Combining Business Intelligence, Indicators, and the User Requirements Notation for Performance Monitoring

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Abstract

Organizations use Business Intelligence (BI) systems to monitor how well they are meeting their goals and objectives. Yet, very often BI systems do not include clear models of the organization's goals or of how to measure whether they are satisfied or not. Several researchers now attempt to integrate goal models into BI systems, but there are still major challenges related to how to get access to the BI data to populate the part of the goal model (often indicators) used to assess goal satisfaction.

This thesis explores a new approach to integrate BI systems with goal models. In particular, it explores the integration of IBM Cognos Business Intelligence, a leading BI tool, with an Eclipse-based goal modeling tool named jUCMNav. jUCMNav is an open source graphical editor for the User Requirements Notation (URN), which includes the Use Case Map notation for scenarios and processes and the Goal-oriented Requirement Language for business objectives. URN was recently extended with the concept of Key Performance Indicator (KPI) to enable performance assessment and monitoring of business processes. In jUCMNav, KPIs are currently calculated or modified manually. The new integration proposed in this thesis maps these KPIs to report elements that are generated automatically by Cognos based on the model defined in jUCMNav at runtime, with minimum effort. We are using IBM Cognos Mashup Service, which includes web services that enable the retrieval of report elements at the most granular level. This transformation provides managers and analysts with useful goal-oriented and process-oriented monitoring views fed by just-in-time BI information. This new solution also automates retrieving data from Cognos servers, which helps reducing the high costs usually caused by the amount of manual work required otherwise.

The novel approach presented in this thesis avoids manual report generation and minimizes any contract with respect to the location of manually created reports, hence leading to better usability and performance. The approach and its tool support are illustrated with an ongoing example, validated with a case study, and verified through testing.

Acknowledgment

I wish to thank my supervisors, Dr. Daniel Amyot and Dr. Gregory Richards, for providing me with necessary resources and for sharing their vision with me.

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I also want to thank my manager at IBM, Mrs. Emilia Clein, for her support during my graduate studies.

Last but not least, I want to thank my parents for their unconditional love and support. I dedicate this thesis to them.

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List of Acronyms

Acronym	Definition
API	Application Programming Interface
BI	Business Intelligence
BAM	Business Activity Monitoring
BPM	Business Process Management
BPMS	Business Process Management System
CMS	Cognos Mashup Service
GRL	Goal-oriented Requirement Language
IT	Information Technology
ITU	International Telecommunication Union
jUCMNav	Java Use Case Map Navigator
KPI	Key Performance Indicator
MUN	Member Unique Name
NFR	Non-Functional Requirement
OCL	Object Constraint Language
OLAP	Online Analytic Processing
REST	Representational State Transfer
SDK	Software Development Kit
SOAP	Simple Object Access Protocol
UCM	Use Case Map
URN	User Requirements Notation
WSDL	Web Service Definition Language
XML	Extensible Markup Language

Chapter 1 Introduction

This thesis explores a new approach to integrate Business Intelligence (BI) systems with goal models in order to improve current ways of monitoring organizations. The new approach proposed in this thesis connects information sources to indicators in goal models in a dynamic way, which avoids manual report generation and storage and which leads to better usability and performance.

1.1 Context and Motivation

The main objective of this thesis is to improve organization performance monitoring and business process monitoring, with a focus on business performance models that take advantage of the User Requirements Notation (URN). As enterprises grow every day, they use different tools and software solutions for different purposes within their enterprise. They use various data repositories internally and externally. They store data related to their employees as well as data about their clients, sales, products and services they provide to their clients. Each of these data elements can be used to create information for different purposes: data about sales can be used to calculate revenues, data about expenses can be used to create information about profit when used in conjunction with revenues, etc. Such information can also be used to support decision making. For example how large or small the profit is can help decide whether current products or services shall be continued. This change will be reflected on the organization's staff and stakeholders. For instance, does the organization need to keep the employees who were working on the discontinued product and services?

In general, modeling the objectives and processes of an organization helps determine what to monitor and helps analyze whether objectives are really met, hence influencing decision making. Business processes and performance models can be described and analyzed through various notations and tools. For example, the User Requirements

Notation (ITU, 2008) offers both a goal-oriented view and a process-oriented view, together with support for indicators, which are suitable for such modeling. Tools such as jUCMNav (Roy, 2006; Kealey, 2007) support different kinds of analyses for URN models that exploit external, factual sources of information, which in turn helps root decision making in evidence.

Business Intelligence (BI) technologies and systems, which focus on the timely distribution of (interactive) reports, also aim to provide information to managers to support their decision-making processes. BI systems however seldom offer a view that reflects the one found in goal models. The integration of a goal-oriented view with more conventional BI portals and dashboards is seen as something beneficial but difficult to achieve with current technologies (Pourshahid *et al.*, 2011). Chen (2008) already proposed an approach to integrate goal models in jUCMNav with BI information sources such as reports generated from IBM Cognos BI, a leading BI tool (Browne *et al.*, 2010).

1.2 Problem Statement

The current integration between BI systems and goal modeling tools, which is best illustrated by Chen's implementation based on Cognos BI and jUCMNav, currently suffers from several limitations.

First, in Chen's approach, a business user needs to be familiar with the BI tool in terms of report authoring and BI content management to be able to create reports for different strategies defined in jUCMNav. This is expensive in terms of training and required expertise. In this thesis, we are interested in seeing if we can reduce manual labour as well as dependency to user expertise needed to generate BI reports and integrate goal models with the generated reports. We will provide a solution where the user's expertise in BI reporting will not be a factor for the integration of goal models with BI reports.

Second, in the existing approach, the user needs to apply bookkeeping within the BI tool to be able to keep track of changes happening in jUCMNav. For example, for a new strategy used to evaluate the goal model, a new folder structure is required to be created within the BI tool and in addition a new report needs to be built. If these items move within the BI environment, then the integration breaks. In this research, we are interested to see if we can find a way to automate the maintenance, linkage and bookkeeping of

generated reports in a BI tool upon the creation of new strategies within a URN tool, without user dependency. We remove this dependency and the user will not have to do any bookkeeping as report authoring and content management will be dynamic.

Third, in Chen's approach, the data retrieval is based on a new web service which is external to both the BI tool and jUCMNav. An expert user is required to install the web service on an application server. In this thesis, we are interested to see if we can perform the data retrieval on the fly without any dependency on an external web service.

In summary, we will be answering the following questions within this thesis:

- Can we reduce the time and manual labour, as well as the dependency to user expertise, needed to generate BI reports and integrate goal models with the generated reports?
- Can we find a way to automate the maintenance, linkage and bookkeeping of generated reports in a BI tool upon the creation of new strategies within a URN tool, without user dependency?
- Can we perform the data retrieval on the fly without any dependency on an external web service?

1.3 Thesis Methodology

The research methodology used in this thesis is based on *design science*. According to Peffers *et al.* (2007), design science involves the creation and evaluation of artefacts to solve organizational problems through a rigorous process for design, research contribution, evaluation of design, and communication of results to appropriate audiences. Any designed object with an embedded solution to a research problem that is understood will include the definition. The process model for this methodology is highlighted in Figure 1.

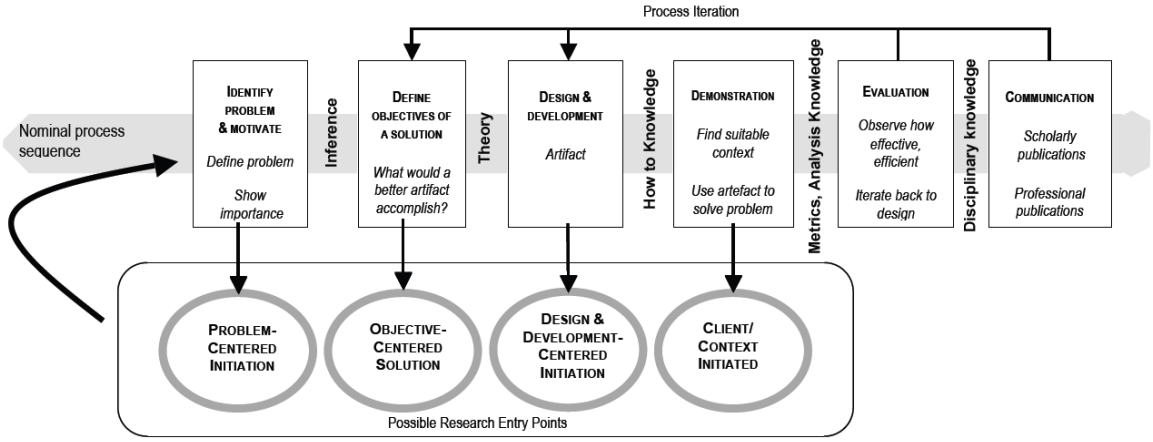


Figure 1: Design science research methodology (from Peffers *et al.*, 2007)

We can break down the thesis content in the context of the design science methodology:

1-Identify problems and motivation: We can summarize the following problems in the context of our research as well as from sections 1.1 and 1.2 and from Chapter 3:

- Excess of manual work to generate reports to monitor the behaviour of the goal model;
- Lack of a framework to eliminate unnecessary tasks to maintain existing and new reports for the goal model;
- Dependence to an external web service for data retrieval.

2-Define objectives of a solution: A proposed solution will provide answers to the problems previously identified. In the context of this research, the objectives of this thesis can be summarized to the creation of the following artefacts:

- An artefact that would decrease the manual work to generate reports;
- An artefact that would possess a framework to maintain existing and new reports for the goal model;
- An artefact that would replace the external web service for data retrieval.

3-Design and development: In this thesis, we follow a typical spiral software development method. In each iteration, an incremental set of features is implemented and tested.

There are three separate iterations in this thesis that led the first and second prototypes explained in Chapter 5 and to the final product presented in Chapter 4. The testing and evaluation are covered in Chapter 7.

4-Demonstration: The final product was demonstrated with existing goal models and sample data. This is explained in Chapter 6 as the case study.

5-Evaluation: Currently, this product has been used only by one person (the thesis author) and it is hence a proof of concept. In the future, we will distribute this artefact to more users.

6-Communication: This thesis well be the communication for the thesis subject.

The summary of the design science methodology adapted to this thesis is shown in Figure 2.

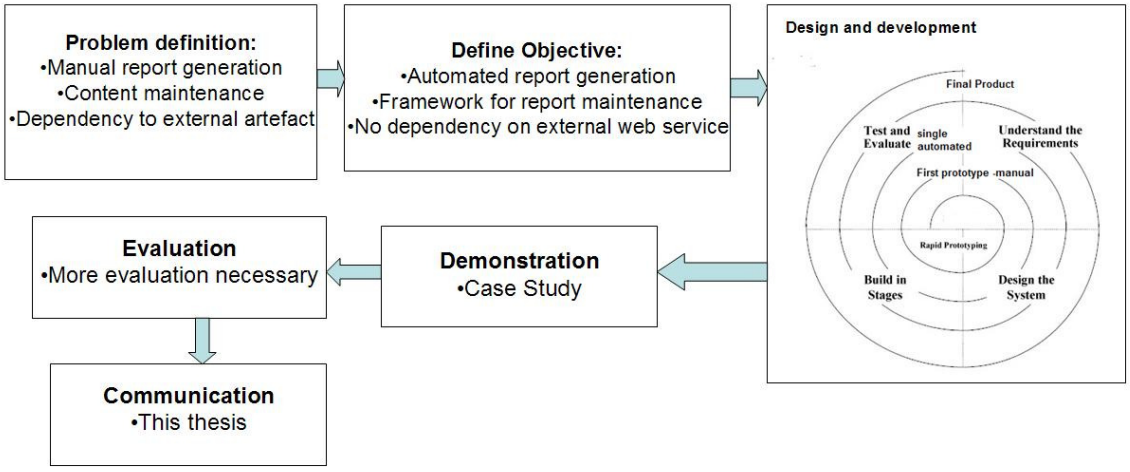


Figure 2: Design science research methodology as used in this thesis

1.4 Thesis Contributions

This thesis is based on research work related to the Framework for Situational Analytics project (Pourshahid *et al.*, 2011) as well as on a previous thesis on goal-oriented business process monitoring by Chen (2008). The main contributions of this thesis focus on an ap-

proach to create dynamic reports for linking jUCMNav to business intelligence content that will result in reduced time and effort for creating and maintain such links. The detailed contributions are as follows:

- A framework for report generation and BI content management: this approach aims to facilitate the data modeling process without requiring users to have a high level of BI expertise.
- A framework for integrating business process and organization monitoring with goal-based evaluation and data retrieval: indicators retrieve their values on the fly through a BI tool and can support real-time monitoring of business processes and organization performance.
- Reduced time and effort for creating and maintaining linkage between a goal-oriented modeling tool (jUCMNav) and a leading Business Intelligence application (Cognos).

From a Requirements Engineering perspective, we are also expanding the current URN based modeling tool, jUCMNav, to integrate with business information providers in real time. The approach described in this thesis minimizes user interaction and builds a system that eliminates much manual work that is currently required from users.

The new approach makes current approaches to business process monitoring in the context of URN more reliable, easier to manage, more efficient, and less expensive. It also opens the door to future research on how best to combine goals and BI by making this process technically more efficient and easier to use.

1.5 Thesis Outline

The detailed thesis structure is as follows:

- Chapter 2: Provides background information about general concepts, Business Intelligence and its capabilities, the Cognos Software Development Kit (SDK), the Cognos Mashup Service, jUCMNav, URN, GRL and Key Performance Indicators (KPIs).

- Chapter 3: Explores the current approach in detail (Chen, 2008) and introduces some of the research results in the field of goal modeling, business process monitoring and KPIs.
- Chapter 4: Explores the criteria for improvement and discusses some of the design decisions made to create the current approach. It also defines and illustrates the solution in detail and how the latter has improved the current state of the art.
- Chapter 5: Discusses other alternatives that were considered during this research and how they compare to the current approach and the proposed solution.
- Chapter 6: Demonstrates, through a case study, the proposed method and how it improves the overall user experience.
- Chapter 7: Describes the testing methodology for the implementation of the approach as well as the test results.
- Chapter 8: Recalls the contributions and describes some of the limitations of the proposed solution together with ideas on how the approach can be further improved to make the user experience more interactive and the tool more efficient.

Chapter 2 Background

This chapter provides background information about Business Intelligence and relevant technologies such as the Cognos Software Development Kit (SDK) and the Cognos Mashup Service (CMS). It also reviews the User Requirements Notation, with its two sub-languages for goals and scenarios, and tool support. How these existing technologies fit in the larger business process management picture is also presented.

2.1 Business Intelligence

In any kind of organization, employees make hundreds of decisions each day. They can range from whether to give customer X a discount, whether to start producing part Y, whether to launch another direct mail campaign, whether to order additional materials, etc. These decisions are sometimes based on facts, but mostly based on experience, accumulated knowledge, and rules of thumb.

Each organization produces a massive amount of data on a daily basis; consequently, data becomes increasingly abundant. This data is later on analyzed and turned into information. Critical decisions are made based on such information. Nowadays organizations take advantage of computational capabilities to do data analysis. Some typical computations include: slicing and dicing data, posing ad-hoc queries, detecting patterns, and measuring performance. These computational capabilities are sets of tools and methods associated with *Business Intelligence* (BI). Enterprises use BI tools to make sense of raw data for various purposes. In a nutshell, good Business Intelligence is all about users taking better business decisions at the right time, with the right information (Barone *et al.*, 2010).

A BI tool is usually the combination of several technologies put together for the purpose of data analysis. Each BI tool can be connected to one or many different types of

data sources. These data sources can be different types of databases, external files, data cubes or a combination thereof (Browne *et al.*, 2010).

A BI tool typically allows users to model, customize, and slice and dice data. Such capabilities come in a form of data modeling components or report generation components in the tool. Data modeling is one of the most important parts of a BI tool. This is where the relationships between data entities are defined. To be more specific, the *metadata* is created in this phase. Metadata is based on the business requirements coming from those interested in a certain analysis of known data (e.g., business analysts). Report generation is used to handle how the end user wants to view the results of the analysis. BI tools usually come with colourful features to support report generation (Browne *et al.*, 2010).

To allow such features, certain technologies are used that help enterprises achieve these tasks in the most usable and efficient way. Due to the large number of BI users, multiple servers are often required to support high efficiency and low response time of the BI tool. Technologies such as web services are used to enable enterprises to reach maximum productivity (Browne *et al.*, 2010).

2.1.1 IBM Cognos Business Intelligence Tool

In the context of this research, the *IBM Cognos Business Intelligence* tool (Browne *et al.*, 2010) is utilized since it is one of the most mature and popular tools currently available, which also includes the vast majority of capabilities from data modeling to report generation and user management. Local expertise with this tool was also available. A few components of this tool, such as IBM Cognos Software Development Kit and IBM Cognos Mashup Service, are especially used in this research to increase performance, precision and efficiency of BI reporting. The BI tool is not used interactively but certain functionalities of the BI tool are integrated within the final product resulting from this thesis.

IBM Cognos Business Intelligence has a three-tier architecture:

- Presentation tier;
- Middleware tier;
- Data tier.

The presentation tier is the for user interactions. It accepts user commands through a web user interface. It is also the layer in which reports are rendered and layouts are generated.

The middleware tier is for routing each request to the proper service as well as communicating with the data layer to query the data requested by the user. This middleware tier includes a query engine as well as services such as a report service responsible for report-related requests (e.g., running reports).

The data tier is responsible for data storage and maintaining different data stores within Cognos' content store. The *content store* is the internal data store used by the Cognos server and stores information on all the artefacts related to business intelligence such as folders, reports and report specifications.

Each tier is comprised of several components that communicate with each other through web services. We are using two of the services within the middleware tier:

- The *Software Development Kit* (SDK), which eliminates the need to use the user interface to send requests to the Cognos server. This service can be used to do all the operations possible within the Cognos server. Some of the operations available include creating report specifications, storing reports in the content store, creating folders to include reports, generating report specifications, and validating reports. This service uses the Simple Object Access Protocol (SOAP) as communication protocol (W3C, 2007).
- The *IBM Cognos Mashup Service*, which takes care of report runs and retrieving the desired value after a report run. This service provides an easy to use Representational State Transfer (REST) application programming interface (API) to facilitate any type of call related to report content retrieval. In the next sections, these two services will be discussed in more details.

2.1.2 IBM Cognos Software Development Kit (SDK)

Major software products usually provide an interface enabling users to customize their products within their context. The Cognos BI tool provides a set of APIs that can automate all the tasks user can do manually in the software. Using these APIs, we can achieve platform-independent automation using different programming languages. Such APIs are usually part of some software development kit (SDK).

Cognos' web-based architecture is built around the following industry standards:

- Web Services Definition Language (WSDL);
- Simple Object Access Protocol (SOAP), with XML and HTTP.

In our research, we are using the Java programming language in conjunction with the IBM Cognos Software Development Kit (Popescu, 2011) in addition to XML for data transfer and data retrieval. We are taking advantage of web service technologies for the following capabilities:

- *Authentication:* a method used to authenticate users to the Cognos server.
- *Report generation:* a specification is generated that describes the data to be returned as well as the layout information.
- *Report storage:* a method to store the specification created as above in the Cognos server's internal database.
- *Report deletion*: The unused report object is deleted from the Cognos server.
- *Folder creation:* A container that will include reports and other folders.

2.1.3 IBM Cognos Mashup Service (CMS)

The IBM Cognos Mashup Service (Sleigh and Johari, 2010; IBM, 2012b) is a new capability provided by the IBM Cognos Business Intelligence tool that facilitates data retrieval from reports. Every generated report includes various pieces of information such as a metamodel, a model, layout information and the data. As enterprises get more complex, the need for flexibility on which data to consider and how the data is retrieved and presented becomes more complex.

Enterprises use various products concurrently since each product satisfies part of their requirements. For example, a Chief Executive Officer may want to see quarterly profits within the same portal used for checking emails. Users may want to access all the information and tools they need for their daily activities in one place and avoid login to different systems for each task.

This new mashup capability provides a way to integrate Cognos reports with other applications. There are two different interfaces to use this technology:

- **Representational State Transfer (REST):** This interface uses basic HTTP requests.

- **Simple Object Access Protocol (SOAP):** This interface can be used to programmatically access the CMS API.

In this research, we are using Cognos Mashup Service to run the reports generated by the Cognos SDK as well as to retrieve the value generated after a report is run. The value is then passed to a third party tool (e.g., jUCMNav) for further use.

The example below demonstrates a complete CMS integration. Figure 3 shows a portion of a sample Cognos report. The report contains sales revenue data for a fictitious company. The data is broken down according to the location of each of the company's offices. Figure 4 shows the result when the report is integrated with a Google Earth map. The sales figures for each office are overlaid on the map according to the office's location. This is accomplished using the Google Maps API along with the CMS REST interface (Sleigh and Johari, 2010).

Sales territory	Country	Region	City	Address line 1	Revenue
Central Europe	Germany	Berlin, Germany	Berlin, Germany	Nestorstraße 83,Berlin, Germany	$422,661.86
			Berlin, Germany		**$1,260,306.02**
		Berlin, Germany			**$1,260,306.02**
		Brandenburg, Germany	Potsdam, Germany	Ahornstraße 82,Potsdam, Germany	$602,109.90
			Potsdam, Germany		**$602,109.90**

Figure 3: Sample Cognos report results in HTML format (from Sleigh and Johari, 2010)

Figure 4: Cognos report results overlaid on Google Earth using IBM CMS (from Sleigh and Johari, 2010)

The standard development kit and the mashup service share many common objectives, but they also differ in a number of ways. Table 1 compares and contrasts the Cognos SDK with CMS.

Table 1: Cognos SDK compared with CMS (from Sleigh and Johari, 2010)

	SDK	CMS
Report authoring	Supports authoring	Does not support authoring
Programming languages	Java®, .NET Languages, VB	Java, .Net Languages, REST interface
Output formats	CSV, HTML, HTML Fragment, MHT, PDF, single XLS, spreadsheet ML, XHTML, XLS, XLWA, XML	LDX, XML, HTML, HTML Fragment, JSON Note: LDX stands for Layout Data XML. This is a new format.
Major functionality	Almost everything that can be done with Cognos Connection, in addition to automating operations	Run and get the report outputs and enable access to report output elements to the smallest granular level possible
Authentication	Yes	Yes - via SDK or own authentication service, for REST one can also use the Cognos 8 logon.
API	Java: Jar files available in sdk folder, Microsoft® .Net: .dll files available in sdk folder	Use of WSDL files to consume available functionality through Web services

2.1.4 Data Modeling

In this research, the user is interested in the value retrieved from a Cognos report, which is associated with a data source. A model is defined based on a subset of data entities from the data source according to the business requirements. For example, if a business requirement dictated by the executive requires having data results ordered based on months rather than years, then the modeling will be different in each case. Therefore, it is important to consider reporting requirements and data access strategies.

First of all, the modeler should understand the data and the reporting requirements. This knowledge allows the modeler to make better decisions with respect to data access strategies, metadata model design, and report package delivery to the BI server.

There is a need to identify which data sources contain the information required for the reporting. In addition, the following questions need to be answered:

1. Is this an appropriate data source?
2. What is the best choice: a transactional system, star schema data warehouse, or a data mart?
3. How fresh does the data need to be?
4. How often does the reporting need to take place? Daily, weekly, or monthly?

Answers to these types of questions can affect dramatically the data access strategy choice (IBM, 2012a).

In this research, data is modeled using *IBM Cognos Framework Manager* and is published and deployed on a Cognos BI server as a package. A metamodel is defined in the context of Cognos BI, which is a description of database elements such as tables, columns, and entity-relationships information.

This eventually will hide the complexity of the data and provide an organized view of the data to the business user, who will have to use this data in the business context. This means that the business user is aware of the relationships between data since that will allow the user to configure third-party tools (e.g., jUCMNav) to retrieve the desired data pieces. In this research, the data consumed is usually multidimensional and can come from different data sources (Figure 5) that may be distributed over different servers; therefore, there are no constraint related to having a centralized data center. This helps to model different entities from different enterprises/organizations should the need arise.

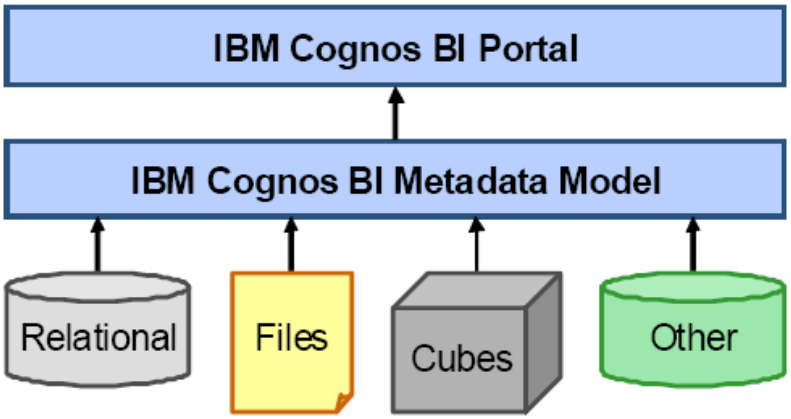


Figure 5: Relationship between data sources, model and BI portal (from IBM, 2012a)

2.2 User Requirements Notation

Requirement engineering is an important phase in any software development process. In this phase, requirements are captured, analyzed, specified and validated. Requirement engineering is a foundation for creating high-quality software in many domains. There are two types of requirements that usually need to be captured:

- Functional Requirement
- Non-Functional Requirement

Capturing these two types of requirements based on a standard and formally defined notation contributes to improved requirements and, in a performance domain, allows decision makers to have more rigorous and predictable results. Improvement in this phase will subsequently help the overall process of software development such as lower cost of software delivery, higher quality of the artefacts delivered, timely delivery of the software and the most important factor increasing the customer satisfaction (Amyot and Mussbacher, 2011).

The ability to capture and visualize goal-oriented and process-oriented requirements was introduced and standardized in 2008 by the International Telecommunications Union (ITU-T, 2008; Amyot and Mussbacher, 2011). According to Amyot and Mussbacher (2011) a single notation is incapable of providing all the features required to capture all the aspects of user requirements. These aspects range from capturing requirements with little detail, providing facilities to express analyze and deal with goals and

non-functional requirements, providing facilities to manage evolving requirement etc. URN combines two notations to achieve this:

- Use Case Maps (UCMs) for operational requirements and business processes.
- Goal-oriented Requirement Language (GRL) for goals;

2.2.1 Use Case Maps

Introduced in 1998 by Buhr and his colleagues (Buhr and Casselman, 1996; Buhr 1998) UCMs describe scenarios as causal flows of responsibilities (e.g., operations, actions, tasks and functions) that can have various underlying structures of components. These components can be categorized into two main entities:

- Software entities (e.g., process);
- Non-software entities (e.g., hardware or user).

Originally meant to describe requirements for telecommunication services, UCMs were later evolved to describe operational requirements, services, and business processes (Weiss and Amyot 2005). UCMs are used to describe multiple scenarios in an abstract and integrated view and also contribute to the understanding and explanation of the whole system. By extracting and defining individual scenarios from the whole view, people can better understand particular functionalities in complex processes. UCMs complement goal models by providing a view that operationalizes goals and their tasks. However, this thesis focuses on the goal view, and hence the UCM view will not be introduced in any further detail.

2.2.2 Goal-oriented Requirement Language

Another important part of URN standard is the Goal-oriented Requirement Language (GRL). This language accommodates large and complex models that capture stakeholders (called actors), their intent (e.g., goals), and the relationships between actors (e.g. dependencies), between actors and intentional elements, and between intentional elements (e.g., decompositions and contributions). This language combines features from the Non-Functional Requirements (NFR) framework of Chung *et al.* (2000) and from the *i** framework (Yu, 1997; Yu *et al.*, 2010). Some of the unique features of GRL are its abil-

ity to support evaluation strategies (and different qualitative and quantitative representation and algorithms), its extension mechanisms (e.g., to support stereotyped elements, as well as new types of relationships through URN links), its integration to a process view with traceability links to UCMs, and more recently its support for indicators/KPIs (just standardized in October 2012).

The syntax of GRL, summarized in Figure 6, is mainly based on the syntax of the *i** language. A GRL diagram depicts both functional requirements, known as *goals*, as well as non-functional requirements, often represented as *softgoals*. GRL intentional elements are in fact of different types, including softgoals, goals, tasks, and resources. *Tasks* are the steps or options taken to reach the goal; they are representation of solutions. *Resources* are what is required for a goal or a softgoal to be reached. *Actors* are the stakeholders who are interested in goals or softgoals being completed; for example, improvement in the environment or the system (Amyot *et al.*, 2010).

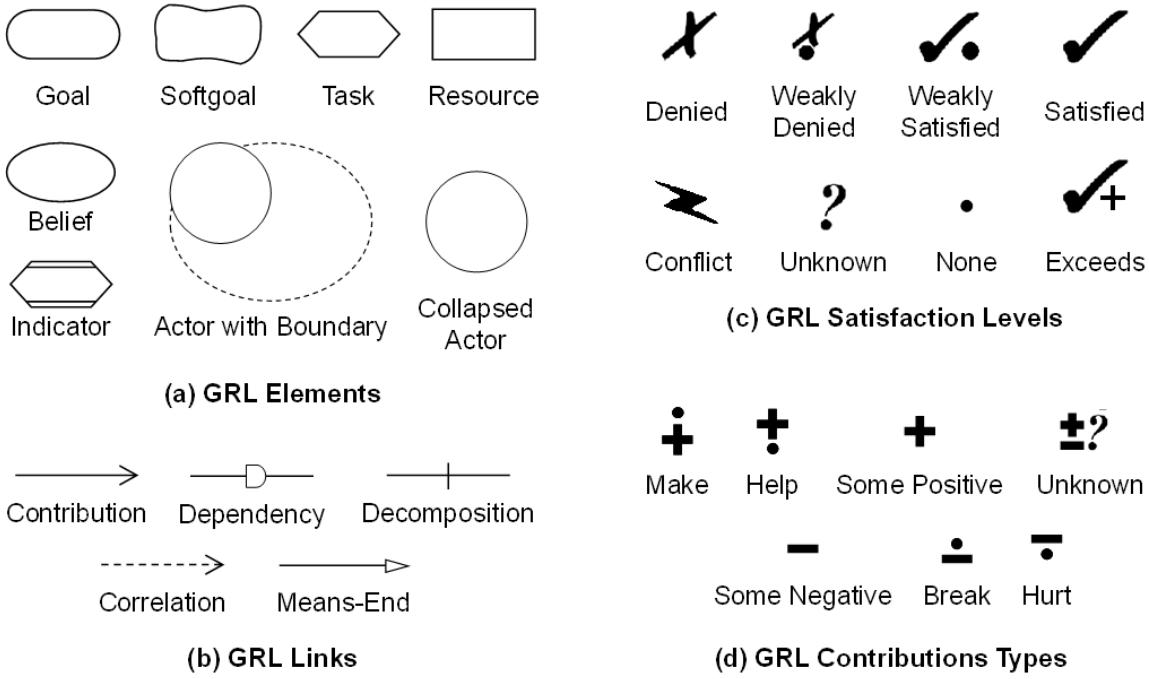


Figure 6: Summary of the GRL notation elements (from ITU-T, 2008)

GRL *links* connect intentional elements in the GRL model. GRL links include contributions, correlations, means-end, dependencies and decompositions. A *dependency link* shows one actor depending on the other actor; a *decomposition* allows one element to be

divided (AND/OR/XOR) into sub-elements; *contribution* and *correlation links* both indicate desired impacts (positive/negative) of one element on another element. The only difference between the two is that a correlation describes side-effects rather than desired impact (Amyot *et al.*, 2010). Contributions and correlations also have weights of different types, which can be qualitative (as in Figure 6d) or quantitative (on a [-100..100] scale).

As an example, Figure 7 shows a goal model how to increase profit in an enterprise. There are two soft goals, which belong to different actors:

- Increasing the profit;
- Having many work hours.

There is a task called Reduce cost, which can help increase profits. The Reduce cost task is composed of two other tasks, namely Reducing marketing cost or Reduce staffing cost. According to the model in Figure 7, reducing the staffing cost has a direct negative effect on the other softgoal related having many work hours. The goal is find the balance or tradeoff between the way these tasks and goals affect each other to come up with the best decision in the enterprise (Pourshahid *et al.*, 2011).

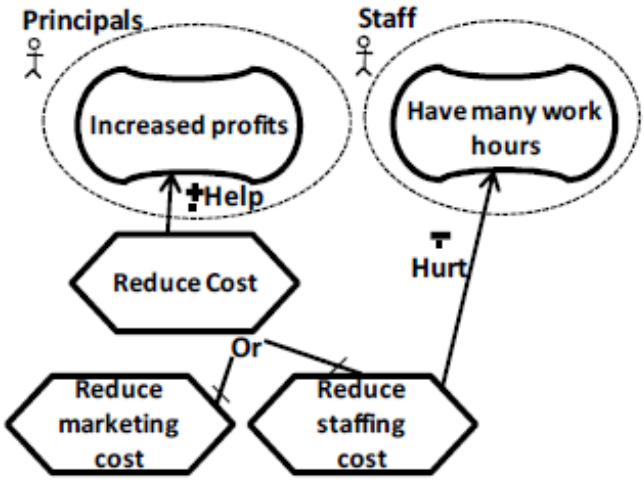


Figure 7: GRL model example (from Pourshahid *et al.*, 2011)

In this research, the satisfaction values of intentional elements in a model, which can also be qualitative (as in Figure 6c) or quantitative (on a [-100..100] scale), will be taken into consideration for analysis and performance monitoring.

2.2.3 Links Between GRL and UCM

GRL elements capture business goals whereas UCMs capture different processes that a business goes through to achieve its goals. By combining the two perspectives, one can see how the two concepts affect each other. GRL focuses on the *why*, *who*, and *what* aspects of business processes whereas UCM focuses (also) on the *what*, *who*, *when*, and *where* aspects. URN includes mechanisms (*URN links*) to create traceability relationships between UCM and GRL elements. Furthermore, one can see how these complementary views can be used in the context of business process monitoring (Chen, 2008).

2.2.4 jUCMNav: a Graphical URN Modeling Tool

jUCMNav (Figure 8) is an Eclipse plug-in that allows the creation and analysis of URN models. One of its interesting capabilities is the ability to support URN links between UCM and GRL, hence creating the foundation for business process monitoring (Roy *et al.*, 2006).

There have been different tools that support subsets of URN. For example, the older UCMNav (Miga, 1998) supports only the UCM notation whereas OpenOME (Horkoff *et al.*, 2011) only supports the GRL modeling portion of URN. jUCMNav is the first tool that supports both UCM and GRL modeling in addition to providing links between the two.

In URN, a *GRL strategy* provides initial satisfaction values to some of the intentional elements in the goal model. These values can then be propagated to the other elements through the various GRL links, resulting in an evaluation of the satisfaction of all intentional elements and actors in the model. jUCMNav supports strategy definitions and provides several bottom-up propagation algorithms for quantitative and qualitative analysis (Amyot *et al.*, 2010). Such mechanisms are good for "what if" evaluations and for monitoring. jUCMNav also supports an experimental top-down, constraint-based algorithm for GRL model evaluation that enables optimizations and the generation of strategies (Luo and Amyot, 2011).

jUCMNav is also the only tool that integrates indicators (as another type of intentional element) in goal models. In jUCMNav, indicators convert a real-world value (in a unit such as dollars, minutes, etc.) into a GRL satisfaction value (in the [-100, 100] range)

by comparing the real-world value against the indicator's target, threshold, and worst-case values (Pourshahid *et al.*, 2009). Indicators are currently undergoing the final stage of standardization as part of the next version of URN. jUCMNav offers a propagation algorithm that provides formula-based KPI aggregation (see Figure 8) for the type of cause-effect analysis performed in a decision-making context (Pourshahid *et al.*, 2011).

jUCMNav is a tool that enables business process monitoring and that allows integration of various software platforms. Chen (2008) integrated monitoring capabilities to jUCMNav that are based on Eclipse's Web Tools Platform (WTP).

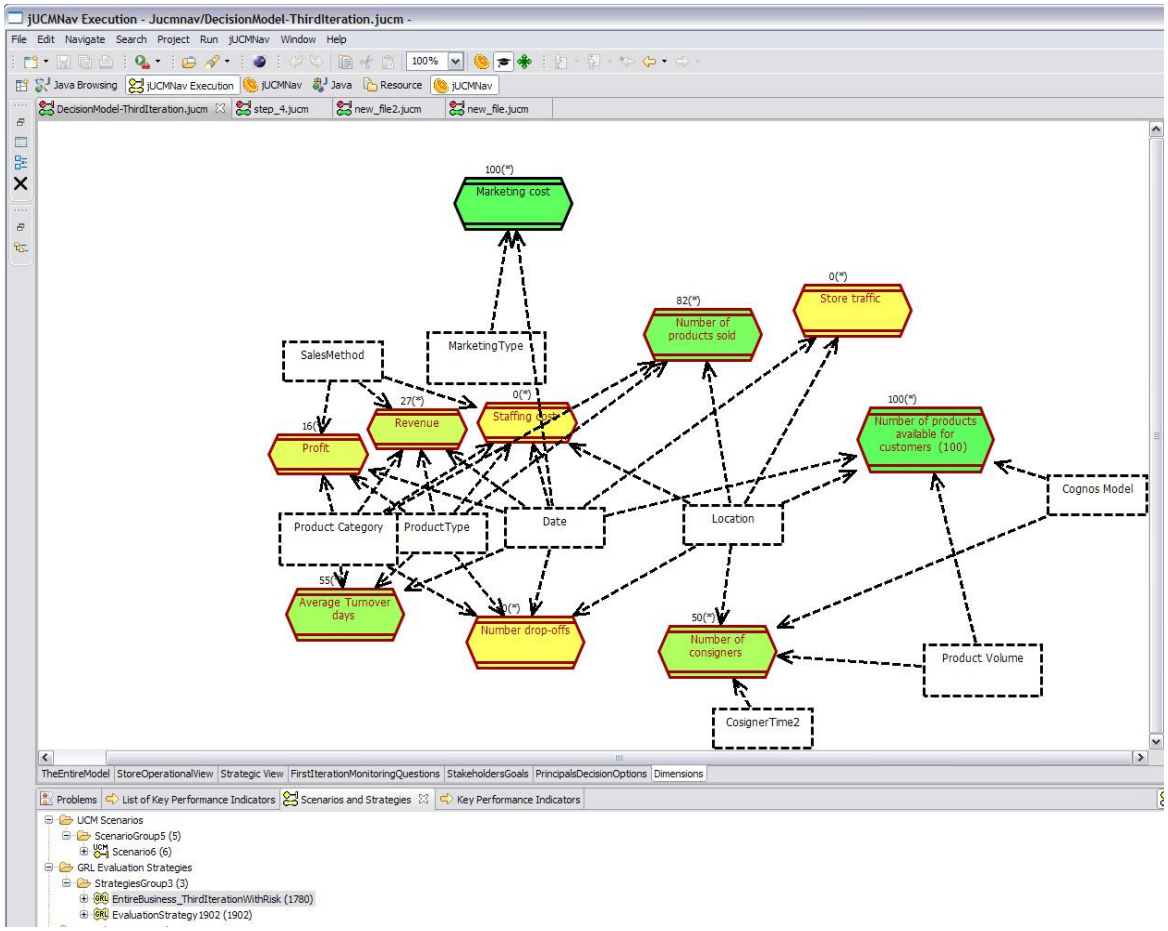


Figure 8: jUCMNav user interface

2.3 Business Process Management

Business process management refers to the collective processes that go into the effective communication of humans and automated systems. A business process management system (BPMS), on the other hand, can be defined as "a generic software system that is driven by explicit process designs to enact and manage operational business processes" (van der Aalst *et al.*, 2003).

A business process can be defined as sequence of activities meant to achieve a business goal. The ability to monitor business processes is a critical task. Each business process is associated with a measure of business that is essential to managers and to the business in general. Monitoring these measures in real time is very important in many domains, in order to enable timely decision-making.

A business process will respond to events or requests in the form of execution of activities. These activities answer the following questions: who, when and why the work needs to be done. In other words, these activities are units of work to be done. That defines the process objective. In Figure 9, the arrows designate the sequence in which the activities will occur. The process has three activities:

- Edit Order;
- Fulfill Order;
- Bill Order.

We have neither determined in this diagram where the order comes from nor whether the activities are fully automated or performed by humans. We might later decide that the activities use other services to fulfill their responsibilities.

Figure 9: Sequence of activities in a process (from van der Aalst *et al.,* 2003)

2.3.1 Roles and Actors

Each process does not go through the sequence of execution by itself. The responsibility is delegated to a person or a team or a software system (record keeping software) or a machine (for example, a manufacturing cell controller). In the context of this research, we call those the actors. An actor will perform the desired tasks or activities and either take the process to completion or pass the current status of work to another actor for completion.

Figure 10 depicts people assigned to roles (this is a non-standard notation for illustration purposes; UCMs could also be used to formalize such concepts). This might be a process in a small enterprise where two people do the work of processing and filling orders. In this process the roles define the need for persons to do the work of editing and filling orders. There may be several people available to do this work, but the roles specify the qualifications of persons required to do the specific work.

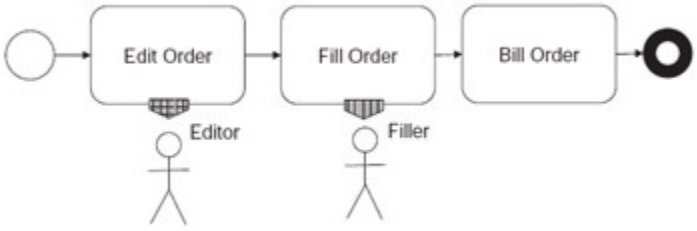


Figure 10: Actors and activities (from van der Aalst *et al.,* 2003)

2.3.2 Business Process Management System

A business result stems from coordination amongst chain of activities towards a business goal if it has repeating cycles. A process is broken down into smaller processes and eventually smaller steps that are carried out by various actors within the organization. These actors may carry one or more roles to complete these tasks. There are various types of processes; processes differ in complexity depending on the number of functional units of an organization they may target.

A simple process may usually target a single functional unit of an organization. Complex processes such as end to end business processes can vary in terms of the number of targets they may affect. They can target a departments or business partners. Inte-

gration between different types of software that play a role in business is not an easy task for two reasons (Rao Vallabhaneni, 2008):

- Software applications are structured into different functional units;
- Organizations are arranged around functions and departments.

Enterprises are focusing on customer and closer relationship with business partners that they can benefit from. This relationship follows different types of cross-organization processes as well as linking different software system and humans together.

Process improvement within the organization is very essential to managers since it can have a direct effect on the profitability of the company. For example, the process of communicating requirements to clients for a solution has been improved by using collaborative tools such as online sharing tools instead of having to travel to client's location. This will save time and cost of travel; therefore, it will have a direct effect on the revenue.

These improvements need to be *tracked* and *managed* and in some cases *computed* for higher level goals; for example, hiring a competent employee for the company is comprised of:

- Candidate search process;
- Candidate comparison and selection process;
- Interview process;
- Final selection;
- Job offer process.

If all these processes are optimized then this will help optimize the final process as well. Studies have shown that most information technology executives consider BPM as one of the most important technologies that can help them achieve their business goals more effectively (Rao Vallabhaneni, 2008).

A Business Process Management System is comprised of many components. One of the most popular such components is Business Activity Monitoring (BAM). BAM starts by gathering data, key performance indicators and business events from multiple applications. This data gathering may require automation and integrations between dif-

ferent applications with different level of complexities. After data gathering, the data is analyzed and real time reports, alerts or significant business events are produced (Chen, 2008).

Reports about analyzed data and KPIs are used by process analyst who will delve into the information result and identify opportunities for improvements or reengineering in the desired process. Not only these results can be used individually but also in some cases they can be fed into simulation software to simulate an environment with optimized processes based on the real life data.

2.3.3 BPM Lifecycle

The iterative nature of a BPM solution can be succinctly captured by Figure 11 (Chen, 2008).

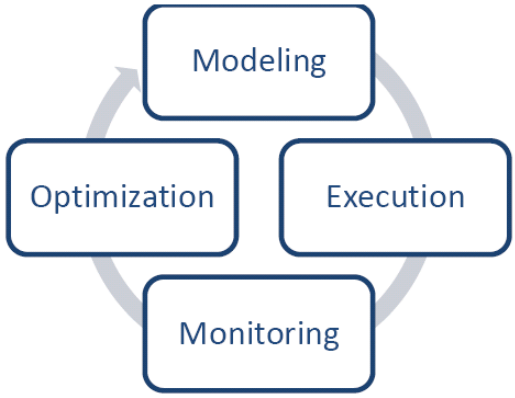


Figure 11: BPM lifecycle (from Chen, 2008)

We see that the steps involved in BPM are a complete understanding of the business process requirements, model building, simulations and defining key performance indicators. The first step in the practical implementation of BPM is to assemble the business processes of interest. A process execution engine should be used to support the execution of operational processes.

The output of the process execution serves as the input for monitoring applications for analysis, either real time or long term analysis.

Ultimately the choice of the solution depends on the specific business requirements. Monitoring is the key to making improvements and for fixing real-time errors without altering process design.

Integration of BPMS

The success of a business process depends on the coherent functioning of modeling, execution, and monitoring work. "SOA provides a standard interface to remove the communication difficulties inherent with different BPM applications and resources" (Chen, 2008).

2.3.4 Key Performance Indicators (KPIs)

Measurement of an organization's performance stems from strategic financial, organizational and several other reasons. Each employee accomplishes tasks which directly or indirectly have an effect on the global accomplishment of the enterprise, and aggregation of this information is required.

These accomplishments are recorded by the employee's supervisors and stored in a data store in the enterprise for future access and analysis. These performance indicators are measured, tracked and reported to produce the organization performance level. Management may introduce new indicators when there are new initiatives for change.

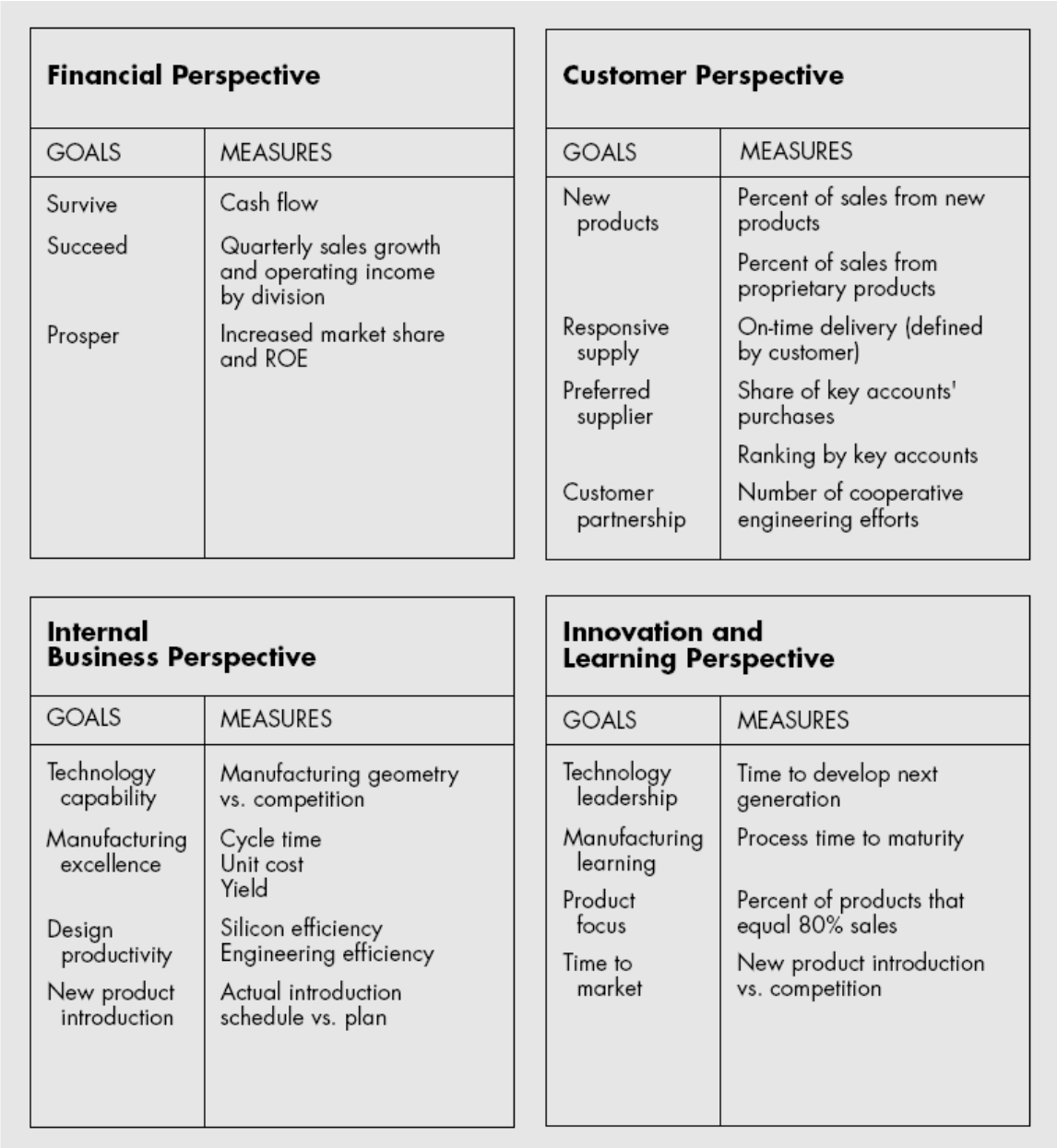
Monitoring KPIs helps increase activities that add more value and eliminate activities with less or no value to the enterprise, which in the end will provide a permanent value for the organization as a whole (Rao Vallabhaneni, 2008).

KPIs are usually extracted from different entities within an enterprise; these entities can be software or non-software entities. An example of these entities is operational goals. These KPIs drive the benchmark reports that define the employee's performance targets.

All the KPIs existing in an organization are equally important since they can affect each other; therefore none of these KPIs should be ignored for the sake of another one. One simply cannot rely on one KPI to evaluate the whole business. According to Kaplan and Norton (1996; 2004) key performance measures should be aligned with the strategies and action plans of the organization. They suggest translating the strategy into

measures that uniquely communicate the vision of the organization. Setting targets for each measure provides the basis for strategy deployment, feedback, and review (Rao Vallabhaneni, 2008).

They divided the strategy-balanced scorecard into four perspectives or categories as shown in Figure 12.



Financial Perspective

GOALS	MEASURES
Survive	Cash flow
Succeed	Quarterly sales growth and operating income by division
Prosper	Increased market share and ROE

Customer Perspective

GOALS	MEASURES
New products	Percent of sales from new products
	Percent of sales from proprietary products
Responsive supply	On-time delivery (defined by customer)
Preferred supplier	Share of key accounts' purchases
	Ranking by key accounts
Customer partnership	Number of cooperative engineering efforts

Internal Business Perspective

GOALS	MEASURES
Technology capability	Manufacturing geometry vs. competition
Manufacturing excellence	Cycle time Unit cost Yield
Design productivity	Silicon efficiency Engineering efficiency
New product introduction	Actual introduction schedule vs. plan

Innovation and Learning Perspective

GOALS	MEASURES
Technology leadership	Time to develop next generation
Manufacturing learning	Process time to maturity
Product focus	Percent of products that equal 80% sales
Time to market	New product introduction vs. competition

Figure 12: Essential measures in corporations (from Rao Vallabhaneni, 2008)

2.3.5 KPIs and jUCMNAV

An indicator, or KPI, takes as input a real-world evaluation value in some units (e.g., hours, Euros, percentage, etc.) and converts it to a GRL satisfaction value (on a [-100, 100] scale) by comparing the evaluation value against defined expectations. Very recently (after first the submission of this thesis), the concept of indicator was standardized in URN. However, this thesis uses the indicator/KPI concept as defined in jUCMNav, prior to standardization. URN's notation for KPIs, which is supported by jUCMNav, is shown in Figure 13.

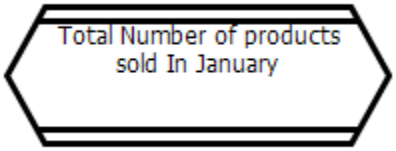


Figure 13: KPI/indicator notation

An indicator is defined as a special type of intentional element in GRL intended to represent KPIs in KPI models. Therefore, KPIs can be linked to other kinds of intentional elements (e.g., tasks and softgoals) in GRL models. Indicators can be assigned to multiple Indicator Groups, which include the four default performance dimensions used in process redesign, i.e. cost, time, quality and flexibility. However, users can add any customized groups to categorize and distinguish their KPIs for any other purposes (Chen, 2008).

Each KPI has 4 new properties when the model is examined within a given strategy:

1- Evaluation value;
2- Target value;
3- Threshold value;
4- Worst value.

The target value, threshold value and worst value are input by the goal modeler for each strategy. The evaluation value is the value that is retrieved from either the external data source (e.g., Cognos BI, Excel worksheets, Web services) or entered manually. Based on the above four values, a satisfaction level is produced. A positive GRL satisfaction value is computed by linear interpolation between the threshold value and the target value. The

closer the evaluation value is to target value, the higher the satisfaction level is. A negative GRL satisfaction value computed by linear interpolation between the threshold value and the worst value. The worst value maps to a -100 GRL satisfaction value, the threshold to 0, and the target to 100. The computed satisfaction value is then propagated the linked intentional elements within the entire goal model.

The KPI components are built on top of the current implementation of UCM and GRL modeling within jUCMNav. jUCMNav uses the Eclipse Modeling Framework (EMF) to implement the URN metamodel and the Graphical Modeling Framework (GMF) to implement graphical editors for UCM and GRL (Figure 14).

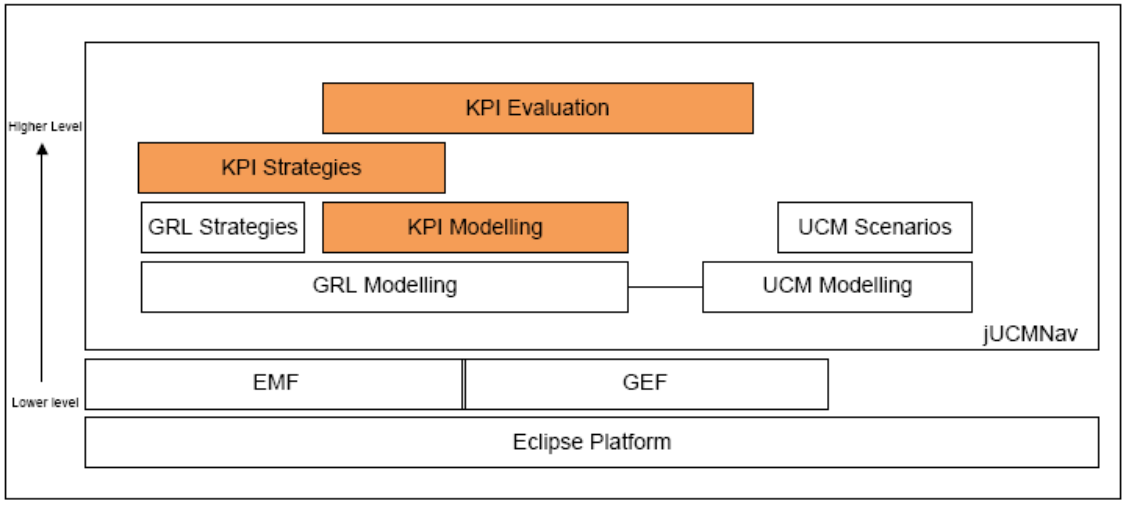


Figure 14: KPI components in jUCMNav (from Chen, 2008)

In jUCMNav, KPIs can retrieve their values from a BI tool or be calculated based on other KPIs; this can help monitor if the business process contribution is in the direction of business goals. This also enables the simulation of what-if situations.

A KPI in jUCMNav holds a numerical value that can be associated to other KPIs or to intentional elements such as softgoals. In jUCMNav, a KPI can be a function of other KPIs; for example, in Figure 15 the "Costs" KPI is a function of "Revenue", "Store costs", "Marketing costs" and "Staffing cost" KPIs. "Costs" KPI is basically a mathematical calculation based on the *evaluation* values from other KPIs.

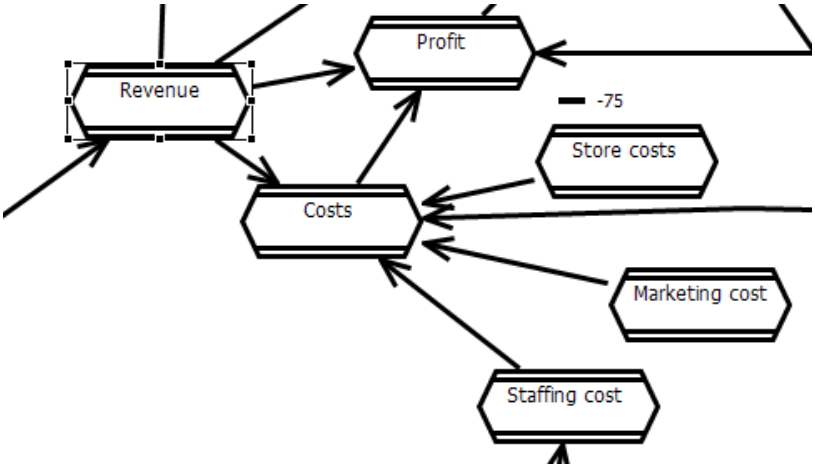


Figure 15: KPI composition

In the other case where the KPI is associated to GRL intentional elements, as shown in Figure 16, the GRL *satisfaction* values computed by the KPIs are propagated (through contribution, decomposition, and dependency links) with conventional GRL propagation algorithms.

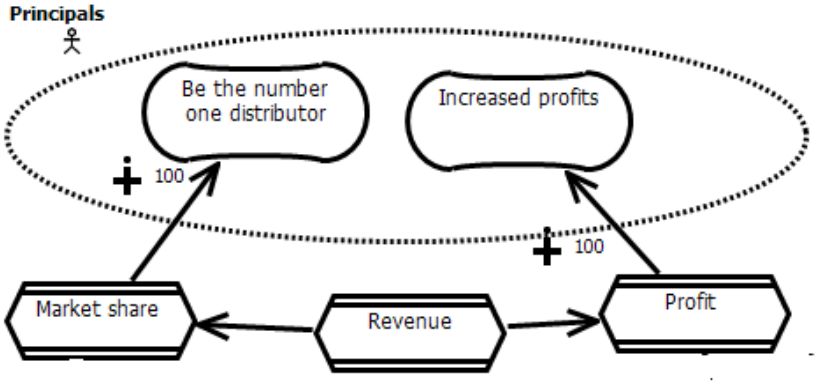


Figure 16: KPIs and soft goals

A *dimension* in jUCMNav is a placeholder for dimensional data properties. A dimension in IBM Cognos BI tool is a hierarchy. These two could be mapped to each other through a reference property from Cognos BI tool to a property of the dimension in jUCMNav.

In a typical dimensional report, there are two dimensions and a measure value. Two dimensions are usually from a hierarchy from the data model. The measure value or the fact is a numerical value also from the data model. A KPI is the numerical value at the intersection of two dimensions. For example, consider the revenues coming from of hand bags in January: hand bags is from a product hierarchy and January is from a time hierarchy, and revenues of hand bags in January is a KPI.

The current implementation details will be further described in the next chapter.

2.4 Chapter Summary

In this chapter, concepts and technologies used in this research were introduced. These include Business Intelligence, Cognos BI and two of its components: Cognos SDK and Cognos Mashup Service. Data modeling in the context of business intelligence as well as data modeling in the context of our research was examined as well.

The URN modeling language and its two components (UCM and GRL) were presented. We also explained why jUCMNav was chosen as the tool to model goals and scenarios in this research.

Then, we introduced business process management and how it relates to this research. Key Performance Indicators and their utilisation in jUCMNav were briefly explained. The next chapter will discuss the efficiency of the current approach to handling KPIs in jUCMNav as well as other related work.

Chapter 3 Related Work

This chapter focuses on an assessment of the current support for KPIs in jUCMNav and also discusses related work in the area of indicators in goal models.

3.1 Current Approach from Chen (2008)

In Chen's work, the notion of Key performance Indicator (KPI) was added to the jUCMNav tool. This allowed the business user to define KPIs within multiple strategies. This also allowed the user to propagate the KPI values to the higher level KPIs and enabled aggregation of KPIs in composite goals.

3.1.1 Concepts and User Interface

From a user interface perspective, Chen introduced the KPI notion into the tool by adding three new types of objects (with new symbols and palette extension, see Figure 17), namely indicators, dimensions, and KPI model links.

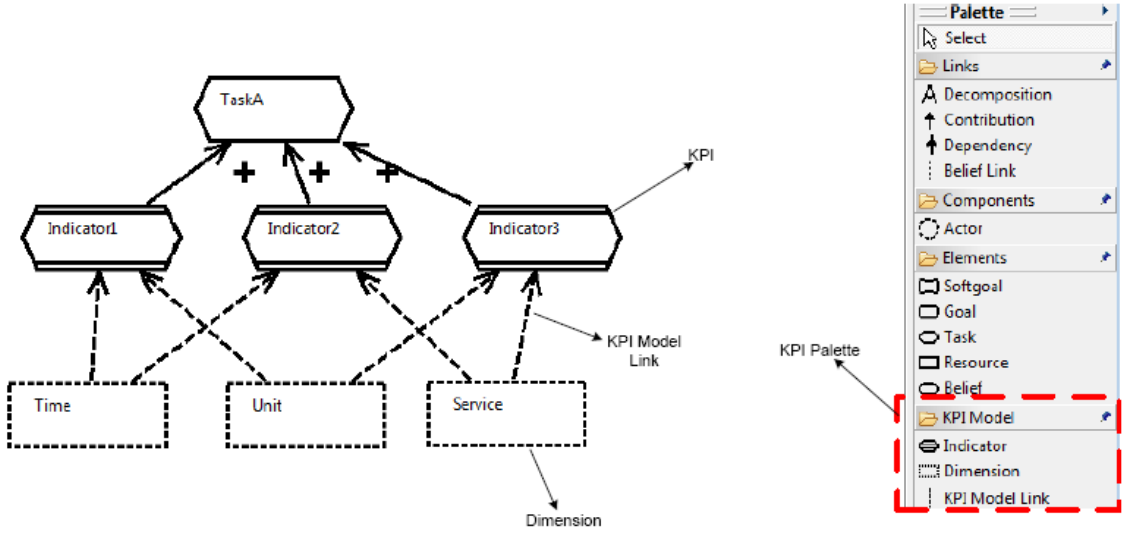


Figure 17: KPI in jUCMNav (from Chen, 2008)

In the above diagram, TaskA is measured by three performance indicators. Each indicator is associated with two dimensions. The notion of dimension returns to the way the business requirements are defined. For example, if a business user wants to monitor fluctuation of a fact (e.g. revenue) within a time range, then a Time dimension should be introduced into the goal model and this dimension should be linked to the key performance indicator or the fact.

In another example, if the business analyst only wants to monitor the quantity of an item in a specific department, then the notion of Time is not required anymore and that analyst works with the Unit and Service Dimension. In this implementation, grouping of KPIs is allowed as well (see Figure 18). Such grouping of KPIs is for ease of use and has no effect on the way KPIs are computed or the way their value is assigned.

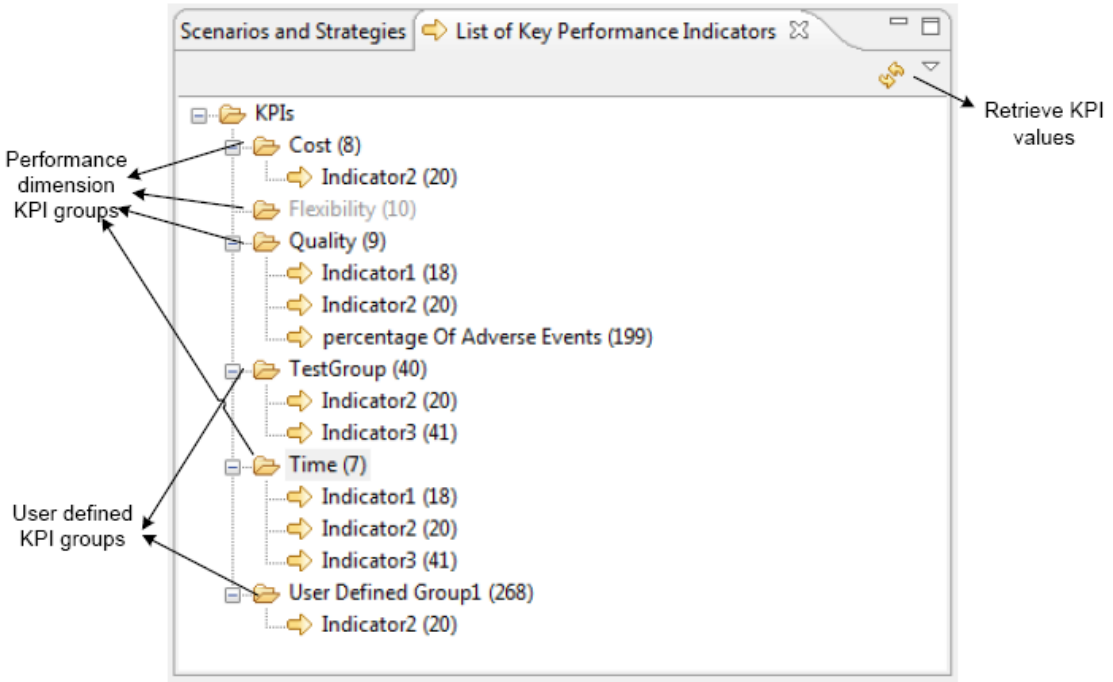


Figure 18: List of KPIs in jUCMNav (from Chen, 2008)

The tool also allows adding and removing a KPI into and out of a group (Figure 19).

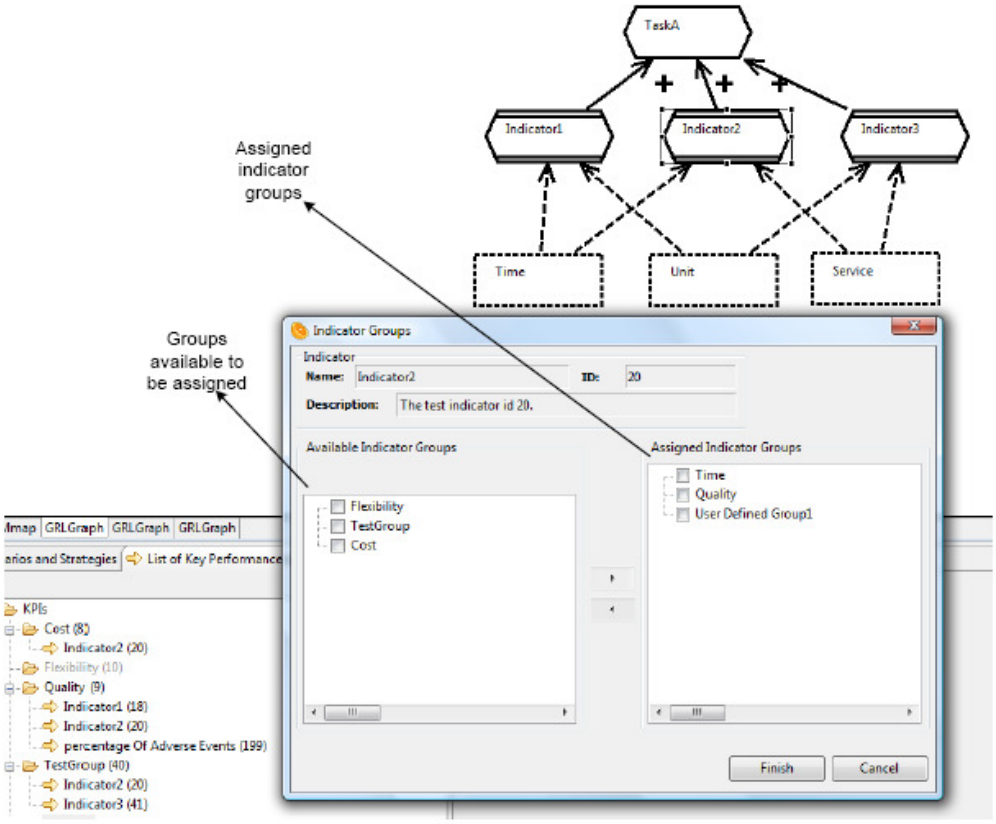


Figure 19: KPI groups in jUCMNav (from Chen, 2008)

There is also a KPI Evaluation section in the tools properties view (Figure 20). An evaluation strategy can define a target value, a threshold value, a worst value, an evaluation value, unit of the indicator, and the level and value of dimension for each KPI information element (Chen, 2008).

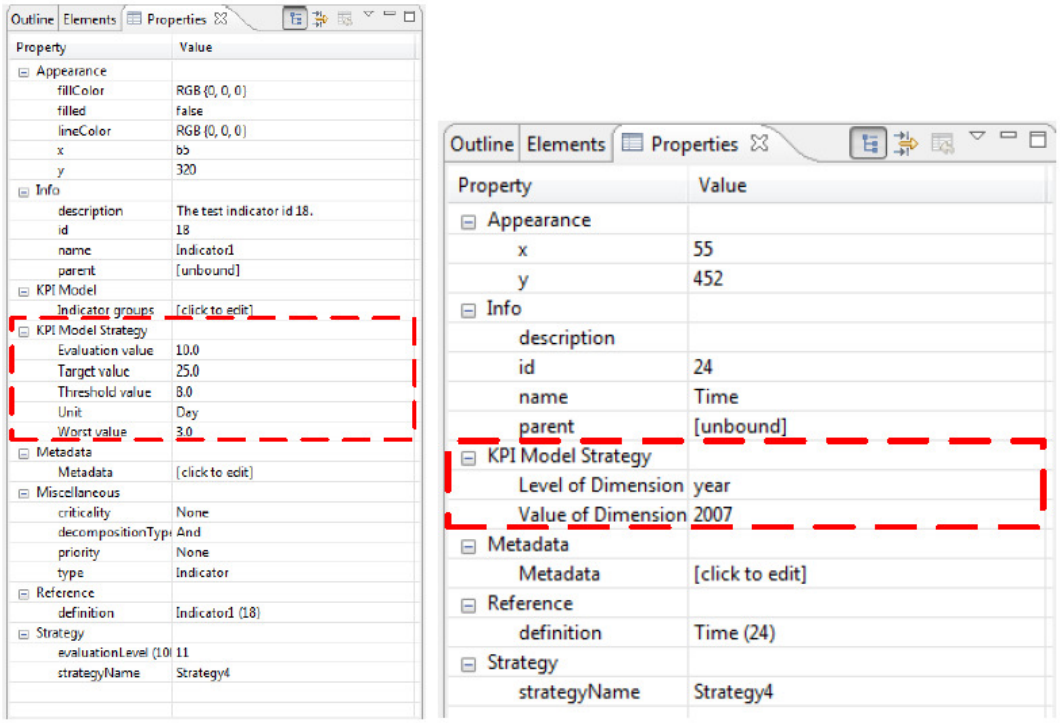


Figure 20: KPI properties in jUCMNav (from Chen, 2008)

KPI strategies are managed the same way as the normal GRL evaluation strategies in the GRL strategy view in jUCMNav (Figure 21).

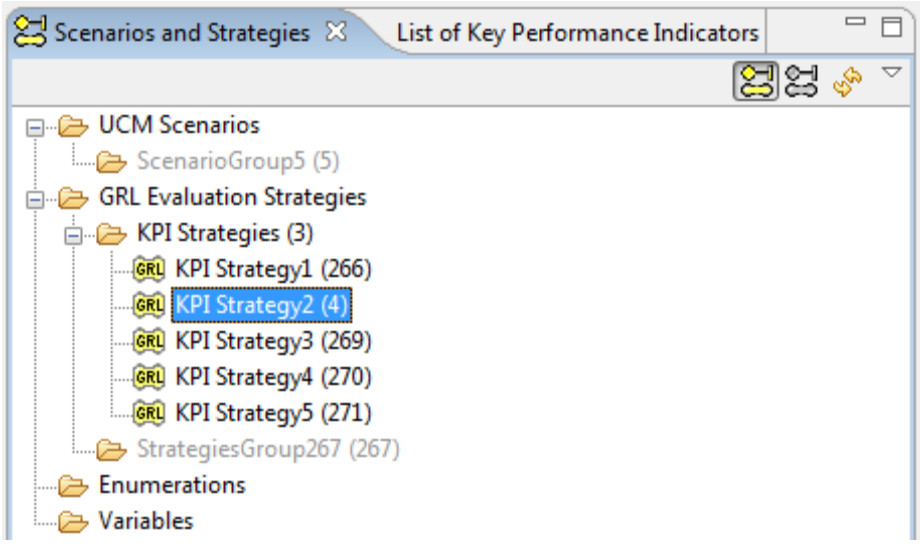


Figure 21: GRL strategies in jUCMNav (from Chen, 2008)

After KPI models are defined and KPI strategies are created, KPI evaluation values (i.e., real-life values) then can be *retrieved* through the monitoring services by clicking on the menu button "Retrieve KPI values", shown in Figure 38.

After the KPI values are retrieved and applied to each KPI in each strategy, the KPI evaluation values can be transformed to GRL satisfaction levels (on a [-100, 100] scale) according to the transformation defined in Figure 22 (Chen, 2008). These satisfaction values can then be propagated, through qualitative and qualitative algorithms (Amyot *et al.*, 2010), to higher-level goals once users trigger any evaluation strategy.

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

Figure 22: Evaluation transformation for KPIs (from Chen, 2008)

After a specific evaluation strategy is triggered, the KPI evaluation status is shown in the KPI list view as icons with different colors (Figure 23): red-down arrow means poor performance, green-up arrow means acceptable or satisfied performance and the yellow arrow means the performance just meets the threshold value.

The KPI view shown in Figure 23 is designed to present the details of KPI evaluation status visually. If a user selects any GRL/UCM element or map that has KPIs defined or if it has KPIs linked directly or indirectly (through URN links), the KPI evaluation status will be displayed in the KPI view. This status presents a general performance view of that process or goal (Chen, 2008).

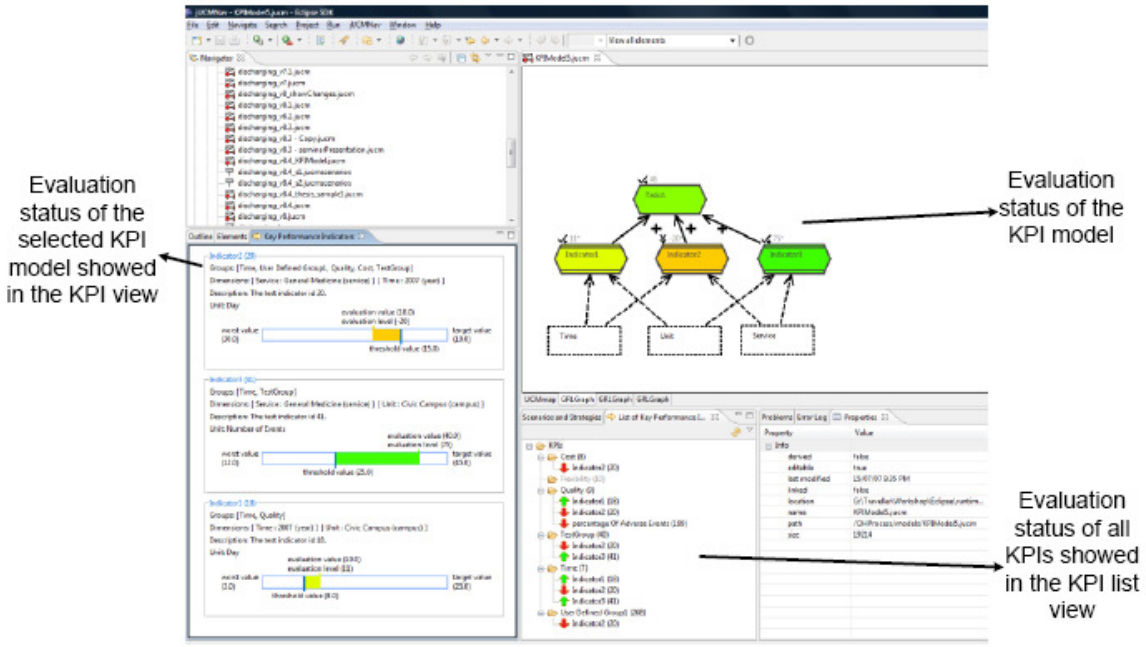


Figure 23: Multiple views of KPIs, strategies and model in jUCMNav (from Chen, 2008)

Business processes and goals can be connected by URN links; therefore, KPIs defined for goal models can also be linked to processes. In this case, when users trigger a strategy and choose a process element, the linked KPIs are shown in the KPI view and the satisfaction level of the connected goal element will be displayed on the target process element. Figure 23 shows the evaluation status of a selected process which has been linked to its goal models through URN links (Chen, 2008).

3.1.2 KPIs and Reports: Concepts and Issues

Chen's implementation relies on the presence of Cognos BI reports to populate the evaluation values of KPIs (via web services). KPI reports in the BI tool are designed and organized in such a way that the client side, i.e. the monitoring services, can easily match the paths of the reports, find and execute them and then retrieve the KPI values from the KPI reports. Since each KPI has an evaluation value under each strategy, KPI reports are categorized and named in the tree hierarchies shown in Figure 24.

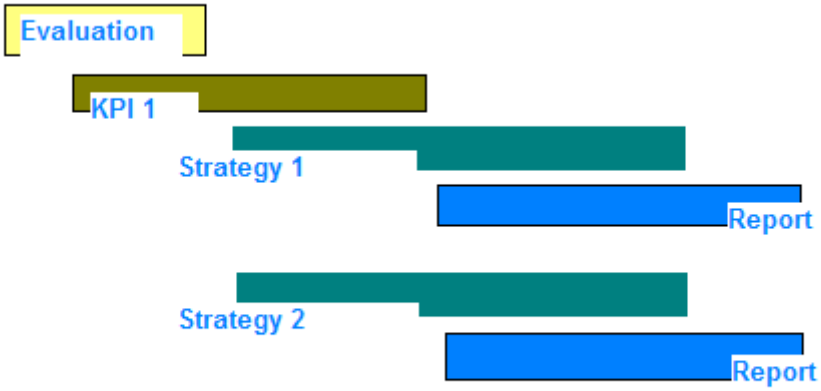


Figure 24: Folder structure of strategies and KPI

In this design, each KPI has a folder and each folder has the same name as the KPI. A folder is a physical container in the Cognos BI tool that can include BI artefacts. BI artefacts can be report objects, folder objects, user portals, etc. In this implementation, all of the folders are under a root folder named KPI Evaluation folder. Each KPI can be present within multiple strategies; therefore, each report associated with the KPI value in a specific strategy in included under a folder associated with that strategy under the KPI folder Figure 24. The main issue with this approach is that for each strategy, it is required to create a separate report *manually*. This can be a very tedious task in cases of a large number of strategies, in addition to the maintenance of the reports inside the Cognos server's internal database.

When a client application looks for a KPI report from the Cognos repository, the complete search path of the KPI includes the folder structure to that report and looks like: ***"/content/package[@name='kpiPackageName']/folder[@name='kpiFolderName']/folder[@name='kpiName ']/report[@name=' kpiStrategyName']"***

KPI reports are created based on Online Analytic Processing (OLAP) cubes and the context information defined in KPI strategies. For a KPI report, a specific KPI evaluation value will be the only measure generated in the report.

An external web service must be implemented to allow monitoring the measure values (Figure 25). It is required to install the web service on an application server. This

causes other issues. For example, if the reports are moved within the Cognos server, then monitoring process will fail and extra work is needed to continue the monitoring process. In addition, there is an extra dependency on the application server that runs the monitoring web service.

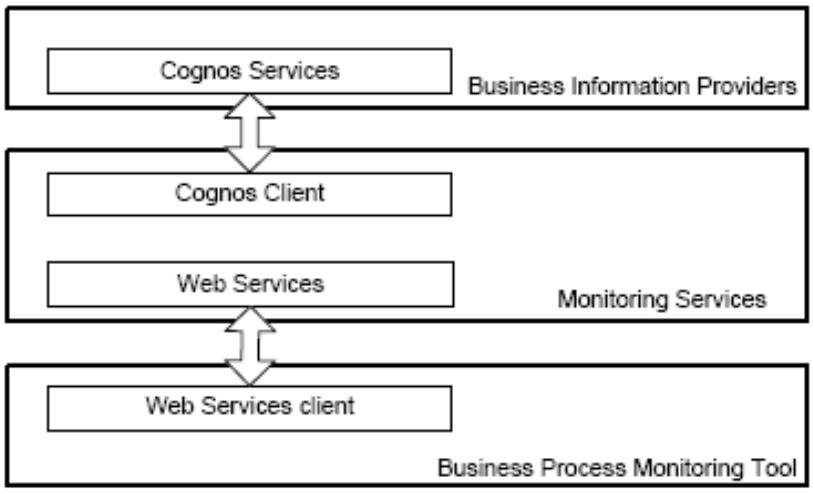


Figure 25: Current architecture (from Chen, 2008)

In this thesis, we are eliminating the dependency to the web service and we deal with report generation and data retrieval dynamically and automatically, at run time. This will augment the easy and efficiency with which goal models with indicators can be used in a BI and performance monitoring context.

3.2 Other Related Research

According to a recent literature survey by Shamsaei *et al.* (2011), the amount of research that involves goal-oriented modeling and KPIs is increasing.

Due to the lack of alignment between business goals and business processes, a new initiative was introduced by Pourshahid *et al.* (2009) to produce a URN-based framework and methodology with Key Performance Indicators. This approach takes advantage of the infrastructure put in place by Chen (2008).

Nigam *et al.* (2008) consider the notion of business artefacts, which is the collection of entities that compose a business operation. In addition, they use the concept of KPI to measure business goals, and they use Event-Condition-Action to monitor and con-

trol the business operation. Their approach bypasses the need for business dashboards and report generation, but it does not answer how one can benefit from Business Intelligence tools in more realistic and frequent situations where actions cannot be automated.

In addition, Borhmer (2009) proposes a KPI framework to resolve the trade-off between effectiveness and economic efficiency. This research focuses on KPI definitions rather than on how KPIs can be monitored in a goal model.

Martin and Refai (2007) propose an approach for measuring and monitoring overall IT security performance. In this approach, business processes are represented as a Security Policies and Procedure Model, whereas the goal view is implemented as Security Goals and Target Achievements. This implementation has a data collection methodology which taps into firewalls, networks, and system logs. It also includes a mechanism to create information from the raw data it collects as well as a reporting engine. The only setback from this approach is the adaptability based on change. IT systems change frequently and it is optimal to decrease the change in dependent systems to minimum. By putting a Business Intelligence tool in the middle, one can decrease this dependency.

Dang *et al.* (2008) implement KPIs as a set of views that can be used to monitor and evaluate performance from different perspectives. The focus of the paper is on perfecting the workflow and data exchange in health care. The notion of KPI is a static concept which has the potential to be expanded to allow data from different data stores be evaluated dynamically within the system if a BI approach is taken into consideration.

In the work of Siena *et al.* (2008), an approach based on Tropos, which is an agent-oriented software development methodology that also has its roots in *i**, is discussed. Tropos captures functional requirements as goals and non-functional requirements as soft goals. In Tropos, a goal graph is a composition of goal nodes with AND/OR relations. Goals are measured by qualitative concepts of satisfiability and deniability. In terms of analysis, forward reasoning and backward reasoning exist; the first focuses on predicting the future based on some initial values and rules defined in the model whereas the second one determines what initial values are required for a desired result. In their research, Siena *et al.* introduced a novel approach called *balanced goalcards* based on the ideas of balanced scorecards framework introduced by Kaplan and Norton (1996; 2004). In this approach, objectives, whether material or immaterial, can be measured via metrics

and a strategy can be the result of balancing these metrics. In addition, the approach supports different perspectives, i.e., customer perspective and internal process perspective, based on the mission statement of the organization. These perspectives constitute the strategic map capturing the interconnected goals.

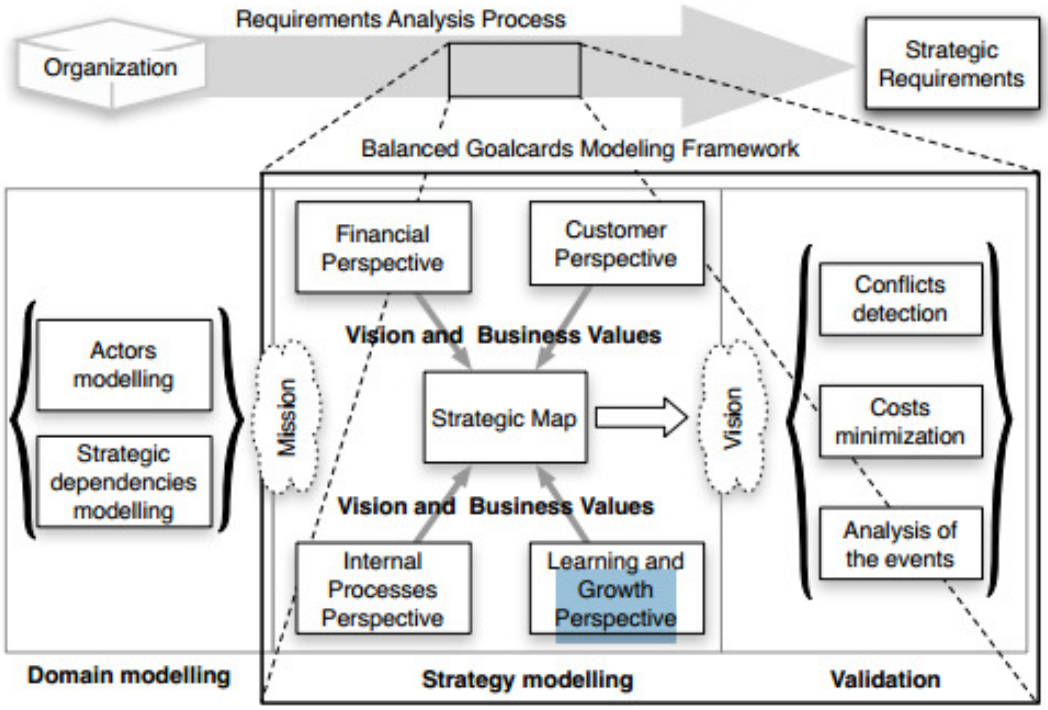


Figure 26: The Balanced Goalcards methodological framework (from Siena *et al.*, 2008)

Balanced goalcards (Figure 26) provides a strategy modeling phase in which goals and business values are presented after initial organizational settings. This view also carries more perspectives than the original balanced scorecards. In this approach, the notion of KPI does not exist, even though there is a notion of metrics representing objectives. In our approach, we are allowing each goal to be measured by contribution relations that are connected to KPIs. These KPIs not only can be populated by forward and backward reasoning mechanisms but also can be calculated through a formula-based algorithm, as supported by jUCMNav. In our method, KPIs can be connected to a Business Intelligence server to retrieve their corresponding values, which enable monitoring the business goals in real-time.

In Martinez *et al.* (2010), another Tropos-based approach is explored. This approach consists of two main processes:

- Defining the method to model business processes from a goal perspective, which includes defining a set of metrics to measure process performance;
- Defining the method to control and monitor business process.

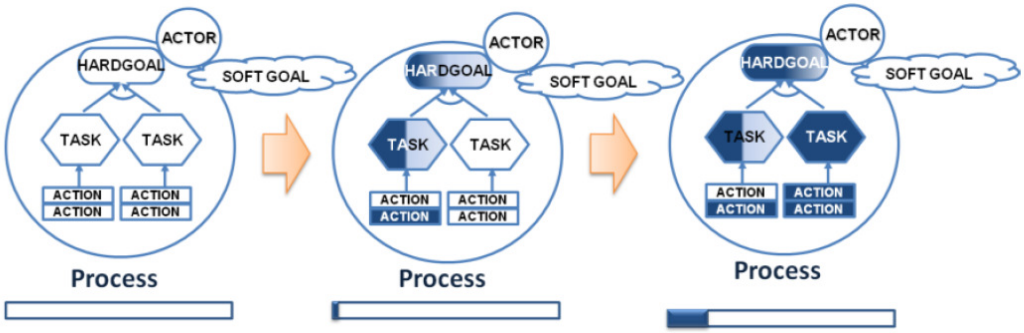


Figure 27: Monitoring method (from Martinez *et al.*, 2010)

Their research focuses more on goal modeling and on how the entities in this framework are interconnected to reflect changes across the goal model. The powerful characteristics of this approach (see Figure 27) are to determine how, why and when the actors develop tasks and process in the business. Metrics defined in their method do not have the concept of dimensions as in our approach. In addition, the capability to integrate with a BI tool to monitor the business process does not exist in their approach.

Popava and Sharpanskykh (2011) introduce a new syntax for goal modeling. Their method includes the notion of top-down and bottom-up analysis. There is a method for evaluation of KPIs called "goal-based performance evaluation", which follows propagation of defined rules when defining the goal model. This research focuses on how goals are interconnected. It also builds on another related paper by Popova and Treur (2005) on formalising a specification language for performance indicators. Even though this research is rich in defining goal models and KPIs, there is still a need for a performance monitoring system in place as well as for the ability to connect to a BI tool, as the latter offer powerful and reusable means to connect to heterogeneous information sources and to reason about data aggregation along different dimensions.

Behnam *et al.* (2009) uses a goal-driven method, considering both organization and system goals, to design and develop patient surveillance software for monitoring ad-

verse events. This method creates a database to store information related to patients and connects the monitoring tool to that database. This approach focuses on creating a monitoring system using jUCMNav with an external database; there is no integration between a BI tool and a monitoring system.

Vrbaski *et al.* (2012) recently combined a rule engine with jUCMNav's goal engine to support the dynamic adaptation of business processes. The rule engine is used for simple conditions whereas a goal model is used to reason about trade-offs involving conflicting goals from different actors. A web service is used to collect information from an external database in order to populate KPI evaluation values. The UCM language was also extended to support interactions with users (input of values, and display of information). Again however, there is no connection to a layer that is as powerful as a leading BI tool.

3.3 Chapter Summary

In this chapter, we discussed the current approach from Chen (2008) in detail, including its implementation in jUCMNav. The main issues with this approach are the manual labor required to produce BI reports (which prevent dynamic updates), and the dependency to a Web service infrastructure.

We also discussed the closest related work that has been conducted in the field of business process monitoring and indicator-based goal modeling. Interesting features and current limitations of these approaches (especially in terms of interoperability with BI infrastructure to populate KPIs in the goal model) were also discussed.

The next chapter will present the details of our new solution to the issue of BI-based KPI updates in goal models targeted at performance monitoring of organizations and of their business processes.

Chapter 4 New Tool-Supported Approach

This chapter enumerates the limitations of the current approach for populating KPI values in goal models based on BI reports. Then, a new and more efficient solution is proposed and illustrated, together with an explanation of important design decisions.

4.1 Limitations of the Current Implementation

In the previous research done by Chen (2008), there are several challenges and shortcomings:

- The user needs to have detailed knowledge of the Cognos Business Intelligence product as an author and content administrator. The user has to create a tree structure based on different strategies within the Cognos environment as well as a separate report for each KPI in each strategy in the goal model (and this grows quickly to a large set of reports). This level of knowledge requires extensive training. Such training is expensive, and there is always a chance that trained employees leave the company. The company then has to reinvest in training newly hired people and bringing them up to speed to where the last person left off. This can usually postpone software releases, which in the end will result in delays in delivering the results to the stakeholders.
- The user needs to have detailed knowledge of web services. To be able to use this approach, the user has to install a web service and hence needs a web application server running (such as Websphere application server). The use of such products requires licensing of the product per user in any organization. In addition, this approach is platform dependent.
- Performance is relatively slow for large number of KPIs, as many reports need to be generated.

- Report maintenance becomes a bottleneck as the number of strategies increase as well as the number of KPIs increases within the strategies.
- Modifications of the KPI values on the fly require the user to access the Cognos environment, create a new structure for the new value, create a report and run the report. This is not convenient in a fast-pace environment, especially if there is no subject matter specialist available.
- KPI value retrieval is limited to only one Cognos server. Nowadays, within an enterprise, there are distributed systems with different levels of user access and capabilities within different servers. One should be able to address KPIs coming from different servers without having to do extra setup or web services deployment.

In the new approach defined in this thesis, all the above shortcomings are addressed and a more efficient solution to the problem is proposed.

4.2 Design Decisions

There are always several ways of designing a solution but in our context we decided to go with the ones that made the design more elegant and paved the way for future extensions.

We decided to automate many activities that were done manually in the previous approach. This is an important step towards a more dynamic approach to Business Process Monitoring. We minimize user interactions on the server side. IBM Cognos SDK is used for all the maintenance and bookkeeping actions. Another option was also considered which consisted in building SOAP messages on the jUCMNav side, sending these messages to the BI server, receiving the response, and building further requests after unmarshalling the message received. This could decrease the load and computation cycle on the server, but would add more complexity to our design. If in the future the message specification changes, we would also need to adapt to these changes and this could lead to a lot of overhead on the jUCMNav developer if one is not familiar with the specifications of Cognos' messaging capabilities. Using the SDK API removes any overhead for

message creation and simplifies adaptability in spite of increasing server load and computation time.

The next decision was to choose between the Cognos SDK and the Cognos Mashup Service (CMS) to **retrieve the data** (for KPI evaluations).There are two types of HTTP-based calls in Cognos product: REST and SOAP calls. Cognos SDK utilises SOAP calls only whereas Cognos mashup service utilizes both REST and SOAP calls. It depends on the user's preference to choose REST or SOAP when using Cognos mashup service. SOAP API for Cognos mashup service provides the user with more control over the retrieved data whereas REST provides fast access to the data retrieved. We decided to use the Cognos SDK for any call *except* data retrieval, e.g., for report creation and for folder creation and authentication. In this thesis, CMS was chosen for report run and data retrieval because CMS supports the use of a more efficient REST API. In addition, the jUCMNav designer would require understanding the Cognos SDK object model to be able to use it in a data retrieval context. CMS uses a REST API and with little programming knowledge designers can retrieve any part of the BI data in a short amount of time. The Cognos SDK would retrieve resulted report in XML format which also require further XML parsing to get the desired value. CMS has the option to return the data in a JSON format, which is currently the fastest data format for web communication, and very minimal parsing is required to get the desired value. XML parsing would likely require including additional libraries. Therefore CMS is the better alternative as it benefits from low utilization overhead, fast transfer rate, and fast value retrieval when compared to Cognos SDK.

In terms of validating the well-formedness of our goal models and data entry in the models, we decided to use the Object Constraint Language. OCL constraints on the URN models allow users to detect errors by applying validation checks before communicating with the BI server. These errors could be caused by user themselves; for example, they might have left a mandatory field behind. One alternative was to write Java validation code, but this could be a cumbersome task as the number of fields grows with different data types of those fields. OCL is an elegant solution to this problem, especially in the context of jUCMNav, which already offers the infrastructure to define and check user-selectable rules and to report violations (Amyot and Yan, 2008). OCL rules used for this

purpose will be discussed in this chapter. Please refer to Appendix A for their complete description in OCL.

4.3 Proposed Solution

The solution proposed in this thesis contains 4 stages:

- Authentication and Configuration (section 4.3.1);
- Dynamic report generation (section 4.3.2);
- KPI values retrieving (section 4.3.3);
- KPI values assignment (also in section 4.3.3).

4.3.1 Authentication and Configuration

The authentication to the Cognos server is initiated from the jUCMNav tool. The authentication and configuration data is entered and stored inside the jUCMNav goal model in a special Dimension element which will hold properties such as user credential, server information, destination folder and model information (Figure 28). Server information such as the dispatcher and the Cognos gateway is required to make the SDK and Cognos mashup calls; two metadata properties are introduced to store these two values as well. All of the above metadata are stored in one GRL Dimension element and it is required to link this element to the goal model's indicators that are expected to feed from the BI tool. One such Dimension element is needed per BI server, and many servers can be supported to populate the KPIs in one goal model.

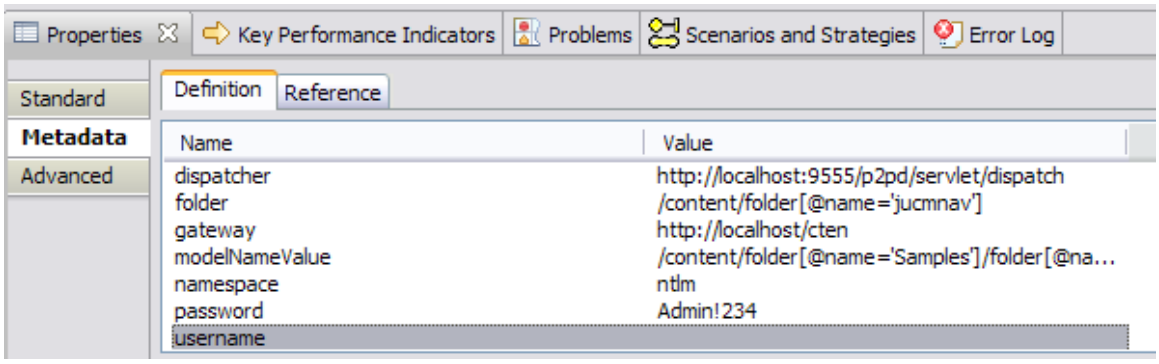


Figure 28: Metadata editor: addition of a model name and other server characteristics

4.3.2 Dynamic Report Generation

The next step consists in defining indicators/KPIs before the dynamic report generation. Each indicator is the intersection of three items in a database. For example, in the cross-tab shown in Figure 29, there are 3 pieces of information.

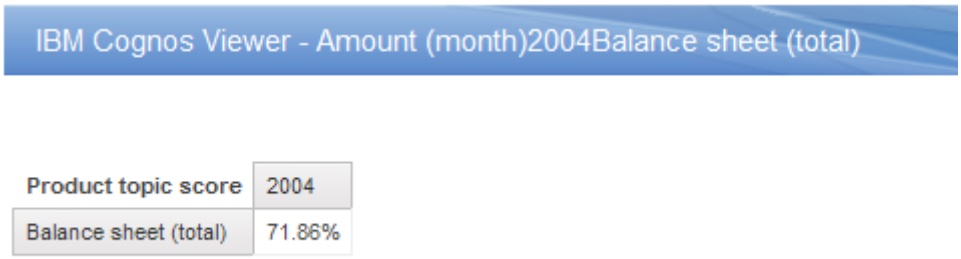


Figure 29: Report result, with desired value

In this example, there is a time dimension with value of 2004 on the *column*. There is a balance sheet dimension with the total as a value on the *row*. Finally, at the intersection of the row and of the column, the value 71.86% represents a *measure* or a *fact* (here the product survey score) and this value can be used as the evaluation value of a KPI for a given strategy in the goal model. As the above crosstab is created manually using the Cognos Report Studio tool, such a manual approach can quickly become a bottleneck when the number of KPIs or of strategies increases, especially if the analyst is not familiar with the BI tool. To solve this issue and to facilitate dynamic report creation, we add three new metadata properties attached to Dimension elements inside the goal model. It is important to be specific when we define these elements. We need to choose one row, one column, and one measure dimension, as described below.

- **Row: two metadata properties** (Figure 30)
  - *rowMunValue*: this is a mandatory string that points to the desired row in the data model.
  - *rowName*: this is a mandatory string field that will help avoid over-writing previous reports.

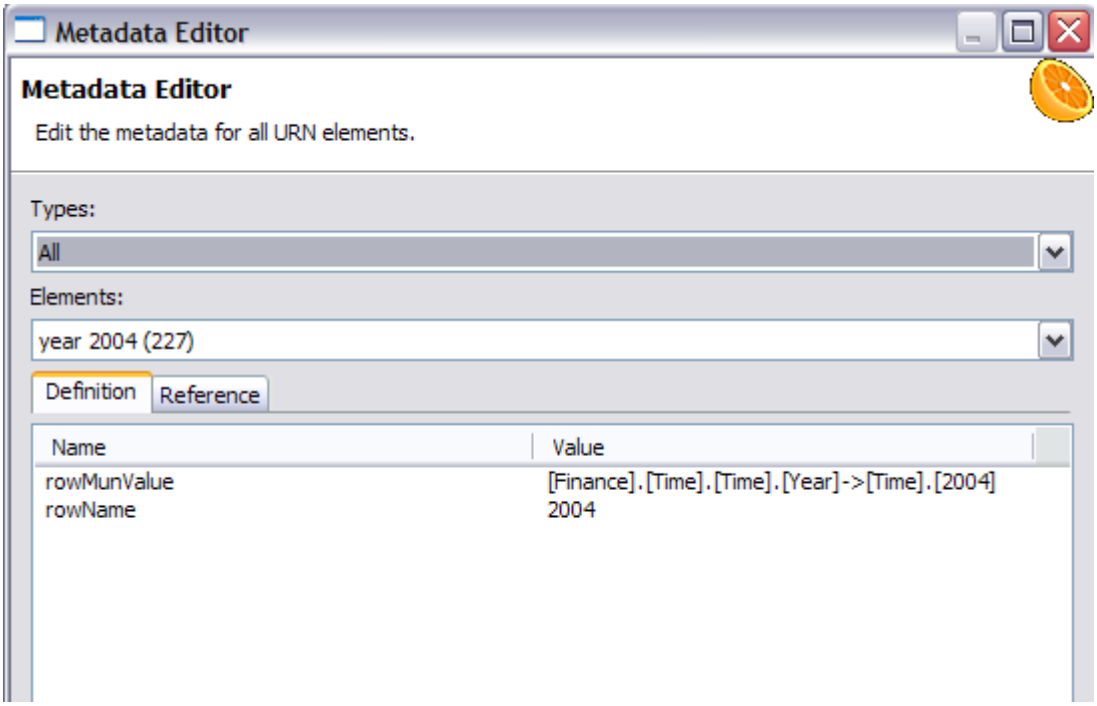


Figure 30: Metadata editor: addition of row information to a GRL dimension

- **Column: two metadata properties** (Figure 31)
  - *colMunValue*: this is a mandatory string that points to the desired column in the data model.
  - *colName*: this is a mandatory string field that will help avoid overwriting previous reports.

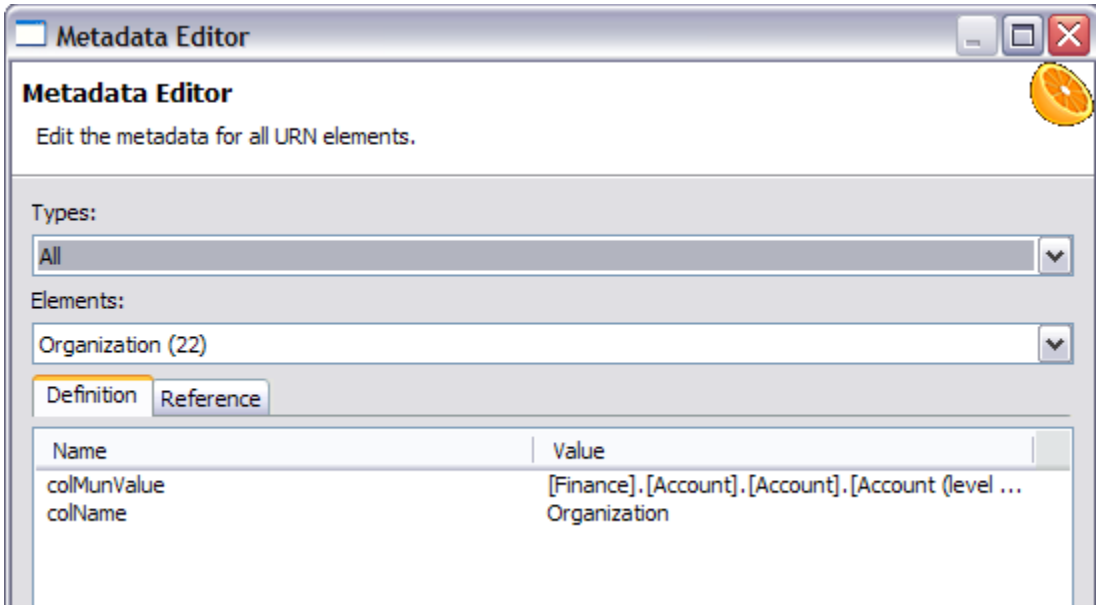


Figure 31: Metadata editor: addition of column information to a GRL dimension

- **Measure: two metadata properties** (Figure 32)
  - *measureMunValue*: this is a mandatory string that points to the desired fact/measure in the data model.
  - *measureName*: this is a mandatory string but that will help to avoid overwriting previous reports.

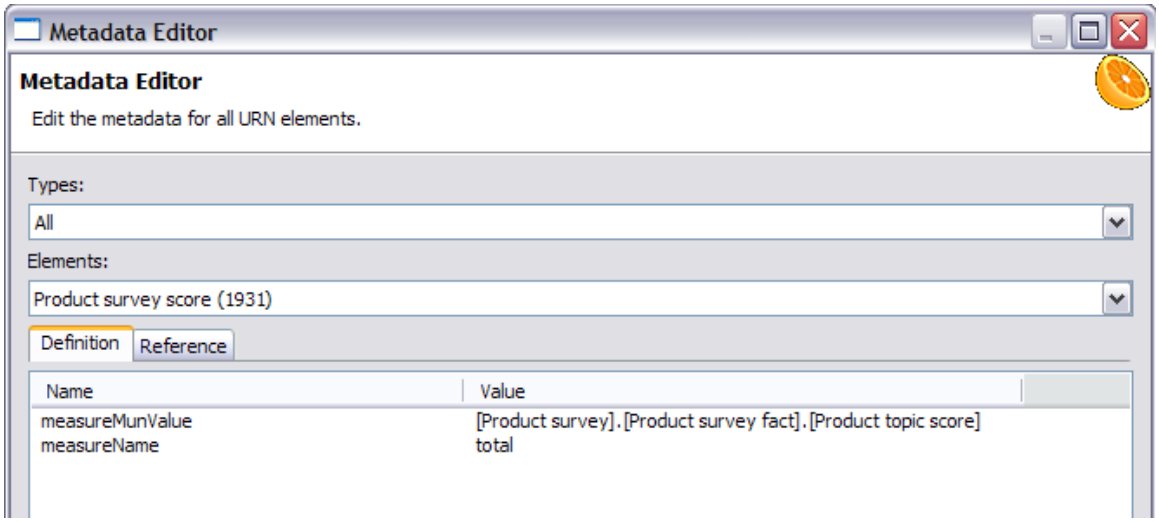


Figure 32: Metadata editor: addition of measure information to a GRL dimension

The metadata measureName, rowName and colName are strings that will help identify different reports that will be generated automatically and will have no effect on the final

retrieved result. However, measureMunValue, rowMunValue and colMunValue are *Member Unique Name* (MUN) values of the dimensions.

Let's explore the idea of *dimensions*, *measures* and *members*. For example, assume that the value we want to assign to a KPI in the goal model is the result of this report run, which is the product score in year 2004 Figure 29. There are two dimensions in this report:

- Rows that cover the total balance sheet dimension;
- Columns that cover the time dimension.

A potential hierarchy for the time dimension is shown in the data model of Figure 33.

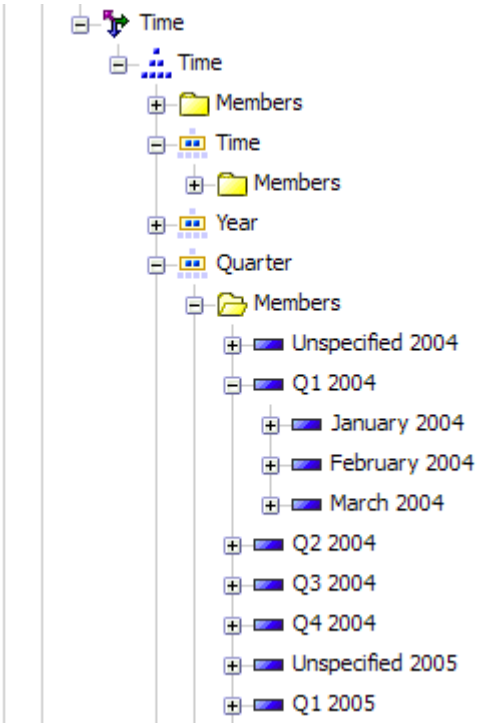


Figure 33: Report studio, data hierarchy

The time and total balance sheet dimensions are different from the product survey score in the sense that product survey score is a *fact* value and it contains numerical value, whereas time and total balance sheet dimensions contain descriptive value (e.g., Q1 2004). Each of the above dimensions is defined with a unique identifier in the data model known as MUN (Member Unique Name). This MUN is composed of the path related to the star schema where it was created.

In Cognos, each dimension is composed of members that can be composed of child nested members. Dynamic report generation does not necessarily have to include the specific dimension level since drill behaviour is available in the Cognos products.

In Figure 34, if a user wants to get to "Assets (total)", one should drill down the Account dimension two times, starting at the root. For the time dimension, one needs to drill down to Account, Balance sheet (total) to get the desired value. Then, one can fetch the product survey score found at the intersection of the selected Account and Time. The challenge is to automate the drilling down to the right dimension.

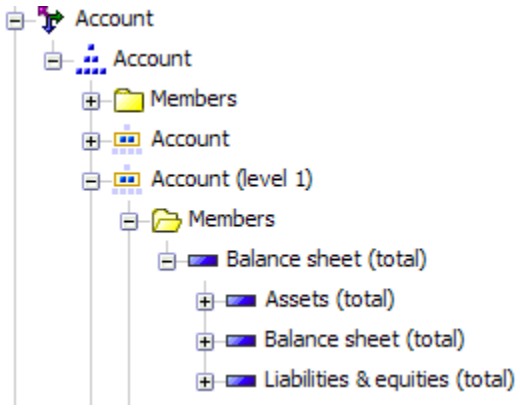


Figure 34: Organization dimension

4.3.2.1 Regular Dimensions

Regular dimensions represent descriptive data that provides context for data modeled in measure dimensions. A regular dimension is broken into groups of information called *levels*.

As shown in Figure 35, the various levels can be organized into *hierarchies*. For example, a product survey dimension can contain the levels Brand Recognition, Reliability, etc. A *Member Unique Name* (MUN) contains the values of the business keys of the current and higher levels. For example, ***[GO Data Warehouse].[Product Survey].[Product Survey].[Product Survey]->[Product survey].[1]*** identifies a member that is on the first level (*Product Survey*) of the hierarchy *Product Survey* of the dimension *Product Survey* that is in the namespace *GO Data Warehouse*. The caption for this product is Product Survey, which is the name shown in the metadata tree and on the report.

A regular dimension may have multiple hierarchies, as explained earlier for the time dimension. However, one can use only *one* hierarchy at a time in a query. For example, one cannot use one hierarchy in the rows of a crosstab report and another hierarchy from the same dimension in the columns. If one needs both hierarchies in the same report, one must create two dimensions, one for each hierarchy.

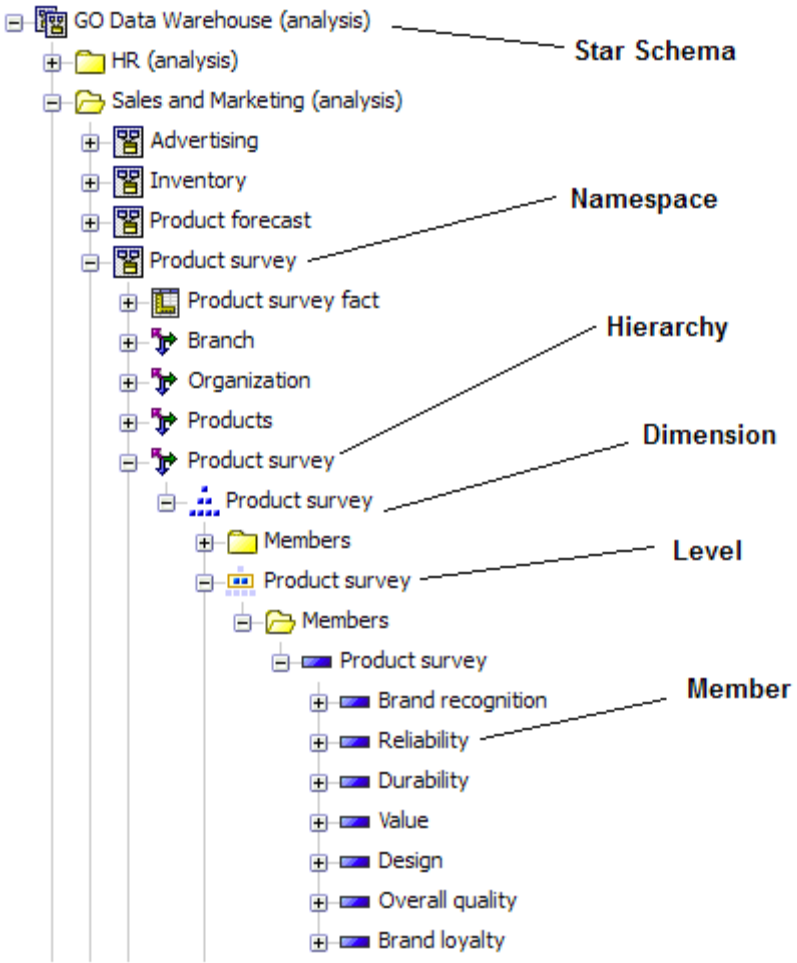


Figure 35: Data hierarchy

4.3.2.2 Measure Dimensions

Measure dimensions represent the quantitative data described by regular dimensions. Known by many terms in various OLAP products, a measure dimension is simply the object that contains the fact data. A measure dimension is not meant to be joined as if it were a relational data object.

For query generation purposes, a measure dimension derives its relationship to a regular dimension through internal reference objects within Cognos products.

4.3.3 Model Design

To be able to address the correct value for KPIs in a goal model (like the one in Figure 36), we need to be able to address the correct namespace, hierarchy, dimension level and member. To facilitate this, a new dimension (StarSchemaInfo) tagged with the authentication and configuration metadata described in section 4.3.1 is brought to the scene. The properties of such dimensions are shown in Figure 43.

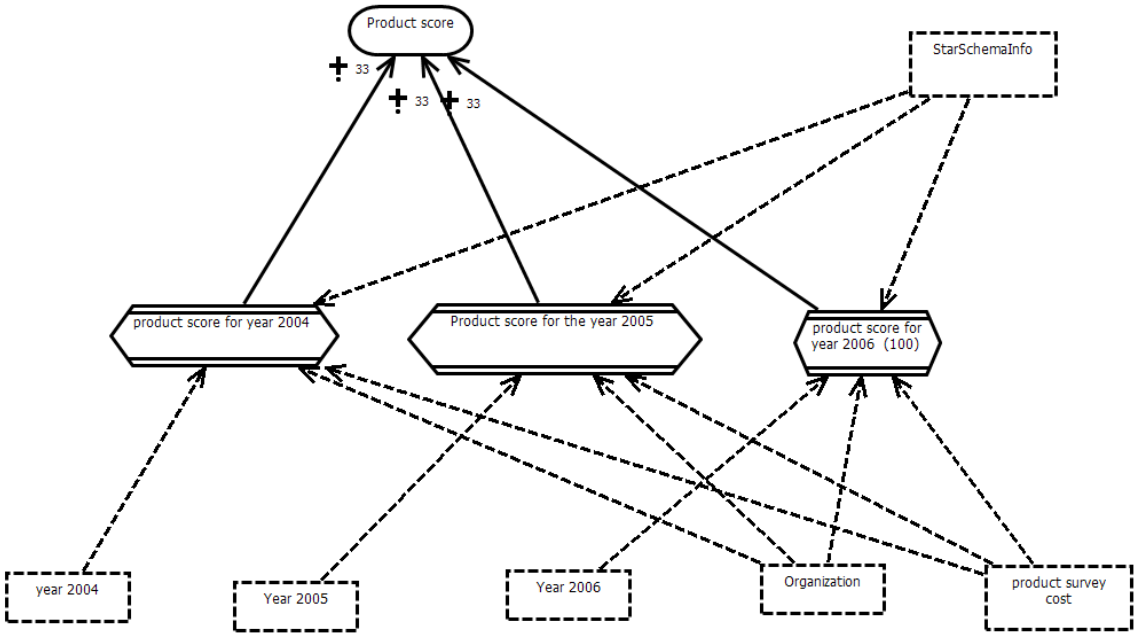


Figure 36: Proposed model

After addressing the columns and rows as described before, it is then required to address KPI values. It should be remembered that conventional KPIs are computed within the jUCMNav model and there should be a way to distinguish between the Cognos KPIs and conventional KPIs. A new metadata property for the KPI object is hence added. This property is a Boolean value called “cognos” (Figure 37). If this value is set to true, then it is assumed that this KPI’s evaluation value is retrieved from a Cognos report that will be created automatically depending on the associations it has with its dimensions.

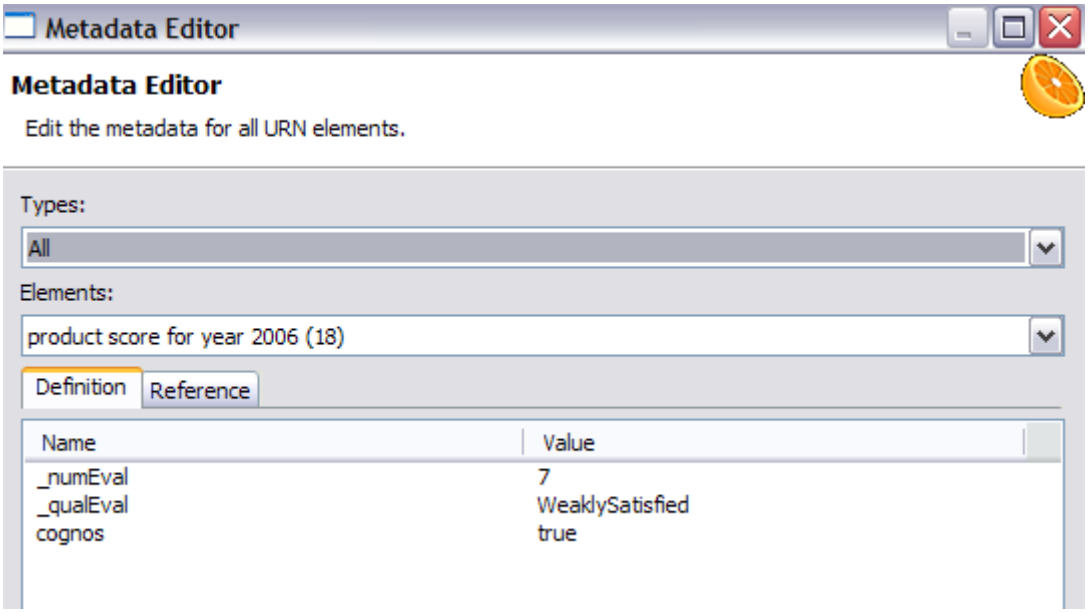


Figure 37: Properties of a KPI retrieved from a Cognos report

A retrieve KPI values command can be issued from jUCMNav's interface (Figure 38).

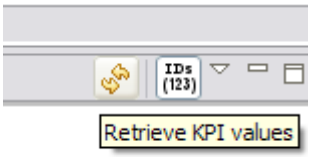


Figure 38: Retrieve KPI values button

The model whose KPI evaluation values will be populated from Cognos will have an equivalent number of reports; these reports will be stored in Cognos' internal database (content store) under the destination folder which was set in the special dimension as folder metadata property. These auto-generated reports are accessible through Cognos BI's user interface. For example, the sample model in Figure 36 has three Cognos KPIs and hence there will be three Cognos reports generated in the Cognos environment under the destination folder (Figure 39).

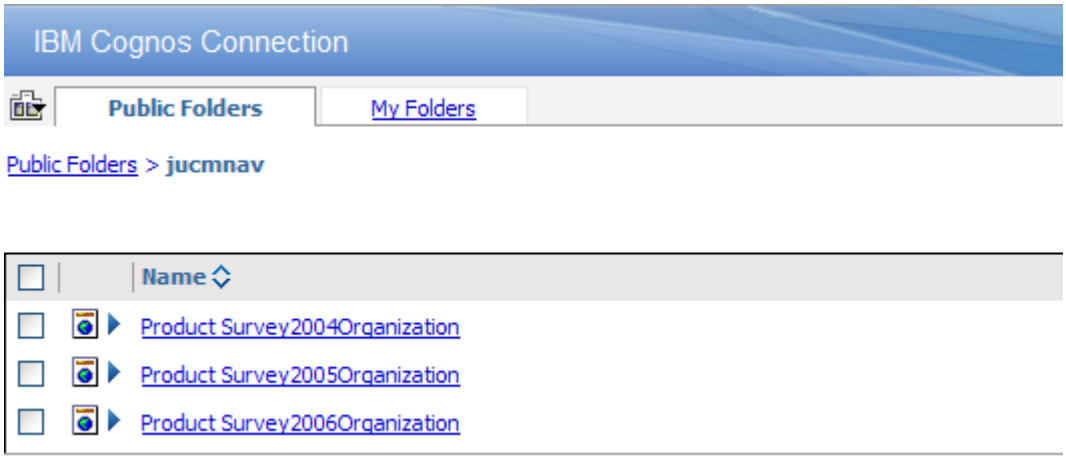


Figure 39: Content of the destination folder for the model in Figure 36

The next step is to run the reports. Cognos Mashup Service will run the reports and will return the value to the jUCMNav tool. jUCMNav will then provide this information to the KPIs in the model and finally the user interface will be updated (see Figure 40 and Figure 41).

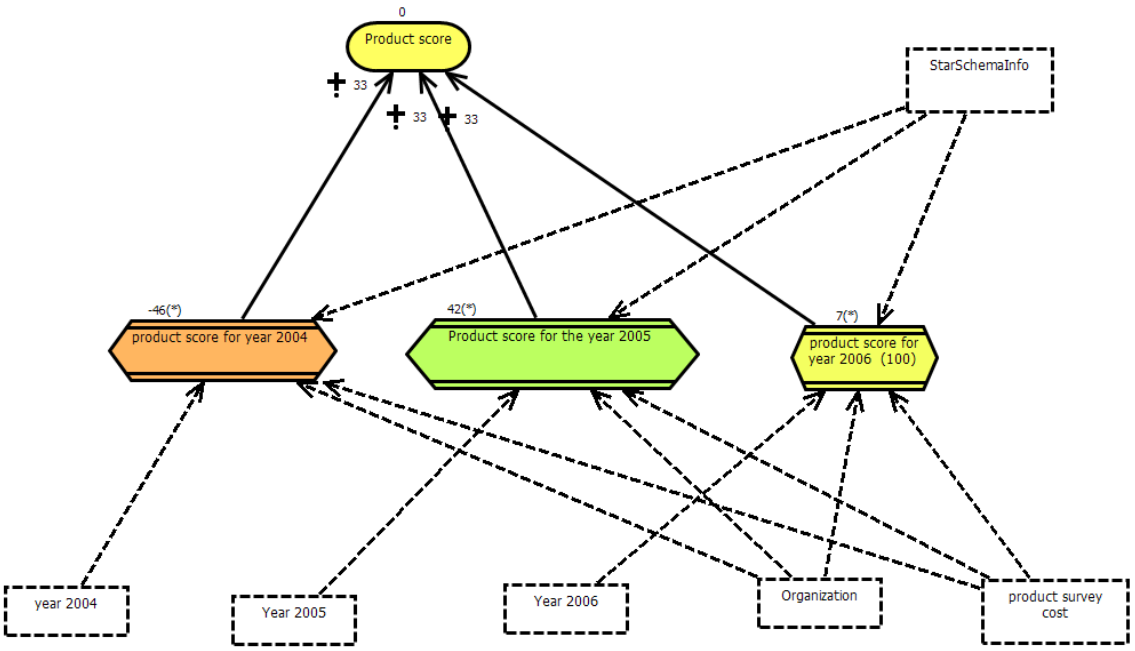


Figure 40: Model view in jUCMNav after retrieving the values

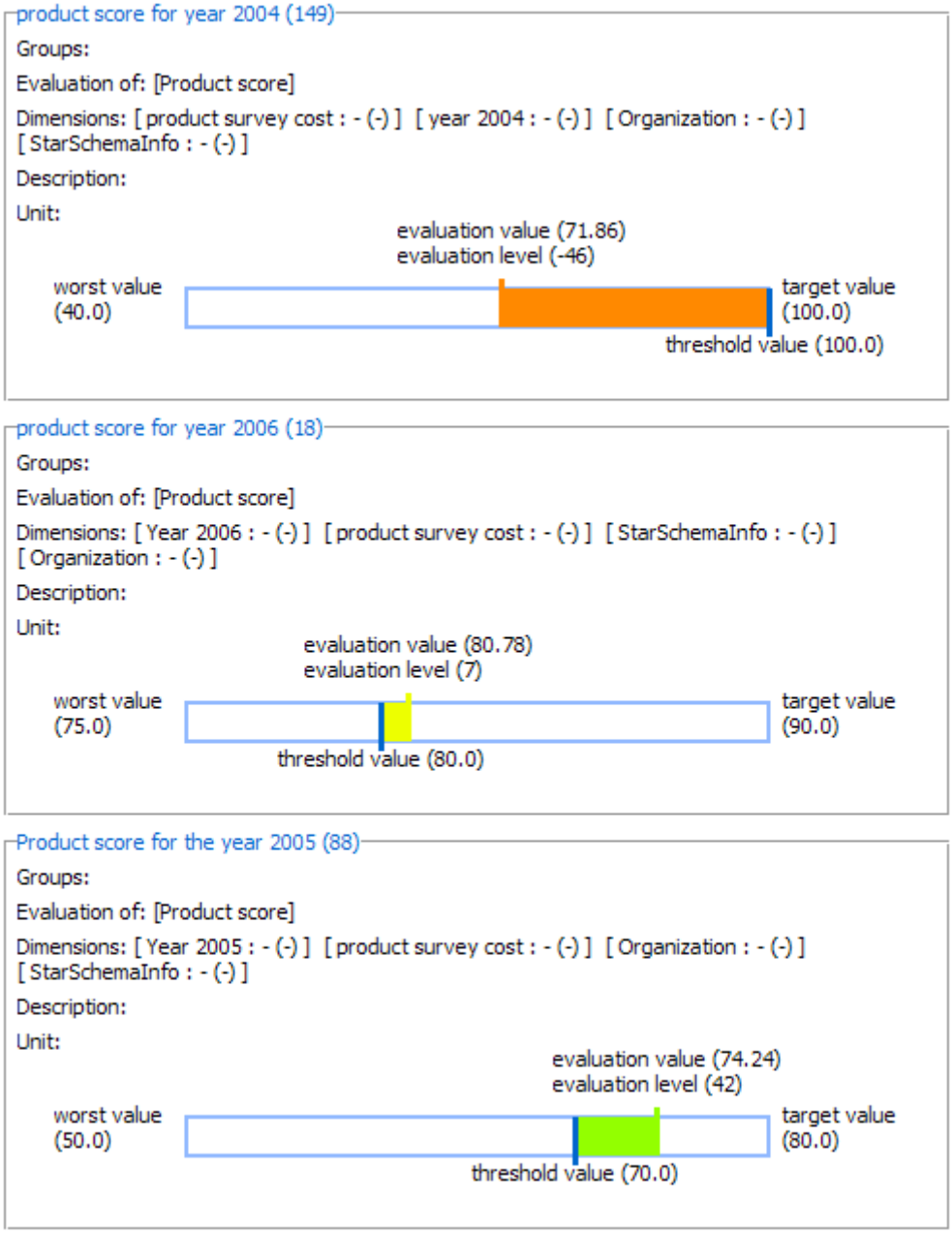


Figure 41: KPI values retrieved

This solution is such that if there is more than one KPI that differ only in one dimension, then it is only needed to associate the KPI with the other dimension to the differing dimension. For example, see "Product score for the year 2005" KPI and "Product score for the year 2004" KPI in Figure 40, which differ only by their time dimensions (Year 2004 vs. Year 2005). Dimensions are hence reusable across many KPIs.

4.3.4 Model Validation

In this new solution, we are using nine OCL rules (Figure 42) to validate the well-formedness of the goal model. These rules are OCL invariants (i.e., constraints) defined on classes from jUCMNav's metamodel. As there are many metadata elements and many types of dimensions and links that are expected, such rules help avoid errors in the construction of the model itself before data is fetched from Cognos reports. Table 2 provides a description of rules that are being checked. Violations of these rules are reported to the modeler automatically. Appendix A provides a complete description of the rules in OCL.

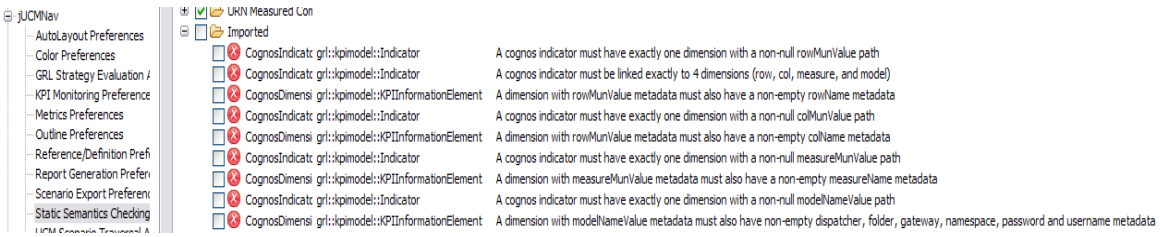


Figure 42: New OCL rules for jUCMNav to check the well-formedness of goal models

Table 2: Description of OCL rules

Rule name	Description
CognosIndicatorRowDimension	A cognos indicator must have exactly one dimension with a non-null rowMunValue path
CognosIndicatorHasFourDimensions	A cognos indicator must be linked exactly to 4 dimensions (row, col, measure, and model)
CognosDimensionRowName	A dimension with rowMunValue metadata must also have a non-empty rowName metadata
CognosIndicatorColDimension	A cognos indicator must have exactly one dimension with a non-null colMunValue path
CognosDimensionColName	A dimension with rowMunValue metadata must also have a non-empty colName metadata
CognosIndicatorMeasureDimension	A cognos indicator must have exactly one dimension with a non-null measureMunValue path
CognosDimensionMeasureName	A dimension with measureMunValue metadata must also have a non-empty measureName metadata
CognosIndicatorModelDimension	A cognos indicator must have exactly one dimension with a non-null modelNameValue path
CognosDimensionModelAttributes	A dimension with modelNameValue metadata must also have non-empty dispatcher, folder, gateway, namespace, password and username metadata

For example, consider the "cognos model" entity definition in our model (Figure 43).

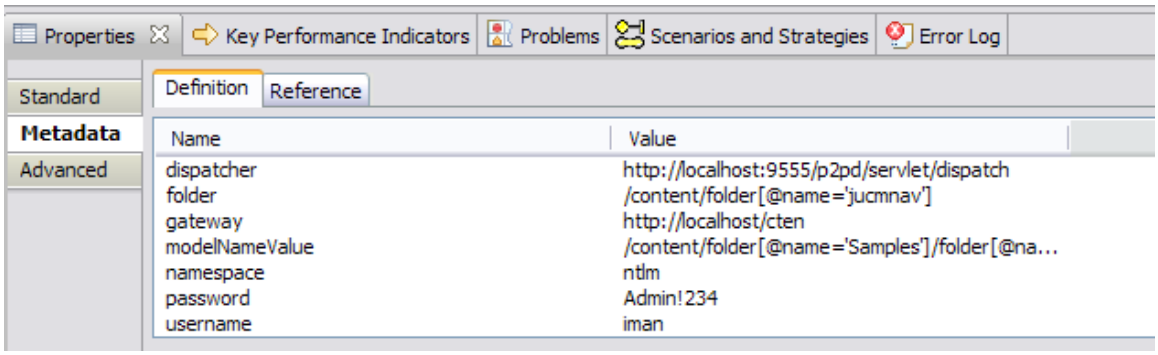


Figure 43: Sample Cognos model entity definition

Now assume that a value is missing for one of the above properties (Figure 44).

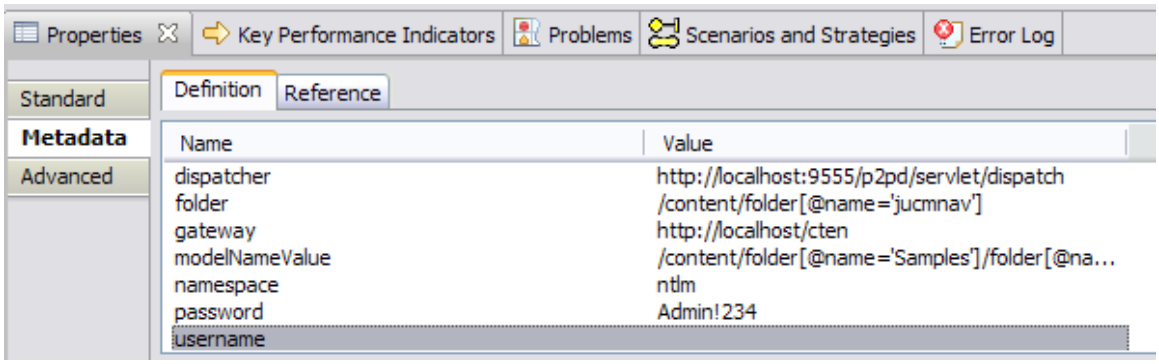


Figure 44: Cognos model without a user name value

jUCMNav allows modelers to check the validity of their models against selected rules (Amyot and Yan, 2008), as shown in Figure 45.

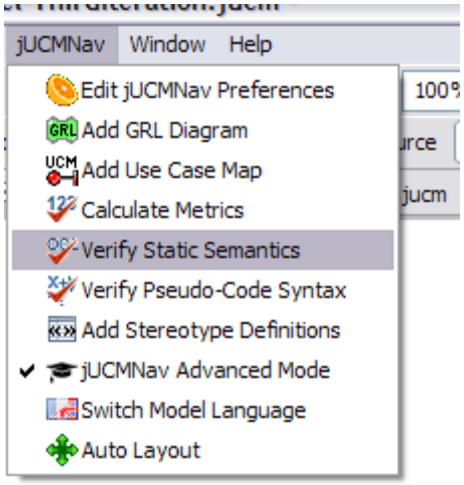


Figure 45: Verifying static semantic rules (constraints) in jUCMNav

By validating a GRL model tagged as in Figure 44 against our nine OCL rules, the tool will detect that one of the rules has been violated (Figure 46).

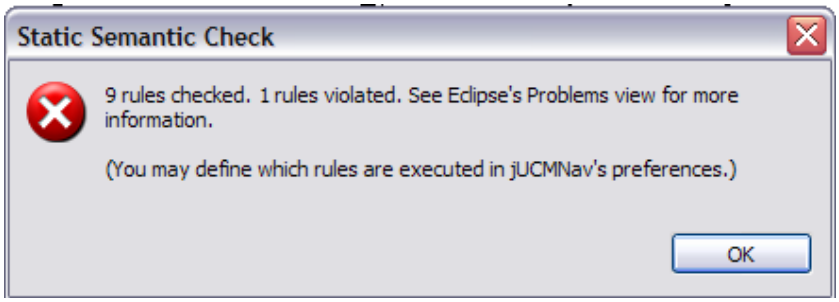


Figure 46: Rule violation

In jUCMNav's Problems view, the violated rules are reported (only one violation in Figure 47). The dimension element that violated that rule is identified, and the description of the rule tells the modeler what is expected from such element to be valid.

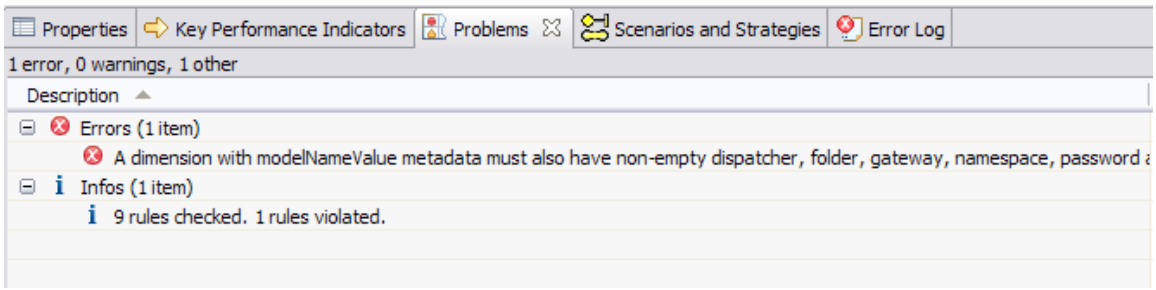


Figure 47: Violation description

4.4 Architecture

The architecture underlying this solution follows a client-server pattern (Figure 48). jUCMNav is the client; all the configuration data and setup is handled inside jUCMNav. jUCMNav also builds the report specifications as well as parses the returned report values. The Cognos server provides two communication methods: SOAP and REST. The SOAP-based method exposes all the functionalities available in a Cognos server. These functionalities include content administration, modeling, report authoring, customizations, output generation, and custom authentication provider. To enable jUCMNav to make SOAP calls to the Cognos server, Java libraries must be imported into jUCMNav. These Java libraries include the Cognos Object model in addition to the Axis 1.4 libraries (Apache, 2006) since Cognos extends Axis' implementation to make SOAP calls. The REST-based method only provides access to report content. REST calls cannot write into the content store where all the Cognos server information is located. To make REST calls, there is no need to use any external libraries, but instead the client must build a

REST URL compliant with the Cognos Mashup Service. This URL is built programmatically inside the jUCMNav client. Once the reports are created, this URL is called through a HTTP request and this triggers a report run. Once the report has finished running, the report results are returned to jUCMNav in the JSON format. jUCMNav parses the JSON message and assign its value to the corresponding KPI through jUCMNav's API.

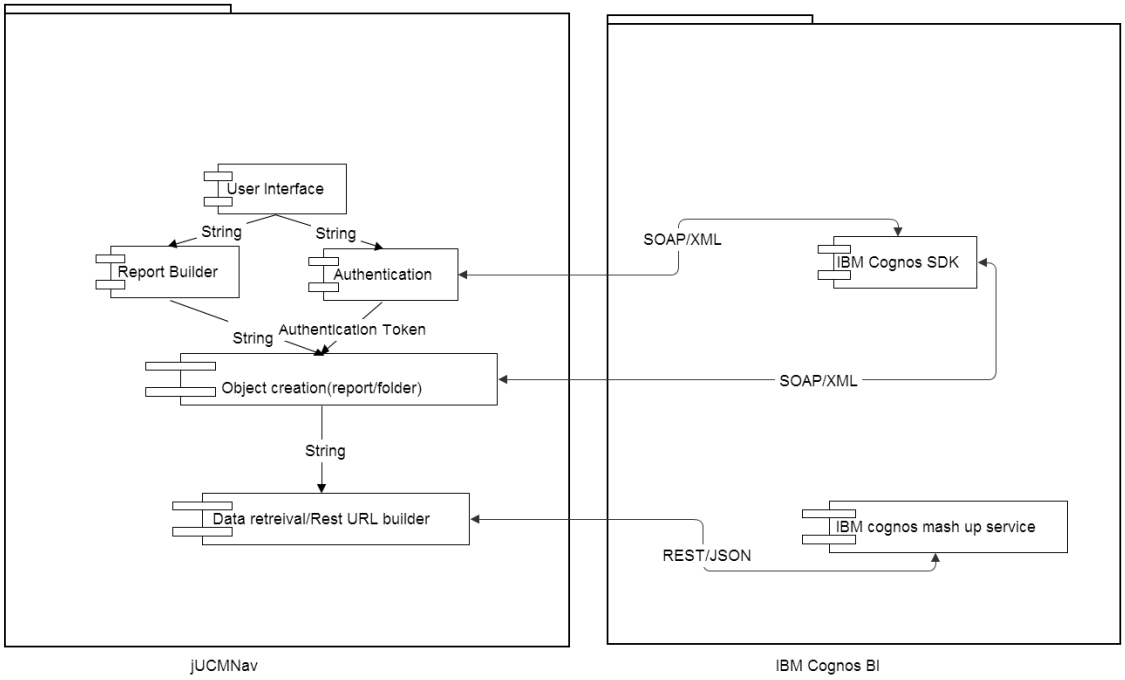


Figure 48: Client-server architecture

4.5 Mechanism

Before making calls to the Cognos server, the modeler is required to prepare the model in jUCMNav. This means that the user must provide the server information, destination folder and user credentials in jUCMNav's goal model (as explained in section 4.3.1). As mentioned section 4.3.1, a special dimension element should be added to the goal model that will include the following metadata properties: username, password, Cognos namespace, dispatcher URL, gateway URL and the destination folder where the auto-generated reports will reside.

Once this configuration is completed, the user can initiate the "Retrieve KPI Value" command through jUCMNav's GUI. Once this command is initiated, there are a series of SOAP and REST calls exchanged with the Cognos server to retrieve the KPI val-

ues. The REST calls are only for data retrieval whereas the SOAP calls are made by Cognos SDK for the rest of the tasks such as report generation, folder creation, and authentication, as illustrated by the typical scenario in the following sequence diagram.

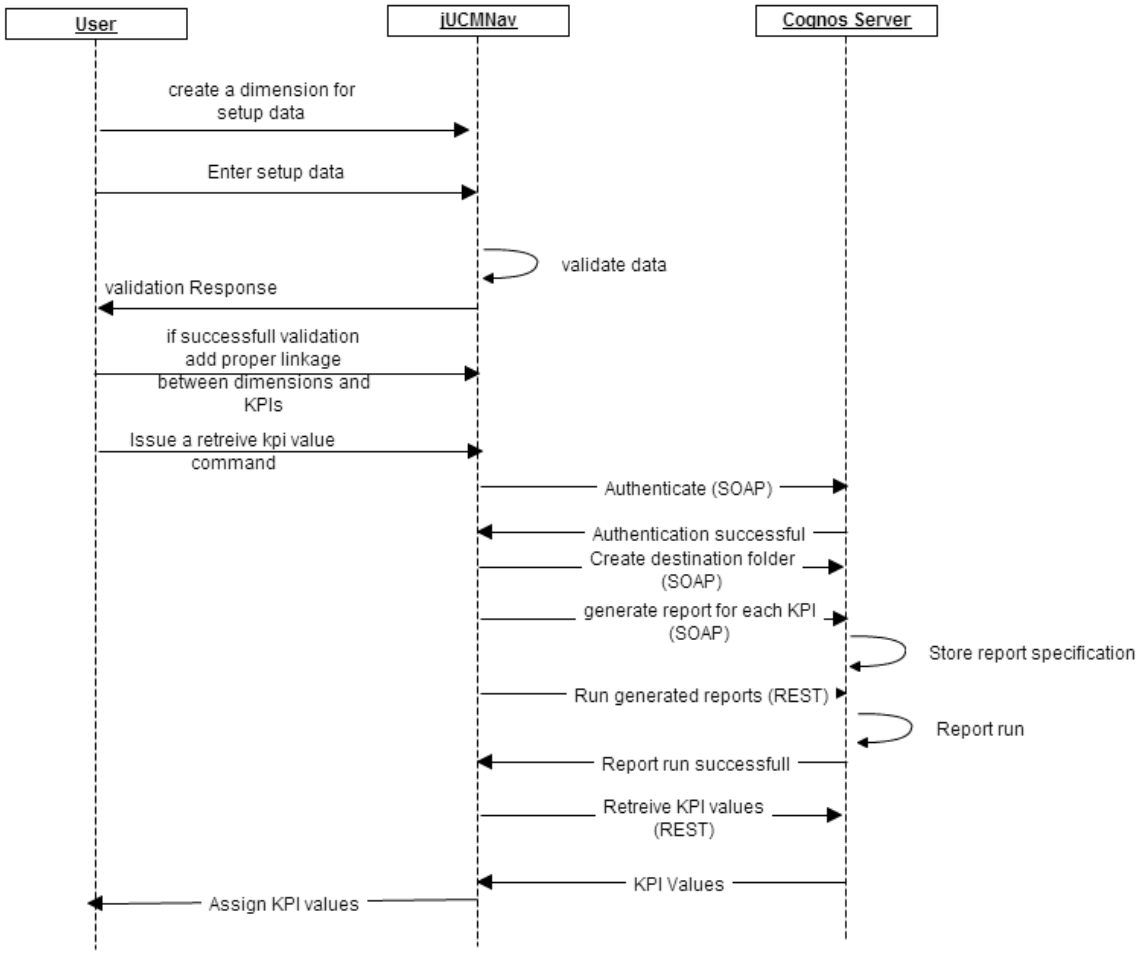


Figure 49: Typical scenario

Once the report is created and run, the report results are currently not cached. The Cognos Report Specification allows users to set a property inside the report specification so that the results can be cached after report run. In this thesis however, this property is not set. Therefore, every time the command to retrieve KPIs is issued, the report is run again. This approach takes a bit more execution time but avoids any surprise caused by caching.

The following abstract algorithm describes how jUCMNav interacts with the Cognos server once the analyst has invoked the command to retrieve KPI values. The

preconditions are that the GRL model satisfies the nine OCL rules defined in Appendix A, that a strategy is selected, and that the Cognos server has the appropriate data sources in place. The postcondition is that the Cognos KPIs in the goal have their evaluation values set.

Algorithm: Retrieve_KPIs
Input: elements *// set of model elements from the GRL model*
strategy *// the selected GRL strategy*
Output: none
Modified: strategy *// the selected GRL strategy*
Steps:

```
serverConfigurations = {e ∈ elements | e is a dimension containing metadata properties
                        username, password, namespace, folder,
                        modelNameValue, gateway and dispatcher}
for each conf in serverConfigurations do {
    // extract configuration as local variables
    username    = get username metadata value from conf
    password    = get password metadata value from conf
    namespace   = get namespace metadata value from conf
    folderName  = get folder metadata value from conf
    dispatcher  = get dispatcher metadata value from conf
    gateway     = get gateway metadata value from conf

    with SDK, authenticate to Cognos server from conf
                        using username, password, namespace, dispatcher
    if (successful authentication) {
        if (folderName does not exist) {
            with SDK, create the destination folder using folderName
        } // if. Else, do nothing.

        kpis = { e ∈ elements | e is a KPI and e is linked to conf}
        reports = empty set of report objects
        for each kpi in kpis do {
            isCognos= get cognos metadata value from kpi
```

```
            if (isCognos is true) {
                modelName   = get modelNameValue metadata value from conf
                col         = get colMunValue from kpi's linked column dimension
                colName     = get colName from kpi's linked column dimension
                row         = get rowMunValue from kpi's linked row dimension
                rowName     = get rowName from kpi's linked row dimension
                measure     = get measureMunValue from kpi's linked measure
                                                                    dimension
                measureName=get measureName from kpi's linked measure dimension
                reportName  = measureName + colName + rowName
                // reports are recreated at each KPI value retrieval
                with SDK,  rs = new report specification (col, row, measure, modelName)
                with SDK,  ro = new report object built from rs
                with SDK,  store ro in conf's content store as reportName in folderName
                add ro to reports
            } // if. Else, simply skip this non-cognos KPI.
        } // for each kpi

        // run reports and update evaluation values in the strategy
        for each report in reports do {
            url = build REST URL for report using gateway
            with REST and CMS, run url
            with REST, receive report_result
            with JSON, val = parse report_result
            strategy (report.kpi) = val
        } // for each report
    } // if successful authentication
    else report error (failed authentication)
} // for each conf
```

4.6 Chapter Summary

In this chapter, we recalled the weaknesses of the previous solution (Chen 2008) and explained the new approach in detail, including design decisions, new metadata properties, the architecture, the underlying mechanism, and simple illustrative examples. Table 3 summarizes the new concepts and properties needed to enable the automation of this so-

lution and captured in the goal model with metadata (to avoid changes to the jUCMNav metamodel).

Table 3: Summary of new properties for URN model elements (metadata)

Profile Concept	**Cognos Concept**	**URN/jUCMNav model element**	**New properties (metadata)**
Authentication and configuration	Authentication and configura-tion	Dimension	modelNameValue (String) dispatcher (URL) folder (String) gateway (URL) namespace (String) password (String) username (String)
Row	Dimension of a hierarchy	Dimension	rowMunValue (String) rowName (String)
Column	Dimension of a hierarchy	Dimension	colMunValue (String) colName (String)
Measure	Fact of a hierarchy	Dimension	measureMunValue (String) measureName (String)
Cognos KPI	Report value	Indicator	cognos (Boolean)

Nine OCL rules were developed to ensure the well-formedness of the models in jUCMNav before interacting with the Cognos BI server.

The next chapter will describe how this new solution compares to Chen's, and also to two other alternatives that were considered while doing this research.

Chapter 5 Assessment

This chapter provides an assessment of the new solution presented in Chapter 4 against two alternative approaches considered while doing this research and against the baseline solution proposed by Chen (2008).

5.1 Two Alternative Approaches

Following a spiral software engineering process in the design and development phase of our design science methodology, we had three major iterations. In each iteration, a limited prototype was completed and enhanced before the final product was developed. The artefact produced at the end of each iteration was considered an alternative since the requirements changed at the end of each iteration. Hence, along these three iterations, we considered two alternative approaches before the final solution presented in the previous chapter:

- The manual approach
- Single automatic approach

Each approach is constructed of the following major steps to achieve the main goal common to all solutions:

1. *Authentication:* Before getting any data from the Business Intelligence server, the user should be authenticated with the proper credentials. Credentials are either provided on the fly or require hardcoded values in a property file stored where the software is deployed.
2. *Report creation:* This can be a major bottleneck. Creation requires the user to have deep knowledge of the product to be able to create reports based on business requirements. The complexity of this task increases as data become multidimensional.

3. *Retrieving the KPI value:* There are different ways to get KPI values. The user either can rely on the result of another third-party tool, accessible as a comma-separated value (.csv) file or as an Excel (.xls) file, or can directly tap into the BI tool and grab the desired values. The second method can be complex since it requires knowledge of different technologies in order to get these values programmatically.
4. *Assignment of the KPI value:* This is the least time-consuming step since it only requires familiarity with the jUCMNav API and is common to all the proposed techniques. This is also transparent to the end-user (modeler or analyst).

5.1.1 The Manual Approach

In the manual approach, a user interface is created so that the user can map the corresponding dimensions with the KPI defined in jUCMNav. The input to the system is a Cognos server URL and the path to the report that has been created for this KPI. In terms of nested dimensions, the user can drill up and down the dimension and choose items in any level. Upon choosing the dimensions, the measure value will be retrieved through IBM Cognos Mashup Services and will be set to the evaluation value of the KPI. The breakdown of the tasks is as follows:

1. *Authentication:* The user is provided with a dialogue to enter the credentials. If the user logged in successfully into the Cognos server, the user can go the next step.
2. *Report creation:* A generic report is created *manually* by the user and contains all the dimensions of data related to the business requirements. The user can modify the path to these pre-made generic reports and can connect to and run these reports.
3. *Retrieving the KPI values:* after the report is run, a crosstab view of the data is created and the user can drill up and down the results to look for the desired intersection of the data. For example, the product survey score of an organization in year 2004.

4. *Assignment of the KPI values:* through the interface provided to the user, the user can select the KPI and simply choose to assign the selected value in step 3 to the desired KPI.

5.1.2 The Single Automatic Approach

In the automatic approach, the need for a GUI to select and set the KPI value is removed, The corresponding report is *created* automatically on the fly based on the KPI value through the Cognos SDK, *stored* on the Cognos server through via the SDK, *run* through the Cognos Mashup Service, and the evaluation value is *set* through the Cognos SDK. The breakdown of the tasks is as follows:

1. *Authentication:* The user neither has to hardcode the credentials in a property file nor has to enter them in a separate login. The user credentials are entered inside the jUCMNav tool as metadata attached to the goal model and is stored with the model.
2. *Report creation:* A report is created on the fly but this is not very efficient since a lot of information bookkeeping data needs to be entered into jUCMNav to create the report.
3. *Retrieving the KPI values:* An automatic approach is introduced to retrieve the KPI value; the created report in step 2 is run and the results are returned efficiently.
4. *Assignment of the KPI Values:* Since there is metadata defined for each KPI, as soon as the KPI retrieval command is sent all the KPIs are updated automatically.

5.2 Comparison

In this section, Chen's approach (discussed in chapter 3) and the above two alternative approaches are compared to our new approach. The comparison criteria used here are some of the main factors (identified in chapters 2 to 4) influencing the satisfaction of the overall objective of this thesis. Essentially, the objective is to have reports created/authored automatically, no web service to deploy, high performance, low maintenance, support for on-the-fly modification of KPIs, and support for multiple source BI

servers. Table 4 summarizes the comparisons of the four approaches, and further details are then provided.

Table 4: Different alternative approaches compared

	Previous approach (Chen, 2008) Method 1	**Manual approach Method 2**	**Single auto-matic approach Method 3**	**New approach (Chapter 4) Method 4**
Manual report authoring	*Yes-for each KPI*	*Yes-only one report*	*No*	*No*
Web service deployment	*Yes*	*No*	*No*	*No*
Performance	*Medium*	*Low*	*Medium-high*	*High*
Maintenance	*High*	*Medium*	*Low*	*Low*
On-the-fly KPI modification	*Not supported*	*Supported but manual*	*Supported*	*Supported*
Multiple server support	*Not supported*	*Not supported*	*Not supported*	*Supported*

5.2.1 Manual Report Authoring

The main difference between method 1 and method 2 is that in the latter a generic report is created manually and is stored in the Cognos environment. To get the KPI value, the user has to run the report through the UI provided inside jUCMNav and start drilling down or up within different dimensions in rows or columns to find the desired value and assign that to the desired KPI. Method 3 provides an automatic way of creating the reports on the fly but it requires much information about the model to do so. In the new approach (method 4), we resolve this issue by providing only three pieces of information about the data model to generate the report.

5.2.2 Web Service Deployment

Methods 2 and 3 do not require any knowledge about web service deployment or access to an application server. They use the Cognos SDK for report generation, report run and data retrieval. In the approach presented in this thesis (method 4), there is no need for web service deployment.

5.2.3 Performance

Method 1 and method 3 have higher performance than method 2 since the data retrieval is automated. They only differ in report authoring. Method 2 has low performance because for each KPI, the user has to manually go and select the KPI and assign the value. This becomes a bottleneck for a high number of KPIs. In method 4, report generation is automated (unlike method 1, which requires manual report generation) and has a higher performance compared to method 3 due to less computations and logic needed to generate the report.

5.2.4 Maintenance

If there are multiple strategies and if within each strategy there is only a slight change within the KPIs, then for method 1 some of the reports need to be created again manually, even though they are going to be similar to the one in the previous strategy. Method 3 generates a new report automatically. Method 2 is manual, therefore it sticks with only one report even though there are different strategies. In method 4, reports are automatically generated but a better approach is taken to manage storage of these reports within the Cognos environment.

5.2.5 On-The-Fly KPI Modifications

Assume the business user wants to examine the result by changing a dimension value, for example revenue growth this month and next month. If method 1 is used, then for each new strategy needs to be defined, a new folder needs to be created in the Cognos environment, and two different reports need to be created to be able to generate the results. However, with method 3, within the same strategy, just by modifying the month to the previous month in the model, the value can be retrieved and no extra action is required. Method 2 is manual therefore it can be useful for a small number of KPIs but as the number of KPIs grow, this can become a bottleneck. In method 4, the same implementation as method 3 is done and they are similar in terms of KPI modifiability.

5.2.6 Multiple Server Support

If there is a need to combine a few KPIs from different data sources from different Cognos servers in one goal model, one cannot benefit from method 1 or method 2 or method 3. The existence of such capability increases the usability, scalability, and functionality of the thesis solution (method 4) and makes it possible to combine and create different reports from different parts of the enterprise whose data is not shared based on different user access and capabilities.

5.3 Chapter Summary

In this chapter, we explored two other alternatives to our final solution and compared how each of them behaved with respect to important assessment criteria. This comparison highlights that the solution demonstrated in chapter 4 represents a major improvement over the previous solution (Chen, 2008) and alternative approaches. The evaluation factors that were considered are report authoring, web services deployment, performance, maintenance, on-the-fly KPI modification, and support for multiple servers. We can observe that our new solution supports dynamic report authoring, eliminates the dependency on web service deployment, increases performance and maintenance by automating several manual tasks, allows KPI modification on the fly, and finally supports multiple servers.

The next chapter will present a case study aimed at illustrating and validating the overall approach and its tool support.

Chapter 6 Case Study

This chapter illustrates the application of our solution with the help of a retail store case study, whose original GRL model was published by Pourshahid *et al.* (2011). This model is adapted to meet the expectations of our tool (e.g., by adding the required metadata to the dimensions and Cognos KPIs). Then, the model is connected to a Cognos BI server that contains data used to populate the Cognos KPIs in the goal model, and hence enable performance monitoring at the organizational level. In this case study, we also describe how a model can support both conventional KPIs (not connected to a BI server) as well as Cognos KPIs.

6.1 Context and Source Goal Model

The retail business studied by Pourshahid *et al.* (2011) is a 15-year old, small enterprise with four stores located in the same city. This Ontario-based business has new owners interested in national and even international growth (through franchises) as one of the main strategic objectives.

The first step of their investigation was to identify actors, high-level goals, and indicators. In addition to the growth objective, the (franchise) store managers were interested in increasing revenues and the number of items sold in their stores. Different objectives were identified for the principals.

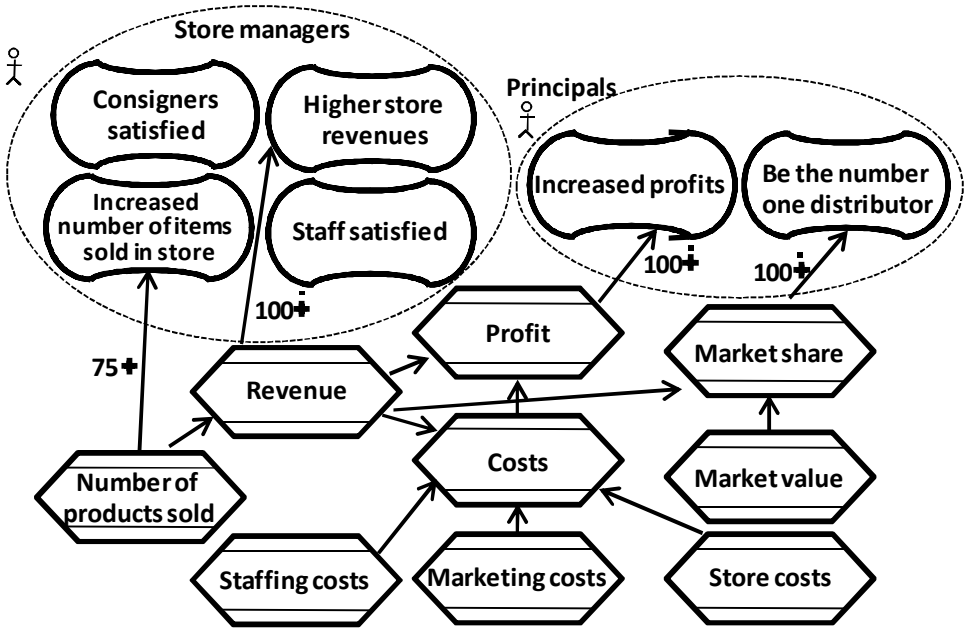


Figure 50: First goal model (from Pourshahid *et al.*, 2011)

As depicted in Figure 50, the identification of high-level business goals and financial targets in addition to KPIs is essential to monitor the business, which leads to making informed decisions about the business.

In addition a dimensional model was created to analyze the impact of the KPIs on goals based on their store locations, in each period of time, by product type, and by product category (Figure 51).

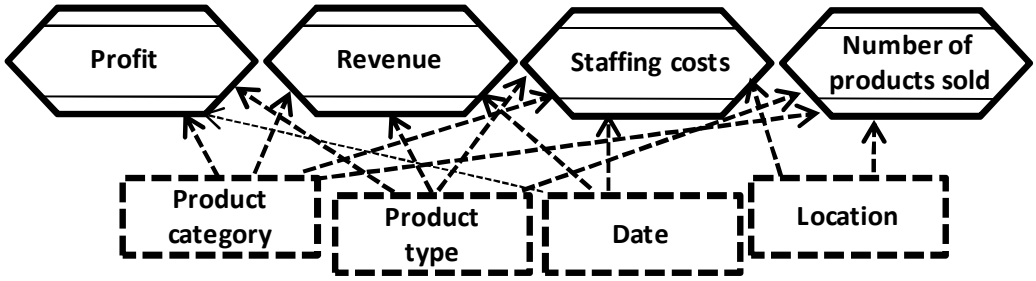


Figure 51: First set of dimensions (from Pourshahid *et al.*, 2011)

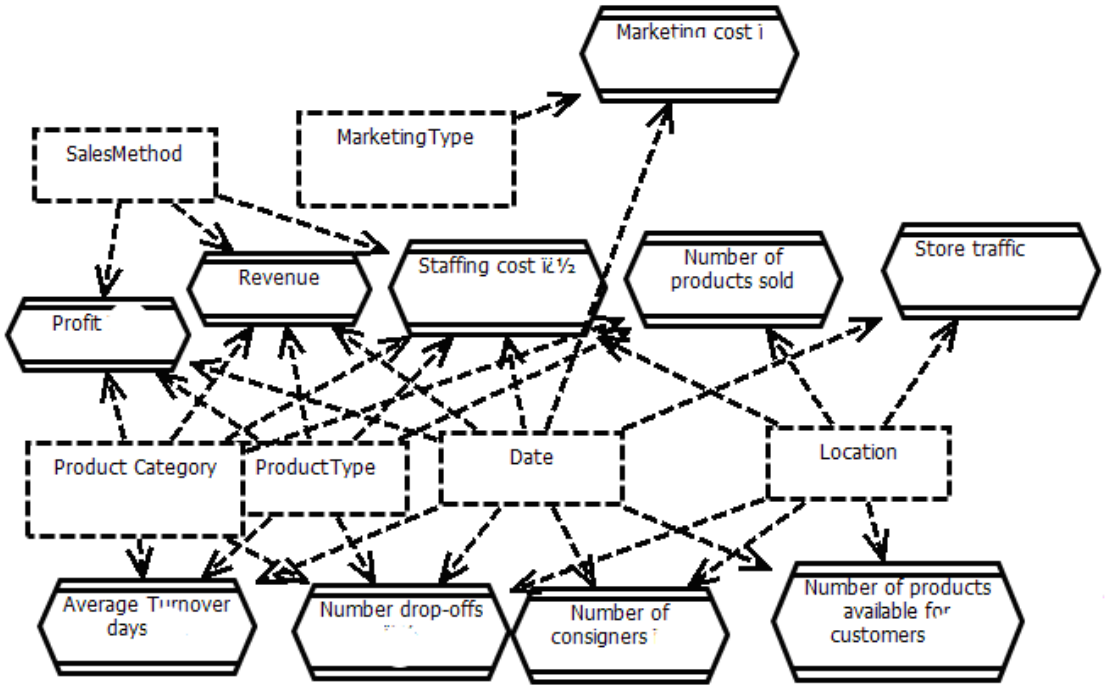


Figure 52: Model with more KPIs (from Pourshahid *et al.*, 2011)

Through refinement, more KPIs were added to the model as drivers and then linked to the high-level financial KPIs and organizational goals (Figure 52). In addition, a view for the decision-making part (Figure 53) was added to the model.

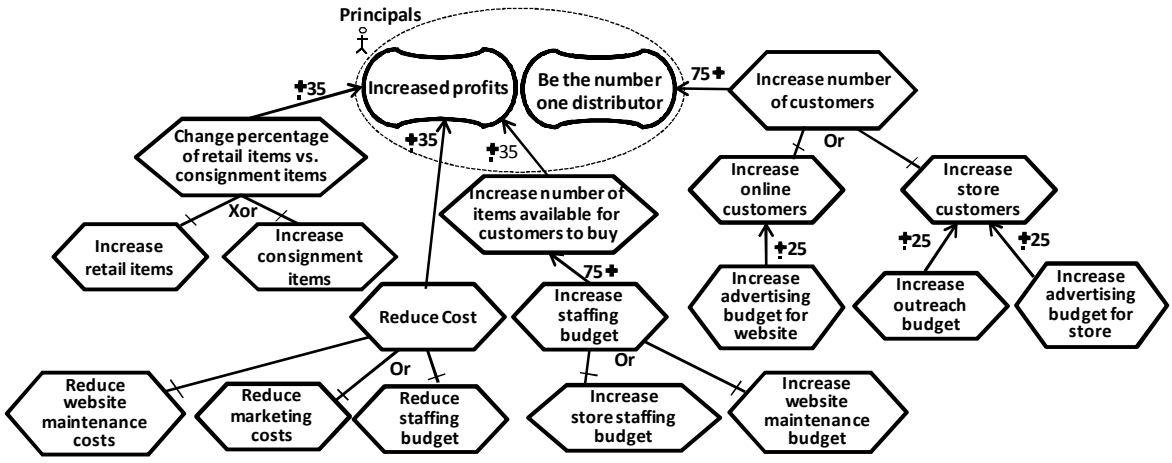


Figure 53: Decision model (from Pourshahid *et al.*, 2011)

Overall, a sizable and realistic GRL model was created, with many KPIs and dimensions. This is actually the largest and best such model we have seen. This model is therefore a

good start point for applying our approach to BI-based performance monitoring. In addition, since this model was created by other people, it helps avoid bias in the construction of this experiment.

6.2 Using the New Tool-Supported Approach

In this experiment, we modify the goal model, and especially the view in Figure 52, to meet the requirements of our tools. In particular, we will change the "Number of products available for customers" KPI in a way that it will get its data from our Cognos Business Intelligence server.

We have created and deployed a sample data source on the Cognos server (Figure 54).

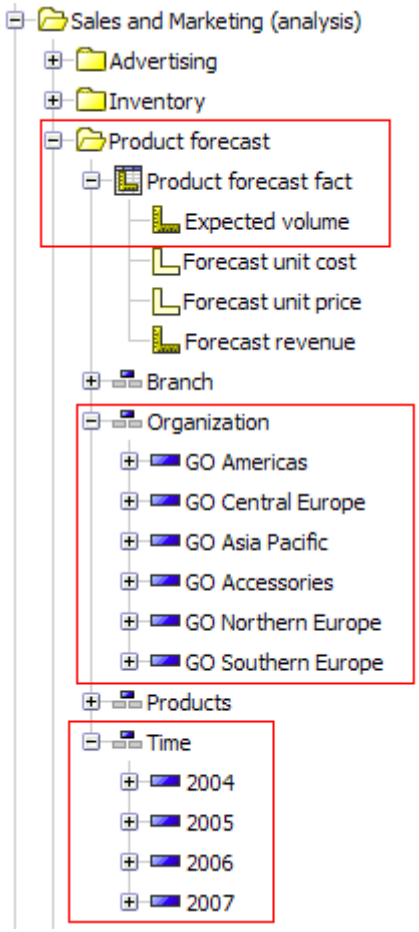


Figure 54: Report studio hierarchy with data source

This data source has a dimensional model. The time dimension (Figure 55) can be used to analyze data based on years, quarters, months, etc. The location dimension (Figure 56) handles places like America, Central Europe, Asia Pacific, etc. The expected volume (Figure 57) is going to be our measure dimension for the facts that we are going to assign to our KPIs.

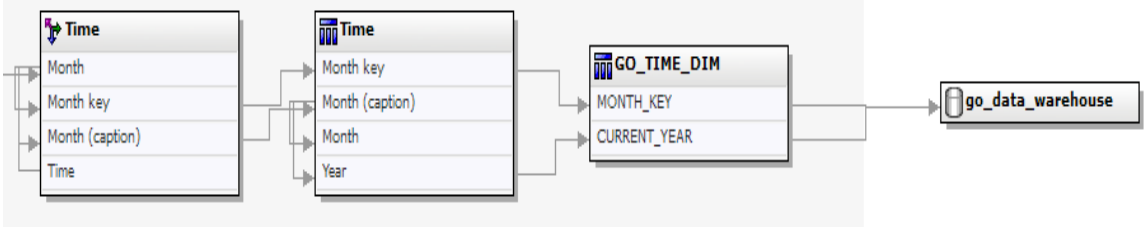


Figure 55: Time dimensional model

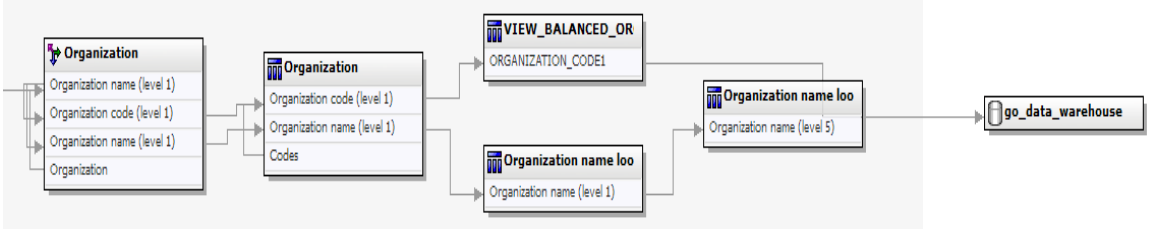


Figure 56: Location dimensional model

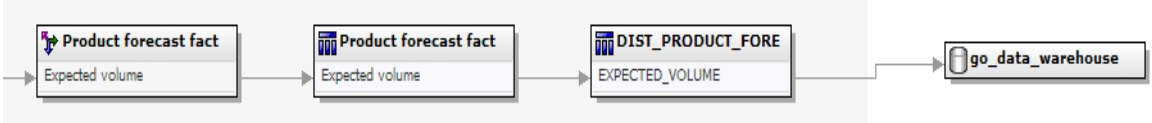


Figure 57: Volume dimensional model

This modeling takes place at the data level and it has no interference with goal modeling on the jUCMNav side.

Now that we have both a BI-unaware goal model and a multi-dimensional data model, we need to modify our initial goal model with dimensions that will include our new metadata properties and satisfy our OCL constraints. First, we need to add is to add a new dimension element for the Product Volume to be able to get the total product count in for specific time and a specific location (Figure 58).

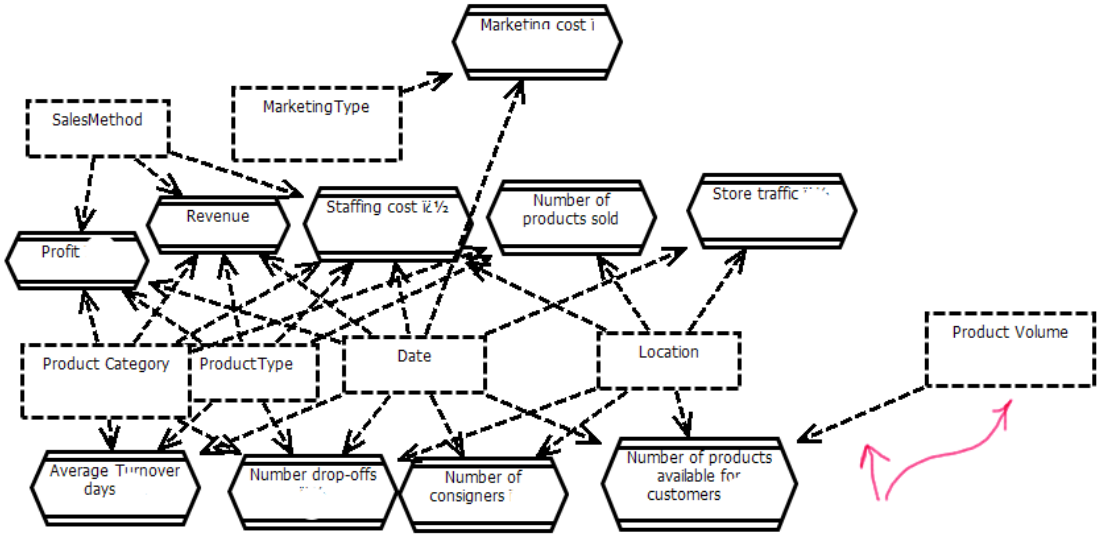


Figure 58: Modified goal model

The next step is to add a metadata to the "Number of products available for customers" KPI to distinguish this from other KPIs. We hence add a "cognos" property with the value "true" to this KPI, as shown in Figure 59. There could be other metadata already defined for this model element; this causes no interference with our tool. As they are not tagged with the "cognos" metadata, the other KPIs will see their evaluation values come from the strategy definitions (as usual) rather than from the BI environment.

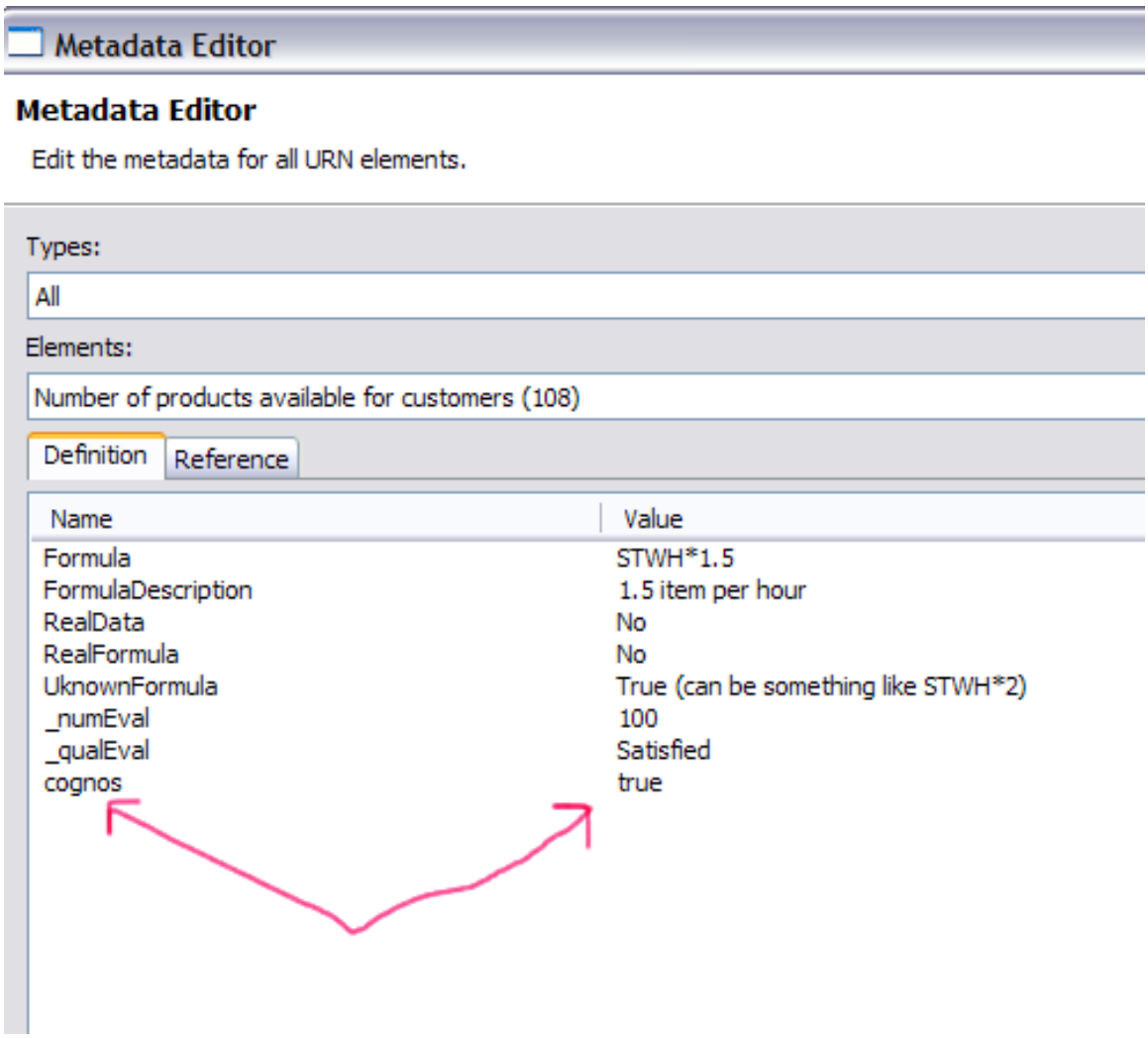


Figure 59: Metadata editor properties

The next step is to add metadata for columns, rows and the measures. In this case study, we need to choose one of the existing dimensions as a Row (e.g., Date) and another dimension as a Column (e.g., Location). Our Measure dimension recently added (Product Volume) stays the same. We are going to make the requirement more precise by choosing a specific date and a specific location. Figure 60 illustrates part of the data available for such dimensions.

Expected volume	GO Americas operations	GO Americas
January 2004	287,690	287,690
February 2004	333,715	333,715
March 2004	295,905	295,905
Q1 2004	917,310	917,310

Figure 60: Aggregated total results

Assume we decide to choose January 2004 as our date and America as the location. In other words, after our setup is completed, the value 287690 should be propagated to the jUCMNav client, in the selected KPI. Therefore, we need path to these data elements. Figure 61 shows the path for January 2004 in the time dimension (row), Figure 62 shows the path to America in the location dimension (column), and finally Figure 63 shows the path to the product volume, used as our measure dimension. These paths can easily be obtained from the Cognos BI environment.

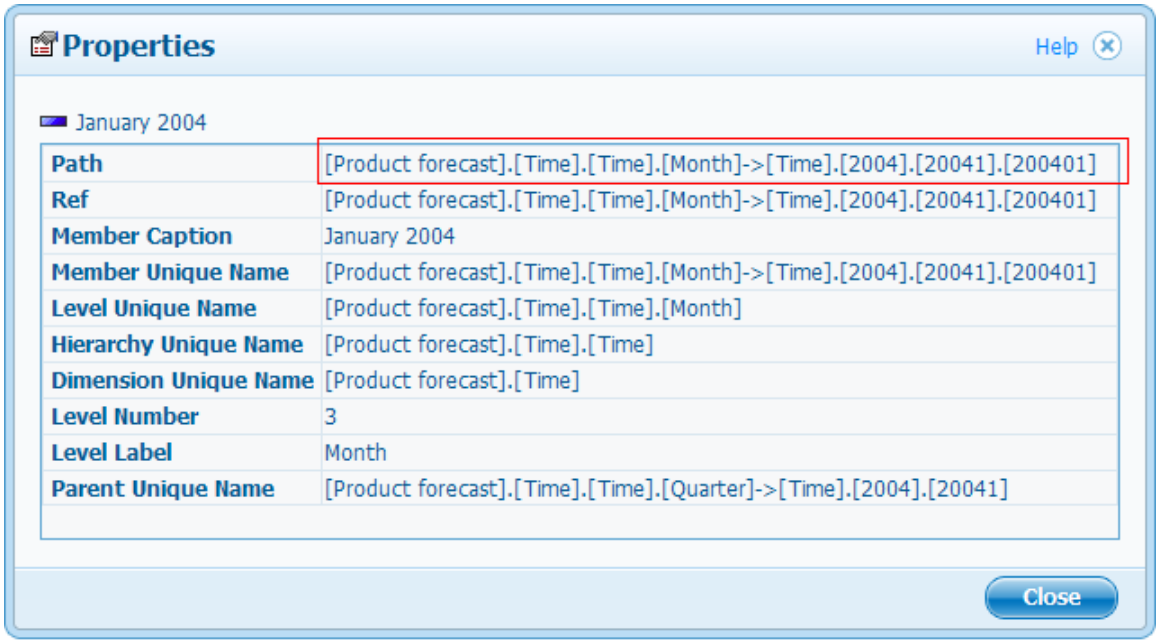


Figure 61: January 2004 metadata path

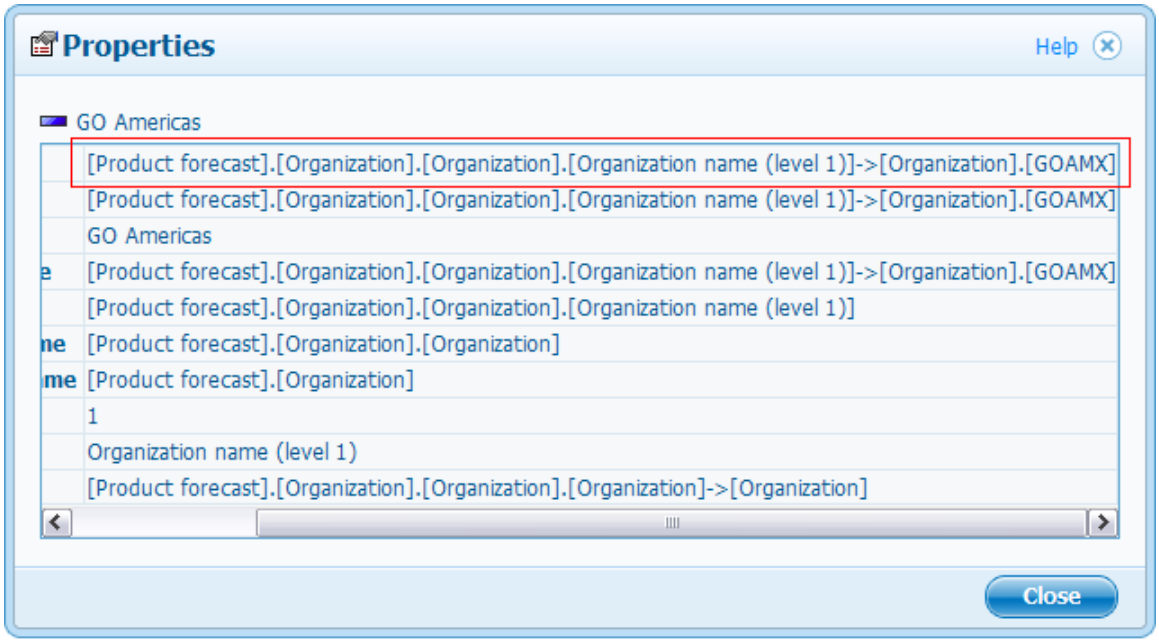


Figure 62: America metadata path

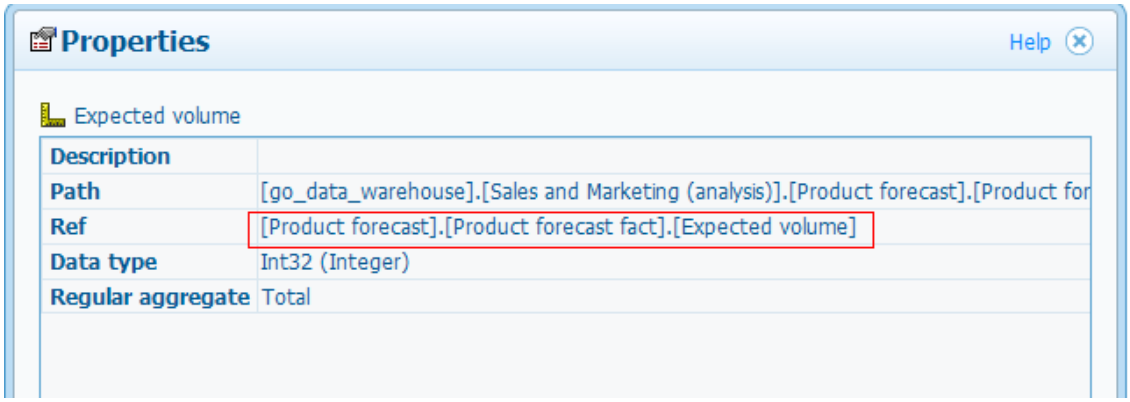


Figure 63: Product Volume metadata path

We can update the source goal model, and especially the corresponding GRL dimension elements (Date, Location, and Product Volume), with three pieces of information regarding the rows, columns and measures/facts (Figure 64). These are the new properties we need to set as metadata.

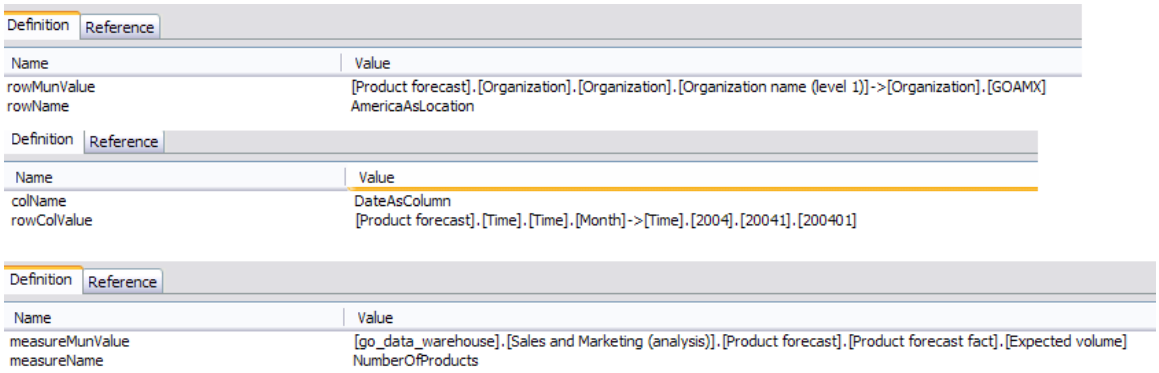


Figure 64: Update of metadata in the goal model

The goal model must also include a reference to the model in Cognos server, with authentication and configuration information. Therefore, we need to create another dimension element (called "Cognos Model" in this example) and set the relevant properties as metadata. These properties include the username, password, namespace, folder (where the temporary reports will be stored for each KPI), gateway and dispatcher (Figure 65). This Cognos Model object only needs to be connected to the KPIs that get their data from that Cognos server (Figure 66). We are basically enabling the model to have different KPIs from different servers.

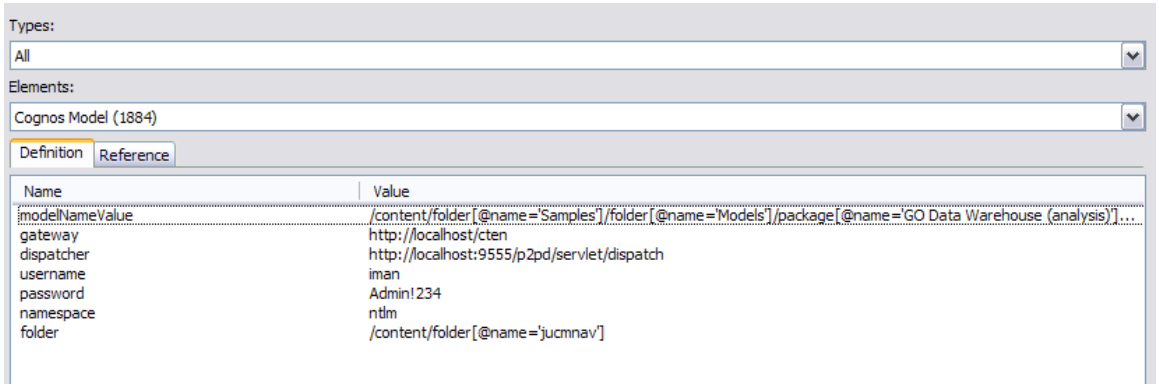


Figure 65: Authentication and configuration metadata

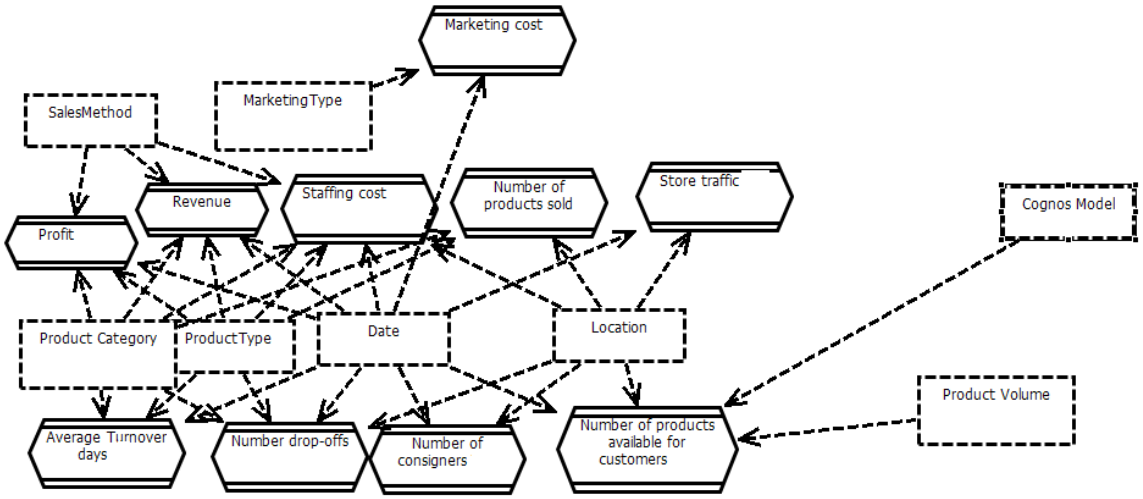


Figure 66: Final model, with appropriate metadata properties

These are all the settings we need to do. At this point, the OCL constraints can be checked by jUCMNav in order to ensure that the properties and links are specified as expected.

After issuing the "Retrieve KPI Value" command in jUCMNav, the process starts and the new value of the KPI is assigned (Figure 67).

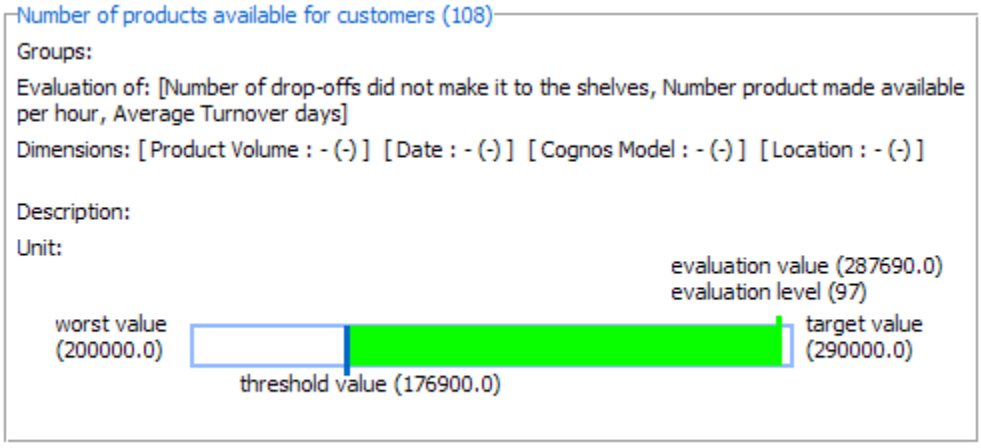


Figure 67: Retrieved KPI value

This evaluation value is converted to a GRL satisfaction value by the KPI, and that satisfaction value is then propagated throughout the other intentional elements of the goal model for the selected strategy.

Now if we have more than one Cognos KPI, our approach will support that situation as well. In the next example, we are going to retrieve another KPI from the Cognos server. Assume that the "number of consigners" is now a Cognos KPI, where the date will be different than the one used for the first Cognos KPI. The modified model is shown in Figure 68.

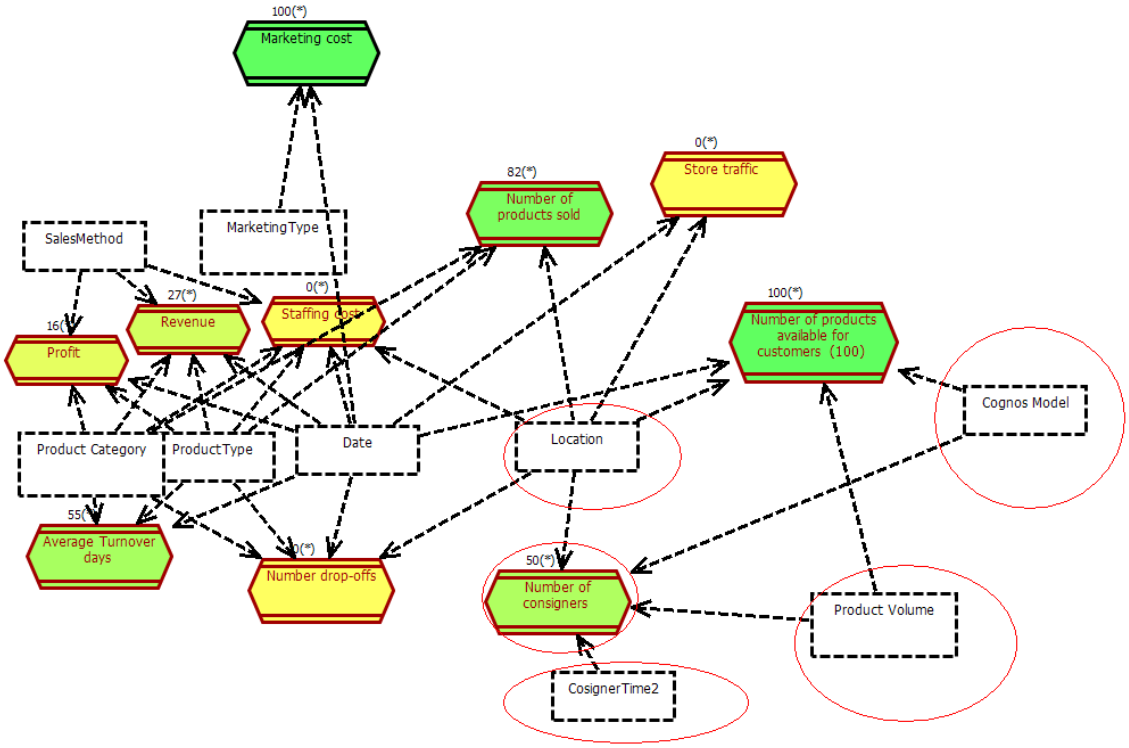


Figure 68: Final goal model

Let us set the time of ConsignerTime2 to February 2004 (Figure 69).

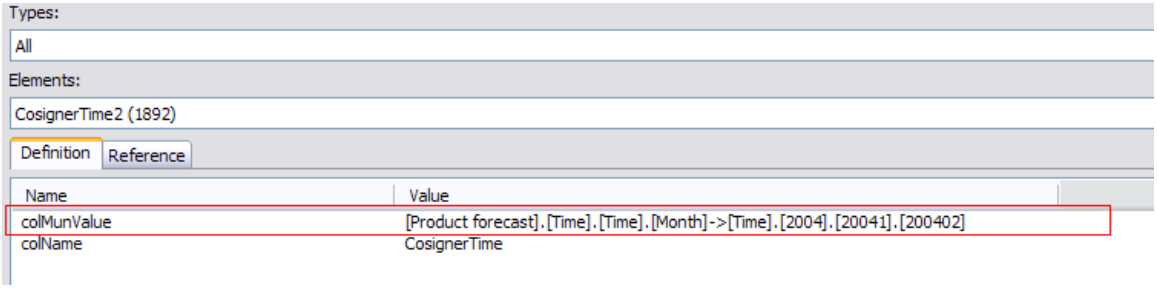


Figure 69: Editing the metadata

After refreshing the values, we can see that there are two reports created and stored in the Cognos environment (Figure 70).

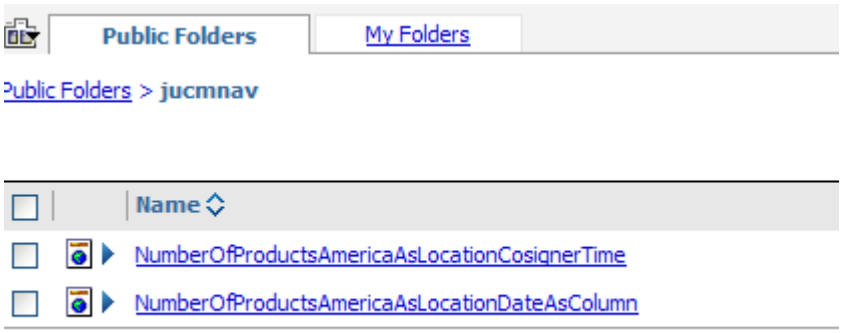


Figure 70: IBM Cognos content

When we run them, we get the following results (Figure 71 and Figure 72)

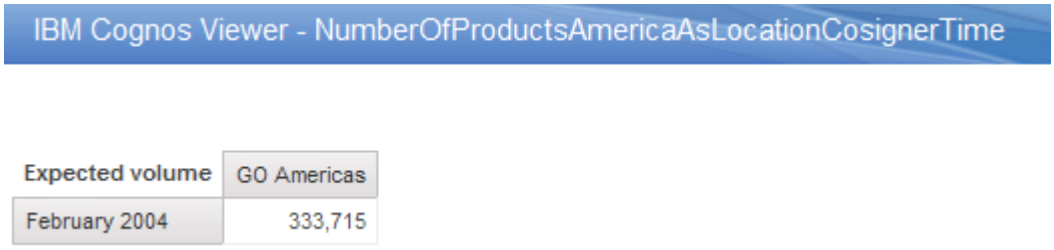


Figure 71: Results for January 2004

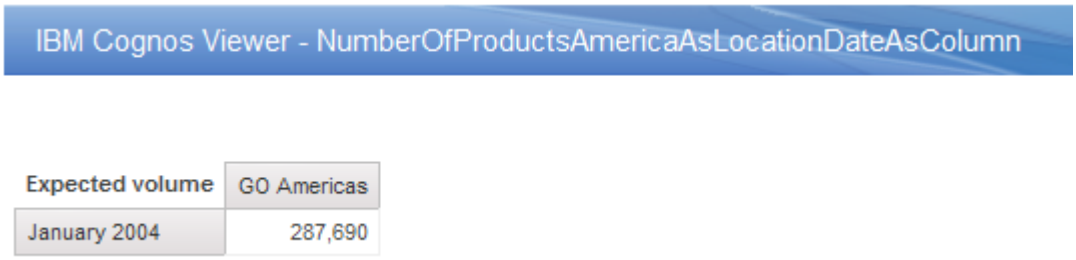


Figure 72: Results for February 2004

6.3 Chapter Summary

In this chapter, we reused an existing and realistic goal model as a case study. This model was adapted to support the dimensions and metadata properties needed for interacting with a realistic data source from a Cognos server. This case study demonstrates the feasibility of the approach and the potential of the new tool support. The next chapter discusses more formal testing of the tool.

Chapter 7 Testing

In this chapter, the testing of the tool functionality is discussed in detail. JUnit, a unit testing framework for Java programs, is used in this thesis. Three types of tests are considered here:

- Unit Testing: A method for testing different modules of the code; a unit can be an entire class or function. In this thesis, the unit of test is a function;
- Functional Testing: A method to test the functionalities of software components under test.
- Constraint Testing: the OCL constraints in Appendix A have also been tested (with jUCMNav directly rather than with JUnit).

There are several software components that communicate with each other to achieve the ultimate goal of this thesis. These components are:

- IBM Cognos SDK;
- IBM Cognos Mashup Service;
- jUCMNav.

It is required to have unit tests for testing functions that will utilize the above components. For example, there is a test case in which the login function is tested. In addition there are automated test cases in which certain requirements are tested; for example testing if the system is able to distinguish between conventional KPIs and Cognos-based KPIs. Conventional KPIs can be KPIs that are calculated from other KPIs based on an algorithm but Cognos based KPIs are the ones whose values are retrieved from the BI server. Cognos-based KPIs override conventional KPIs. This functionality is tested amongst other functional and unit tests discussed in the following sections.

Note that all the test descriptions presented here were implemented and checked, and they all passed successfully.

7.1 Functional Testing

In functional testing, different high-level requirements associated with Cognos SDK, Cognos Mashup Service and jUCMNav are checked. Functional testing for Cognos SDK includes the following items, to be covered in the next sub-sections:

- Login;
- Report creation and storage.

Functional testing for CMS includes:

- Login;
- Report run and data retrieval.

Functional testing for jUCMNav includes:

- Metadata retrieval;
- KPI value assignment;
- Detection of Cognos KPI vs. conventional KPI.

7.1.1 Functional Testing of Cognos SDK Usage

Login

Input: username, password, namespace, URL to IBM Cognos Dispatcher.

Output: a session variable and a visa (certificate) for further interactions.

Error handling: the following scenarios must be dealt with separately and proper error messages shall be presented to the user for proper reaction.

1-Invalid Credentials: a proper message should be delivered to the user and suggest the re-entry of credentials.

2-Invalid URL: a proper message should be delivered to the user and suggest testing the URL entered.

Report creation and storage

Input: dimension values in the form of rows, columns, and facts for each KPI as well as a location to store them on the Cognos server.

Output: Several number of reports stored in the proper location.

Error handling: the following scenarios must be dealt with separately.

1-Check for null: the tool should check null values before passing them to the Cognos server.

2-Validate created reports: the specification of the reports should be validated before storing the latter on the Cognos server. Users should not have to troubleshoot if a wrong report specification was created before retrieving the values.

3-Check for duplicates: there should be proper actions taken place when dealing with duplicate entries within the storage folder. Users should be able to choose either to replace the existing report objects within the content store or preserve them and instead provide the user with other options such as renaming the report object in the storage folder.

7.1.2 Functional Testing of Cognos Mashup Service Usage

Login

Input: the visa created by Cognos SDK.

Output: a confirmation that user is still logged in.

Error handling: If the visa is not valid anymore, then prompt the user for re-login.

Report run and data retrieval

Input: the search path created by Cognos SDK and associated with the current KPI.

Output: the value of the KPI.

Error handling: the following scenarios should be considered.

1-Report run error: if for any reason the report run failed, the user should be provided with the proper message to be able to take the proper action.

2-Data retrieval error: if the data returned from the report is null, then it could be due to an error in the report run or there might be no associated data for that row and column.

7.1.3 Functional Testing for jUCMNav API

Metadata retrieval

Input: metadata information for dimension objects.

Output: the values assigned to each metadata.

Error handling: validate metadata properties entered for dimensions or KPI for null values.

KPI assignment

Input: specific KPI.

Output: a value assigned to that KPI.

Error handling: confirm that the value passed to the jUCMNav API is assigned to the proper KPI where there exist multiple KPIs.

Detection of Cognos KPI vs. conventional KPI

Input: A KPI with metadata information pertaining to a conventional KPI, e.g., a calculated KPI based on algorithm, and metadata information related to Cognos ("cognos" property), together with connections to two dimensions and to a fact dimension.

Output: Confirm that if the "cognos" property is set to "true" then the KPI is evaluated based on the connected dimensions and fact, and if the "cognos" property is set to "false" or is absent, then the KPI is evaluated based on the conventional algorithm.

7.2 Unit Testing

There are two classes in which modifications take place:

- seg.jUCMNav.views.kpi.KPIListView;
- grl.kpi.sdkReport.GenericReport.

Class seg.jUCMNav.views.kpi.KPIListView contains two methods:

- addReport;
- login.

Class grl.kpi.sdkReport.GenericReport.GenericReport contains 1 constructor and 9 methods:

- GenericReport (constructor);
- buildColumnRelatedData;
- buildMeasureRelatedData;
- buildRowRelatedData;
- buildSpecification;
- modifyTemplateFile;
- readTemplateFile;
- removeBrackets;
- splitByArrow;
- splitByDot.

In the following subsections, unit testing of each of the methods is discussed in details.

7.2.1 Unit Testing for seg.jUCMNav.views.kpi.KPIListView

1-seg.jUCMNav.views.kpi.KPIListView.addReport: adds a report to the content store.
Unit test: create a report object and ensure that the object is created in the Cognos content store.
Error handling: In case of unsuccessful addition of the report to the content store, log error in a related log file so that further failures can be tracked to this error.

2- seg.jUCMNav.views.kpi.KPIListView.logon: login to Cognos server.
Unit test: Provide two scenarios for successful and unsuccessful login.
Error handling: Provide proper logging in case of successful or unsuccessful login.

7.2.2 Unit Testing for grl.kpi.sdkReport.GenericReport.GenericReport:

1-grl.kpi.sdkReport.GenericReport.GenericReport: This is a constructor – no unit testing required.

2-grl.kpi.sdkReport.GenericReport.buildColumnRelatedData: this method builds part of the report related the columns in the final report.
Unit test: provide a unit test to ensure proper column creation.
Error handling: check the passed values for null and provide proper error messages if any of the values is null.

3-grl.kpi.sdkReport.GenericReport.buildMeasureRelatedData: this method builds part of the report related to the measures/facts in the final report.
Unit test: provide a unit test to ensure proper measure creation.
Error handling: check the passed values for null and provide proper error messages if any of the values is null.

4-grl.kpi.sdkReport.GenericReport.buildRowRelatedData: this method builds part of the report related to the rows in the final report.
Unit test: provide a unit test to ensure proper row creation.
Error handling: check the passed values for null and provide proper error messages if any of the values is null.

5-grl.kpi.sdkReport.GenericReport.buildSpecification: this method builds the report specification
Unit test: test the creation of a report specification.
Error handling: check whether the created report validates with Cognos server, and if not then provide the user with proper messages about what went wrong.

6-grl.kpi.sdkReport.GenericReport.ModifyTemplateFile: this method creates the report specification based on the template provided.
Unit test: this method is used within the “buildSpecification” method and is tested indirectly when testing the “buildSpecificaiton” method

7-grl.kpi.sdkReport.GenericReport.ReadTemplateFile: this method reads the template report specification.
Unit test: check whether the template report file exists and can be read.
Error handling: in case the template report file does not exist, provide the user with a proper error message.

8-grl.kpi.sdkReport.GenericReport.removeBrackets: this method is a utility function for speciation creation.
Unit test: provide a test case for proper string manipulation.

9-grl.kpi.sdkReport.GenericReport.splitByArrow: this method is a utility function for specification creation.
Unit test: provide a test case for proper string manipulation.

10-grl.kpi.sdkReport.GenericReport.splitByDot: this method is a utility function for specification creation.
Unit test: provide a test case for proper string manipulation.

7.3 Constraint Testing

Each of the nine OCL constraints described in Appendix A was tested on two URN models:

- The model for the case study presented in section 6.2, to check that the constraints do not detect false violations.
- A variant of the model for the case study where errors were deliberately injected (to cover all categories of errors detectable by the rules), to check that the constraints detect true violations.

No unexpected result was observed while testing (and using) the OCL constraints.

7.4 Chapter Summary

Testing is an important phase in the software development lifecycle. This chapter presented the types of testing performed to check the system's functions and different requirements of components that communicate with each other. Unit tests were added to test the product at a very granular level and functional tests were used to test higher-level functionalities. These tests were performed on components such as Cognos SDK, Cognos Mashup Service and jUCMNav, as well as on the two classes that were modified (GenericReport and KPIListView). Finally, the OCL constraints were tested to ensure they can detect true violations and that they do not report false violations.

Chapter 8 Conclusions

8.1 Summary of Contributions

This thesis introduces a new approach for implementing a goal-oriented performance monitoring system for business processes and organization. This approach combines a goal view where indicator values are populated through a business intelligence engine. This goal view is based on the User Requirements Notation's Goal-oriented Requirement Language. This notation is interesting as it includes the concept of indicator. Indicators in GRL were undergoing standardization while this thesis was written, and were approved just before producing the revised and final version of this thesis. Tool support for this approach is composed of a modeling and monitoring tool for goals and processes (jUCMNav tool) and of a leading business intelligence information provider (IBM Cognos BI tool).

Through the implementation of this approach, the following contributions are made in this thesis:

- A framework for report generation and BI content management: this approach aims to facilitate the data modeling process without requiring users to be experts in BI report generation. A general knowledge of goal modeling and of the dimensions available in the BI environment is sufficient. The user does not need to know anything about IBM Cognos SDK or about IBM Cognos mashup service. New user training is very minimal and is only required for the goal modeling tool and the data model used for the goal model.
- Reduced time and effort for creating and maintaining linkage between a goal-oriented modeling tool (jUCMNav) and a leading Business Intelligence application (Cognos) through automation. The analyst now can work in the goal modeling environment only (by annotating URN model elements with metadata properties), without having to manipulate BI objects (such as reports) direct-

ly. With this additional change, the new user does not need any training to accomplish this task since this task is completely independent of the user.

- A framework for integrating business process and organization monitoring with goal-based evaluation and data retrieval: indicators retrieve their values on the fly through a BI tool (without the need for manual intervention). In our approach, this is achieved through the use of the Cognos SDK for report generation and the Cognos Mashup Service for running reports and getting results. This feature can help with the real-time monitoring of business processes and organization performance.

The thesis also provides justifications for many design choices, illustrative examples and a case study, OCL rules to automate the checking of the well-formedness of input goal models with metadata, a description of the main parts of the architecture and of the core algorithm, and a description of the tests performed on the implementation. A comparison with related work and with other design alternatives highlighted the benefits of the approach.

8.2 Limitations and Future Work

There are several limitations to our approach that represent potential topics for future work.

First, at the moment, data retrieval is considered only for two dimensions and one fact, and this can be a limitation in some contexts. For example, if a business analyst is interested in "revenues in 2005 in North America for a specific product" (3 dimensions and one fact), our approach can only answer sub-questions with regards to "revenues in 2005" or "revenues of a specific product in 2005", to name a few. This thesis does not implement a filtering capability to slice and dice data. A filtering capability would allow analysts to bring more dimensions into the computation of a result. In addition, in this thesis, multidimensional data is the only type of data that can be processed, and relational data is not considered. This can also be a subject of future research.

Second, in terms of maintaining the auto-generated reports, a report deletion mechanism is missing. Currently, the reports that are created can be cached within the

Cognos internal database but there is a need to enforce deleting current reports to maintain the Cognos internal database to a reasonable size. IBM Cognos report specification has the ability to modify a property that will enable or disable caching report results; in this thesis this value is disabled. Cognos does not provide a mechanism to auto-delete reports after a timestamp. A scheduled or manual report deletion mechanism can be the subject of future research.

Third, in terms of scalability, the performance of the system for large a number of users and a large number of KPIs/strategies can likely be improved. There are two time-intensive activities that take place in this process:

1- Report generation;

2- Report run.

From experience using our tool on goal models, report generation usually takes 2-3 seconds per report and a report run takes about 1-2 seconds. Report generation is a sequential activity. For example, if there are 100 Cognos KPIs in the goal model for a given strategy, about 4-5 minutes will be required for report generation. Report run time would take an additional 2 minutes, approximately. A solution to improve this situation is to use multi-threading for report creation. A new property can be introduced as “threshold value”. This value can be used to divide the report generation tasks amongst several threads. For example, if the threshold value is 10, then the task of report generation is delegated to one thread for every 10 KPIs. This could decrease the report generation time by a factor of 10, assuming that computation resources are available. There are also server configurations that can be manipulated for better performance. This allows routing requests to different dispatchers within the Cognos server; the latter allows for a multi-server infrastructure and it provides several routing mechanisms for incoming requests.

Fourth, there could be additional usability improvements. Currently, the entry of KPI properties such as “rowMunValue” or “rowColValue” is textual. A user has to type the value of these properties into the jUCMNav GUI. If the user types these values incorrectly, the user cannot be notified until the OCL rules are checked. There are two alternatives for future improvements:

1- A user interface in which the user is presented with a data selection control;

2- A validation mechanism while the user types property values.

Fifth, every time the "retrieve KPI values" command is issued, all the reports auto-generated for Cognos KPIs present in the model will be recreated again. This can decrease the performance of value retrieval drastically when the number of KPIs is large and the user is not interested in recreation of the reports again unless there have been changes in the dimension values. One alternative approach to investigate is the splitting of report generation from report run, and to enable users to invoke them at will, one at a time or together. One research issue is to detect situations when re-generating the reports is absolutely necessary in order to avoid returning invalid report results after a run.

Sixth, usability studies can be conducted to detect the weaknesses of the current approach in terms of user interface design and interaction with the user. User interface prototypes can be developed and evaluated to improve the current interface, especially the part where information needs to be input manually (new attributes).

Seventh, we have only considered one case study involving only one user. In the future, more case studies can be conducted in different areas, and different types of users can be given the product to use and evaluate. This can help produce less biased results as well as a more robust product.

Eigth, one can explore the generalization of the concepts so that other goal modeling languages and BI tools could be used in the future.

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Appendix A: OCL Constraints

These nine OCL invariants are constraints (or simply rules) selectable within the jUCMNav tool to ensure the well-formedness of input models such that they can operate properly with Cognos BI through our new mechanism.

Rule Name: CognosIndicatorRowDimension

Context grl::kpimodel::Indicator

```
self.getMetadata('cognos') = 'true'
implies
self.kpiModelLinksDest.kpiInformationElementSrc ->
select (dim | dim.getMetadata('rowMunValue') <> '') -> size() = 1
```

Description: A cognos indicator must have exactly one dimension with a non-null rowMunValue path

Rule Name: CognosIndicatorHasFourDimensions

Context: grl::kpimodel::Indicator

```
self.getMetadata('cognos') = 'true'
implies
self.kpiModelLinksDest.kpiInformationElementSrc -> size() = 4
```

Description: A cognos indicator must be linked exactly to 4 dimensions (row, col, measure, and model)

Rule Name: CognosDimensionRowName

Context: grl::kpimodel::KPIInformationElement

self.hasMetadata('rowMunValue')

implies

self.getMetadata('rowName') <> ''

Description: A dimension with rowMunValue metadata must also have a non-empty rowName metadata

Rule Name: CognosIndicatorColDimension

Context: grl::kpimodel::Indicator

self.getMetadata('cognos') = 'true'

implies

self.kpiModelLinksDest.kpiInformationElementSrc ->

select (dim | dim.getMetadata('colMunValue') <> '') -> size() = 1

Description: A cognos indicator must have exactly one dimension with a non-null colMunValue path

Rule Name: CognosDimensionColName

Context: grl::kpimodel::KPIInformationElement

self.hasMetadata('colMunValue')

implies

self.getMetadata('colName') <> ''

Description: A dimension with rowMunValue metadata must also have a non-empty colName metadata

Rule Name: CognosIndicatorMeasureDimension

Context: grl::kpimodel::Indicator

self.getMetadata('cognos') = 'true'

implies

self.kpiModelLinksDest.kpiInformationElementSrc ->

select (dim | dim.getMetadata('measureMunValue') <> '') -> size() = 1

Description: A cognos indicator must have exactly one dimension with a non-null measureMunValue path

Rule Name: CognosDimensionMeasureName

Context: grl::kpimodel::KPIInformationElement

self.hasMetadata('measureMunValue')

implies

self.getMetadata('measureName') <> ''

Description: A dimension with measureMunValue metadata must also have a non-empty measureName metadata

Rule Name: CognosIndicatorModelDimension

Context: grl::kpimodel::Indicator

self.getMetadata('cognos') = 'true'

implies

self.kpiModelLinksDest.kpiInformationElementSrc ->

select (dim | dim.getMetadata('modelNameValue') <> '') -> size() = 1

Description: A cognos indicator must have exactly one dimension with a non-null modelNameValue path

Rule Name: CognosDimensionModelAttributes

Context: grl::kpimodel::KPIInformationElement

```
self.hasMetadata('modelNameValue')
implies
(
  self.getMetadata('dispatcher') <> ''  and
  self.getMetadata('folder') <> '' and
  self.getMetadata('gateway') <> '' and
  self.getMetadata('namespace') <> '' and
  self.getMetadata('password') <> '' and
  self.getMetadata('username') <> ''
)
```

Description: A dimension with modelNameValue metadata must also have non-empty dispatcher, folder, gateway, namespace, password and username metadata**.**