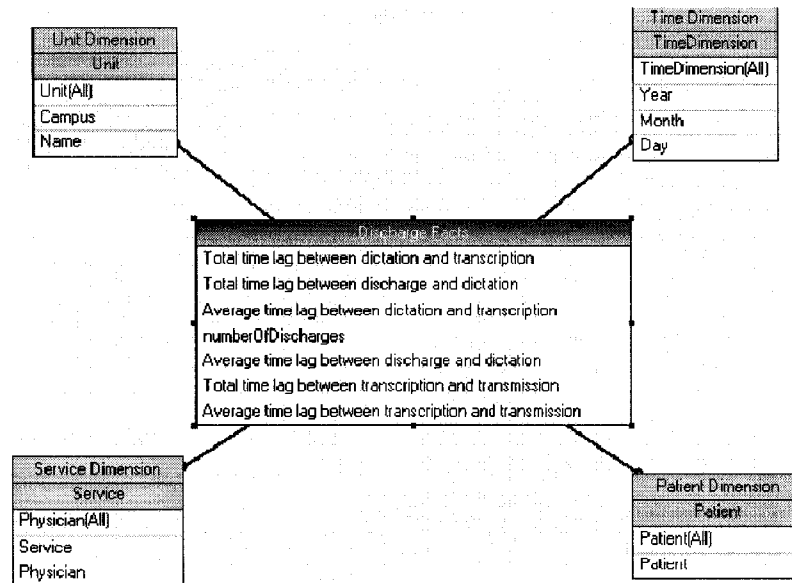


Figure 24: Dimensional model providing discharge process KPIs (Chen, 2007)

In this scenario, a DW based on TOHDW schema was replicated in our lab at the University of Ottawa for research purposes. The data in this replicated DW, however, is not real data due to TOH privacy concerns. The data was generated artificially using the tool provided by (Zhan, 2007) and with information received from process experts to produce data looking similar (in size and trends) to what is usually seen in reality.

After providing the main data source, the data mart and dimensional models specific to these KPIs were developed - Figure 24 (Chen, 2007). By dimensions in this context, we mean for example hospital units, services, and different time periods. Studying the process from different dimension helps hospitals to better understand the aspects that are involved in the process inadequacies and the parts of the organization that contribute the most to the process weaknesses. This model was developed using the Cognos' Business Intelligence modeling tool called Framework Manager.

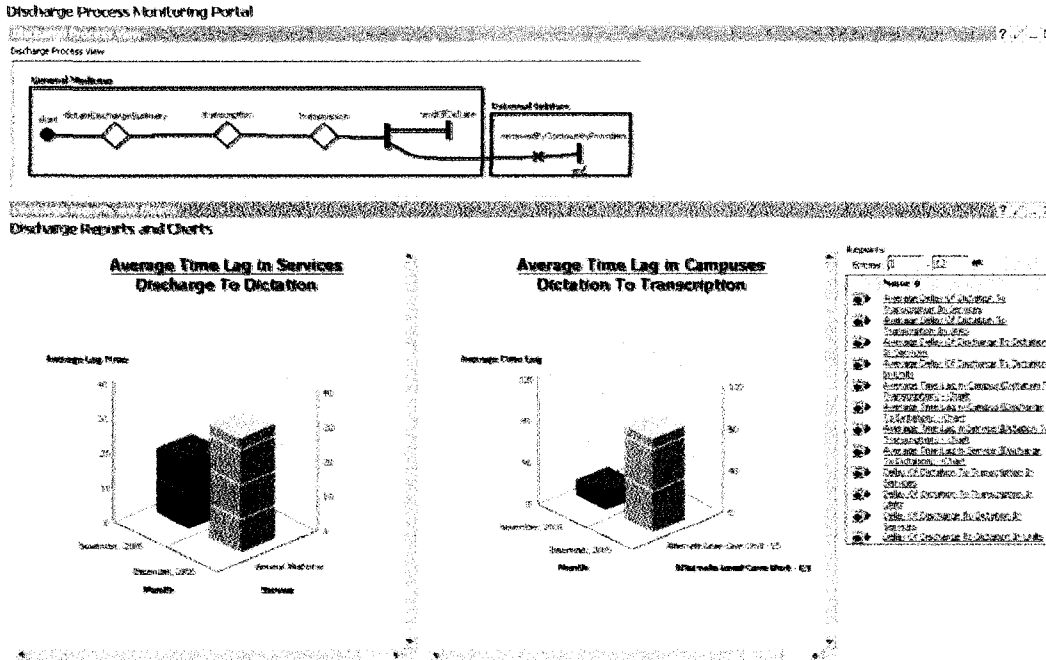


Figure 25: Dictation process performance monitoring portal

This model combined with the reporting tool provided by the Cognos BI software can be used to provide information about the KPIs that we are interested in. Although these reports are useful to gain an initial understanding about process performance, they are not integrated with our process and goal modeling tool. As a result, further analysis on processes performance and impact on organizational goals is not possible. It is possible to manually enter the data into the process modeling tool for further analysis. This method, however, does not scale for large processes with hundreds or even tens of KPIs. For instance, each time the data is changed, we have to redo this tedious work. As a result, online monitoring is also impractical. For this first scenario though, we provided a portal with related information about the process and the KPIs that was useful to provide us with an overall understanding about how the process is performing. This portal also had the capability of drilling down and up the different dimensions and hence offering more detailed information about the KPIs. A snapshot of this portal is shown in Figure 25.

3.5 Towards Model Analysis: What Would We Like to Do Next?

The analysis that could be provided at the BI portal is decoupled from the business process modeling tool. There is more we can do by integrating these tools with business process and goal modeling tools. BPI systems combine these two areas to provide the next level of interaction for process analysts with sources of information across the organization (Grigori, et al., 2004).

Our next goal was to enable users to link the process modeling tool to the BI as a source of information and give users the ability to monitor the process directly inside the modeling tool. This not only provides more capabilities for users but also makes their life easier by giving them a single user interface to interact with when investigating business processes. In addition, this provides a mean of communication between process analysts, who define the appropriate KPIs on process models, and IT personnel who provide the sources of information.

We would also like to show all the KPIs defined for a process in a model that we call *performance model*. This model evaluates the performance of the sub-process for which the KPIs have been defined (e.g. dictation). This could help business users to understand how the part of the process under investigation performs based on its custom-defined KPIs.

Furthermore, it would be interesting to know what the overall performance of this sub-process means for the organization. In other words, if we could show the impact of this process performance on the goal model of the organization, then we would be able to move toward answering the following questions:

- Does this performance satisfy the current goals of the organization?
- Do we need to increase the performance to satisfy our goals?
- How much additional performance do we need to move our goals to the green state?
- What is the value of this sub-process for the organization?
- Is it important that this sub-process does not perform well?
- Does this sub-process have the highest priority for improvement?

This helps organizations like TOH understand how serious the issue under investigation really is compared to other issues and other processes inadequacies. Consequently, a hospital can prioritize its resources and budget for improvement of the processes that currently have the most negative impact on the hospital goals or for those that have the most positive impact on the bottom line.

At the time, we started this project, URN and jUCMNav only enabled us to model the process and goals as depicted in the figures represented in this chapter. The modeling notation did not have the means for modeling KPIs. In addition, the meta-model of the notation did not support any semantic for KPI modeling. Furthermore, the tool was not capable of integration with external sources of information that can be used for business process monitoring. Therefore, the targets discussed for the next steps of the project were not possible without the contributions in this thesis and in (Chen, 2007).

3.6 Summary

In this chapter, we illustrated the process that was used as the first scenario in this research. In addition, we demonstrated the current capabilities in URN and its supporting tool. Furthermore, the shortcomings of the notation and the tool to provide goal-oriented process monitoring were specified. Moreover, some of the pitfalls of doing monitoring with current abilities have been illustrated.

The goal of this chapter was to highlight the problem area and the benefits of solving the problem. Now that we have a better understanding of our target for this research, we propose a solution to this problem in the next chapter. In addition, we will use the scenario introduced in this chapter to illustrate the solution.

Chapter 4. Extending URN to Support Performance Modeling and Monitoring

In this chapter, we introduce extension to URN that support performance modeling. We performed this enhancement in two iterations and will explain both. In addition, we demonstrate the application of this extension in the context of the scenario introduced in the previous chapter and explain the next step of the monitoring project.

4.1 An Overview of the Existing URN Meta-Model

As we discussed in Chapter 1 and illustrated in Chapter 3, URN's lack of KPI modeling support prevents business users from providing performance models for process improvement. URN, however, has a very powerful and well designed meta-model that one can extend to provide new features or applications as required. Figure 26 gives a high-level view of the existing URN meta-model. This figure shows that a URN model (URNspec) is constructed using several classes including GRLspec, UCMspec and URNlink. URNlink is used to link two URNmodelElements, a superclass of almost every GRL and UCM modeling elements.

In addition, Figure 26 shows that GRL IntentionalElement (goals, softgoals, tasks) inherits from GRLmodelElement. Furthermore, intentional elements support an evaluation mechanism used in GRL to evaluate goal models. The evaluation is done based on an initial evaluation level assigned to the model's intentional elements and a propagation process from lower level goals to higher-level goals.

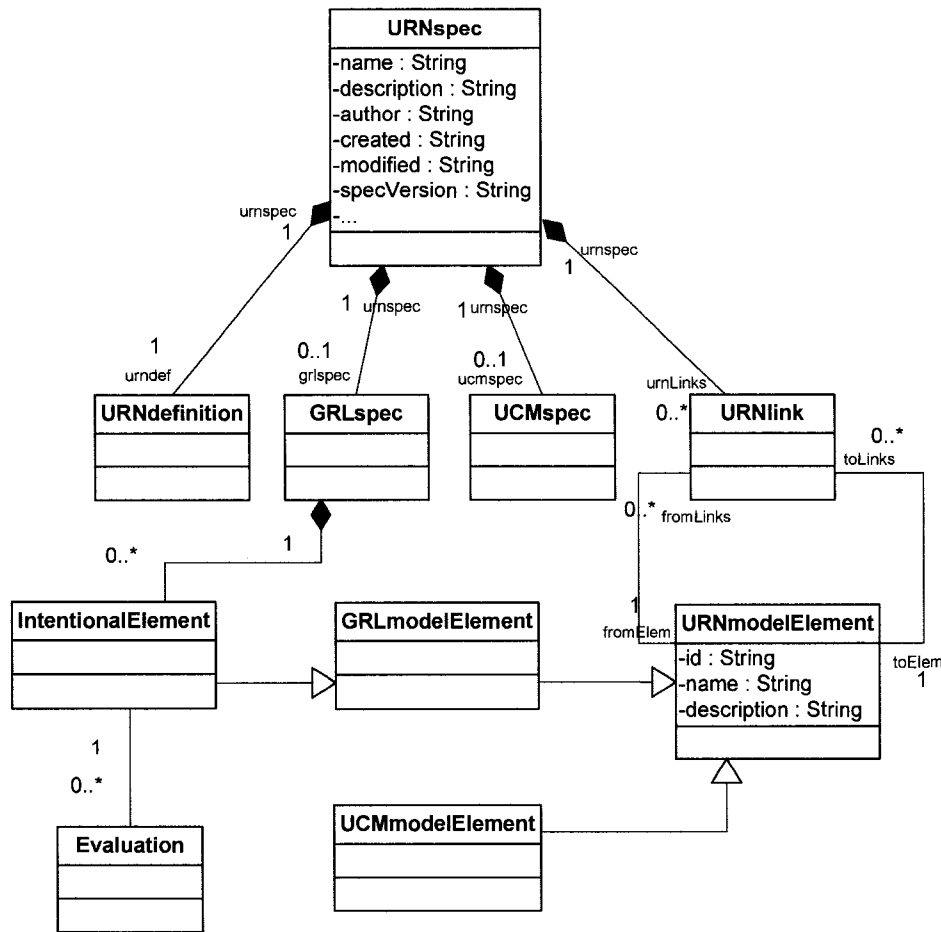


Figure 26: URN existing meta-model – high-level view of specs and model elements

4.2 Extending URN for Performance Monitoring – First Iteration

KPI models will be involved in the GRL evaluation process and KPI values will be used to initialize the evaluation level of intentional elements in GRL models. In addition, KPI should be allowed to be linked to the associated process. Therefore, and based on the existing URN meta-model, a good way to enhance this meta-model to provide KPI modeling is to extend `GRLmodelElement` and provide a class customized for KPI modeling. In this case, it is easier to achieve our objective, which is to demonstrate the impact of processes on the goal model based on the evaluation of KPIs defined for processes.

Since a KPI is considered a `GRLmodelElement`, it will be well integrated with the goal models. Consequently, the result of KPI evaluation can be easily used as the initial evaluation level of goal model elements. In addition, extending GRL to support KPI

modeling allows us to reuse existing GRL features including URN links, contribution links, and the evaluation mechanism.

URNlink, which we currently use for connecting goals and processes, can be used to associate KPIs with processes as well. Furthermore, one can use GRL contribution and decomposition links to connect all related indicators of a process model together to form a *KPI model*. Using GRL contribution links to connect the KPIs defined in the KPI model allows process analysts to allocate appropriate weight and levels of contribution (e.g. positive, negative or neutral, and sufficient, insufficient or unknown) to each individual KPI. In addition, the evaluation of this KPI model using GRL's evaluation mechanism shows the performance of the process as one measurable quantitative value. Figure 27 gives a high-level overview of how a KPI model extending GRL is used to show the impact of processes performance on the goal models. We use the KPI model to fill the gap between operational-level tasks represented in business processes and high-level goals depicted in the goal models.

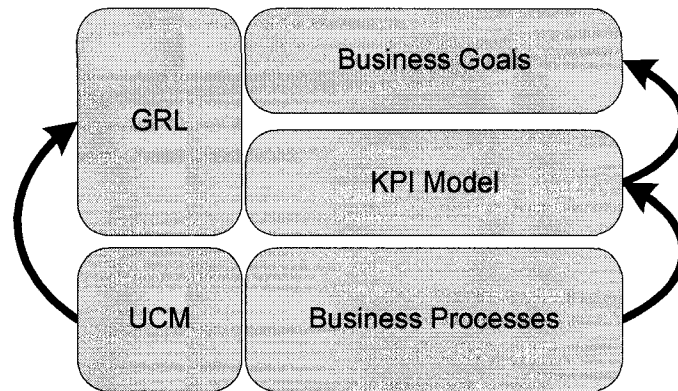


Figure 27: KPI model with UCM and GRL

Figure 28 illustrates the first iteration of our URN meta-model extension to support KPI modeling (Pourshahid, et al., 2007). Indicator was considered as an extension of `GRLmodelElement`. In addition, an `IndicatorGroup` class was considered to allow business users to group the defined indicators. Such grouping is mainly motivated by usability purposes (e.g. for filtering KPI, which are part of a specific group). Indicators can be associated to intentional elements. Each intentional element can have multiple indicators.

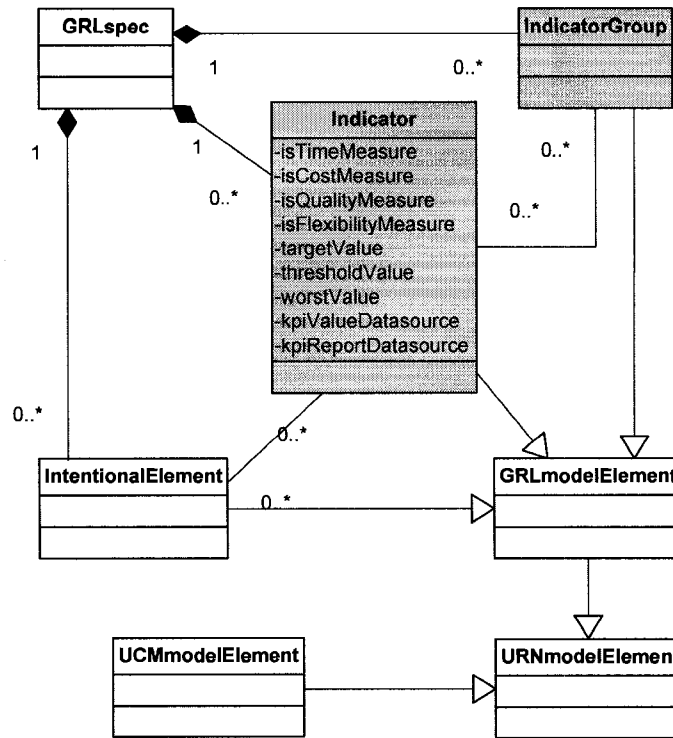


Figure 28: URN meta-model extension to support KPI modeling – first iteration

The attributes considered for indicators were based on the applications of indicators in our monitoring methodology. The first group of attributes (i.e. `isTimeMeasure`, `isCostMeasure`, `isQualityMeasure`, and `isFlexibilityMeasure`) was considered to allow users to specify the type of KPIs. These four attributes were selected based on four main measures of process redesign proposed by van der Kolk (1995) and cited in (Reijers, 2005 p. 210). These four measures are known as the *Devil's Quadrangle* – Figure 29. This framework demonstrates that although improvement in these four main areas is the target of process improvement projects, it is not possible to improve all aspects at once and improvement in one dimension might affect the other dimensions negatively. We picked these four dimensions as the attributes of our indicators to enable the choice of some of the well-known redesigned patterns that have been categorized in (Reijers, 2005) for improvement of the process after the monitoring step. We have also summarized these redesign patterns and their impact on these dimensions in Table 3. Since each indicator can be representative of more than one of these dimensions (e.g. time lag between two tasks can

be considered as both Time and Quality measures), we decided to allow users to pick more than one dimension for indicators.

Table 3 Redesign patterns categorised based on devil's quadrangle dimensions

Redesign Patterns	Time	Cost	Quality	Flexibility
Task Patterns				
Task Elimination	↑	↑	↓	N/A
Task Composition	↑	N/A	↑	↓
Task Automation	↑	↑	↑	↓
Routing Patterns				
Resequencing	↑	↑	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
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

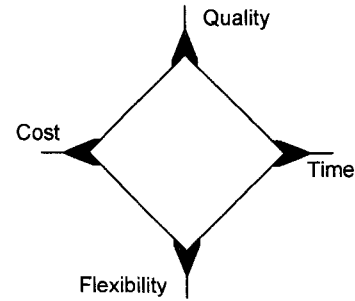


Figure 29: Devil's Quadrangle

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

The next group of attributes was defined for evaluation purposes. *Target Value*, was considered to allow users to specify the target of a KPI. This is the target that a user wants to reach through the improvement process. The least acceptable value for an indicator is defined as the *Threshold Value*. In other words, any value between Target Value and Threshold Value is acceptable from the process analyst's perspective. Finally, any values between Threshold Value and Worst Value are not acceptable. Although any such value is unacceptable, the definition of a *Worst Value* helps specify the level of dissatisfaction.

Although an initial GRL evaluation level could be in any range of values, in jUCMNav a GRL initial evaluation level is a value between -100 and 100. Consequently, to map the actual value of an indicator (e.g. 10 days) to a number in this range, indicator also should have a range associated to it. In other words we need to define both the lowest and highest possible values for each indicator to map them to -100 and 100 respectively. This mapping method is demonstrated in Figure 30. As illustrated, Target Value is mapped to 100, Threshold Value is mapped to 0 and Worst Value is mapped to -100. The formulas for this mapping are demonstrated in Table 4. This formula has been obtained from the general equation for the graph drawn using three points of (Target Value, ± 100), (Worst Value, ± 100), and (Threshold Value, 0) (see Figure 31). Depending on Target Value being greater or smaller than Worst Value, the mapping graph and the equation are changed. If the KPI Evaluation Value is greater or smaller than the defined boundaries (i.e. worst value, target value), we consider the highest possible level of GRL evaluation level (i.e. ± 100) (Pourshahid, et al., 2007)(Chen, 2007).

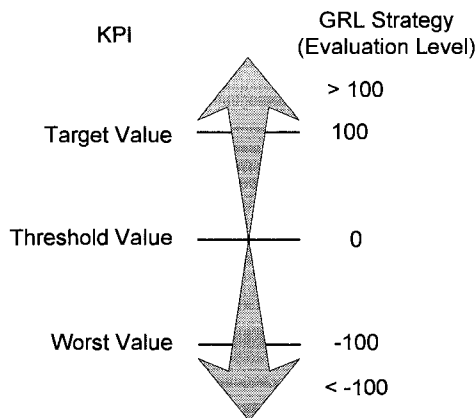


Figure 30: KPI value and GRL evaluation level

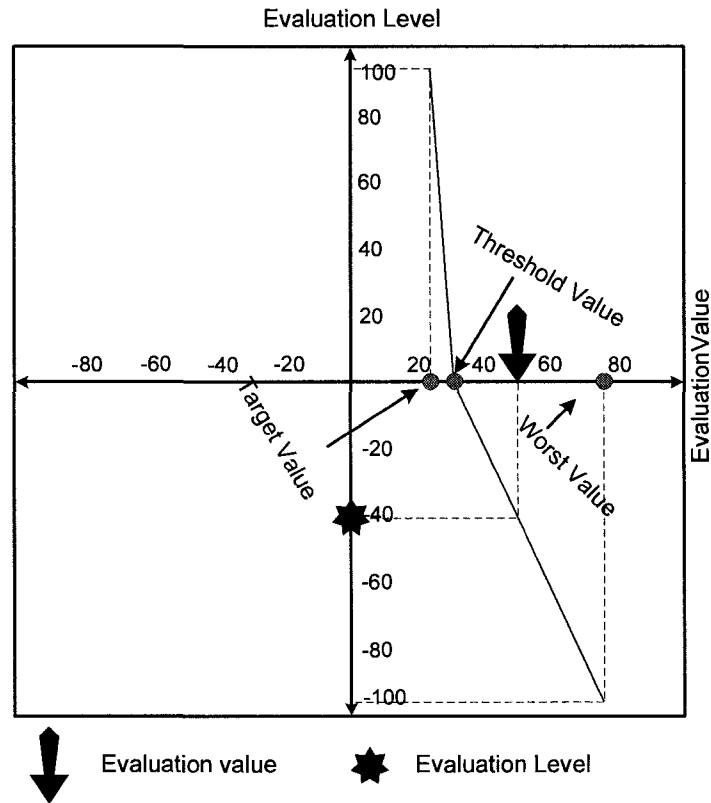


Figure 31: KPI evaluation value mapped to GRL evaluation level

Table 4 Formula for mapping KPI evaluation value to GRL evaluation level

	Condition	Evaluation Level
Target Value < Worst Value	Evaluation Value ≤ Target Value	+100
	Evaluation Value ≥ Worst Value	-100
	Target Value < Evaluation Value ≤ Threshold Value	$\left(\frac{\text{Threshold Value} - \text{Evaluation Value}}{\text{Threshold Value} - \text{Target Value}} \right) \times 100$
	Threshold Value < Evaluation Value < Worst Value	$\left(\frac{\text{Evaluation Value} - \text{Threshold Value}}{\text{Worst Value} - \text{Threshold Value}} \right) \times -100$
Target Value ≥ Worst Value	Evaluation Value ≥ Target Value	+100
	Evaluation Value ≤ Worst Value	-100
	Threshold Value ≤ Evaluation Value < Target Value	$\left(\frac{\text{Evaluation Value} - \text{Threshold Value}}{\text{Target Value} - \text{Threshold Value}} \right) \times 100$
	Worst Value < Evaluation Value < Threshold Value	$\left(\frac{\text{Threshold Value} - \text{Evaluation Value}}{\text{Threshold Value} - \text{Target Value}} \right) \times -100$

The last group of attributes considered for the indicator in the first iteration was to provide appropriate data sources to the tool in order to obtain the value of KPIs and allow users to perform further analysis. `kpiValueDataSource` is used to specify the URL of the Data Source that provides the value of each individual KPI. This data source can be of any kind, however for the first step we decided to use BI tools as our source of information. Since BI tools provide most of the required aggregation and calculation, they can be used as a source returning the value of KPIs.

Although with this method we can obtain the values of KPIs and achieve what we are mainly looking for (i.e. showing the impact of process performance on business goals), we could not gain more information and perform further analysis on the KPI values, which are aggregated values and therefore can cause some misunderstandings. To elaborate, as demonstrated in Figure 32, the KPI values will be the same for two situations, however since their distribution is not the same and their variance is different, they can have different meanings in the process analysis. Consequently, having only a KPI with the value in the acceptable range, one cannot properly judge the condition of a process. Therefore, we should provide capabilities for more in-depth analysis about the KPI values. `kpiReportDataSource` is used to allow users to fetch complementary reports from external sources (e.g. BI tools) to gain additional knowledge about KPI values.

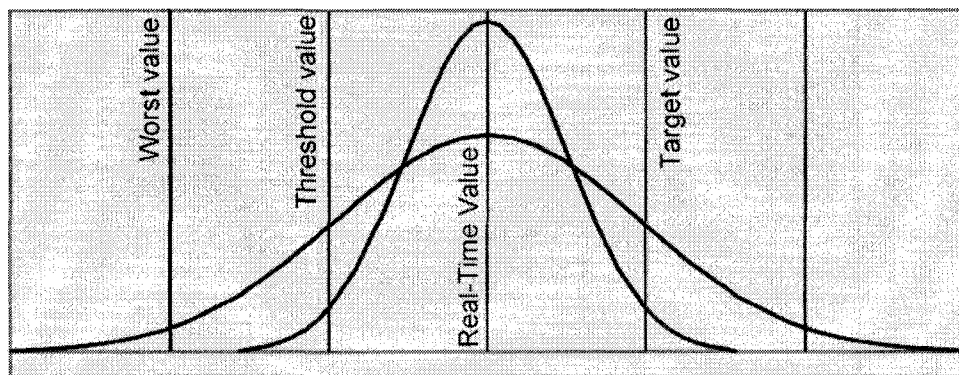


Figure 32: Sample distribution curve for two KPI values

4.3 Discharge Process KPI Model – First Iteration

We presented the discharge process in Chapter 3, together with the KPIs to be monitored to gain knowledge about the process potential defects. We also claimed that with the existing URN meta-model, we are unable to model KPIs and link them to the process and goal models. In this section, we use two of the KPIs specified in Chapter 3 to illustrate how to use the URN extensions specified in section 4.2 for KPI modeling.

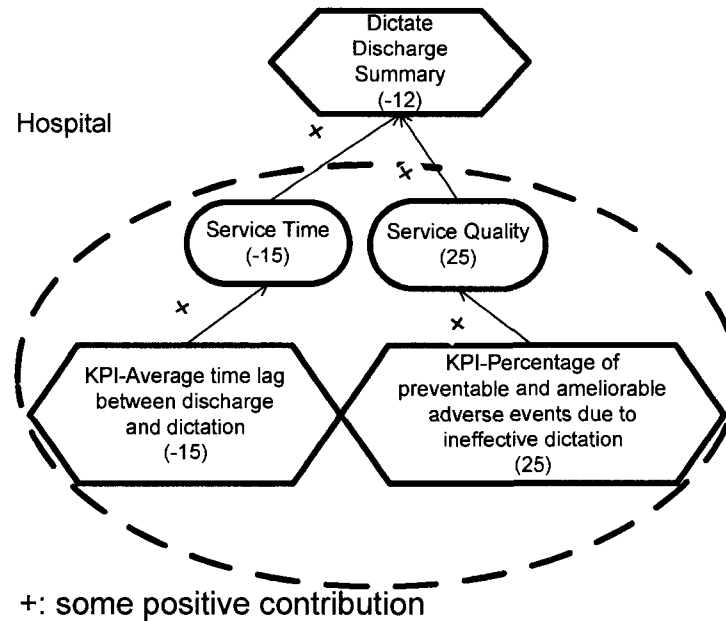


Figure 33: Dictate discharge summary KPI model

Figure 33 depicts the KPI model defined for “Dictate discharge summary”, which is one of the tasks in the dictation sub processes illustrated in Figure 22. The KPIs modeled in this case are “Average time lag between discharge and dictation” and “Percentage of preventable and ameliorable adverse events due to ineffective dictation”. In this model, two KPIs of different kinds are used to express the performance of the targeted sub-process. We have used GRL hard goals to distinguish different KPI types in our model. This separation can also be used to specify the weight of each KPI type contribution in the KPI model and therefore the overall process performance. In addition, we have used a GRL actor (dashed ellipse) to illustrate the fact that these KPIs are specified by the hospital. This modeling technique also helps to distinguish the KPIs defined by different stakeholders of the process. This technique not only helps with the visualization of the KPIs

but also with more flexible calculations of the process performance. For example, process analysts can use GRL contribution links to give different contributing weights to KPIs of different stakeholders contributing to the KPI model of a process.

The numbers shown in the model are the evaluation levels of the KPI calculated using the formula discussed in Figure 31 and Table 4. Figure 35 shows the mapping of evaluation values for “Average time lag between discharge and dictation” to GRL evaluation levels. The actual value for this KPI is 21 days, the target value is 7 days, the threshold value is 14 days, and the worst value is 60 days. The evaluation level for this KPI after mapping becomes -15. As demonstrated in Figure 33 and Figure 34, this value is aggregated with the other KPIs defined and is propagated to the higher-level goals in the model. In addition, it is also combined with the value obtained from other tasks (e.g. transcription). Therefore, if we define KPI models for the targeted sub-processes, we can see their impact on the business goals and understand how the overall performance of the monitored processes affects our business goals.

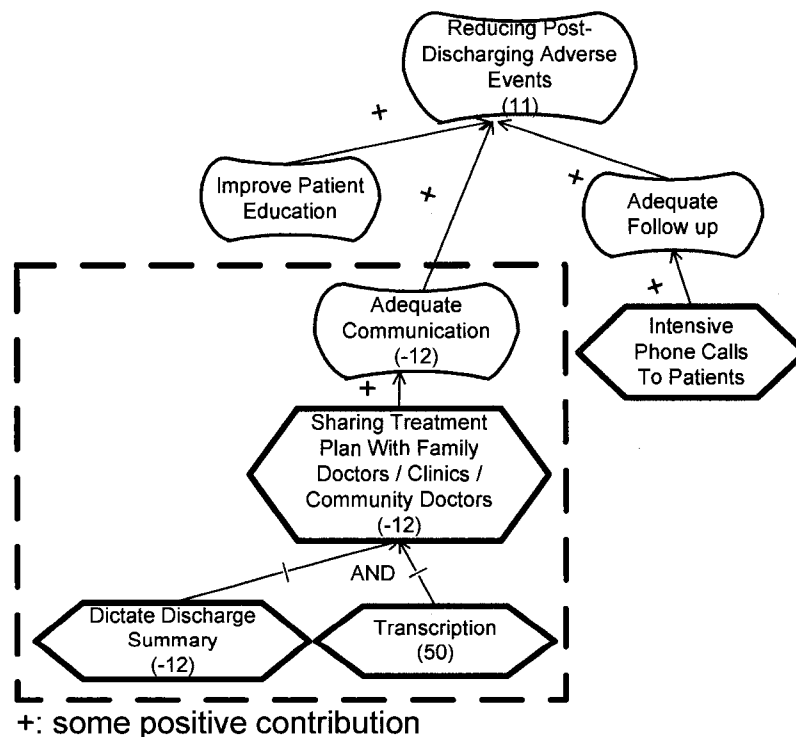


Figure 34: Propagation of KPI model values to the higher level goals

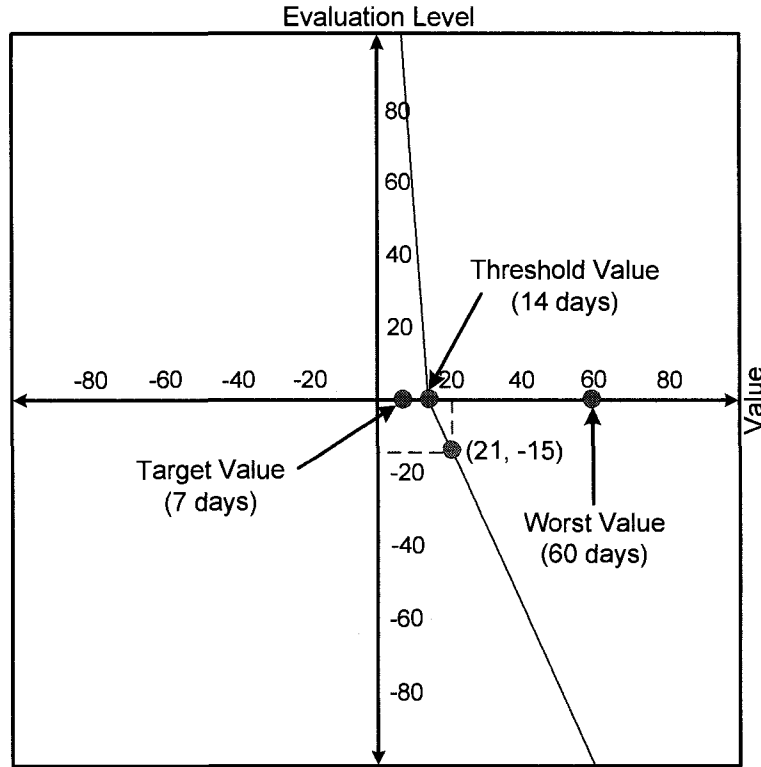


Figure 35: Mapping average time lag KPI value to GRL evaluation level

In the context of the test scenario with the first proposed extension for URN, we are now able to model a single KPI. In addition, using GRL contribution links, we can connect multiple KPIs from different groups and types and stakeholders, and consider them all as a representation of the process performance, which from now on we call “process performance model”. In addition, using different GRL contribution links, we can specify the weights of contributions of each individual KPI to the process performance model, which gives us better capabilities for flexible and reasonable calculation of the process performance.

Although we have all these capabilities, the proposed URN extension in the first iteration still has room for improvement. After presenting this extension at WER 2007 (Pourshahid, et al., 2007) and doing further work on modeling KPIs specified in the discharge process, we went through a second iteration of the extension, introduced in section 4.4. This extension further enhances the KPI modeling capabilities and evaluation method.

4.4 Extending URN for Performance Monitoring – Final Iteration

In this section, we elaborate on the second and final major iteration of our URN extension for performance modeling. There are several improvements in this model compared to the first iteration of the meta-model introduced in section 4.1. In our new meta-model, we have introduced a new model element called `kpiInformation`. In addition, indicators can now use GRL strategies as this gives more flexibility to process analysts by allowing them to analyze different alternative strategies.

Figure 36 shows the `Indicator` and `IndicatorGroup` elements in the meta-model. We removed the indicator attributes introduced in the first iteration (Figure 28). Also, `Indicator` now inherits from `IntentionalElement` instead of having an association relationship. This enables the use of existing capabilities of intentional elements for our indicators, including GRL strategies. Furthermore, `IndicatorGroup` has a new attribute that allows a user to specify a group as a redesign group. In this revision, instead of having four specific redesign groups based on the devil’s quadrangle, we allow users to define any type of group and specify them as a redesign group if required. Consequently, we do not limit users to only four design groups but let them choose and use the framework in a more flexible manner.

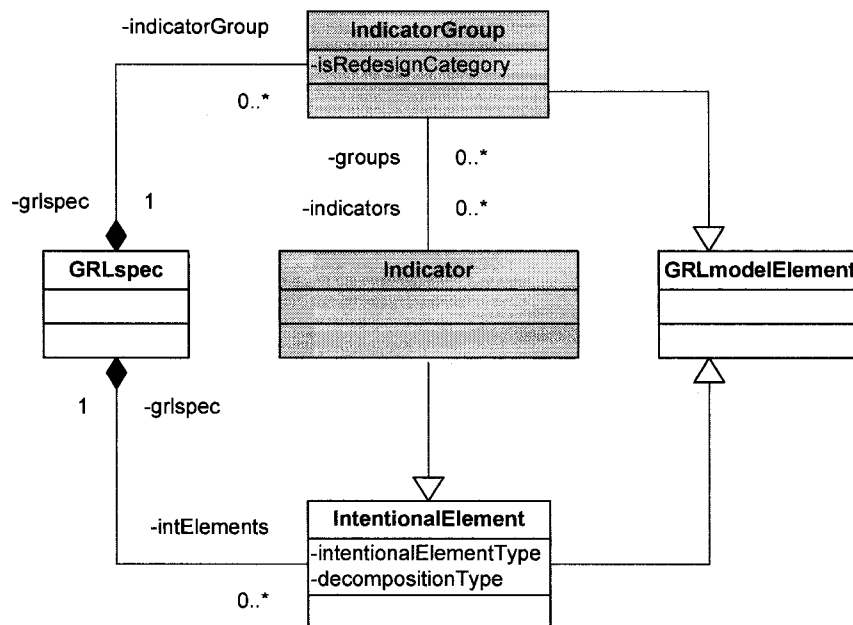


Figure 36: Indicator and indicator group in the final meta-model

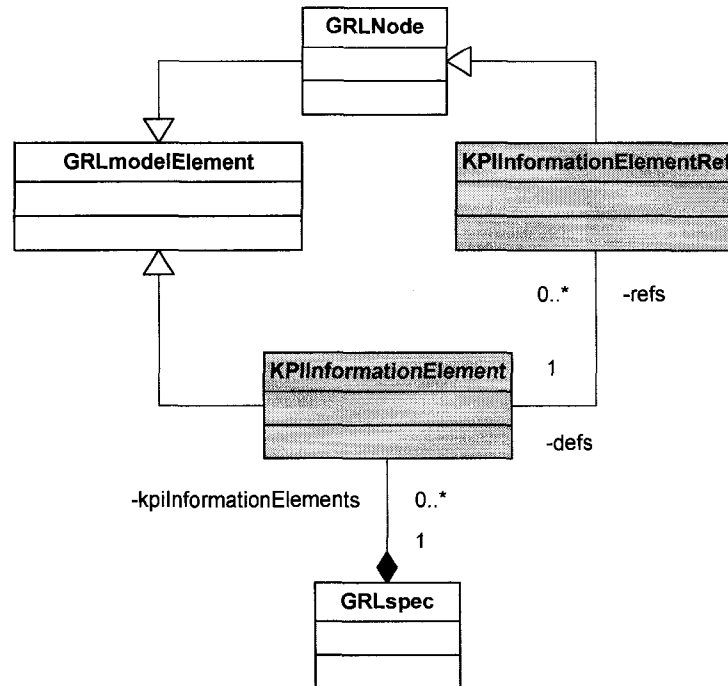


Figure 37: KPI information element

KPIInformationElement is a new model element added to the final version of our meta-model (Figure 37). One of the problems noticed in the first iteration of the meta-model was the incapability of specifying the dimensions for a KPI. The first iteration was not only limited in terms of modeling the dimensions but also in terms of using them for monitoring. Although we had to specify the dimension in the data model, the process monitoring tool could not model and communicate this type of information with the data model layer. Using this additional model element, business analysts can specify all the required elements for monitoring of processes and observe the results. Although the main purpose of **KPIInformationElement** is to enable dimension modeling, the name of this model element was selected to show it can be used for other purposes as well. In other words, any kind of evaluation-related information that is required to be attached to the KPIs can be specified using this model element. With dimensions, however, users have some additional capabilities such as defining the level and value of the dimension for each defined GRL strategy. **KPIInformationElementRef** is used to allow users to reference and use instances of a **KPIInformationElement** in multiple places in the model (e.g., in different diagrams) as opposed to define a new one each and every time.

tion of dimensions. The attribute `levelOfDimension` specifies the type of data in a dimension (e.g. in a dimension that has patient-type hierarchy, patient type is a level) whereas `valueOfDimension` specifies the exact value for a level (e.g., emergency is a value for patient type). In dimensional data modeling, value is also called member.

`KPIEvaluationValueSet` consists of attributes constructing an `EvaluationStrategy`. In addition, `KPIInformationConfig` is also a constructor of evaluation strategies. These two new classes are only used in `EvaluationStrategy` if the intentional element is an indicator. As illustrated in Figure 39, each intentional element, including our indicators/KPIs can have multiple evaluations as part of multiple strategies.

The use of multiple strategies allows process analysts to define different situations and try different “what if” scenarios while they evaluate a process. To elaborate, they can define different targets, threshold, and worst values, and investigate and compare these different cases. Furthermore, they can have different evaluation values and compare them to see how each distinct situation affects business goals.

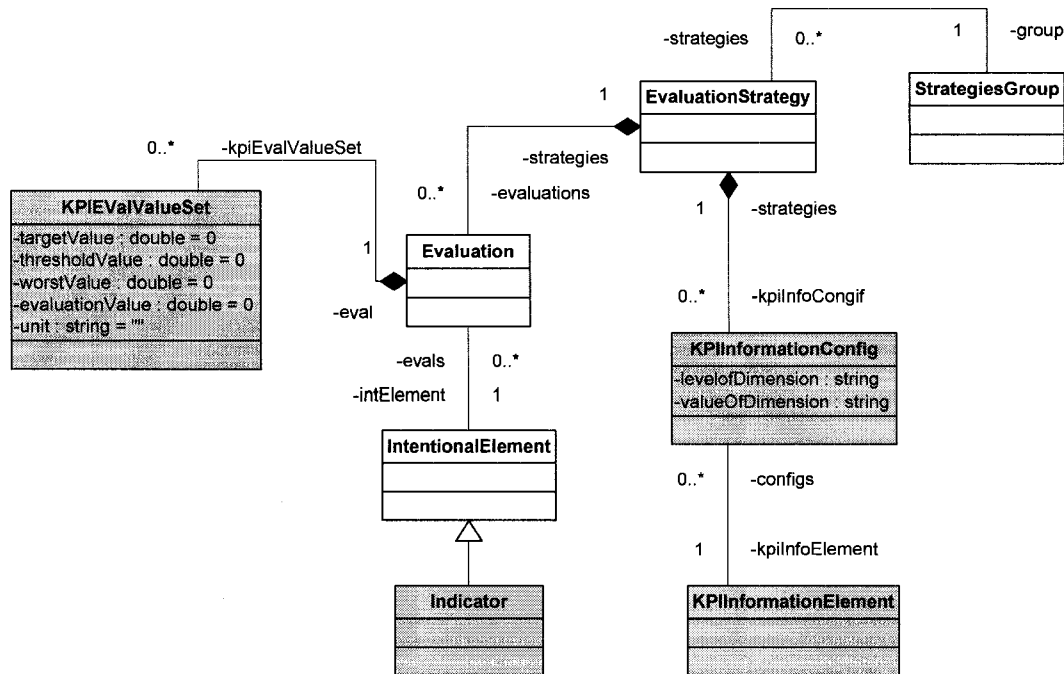


Figure 39: Using GRL evaluation and strategy in a KPI modeling context

4.5 Discharge Process KPI Model – Final Iteration

We have already explained the process and the KPIs used for monitoring the discharge process in Chapter 3. In this section, we elaborate on the concepts and new capabilities discussed in section 4.4 using our discharge process scenario. The main focus of this section is to demonstrate the use of `KPIInformationElement` and strategies that have been added to the final version of the meta-model.

Figure 40 shows the use of `KPIInformationElement` for one of the KPIs defined for the discharge process. Time, unit, and service are three dimensions depicted to illustrate how users want to monitor this KPI. These dimensions allow users to understand what is the average time lag for each unit or service in the hospital and how it is different from time to time or for a specific duration. In addition, Figure 40 depicts the use of `KPIModelLink` and its graphical representation. One can use this link to connect dimensions to the appropriate KPIs.

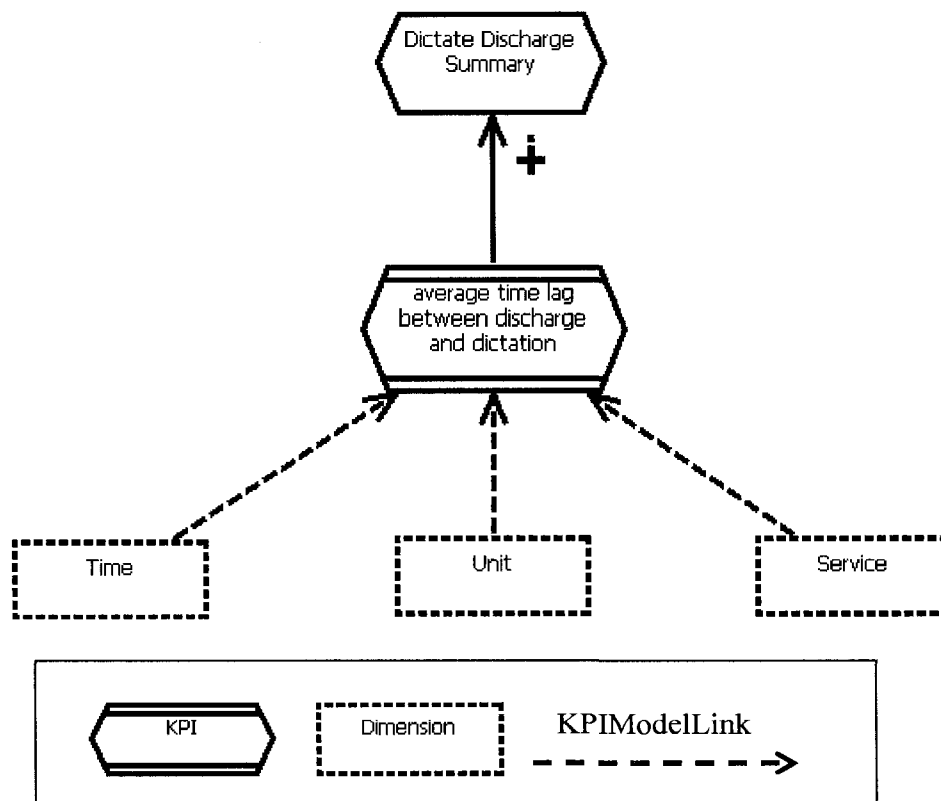


Figure 40: Dimensions of average time lag between discharge and dictation

Figure 41 shows the use of KPIInformationElementRef. All three KPIs defined for the sub-processes of dictation process use the same dimensions we have used in Figure 40. These dimensions are defined once and can be used several times in the performance model.

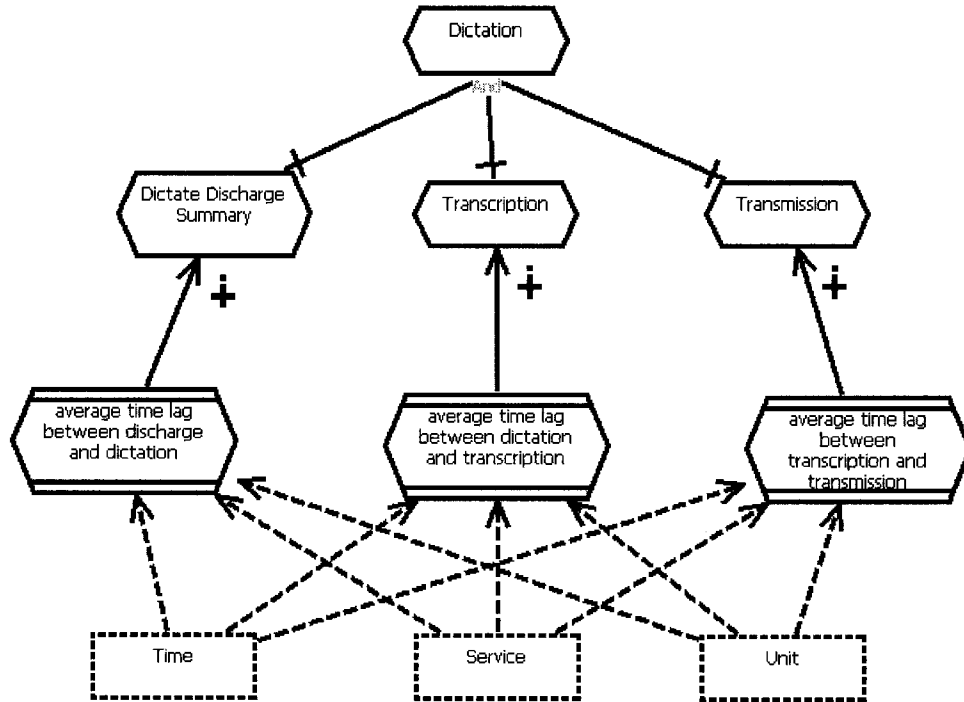


Figure 41: KPIs defined for the dictation process use the same dimensions

As discussed in section 4.4, we can now use strategies to initialize the values of the KPIEvalValueSet and KPIInformationConfig attributes. Each strategy can be used to monitor the process using different levels of dimensions or different evaluation ranges (i.e. target value, worst value, and threshold value). Table 5 shows four different strategies used to initialize and evaluate the KPIs illustrated in Figure 41. In addition, we included the propagation of GRL evaluation values to processes, which we call process performance, and also to higher level goals, which we call impact of processes on high-level goals. Furthermore, Figure 42, Figure 43, and Figure 44 demonstrate the propagation of evaluation values for strategies 3 and 4 which are similar. We observed in this test scenario that changes to the KPIs do not have much impact on higher level goals, but the impact on process performance values is visible. Although we have used zeros as initial evaluation values for the other tasks and goals defined in the GRL model, the impact of changes on lower levels is reduced as we go to the upper levels of the model. Based on

this observation, the GRL propagation algorithm should be improved to be more sensitive to changes. Since this is out of scope for this thesis, we did not investigate this issue further.

Table 5 Discharge process monitoring – comparing four different strategies

Strategies:		Strategy 1	Strategy 2	Strategy 3	Strategy 4
KPI					
Average time lag between discharge and dictation	Unit	Day	Day	Day	Day
	Target Value	3	5	3	3
	Worst Value	15	18	15	15
	Threshold Value	10	12	10	10
	Evaluation Value	5.5	7	7	7
	Evaluation Level	64	71	42	42
Average time lag between dictation and transcription	Target Value	7	9	7	7
	Worst Value	30	30	30	30
	Threshold Value	18	18	18	18
	Evaluation Value	17	19	19	19
	Evaluation Level	9	-8	-8	-8
Average time lag between transcription and transmission	Target Value	3	5	3	3
	Worst Value	15	20	15	15
	Threshold Value	7	10	7	7
	Evaluation Value	10	12	12	12
	Evaluation Level	-37	-20	-62	
Dimensions					
Time	Level	Year	Year	Year	Month
	Value	2006	2005	2006	Last month
Service	Level	Service	Service	Service	Service
	Value	General Medicine	General Medicine	General Medicine	General Medicine
Unit	Level	Campus	Campus	Campus	Campus
	Value	Civic	Civic	General	General
Process Performance					
Dictate discharge summary		82	85	71	71
Transcription		54	46	46	46
Transmission		32	40	19	19
Dictation		32	40	19	19
Impact on high-level goals					
Reducing post discharge adverse events		14	14	14	14
Reducing rate of readmission		14	14	14	14
Improving discharge process		28	28	28	28
Improving healthcare outcomes		16	16	16	16

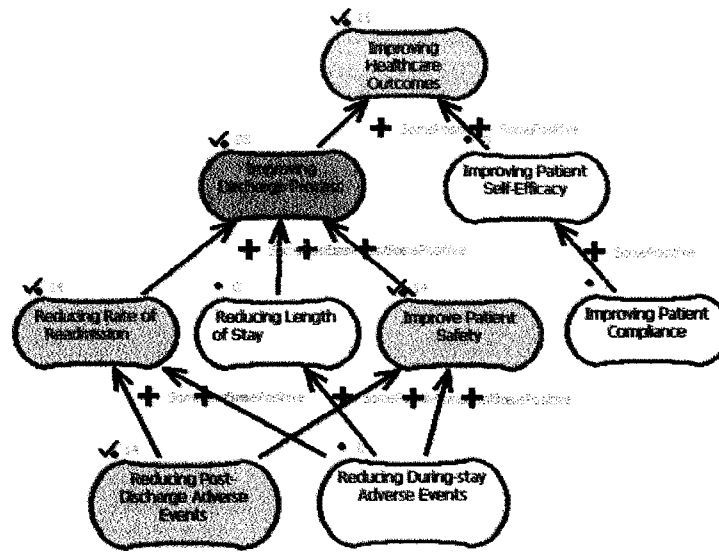


Figure 42: Impact on high-level goals of the hospital

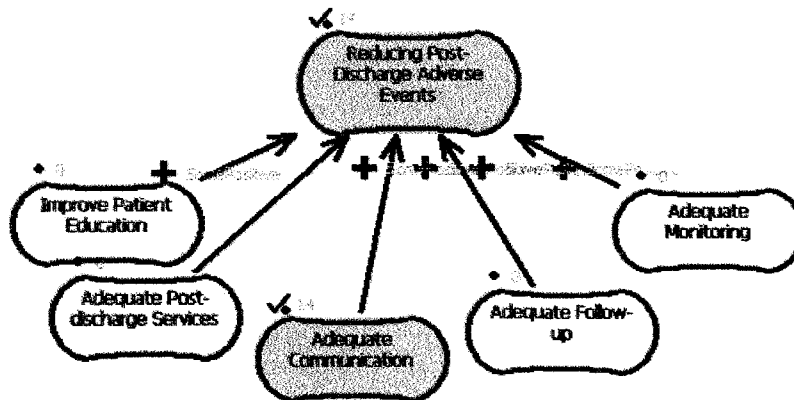


Figure 43: Impact on post discharge adverse events

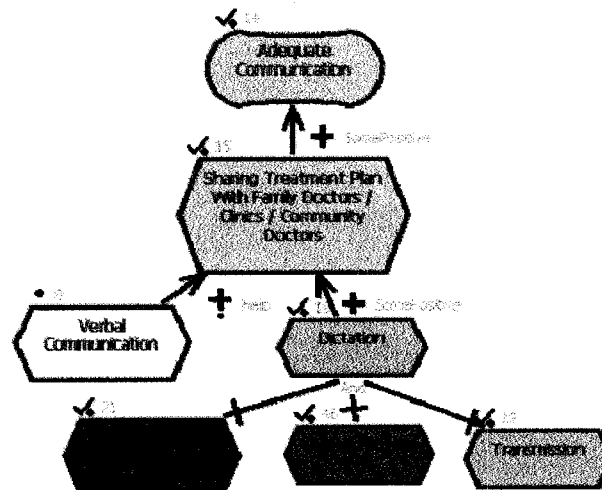


Figure 44: Discharge process tasks performance

4.6 Summary

In this chapter, we have discussed our proposed extensions to the URN meta-model, which allow URN to be used for describing process performance models and for monitoring processes. We have discussed the first iteration of the suggested meta-model and illustrated the attributes and properties required to provide this capability. Then, we depicted the final version and discussed the improvements we have made to the meta-model after receiving feedback and doing further research on the subject matter. Furthermore, using the patient discharge test scenario, we demonstrated how our enhancements to URN can be used for process monitoring.

In the next chapter, we use the new capabilities and the experience we gained through the test scenario to suggest a general methodology for using URN as a process monitoring tool.

Chapter 5. Methodology and Tool Support

As argued in section 1.2, current process monitoring, and business activity systems do not provide a visual method for goal-oriented process monitoring. In addition, existing quality methods and process improvement techniques are based on management and statistical tools and do not provide proper integration with information sources for process monitoring. Furthermore, URN as a modeling language and as the only standardization effort that supports goal modeling as well as process modeling does not provide process performance modeling and process monitoring. In Chapter 4, we addressed one part of this problem by extending URN to define process performance models. In this chapter, we elaborate on a methodology for using the enhanced URN as a process monitoring tool. In addition, we suggest two new tool features to provide better analysis capabilities to end users.

5.1 Core Concepts of the Methodology

The main purpose of the methodology is to suggest the standard steps required for performing goal-oriented business process monitoring using URN. As demonstrated in Figure 45, this methodology can help businesses align their processes with their goals and vice versa. Performance models and KPIs are modelled based on the organizational goals to monitor the processes. Therefore, the value sets of the KPIs (e.g. target value) are specified based on the organizational goals. Comparing the defined value sets and real time values of the KPIs (i.e. KPI evaluation values), we specify the status of the business process. Based on the monitoring results, we determine whether the process needs to be enhanced to meet the targets specified by the organizational goals, or whether the goals need to be further improved even though the specified targets have already been met by the current business process. When we adjust the business goals, we increase our expectations regarding the outcomes of the process. This will happen, if a process already satisfies the target values by a good margin, and we see an opportunity to increase the expect-

tations even further. As illustrated in Figure 45, this is a bi-directional iterative approach that not only improves business processes, but also business goals.

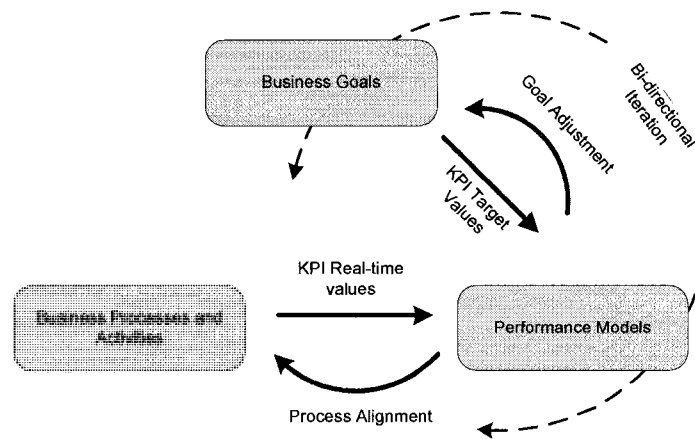


Figure 45: Business process and goal alignment

At the highest level of abstraction, the core artifacts of the methodology are the goal model (GM), the process model (PrM) and the performance model (PeM). Figure 46 shows these artifacts and their relationships. GM, PrM, and PeM are all structured and organized in a hierarchical manner and span multiple levels of abstraction.

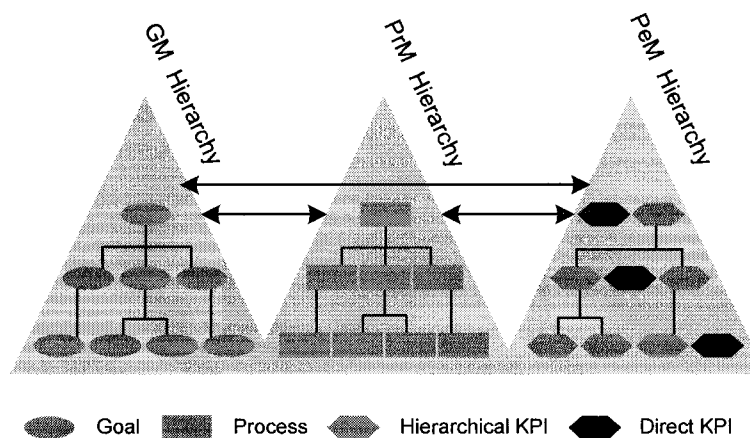


Figure 46: Methodology core artifacts organization

Goal model hierarchies are formed based on the decomposition of high-level goals into low-level ones, and further into tasks that support those goals. The process model hierarchy, though, is usually based on decomposition of high-level processes into sub-processes and then to tasks (using plug-in maps and responsibilities in UCM terms). For

each level in the process model there can be an associated goal model level used to demonstrate the exact correlation between goals and supporting processes. The performance model usually has an associated model in each level of the process as well. Although KPIs are usually hierarchical in the performance model, we can also define some direct KPIs. Direct KPIs do not have any effect on the higher levels of the performance model and are only used to measure the performance of a process at their associated level.

The main artifacts of the methodology are modeled using the conceptual meta-model demonstrated in Figure 47. As illustrated, goals and processes are associated with requirements. A process portfolio is a collection of related processes analyzed and monitored together. Each process model could have single or multiple associated goal models and each goal model can describe the objectives of one or multiple processes. Furthermore, process models contain processes, which can be further composed from sub-processes in a hierarchical manner. In addition, performance models are always associated with a goal, and each evaluated process can have multiple performance models. Finally, a performance model consists of KPI information elements, KPIs and performance goals. Performance goals are used to specify the objectives of the KPIs defined by the performance model, and to aggregate the evaluation results of related KPIs.

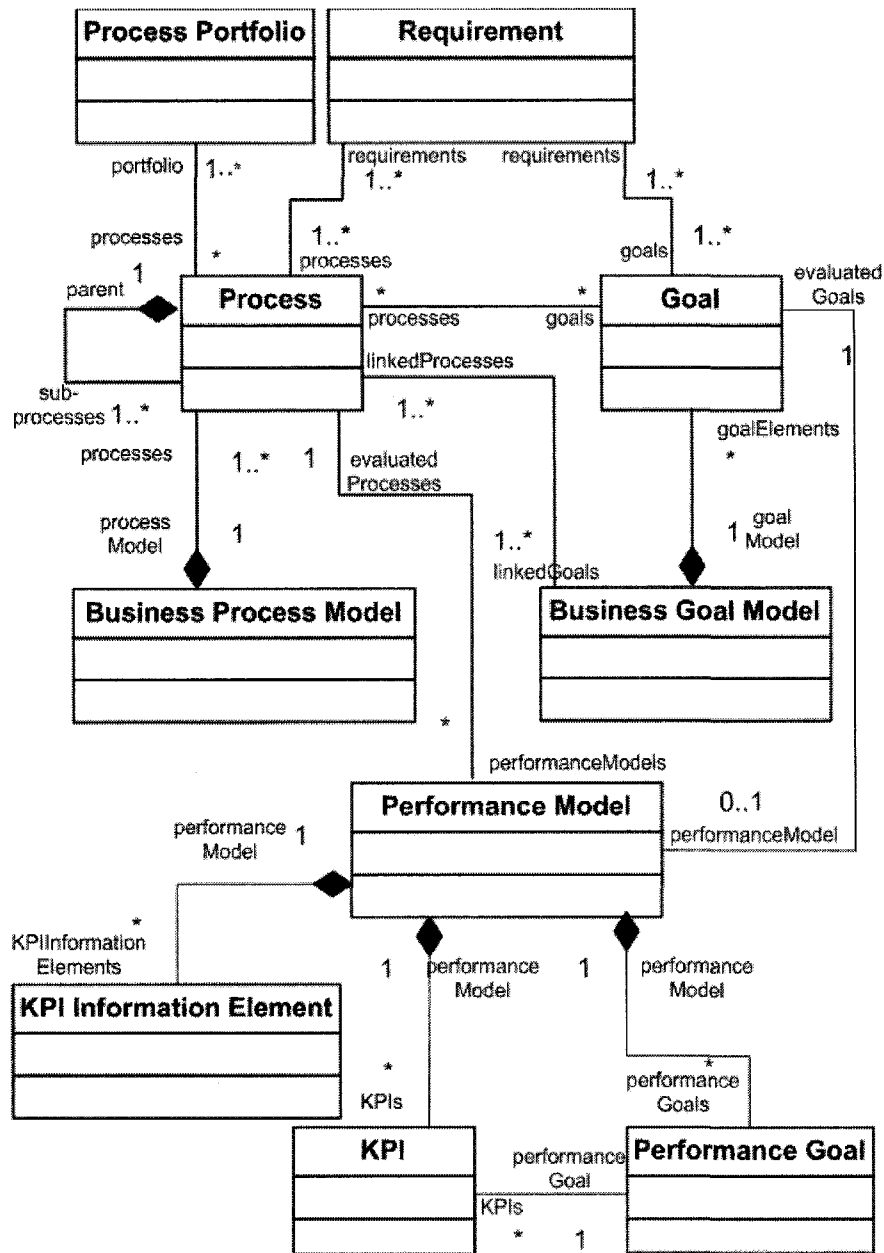


Figure 47: Conceptual meta-model of the Methodology's core artifacts

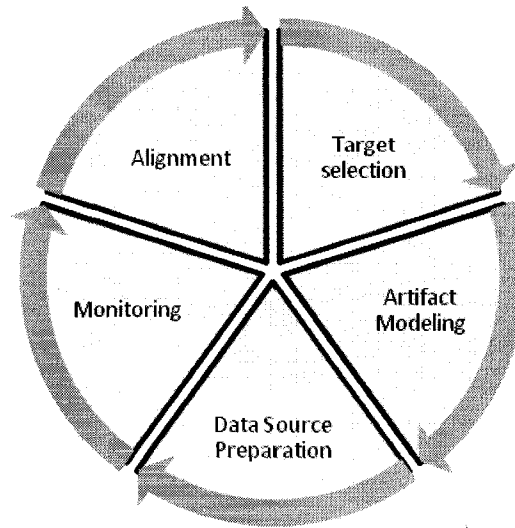


Figure 48: Methodology steps – high-level view

Our methodology is iterative and consists of several steps. Figure 48 shows the high-level steps of the methodology, which will be detailed in section 5.2. The initial step is the selection of the target process that we want to monitor. This is done based on business priority or results of pervious iterations of the monitoring process. The next step, artifact modeling, comprises the creation of goal models, models of sub-processes, and performance models of the target process, and the specification of their relationships. Then, the required information sources are prepared. This step consists in specifying the original data sources and modeling a data mart to achieve the objectives specified in the performance model. Subsequently, the process is monitored by observing the performance models and goal models. If a process does not meet the planned target, process improvement methods will be suggested.

Figure 49 shows several tools used to support the methodology: a URN modeling tool (i.e. jUCMNav) to model the artifacts, a database to gather all required information in the DW, as well as a BI tool to extract the parts of data required for the targeted process and to design a customized data mart based on the dimensions defined in the performance model. In addition, the BI tool calculates the initial evaluation value of the KPIs. Furthermore, depending on how the BI tool and the URN modeling tool exchange data, there might be other tools required. In the implemented prototype, Chen (2007) used web services for transferring data to jUCMNav and an application server for providing the services.

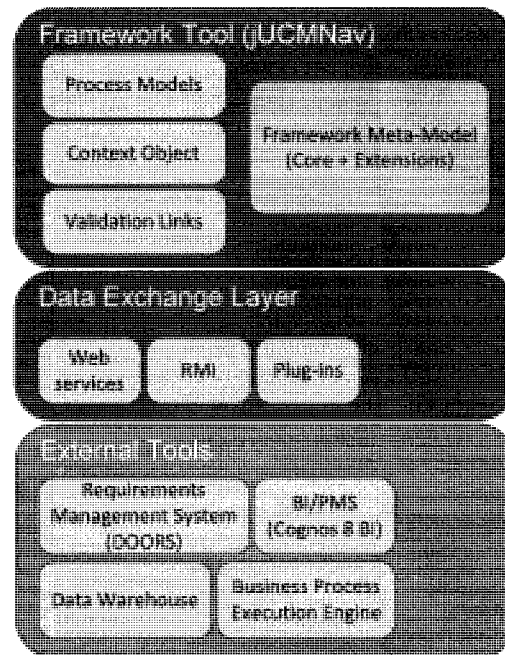


Figure 49: Methodology implementation environment – tools perspective

Figure 49 also depicts the required environment for a complete Business Process Management framework (Pourshahid, et al., 2008). The context objects are the performance models presented in Chapter 4 and the compliance models introduced in (Ghanavati, et al., 2007). The validation links are links to external tools providing the information required for validating the processes using context objects. Furthermore, we have specified three methods in the Data Exchange Layer including web services, Remote Method Invocation (RMI), and Eclipse plug-ins. In the supporting tool provided by (Chen, 2007), web services have been used for data the exchange layer. However, since the tool is based on Eclipse and java platforms, one can use the other two methods as well. In addition, as discussed in (Pourshahid, et al., 2008) an external requirements management system can be used to provide traceability between requirements and process/goal model, as well as traceability between legal documents and compliance goals. In future work, a business process execution engine could be integrated into the framework to run the processes in an automated manner.

Implementing the methodology will require the involvement of process experts, business analysts, requirement engineers, process modelers, DW and BI experts, and software developers. Process experts, business analysts and requirement engineers are

responsible for specifying the target process, modeling the process, goal, and performance models, and linking them with the requirements. Process modelers will use the tool to model the artifacts, although process experts or business analysts can play this role as well. DW and BI experts will provide the data sources for monitoring. Software developers deal with integration issues and customized development of web services as required. Depending on the size of a project and on the expertise of the people involved, one or more people can fulfill the technical roles (modeler, DW and BI, expert and software developer).

5.2 Steps of the Methodology

In this section, we elaborate on the steps of the methodology in more detail and specify their objectives, actions, specific tasks, and tools. A summary of the steps' details can be found in Table 7.

5.2.1 Target Selection

From the literature reviewed in Chapter 2, we concluded that a common best practice among quality methods is to develop projects in an incremental and iterative manner. We have used this best practice in our methodology.

In the first iteration, we pick a feasible number of target processes based on available resources for the project. This could be multiple processes, one process, or even only a sub-process. Business analysts and process experts should perform some preliminary tasks to assist with specifying the targets. Illustrating a high-level picture of the business and providing a business process portfolio is part of their activities. At this stage, business analysts, process experts, and requirement engineers work together to create the high-level view of the business including business goals, business processes, and requirements. Furthermore, they specify the relationships between these artifacts. Based on the priority of requirements and relative importance of goals, the corresponding process, which satisfies the high priority requirements and goals, is selected as the target. If the selected process is still too large for available resources and project timeline, then one or multiple sub-processes of that process are selected and modeled. In parallel, goal models are also decomposed to reach to the same level as the process. Furthermore, based on the

selected target, an iteration plan is provided, which includes the schedules for the iteration. Software developers and BI & DW experts also help with planning the project by sizing their subsequent related tasks in subsequent phases of the project.

For example, in Chapter 3, we initially focused on the dictation sub-process of the patient discharge process, since the discharge process was too large. Based on existing research, we knew that this sub-process caused adverse events. We picked it as our first target for monitoring to gain more information about the underlying problems.

After a full cycle of the project and when we have a complete environment with all processes modeled and monitored, the selection of target processes is easier. At this point, we can select the targets based on monitoring results, the performance of the processes and their impact on business goals. In section 5.3.1, we propose an extension to the existing tool to assist process experts and business analysts in selecting targets (Pourshahid, et al., 2008).

5.2.2 Artifact Modeling

In the second step of the methodology, process experts, business analysts, and process modelers create the goal, process, and performance models for the selected process accurately and in detail. They use jUCMNav extensively to model all the artifacts and to link them together. Additionally, they specify the performance objectives along the way and use GRL strategies to reflect them into the models. Furthermore, they define monitoring dimensions and map them to performance models. At this point in time, the models are ready and, with the artifacts produced so far, it becomes possible to experiment with “what if” scenarios by assigning evaluation values manually and observing the results of process performance impact on the goal models. We must go to the next step of the methodology only if we need to perform the monitoring automatically and based on information received from external sources on an ongoing basis. Otherwise, we already have a complete working model that integrates goals, processes, and performance.

5.2.3 Data Source Preparation

In this third step, the information sources required to monitor the process are provided. The required tasks in this step are elaborated in (Chen, 2007) as a part of the implementa-

tion of the supporting tool for this methodology. Software engineers first identify the operational information systems generating the related information to the target process. Depending on the target process and operational information systems, this could be as simple as finding one source of data. In more complex environments, this might involve going beyond the boundaries of the organization. This task should be sized and its required resources should be considered as per section 5.2.1.

Next, operational data is gathered in the DW. If a DW already exists, then it is customized as necessary to provide the required data. Using the data stored in the DW, a data mart, a corresponding OLAP model, and KPI reports is generated. Detailed instructions on how to provide these artifacts have been suggested in (Chen, 2007 pp. 72-75) and are summarized below.

A data mart contains the required information related to multiple processes and performance models. Performance models created in jUCMNav in the previous step are used to help DW and BI experts come up with the data mart model. Dimensions, the associated process, the granularity of the data mart schema, and the facts are defined using Table 6 (Chen, 2007 p. 72). This table shows the mapping between information presented in the performance models and required information for designing a data mart.

Subsequently, the specific dimensional model (OLAP data source) used for evaluation of the KPIs is designed. This OLAP data source consists of measures and dimensions that are representations of the KPIs and dimensions defined in the performance model. The dimension levels provided in the dimension model should be designed carefully to satisfy the expectations of business analysts and process experts. These levels must be the same as the ones in the performance model strategies when we define *levelofDimension* and *valueofDimension*. Therefore, they should support all levels and values that may be used during the monitoring period. After preparing the dimensional model, BI experts define the KPIs reports to extract the KPI values from the provided data sources. Each report defined is used to provide the KPI value for a particular strategy. More details on designing dimensional models and organizing and accessing KPI reports are available in (Chen, 2007 pp. 73-75).

Table 6 Mappings between performance model and required data mart

Data mart design elements	Performance model information
Dimensions	Information elements
The associated process	Linked process to the KPIs
Granularity of data mart schema (The smallest grain of Data mart)	The lowest level of detail in all performance strategies defined on all related KPIs; or, the lowest possible level of detail.
Facts (What is being measured)	The essential metrics required to calculate KPIs

After preparing the sources required for calculating the value of KPIs, we should also provide the infrastructure in the data exchange layer for communicating the data with the process monitoring tool. In the implemented supporting tool (Chen, 2007), web services and an Enterprise Java Beans based architecture have been suggested for this purpose. Software developers play a significant role at this stage for customizing or implementing a suitable data exchange layer. If done properly, this is a one-time task in the first iteration that does not need to be repeated in subsequent iterations. In addition, if the infrastructure already developed in (Chen, 2007) satisfies the requirements, then there is no further development required. Figure 50 gives a high-level view of the environment discussed.

This infrastructure is not necessary unless we want to use the monitoring tool in an enterprise environment. We can use the monitoring tool in a standalone environment using manual data entry. The standalone usage of the tool, however, is more suitable for a small group of people in a controlled environment. In larger projects with a higher number of people involved, there is a risk of ad hoc data entry which can produce misleading results. Going through the specified steps for designing the data sources and using the specified architecture helps preventing uncontrolled data entry. To elaborate, if dimensional data sources are designed according to the guidelines, they will be consistent with the performance models. In addition, using a BI tool to calculate the KPI values reduces data discrepancy and inconsistency compared to a situation where the same values are obtained from different sources.

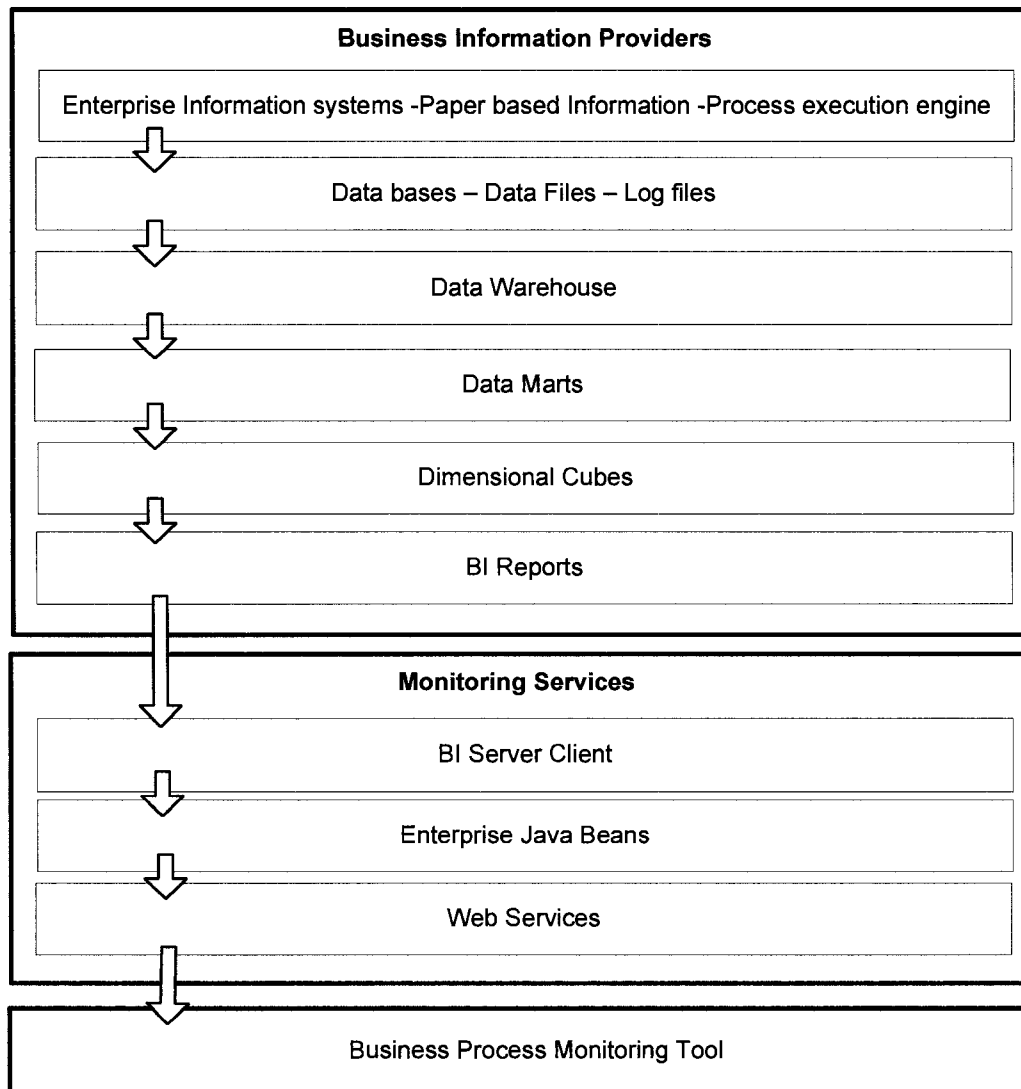


Figure 50: The architecture and information flow of the monitoring system

5.2.4 Monitoring

The objective of the monitoring step is to perform business performance analysis, business goal impact analysis, and improved candidate selection. Performance analysis involves triggering the defined performance strategies and observing the performance models and evaluation values as they are propagated from KPIs up to the task or sub-process attached to the performance model. Impact analysis involves observing the goal models to see which goals or sub-goals are impacted by the current performance of the process. In addition, the existing strategies can be altered or new strategies may be defined to

monitor the process in other dimensions or based on different value sets. This can be done through further investigation or by exploring “what if” scenarios.

Business analysts and process experts collaborate to generate an analysis report from the observed results and specify either the process model or the goal model as the candidate for the alignment step. During the initial iterations, the selection of alignment candidates will not be difficult, since the number of processes under investigation is not high. After a complete process portfolio prioritization, however, candidate selection can be challenging. We have addressed this issue by suggesting a supporting tool as discussed in (Pourshahid, et al., 2008) and in section 5.3 of this thesis.

5.2.5 Alignment

The last step, alignment, consists of business processes and business goal improvement. We suggest using the process redesign patterns introduced in Table 3. Although currently we do not have a detailed guideline for using these patterns, we have categorized them in four groups (time, cost, quality, and flexibility) to make their selection easier based on the improvement target. On the other hand, in case of healthy processes, which meet or surpass the specified target values, the goals may need to be revisited and the expectation bar may have to be raised. Goal improvement, however, may only be considered when there are no other priorities (e.g. other critical processes).

After the alignment step, the project moves forward to the next iteration. In the process modeling step of the next iteration, the suggested redesign patterns are applied to the processes. In addition, if there are still processes that need to be added to the process portfolio, one of them is selected based on its priority.

Table 7 Summary of the methodology steps

Step	Objectives	Tasks	Artifacts	Roles	Tools
Target Selection	Clarify the high-level picture of the business and pick the right target for the first iteration of the project.	• Identify Re, BG and Pr • Specify the relationship between above artifacts • Indicate the target process	RD GM PrM Iteration Plan	Process Expert Business Analyst Requirement Engineer Process Modeler Software Engineer DW & BI Expert	RMS jUCMNav
Artifact Modeling	Complete the modeling of main three artifacts and specify their relationship.	• Model GM till task level • Model PrM till task level • Link GM and PrM models • Specify performance objectives and designing PeM • Link PeM with PrM and GM	GM PrM PeM Strategies	Process Expert Business Analyst Process Modeler	jUCMNav
Data Source Preparation	Provide the required sources of information for monitoring the process from available resources across the organization	• Find main sources of data • Design a DW as central repository • Extract a data mart from DW • Design dimensional model • Provide required KPI reports • Provide the require WS	DW BI Model BI Reports WS	Process Modeler DW & BI Expert Software Engineer /Developer	Database BI tool App Server
Monitoring	Observe the performance of processes based on defined performance model and their impact on the business goals	• Performance analysis • Impact analysis • Select the improvement candidates	Altered Strategies New Strategies Analysis Reports	Business Analyst Process Expert Process Modeler	jUCMNav BI Tool
Alignment	Suggest improvement to processes or goals.	• Use redesign patterns to improve the processes • Adjust business goals	Remodeled GM Remodeled PrM Remodeled PeM Altered Strategies	Process Expert Business Analyst Process redesign expert	jUCMNav Documentation Redesign Patterns

App: Application
BG: Business Goals
BPM: Business Process Management System
DES: Data Exchange Services
GM: Business Goals Models
Re: Requirements

RD: Requirements Documents
Pr: Processes
PrM: Process Models
PeM: Performance Models
PMR: Performance Management Reports
PMS: Performance Management System
RMS: Requirements Management System

5.3 Suggested Features for the Supporting Tool

In this section, we suggest two new feature enhancements to our existing URN modeling tool (jUCMNav) that are mainly used in the monitoring step of the methodology by process experts, business analysts, and process modelers. These features assist end users with investigating defects in processes, prioritizing improvement targets, and partial analysis of the process portfolio. If these features are implemented, then the practitioners of the methodology will likely achieve their objectives more easily and will have a powerful assistant for decision making. The implementation of the suggested features, however, is out of the scope of this thesis and is left for future work.

5.3.1 Process Portfolio Quadrant

As discussed in the context of Figure 47, a process portfolio consists of all under monitoring processes in the project. It shows the processes in one of four quadrants. The axes of this quadrant view are *performance* and *importance* of the processes. This view helps users get a comparative understanding about the status of processes under investigation. The processes falling into the section of the quadrant with high importance and low performance need immediate attention and will be improvement candidates, whereas processes in the section with high performance and low importance do not need much attention. Processes with low importance and low performance are good candidates for out-sourcing. This idea has been already introduced in (Heß, 2006). Using URN, however, to provide a hierarchical quadrant view with drill down and up capabilities is a new concept.

In our interpretation of the process portfolio quadrant view, we calculate the importance values of the processes based on the impact of the process on the goal model and the contribution of the processes to the goal model. Importance is computed as the average of top-level business goals' satisfaction levels when the initial evaluation level of the process is 100 or, in other words, when the process performs at 100% capacity. The performance, on the other hand, is calculated using the KPIs and performance model defined for the process.

Furthermore, the drill-down/up capability is enabled by the (UCM) process hierarchy. When a user clicks on a process, at the next layer of the process portfolio quadrant

they will see all the underneath sub-processes (stubs) and responsibilities. The process portfolio quadrant view should be synchronized with the process model view and KPI view so when users browse through each of them the rest is updated accordingly.

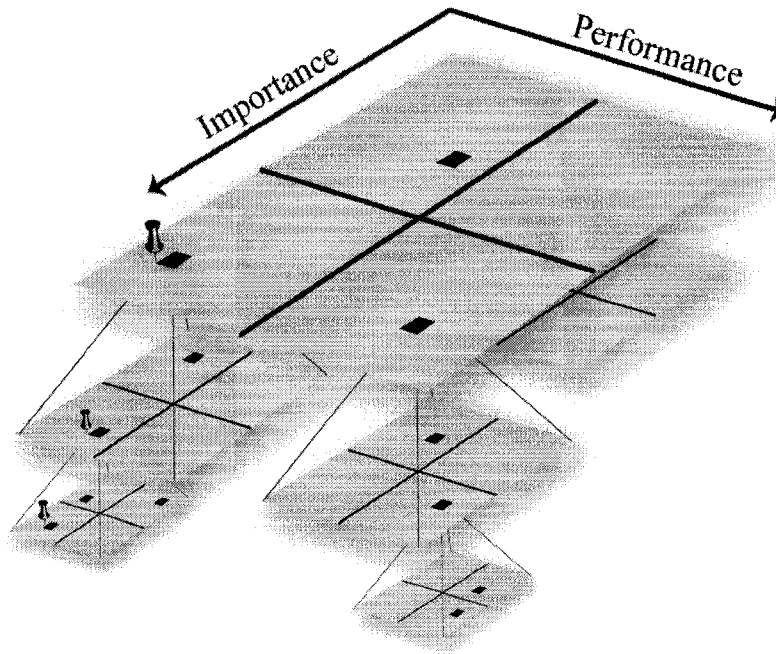


Figure 51: Process portfolio – drill down scenario

Figure 51 illustrates a drill down scenario, where a user observes a high importance process with low performance (this process is specified by a pin). The user clicks on the process to understand the problem better. In the second level of the process hierarchy, the user finds two sub-processes, one of which has a high importance and low performance. In the next move, the user drills further down to the third and last level of the process and identifies that among the three sub-processes present one has a high importance and low performance, which is probably the main source of the problem in the top-level process under investigation.

As illustrated, this feature could be very helpful to offer an overall picture of the process portfolio and to determine the root causes of problems.

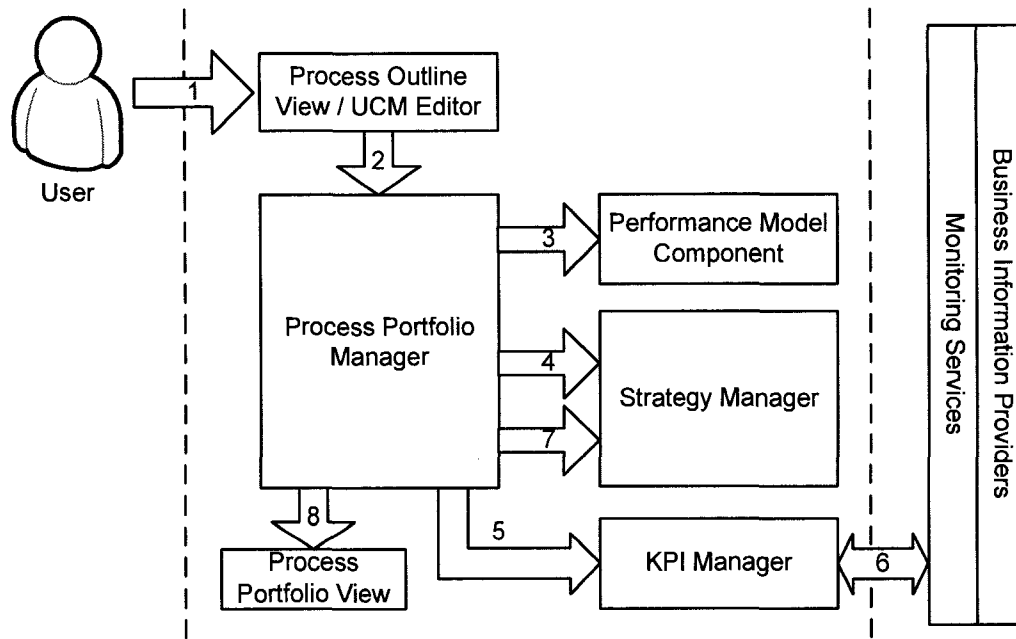


Figure 52: Process portfolio quadrant: run-time sequence model

Figure 52, illustrates the suggested conceptual workflow for the implementation of the process portfolio quadrant. After a user selects a process in the outline view or in the UCM editor by clicking on a stub (drill-down), a request is sent to the process portfolio manager, which uses other modules of the framework to provide the elaborated feature for the end users. In step 3, to find the relevant performance models to the explored process, the process portfolio manager interacts with the performance model component. In step 4, using a strategy manager, the portfolio manager generates, initializes, and triggers an importance strategy on the fly to calculate the importance value. Next, the values of KPIs are retrieved from information sources. In Figure 52, monitoring services, introduced in Figure 50, are used to extract the information from business information providers. One, however, can also use this feature without being connected to external sources, i.e., simply by initializing the evaluation values internally for simulation purpose. Finally, the performance value that uses the evaluation results of the performance strategies is also provided. Having both importance values and performance values, the processes are placed in proper locations on the process portfolio quadrant view.

5.3.2 Scenario-Based Performance and Impact Analysis

Most of the business processes in today's business environment, and especially in the e-business world, are cross-functional and cross-organizational and provide a composite service to fulfill the requirement of stakeholders. Hence, analysis and monitoring of business processes require more than the offerings of existing BI tools (Nicholls, 2006).

Scenario based performance and impact analysis is our new feature suggestion for our supporting monitoring tool to allow end users to analyse the process in a partial manner. This feature allows users to specify the part of the process they want to concentrate on. Therefore, the tool only calculates performance of the specified parts and evaluates their impact on the business goals. To achieve this goal we need to combine business process monitoring with UCM scenarios (Kealey, 2007).

Considering the work done for integrating scenarios and goals in (Roy, 2007), monitoring and performance analysis of processes in an automated and integrated manner is a new concept that demonstrates the real value of URN in the context of BPM.

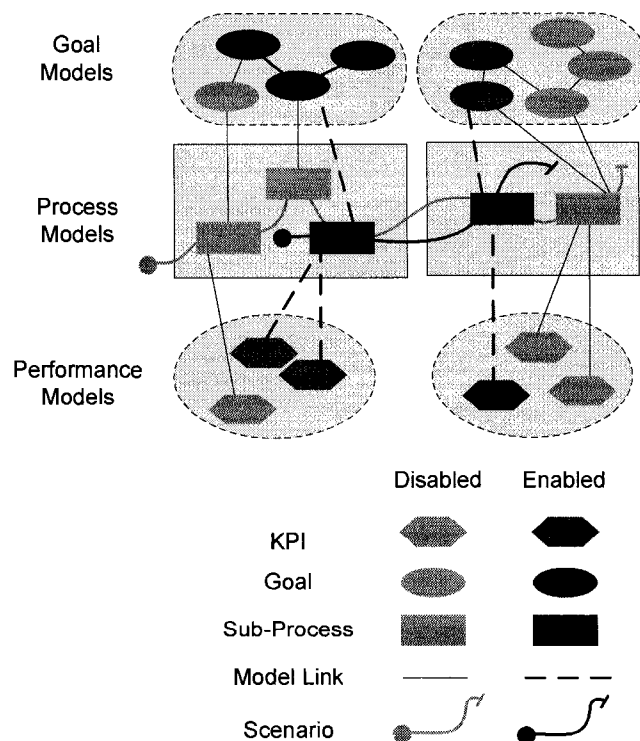


Figure 53: Scenario-based process analysis

As demonstrated in Figure 53, scenarios are used to highlight one particular part of the process in which the user is interested. The highlighted part could consist of tasks and sub-processes in one unit or in multiple units of the organizations that the end-to-end process covers. As illustrated here, and as discussed in section 5.1, the process models are connected to goal models from one side and to performance models from the other side. Enabling the defined scenario, the scenario manager triggers the evaluation algorithm only for those KPIs defined in the path of the highlighted scenario. Therefore, the impact of the highlighted parts of the process on the goal models will also be illustrated.

This feature gives great power to business analysts and process experts to do further research on various parts of the process independent of other parts, e.g. for sensitivity analysis. This feature does not only provide help for the monitoring step but also the improvement step. For example, in the monitoring step, an analyst would be able to find the real sources of negative or positive contributions to the business goals. Furthermore, in the improvement step, this feature can help analysts to concentrate on a modified part of the process and to observe the impact of the modification on the business goals.

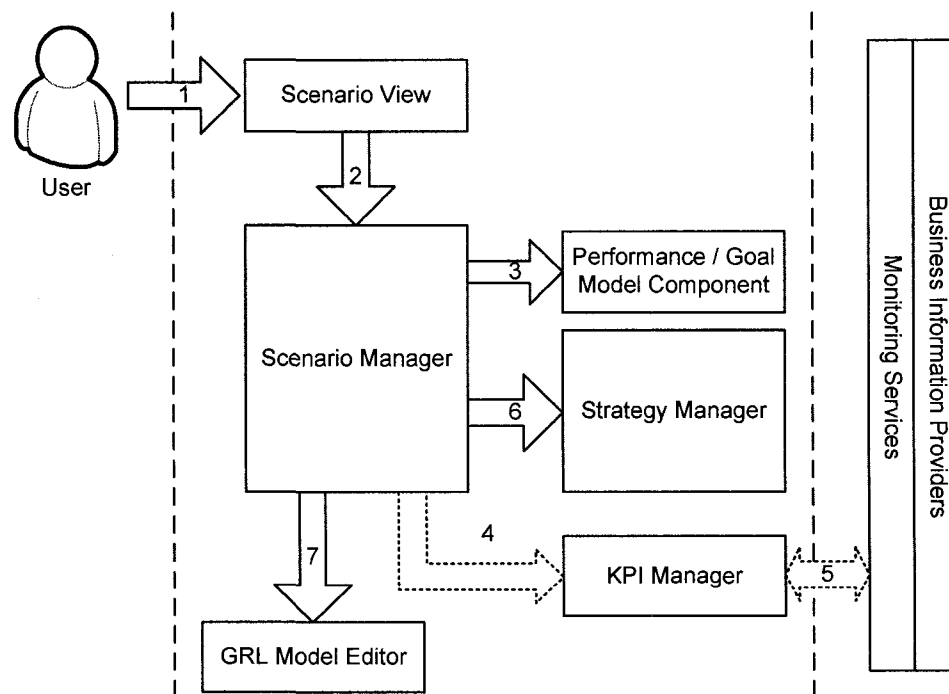


Figure 54: Scenario-based performance and impact analysis: run-time sequence model

Figure 54 illustrates the suggested conceptual workflow for the implementation of scenario-based performance and impact analysis. First, the scenario and strategy selected by the analyst (user) is passed to the scenario manager. Next, in step 3, the scenario manager interacts with the performance/goal model component to find the relevant performance models and map them to their associated processes and tasks. Afterward, the scenario manager sends a request to the KPI manager and the KPI values are retrieved during steps 4 and 5. Finally, based on the returned KPI values, the selected strategy will be initialized and triggered in step 6 and the results are sent to the user in the last step.

5.4 Summary

In this chapter, we have proposed a methodology as a guideline for exploiting the URN extensions introduced in Chapter 4. The methodology includes several steps for which we have introduced objectives, tasks, artifacts, tools, and roles. In addition, the main artifacts of the methodology, i.e. processes, goals, performance models, and their hierarchical relationships, have been discussed and modeled conceptually.

The five steps of the methodology are: Target Selection, Artifact Modeling, Data Source Preparation, Monitoring, and Alignment. The methodology covers the required steps from the very first point of the project when there is no process included in the process portfolio until the point when defective processes are found through the monitoring step and required alignments are suggested. The suggested methodology is an ongoing and iterative approach, which will make the process portfolio more comprehensive after each iteration. Although it takes several iterations to provide a complete process portfolio, practitioners can observe the benefits and see the results on the target process after the very first iteration.

Furthermore, we proposed two new features for our URN modeling and monitoring tool to provide better monitoring capabilities for the analysts. These features allow users to identify more easily the root causes of a problem in a process portfolio using a hierarchical quadrant view and to partially investigate a process using UCM scenarios combined with performance strategies.

Chapter 6. Validation

In this chapter, we use a validation scenario to utilize the proposed URN extension (Chapter 4), methodology, and tool enhancements (Chapter 5) in practice and validate and demonstrate their applicability in a real scenario. In sections 6.1 to 6.5, we go through the steps of our methodology to clarify their application and make them more tangible. Based on our observations during the experiment, we suggest potential areas for improvement and future work in section 6.6.

The process selected for this validation scenario is called “DW access approval process”. This process is a healthcare administration process used by a major teaching hospital. The privacy aspects of this process have been discussed in (Ghanavati, 2007). We demonstrate the goal model and process model of the process and develop a performance model to monitor the process based on the organization’s goals.

6.1 Target Selection - DW Access Approval Process

The target process is the DW access approval process. The objectives of this process are to give researchers and administration staff the authority to have access to the hospital DW while making sure privacy legislation and ethical rules are not violated. The main goal of the organization for having this process in place is to improve the quality and efficiency of the healthcare delivery by giving researches and business users better access to the appropriate data. At the same time, the hospital is responsible to protect patients health records and needs to be compliant with privacy regulations including PHIPA (Ghanavati, 2007).

Figure 55 illustrates the process goal model. As depicted, improvement in this process encourages the users to have access to the DW and thus more data will be analysed and quality and efficiency of the healthcare will be improved in the organization. In addition, the process helps prevent users from having access to unauthorized information. Therefore, it protects the hospital against privacy violation and assists it to be compliant

with regulations. Furthermore, the process is supposed to be updated based on new regulations and increase the agility and responsiveness of the hospital to the new regulation.

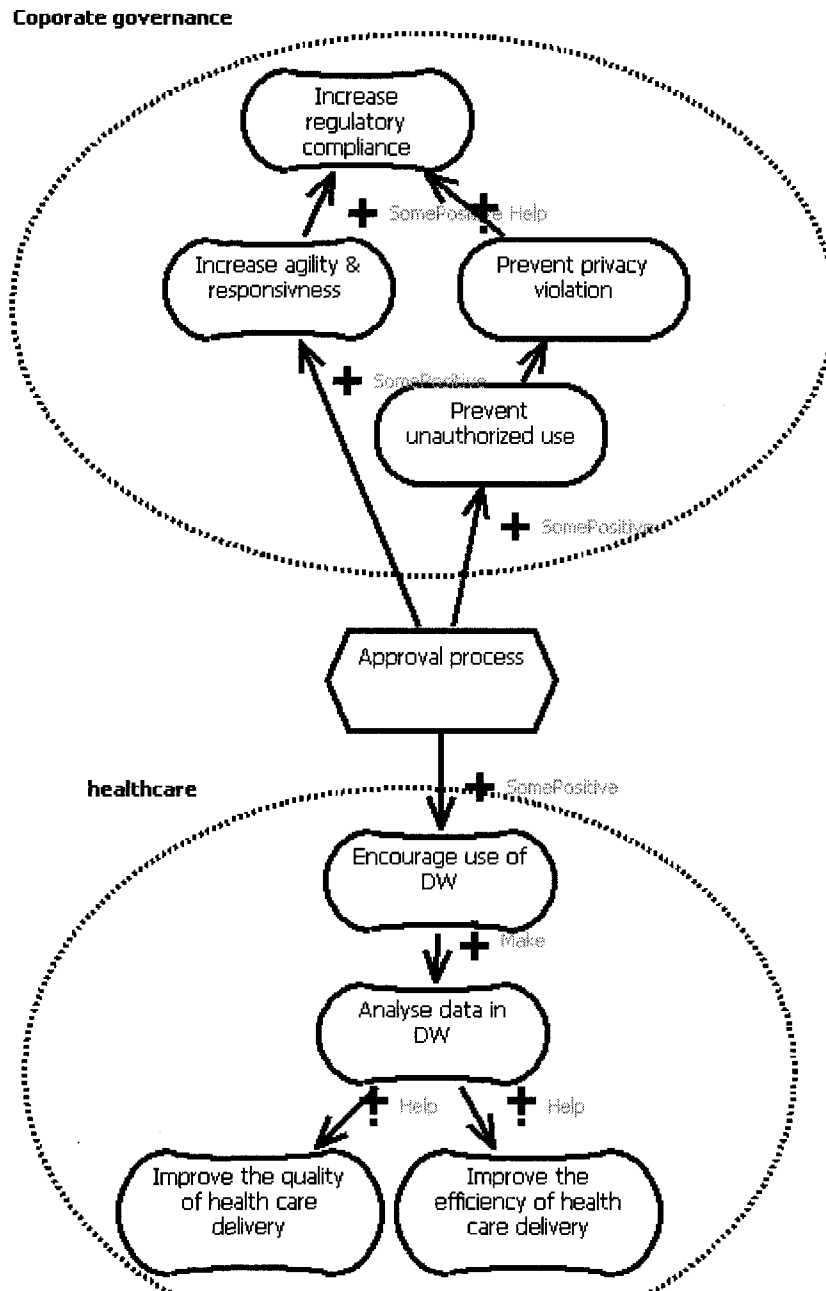


Figure 55: DW access approval process goals

Figure 56 gives a high-level view of the process. At a high-level, the process consists of three main steps (Ghanavati, 2007):

- submit a data request form (`requestForPHI`),
- review the data request form (`reviewRequest`),
- and amend the data request form (`amendDocuments`).

As illustrated, researchers send a request to the DW team including the data required. Then, the hospital reviews the request. Based on the results of the review, the request will be either accepted or rejected. In case of rejection, however, researchers still have time to send an amendment to the first request based on the received results. As a result of current inadequacies in the process including the tie to get approval, the number of current DW users is only 1% of the projected number. There, however, have been some efforts to put this process online to reduce the bureaucracy and turn-around time of the process (Peyton, et al., 2007).

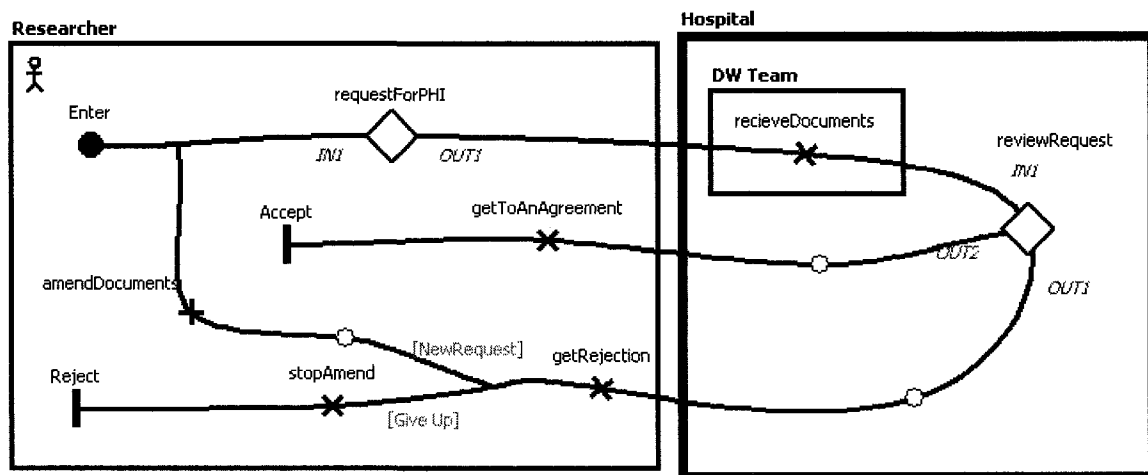


Figure 56: DW access approval process – high-level view

Based on the existing work on this process (Ghanavati, 2007)(Peyton, et al., 2007), the most important part of the process is the review sub process, which has been encapsulated in the `reviewRequest` stub in Figure 56. This part of the process contributes not only to privacy protection goals but also to users' encouragement by becoming faster. Therefore, we pick this sub-process as the main target of our study.

6.2 Artifact Modeling – Review Request Detail Models

Based on the guidelines of the methodology in the second step, after selecting the target of the study, the goal, process, and performance models of the selected target are elaborated. In addition, performance objectives are also specified and performance models are created to monitor them. Furthermore, the modeled artifacts are linked together.

Figure 57 illustrates the Review Request sub-process in more detail. As illustrated, this process has three main steps. In the first step, the application is reviewed by the chief privacy officer (CPO) to make sure the request does not violate privacy regulations or cause privacy violation issues (see Figure 58). Subsequently, the Research Ethics Board (REB) evaluates the request from an ethical perspective. In addition, the REB makes sure the disposal of data is done safely once it is no longer required for analysis. Furthermore, the REB makes sure users cannot use the requested data to identify the patients. In the last step, DW administrators review the application from a technical point of view to assess the availability of requested data. Furthermore, in this step, DW administrators grant access rights to the users in an appropriate manner. The detailed steps of the processes were specified based on the jUCMNav models in (Ghanavati, 2007).

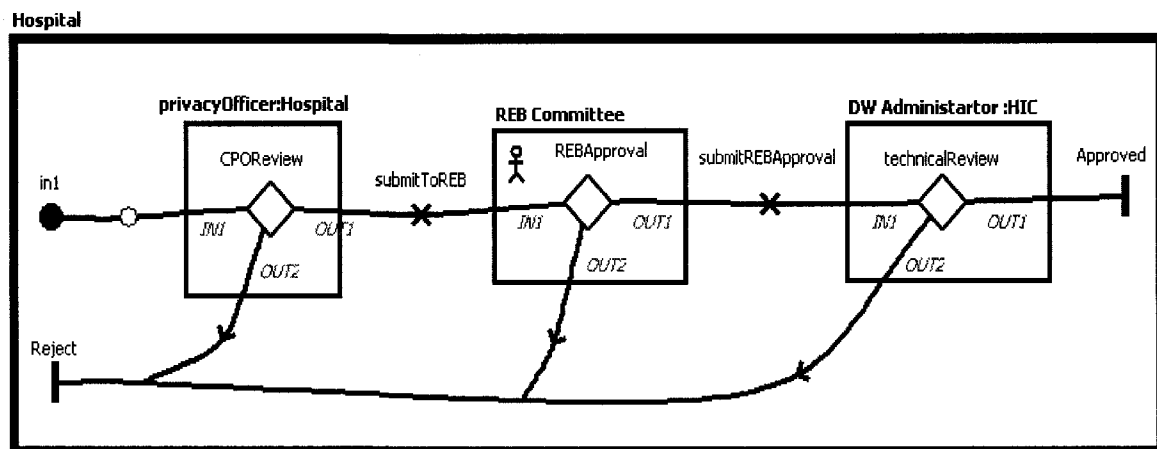


Figure 57: Review request sub-process

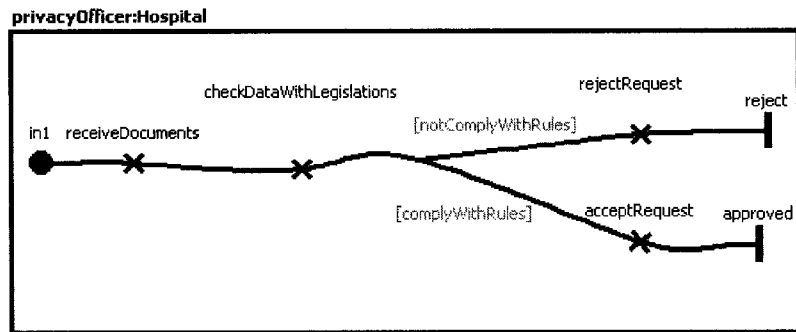


Figure 58: CPO review sub-process

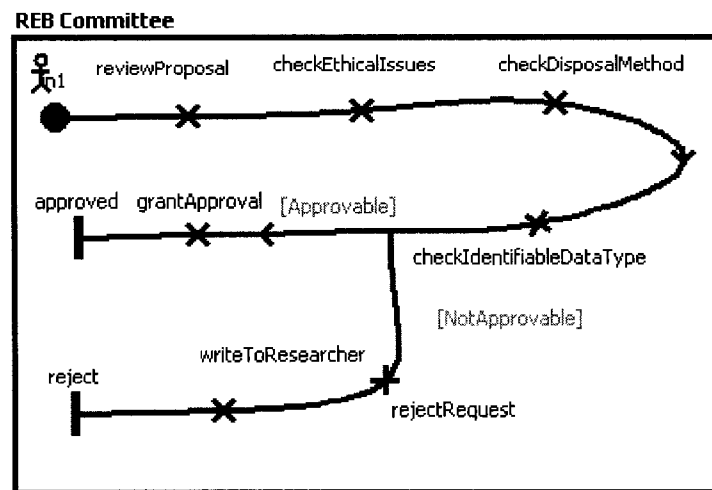


Figure 59: REB review sub-process

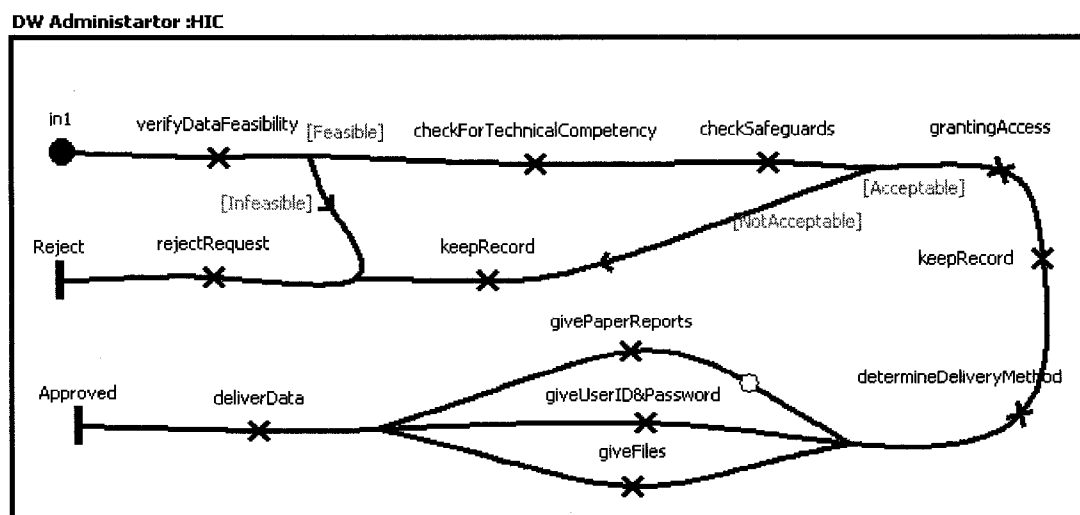


Figure 60: Technical review sub-process

The contributions of the target sub-processes to the business goals are shown in Figure 61 to Figure 63. All sub-processes contribute to the “Provide Access via Approval Process” goal. This goal is a hard goal for the organization. They also contribute to “Protect Privacy, Confidentiality and Security of Data”, which is one of the high-level soft goals of the organization. In addition, technical review contributes to “Ensure Accountability of Data User” and “Ensure Security of Data”. Furthermore, the REB Review process helps to “Limit Access to Identified Data”. The contributions of these sub-processes to business goals are specified using various GRL contribution types.

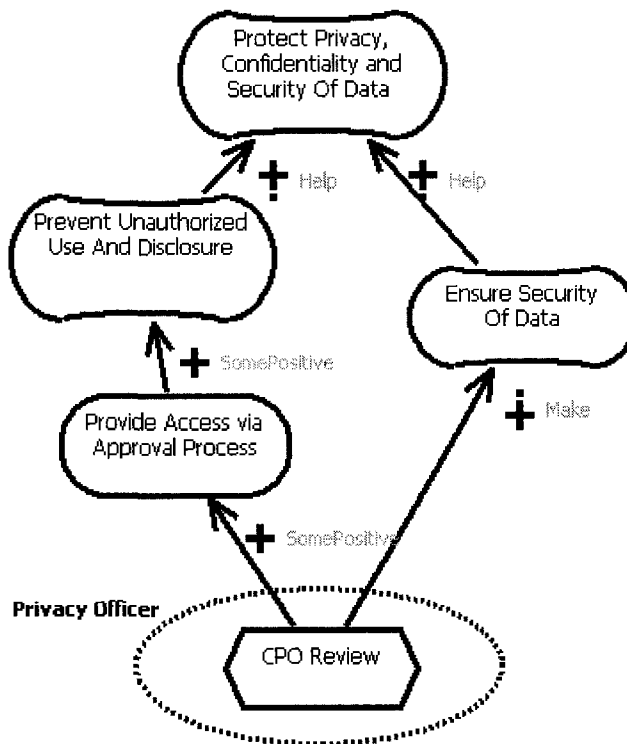


Figure 61: CPO review goal model

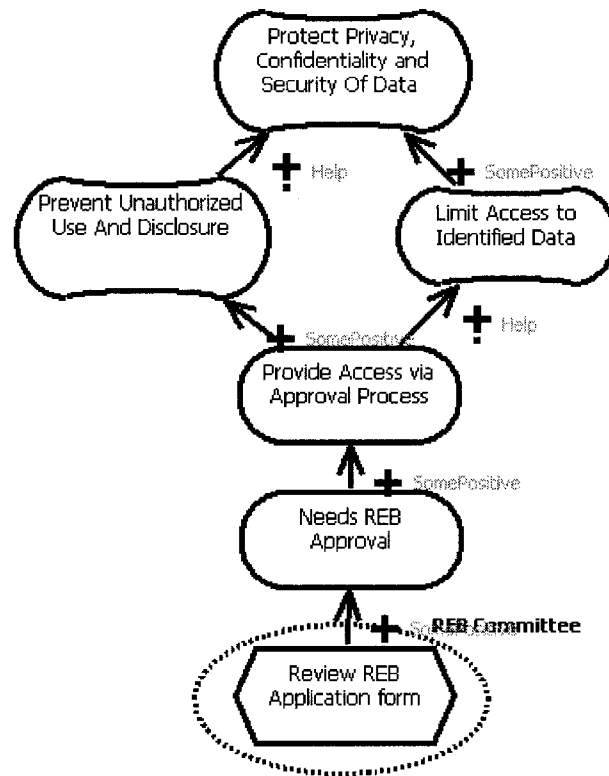


Figure 62: REB review goal model

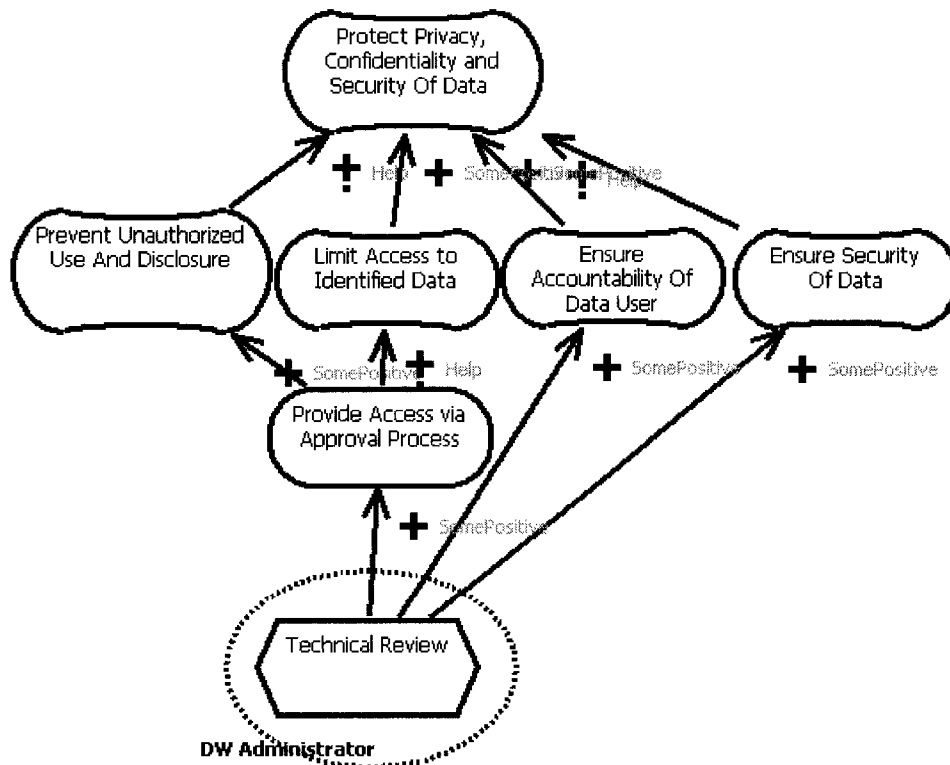


Figure 63: Technical review goal model

Figure 64 to Figure 67 illustrate the performance models of the target process. While Figure 64 shows the performance model for the whole approval process, the other models describe the review sub-processes. The main objective followed for these performance models is to evaluate the target process from the quality and time perspectives. Quality in the context of this process is the “Number of Complaints”. In addition, “Number of users” is an indication of the quality of the process by specifying how effective the process is in keeping the users satisfied. Moreover, we would also like to reduce the cost of the process and to decrease the end users’ efforts. The performance models are shown using the URN extension introduced in Chapter 4.

The first performance model, illustrated in Figure 64, describes the goals of the entire process:

- reduce number of complaints,
- reduce time of approval,
- reduce process costs, and
- reduce process efforts.

This model illustrates exactly what we mean by a performance goal and how one may connect performance goals to the other elements of the model. As illustrated, we have defined a KPI for each goal to evaluate the performance of the process quantitatively. KPIs are defined using hexagon symbols with two parallel lines to distinguish them from GRL tasks. All KPIs will contribute to process performance, either directly or indirectly, through the goals they contribute to. As an example, while the number of users contributes directly, the average cost per application contributes via “Reduce Process Costs”.

The dimensions defined for these performance models are unit, time, and service. Unit and service are hospital entities involved in the process. We defined these dimensions using a `KPIInformationElement`. As demonstrated, one can use a defined dimension for multiple KPIs. We have connected these dimensions to the KPIs using a `KPIModelLink`.

We have linked the performance model to the business goal model through the “Approval Process” task. Although this model element exists in both Figure 64 (performance model) and Figure 55 (goal model), it corresponds to the same underlying model

element. The evaluation values calculated for the KPIs in the performance model are converted to evaluation levels. These evaluation levels are then propagated, aggregated, and used as the evaluation level of the “Approval process” task. This evaluation level is finally used in the goal model to visualize the impact of the “Approval Process” on the business goals.

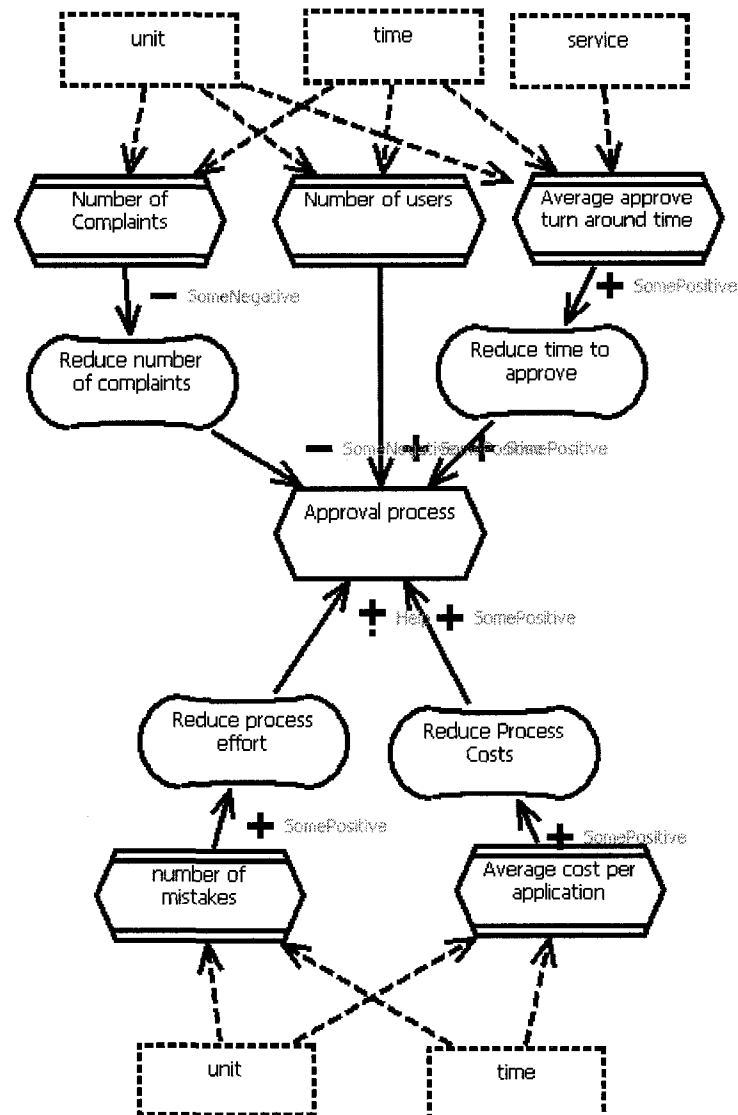


Figure 64: Approval process performance model

Figure 65 shows the performance model for the CPO sub-process. In this diagram, two KPIs have been defined, “Average CPO review turnaround time” and “number of privacy

related complaints”. The KPIs are in-line with the whole objective of the performance models. Although these KPIs are specific to CPO Review, i.e. the monitored sub-process in this performance model, they have the same objective as the higher level performance model (Figure 64). Even if the framework allows us to define completely different KPIs at different levels, we recommend following the same objectives throughout the models. This approach assists analysts in drilling down into the models to identify the root cause of a problem. For example, if the “Average turnaround time” for the whole process is high, we can determine whether the CPO Review sub-process is the root cause or not.

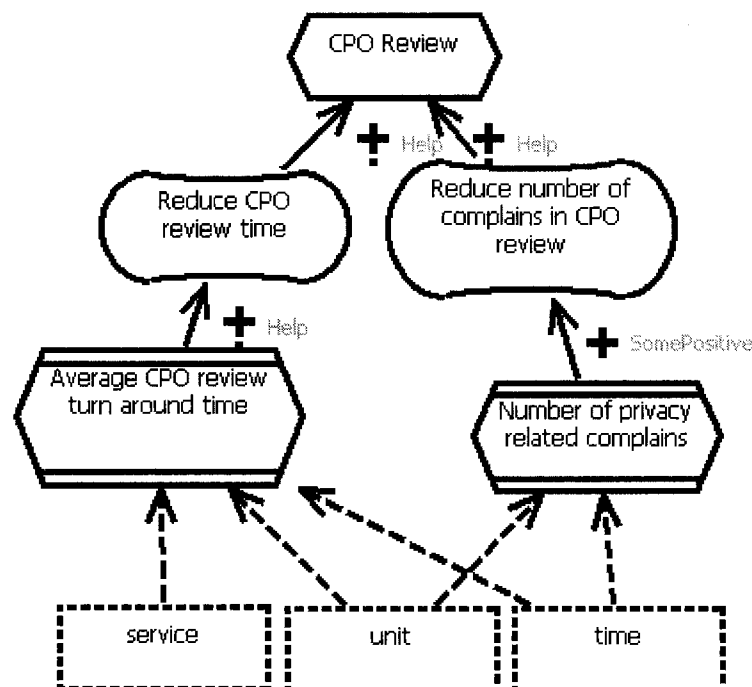


Figure 65: CPO review performance model

As part of our future work, we plan to use process model elements and process abstraction levels as dimensions (see section 7.3 for more details). This allows users to define a KPI at a high-level and observe the value of the same KPI for sub-processes or tasks by drilling down or up in the process model. To provide this capability, we need a mapping method between process structure and dimensions defined in the dimensional data sources (OLAP models).

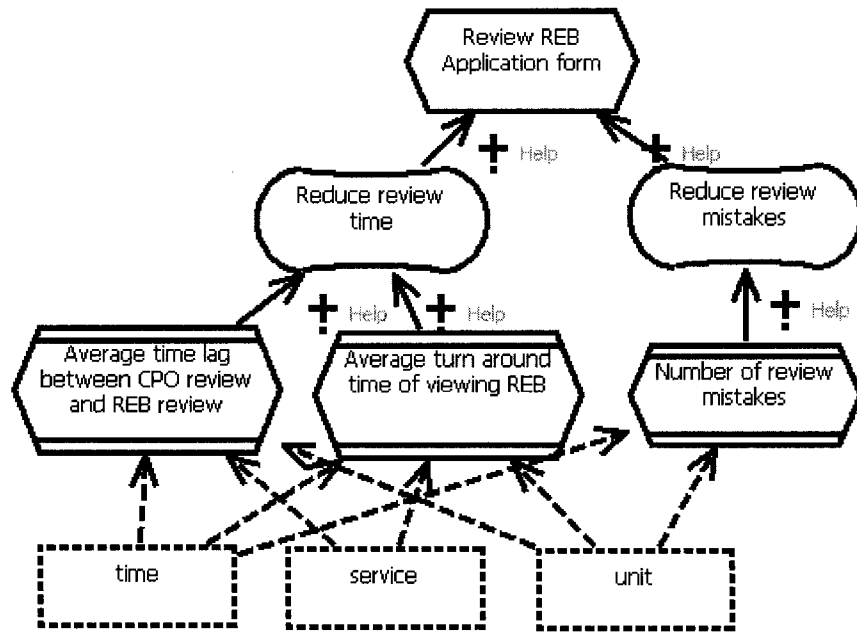


Figure 66: REB review performance model

The REB Review performance model is illustrated in Figure 66. The performance goals defined in this model are in line with the performance goals defined at a higher level. In this model, we consider three KPIs to monitor the REB sub-process. In addition to turnaround time KPI, we have also added another KPI called “Average time lag between CPO review and REB review”, which measures the idle time of the process between REB review and CPO review. Although this KPI might look like a shared KPI between the REB and CPO sub-processes, it is more appropriate to consider this KPI as a REB performance metric since it measures the time from when CPO handed off its output to the REB input queue, and any delay is a consequence of REB’s speed in processing its input. Therefore, the “Number of review mistakes” and “Turnaround time” KPIs are defined to fulfill the performance monitoring objectives.

Figure 67 illustrates the technical review performance model. This view measures the technical review turnaround time as well as the quality of the review using the number of technical review mistakes.

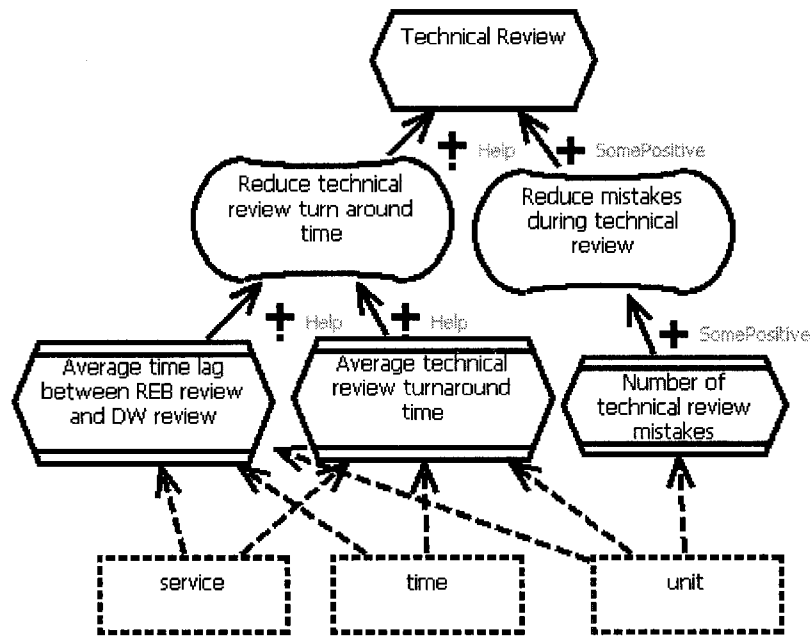


Figure 67: Technical review performance model

6.3 Data Source Preparation – Dimensional Data Source

The next step in the methodology is the data source preparation. During the experiment, we did not have access to any existing computer-based data sources related to this process and the information required to evaluate the KPIs was not available. Therefore, based on the initial statistical information received from process experts, we have generated artificial KPI evaluation values to continue with the rest of the experiment and exercise all the steps of the methodology. In this section, we demonstrate how the mapping between the performance model and a dimensional data source designed for this process works. We can use this dimensional data source to extract the real KPI values from the appropriate sources of information after they become available in the hospital.

Data source preparation, including the dimensional data source design method, was elaborated in (Chen, 2007 pp. 94 - 99). We use the same principles here to design our data sources.

Table 8 and Table 9 demonstrate the information required for designing the dimensional data source. These tables include dimension levels and values as well as KPI units. Based on this initial information, we can extract the required data mart from the

DW or from operational data sources. Then, we generate a dimensional model similar to Figure 68.

Table 8 Approval process performance model dimensions levels and values

	Level enumeration	Value enumeration
Unit	Campus	Civic General
Time	Year Month Day	2005 January Monday, December 24, 2007
Service	Service	General Medicine Emergency Department

Table 9 Approval process performance model KPI unit

	Unit	Metrics
Number of Complaints	Integer	Complaints
Average Approve turnaround time	Day	Application submission time Application response time
Number of mistakes	Integer	mistakes
Number of Users	Integer	Users
Average CPO review turnaround time	Day	CPO review start time CPO review finish time
Number of privacy related complaints	Integer	Complaints
Average time between CPO review and REB review	Day	CPO review finish time REB review start time
Average REB review turnaround time	Day	REB review start time REB review finish time
Number of review mistakes	Integer	mistakes
Average time lag between REB review and Technical review	Day	REB review finish time Technical review start time
Average technical review turnaround time	Day	Technical review start time Technical review finish time
Number of technical review mistakes	Integer	mistakes

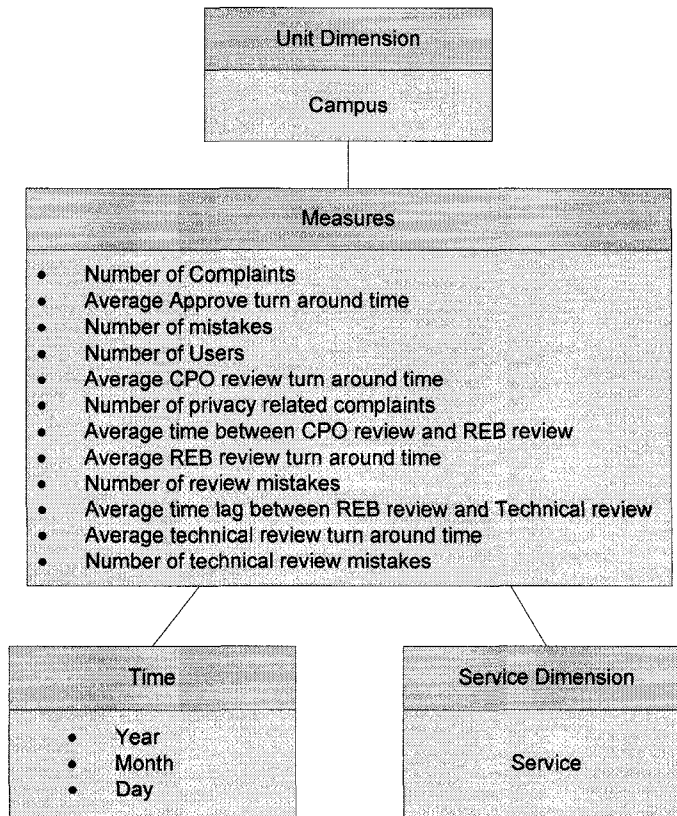


Figure 68: Approval process dimensional data source

6.4 Monitoring

After providing the required performance models, we can now start monitoring the process. To perform monitoring, we have to define the monitoring strategies including KPI value sets. To show the capabilities of our methodology and its supporting tool, we have two different strategies with different KPI evaluation values. One of the strategies simulates the condition in which the DW is at its initial stages and only has few users. The second one, based on a set of assumptions, illustrates what would happen to the indicators if the number of DW users increased. In both cases, we have calculated the performance value and importance value of the sub-processes monitored and we demonstrate how our process portfolio monitoring view would look like. Furthermore, since the tool for calculating the importance value automatically was not available at the time of this experiment, we have used four other strategies to calculate the importance value of each sub-process monitored.

Table 10 KPI value sets – first performance strategy

KPIs	T	Th	W	EV	EL
Average CPO review turnaround time (days)	3	15	30	7	66
Number of privacy related complaints	2	7	15	4	60
Average time lag between CPO review and REB review (days)	1	5	15	3	50
Average turnaround time of viewing REB (days)	2	8	15	6	33
Number of review mistakes	5	12	20	8	57
Average time lag between REB review and DW review (days)	2	6	16	3	75
Average technical review turnaround time (days)	2	7	15	5	40
Number of technical review mistakes	5	8	15	6	66
Number of complaints	5	15	30	9	60
Number of users	100	30	10	35	7
Average approve turnaround time (days)	7	30	60	18	52
Number of mistakes	10	20	35	12	80

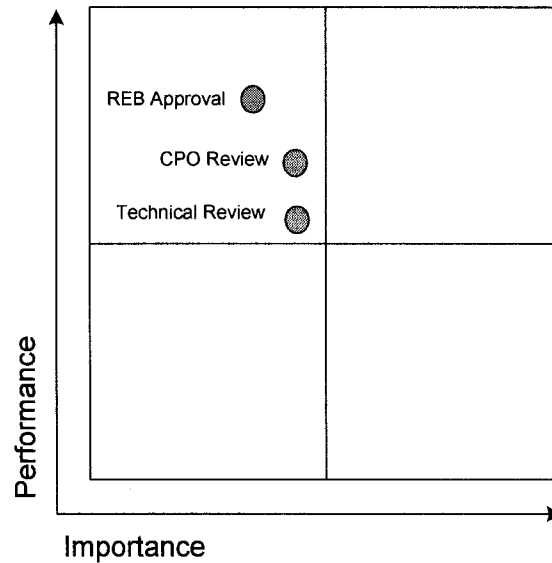
T: Target Value; **Th:** Threshold Value; **W:** Worst Value

EV: Evaluation Value; **EL:** Evaluation Level (GRL)

Table 10 shows the first strategy value set. In this table, we have defined Target, Threshold, Worst, and Evaluation values. In addition, we have shown the corresponding GRL evaluation levels for each KPI. The performance values in Table 11 are the result of the first performance strategy and each importance value is the result of the strategy specifically initialized for that purpose. The KPIs defined with the first strategy value set shows a healthy condition for the monitored processes. The calculated performance for the approval process is 89 and most of the KPI evaluation values are in the required range – between threshold value and target value. Figure 69 illustrates process portfolio view with importance and performance as its axes. This view is depicted based on the values in Table 11. While REB has slightly lower importance values than other monitored sub-processes, it has the highest performance of all.

Table 11 Initial results

	CPO Review	REB Review	Technical Review	Approval Process
Importance	37.6	36.7	37.6	32.67
Performance	71	78	60	89

**Figure 69:** Initial process portfolio view

In the second round of the monitoring, we have used the second performance strategy to simulate a condition in which the number of users has substantially increased, accompanied by a raise in the number of complaints. The KPIs with modified values are shown in Table 12. In this new context, the number of users went from 35 to 80 and the number of complaints from 9 to 16. In addition, the number of mistakes has also increased, from 12 to 15. These problems all together have resulted in a drop of the performance of the approval process from 89 to 55.

Table 12 KPI value sets – second performance strategy

KPIs	T	Th	W	EV	EL
Number of complaints	5	15	30	16	-6
Number of users	100	30	10	80	28
Number of mistakes	10	20	35	15	50

Among the 16 complaints, 10 are related to DW performance issues. The high number of DW performance complaints shows we can easily have other types of complaints than privacy complaints, initially considered in our model. Therefore, adding this new type of complaints to the performance model and considering a complaint type dimension to enable further analysis on this issue makes our performance monitoring model more complete and in-line with the reality. Furthermore, we should also add a new goal to our performance model to reduce the number of technical complaints. Figure 70 illustrates the updated performance model for the technical review sub-process based on the monitoring result (the original model is found in Figure 67). Obviously, corresponding changes in the data model are required to enable us to retrieve the new KPIs and dimensions added to the model.

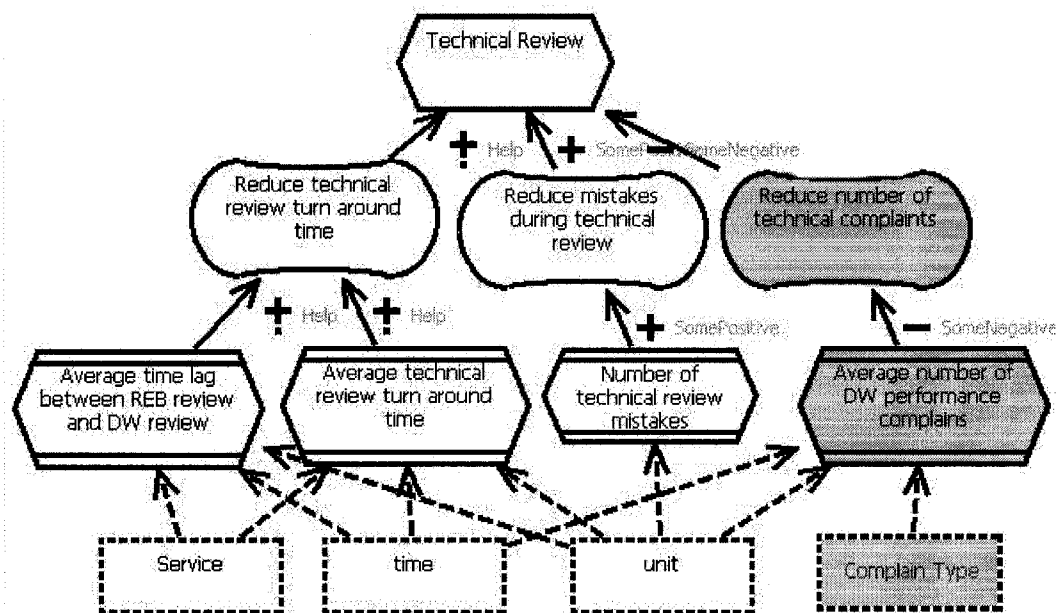


Figure 70: Updated technical review performance model

As illustrated, our methodology, the extended URN meta-model, and the supporting tool we developed all helped monitor and observe the changes in the process condition. Furthermore, the modeling tool assisted us in adding a new KPI on demand based on our new findings, leading to a better understanding of the organization as it evolves.

6.5 Alignment – Goal Model and Process Improvement

The objective of the alignment phase is to adjust and improve goal or process models based on the observations in the monitoring phase. In this section, we demonstrate how the monitoring results can be used to change both goal models and process models. Such change can be either an adjustment or an improvement to better reflect the reality of monitored processes or to reduce some of the observed problems respectively.

Based on the monitoring results, there is a correlation between an increase in the number of users and a performance reduction in the DW. This issue shows that the approval process has an impact on other organizational goals like “increase quality of internal services”, which were not described in our initial goal model. Figure 71 illustrates the updated goal model.

Based on the new goal model and performance model, we compute the importance and performance once more, as shown in Table 13. Since the technical review now influences more the organizational goals than in the original model, its importance value has increased from 37.6 to 57.75. On the other hand, the performance of this sub-process went down because of the newly added KPI (technical complaints) and its negative impact on the model.

Table 13 Updated importance and performance values based on new models

	CPO Review	REB Review	Technical Review	Approval Process
Importance	28.25	27.5	57.75	40
Performance	50	76	49	55

Considering these new importance and performance values, the process portfolio view has been updated - Figure 72. This view simply shows that the most important sub-process does not perform well comparing to other sub-processes. Therefore, the main candidate for improvement is the technical review sub-process.

Based on the monitoring results, including the number of complaints, the main current problem is the impact of the approval process on the DW performance. To solve this issue, we should improve the technical review sub-process by adding proper tasks to prevent further negative impact on its performance. Figure 73 illustrates the suggested improved technical review sub-process. To address its problems, we added a new task to

the process to test performance impacts before finalizing the delivery method. If the initial delivery method has a negative performance impact, DW administrators will modify it to meet the performance requirement. This additional task might however have a negative impact on the technical review turnaround time. We can address this issue by observing the technical review turnaround time in the next monitoring cycle and make further adjustments.

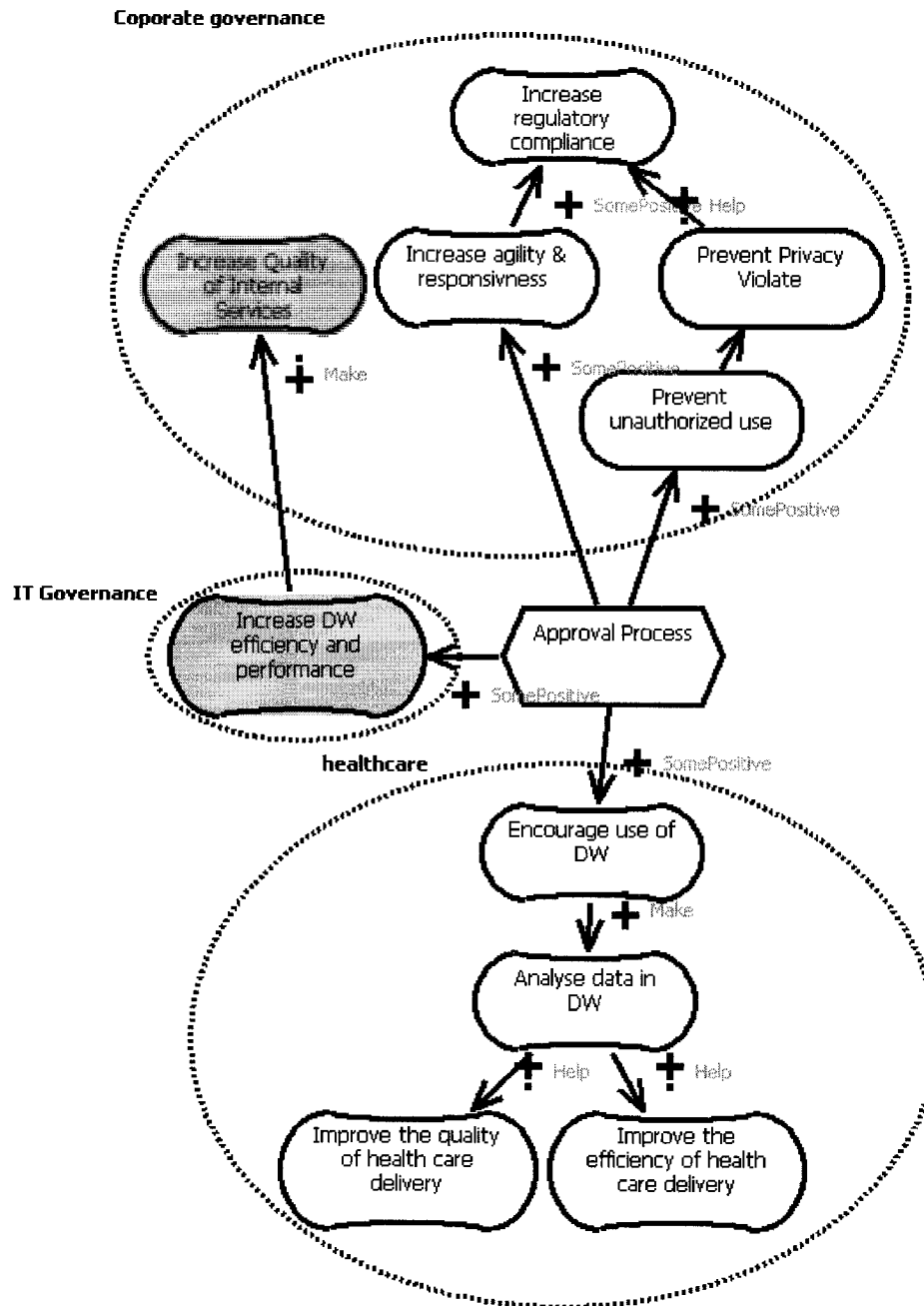


Figure 71: Updated DW access approval process goals

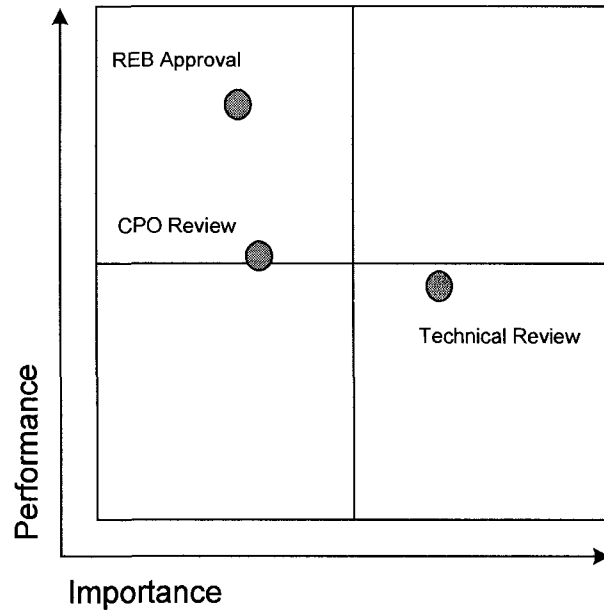


Figure 72: Updated process portfolio view

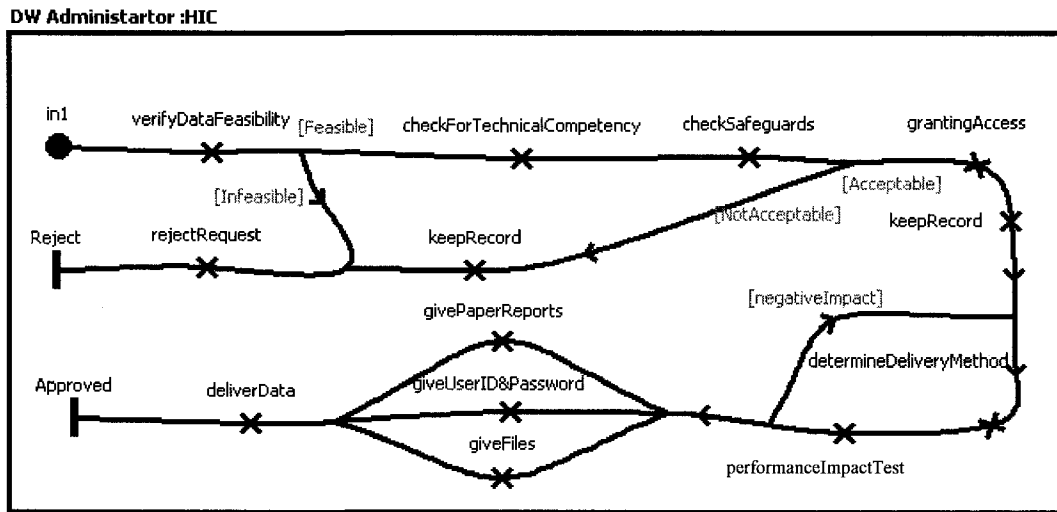


Figure 73: Updated technical review sub-process

6.6 Issues and Suggested Improvements

During this experiment, we have observed several issues in the supporting tool and overall framework we will briefly discuss here. The main potential improvement areas are:

- Propagation algorithm
- Integration with data source layer
- Process dimension
- Redesign patterns utilization

The current propagation algorithm in jUCMNav prevents user from using the performance-monitoring tool at its full capacity and, in some cases, it even prevents users from observing the expected results. The main issue relates to how negative contributions are handled. To illustrate, when a KPI has a negative evaluation level (e.g. -80) and when it is connected to an intentional element through a positive contribution of one type, the expected result is to observe the negative impact on the intentional elements. As shown in Figure 74, although the only contributing intentional element to the sample soft goals are the sample indicators connected to them and the evaluation level of sample indicators is -80, the impact on goals is still positive, which is not what is intuitively expected by business users. This issue prevents business users from showing any negative impact on the goal models. Although as a work around, we have used negative contribution links in our study to show the negative impact on the goal models, using negative contribution links for this purpose is also not as easy as it seems to be. As demonstrated in Figure 74 and Figure 75, for negative contributions, positive and negative evaluation levels in the source intentional element can produce negative result on the target. This result also looks illogical to a business user. In addition, as demonstrated in the same figures, the results produced by current qualitative contribution links (e.g. SomePositive, Help, Hurt) are out of the end users control and are based on internal assumptions of the propagation algorithm, which might not be suitable for all application.

To solve all these problems, we should add *quantitative* contribution links to offer a much more granular control to the users. In addition, we should improve the propagation algorithm especially for negative evaluation levels or add new algorithms for our application. Since the design of the supporting tool allows modelers to use various algorithms as required during analysis (Roy, 2007 p. 63), we could develop a propagation algorithm more in line with the expectations of business modelers and analysts.

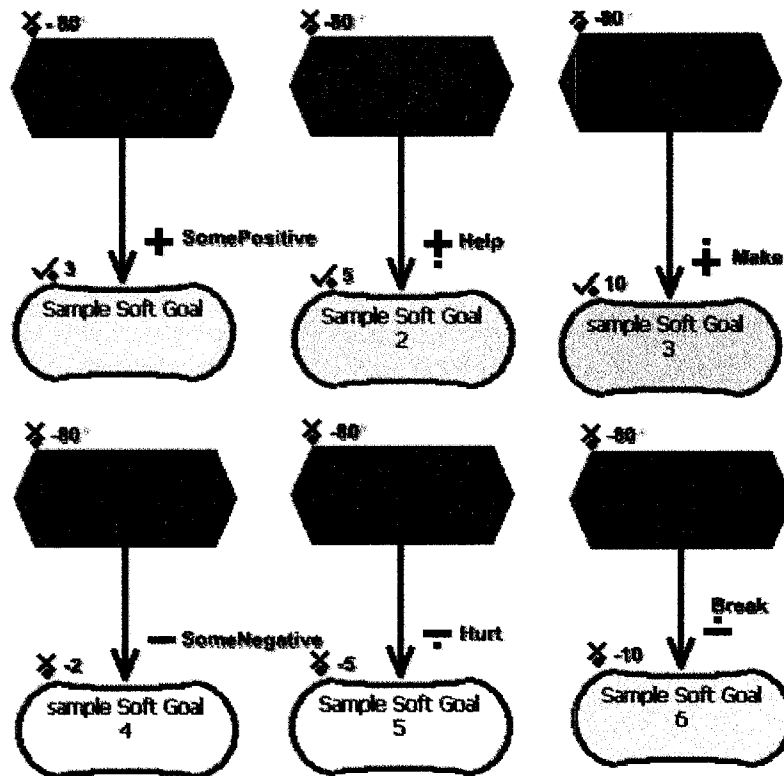


Figure 74: Negative evaluation value

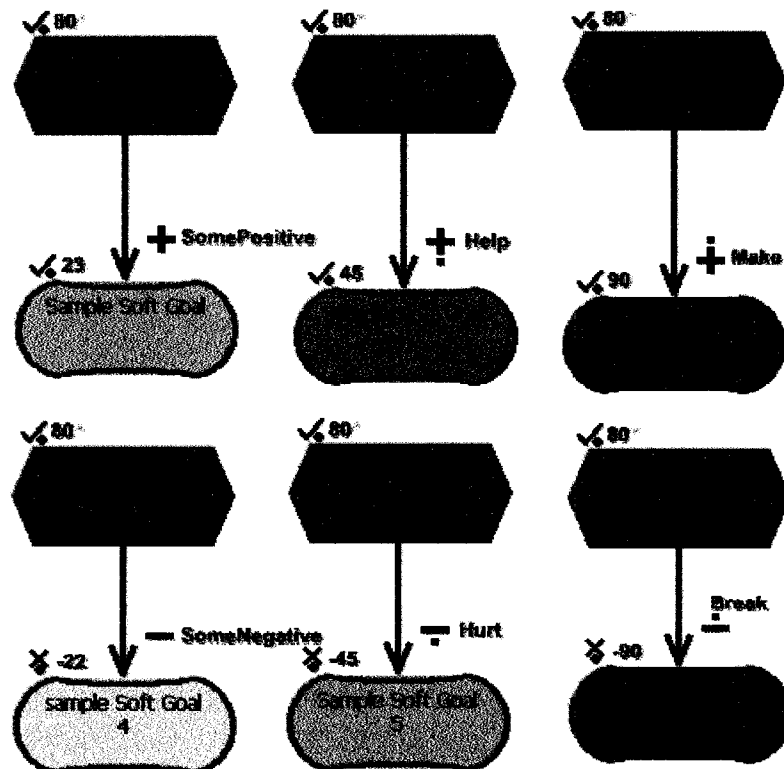


Figure 75: Positive evaluation value

Another potential area of improvement is a better integration with data source providers. As demonstrated in the validation scenario, in some situations, end users need to add new KPIs and dimensions to the model. Currently, for any new KPI or dimension, the dimensional data source should be altered from a different interface and by a different user (e.g. DW and BI expert). This process makes performance model changes dependent on other entities than direct users of these models, which reduces the responsiveness of the performance monitoring tool. The tool should enable users to perform this task without being dependent on other entities, at least in a defined boundary. Although this can partially be provided by preparing a set of KPIs and dimensions in the dimensional data source, the ultimate goal is to give users the flexibility to generate any kind of KPI in the context of the monitored process.

Furthermore, providing a process dimension in the performance model can reduce some of the above challenges. A process dimension allows users to drill down and up through different levels of abstraction in the process and observe the value of KPIs defined in all these levels. This is very useful for finding the root cause of problems and for reducing drastically the number of required KPIs for monitoring.

Finally, we should utilize the redesign patterns suggested in Table 3 in the improvement process. Although we have categorized these design patterns and our tool allows categorization of the KPIs based on these patterns, currently we do not have mature guidelines for using them. In future studies, we propose to not only provide such guidelines but also automate the process of suggesting and applying predefined design patterns to modeled processes.

6.7 Summary

In this chapter, we have demonstrated the application of our process monitoring methodology using a validation scenario. We illustrated all steps of the methodology and went through a complete monitoring cycle (including the modification of goals and processes during alignment) to validate the applicability of our approach and of our URN extensions. Finally, we discussed the problems and challenges observed during our experiment with this scenario and suggested potential future improvements.

Chapter 7. Conclusion

7.1 Summary

In this thesis, we have defined a goal-oriented process monitoring methodology based on the User Requirements Notation as our modeling language, jUCMNav as the supporting tool for modeling and monitoring processes, and Data Warehouses and Business Intelligence Systems as our information sources. This methodology and its supporting tools help businesses define their Key Performance Indicators (KPIs) based on their business goals. Using GRL contribution and decomposition links, these performance indicators can be linked together to form a performance model for a process model. Consequently, one can visually observe the impact of business process performance on business goals. Since URN allows one to model processes, goals, and performance models in different layers of abstraction it is possible to use the tool in both strategic level applications and operational layers of the organization. Generally speaking, this methodology can ultimately be used to align business processes with business goals. This alignment could either take the form of an improvement or a modification to existing business processes or an adjustment of business goals and can be done in all layers of the organization.

In this thesis, we addressed several problems and limitations observed in existing process improvement methodologies, in Business Process Management Systems, and in the current User Requirements Notation. Table 14 represents a summary of these problems and of the solutions we provided.

In this thesis, we followed the following research process. First, in section 2.1, we reviewed the literature on existing process improvement and quality methodologies to gain more knowledge about the appropriate steps of a quality methodology as well as about the inadequacies of current methods. In addition, in section 2.2, we studied several modeling notations and discussed the benefits of URN for our application over other notations. Furthermore, in section 2.2.2, we briefly described URN, including the main UCM and GRL notation elements and the GRL evaluation mechanism. We also reviewed

the results of the Business Process Modeling Systems study in (Chen, 2007) that illustrates the shortcomings of these systems in goal modeling, process evaluation, and traceability between processes and goals (see section 2.3 for details).

Second, in Chapter 3, we elaborated on the problem and demonstrated it using a test scenario – a patient discharge process. Using this example, we illustrated the capabilities of URN before the extensions proposed in this thesis.

We formalized the extensions to the URN meta-model in the third step (Chapter 4). Then, we used the same scenario to demonstrate that the suggested extension is sufficient to address the observed problem.

In the fourth step (Chapter 5), we suggested a methodology and guidelines based on the extended URN for goal-oriented business process monitoring. At this stage, we provided detailed descriptions about actions, roles, artifacts, and tools in each step of the methodology. Furthermore, in section 5.3, we suggested two new features for the supporting tool to enhance the monitoring and analysis capability for the users. The first feature is called business process portfolio quadrant. This feature helps users investigate the root of the problems while they monitor a process and its sub-processes. The second feature is called scenario-based performance and impact analysis that helps users monitor and investigate a specific part of the process based on a defined scenario.

Finally, we validated the suggested URN extension as well as methodology steps using a realistic validation scenario (see Chapter 6 for details). In this step, we went through the entire methodology and demonstrated its applicability to a “DW Approval Process”. We demonstrated that the methodology and its supporting tool are capable of monitoring processes, capturing variations, and helping with adjustment of goals and improvement of processes.

7.2 Conclusion

Table 14 summarizes the problems we observed and the corresponding solutions. As illustrated, all stated problems have been addressed over the course of this study and in (Chen, 2007). URN has been extended successfully to provide performance modeling capabilities. In addition, a methodology has been developed which provides guidelines for using URN as a process performance monitoring tool. Using URN and the suggested

methodology, we have addressed some of the discussed shortcomings of existing methodologies and monitoring tools. We, however, should do further research to provide a more comprehensive business process management framework based on URN, and to determine how it can complement or enhance existing methodologies.

The scenario used for validating our methodology demonstrated its applicability and illustrated the usage of our URN extensions. Based on this experiment, all steps of the methodology appear to work well in practice. The only concern based on our experiment regarding the performance of the approach in practice is the required modifications in the information source layer after any new addition to the performance models. Furthermore, the current propagation algorithm used for evaluating performance and goal models has some difficulties especially in case of negative contributions. To solve this issue, we should enhance the current algorithm or develop a new algorithm specifically designed for monitoring purposes.

Table 14 Summary of problems and provided solutions

Problem	Solution
Since improvement methodologies and process monitoring tools do not utilize a goal modeling language, they are unable to visualize the impact of process performance on business goals.	We have suggested a novel process monitoring approach using the User Requirements Notation, a language with the ability to model both goals and business processes.
Using tools traditionally used by management and statistics-oriented methodologies does not allow us to have access to the process-related information dispersed inside and outside the organizations.	We have suggested an approach based on an open layer of data access that can be used to provide access to any kind of information related to the processes and using them for process monitoring purposes.
Methodologies with supporting software have integration issues with different information systems generating related information.	Based on the suggested method in this thesis, a supporting tool has been developed in (Chen, 2007) to use DW and BI as sources of information communicating with a layer of web services that pass the information to jUCMNav.
The main URN supporting tool – jUCMNav – cannot support the use of data dispersed across different information systems as source for process monitoring.	
URN does not have the capability for defining metrics and indicators to perform process monitoring.	The URN meta-model has been extended to provide the required capabilities for performance monitoring.
There is no guideline or methodology on how to use URN with a set of integrated tools to perform process monitoring.	We suggested a methodology that one can use as guidelines with the extended URN and supporting tools for business process monitoring.

7.3 Future Work

Our extensions to URN, the monitoring framework, and the supporting tool represent a significant step toward achieving our vision for providing a URN-based business process management framework.

To complete the improvement cycle of our methodology, business process reengineering patterns should be used and detailed guidelines on how to use them in different situations based on monitoring results should be provided. In addition, the tool support required to recommend patterns to users automatically and to apply these patterns to the appropriate parts of the process should be developed. Moreover, detailed guidelines on how to make the best use of the performance strategy definition capability will be provided. This feature can be used for simulation and validation of the suggested improvements. Furthermore, to provide better process analysis capabilities to end users, the features we have suggested in Section 5.3 including process portfolio analysis and scenario based performance and impact analysis should be implemented.

Another area of focus would be improvements to the current evaluation mechanism by providing suitable propagation algorithms for different applications. At the same time, alternative quantitative contribution links to the existing qualitative ones need to be supported. A combination of new algorithms and qualitative contribution links will give users more power to control the propagation results. In addition, the possible improvements of designed meta-model will be investigated. One of the improvement candidates is the KPIValueSet part of the meta-model that currently has four hardcoded values. We will try to give users more flexibility by allowing them to define their own customized set of boundaries and value sets.

In terms of integration with external tools, two major improvements are required. First, a better integration with the data source layer to allow users to add a new KPI automatically should be provided. Based on our observations, this enhancement could improve the performance and cycle time of the suggested methodology. Second, our supporting tool should be integrated with process execution engines to be able to automate the modeled processes and workflow as part of our Business Process Management Framework.

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Appendix A: Supporting Tool: jUCMNav

jUCMNav is the URN supporting tool used in this study. jUCMNav supports modeling both UCM and GRL notations. In addition, it provides traceability between GRL and UCM. Furthermore, jUCMNav supports evaluation of strategies and UCM scenarios (Roy, et al., 2006). In (Chen, 2007), the URN extensions and connections to external sources proposed in this thesis were implemented and added to jUCMNav.

jUCMNav is an Eclipse plug-in built using the Eclipse Modeling Framework (EMF) and the Graphical Editing Framework (GEF). Figure 76 shows the conceptual architecture of jUCMNav. As shown, the latest version of this tool is capable of using Cognos BI as a source of information for business process monitoring.

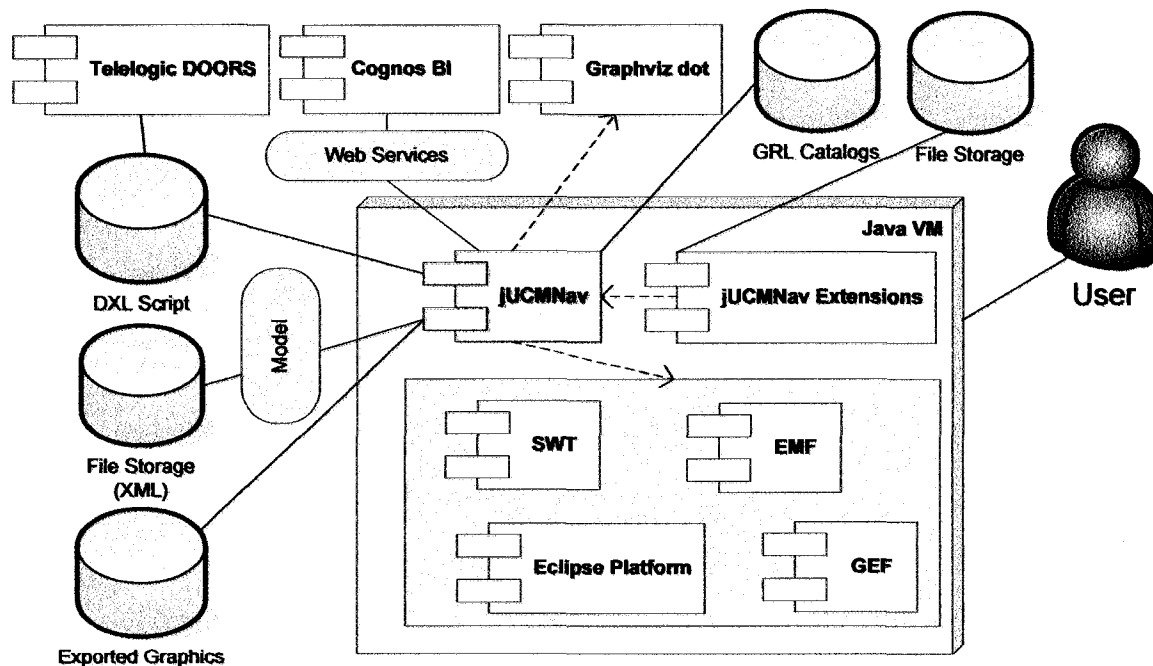


Figure 76: jUCMNav Architecture (jUCMNav, 2007)

Figure 77 is a screenshot from jUCMNav with the new features developed for performance monitoring. In the center, an evaluated performance model is illustrated.

This model is evaluated based on the strategy selected on the left side in the scenarios and strategies view. On the right side, the Key Performance Indicators view shows detailed information related to all the KPIs defined in the performance model. This view is synchronized with the diagram currently studied by the user. In other words, if we switch to another diagram of this model, the KPI view will be updated accordingly. On the left hand side, we also have the list of Key Performance Indicators with their statuses.

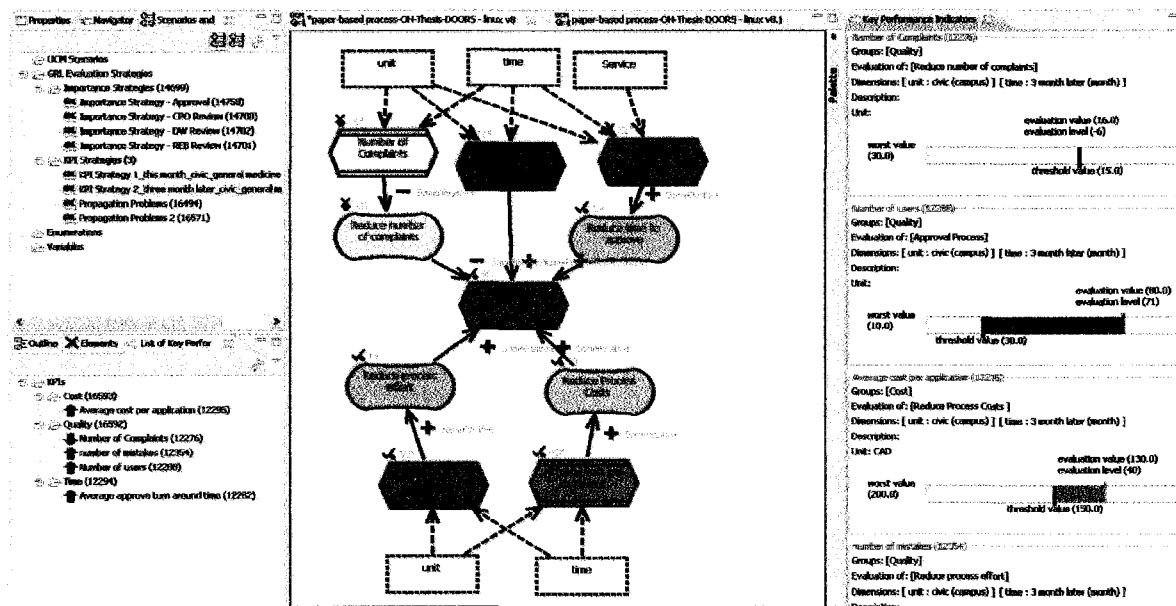


Figure 77: jUCMNav screenshot with monitoring features views