

Business Intelligence - Enabled Adaptive Enterprise Architecture

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Abstract

The desire to obtain value and justify investments from the different Information Systems in place in organizations has been around for a long time. Organizations constantly theorize and implement different approaches that provide some sort of alignment between their different business objectives and Information Systems. Unfortunately, the environments in which these organizations operate are often dynamic, constantly changing with influence from external and internal factors that require continual realignment of the Information Systems with business objectives to provide value.

When businesses evolve, leading to changes in business requirements, it is hard to know what direct Information System changes are needed to respond to the new requirements. Similarly, when there are changes in the Information System, it is not often easy to discern which business objectives are directly affected. Whilst the different Enterprise Architecture frameworks available today provide and propose some form of alignment, in their implementation, they do not show links between business objectives and Information Systems, i.e., indicating what Information System is directly responsible for different business objectives thereby allowing for anticipation and support of changes as the business evolves.

This thesis utilizes insights from Business Intelligence and uses the User Requirements Notation (URN), which enables modeling of business processes and goals, to provide a framework that exploits links between business objectives and Information Systems. This *Business Intelligence - Enabled Adaptive Enterprise Architecture* framework allows for anticipating and supporting proactively the adaptation of Enterprise Architecture as and when the business evolves. The thesis also identifies and models levels within the enterprise where responses to change as the business evolves are needed and the ways the changes are presented. The tool-supported framework is evaluated against the different levels and types of changes on a realistic Enterprise Architecture at a Government of Canada department, with encouraging results.

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List of Acronyms

Acronym	Definition
BI	Business Intelligence
BI-EAEA	Business Intelligence-Enabled Adaptive Enterprise Architecture
CATS	Complex Adaptive Systems
CIC	(Department of) Citizenship and Immigration Canada
DOLCE	Descriptive Ontology for Linguistic and Cognitive Engineering
DSS	Decision Support System
EA	Enterprise Architecture
GDI	Goals Decisions Information
GRL	Goal-oriented Requirement Language
HP	Hewlett-Packard
ICT	Information and Communication Technology
IS	Information Systems
IT	Information Technology
ITU	International Telecommunication Union
ITIL	Information Technology Infrastructure Library
jUCMNav	Java Use Case Maps Navigator
KASRAF	KASRA Framework
KPI	Key Performance Indicator
OCL	Object Constraint Language
OMG	Object Management Group
SO	Service Oriented
SOA	Service Oriented Architecture
TOGAF	The Open Group Architectural Framework
UCM	Use Case Maps
UML	Unified Modeling Language
URN	User Requirements Notation
US	United States

Chapter 1. Introduction

This thesis defines and illustrates a framework, named *Business Intelligence - Enabled Adaptive Enterprise Architecture* (BI-EAEA), for achieving adaptiveness in Enterprise Architectures. The framework, consisting of a model, a methodology and tool-support, promotes anticipation and adaptation as changes occurs in either the business objectives or Information Systems. It exploits goals, processes, indicator modeling and analysis in establishing links between an organization's business objectives and Information Systems.

1.1. Motivation

Aligning business objectives with Information Systems (IS) to deal with collecting, processing, storing, retrieving and presenting the different types of information organizations deal with have always presented a challenge to organizations. While ongoing success is being recorded in innovation and research around the diverse areas of IS, what they comprise of, what they do and how they function, it is argued that IS still tend to be hard to use, are inflexible to the business needs, and fail to support or reflect the businesses they were designed to support; “*most information systems are technical successes but organization failures*” (Laudon and Laudon, 2005). It is further argued that the social and political process of developing IS can constrain the ability to understand organization's business objectives and the decisions that drive them (Barone et al., 2010; Horkoff et al., 2012; TOGAF, 2013; Yu et al., 2013). Needless to say, Chief Information Officers of most fortune 500 companies agree that making IS simple and closely aligned to the businesses they support remains their uppermost priority today (Nash, 2012).

A good IS should be able to do what it was designed to do with little or no support, and be flexible and adaptable to the organization and users who need it to go about the organization's objectives. Basically, organizations are seen and known based on the product and services they offer and not what software functionality, database content,

network configuration, enterprise architecture or cloud solution they currently use. Interestingly, the fundamental premise of Enterprise Architecture (EA) is the alignment of an organization's business objectives with the IS that support them. Good alignment reduces complexity of IS. Frameworks for EA design have been used for over 30 years with four major frameworks noted: the Zachman Framework for Enterprise Architecture (Zachman, 1987; 2013), The Open Group Architectural Framework, TOGAF (TOGAF, 2013), The Federal Enterprise Architecture (The White House, 2013) and The Gartner Methodology (Bittler and Gregg, 2008). Such frameworks and their companion methodologies, although used in over 90% of EA designs and implementations by different organizations and sectors across the globe, do not seem to address the misalignment of IS to business objectives, which still continues to be an issue and leaves a lot to be desired in IS delivering timely and genuine value to the businesses they support. These frameworks suggest that business objectives should be at the center of EA because they relate to what information is used to make decisions. The question that does arise is how the centrality of business objectives allows organizations to adapt their architectures in the current dynamic business environment characterized by rapid and often discontinuous changes.

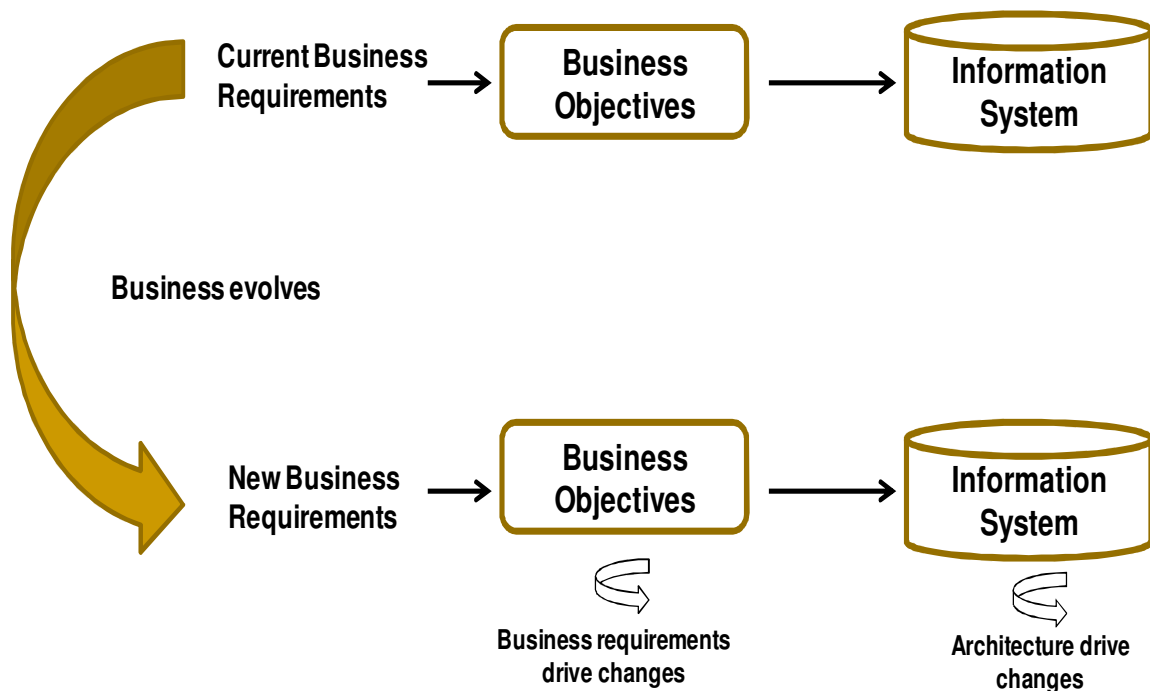


Figure 1: Levels of changes relating to Business Objectives and Information System.

As depicted in Figure 1, current business requirements feed and drive the IS. When new business requirements emerge, business objectives might change, requiring further changes in the IS to enable modified business objectives. Since the specific linkages between business objectives and IS artifacts are often unknown, the required changes tend to be reactive, with considerable latency, leading to inconsistent alignment between business objectives and the IS. As the business evolves, an adaptive architecture which links IS to business objectives and allowing for seamless co-evolution of the information structure would greatly enable adaptation.

Interestingly amongst the different types of IS organizations tend to implement to support their operation, Business Intelligence (BI) solutions at the moment capture and enable organizational decision making processes the most by providing to decision makers access to relevant data as well as ways to analyze and consume the data in clear and understandable formats. The amount of data these organizations deal with however in recent times is increasing exponentially, mainly from social media and the web in semi-structured and unstructured formats. This poses problems as organizations grow given that different decision makers and users will need different bits of information from these different sources and in different formats. A scenario most organizations frequently face is what to do with the loads of information from their reports and indicators derived by their numerous business processes. More so as the business evolves, what happens? The way information needs are structured and delivered within organizations in the light of this, therefore, needs to be adaptive and agile enough so the intended users of the information has the capability to get new and needed information as the business evolves.

Fortunately, it is gradually coming to light that the reason for these shortcomings is that the development, implementation and subsequent use of IS are described in terms of organizational structures and people, (May, 2009; Wand et al., 1999). To be adaptive, decisions made towards achieving organizational business objectives needs to take priority in the design and implementation of IS structures since they influence the sourcing and subsequent use of information. To do this requires a decision-based approach. This approach makes decision-making the key business objective of information delivery. Linking the decisions regularly made by business managers in achieving their organization's objectives to the IS providing the information utilized, in such a way as to inform the de-

sign and implementation of EA, is the aspiration of this research. This approach will not only deliver information to purpose in an adaptive and personalized manner, but also lead to more proactive and agile IS that improves overall business effectiveness.

1.2. Research Question

The research question addressed in this thesis is as follows: *Can the modeling of organizational information needs based on concepts from the User Requirement Notation (URN) allow for adaptive architecture design and if so, to what extent?*

The emphasis in the research question is on assessing if the modeling of links between business objectives, decisions and IS shows opportunities to trace, monitor and address change. Changes in business objectives which influences change in decisions and IS, changes in decisions which influences change in business objectives and IS as well as changes in the IS which influence changes in business objectives and IS in organizations were investigated.

1.3. Research Methodology

Adaptation, which can be systematic, is basically response to change. Furthermore, change within the context of IS can be described as an *addition*, a *modification* or a *deletion* of one or many IT artifacts within the different levels of the organizations. These levels are 1) organization's business objectives, 2) decision maker's decisions made towards achieving business objectives, and 3) IS that provide the information utilized in achieving objectives. In addressing adaptation, any suggested approach used should be able to address scenarios that involve additions, modifications, deletions or their aggregates related to these IT artifacts.

Based on this rationale, the methodology adopted for this study is the *design science* research methodology of Hevner et al. (2004), which seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts to solve organizational problems. In this context, the process model of Design Science Research Methodology proposed by Pepper (2007), a variant of Hevner's approach illustrated in Figure 2, was used.

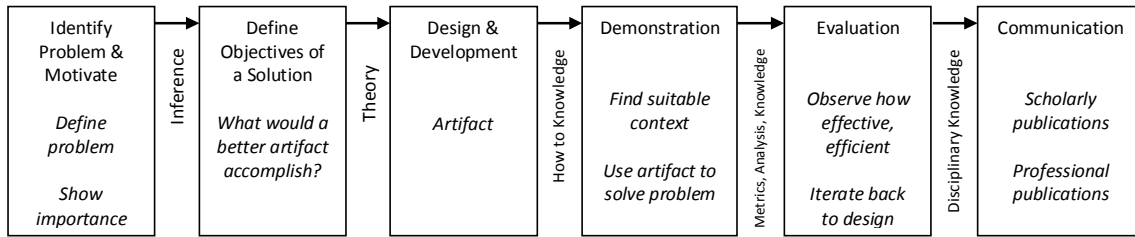


Figure 2: Design science research methodology process model (Peffers et al., 2007).

The following steps were chosen in conducting the research:

- 1) Problem identification and motivation: Issues regarding achieving adaptiveness in EA were identified.
- 2) Define the objective of a solution: Creation of a framework for achieving adaptiveness in EA.
- 3) Design and development: The framework consisting of a model, methodology and tool support to achieve adaptiveness in EA was described.
- 4) Demonstration: The framework was applied to a real EA.
- 5) Evaluation: The performance of the model in anticipating and supporting adaptation in the EA was evaluated.
- 6) Communication: The results obtained from the evaluation are described in this thesis.

In defining an approach to the BI-Enabled Adaptive Enterprise Architecture, goal modeling based on the User Requirements Notation (URN) is examined. URN, the first international standard to combine goal modeling (Goal-oriented Requirement Language – GRL) with scenario modeling (Use Case Map notation – UCM) (Amyot et al., 2011; Mussbacher and Amyot, 2009) enables a focus on the rationale for behavior and/or structure, provides a conceptual view of what capabilities and architectures are required as well as allows consideration of potential prospect and vulnerabilities stakeholders seek to identify and avoid, respectively, within their unique operational environment. It also facilitates the identification of capabilities, services and architectures needed to fulfill stakeholder goals.

Using jUCMNav (Amyot et al., 2011), a free Eclipse-based tool utilized in analyzing and managing URN models, a model capturing business scenarios and reports that indicates information needs of part of a real government department, namely Citizenship and Immigration Canada (CIC), is created. This model also captures actors involved, their intentions in terms of organizational goals and softgoals, task they perform in actualizing these goals as well as the IS that support the processes. Finally, in keeping with the design science approach, the results obtained from participants of the organization who were exposed to the model are evaluated to assess the model's ability to enable adaptive anticipation and support of architectural changes.

1.4. Thesis Contributions

To make business-critical decisions and respond to constantly changing conditions, organizations have to intelligently acquire, process and present increasing and enormous amount of information from different sources and formats; some in structured, semi-structured and in recent times unstructured formats. Consequently to stand out and have a competitive edge, organizations need to go a step further in evaluating if their current procedures for alignment are causing architectural rigidities in either their IT offerings or organizational processes and proactively ensure that the architectures in place are flexible and adaptable to meet promptly continuing changing demands.

As its main contribution, this thesis addresses the ongoing problem of dynamically aligning IS to business strategies, priorities and objectives by developing a framework (BI-EAEA) exploiting a URN-based model, which links enterprise architecture elements to business goals and decisions. The model design facilitates the representation of business and information needs within the organization as well as impact of their changes.

The other contributions of this thesis are:

- Systematic handling of change (addition, modification and deletion) of objectives, decisions, IS, their attributes and their relationship, in order to support adaptation.
- A modeling style for URN, which exploits existing tool support (jUCMNav), to which new well-formedness rules were added as selectable OCL constraints. This style also uses KPIs potentially fed by BI systems.

- A new methodology based on Analytical Hierarchy Process to compute contribution levels in GRL models.
- Further debate/dialogue on the influence of decision makers' actions, and on organization's business objectives and IS that support them, as an important consideration in adaptive EA.

1.5. Thesis Outline

The thesis continues in Chapter 2 with and exploration of the background concepts such as EA, adaptive EA, BI, URN and jUCMNav. Chapter 3 describes the methodology used for the BI-Enabled Adaptive Enterprise Architecture as well as tool support and evaluation strategy. In Chapter 4, a detailed illustration of the methodology and model design is presented, with Chapter 5 validating the methodology using a test scenario, namely CIC's "Grants and Contributions" business process¹. Chapter 6 evaluates the results obtained from participant surveys to validate the efficiency of the approach. The thesis concludes in Chapter 7 with the discussion of lessons learned, limitations of this work and recommendations for future work.

¹ <http://www.cic.gc.ca/english/multiculturalism/funding/index.asp>

Chapter 2. Background and Literature Review

To give perspective to this thesis, and enable understanding and appreciation of the work, this chapter provides an overview of adaptation as it relates to enterprise architectures. Current attempts at achieving adaptive EA are also addressed as well as concepts and tools utilized in the thesis, including BI, URN, and jUCMNav.

2.1. Enterprise Architecture and Framework

The discipline of EA has its origins in Zachman's treatise on Information System Architecture (Zachman, 1987; 1997). It draws from experiences learnt from the airplane engineering and manufacturing industries as well as architecture and construction industries in representing different intersecting characteristics: structure, functions, behavior of its people, processes, technologies and concerns such as security, accessibility, privacy and interoperability, and how they all relate and affect the organization as a whole.

In defining EA as “that set of descriptive representations (i.e. “models”) that are relevant for describing an Enterprise such that it can be produced to management requirements (quality) and maintained over the period of its useful life (change)” (Zachman, 1997), Zachman identified the generic logic structure that organizes or classifies the descriptive representations of complex objects such as enterprises. An EA is the architecture of an entire organization and it involves multiple systems working towards the organization's objectives. Its helps guide the evolution of an organization's systems and processes towards achieving desired levels of consistency, effectiveness and efficiency as it is used to depict the current states of the organization and its desired future state. EA is attributed to be composed of different domains (Pereira and Pedro, 2004), each a unique architectural discipline which EA holds together (Figure 3). They include:

- a) Business Architecture – the basis for identifying IS requirements that support business needs. It is the result of defining business strategies, processes and functional requirements.
- b) Application Architecture – provides required frameworks focused on developing and implementing applications to fulfill identified business requirements at the quality that meets business needs.
- c) Information Architecture – the results of modeling needed information to support business processes and functions of the enterprise, it describes the physical and logical aspects of data and management of data resources.
- d) Technical Architecture – identifies and plans computing services that form the technical infrastructure for the enterprise that supports business processes, data and applications identified in the other architecture layer.
- e) Product Architecture – identifies standards and configurations required for enabling technologies and products within the Technical Architecture layer.

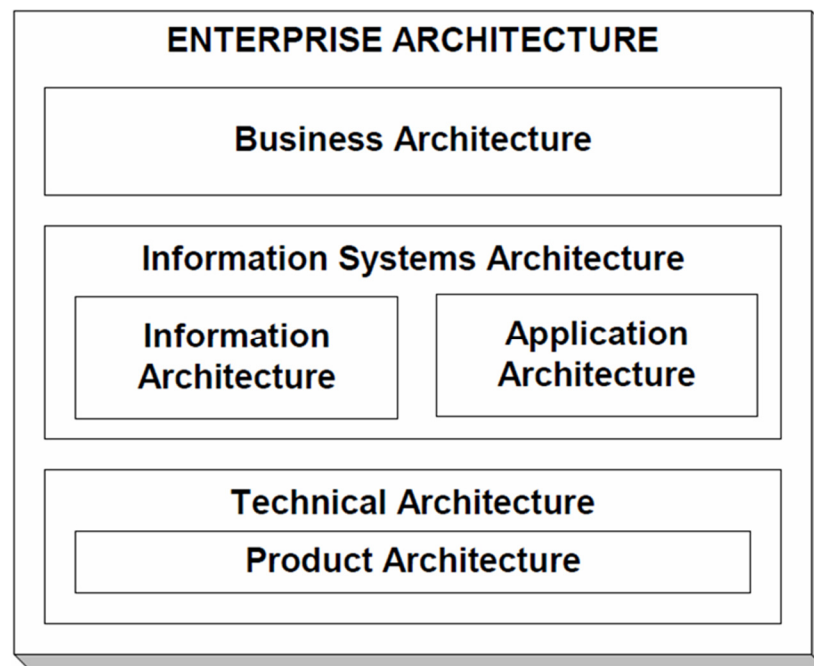


Figure 3: Enterprise Architecture relationships (Pereira and Pedro, 2004).

Tools and methodologies based on fundamental principles are required to design and manage EA through their lifecycles. These fundamental principles are referred to as an

architecture framework. The ISO/IEC/IEEE 42010 standard (ISO/IEC/IEEE 42010, 2011) defines an architecture framework as “*conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders*”. They establish a common practice for creating, interpreting, analyzing and using architecture descriptions within a particular domain of application or stakeholder community.

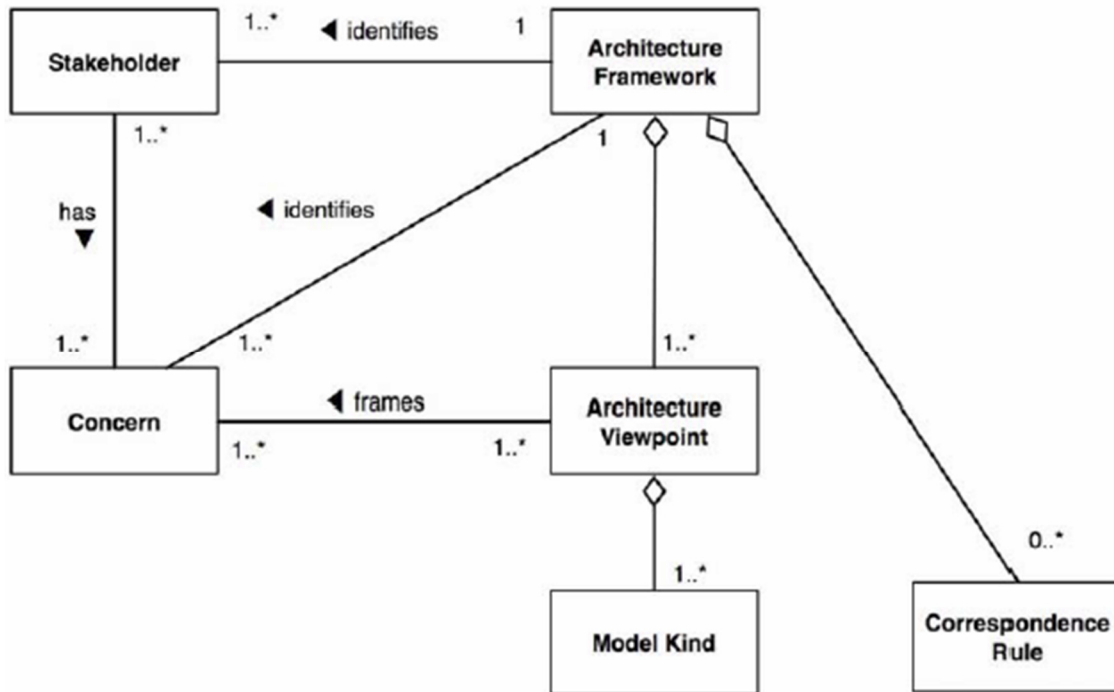


Figure 4: Conceptual model of an architecture framework (ISO/IEC/IEEE 42010, 2011).

The standard goes on to define the contents of an architecture framework (shown in Figure 4) as:

- a) Stakeholder: individual, team, organization or classes thereof, having an interest in a system.
- b) Model Kind: conventions for a type of modeling
- c) Concern: interest in a system relevant to one or more of its stakeholders.
- d) Architecture Viewpoint: work product establishing the conventions for the construction, interpretation and use of architecture views to frame specific system concerns.

- e) Correspondence Rule: used to enforce relations within an architecture description (or between architecture descriptions).

An EA framework is therefore sets of conventions, principles and practices that influence the design of conceptual tools used to guide the development of an EA. They indicate the stakeholders, concerns, architecture viewpoints, model kinds and correspondence rules as well as how they interrelate towards achieving business-IT alignment within the organization. Many EA frameworks exist today, notably:

- Zachman's framework for EA, a two-dimensional classification scheme for the descriptive representation of an enterprise (Zachman, 2002; 2013).
- The Open Group Architectural Framework, TOGAF (TOGAF, 2013), a detailed method and set of supporting resources for developing an EA promoted by the 'The Open Group', a global consortium that enables the achievement of business objectives through IT standards.
- The Federal Enterprise Architecture (The White House, 2013), the EA of a federal government consisting of principles and standards for how business, information, and technology architectures should be developed across the U.S. Federal Government.
- The Gartner Methodology (Gartner, 2013; Bittler and Gregg, 2005), a strategy focusing on where an organization is going and how it will get there. It concentrates on bringing together business owners, information specialists and technology implementers.
- The US Department of Defense Architecture Framework (DoDAF) is an architecture framework for the Department of Defense (2011) that provides visualization infrastructure for specific stakeholders concerns through viewpoints organized by various views. DoDAF is prescribed for the use and development of architectural descriptions in that department.
- The US Office of the Deputy Chief Management Officer (DCMO) annually delivers the Business Enterprise Architecture (BEA, 2013), which is aligned with DODAF, to help defense business system owners and program managers make informed decisions. Canada also has its own version of DODAF in the form of the

Department of National Defence / Canadian Armed Forces Architecture Framework (DNDAF).

Each represents a method that enables the various parts of an organization articulate how information and technology can be used in the context of business strategy.

In providing a holistic view of the business, an EA not only captures and watches over the essentials of the business but should allow for maximal flexibility and adaptability (Jonkers et al., 2006). The reality, however, is that within the different domains of EA are different architectural practices and ways of addressing concerns in these domains. These practices each come with varying degrees of maturity and different methods or techniques for handling the architecture. When changes in business objectives do occur, the resulting adaptive responses, as described in Section 1.1, tend to be disparate, leading to local adaptation but not in the organization as a whole, a situation not desired by the organization. An EA framework that enables provision of insights needed to balance varying and changing requirements across the domains of the EA while facilitating rendering of organization's business objectives into daily achievable operations should be the goal.

2.2. The Adaptive Enterprise and Architecture

The advent of IT transformed the way organizations deal with the information they use to make decisions by moving from a paper-based environment to more digital and electronic offerings. It also gave rise to different kinds of IS used to deal with collecting, processing, storing, retrieving and presenting the different types of information organizations deal with. Nonetheless, organizations still face the challenge of thriving and surviving while innovating continually to remain relevant in the face of changing business environments, technological advancement, dynamic customer requirements, market structures and government policies. The reality is that organizations are open systems that evolve through interaction with the environment around them (Kast and Rosenzweig, 1985). To survive, some form of adaptation is required to correspond and respond to the changing environment. Likewise, the IS in place must adapt to the new business demands resulting from the evolving business either by request of the organizations they function in or con-

ventionally by influence from the environments (external or internal) in which they operate.

In addressing this problem, most organizations tackle it using a deliberate approach rather than an interconnected approach (Peko and Sudraram, 2010). The deliberate approach follows specific sets of change management strategies or groups of strategies in managing business process requirements responses, while the interconnected approach takes advantage of the existing relationships between the different components of the business such as its strategic direction, business processes, organizational structure and IS in place. As illustrated in Figure 5, a deliberate approach involves defining a strategy after the external environment is analyzed.



Figure 5: Deliberate approach of adaptation.

Upon acceptance of the strategy, stakeholders are communicated about the strategy and then it is implemented. The approach continues with the collection and assessment of

feedback obtained after implementation, which then informs a cycle of reformulation, communication and implementation. Naturally, IS implemented with this approach tend to be rigid, structured and deliberate, adhering strictly to the strategies in place. Once implemented and configured, they are difficult to change and provide little room for flexibility. With this approach, organizations do not respond to changes as the business evolves that well. Any change in any of the processes costs a lot in terms of resources such as time, workforce, political will and money, and causes diverse effects on the business. This is a situation organizations try to avoid, especially in the face of continuous unstable business environments. These scenarios gave rise to the adoption of a different and emergent approach; the organizations reacting to the ongoing changes by implementing mostly in parts, strategies to respond to changes as they occur (Peko and Sudraram, 2010).

Amongst emergent approaches is the ongoing widespread adoption of EA frameworks. This has easily gained prominence and liking, especially within the business community, since EA approaches appeal primarily to addressing the application of IT in alignment to the business (Yu et al., 2006; Luftman and Brier, 1999), a form of adaptive strategy as it were. Unfortunately, EA frameworks themselves, as discussed in Section 2.1, do not address cohesively the issues of dealing with change or changes at different levels within the organization, nor do they proffer a way of addressing the complex sets of alignment processes that exist in organizations. This is because of the heterogeneous methods and techniques currently used in EA. They make determining the interrelations within domains difficult, leading to a lack of integration between business objectives, processes and resources. There is also the lack of well-defined alignment between services delivered at every level of the organization, and of support for cross-organizational interaction (Yu et al., 2012; Najafi and Baraani, 2010b; Jonkers et al., 2006). These limitations of EA are encouraging more conversations about anticipating and responding to changes within the enterprise while still achieving the needed alignment of IS with business objectives: an adaptive EA.

Although quite new, the current attempts at adaptive EA do not address the heterogeneous approach and interrelations within domains. They recommend integrating into a framework, enterprise strategy and architecture to facilitate strategic assessment and

adoption or de-adoption of technology in response to constantly changing business. Others focus more on making IT, as a driver of the business, more adaptive, which leads to the business being adaptive, or focus on a Service Oriented (SO) paradigm. They are discussed below.

2.2.1 The Gill Framework for Enterprise Adaptation

Also known as The Gill Framework for Enterprise Service System Adaptation (Gill, 2012), this framework is a set of key disciplines, practices, artifacts and guidelines (Figure 6).

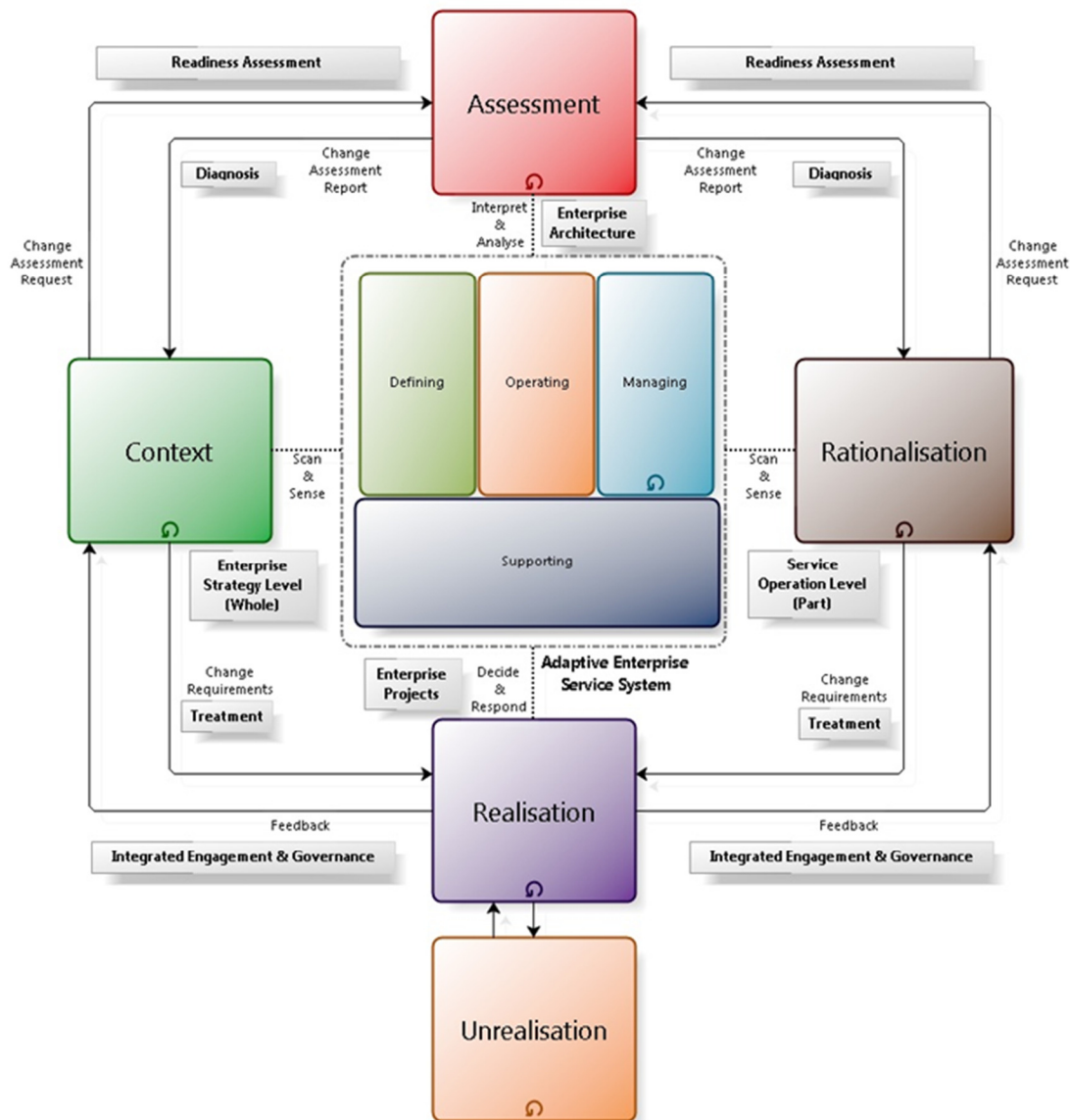


Figure 6: The Gill Framework - Adaptive Enterprise Service System Toolkit (Gill, 2013).

The framework builds upon agility and Complex Adaptive Systems (CAS) theories as well as up-to-date industry-based work on enterprise strategy, EA and agile project management disciplines. It applies a flexible and human-oriented approach for responding to change by integrating EA with other related enterprise disciplines such as enterprise strategy, projects, services and requirements management. The framework guides how the adaptive enterprise requirements, strategy, architecture, project and enterprise service management disciplines fit together and can be used for enabling smooth and consistent enterprise adaptation. It also helps to simplify and speedup the complex non-technology and technology-driven enterprise adaptations.

The framework comprises two main layers: an inner one and an outer one. The inner layer, defined as the Adaptive Enterprise Service System, presents a holistic view of the organization as a living system of service systems using four elements:

- 1) Defining – addresses defining and understanding the boundary or scope of the intended solutions, which respond to the changes before embarking on them.
- 2) Operating – addresses operating the new solutions as trusted with capability to seamlessly mash-up and integrate with the current external and in-house sourced IT services.
- 3) Managing – addresses integrating the core management disciplines (requirements, strategy, architecture, project and service management) for managing the new response environment for delivery of situation-specific adaptive services systems for value creation.
- 4) Supporting – addresses augmenting core management disciplines through support disciplines.

The outer layer termed the Enterprise Architecture Adaptation Method, presents five stages of adaptation, namely:

- 1) Context – continuously scan and sense opportunities for improvement or changes at the enterprise level (horizontal).
- 2) Rationalisation – continuously scan and sense opportunities for improvement or changes at the individual capability or service level (vertical).

- 3) Assessment – use EA as a lens and interpret and analyse change opportunities identified both at the context and rationalisation stages. Make recommendation as appropriate.
- 4) Realisation – decide and take action to realise the change recommendations.
- 5) Unrealisation – defer opportunities that are not relevant at this stage and could be reconsidered in the future.

The inner layer, guided by the outer layer, allows for collaboration and interaction to enable enterprise service system architecture adaptation or agility.

2.2.2 HP Adaptive Enterprise Architecture

The approach of the Hewlett Packard (HP) Adaptive Enterprise Architecture (Vitantonio et al., 2006; Wilkinson, 2006) is that in building processes and applications of an organization over an IT infrastructure that is itself adaptive, adaptation is achievable.

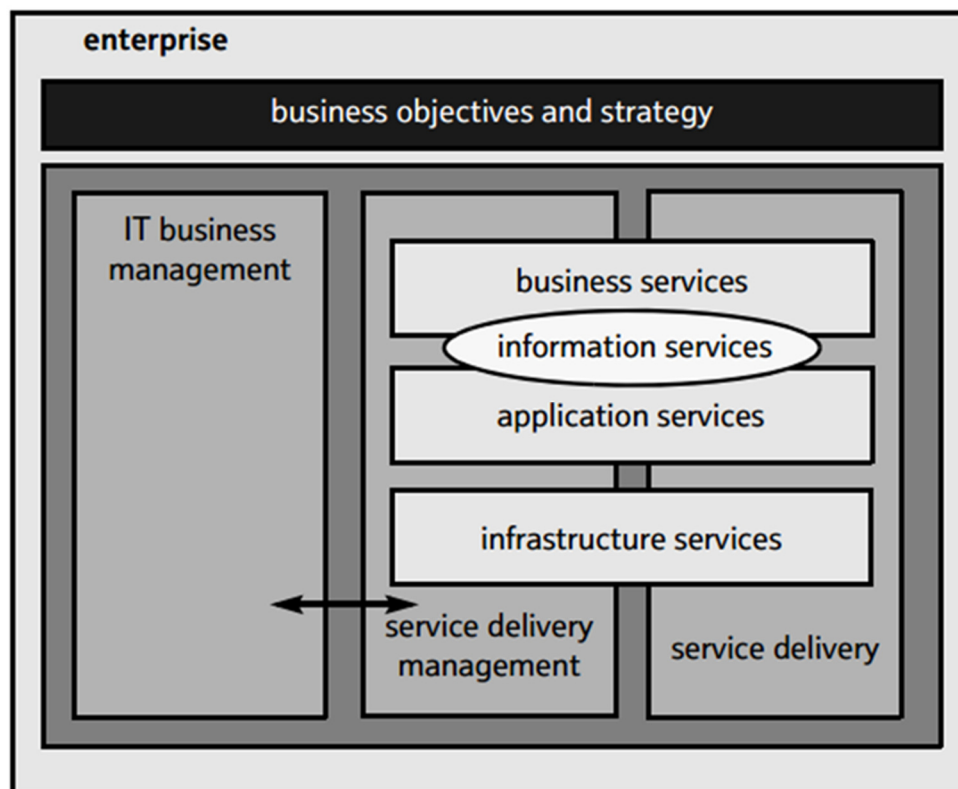


Figure 7: HP's Adaptive Enterprise Architecture (Wilkinson, 2006).

IT resources are optimized to achieve performance indicators associated with business processes and operations by allowing the synchronization of these business processes, operations and the Information and Communication Technology (ICT) services, applications and infrastructure that supports them. This leads to an effective response to change. The approach, which is data-centric, brings together hardware, software and services to drive towards a data center that operates more efficiently and responds faster.

The column on the right of Figure 7 shows the service delivery function, the business logic that defines the functional capability of a service and everything that directly supports the execution of the business logic from applications, operating systems to physical infrastructure. The left column is IT business management. The guiding principles of adaptation are applied both within and across layers as well as defining how management is applied to the component service layers. The Adaptive IT infrastructure is one that adapts its resources, processing, storage and connectivity automatically according to fluctuations in business demands and in a 24×7 computing environment.

The following were identified as technical enablers that can be used to create such Adaptive Infrastructures (Vitantonio et al., 2006):

- a) Standards-based computing and storages systems, which simplify the IT environments by providing modular building blocks.
- b) Virtualisation technologies that enable pooling and sharing of resources, which increase resource utilization and allow supply to automatically meet demand.
- c) Security technologies, which better protect the data centre against new threats posed by virtualised environments.
- d) Automation technologies that use model-based approaches to automate expensive and error-prone processes, thus making IT more responsive to business demands while reducing human errors.
- e) Infrastructure management solutions that allow IT management of end-to-end infrastructure in an integrated fashion.
- f) Innovative power and cooling solutions that help control energy consumption in a 24×7 operating environment.

The HP Adaptive EA strategy spans three areas of concern: to support the IT strategy, business and IT alignment, and IT support for business innovation. It also has five focus areas:

- i) Run IT as a service-delivery business by making IT a strategic partner to improve the value it delivers to the business.
- ii) Use adaptable infrastructure (next generation data centers).
- iii) Promote a mobile enterprise and next generation workplace.
- iv) Use Service-Oriented Architecture application service.
- v) Digitise the enterprise by utilizing available tools and methodology to move from paper-based processes to digital processes for better integration, efficiency and value.

2.2.3 KASRA Framework (KASRAF)

The KASRA Framework (Najafi and Baraani, 2010a) is based on the Service Oriented Architecture (SOA) framework.

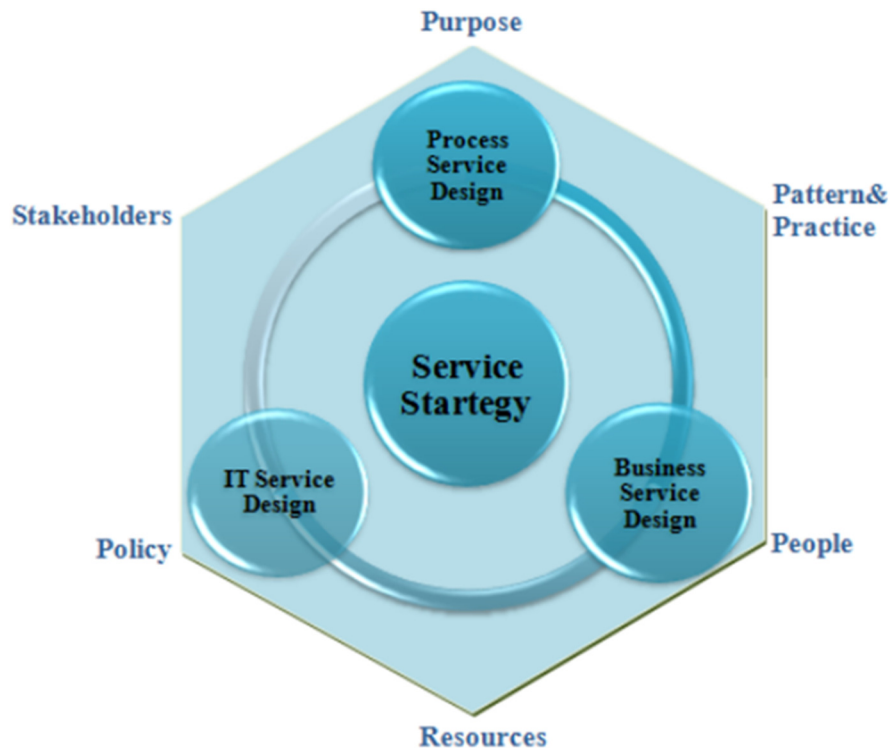


Figure 8: KASRA Framework (Najafi and Baraani, 2010a).

The framework involves a Service Oriented (SO) Lifecycle that is compatible with Information Technology Infrastructure Library (ITIL) best practices, along with a classification schema with four rows and six columns, a meta-model and a life history. It is patterned after the ITIL Service Operation (ITIL, 2013) and is related to many categories of the services computing taxonomy (Zhang, 2008). It includes the first two phases of ITIL, “Service Strategy” and “Service Design” and covers the three phases of the service lifecycles, “Consulting and Strategic Planning”, “Services Engagement” and “Services Delivery”. At the core of the KASRA Framework as seen in Figure 8, is Service Strategy, with the steps of Service Design in a circular way. The classification schema is a 4×6 matrix (see Figure 9), encompassing a collection of different views and aspects of the enterprise, which constitute a comprehensive overview.

		Purpose	Policy	Pattern Practice	Stakeholder	People		Resource
Service Strategy		Strategic Headline	Strategic policy	Strategic pattern	Partner. Providers Competitor	Owner CEO Top Manager		Raw Materials Technological resources Finance resources Environment
Service Design	Process	Business Goal	Orchestration policy	Process pattern				
	Business	Business objectives	Business policy	Business pattern			Middle manager Supervisor User	
	IT	IT targets	IT policy	IT pattern				

Figure 9: KASRA Framework’s classification schema (Najafi and Baraani, 2010a).

The classification schema describes different aspects of an organization from different viewpoints with a template composed of rows and columns. The rows of the template consist of viewpoints of the business, namely “Strategist”, “Business Leader”, “Business User” and “IT Specialist”, while the column describes all aspects of the service lifecycle key factors, suggested in the work on service computing taxonomy (Zhang, 2008). These aspects are decomposed in six categories: “Purpose”, “Policy”, “Pattern or Practice”, “Stakeholder”, “People” and “Resource”. The meta-model provides a holistic view of the KASRA framework entities and the relations between these entities while the life history, namely the sequence of steps systems have gone or will likely go through during their life time, represents the system dynamic model of the framework.

2.2.4 Summary of Current Adaptive Enterprise Architectures Approaches

In this section, we have reviewed current available approaches to achieve adaptive EAs. Table 1 provides a summary of these frameworks including their objectives, approaches, elements and tools. Reviewing the literature related to these adaptive EA frameworks helped us gain a better understanding about existing frameworks and the common approaches used. This knowledge was applied in the development of our BI-enabled Adaptive Enterprise Architecture discussed in Chapter 4.

Table 1: Summary of reviewed adaptive EA frameworks

	Gill Framework	HP Adaptive EA	KARSA Framework
Objective	Enable enterprise service system adaptation.	Builds processes and applications over an IT infrastructure that is adaptive.	Leverage services as key elements in addressing adaptation.
Approach	Use of sets of integrated adaptive disciplines for developing and managing EA adaptation.	Use of an architecture that brings together hardware, software and services to drive towards a data centre that operates more efficiently, delivers on more stringent SLAs and responds faster to business needs.	Use of ITIL Service Operation and Service Computing Taxonomy to address EA and Service Oriented issues
Elements	Inner Layer: Defining, Operating, Managing, Supporting. Outer Layer: Context, Rationalisation, Assessment, Realization, Unrealization.	A model composed of strategic objectives, KPIs and operational performance measures.	SO Lifecycle, Classification Schema, meta-model and Life History Model.
Tools	None.	HP Virtual Server Environment and HP BladeSystem Infrastructure.	None.
Based on	TOGAF	HP	SO, ITIL

2.3. Decision Support Systems and Business Intelligence

BI activities focus on the collection of data, evaluation of data validity and reliability, analysis, storage of data and intelligence, and dissemination (Gilad and Gilad, 1986). With these, there exists potential in BI to be an adaptive tool if there is a change to the context with which it is viewed and approached. Currently in its use, BI helps organizations make meaning of information they deal with and how they relate with themselves and their dynamic environments (Nalchigar and Yu, 2013; Yu et al., 2012). This is because it is utilized to provide insights with which decisions are made. The potential for adaptability rests in this view of BI as a process with products, the decisions being made with the insights provided. This is because in deciding about business objectives, the decision makers' use of insights provided by BI informs how BI should go about capturing, processing and presenting the insights needed. These, therefore, point to links from decision to business objective and from BI system to decisions, indicating decisions as the connectors between business objectives and IS.

In defining BI, most definitions are either a description of what it does, a list of its components, a description of how or where it is presumed to fit in organizational structures, or the results it gives. It is common to see definitions like: a concept (Scholz et al., 2010), intelligence which produces intelligent information (Ranjan, 2009), a management approach or strategy (Nelson, 2010; Pirttimaki and Hannula, 2003; Vitt et al., 2002), a product of previous decision support systems (Gary, 2003), a data-driven decision support system (Negash and Gray, 2003), a system composed of both technical and organizational elements (Isik et al., 2011), a process and a product (Jourdan et al., 2008), a set of mathematical models and analysis methodology (Indrajani and Lisanti, 2011), or data reporting and visualization (Ranjan, 2009). It is further observed that all definitions of BI are either those already listed above or close variants. These definitions point simply to getting data in and out through a means, seemingly – BI in its simplest form (Figure 10).



Figure 10: Business Intelligence in its simplest form.

In addition to BI definitions pointing to getting data in and out, a clear and distinct relationship between information and decision-making exists. The underlying theme therefore with any definition of BI is the need to produce essential information from existing data to make accurate decisions; arguably the reason organizations implement IS.

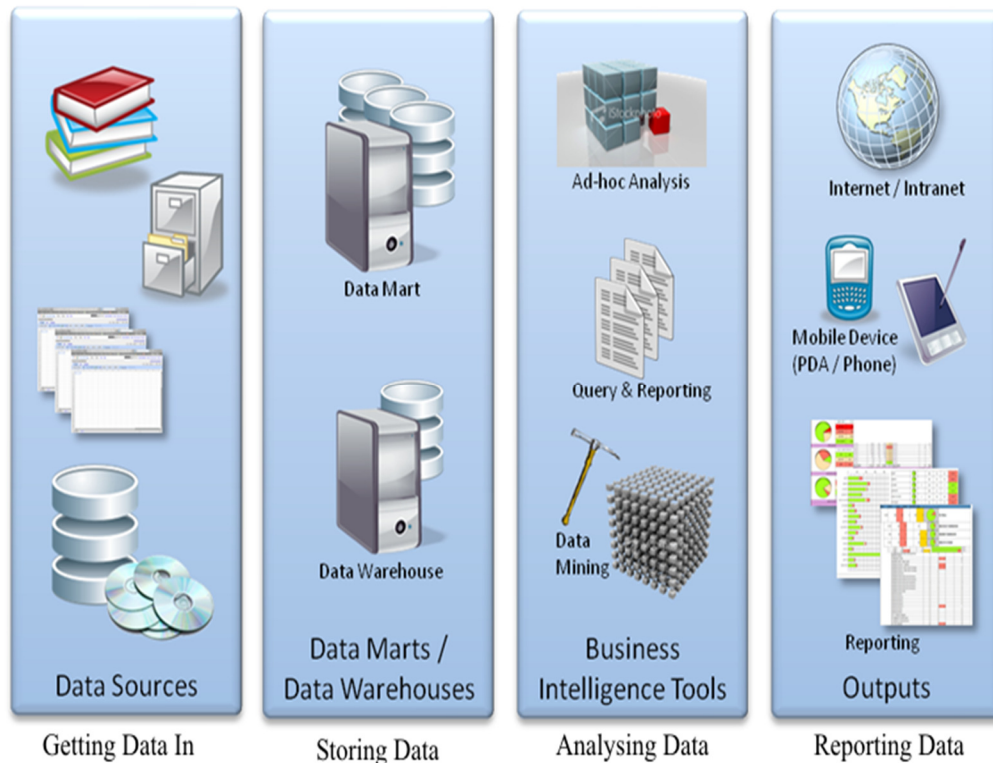


Figure 11: Business Intelligence process (iware Logic Solutions, 2012).

One is quick to conclude therefore that BI is simply another addition to the Decision Support System family since its definitions points towards decision-making. The components that constitute a BI solution are fashioned to capture the entire process of getting data, storing data, analyzing data and reporting the results of the analyzed data in formats required (Figure 11). Decision Support Systems, which have roots in research done in the 1960s to use computers in supporting the decision-making process of managers, are part of the IS discipline focused on the same theme: supporting and improving managerial decision making. Decision Support Systems include decision machines (which perform automations utilizing one-to-one correspondences between diagnosed current states and actions), simulation machines (which perform what-if, sensitivity or robustness analyses),

and look-ahead machines (which perform look-ahead functions like predictions and forecasting). They are further classified as data-driven, document-driven, knowledge-driven, model-driven and communication-driven (Adam, 2008; Burstein et al., 2008; Power, 2004). Decision support scholars attribute such systems to be more of a philosophy of IS development and use rather than a technology (Adam, 2008).

We observe that the components of BI clearly work towards a decision agenda and indicates that it is all about “.... *supporting and improving managerial decision making*” (Arnott and Pervan, 2005). In addition to the decision process BI encompass is a product, the insights produced, as well as the decisions taken with these insights (Figure 12).

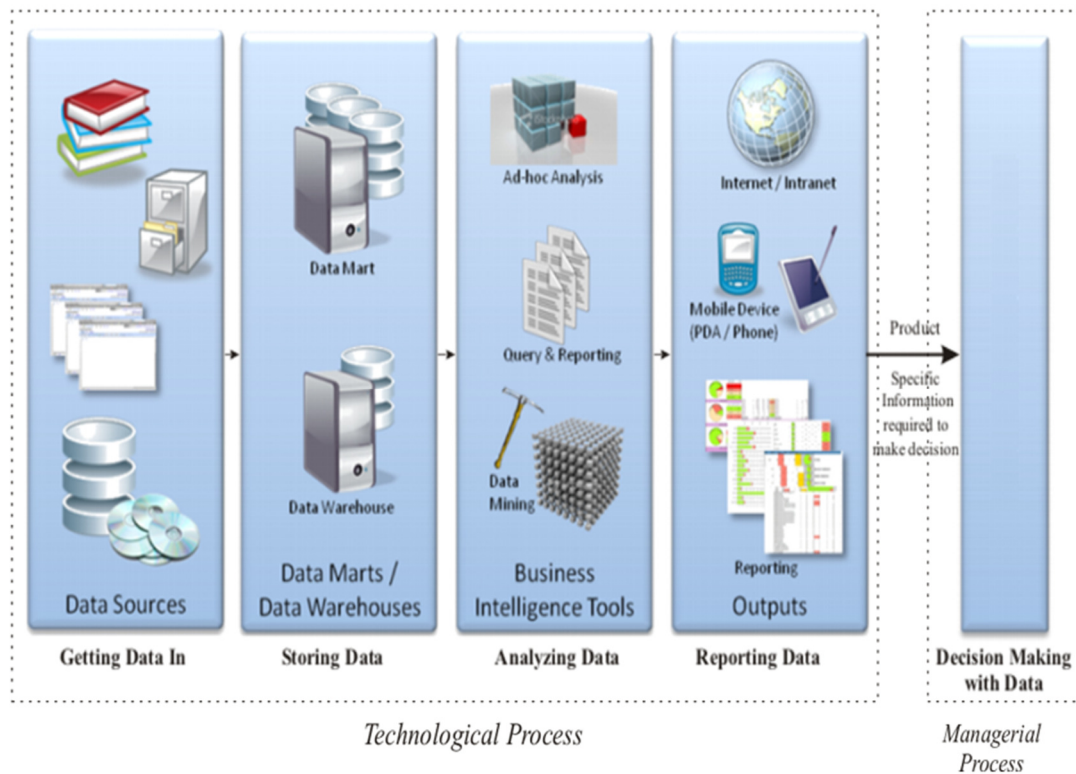


Figure 12: Business Intelligence as a process with a product.

BI as a process and a product brings focus to organizational strategies and priorities and this includes the various components that combine to work in getting data in and out in required formats with which to make required decisions. A look in context therefore shows that the process performs two distinct actions, getting and processing data with a

resultant product and using the product to enable decision-making. While the first is more technical, somewhat machine based, and referred to as the “Technological Process”, the other one, which we can call “Managerial Process”, is action based and involves the managers looking at the insights derived, interacting with and deciding upon them in terms of the decisions they need to make. We can observe that much work has been done and is still done as regards the technological process while little is being done in the equally and perhaps more crucial managerial process.

This thesis exploits the potential given by the managerial process which is: how decision makers use insights from BI to reason about and decide on business objectives and the IS that provide them (Figure 13). This influences adaptive EA design, as the link from IS serving as information sources, to decisions made with this information, and to the objectives the information is used to achieve, shows a clear opportunity to trace, monitor and address change. This link also addresses the challenge of connecting insights from BI with enterprise decisions and actions as the business evolves (Nalchigar and Yu, 2013).

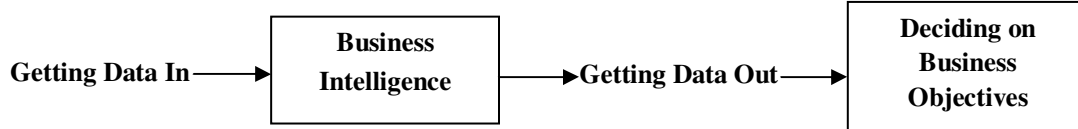


Figure 13: Proposed view of Business Intelligence.

Furthermore, with this view of BI, we become able to apply principles of business process modeling in showing the relationships between the IS, decision makers, and the objectives they achieve, as well as showing changes and adaptation. Indicators fed by insights from BI can be used to represent characteristics of the IS, which propagates satisfaction levels for decision makers actions and business objectives. As URN supports processes, goals and indicators (that can be fed from BI sources), using URN models can enable us to observe and manage adaptation in terms of satisfaction levels of the IS, decisions and business objectives.

2.4. User Requirements Notation (URN)

Business Process Modeling (BPM) enables the graphical displaying and modeling of business processes. BPM is also a structural method that helps stakeholders analyze their processes and find possible points of improvement (Pourshahid, 2008). Business process modeling notations should be able to represent processes and their goals. Ideally, if business processes are modeled with stakeholders, their objectives, connections and drivers, the relationships between all these elements can be seen and exploited during analysis. These relationships are vital in addressing adaptation, as observing how changes within the business influence the modeled entities and how they affect each other, allows for anticipation and support of changes when they occur. The User Requirements Notation (URN), one such notation, is adopted in this thesis to model stakeholders with their objectives, the different connections and drivers, as well as relationships between all the modeled entities. URN is a standard produced in 2008 and revised in 2012 by the International Telecommunication Union (ITU, 2012). URN has concepts for the specification of goals, non-functional requirements, rationales, indicators, behavior, scenarios, and structuring, for the elicitation, analysis, specification and validation of requirements. The standard states further that URN allows for discovery and specification of requirements used for a proposed system or an evolving system and analyzes such requirements for correctness and completeness (ITU, 2012). URN combines two sub-languages: the Goal-oriented Requirement Language (GRL) for modeling actors and their intentions, and the Use Case Maps notation (UCM) for describing scenarios/processes and architectures. It is emerging as a foremost goal-driven and scenario oriented modeling language with its application reach moving from telecommunications and reactive systems to business process management, web application services, performance analysis, test and verification, legal compliance, user interface engineering and beyond (Amyot and Mussbacher, 2011).

GRL has its roots in the Non-Functional Requirements (NFR) and *i** frameworks (Chung et al. 2000; Yu 1997). It is a graphical and visual goal modeling language that links intentional elements with evaluation mechanisms. In connecting requirements to business strategies and priorities, it builds upon the concept of rationale (i.e., reasoning) that leads to system creation or development. It models and answers “why” aspects and hence captures stakeholders’ goals, alternatives to be considered, decisions made and ra-

tionales that aided making those decisions. It has four primary concepts illustrated in Figure 14, *intentional elements* (such as goals, softgoals, task, resource, and beliefs), *indicators* (or KPIs), *intentional links* (such as contributions, correlations, dependencies and decompositions), and *actors* (basically various forms of stakeholders, or the system itself).

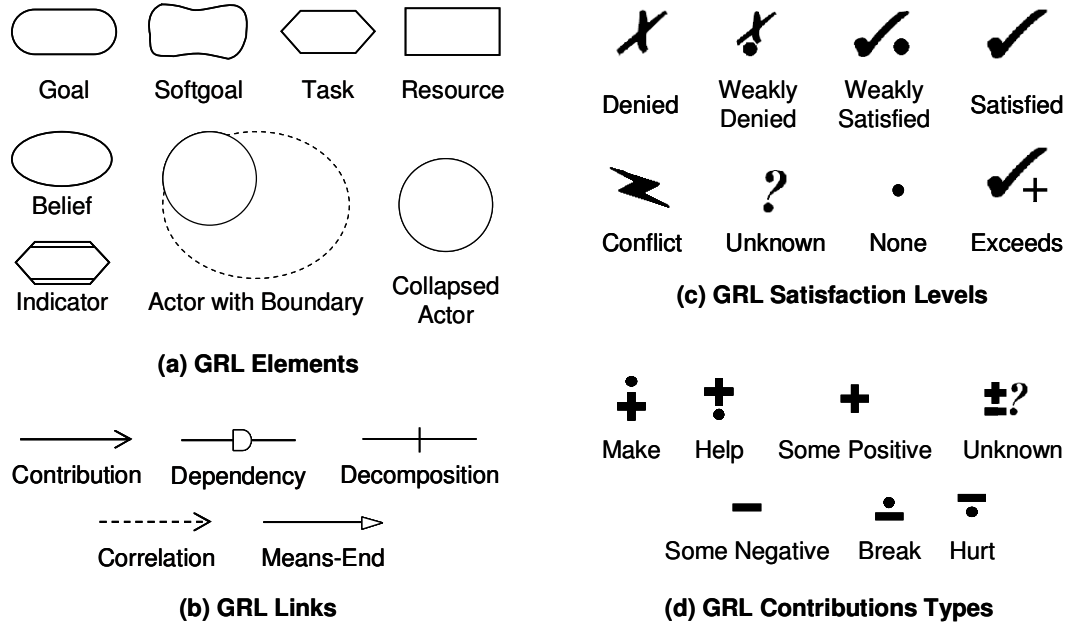


Figure 14: Goal-oriented Requirement Language (GRL): notation elements (ITU, 2012).

In GRL, actors are active entities in the system or its environment who want goals to be achieved, tasks to be performed, resources to be available, and softgoals to be satisfied. Goals can be satisfied fully whereas softgoals relate more to non-functional requirements and are usually achieved not fully, but to a suitable extent. Tasks represent solutions to goals or softgoals and mostly require resources to be utilized in achieving them (Amyot and Mussbacher, 2011; Shamsaei, 2012).

Links connect elements in a goal graph. They include decompositions links (which allow elements to be decomposed into sub-elements through AND/OR/XOR relationships), contribution links (which point to desired impacts of elements on other elements qualitatively or quantitatively), correlation links (which describe side effects rather than impacts) and dependency links (which model relationships between actors). The GRL approach describes a particular configuration of alternatives and satisfaction values

in the GRL model by assigning an initial qualitative or quantitative satisfaction level to some intentional elements in the model (and such initialization is called a *strategy*), while a GRL *evaluation algorithm* disseminates this information to other intentional elements of the model through their links and computes their satisfaction level either manually as part of a strategy definition or automatically from a data sources such as a BI system. To aid better visibility and comprehension of satisfaction levels, color-coding of the intentional elements is used (the greener, the better, while the redder, the worse), as shown in Figure 15. Furthermore, strategies can be compared to each other to aid getting the most appropriate trade-offs amongst other conflicting stakeholders' goals (Amyot and Mussbacher, 2011; Shamsaei, 2012).

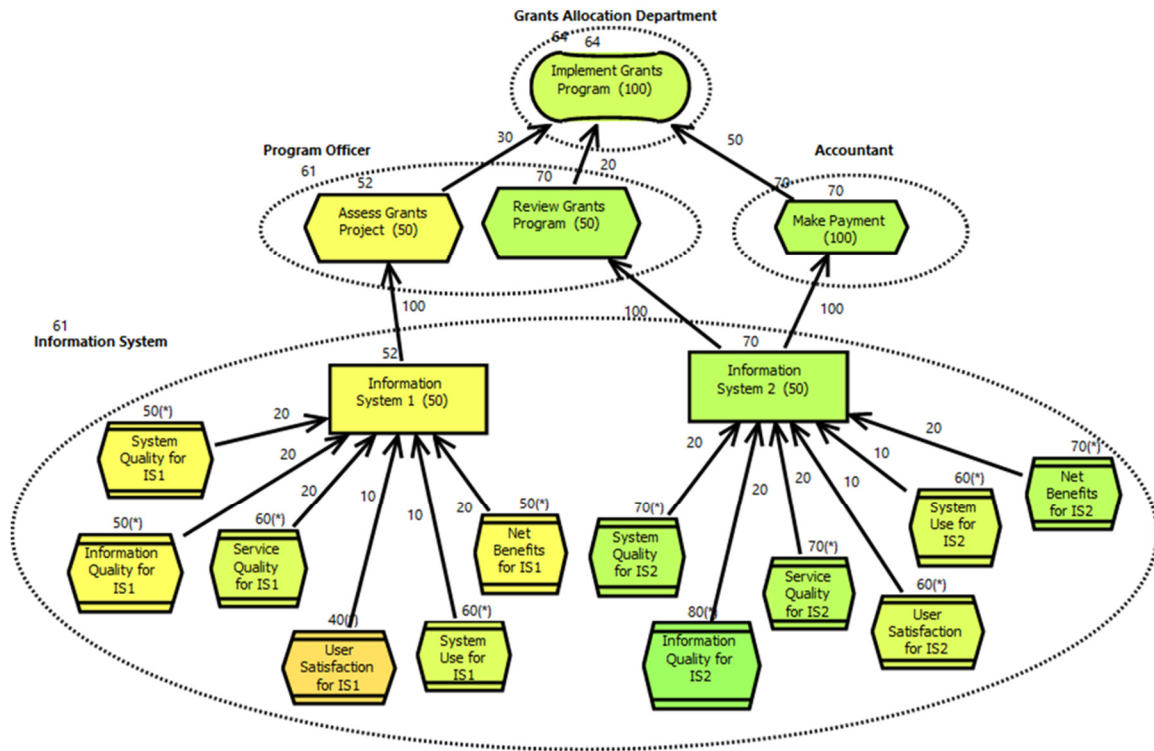


Figure 15: Model example of the Goal-oriented Requirement Language.

URN's other sub-language, UCM, is a visual scenario notation used to model functional or operational requirements. It describes the causal flow of relationships between responsibilities that can be discretionarily allocated to a structure of components that portrays architectural entities. It can capture business processes while connecting them to their objectives, expressed with GRL. UCM's primary elements include *maps* (which contain

any number of paths and components), *paths* (which expresses causal sequences and may contain several types of path nodes), *responsibilities* (which represent actions or tasks performed during scenarios), *joins* (OR-Joins to show merging and AND-Joins to show synchronization), forks (OR-Forks to show alternatives mostly with conditions, AND-Fork to show concurrency), *waiting places* and *timers* (which model delays and timed synchronization). Generally, UCM models are composed of a root map, which can be broken down recursively using *stubs* (path elements that contain sub-maps called *plug-in* maps). Stubs can either be static (with at most one plug-in map) or dynamic (with many plug-in maps). These notational elements are illustrated in Figure 16, with an example model in Figure 17. UCMs also support *scenario definitions*, which characterize a precise path through the UCM model by providing initial values for variables used in conditions, and by identifying which start points are initially triggered (Amyot and Mussbacher, 2011; Shamsaei, 2012). A scenario traversal mechanism enables one to simulate scenario definitions and highlight in red the paths traversed in the model.

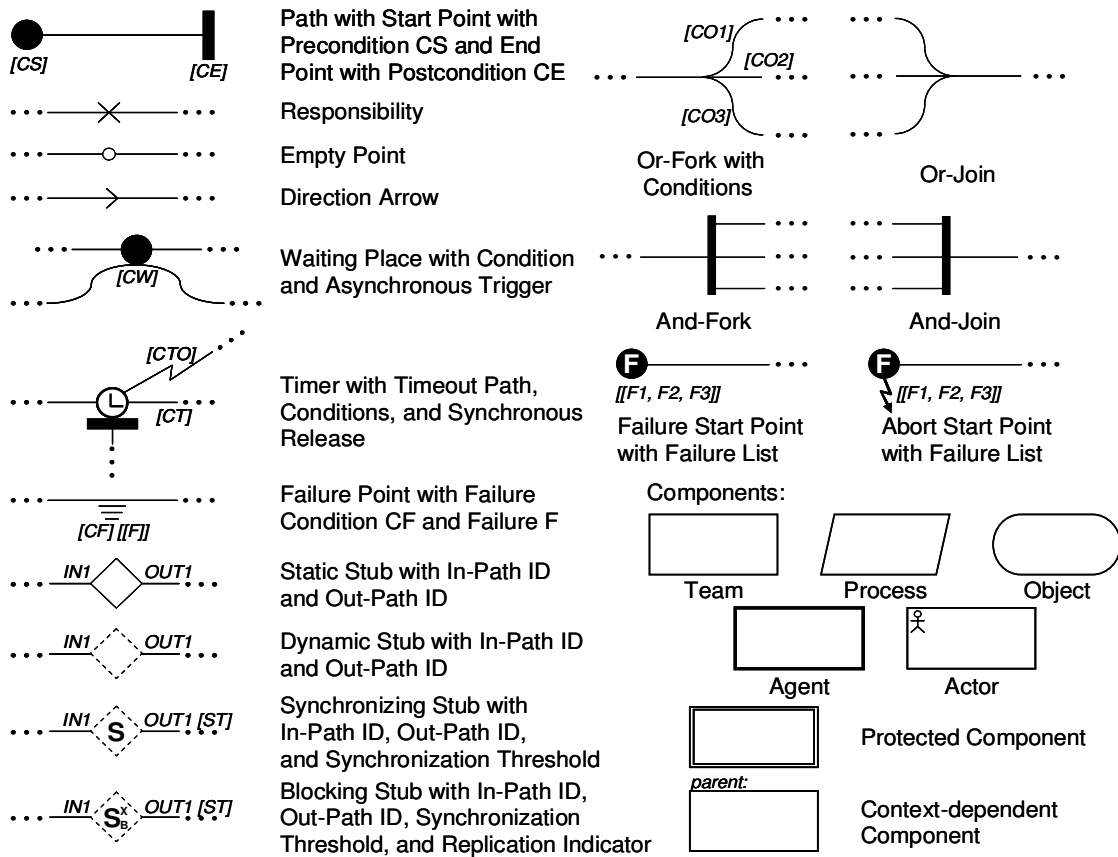


Figure 16: Use Case Maps (UCM): notation elements (ITU, 2012).

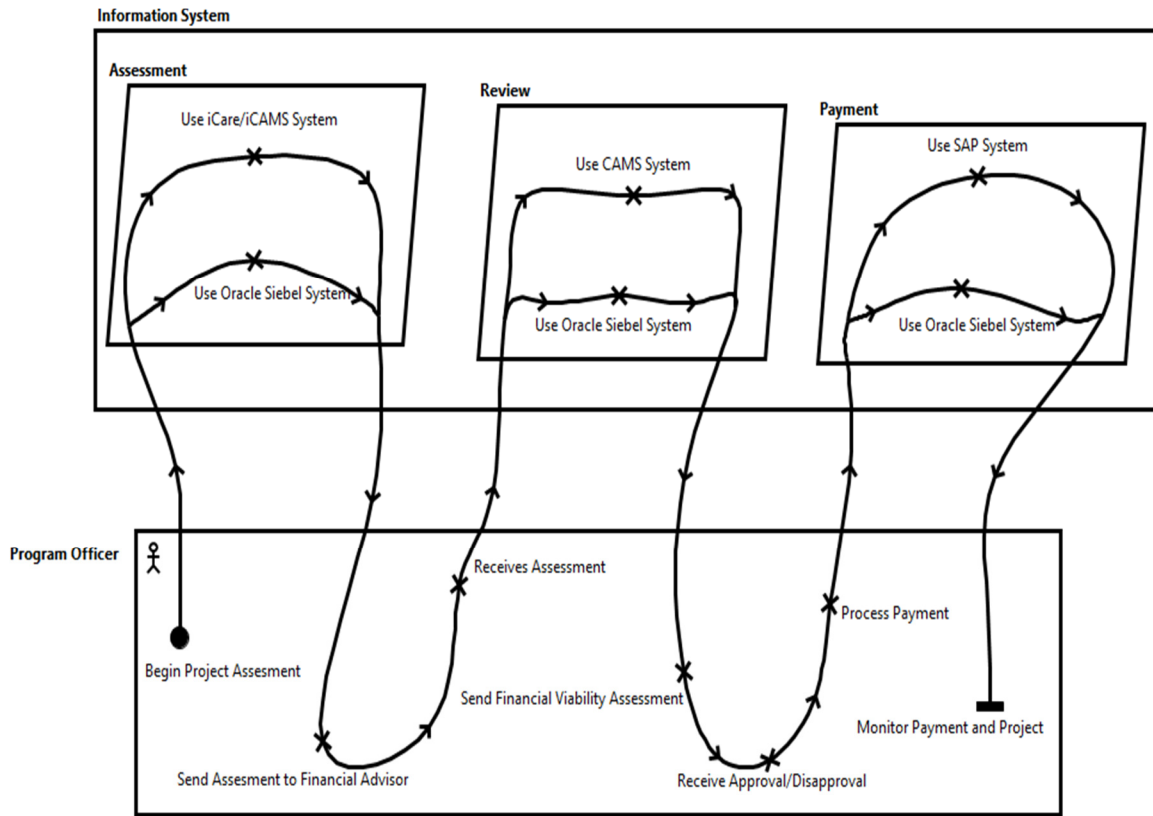


Figure 17: Model example of the Use Case Maps notation.

jUCMNav (Amyot et al., 2011; Amyot et al., 2013; jUCMNav, 2013a) is a free and comprehensive Eclipse-based graphical editor and an analysis and transformation tool for URN (Figure 18). While other tools exist that support the URN, they only support one and not both of the two URN sub-languages (Roy et al., 2006). jUCMNav is the only tool that supports GRL and UCM modeling, together with many GRL propagation algorithms and one UCM traversal algorithm. For GRL evaluations, two scales are available: [-100..100] (the standard) and [0..100] (more intuitive in some domains, and used in this thesis). jUCMNav also enables the definition of relationships between GRL and UCM elements by means of *URN links*. URN model elements can also be tagged with *metadata*, which are name-value pairs. The tool can also enable users to define and check well-formedness rules on models. These features are valuable in corroborating new ideas and concepts for URN and in demonstrating the usefulness of notation across domains.

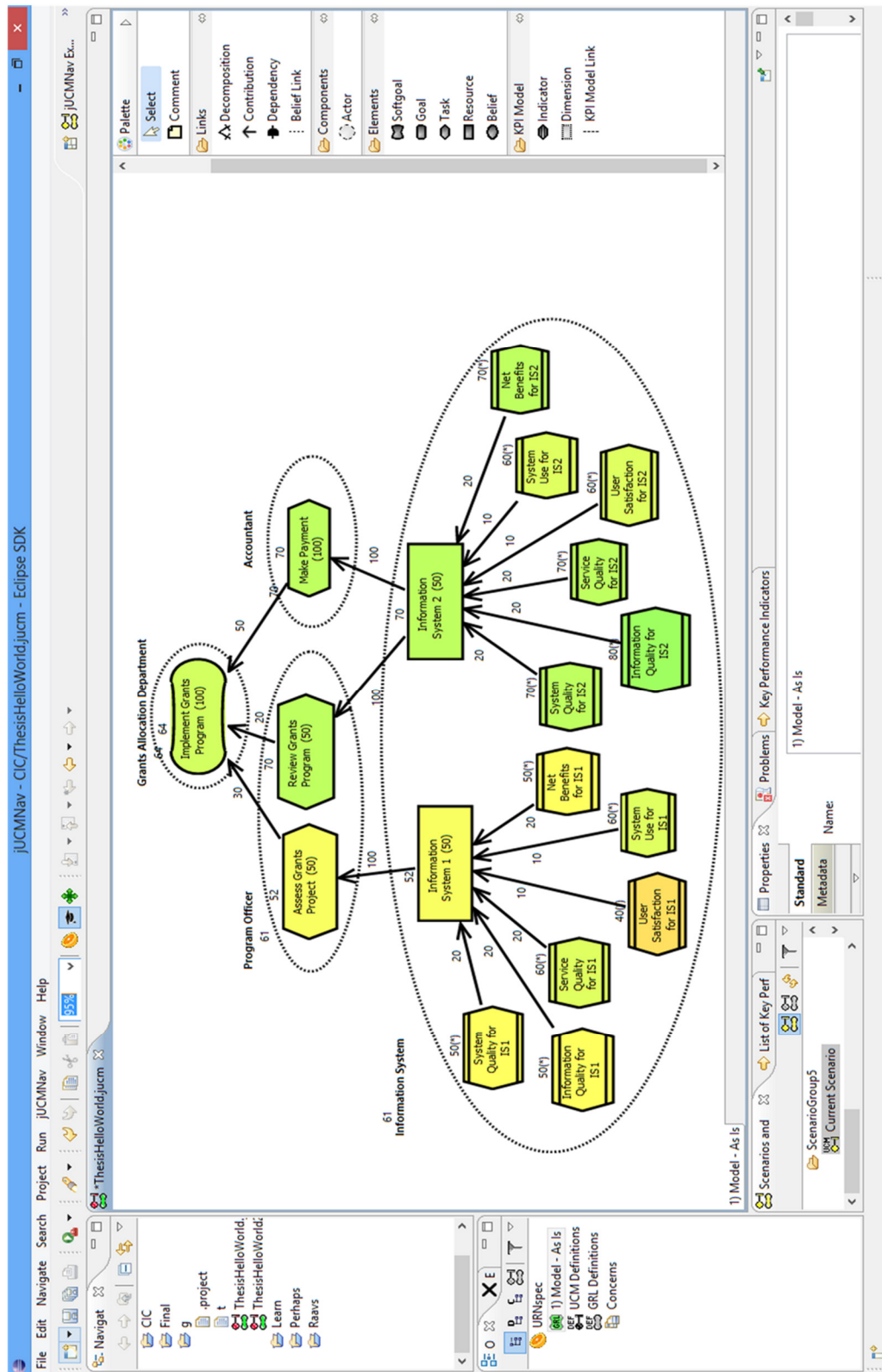


Figure 18: Requirements modeling and analysis using jUCMNav.

This thesis takes advantage of URN's support for business processes (Amyot and Mussbacher, 2003; Pourshahid et al., 2007; Weiss and Amyot, 2005), by utilizing jUCMNav to create, manage and analyze the proposed model of stakeholders, their objectives and connections. GRL can also be used to model the organization's business objectives and IS. GRL was preferred to other goal modeling languages because of the following:

- Its support for evaluation strategies and analysis mechanisms, such as bottom-up quantitative, qualitative, hybrid, formula-based and constraint-based algorithms (Amyot et al. 2010; Luo and Amyot, 2011; Pourshahid et al., 2011; Shamsaei 2012), to analyze impacts of changes on the model entities.
- Its support for providing a scalable and consistent representation of multiple views/diagrams of the same goal model.
- Its support for quantitative (and qualitative) attributes for contribution levels and satisfaction levels.
- Its support for contribution overrides, enabling one to model different sets of GRL contribution weights in one model;
- A clear separation of GRL model elements from their graphical representation.
- Its support for tailoring the language to particular domains via metadata, URN links, and OCL constraints, as a *profile* (Amyot et al., 2009).

In addition to the above reasons, GRL is part of the URN and hence is an international standard.

2.5. Key Performance Indicators in URN

Key Performance Indicators (KPI), also known as indicators in URN, are a generally known approach used by organizations to evaluate performance with respect to some objectives and goals. They constitute important elements of business modeling (Barone et al., 2011a; 2011b) as they demonstrate if an organization is attaining its objectives or goals qualitatively. In addition to intentional elements, the GRL part of standard URN supports KPI to measure and align business processes with goals (Chen, 2007; ITU,

2012). In GRL, indicators are connected to other intentional elements with intentional links, while they are connected to (UCM) business processes with URN links.

Indicators (e.g., number of users, usage percentage, wait time, etc.) are used for evaluating the satisfaction levels of intentional elements in similar ways to tasks and goals in a GRL model. When evaluating KPIs with GRL strategies, each KPI takes into consideration four new values (Chen, 2007; Pourshahid, 2008):

- *Target Value* (used to specify the target for the KPI, corresponding to a satisfaction value of 100);
- *Threshold Value* (specifies the least acceptable value for the KPI, corresponding to 50 on a [0..100] satisfaction scale);
- *Worst Value* (specifies the maximum value of dissatisfaction, corresponding to a satisfaction of 0 on a [0..100] satisfaction scale); and
- *Evaluation Value* (specifies the actual measured value of the KPI).

These values can be entered into the KPI manually as part of strategy definitions (or imported from Excel worksheets, see Amyot et al. (2013)) with the exception of the Evaluation value, which can be entered manually, imported, or obtained automatically from an external data source such as a BI solution (Johari, 2012). The KPI is responsible to convert the evaluation value to a GRL satisfaction value through a comparison with the KPI's worst, threshold, and target values. Thus, an actual measured value for the KPI between the Threshold value and the Target value is acceptable (to various degrees, computed via linear interpolation) as satisfaction, while actual measured value between the Threshold value and the Worst value is not acceptable, leading to dissatisfaction.

The satisfaction level is transmitted to other elements as required by the selected GRL propagation mechanism. A formula-based algorithm, which allows aggregating several KPIs into one KPI using a mathematical formula, was recently proposed (Pourshahid et al., 2011) and is supported in jUCMNav. The support of KPIs by URN allows for numeric quantification of goals achievement in the approach for adaptive EA this thesis utilizes. This makes performance analysis in the modeled EA feasible (Cardoso, 2013).

In general, using indicators, we can attribute indices to intentional elements and scenarios within URN. With this, we represent indicators as desired characteristics of an IS, which shows if the IS is properly aligned with an organization's business objectives. Also, since the performance of an IS can be measured quantitatively, these indicators can be attributed to any representation of the IS as indicative of their performance level in meeting business objectives. With this concept in mind, in modeling the EA, this thesis uses indicators to representing the performance levels of the IS. The groups of indicators representing different performance characteristics, individually propagates satisfaction levels to get a collective satisfaction level for each subsystems of the IS in the model.

2.6. Summary

This chapter addressed EA, frameworks that influence the design of EA, and the limitations that changing business objectives pose to the adaptation of EAs. It also took a look at approaches organizations take to address these changes and presented an overview of current existing Adaptive Enterprise Architecture frameworks and methods. Concepts used in this research (BI; DSS; URN and its two sub-languages: GRL and UCM; as well as jUCMNav, the tool used to create models and analyze how they adapt to changes) were also presented.

While conversations around Adaptive Enterprise Architecture are at early stages, we observe that current attempts are shy of addressing the different levels of changes that occur when businesses evolve in the business objectives/processes and the IS that support these objectives/processes. They also do not show the relationships between business objectives, decision makers, and IS. To achieve an Adaptive Enterprise Architecture that responds to the dynamic business environment we see today, we recommend a change to the way we view the relationships between business objectives and IS. In reasoning about BI from simply a means to get required insights to decide upon to include the decisions we make with the insights we obtain, we see that BI enables adaptation in the EA. This view allows us see the links from "business objectives" to "information utilized to meet these objectives" to "Information Systems which provides and support this information", a link which can be traced and monitored to address change.

The next chapter will discuss the methodology applied to obtain a Business Intelligence Enabled - Adaptive Enterprise Architecture.

Chapter 3. Methodology and Tool Support

In Chapter 2 we argue that an EA that shows the relationships between stakeholders, objectives, decisions, information systems, and their connections is key for an adaptive EA. In addition, we showed how URN as a modeling language and sole standardized language that support goal modeling, process modeling as well as the use of KPIs, can be used to model these relationships. In this chapter, we elaborate on a methodology for using URN towards achieving adaptive EAs (which we called BI-EAEA). In addition, we contribute new automated rules to provide better analysis within the leading URN tool: jUCMNav.

3.1. Overview of the Methodology

This thesis utilizes the design science research methodology in taking a problem-solution approach by introduction of a new artifact to solve existing problems (Hevner et al., 2004; March and Smith, 1995; Peffers et al., 2007). This new artifact, which provides anticipation and support for changes in an EA, is an URN model developed with jUCMNav that follows particular well-formedness rules.

Through the exploration of two fundamental questions, we identified problems organizations face in adapting their enterprise, including people, processes and technologies, to evolving business environments. We address these problems with a model designed for traceability, which maps the organization's business processes to the IS used to support execution of these processes. The fundamental questions we address are:

- a) Do architectures in place adapt reactively as the business changes?
- b) Are these architectures able to anticipate changes in the business?

There exist two dimensional frameworks for research in IT based on design science (March and Smith 1995). They suggest developing an understanding of how and why IS

work or do not work. This is done either through a broad type of design and natural science research activity such as *build, evaluate, theorize* and *justify* or broad types of output produced by design research such as *representational constructs, models, methods* and *instantiations*. In this respect, in this thesis, we accentuated on the design research framework in building and evaluating a model, which can be employed to anticipate and support adaptiveness of EA as changes occur in the business.

For the research outputs, *constructs* were used to represent organizational business processes with concepts from the URN described in sections 2.4 and 2.5. In particular:

- GRL actors are used to represent business *stakeholders, decision makers*, as well as the set of *IS*;
- GRL goals and softgoals capture *business objectives, or decisions*;
- GRL tasks represent process elements, or *decisions*;
- GRL resources capture individual *information systems, or decisions*;
- GRL indicators capture *KPIs* used to assess the performance of *IS*;
- GRL intentional links (decomposition, dependencies, contributions and correlations) are used to represent the *relationships* between the above constructs, and in particular contribution levels represent the *priority* of source element to its target; and
- GRL strategies are used to assess the *impact* of situations, decisions, and changes.

They form the vocabulary of a domain, i.e., the concepts used to describe problems within the domain and to specify solutions. The *model*, which regroups these constructs to form a high-level, self-contained construct, is used to represent situations of EA adaptability as problems and solution statements. It is a set of propositions or statements expressing the relationships amongst lower-level constructs. *Methods*, which are steps, algorithms or guides used to perform a task based on constructs and models, are described with existing GRL propagation algorithms and new well-formedness rules, all implemented in jUCMNav. Finally to demonstrate the feasibility and effectiveness of the *constructs, model* and *method* used in this thesis, an *instantiation*, was achieved. This is the

realization of an artifact in its environment, which is making the artifact operational. This was achieved by implementing the model to business scenarios within the Department of Citizenship and Immigration Canada to anticipate and support adaptiveness of the EA as changes occur. The results obtained are evaluated and reported in this thesis.

3.2. Phases and Steps of the Methodology

The BI-EAEA methodology is iterative and consists of two phases and four steps, as shown in

Figure 19. The steps are categorized in the two phases, i.e., the “As Is Scenario” and “To Be Scenario”, and are in line with the evolution of an enterprise. The former phase represents the organization’s EA as it currently exists and functions while the latter indicates how the EA will be after the anticipated change due to the business or IS evolving. As the business/IS evolve and adaptation occurs, the present adaption becomes the new “As Is Scenario” until the business evolves again, requiring further adaptation. The methodology allows for iteration between the phases and within them, in the steps, as the business evolves and business and architectural needs become clearer.

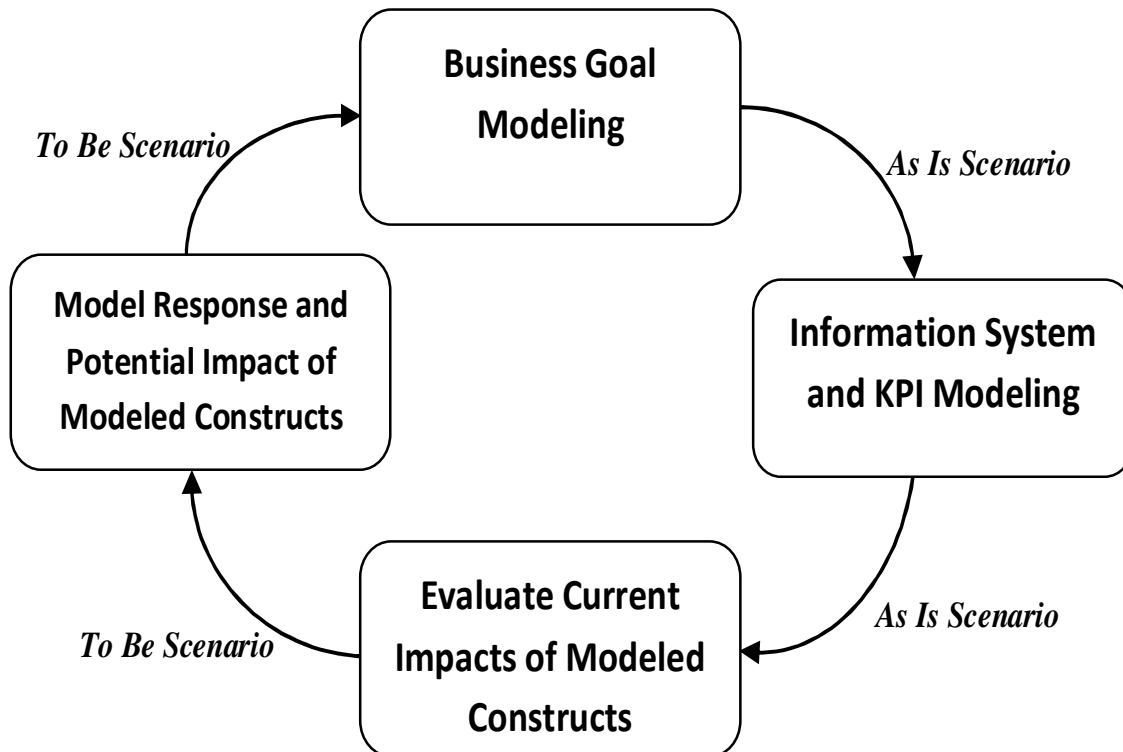


Figure 19: The phases and steps of the BI-EAEA methodology.

As discussed in Section 2.5, the URN pedigree as a foremost goal-driven and scenario-oriented modeling language makes it the best choice for use with the methodology. The GRL ability to enable users to build multi-level goal hierarchies with contributions assigned among intentional elements also makes it adoptable for the goal modeling in the implementation of this methodology. The first step of the methodology (**Business Goal Modeling**) therefore is to build the organization's business goals showing stakeholders as actors and their goals or softgoals, tasks and resources being utilized in achieving business objectives.

In the second step (**Information System and KPI Modeling**), each IS that provides the information with which decisions about the goals are made, is modeled. KPIs, which represent characteristics indicating the performance level of the IS in alignment with business objectives of the organization, are also modeled. These KPIs are integrated with the GRL model of the IS. KPI evaluation strategies are developed to set context for evaluation of these KPIs.

In the third step (**Evaluate Current Impacts of Modeled Constructs**), each modeled IS is linked to the business goals, indicating which IS supports what business goal(s). This gives a depiction of the EA with links from business objectives (represented as goals or softgoals) to actions of decision makers (represented as goals, softgoals, resources or tasks) to information utilized to meet the objectives (represented as the IS with KPIs for their characteristics). Each link is assessed to see the level of contributions or influence all modeled elements currently have on each other. The satisfactions levels are also checked to determine whether they are in line with the "As Is Scenario" of the EA.

In the fourth step of the methodology (**Model Response and Potential Impact of Modeled Constructs**), the anticipated changes in the modeled business objectives, actions of decision makers and/or IS, are assessed to see the effects in the contributions to, or influence on, the other modeled entities' satisfaction levels, thereby indicating and informing the methodology users of the anticipated changes in the EA, which allows for support as required.

This methodology can be used by organization at any level of EA maturity for addressing adaptation. For organizations with a low maturity level, it can guide developing business process modeling initiatives that address change requirements. For organizations

with a medium maturity level, the methodology can highlight missing linkages across the architecture. Finally, organizations with a more mature maturity level can use the methodology to optimize their responses to change as and when they occur.

3.3. Tool Support

In this section, we describe two sets of features that influence the representation and evaluation of URN models in jUCMNav for adaptive enterprise architectures. These features help ensure that the modeled importance for the business objectives and attributed priorities (i.e., GRL contribution levels) are adequately represented. They also ensure that the models have been built and are in use correctly based on stylistic constraints on the models implemented as Object Constraint Language (OCL) well-formedness rules.

3.3.1 Pairwise Comparison of Business Objectives and IS

In addition to the complexity of processes at play within enterprises, modelers have to take into consideration techno-social (Hoogervorst, 2004) and political paradigms. These paradigms bring to the fore conflicts to be resolved among stakeholders whenever the issues of prioritizing objectives, taking actions, using information systems, or handling change arise in the organization. These conflicts, which relate to concerns on things such as subjects, context, interest, values, cost, relations or structures, influence the importance and priority attributed to business objectives, actions and IS within the organization. It is not uncommon for IS specialists to complain that the business decision makers do not know the implementation complexity of some of their requirements, or for business decision makers to complain that IS specialists do not know the business value of some requirements. Common questions that exist include: of all the available options, which is most important, or where should the most resources be invested?

Finding a suitable trade-off to satisfy multiple conflicting factors is often done through multi-criteria decision making. A popular such approach is the Analytic Hierarchy Process (AHP), in which factors are arranged in a hierarchical structure (Saaty, 1988; 1990). AHP is used in this thesis to evaluate and obtain importance levels and priorities. This approach can help accommodate and resolve various techno-social-political paradigms at play in enterprises by eliciting and aggregating quantitative measures of these

concerns. Although AHP has been used recently on goal models in other languages (Liaskos et al., 2012), to our knowledge, this is the first time AHP is used in GRL models, which do support quantitative measures for contribution and importance levels. Different business objectives, actions of actors, IS in place as well as their priorities are compared against each other using AHP's pairwise comparison technique to get importance levels and priority/contribution levels, thus giving an agreeable representation of all concerns.

The steps utilized are the following:

- Develop a pairwise comparison matrix for each business objective importance level or priority;
- Normalize the matrix; and
- Average the value of each row to get the corresponding rating.

In this thesis, the rating scale below was used to obtain initial values for the matrix:

Table 2: Rating scale and symbols for pairwise comparison

SYMBOL	RATING	DESCRIPTION
<<	1/5	is much less than
<	1/3	is less than
=	1	is equal to
>	3	is greater than
>>	5	is much greater than

Assuming a comparison by an expert of the importance levels of 3 business objectives represented as goals A, B, C gives us the following:

A	<<	<	=	>	>>	B
A	<<	<	=	>	>>	C
B	<<	<	=	>	>>	C

Indicating that Goal A is less important than Goal B but of greater importance than Goal C. Goal B is of *much* greater importance than Goal C.

The next step is to represent this in the matrix as shown in Table 3, to show the pairwise comparison.

Table 3: Pairwise comparison matrix example

	A	B	C
A	1	1/3	3
B	3	1	5
C	1/3	1/5	1

Then the matrix is normalized.

- First we add up all values in each column:

Table 4: Addition of each column

	A	B	C
A	1 +	0.33 +	3 +
B	3 +	1 +	5 +
C	0.33	0.20	1
Sum	4.33	1.53	9

- And then divide by the corresponding column sum:

Table 5: Divide each value by the sum of its column

	A	B	C
A	1/4.33	0.33/1.53	3/9
B	3/4.33	1/1.53	5/9
C	0.33/4.33	0.20/1.53	1/9

- We make sure the values in each column add up to 1, as shown in Table 6.

Table 6: The new sum of each column

	A	B	C
A	0.23	0.22	0.33
B	0.69	0.65	0.56
C	0.08	0.13	0.11
Sum	1	1	1

Finally, we get the average of each row to get the corresponding rating (in this thesis, we use a ranking of 0 to 100 for GRL contribution and importance levels, so we multiply each row average by 100).

Table 7: Calculated importance level of the each goals relative to the other

	A	B	C	Row Average	x 100
A	0.23	0.22	0.33	0.26	26
B	0.69	0.65	0.56	0.63	63
C	0.08	0.13	0.11	0.11	11
Sum	1	1	1	1	100

Figure 20 below shows a representation of the goals with their calculated level of importance. This can now be represented in the goal model as an adequate representation of the different goals.



Figure 20: Calculated importance levels of the goals.

The same process can be applied for calculating and presenting the relative priority attributed to the business objectives, captured by contribution levels summing up to 100 for a same target intentional element. For enterprises where objectives, actions of decision makers or IS have not be identified, a similar approach can also be used to identify and select the best alternatives (Vinay et al., 2012).

3.3.2 Well-Formedness Constraints

To ensure that models, including the organization’s objectives and IS in place, together with their relationships, have been built correctly with respect to assumptions we make during analysis, they are checked against well-formedness rules. These rules are constraints for GRL models designed in UML’s Object Constraints Language (OCL) (Warmer and Kleppe, 2003) and checked by jUCMNav (Amyot and Yan, 2008). This thesis defines a set of nine new well-formedness rules written in OCL in addition to a selection of the currently existing URN well-formedness rules that are supported by jUCMNav (jUCMNav, 2013b). These new rules and related existing rules are part of the *profile for Adaptive EA*, which consists of 28 rules. The new rules are formally defined in Appendix A and their application will be discussed in Chapter 4. The new and selected existing rules are presented in Table 8 and Table 9 respectively.

Table 8: New OCL Rules for Adaptive EA

S/N	RULE NAME	DESCRIPTION
1	IShasOnlyResourcesAndKPIs	The modeled IS actor must only contain resources and KPI/Indicators
2	NoContributionsToIS	The elements of the modeled IS, must not receive contributions from any other actors.
3	GRLtotalIncomingContribNot-MoreThan100	Contributions to an intentional element should not sum up to a value higher than 100.
4	GRLtotalIncomingContribNot-LessThan100	Contributions to an intentional element should not sum up to a value less than 100.
5	GRLcontributionContextSumMoreThan100	A contribution change should not make the sum of contributions to an intentional element, be more than 100.
6	GRLcontributionContextSumLessThan100	A contribution change should not make the sum of contributions to an intentional element, be less than 100.
7	GRLtotalImportanceNotMoreThan100	The sum of the importance values of the intentional elements of an actor must not be higher than 100.
8	GRLtotalImportanceNotLessThan100	The sum of the importance values of the intentional elements of an actor must not be lower than 100.
9	GRLintentionalElementWithout-Link	An Intentional Element (e.g., goal or resource) should have links.

Once created with the methodology described in Section 3.2, models are checked against these rules to ensure they are in conformity to the style expected for the analysis. Figure 21 shows a model that conforms to the rules.

Table 9: Existing OCL rules incorporated into the Adaptive EA profile (jUCMNav, 2013b)

S/N	RULE NAME	DESCRIPTION
1	GRLstrategyWithIncorrectXORinit	GRL strategy initializes more than one child of an XOR decomposition.
2	GRLindicatorThresholdConsistency	Indicator threshold value must be between the target and worst values.
3	GRLdependencyEvaluationConsistency	The depender of a GRL dependency should not have an evaluation value higher than its dependee's.
4	GRLactorNoCycle	GRL actor must not be part of a containment cycle.
5	GRLintentionalElementInManyActors	GRL intentional element must not be bound to more than one actor.
6	GRLnoOverlappingActors	GRL actor boundary must not overlap with the boundary of another actor.
7	GRLnoOverlappingIEonActor	GRL intentional element must not overlap with the boundary of an actor.
8	GRLnoOverlappingIEonIE	GRL intentional element must not overlap with another intentional element.
9	GRLintentionElemInsideButUnbound	GRL intentional element is visually contained by actor but is not bound to it.
10	TooManyGRLelementsInGraph	Too many #GRL visual elements in graph.
11	GRLgraphEmpty	GRL graph is empty.
12	GRLactorEmpty	GRL actor is empty.
13	GRLactorWithoutRef	GRL actor definition without any reference.
14	GRLintentionalElemWithoutRef	GRL intentional element definition without any reference.
15	GRLintentionalLinkWithoutRef	GRL intentional link definition without any reference.
16	GRLcontributionNoUnknown	There should not be unknown contributions in GRL models, except between two KPIs.
17	GRLcontributionRange	GRL quantitative contribution must be between -100 and 100.
18	GRLimportanceRange	GRL quantitative importance must be between 0 and 100.
19	GRLevaluationRange	GRL strategy evaluation must be between -102 and 100.

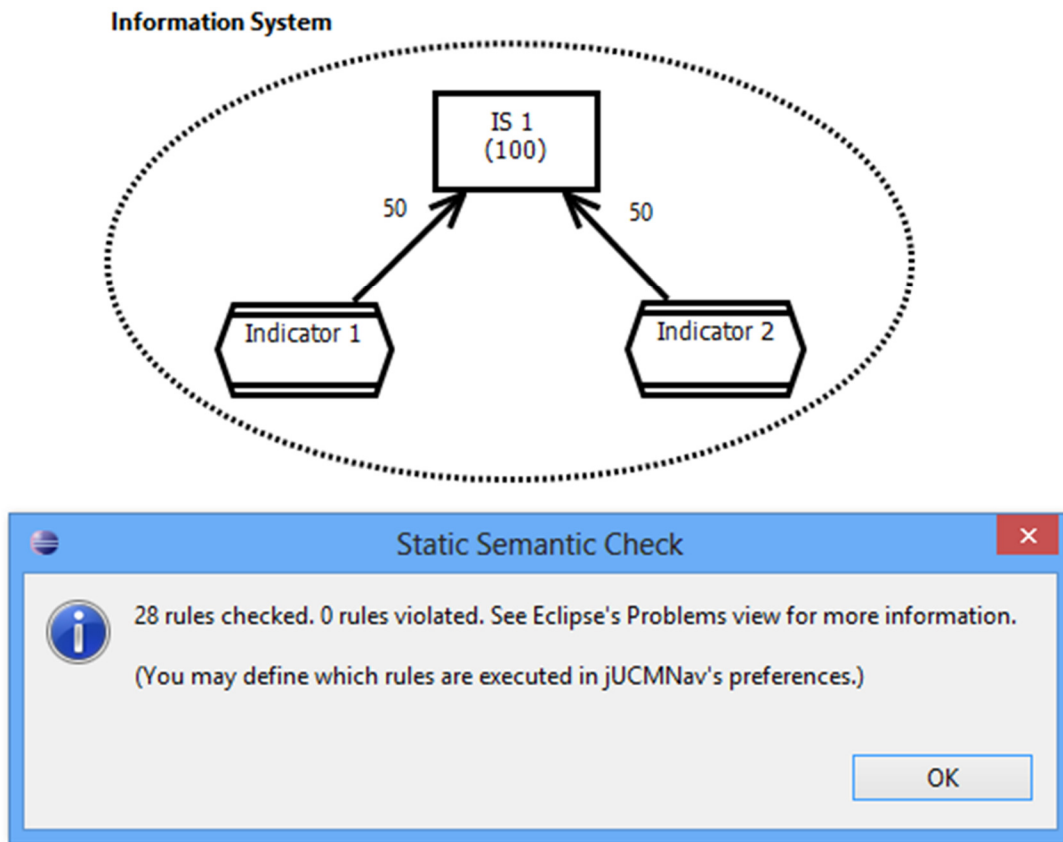


Figure 21: Example of a model conforming to the defined OCL rules for adaptive EA in jUCMNav.

Violations to any of the defined well-formedness rules are reported in jUCMNav's Problems view as a list of problems. The modeler can view the violating element or diagram of the model by clicking on the problem in the Problems view. Figure 22 shows an example of some of the rules violated. They consist of a mixture of errors and warnings. Errors are severe enough to affect the result of the model evaluation while warnings only indicate potential "bad smells" that the modeler may want to reconsider.

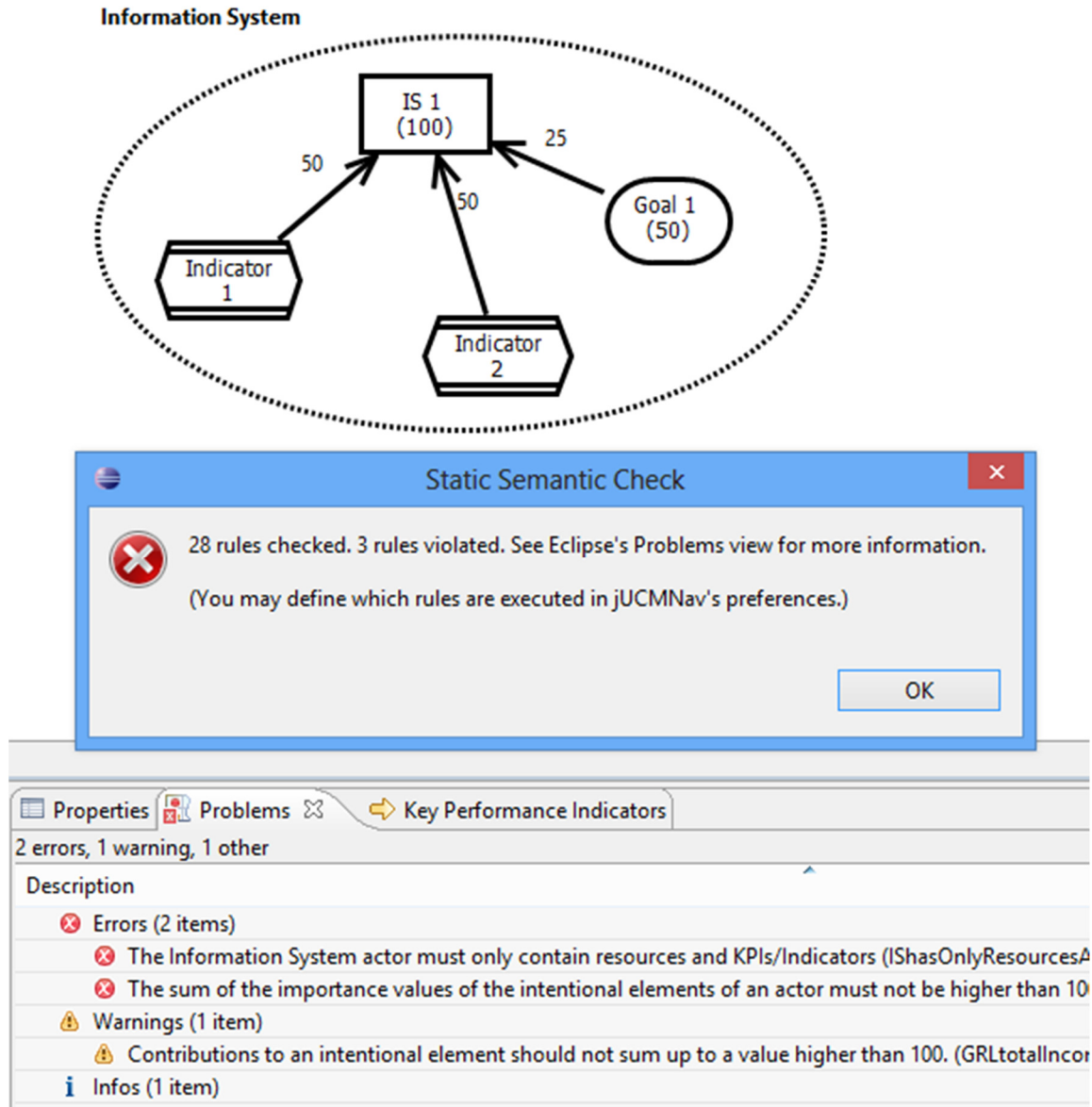


Figure 22: Example of a model violating the defined OCL rules and the rules violated in jUCMNav.

3.4. Methodology Evaluation

Ideally, the evaluation of a methodology should lie in metrics developed to compare the performance of construct, models, methods and instantiations. Since the domain of adaptive EA is relatively emerging, this thesis uses the work of Yu et al. (2012), which proposed key characteristics of an adaptive enterprise, and characterizes what an EA framework for the adaptive enterprise should be able to do and what it issues it should encom-

pass, to evaluate the methodology. The following characteristics are used to gauge feasibility and effectiveness as objectives the model should meet:

1. *Diversity and Variability*: the model's ability to recognize and support change along all variables and diverse dimensions relevant to the enterprise.
2. *Uncertainty and Commitment*: its steadiness to anticipate specific kinds of changes in order to have built-in provisions, which allows for changes if and when they materialize.
3. *Sensing and Effecting Change*: its ability to quickly and effectively respond to different types of changes.
4. *Barrier to Change*: how aware it is to barrier and resistance to change, either social political, or technical in nature.
5. *Multiple Levels of Dynamics*: its recognition of different types and rates of changes, their characteristics, and cycle times to provide appropriate adaptation support.
6. *Dynamic Systems, Boundaries and Closure*: its support for the perception of an enterprise being a collection of interrelated bounded dynamic systems.
7. *Actor Autonomy and Alignment*: its alignment of interest between the idealized dynamic system and participating actors with their goals.
8. *Business-IT Alignment*: its accommodation and support of a distributed view of business-IT alignment, and the different mechanisms that contribute to this view.
9. *Adaptiveness as a Business Requirement*: its adopting techniques from requirements engineering in viewing adaptive requirements as goals within scenarios.

The model created with this methodology for the target organization (CIC in this case) was assessed against these characteristics using a questionnaire (see Appendix B). Personnel of the organization who had access to and made use of the model were asked a series of questions with quantitative values derived from these characteristics. The responses obtained were assessed to see if the model's performance was in line with the characteristics of an adaptive EA as outlined by Yu et al. (2012). The responses to each question will be discussed in Chapter 6. Also the average current performance of the

model for each characteristic is compared with the average ideal performance of the model.

3.5. Summary

In addressing the fundamental questions to be asked regarding adaptive EA, this chapter described the methodology used in this work to model links from organization's business objectives to actions of decision makers deciding on the objectives, and then to the IS that provide the information utilized. The phases and steps of the methodology, tool support within jUCMNav, as well as the evaluation strategy used to verify the methodology, were described and discussed.

The next chapter presents the phases and steps of the methodology in more detail, clearly showing how it is applied in addressing different adaptation scenarios as changes in the business objectives, actions of decision makers, or IS cause the business to evolve, requiring the EA to adapt.

Chapter 4. BI-Enabled Adaptive Enterprise Architecture

The reasons for adaptation generally include responding to change in ways that makes the new state more suitable for the new use or purpose. In its application to EA, adaptation represents how the enterprise and architecture in place respond to various forms of changes, which make the new EA more suitable. In addressing adaptive EAs, this thesis identifies the reasons for adaptation, how they are presented, and the levels within the enterprise in which they occur.

The need for adaptation appears as requirements to increase or decrease the importance or priorities attributed to existing business objectives, action carried out by decision makers to achieve these objectives, or the IS providing information with which the objectives are achieved. They also appear as objectives that have been achieved, finished actions or actions by decision makers that are no longer needed, decommissioned or failed IS and the introduction of new objectives, new decisions or IS (and IS opportunities). In reference to adaptation, these appearances can be seen as:

- **Modifications:** increase or decrease in importance or priority attributed to objectives, decision maker's actions, or IS.
- **Deletions:** objectives have been achieved or are not needed anymore; decision makers are no longer involved; decision maker's actions are finished or are not needed anymore; or IS are decommissioned or have failed.
- **Additions:** emergence of new objectives, decision makers, actions or IS opportunity, with their importance or priorities.

Clearly, we observe that instances of modifications, deletions or additions occur in 3 levels within the organization, regardless of abstractions. These levels are: in the business objectives of the organization (which we refer to as *High level*), within actions of decision makers required to achieve these objectives (referred to as *Decisions*), and lastly in

the IS that provides the information utilized in achieving these objectives (referred to as *IS*). This approach is consistent with the *goals-decisions-information* (GDI) literature (Prakash and Gosain, 2003; 2008) where goals (business objectives) identify the sets of decisions (actions of decision-makers) that are relevant, which in turn help in determining the information needed to support the decisions.

This chapter expands on the phases and steps of the BI-EAEA methodology in more details. It shows links from modeled elements of the three levels: IS to Decisions to High level. It also addresses adaptation in terms of Modifications, Deletions or Additions at each level.

4.1. The “As Is Scenario” Phase

The methodology starts out with the first phase, the “As Is Scenario”, by modeling the organization’s current business objectives, decision maker’s actions and IS that provide the information utilized to achieve them, using the GRL notation. This leads to a graphical model and documentation of the different business goals and non-functional requirements of interest to different stakeholders in the organization. This also shows alternative means for achieving these goals and requirements.

In modeling the business goals of the organization, the extensive works on modeling organizations using GRL and UCM by Weiss and Amyot (2005) and Pourshahid et al. (2005, 2007, 2009) provide a strong basis. Their work, based on experiences with case studies, lessons learned from other domains, as well as other methodology guidelines, provides a detailed approach for modeling organizations. It does this in line with project development best practices that promote developing projects in an incremental and iterative manner (Pourshahid, 2008). From the methodology described in Section 3.2, the steps in this phase are further detailed below.

4.1.1 Business Goal Modeling

In the first step of the methodology, based on the organization’s priority, requirements and relative importance of respective goals, the corresponding process that satisfies high priority requirements and goals is selected as targets for modeling. If the selected process appears to be too large for available resources and project timelines, one or more sub-

processes of that process should be selected and modeled. With this, identified goal models are also decomposed to reach the same level as the selected sub-process. After a full cycle of the project, with a complete environment of all important processes modeled and monitored, the subsequent selection of target processes becomes easier than the first time this exercise is done.

From the process identified, the organization’s business process experts (such as Enterprise Architects, Technical Architects, Business Architects, Project Managers or Business Analysts) model goals, softgoals, tasks or resources along with their links, current importance levels and priorities, for each selected process. The pairwise comparison approach described in Section 3.3.1 is used for this process. The organization’s business goals are modeled using the conceptual meta-model shown in Figure 23 below.

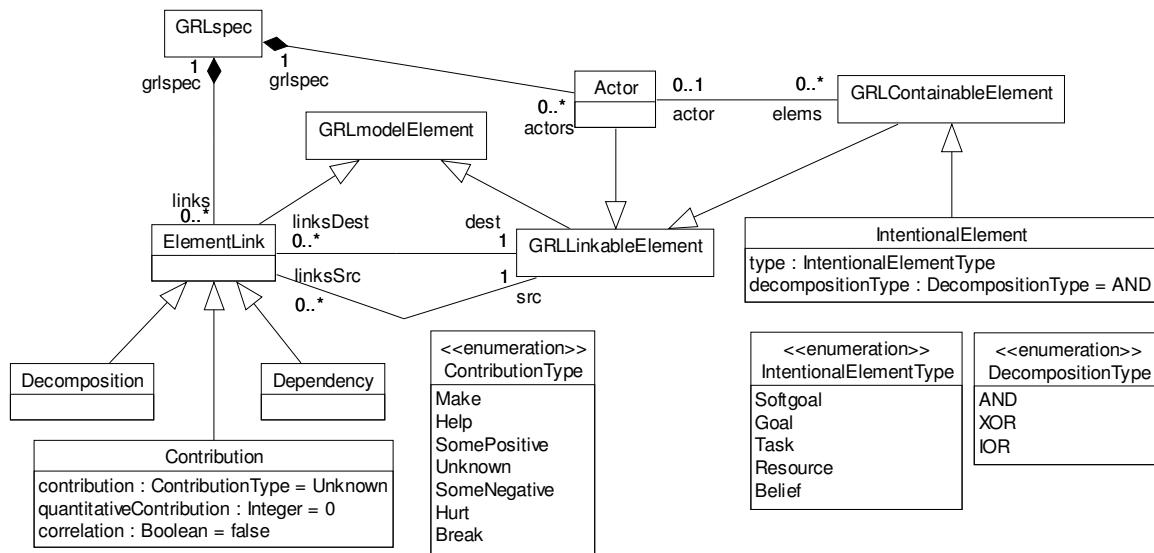


Figure 23: Core conceptual meta-model elements of GRL (ITU, 2012).

As explained in Section 2.4, actors, which represent the system or stakeholders are represented in GRL with . Actors contain GRL intentional elements such as: goals , softgoals , tasks , and resources . These elements are connected to other GRL intentional elements through links such as AND/OR decompositions , contributions , correlation  and dependencies .

Example

Consider an organization's department involved in administering grants. This is a highly dynamic department with influence from changing policies and a frequently evolving IT landscape as new IS technologies emerge. Figure 24 illustrates a partial GRL model of this department's grants implementation program. It shows actors, a softgoal, tasks, resources, and their respective importance levels together with contribution links and their weights.

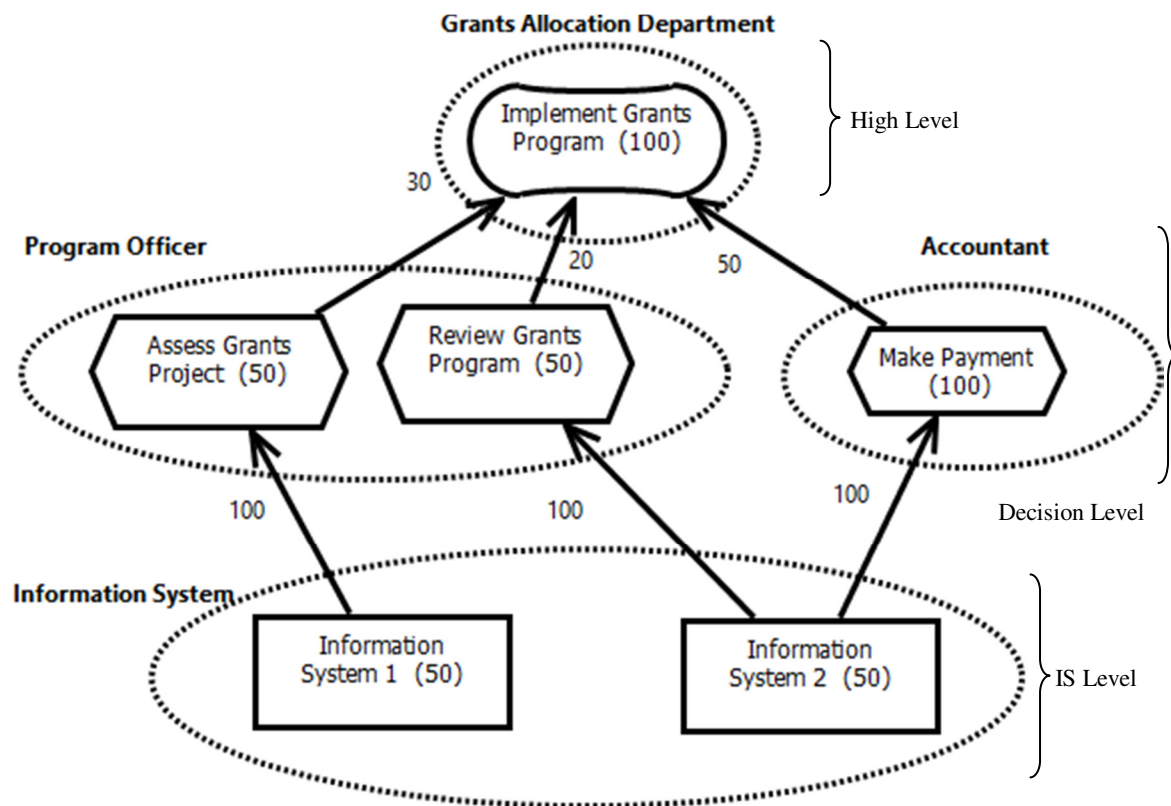


Figure 24: GRL model example of a Grants Implementation Program.

The model contains the business objective of the organization represented as a softgoal “Implement Grants Program” with a 100 importance level (on a 0-100 scale). This is an objective of the actor “Grants Allocation Department” in the *High level* view of the model. The other stakeholders associated with this objective are the decision makers represented as actors, “Program Officer” and “Accountant”, in the *Decision* level. They both have different tasks that they act upon utilizing the resources “Information System 1” and “Information System 2” of the actor “Information System” (at the *IS* level), to contribute

to achieving the softgoal. The tasks and resources each have an importance level, summing up to 100 for each actor, in conformity to OCL rules defined in Section 3.3.2. Respective contribution weights are also illustrated, and they too sum up to 100 for each target intentional element.

4.1.2 Information System Modeling and KPI Modeling

The next step of the methodology is the modeling of the IS, which serve as sources of information utilized in achieving organizational business objectives. Ideally, the modeling procedure utilized in the previous step of the methodology should be sufficient as described in Section 4.1. Unfortunately, the representation of IS in goal-modeling notations such as the URN, is mainly about their functions; they are not represented as whole entities. This is because the use of IS in organizations is to deal with collecting, processing, storing, retrieving and presenting the different types of information organizations deal with. As such, the emphasis is on these attributes of IS, which on their own form parts of processes of organizations, rather than representing the IS itself and how it performs. To address this issue, this thesis introduces a novel way of modeling IS by representing them along the line of “...*how aligned the Information System is with the organization’s business objectives, as it performs its required functions*”. This allows the modeling of IS themselves and not their functions.

We use the performance characteristics that IS possess to do this. These characteristics also indicate how IS are considered and judged to be of benefit by organizations in collecting, processing, storing, retrieving and presenting information. For modeling IS, this thesis represents them as GRL *resources* with *indicators*. In providing information that is utilized to achieve goals, they act as resources while indicators are used to quantify their characteristics, which indicate how well they are performing (and hence their alignment level to business objectives). With these, we can show how well the organizations perceive the IS to be performing and, in doing that, how they are meeting desired business objectives, which is a measure of the IS-objectives alignment. When business objectives change and adaptation is required, the modeler can observe how the IS currently performs and quantify the performance level required to meet the new objectives.

The six characteristics used to measure IS success described by DeLone and McLean (1992, 2002, and 2003) are used in this thesis to represent characteristics of IS performance. DeLone and McLean’s work is a synthesis of various researches around IS success, covering different evaluation perspectives, and thus it represents a coherent body of knowledge. The authors provide elaborate and comprehensive means of measuring IS success with the use of six interrelated (rather than interdependent) success characteristics. The DeLone and McLean model is shown in Figure 25 below and identifies the interrelations of the six characteristics.

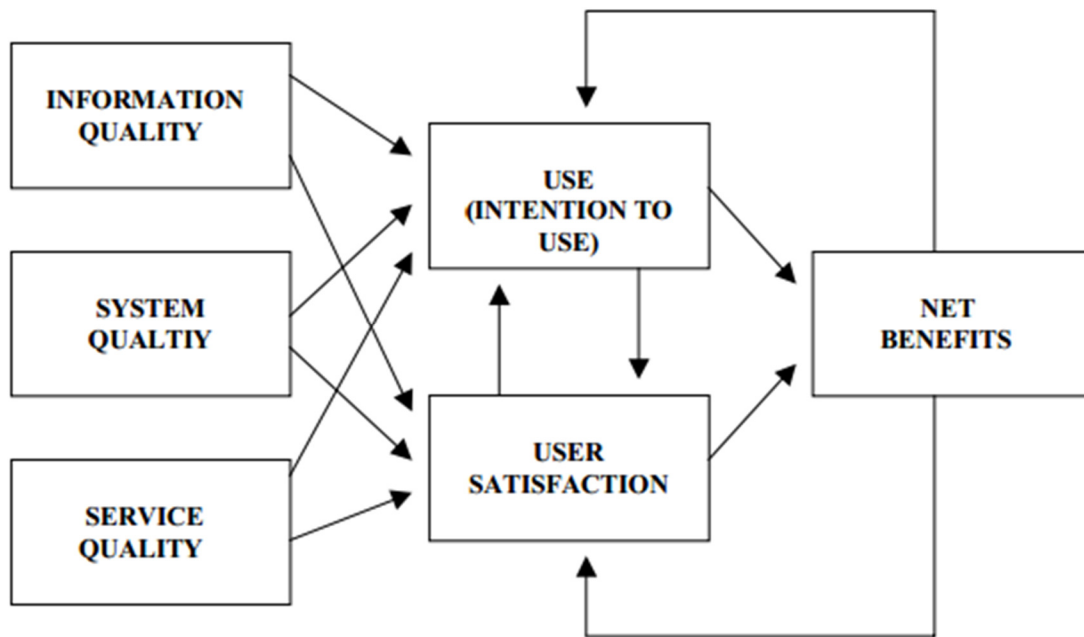


Figure 25: DeLone and McLean’s information system success model (DeLone and McLean, 2002).

The model has been found to be a useful framework for organizing IS success measurement, since amongst other benefits, it attempts to capture the multidimensional and interdependent nature of IS success (Delone and McLean, 2003). The characteristics are the following:

- **System Quality:** indicates characteristics such as reliability, flexibility, ease of learning, sophistication, feature of intuitiveness, etc.

- **Information Quality:** indicates characteristics of the information system output such as relevance, understandability, accuracy, completeness, usability, etc.
- **Service Quality:** indicates whether the quality of support the system users receive from IT personnel is responsive, accurate, reliable, provided with empathy, etc.
- **System Use:** indicates the degree and manner that all stakeholders utilize the capabilities of the information system in terms of amount of usage, frequency of use, nature of use, appropriateness of use, extent of use, purpose of use, etc.
- **User Satisfaction:** indicates the users' level of satisfaction with reports, websites, and data they get from the information system.
- **Net Benefits:** indicates the extent to which the information system contributes to the success of individuals, groups, and organizations that use it, in terms of improved decision-making, improved productivity, increased sales, cost reduction, etc.

As discussed in Section 2.5, these characteristics are modeled as KPIs, which GRL represents with . They are linked to each IS resource using contribution links. The comprehensive pairwise comparison done based on available literature relating to a variety of industries and IS by Peter et al. (2008), though generic, validates the use of the pairwise comparison approach described in Section 3.3.1 to determine the different weights each characteristic contributes to the IS. BI tools can be used to capture or compute values for some of these KPIs, as described by Johari (2012), who explains how to connect a commercial BI tool (IBM Cognos BI) to URN models in jUCMNav. Organizations can also create other indicators to measure elements of the six characteristics, which in turn contribute to the characteristics (in a tree-like fashion). Note however that, unlike what is implied in Figure 25, the IS KPIs used in our models are represented separately, in a flattened way, so we can better see how they all individually contribute to the IS total performance. Individual contributions are simpler to determine (e.g., through AHP) and understand by stakeholders. The contribution levels of each KPI, as well as their target, threshold, and worst-case values, can also vary from one information system to another.

Example

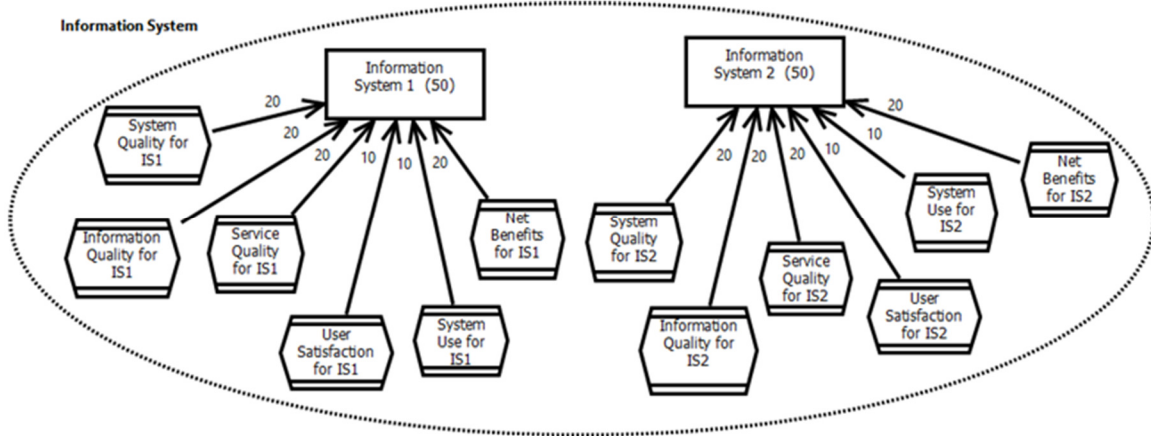


Figure 26: GRL model example of an Information System of the Grant and Implementation Program.

Figure 26 shows the IS from the GRL model example of the grants implementation program described in Section 4.1.1. It models the IS actor and the respective IS resources: “Information System 1” and “Information System 2”, which provide information utilized to achieve the business objective “Implement Grants Program” through tasks of the actors “Program Officer” and “Accountant”. It also shows the six characteristics of each IS, which are measuring the IS performance level via weighted contributions.

4.1.3 Evaluation of Modeled Constructs

The next step in the methodology is the evaluation or assessment of the current state of the modeled EA. It shows the satisfaction levels of the modeled business objectives, actions of decision makers, and IS performing in line with business objectives. It also shows the impact on the organization’s goals, softgoals, tasks or resources by the performance of the IS supporting them.

First, the model is checked against the OCL rules described in Section 3.3.2 to ensure it was built correctly. Then, GRL strategies are used to evaluate the degree of satisfaction or dissatisfaction of the business goals, softgoals, tasks, resources, IS and KPIs. These strategies define a set of initial values for the leaf elements of the GRL model (in this case the KPIs), and the values are then propagated to the decision level and higher level’s intentional elements in order to compute their satisfaction levels, using a bottom-

up propagation algorithm (Amyot et al., 2010). This GRL evaluation algorithm can be selected within jUCMNav as the “Quantitative GRL Algorithm”, as we are interested in quantitative evaluations of satisfaction levels. For the KPIs, the GRL strategies also have the value sets defined: the “Target Value” (used to specify the target the KPI should attain), the “Threshold Value” (specifying the least acceptable value for the KPI), and the “Worst Value” (specifying the maximum value of dissatisfaction for the KPI). The strategy also defines the “Evaluation Value” (specifying the actual measured value of the KPI). These values can be entered for the KPIs in jUCMNav manually, imported through an Excel sheet (Amyot et al., 2013), or derived and fed in from BI tools assessing the specific characteristics by the organization to generate a satisfaction value (see Table 10).

Table 10: Sample list of values for KPIs of an IS.

	Target Value	Threshold Value	Worst Value	Evaluation Value
System Quality	100	75	50	80
Information Quality	100	75	50	90
Service Quality	100	75	50	75
User Satisfaction	100	75	50	80
System Use	100	75	50	90
Net Benefits	100	75	50	75

An actual measured value for the KPI between the “Threshold value” and the “Target value” for any characteristics indicates that the IS tends to perform satisfactorily in line with the business objectives of the organization for that characteristic. An actual measure value between the “Threshold value” and the “Worst Value” for any characteristics indicates that the IS tends not to perform satisfactorily for that characteristic. These satisfaction or dissatisfaction levels of the KPIs are then propagated to the IS resource, Decision level and High level intentional elements to compute the satisfaction levels of the EA according to the goal evaluation algorithm in Amyot et al. (2010). The satisfaction or dissatisfaction levels are represented with numerical values between 0 (indicating a full dissatisfaction level) to 100 (indicating a full satisfaction level). Color coding varying from

red (0) to yellow (50) to green (100) also indicates the evaluations levels of the intentional elements as dissatisfied, neutral or satisfied.

A comparison between an ideal scenario, where all GRL elements are fully satisfied can be used as a base with which to compare the “As is Scenario” of the EA to see how well it currently operates in comparison to an ideal scenario.

Example

Figure 27 illustrates the GRL model described in Figure 24, checked to ensure it conforms to all defined OCL rules.

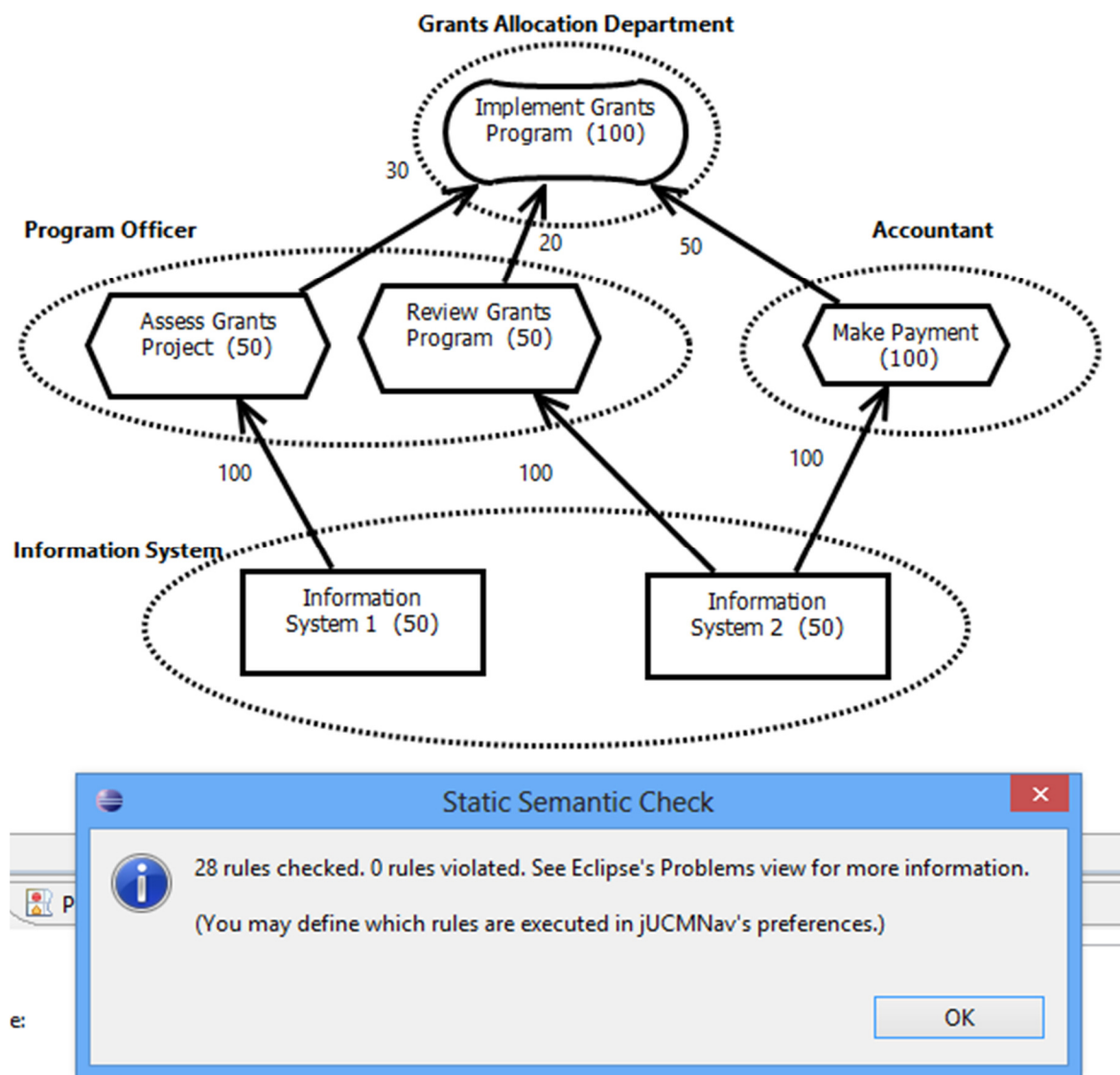


Figure 27: GRL model in conformity to selected OCL rules.

Figure 28 illustrates the GRL model for one of the IS resource and its six KPIs. The KPIs are initialized using the values in Table 10. Their propagated contributions indicate the level of satisfaction of the resource “Information System 1” and the actor “Information System” performing in line with the organization is at a satisfaction level of 59 out of a possible 100. The region enclosed within the red box (in the Properties view of Eclipse) shows the respective evaluation value, target value, threshold value and worst value for the “Service Quality” KPI of “Information System 1”.

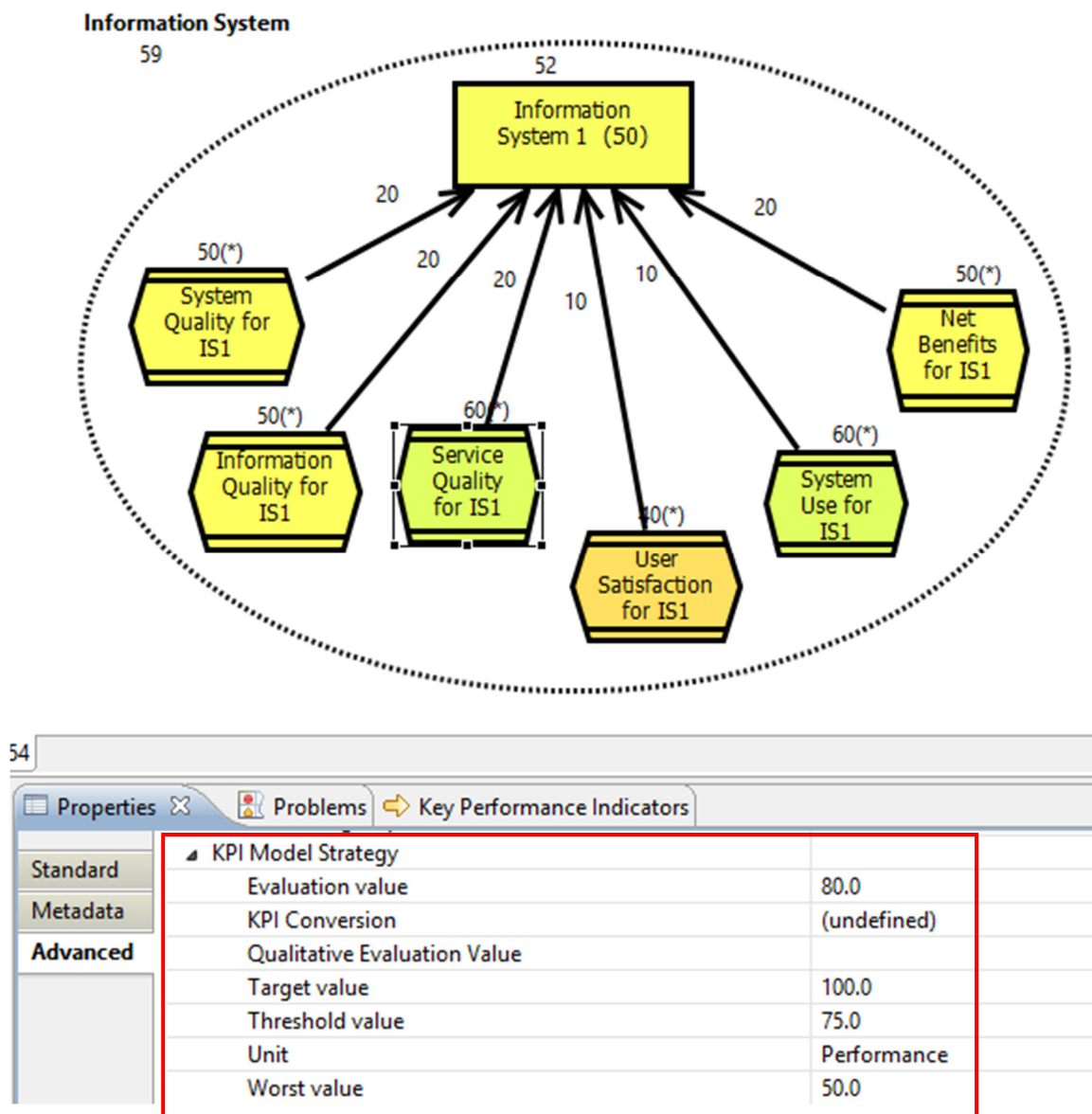


Figure 28: GRL model example of an IS with a GRL strategy indicating satisfaction of the KPI and IS.

Figure 29 and Figure 30 illustrate the evaluated GRL model (indicating IS, Decision and High levels) with propagated values from the KPI. Figure 29 indicates the current satisfaction level while Figure 30 shows an ideal scenario where the EA is fully satisfied. Both models can be compared using jUCMNav’s “Strategy Difference Mode” (Amyot et al., 2011). Figure 31 shows a model comparing Figure 29 and Figure 30. It indicates how much the model with the current As Is scenario deviates from the fully satisfied model, and what satisfaction levels need to improve (and by how much, as shown between angle brackets < and >) to attain the ideal scenario.

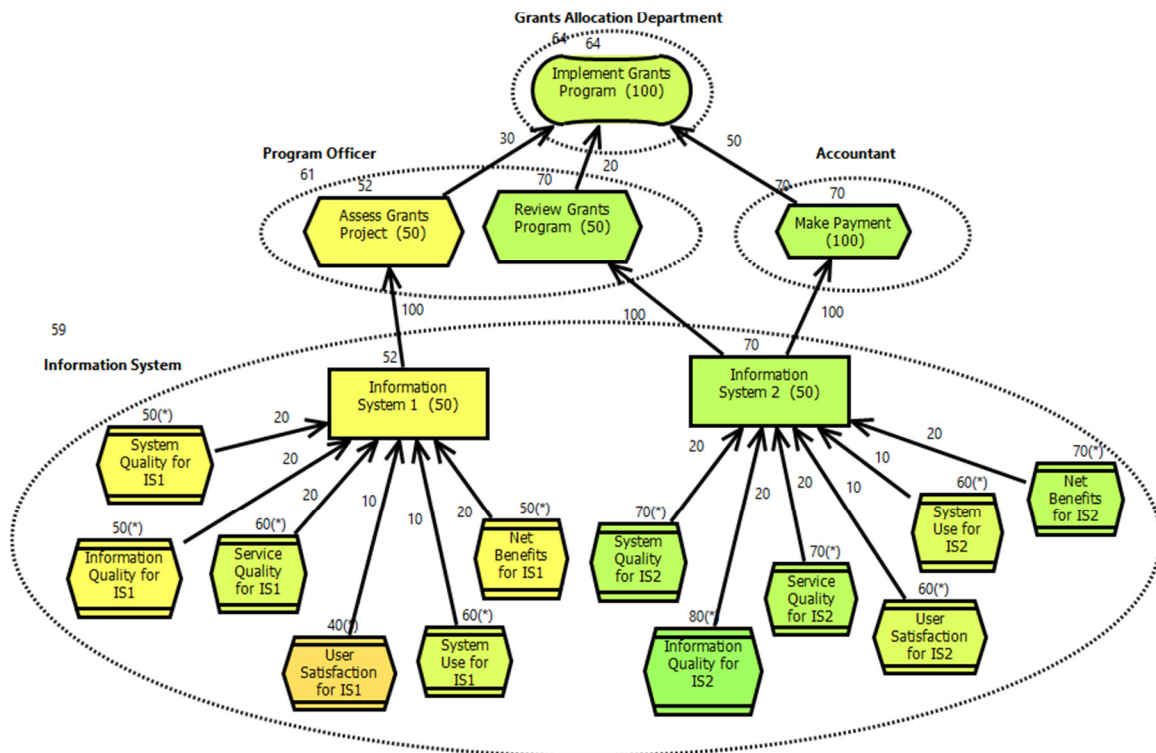


Figure 29: Sample model showing current satisfaction level of the IS, Decision Maker's and High Level.

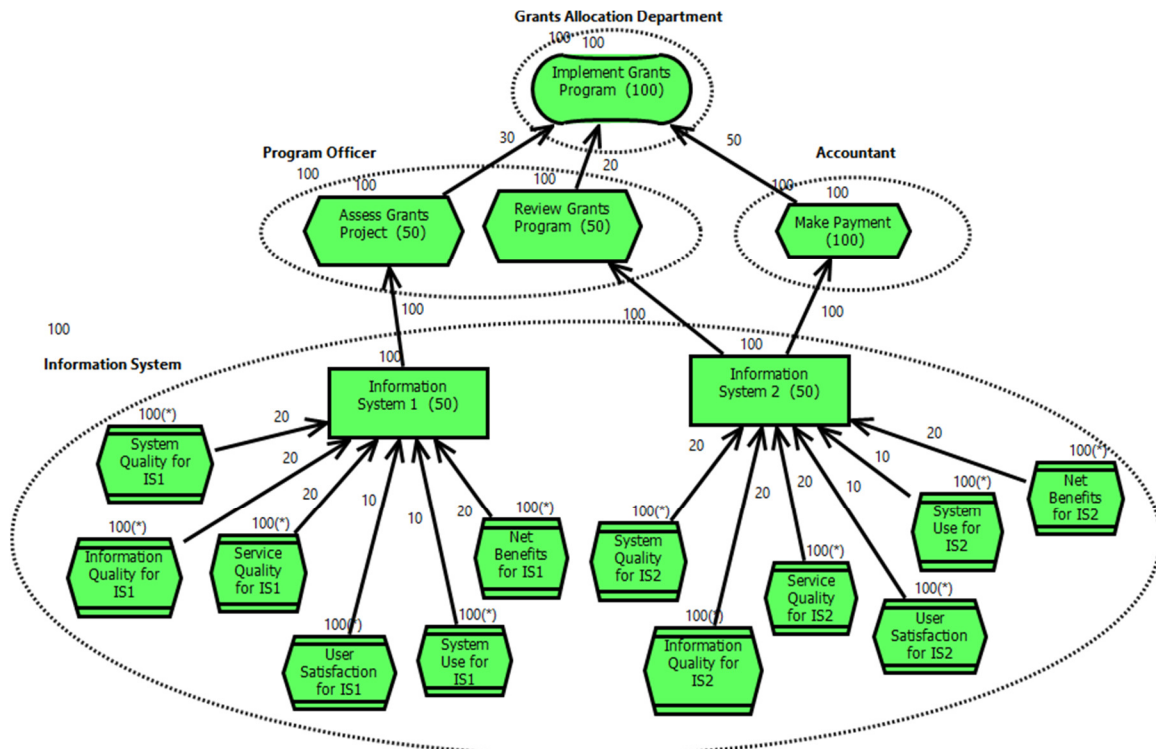


Figure 30: Sample model showing an ideal satisfaction of the IS, Decision Maker's and High level.

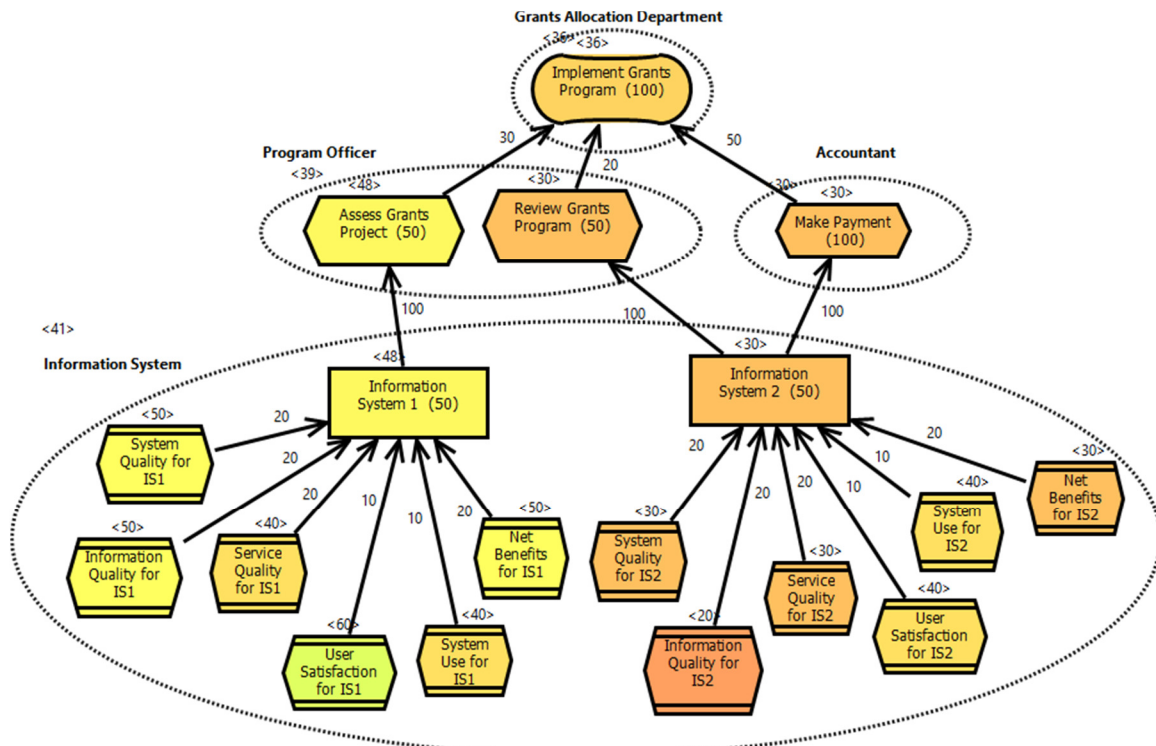


Figure 31: Model showing the difference between the As-Is and full satisfaction levels.

4.2. The “To Be Scenario” Phase

The second phase of the methodology, the “To Be Scenario”, shows how the model responds to the needs for change in the enterprise. It also presents the adapted state, showing the impact of these changes. Interestingly, the “To Be Scenario” becomes the new “As Is Scenario” with every new change requiring adaptation. As described, these adaptations are observed as modifications, deletions or additions in the 3 levels within the enterprise: the organization’s business objectives (High level), actions of decision makers in achieving these objectives (Decision level) and, lastly, the IS providing the information utilized (IS level).

4.2.1 Evaluation of Potential Impacts of Modeled Constructs - Modification

Modifications often occur within organizations. As described, they occur in the 3 levels of the organization as an increase or a decrease in importance levels or attributed priority. They can also occur as needs to have higher or lower satisfaction levels. These results in some increase or decrease in the importance level of the modeled GRL intentional elements, weights of their contributions links, or their satisfaction levels in strategies. The model responds to these through checking against defined OCL rules for violations and through the use of evaluation strategies within jUCMNav, which indicate the potential increase or decrease in satisfaction levels. This allows for monitoring the impact of the potential change (*what-if* analysis), while making sure the model is still used in line with business objectives.

Using the fictitious grants and implementation program of Section 4.1, we show below the three main categories of modifications:

1) Modification of importance levels

As business needs evolve, stakeholders begin to look at other possibilities or alternatives as ways to respond to the needed change. This could result in changing the *importance* (represented between parentheses in GRL intentional elements) they give to objectives being achieved, decisions currently taken, or IS in use. To adapt in such context, using the pairwise comparison approach described in Section 3.3.1, new importance levels can be computed in the model. jUCMNav eval-

uation strategies are then used to evaluate the impacts of the new situation in terms of satisfaction levels.

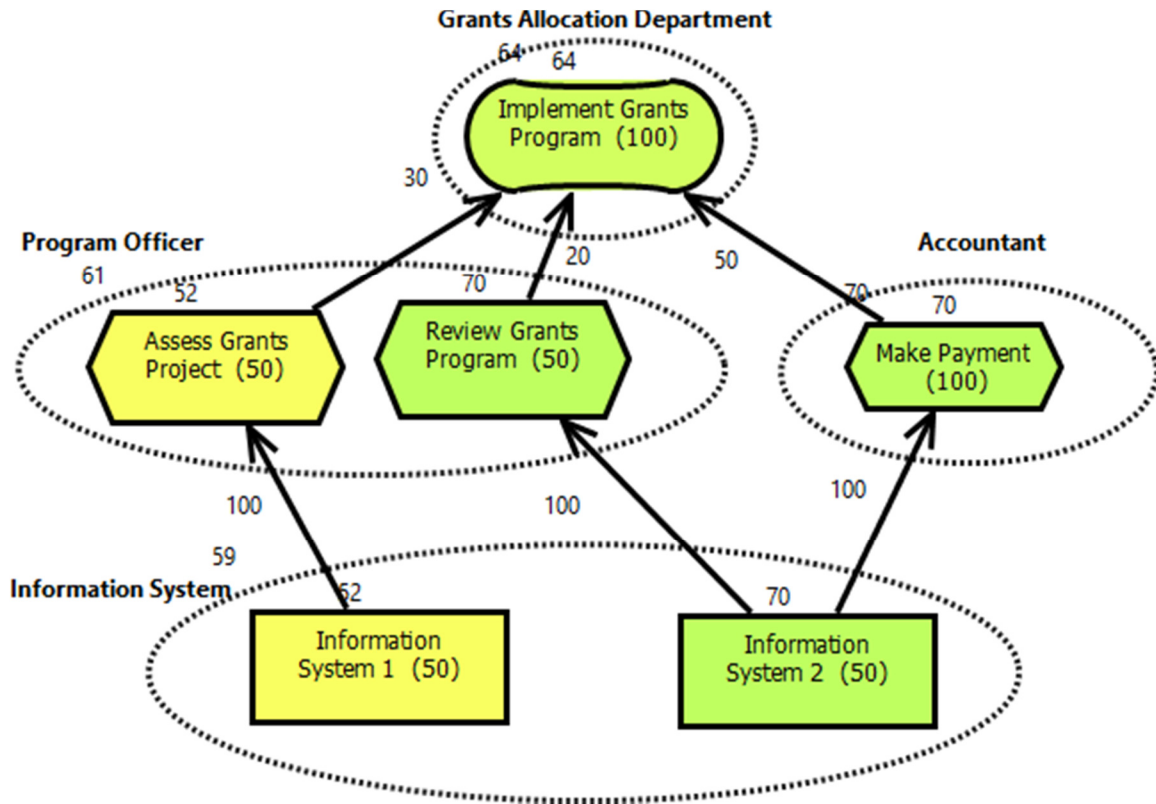


Figure 32: Model before modification of importance levels.

Consider the model in Figure 32. As the business evolves, in contributing towards satisfying the “Implement Grants Program” softgoal, the “Program Officer” may be required to have a higher satisfaction level. In response to this change, he may have to change the importance levels of the “Assess Grants Project” and “Review Grants Project” tasks. Upon pairwise comparison for new importance levels, Figure 33 and Figure 34 illustrate modeled and evaluated impacts of the new satisfaction levels using jUCMNav evaluation strategies. We observe a decrease in the satisfaction level from 61 to 51 when the importance level of the “Assess Grants Project” is higher than the “Review Grants Program” (70 to 30). There is an increase from 61 to 64 when the importance level of the “Review Grants Program” is higher than the “Assess Grants Program (70 to 30). With this information, the “Program Officer” is now informed of the impact of this change and can better decide between both alternatives to get the required higher satisfaction level.

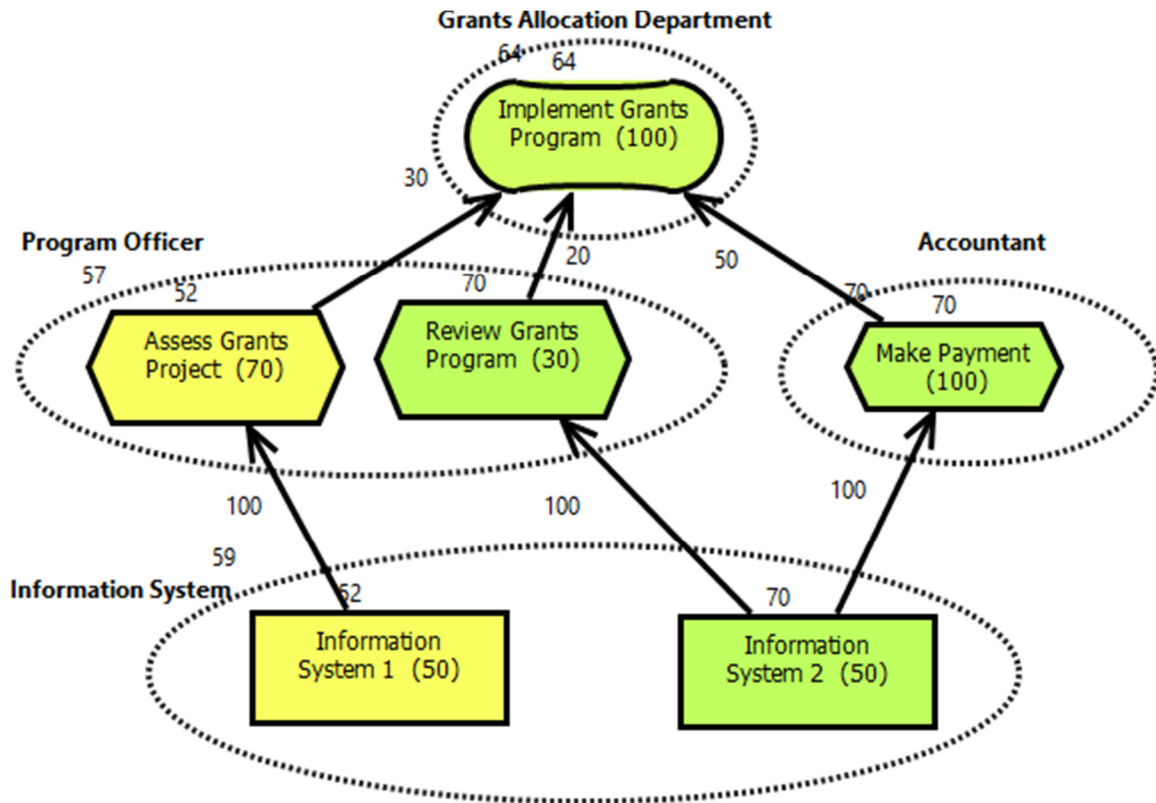


Figure 33: Model after modification of the “Assess Grants Program” importance level.

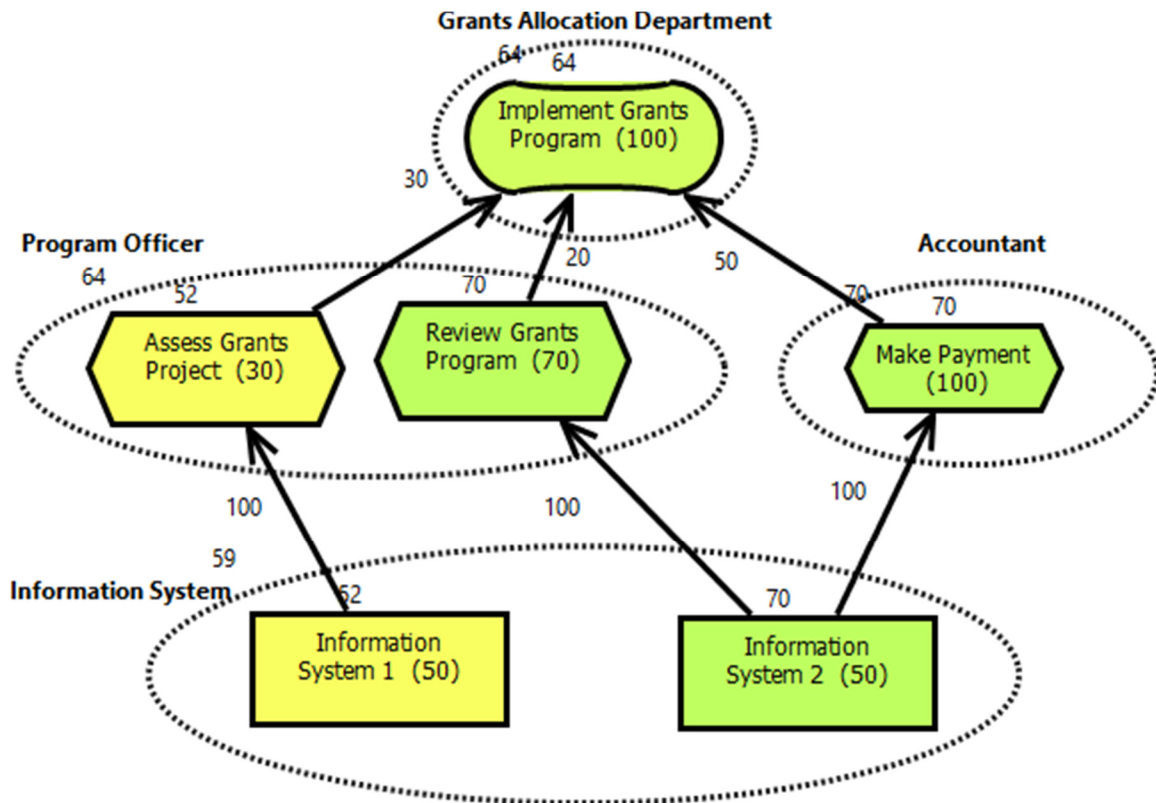


Figure 34: Model after modification of the “Review Grants Program” importance level.

2) Modification of contribution weights

With changing business needs, the contributions to a decision maker's actions by an IS or to a business objective by the decision maker's actions might need to increase or decrease. Also, a KPI's contribution to an IS might need to increase or decrease as well. To adapt to this context, as for the modification of the importance levels, pairwise comparisons are used to compute new contribution weights. The profile's OCL rules within jUCMNav are used to check for violations after implementing this adaptation. jUCMNav evaluation strategies are then used to evaluate the impacts on the enterprise.

Consider the model in Figure 32. As the business evolves, if the nature of the softgoal "Implement Grants Program" changes slightly, the weights of the contributions of the actions by the "Program Officer" and "Accountant" may have to be reassessed.

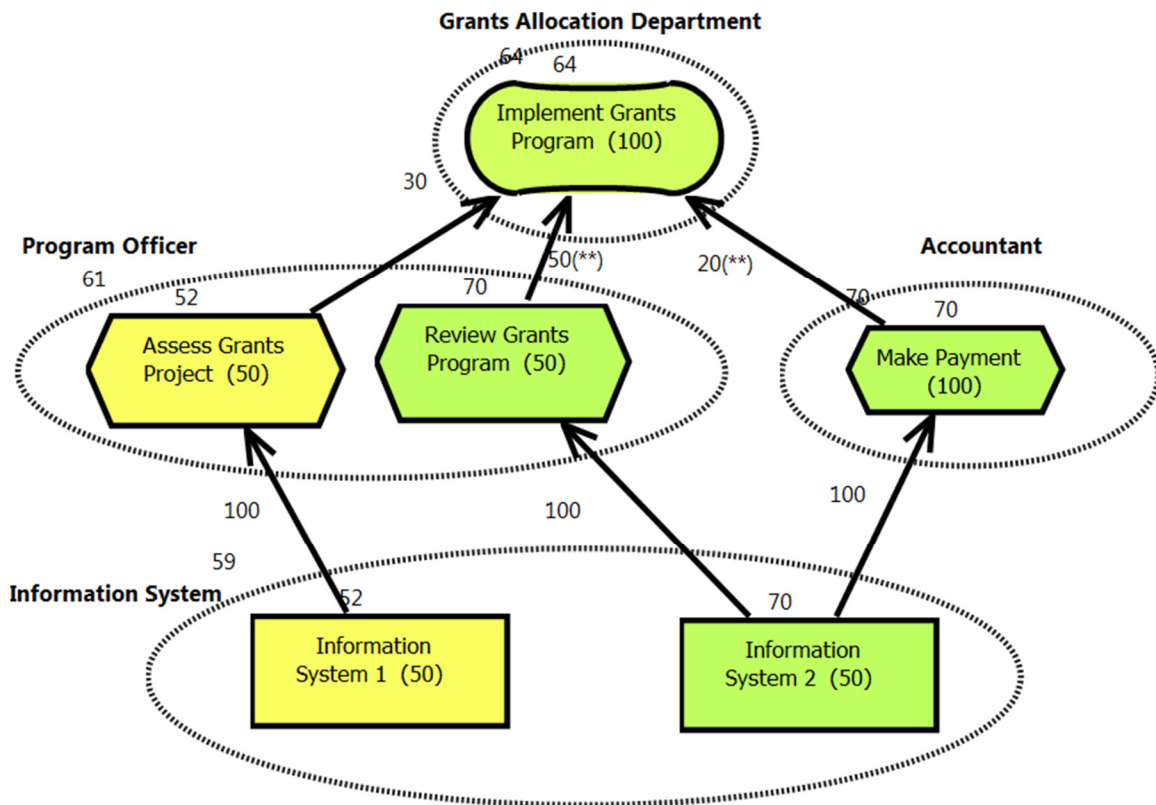


Figure 35: Model with increased and decreased contribution weights.

After a pairwise comparison for new contribution weights, these changes can be implemented in jUCMNav using contribution overrides (a lightweight but standardized mechanism that enables one to define sets of changes to contribution weights and apply them to the model, without changing the model – see Amyot et al., 2012), the model could be as shown in Figure 35. In jUCMNav, overridden contribution weights are indicated with (**). In this example, the 20 and 50 contributions to the softgoal were inverted.

The stakeholders are informed that increasing the priority of the “Review Grants Program” (by increasing the corresponding contribution level) and decreasing the priority of the “Make Payment” task does not affect the satisfaction level of the “Implement Grants Program” in the current context. In fact, the “Strategy Difference Mode” within jUCMNav can be used to view the impact of this modification on the satisfaction levels; Figure 36 highlights the fact that there are no differences anywhere.

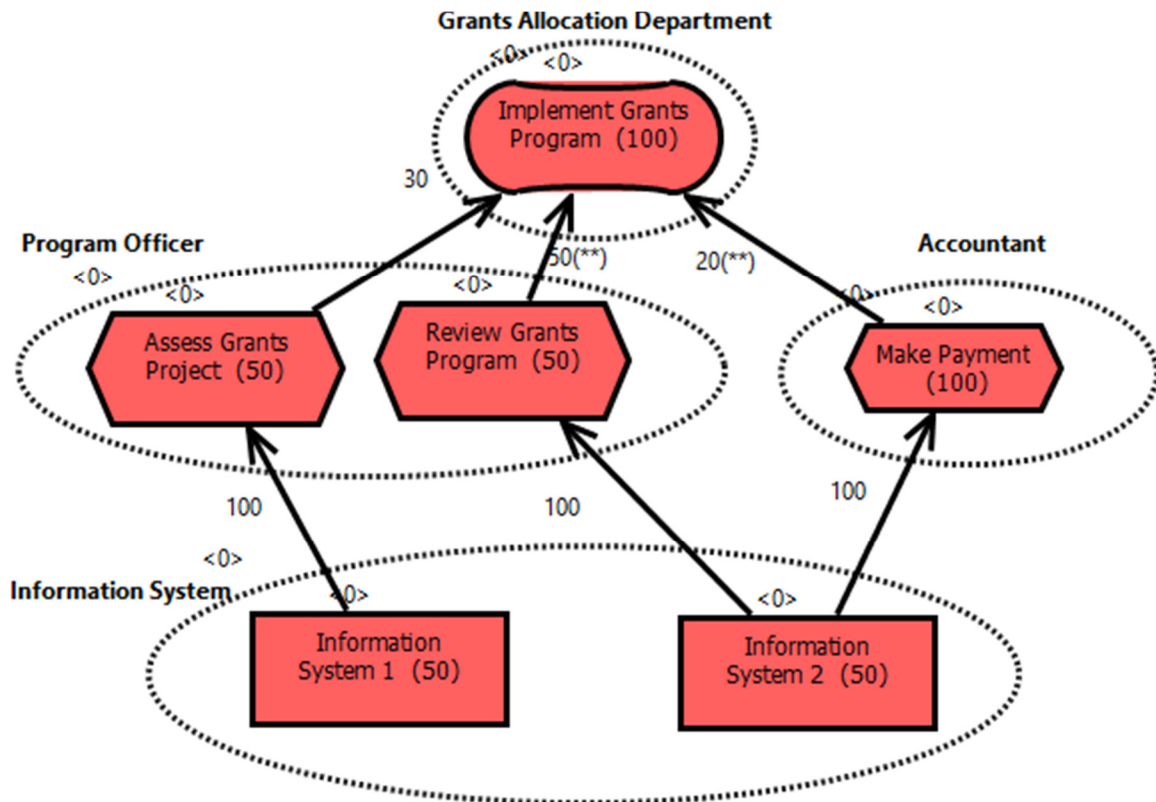


Figure 36: Impact on model showing the comparison of increase or decrease in contribution weights in Figure 35.

3) Modification of satisfaction levels

Changing business needs could require a satisfaction level of a modeled intentional element in any of the 3 levels of the enterprise to increase or decrease to a certain level. While the continuous monitoring of KPIs values can indicate an observable trend in increase or decrease (and such trends can also be visualized with jUCMNav, see Amyot et al., 2013), stakeholders might require knowing what impacts a target satisfaction level has on the enterprise.

With the possibility of this occurring at any of the 3 levels, the GRL bottom-up propagation algorithm (Amyot et al., 2010) does not show what needs to change in lower levels if required changes occur in the top levels. The modeling of the links from IS to decisions to business objectives show what connecting modeled intentional elements need to change to achieve this. The work by Luo and Amyot (2011) on a top-down and inside-out evaluation strategy, named “Constraint-Oriented GRL Algorithm” in jUCMNav, provides the best suited analysis in such situations. Executing the algorithm indicates for a required satisfaction level what connecting elements need to change, with a possible satisfaction level needed to support this required change. Unfortunately the current implementation of this algorithm does not scale well for large, complex models.

Consider a desired satisfaction level of 80 (instead of 52) for the “Assess Grants Project” task of the “Program Officer as shown in Figure 37, and highlighted in a dashed red outline in jUCMNav.

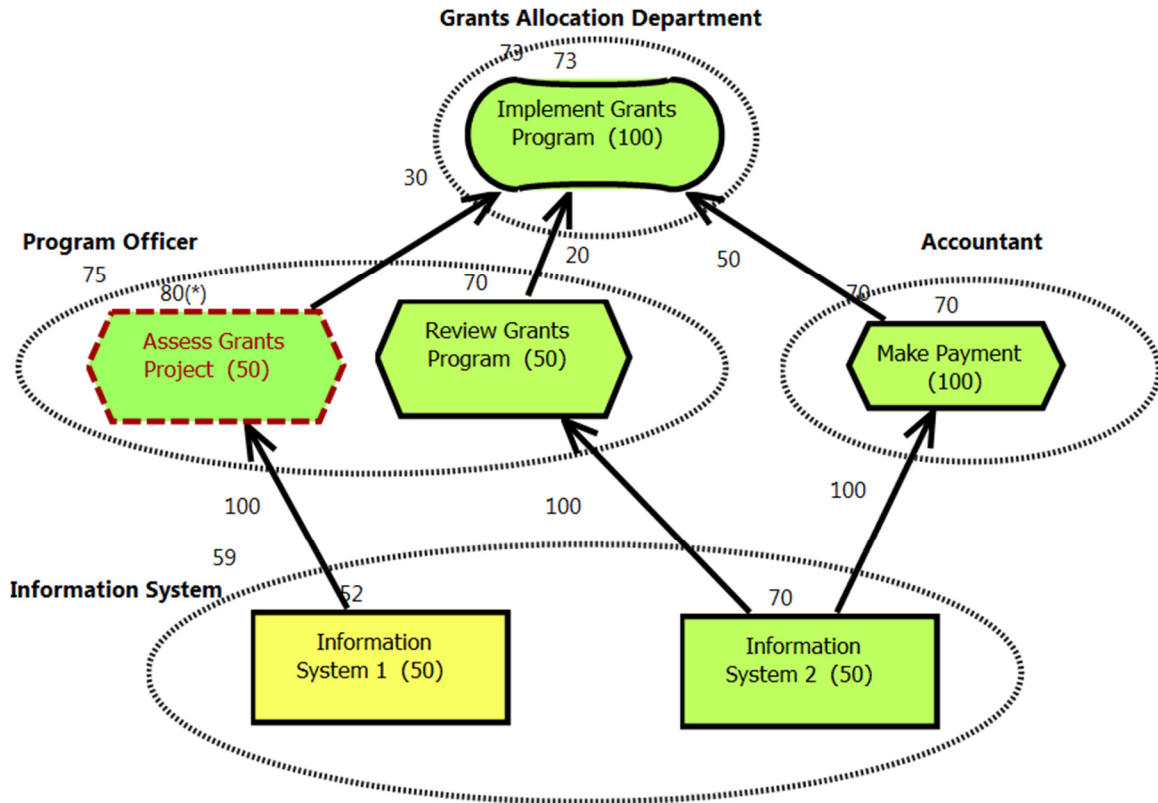


Figure 37: Model with a desired satisfaction level for an intentional element.

Upon viewing the model, we can see the impact of this increase in satisfaction level of the task. The “Program Officer” decision maker will have his satisfaction level increased from 61 to 75 while the “Implement Grants Program” objective will have its satisfaction level increased from 64 to 73. Looking at the links we see that the performance of the resource “Information System 1” needs to increase to achieve this. Using the “Constraint-Oriented GRL Algorithm” in Figure 38, we see the modeled intentional elements that will be affected by this desired satisfaction level.

The intentional elements are blue because, given the constraints coming from the KPIs initialized in the current strategy, the algorithm cannot find a solution that will lead to a value of 80 for this task. This conflict is indicated by the light blue color and -101 satisfaction level of modeled intentional elements affected by this change. This indicates that some constraints (i.e., some KPI initial val-

ues in the strategy) must be *removed* for providing the required flexibility to find a solution.

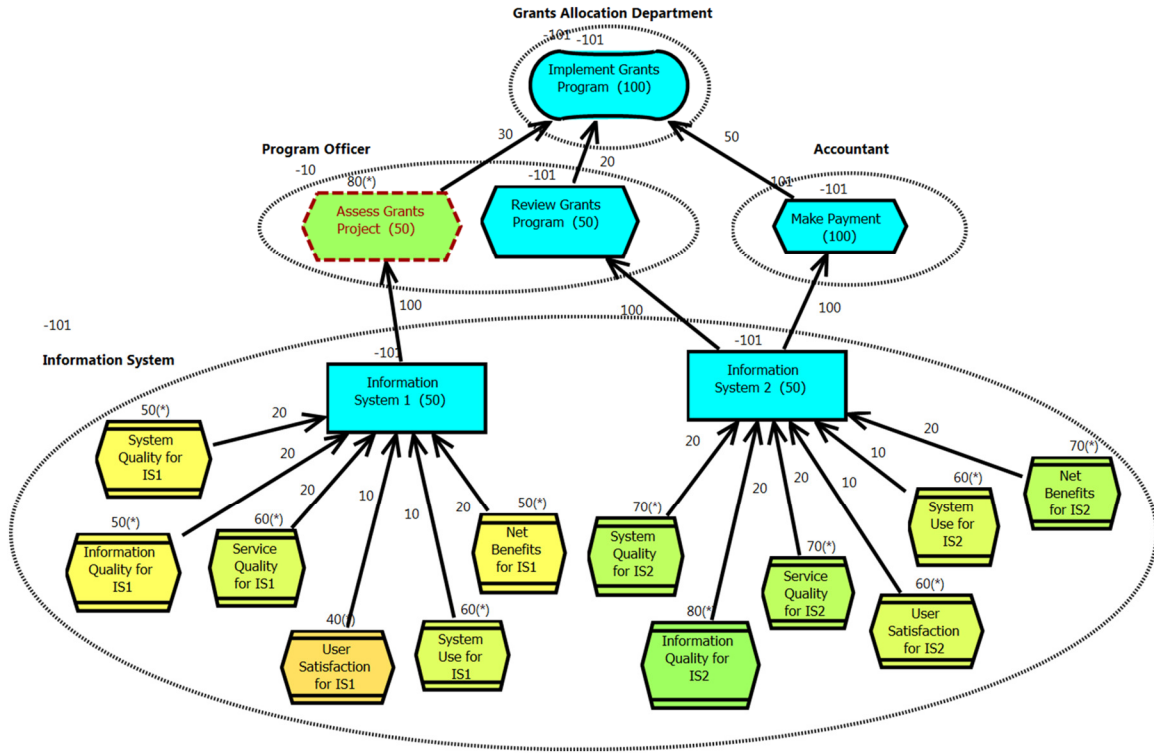


Figure 38: Model evaluation for a desired satisfaction level for an intentional element using the “Constraint-Oriented GRL Algorithm”.

Figure 39 shows a possible solution to achieving this desired satisfaction level by removing from the GRL strategy the satisfaction values of the “System Quality”, “Information Quality” and “Service Quality” KPIs of the resources “Information System 1”. In this example, the algorithm indicates that these three KPIs must have a satisfaction of 100 (if the other three KPIs for “Information System 1” remain the same) for the “Assess Grants Project” task to reach a satisfaction of 80. In terms of KPI characteristics such as those in Table 10, this means that, for IS1, the current KPI Evaluation Value of each of these three indicators must be equal or better than their respective KPI Target Value. Figure 40 shows a model comparison indicating exact amount of required increase, in terms of satisfactions levels. Flexibility (i.e., fewer constraints) could be given to different subsets of IS1’s KPIs, to assess various alternatives in trying to meet the required objective.

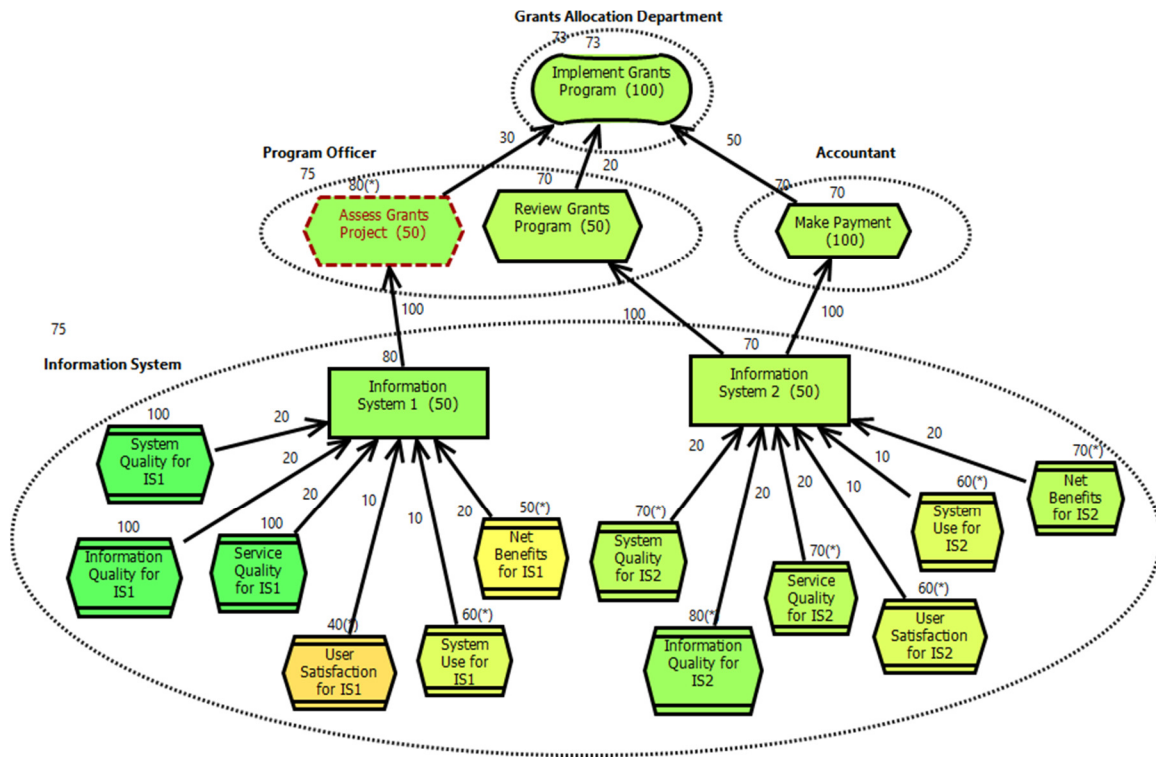


Figure 39: Possible solution to achieve desired satisfaction level by increasing KPI satisfaction levels.

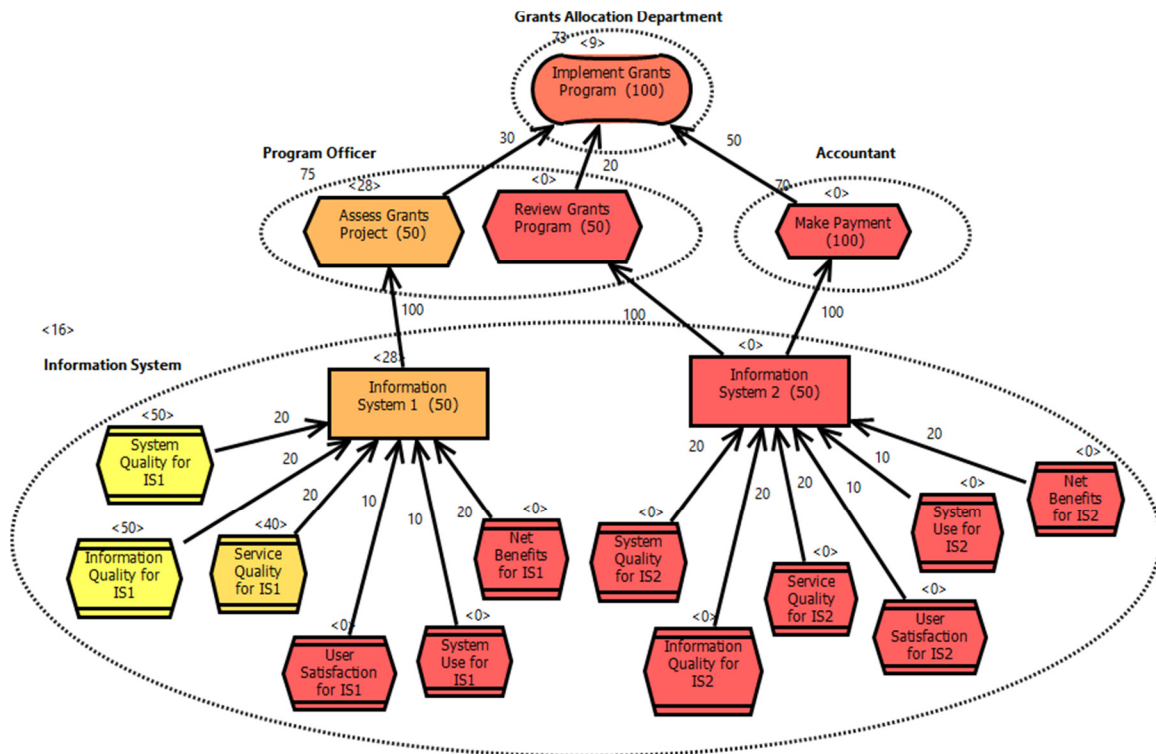


Figure 40: Comparison of desired satisfaction level to current satisfaction level.

4.2.2 Evaluation of Potential Impacts of Modeled Constructs - Deletion

Deletions as forms of changes requiring adaptation also occur in organizations. They take the form of achievement of business objectives, i.e., realization that objectives are no longer needed in the High level. In the Decision level, they appear as actions that have been completed or that are not needed again, and in the IS level as decommissioned or failed IS. When these occur, they have to be removed or deleted from the model. These actions change the structure of the model as intentional elements or contributions weights are removed, requiring the creation of another copy of the model. As in modifications, the model responds to these through checking against defined OCL rules for violations and the use of evaluation strategies within jUCMNav, which indicates the potential deletion. This as well allows for monitoring the impact of the potential change, while making sure the model is still in line with business objectives.

Using the fictitious grants implementation program of Section 4.1, we show below the two main categories of deletions:

1) Deletion of modeled intentional elements

As described in sections 4.1.1 and 4.1.2, GRL intentional elements are used to represents the organization's business objectives, decision maker's actions and IS. These intentional elements could be goals, softgoals, resources, tasks and KPIs. As such, they can be deleted or removed from the model as indicative of the objective, decision or IS being no longer considered relevant by the enterprise for any of the reasons described earlier.

For the sample model in Figure 32, consider the situation where a change in business needs requires the resource "Information System 2" to be decommissioned, illustrated in Figure 41 as a removal of "Information System 2" along with its KPIs and contribution links. The model responds with checking OCL rules for any violations and indicates that the sum of importance values for the actor "Information System" is less than 100. Also the modeler can observe a reduction (from 70 to 0) in satisfaction levels of the "Review Grants Program" and "Make Payment" tasks which "Information System 2" supports; a clear hint that something is missing. There is additional reduction in the sat-

isfaction levels of the actors “Information System” from 59 to 52, “Program Officer” from 61 to 26, “Accountant” from 70 to 0 and “Grants Allocation Department” from 64 to 15 as well. With this information and based on the existing requirements in play within the organization, the modeler either determines if the existing IS in place (“Information System 1”) can evolve to contribute to the existing task or if a new IS is required to contribute to the existing tasks, or if a mix of the existing IS and a new IS is what is required.

With the chosen solution to address this deletion, pairwise comparisons are done to compute new importance levels or contributions weights as required. jUCMNav evaluation strategies are then used to evaluate the impacts of the deletions on the enterprise. Since a deletion affects the structure of the model requiring creation of a new model, Figure 42 shows a model comparison using jUCMNav of the model before and after deletion. This comparison informs the modeler on the differences in the model versions such as element attributes, individual intentional elements, and strategies affected by the deletion.

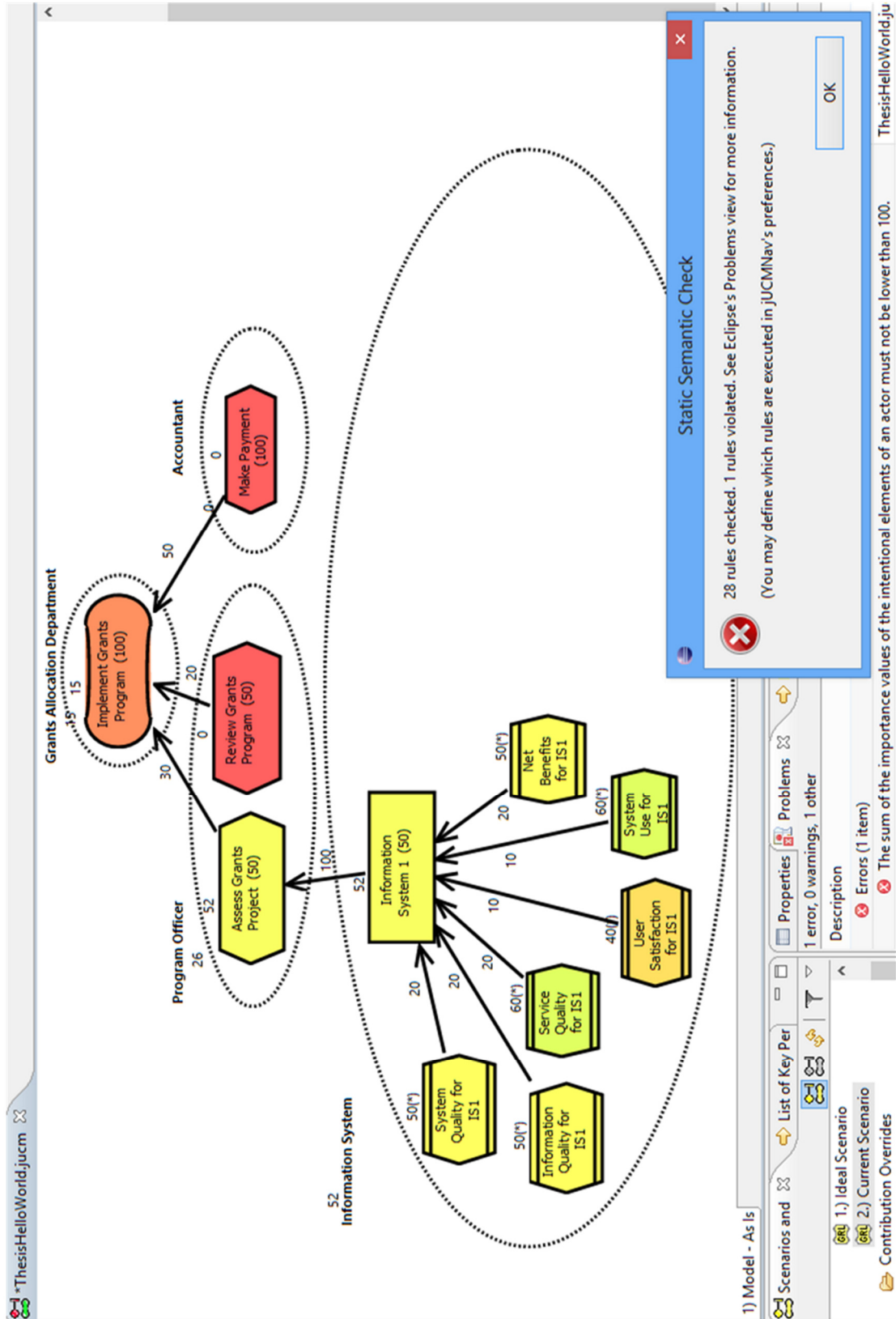


Figure 41: OCL rules showing violations after deletion of an IS, its KPIs and contribution links.

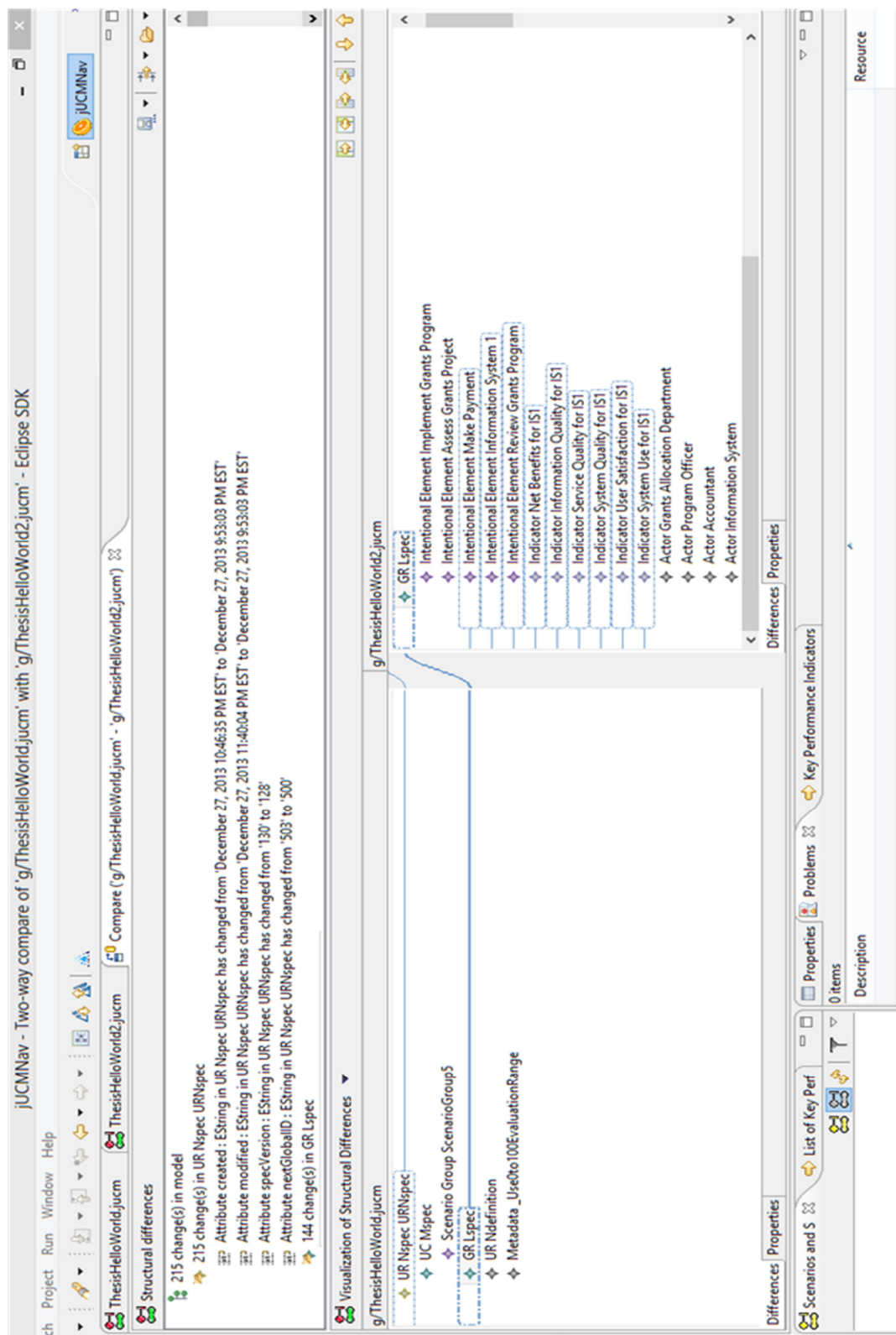


Figure 42: Models comparison showing all differences between the model before and after deletion.

2) Deletion of contribution links

The need for change as the business evolves in terms of deletion is presented as a decision maker no longer contributing to a high-level objective or an IS no longer contributing to a decision maker's actions. These forms of deletion cannot occur in the IS level with KPIs contributing to an IS resource as described in Section 4.1.2. This is because the six characteristics exist with their respective IS at the same time. To adapt to such deletions, the model uses jUCMNav contributions override strategies to set the contribution weights to 0. If necessary (and if feasible in the enterprise), pairwise comparisons are used to compute the contribution weights of the destination intentional element to conform to defined OCL rules. jUCMNav evaluation strategies are then used to evaluate the impact of the deletion.

Considering the model described in Figure 32, if changing business needs requires the resource "Information System 1" to stop contributing to the task "Assess Grants Project", illustrated in Figure 43 with a contribution weight of 0. The impact of this deletion is observed as the dissatisfaction level of 0 for the task "Assess Grants Project" and reduction in satisfaction level of the actor "Program Officer" from 61 to 35. It also includes reduction in the satisfaction level of "Implement Grants Program" and "Grants Allocation Department". Again, this indicates where improvement is now needed, maybe through contributions of an existing system or the introduction of a new one.

Note that an actor could also be deleted (reflecting the fact that that a stakeholder in the High level or in the Decision level is no longer relevant or available. In this case, the actor's intentional elements with their links are deleted, as explained above.

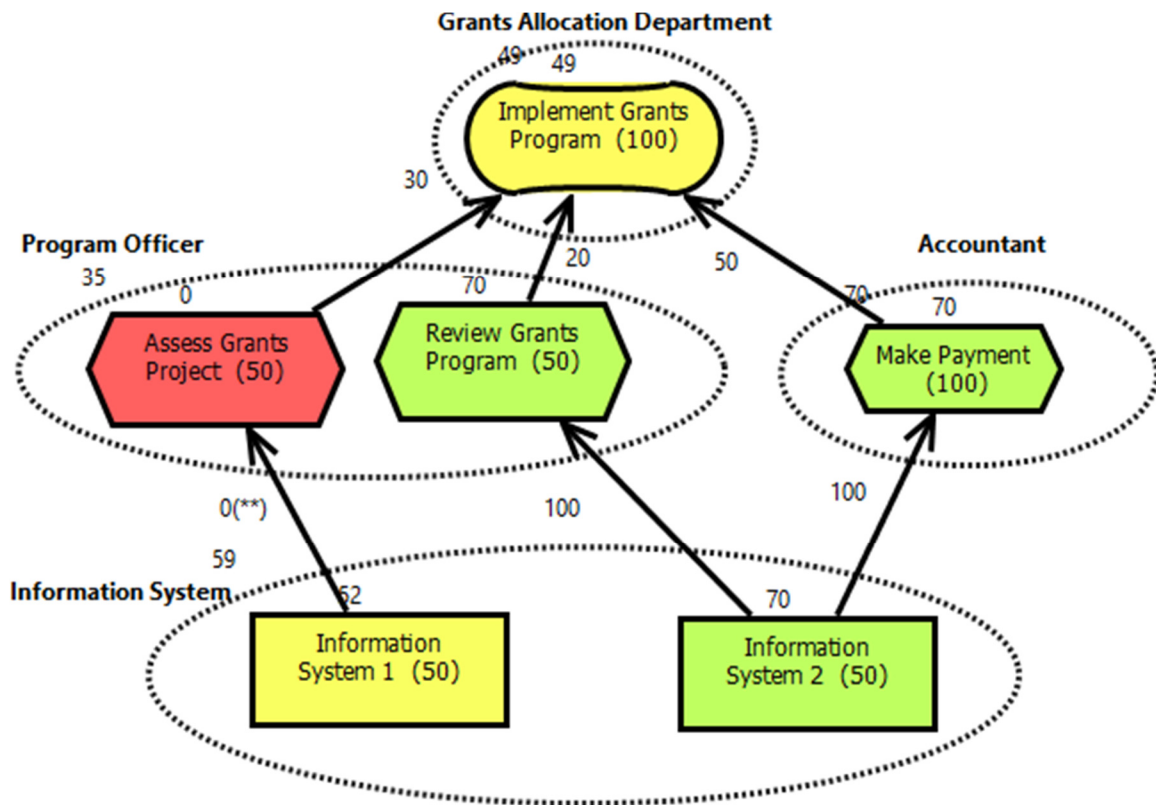


Figure 43: Deletion of contributions from an IS to a decision maker's task.

4.2.3 Evaluation of Potential Impacts of Modeled Constructs - Addition

Additions do occur within the organization. They imply that the organization is interested in pursuing new business objectives, that decision makers are making new decisions, that new IS have been acquired, or that a new actor with a different mandate is now involved. Additions, like deletions, also change the existing structure of the model, hence needing the creation of a new model. The representation and analysis of the impact of additions takes the same form as described in sections 4.2.1 and 4.2.2 for modifications and deletions. This time, such additions could lead to extra capacity in the EA, giving opportunities for further changes (e.g., decreases) in other aspects of the organization.

Consider the model described in Figure 32. Assume the changing business needs require the actor “Accountant” to have a new task “Review Payments”. The respective importance levels and contributions weights are computed using pairwise comparisons, as shown in Figure 44. jUCMNav’s evaluation strategies are also used to evaluate the impacts of this addition.

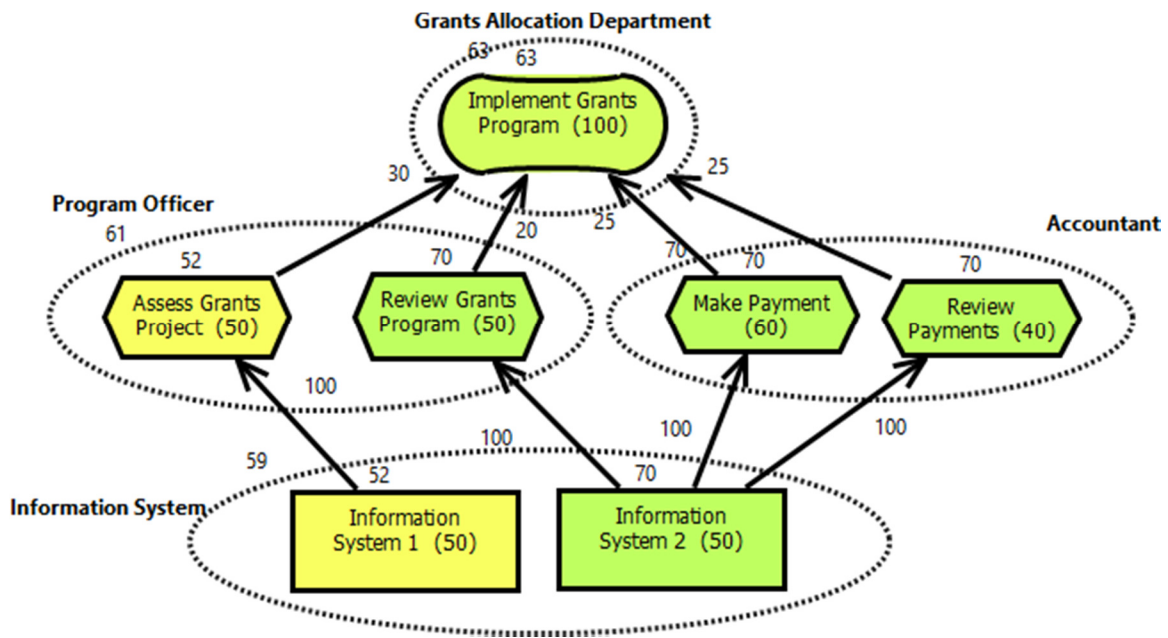


Figure 44: Model showing the addition of a new task, with new contributions and re-assessed importance levels and contribution weights.

4.3. Summary

Adaptation involves responses to change by modifying, deleting or adding business objectives, decision makers' actions towards achieving objectives, or the IS that provide the information utilized to achieve these objectives. This chapter described the steps of the methodology for the Business Intelligence Adaptive Enterprise Architecture framework. It showed how the model is built and evaluated. The chapter also showed how the model responds to adaptation as well as how the methodology evaluates impact on the enterprise as a result of adaptation.

We observe that these instances of modification, deletion and addition can appear in the *IS level* as requirements to increase or decrease the importance level of the KPIs or IS resources, or of contribution weights from the KPIs to the IS resources. They can also appear as deletion (or decommission) of an IS resource along with its KPIs and their contribution weights or the addition of an IS resource with its KPIs and their contribution weights. Similarly, these changes in importance levels or contribution weights, deletion or addition of an actor or intentional elements (goals, softgoal, task, resource) along with their importance levels or contribution weights, appear in the *Decision* and *High level*.

Twenty-three of these instances of modification, deletion and addition can occur. They are, in the *IS level*: modifications such as requirements to increase or decrease the evaluation values of the KPIs, increase or decrease importance levels of the IS resource, and increase or decrease of the satisfaction levels of IS resource. They also include increase or decrease of the contribution weights from the KPIs to the IS resource. There are also deletions such as requirements to delete an IS resource, its KPIs and their contribution weights, as well as additions of an IS resource, its KPIs and their contribution weights. Note that KPIs cannot be added as their number is fixed for each IS. In the *Decision level*, we find: modifications such as requirements to increase or decrease the importance levels of the decision-makers intentional elements, increase or decrease of their satisfaction levels, and increase or decrease of contributions weights from the IS resources. Deletions such as requirements to remove an actor along with its intentional elements, their importance and satisfaction levels, deletion of an intentional element, its importance and satisfaction levels, and deletion of contribution weights from an IS resource. Additions such as requirements to add an actor along with its intentional elements, their importance and satisfaction levels, addition of an intentional element, its importance and satisfaction levels and addition of contribution weights from an IS resource.

In the *High level*, we find: modifications such as requirements to increase or decrease the importance levels of intentional elements, increase or decrease their satisfaction levels or increase or decrease the contribution weights from the *Decision level*. Deletions such as requirements to remove an actor along with its intentional elements, their importance and satisfaction levels, deletion of an intentional element, its importance and satisfaction levels and deletion of contribution weights from the *Decision level*. Additions such as requirements to add an actor along with its intentional elements, their importance and satisfaction levels, addition of an intentional element, its importance and satisfaction levels and addition of contribution weights from the *Decision level*.

We can therefore categorize these occurrences of modification, deletion and addition into seven groups based on their pattern of appearance in the *IS*, *Decision* or *High levels*. Table 11 provides a categorization of these changes, the steps the model takes to adapt to them, as well as corresponding automated responses based on jUCMNav.

Table 11: Summary of types of adaptation and automated responses

Change Need	Adaptation	Automation
Modification of importance level of a High level, Decision level or IS level modeled intentional element.	1) Locate goal, decision or IS. 2) Increase or decrease importance level as required. 3) Check the sum of importance level. 4) Execute As Is Strategy.	2) Pairwise comparison to compute new levels. 3) OCL rule checks violation. 4) jUCMNav evaluations to indicate impact.
Modification of the contribution weights to a High level, Decision level or IS level modeled intentional element.	1) Locate contribution. 2) Increase or decrease contribution link. 3) Check the sum of contribution links to goal, decision or IS. 4) Execute As Is Strategy.	2) Pairwise comparison to compute new values. Use of jUCMNav contributions overrides for new weights. 3) OCL rule checks violation. 4) jUCMNav evaluations to indicate impact.
Modification of the KPIs definitions or current evaluations.	1) Change in KPI values as fed by BI System (or manual increase or decrease). 2) Execute As Is Strategy.	1) Feeds from BI systems. 2) jUCMNav evaluations (quantitative GRL algorithm) to indicate impact.
Modification of the desired satisfaction level of a High level, Decision level or IS level modeled intentional element.	1) Locate objective, decision or IS. 2) Increase or decrease satisfaction level as required. 3) Execute As Is Strategy.	2) OCL rule checks violation. 3) jUCMNav evaluations (Constraint-Oriented GRL Algorithm) to indicate impact.
Deletion of a High level, Decision level or IS level modeled actor or intentional element (their importance and satisfaction levels as well).	1) Locate actor, goal, decision or IS. 2) Remove actor, goal, decision or IS from model (in a <i>copy</i> of the model). 3) Check the sum of importance levels of actor's intentional elements. Also sum of related destination contributions links if applicable. 4) Execute As Is Strategy.	3) Pairwise comparison to compute new values. OCL rule checks violation. 4) jUCMNav evaluations to indicate impact.
Deletion of contribution links to a High level, Decision level or IS level modeled intentional element.	1) Locate contribution. 2) Set contribution link to 0. 3) Check the sum of importance level. 4) Execute As Is Strategy.	2) jUCMNav contributions override. 3) OCL rule checks violation. 4) jUCMNav evaluations to indicate impact.
Addition of an actor, or intentional element or their contributions to a High level, Decision level or IS level.	1) Include actor, goal, decision, IS (and characteristics) or contribution link (in a <i>copy</i> of the model). 2) Check that they are linked. 3) Execute As Is Strategy.	2) OCL rule checks violation. 3) jUCMNav evaluations to indicate impact.

The next chapter shows the application of the methodology to CIC's Grants and Contributions program.

Chapter 5. Validation

In this chapter, we use a validation scenario to show the BI-EAEA framework and methodology in practice, validating and demonstrating its applicability in a real-work context. The validation focuses on the Grants and Contributions program of the Department of Citizenship and Immigration Canada (CIC). We develop the “As Is Scenario” composed of the business goal, decision, IS and KPI modeling, and then provide an “As Is” strategy. We investigate one particular “To Be Scenario” mainly based on a deletion, with the potential impact on the modeled constructs.

5.1. As Is Scenario – Goal and Decision Modeling

Based on discussions we had with personnel at the CIC responsible for their enterprise architecture (a Director, a Business Architect, the Technical Architect and Project Managers), the Grants and Contributions Program, was selected as the target for this research. The following factors were considered in this selection:

- a) The CIC, like most Canadian government departments, is currently implementing and addressing EA-related concerns.
- b) The manual processes within the Grants and Contributions Program are being automated.
- c) All provincial and regional officers are integrating their processes with the headquarters in Ottawa.
- d) An Oracle Siebel System was being implemented while certain other IS were in the process of being decommissioned.
- e) With the implementation of the new IS and the automation of processes, a proof of concept for the “Implement and Deliver Program” process of the Grants and Contributions Program was initiated to evaluate the impact of the new IS and processes. As represented in Figure 17, this proof of concept process can also be

specified in UCM and connected to objectives expressed with GRL through URN links.

These changes in the Grants and Contributions Program, the current priority of EA in the eyes of the CIC, and the availability of the proof of concept process, made it an adequate test scenario.

With this “Implement and Delivery Program” process identified as the process that satisfies high priority requirements and goals, the business goal modeling step involved identifying the stakeholders, goals, softgoals and tasks involved in this process. We used the pairwise comparison technique described in Section 3.3.1 to compute the importance levels of GRL intentional elements and contribution weights using a set of questionnaires (see Appendices C and D). In the *High level*, illustrated in Figure 45, there are 3 actors involved in achieving the main objective.

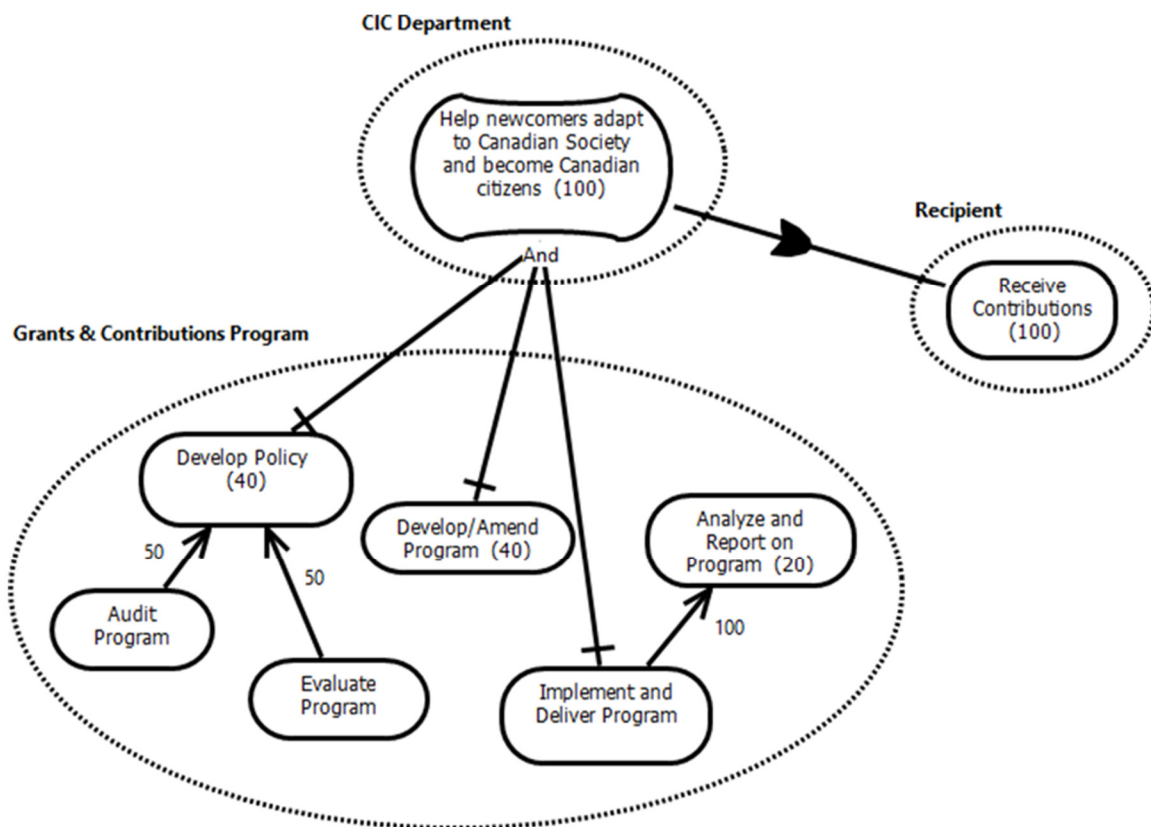


Figure 45: Grants and Contributions Program High level model.

These actors are the “CIC Department”, the “Grants and Contributions Program” itself, and “Recipients”. The “CIC Department” has its main objective “Help newcomers adapt to Canadian Society and become Canadian citizens” represented as a softgoal with a 100 importance level (on a 0-100 scale). The softgoal is dependent on the “Receive Contributions” goal of the “Recipient” actor, and is decomposed into other goals in the “Grants and Contributions Program” actor with the AND operator (indicating that they all have to exist for it to be satisfied). The subgoals are “Develop Policy”, “Develop/Amend Program” and “Implement and Deliver Program”. In the actor “Grants and Contributions Program”, the goal “Implement and Deliver Program” contributes to the “Analyze and Report on Program” goal with a contribution weight of 100, while the “Audit Program” and “Evaluate Program” goals both contribute weights of 50 each to the “Develop Policy” goal. In conformity with the OCL rules defined in Section 3.3.2, each actor has the importance levels of its intentional elements summing up to 100.

In the *Decision level*, we have two abstractions, the process for the “Implement and Deliver Program” goal and the process for the “Application, Risk and FVA Assessment” goal, illustrated in Figure 46 and Figure 47 respectively. In the first abstraction, we have five actors with goals, softgoals, resources and their computed importance levels and contribution weights. The “Grants and Contributions Program” actor has its goal “Implement and Deliver Program” decomposed into two goals with the AND operator and contained by the same actor: “Implement Program” and “Deliver Program”. The “Implement Program” is further decomposed into other goals and softgoals in the “IMFB Functional” and “Regional/NHQ” actors. These actors’ goals and softgoals are achieved using information from the five IS resources in place in the actor “Information System”. Finally, the “eSubmission System” and “SAP System” resources of the “Information System” actor and the “Support Recipient with Technical Advise” softgoal of the actor “Regions/NHQ”, both contribute to the decomposed goals of the “Recipient” actor: “Complete Application” and “Receive Payment”.

In the second abstraction, illustrated in Figure 47, we have four actors, a softgoal, resources and tasks along with their computed importance levels and contribution weights. The “Regions/NHQ” actor has the softgoal “Application, Risk and FVA Assessments” with resources belonging to same actor.

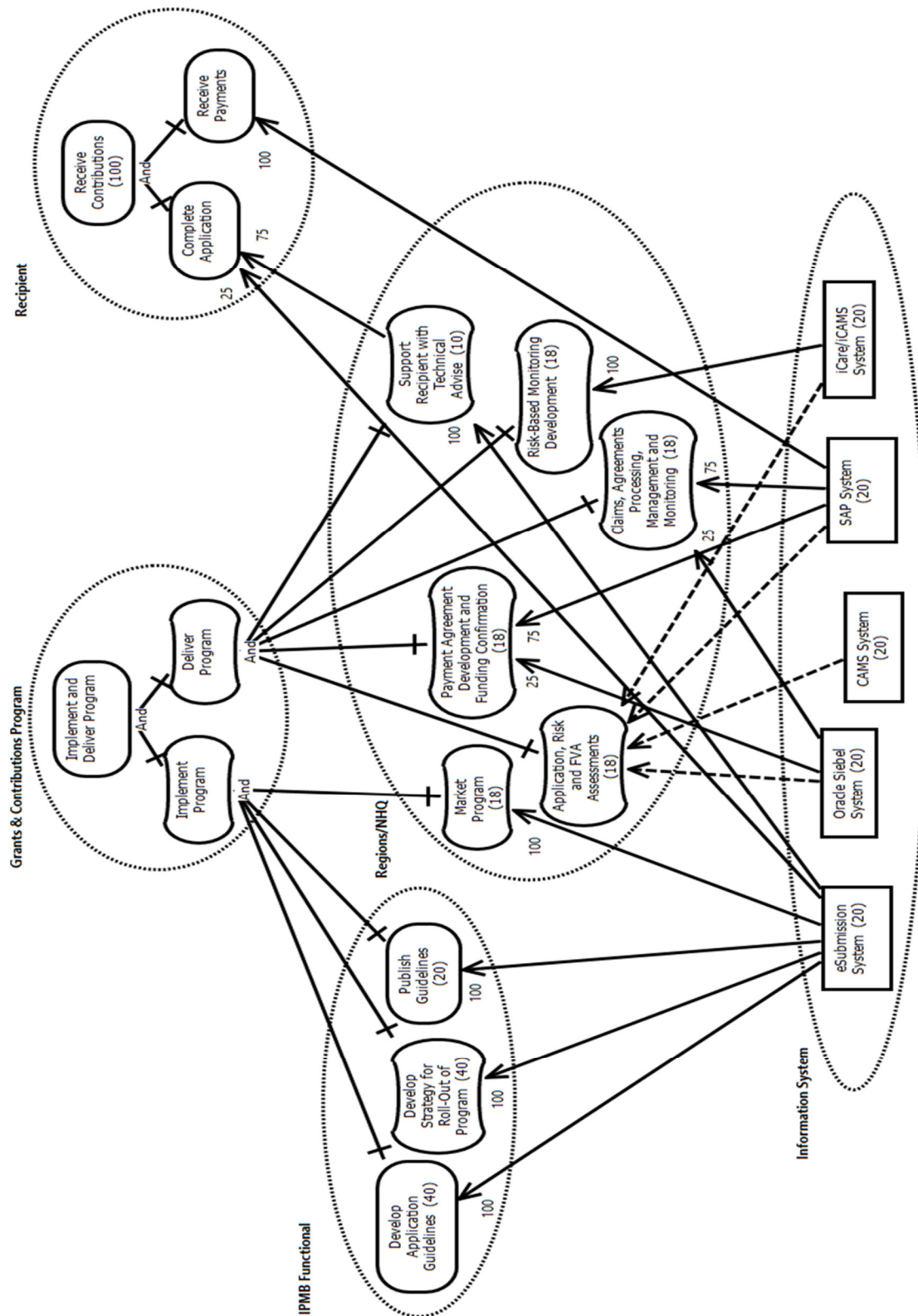


Figure 46: Implement and Deliver Program goal model.

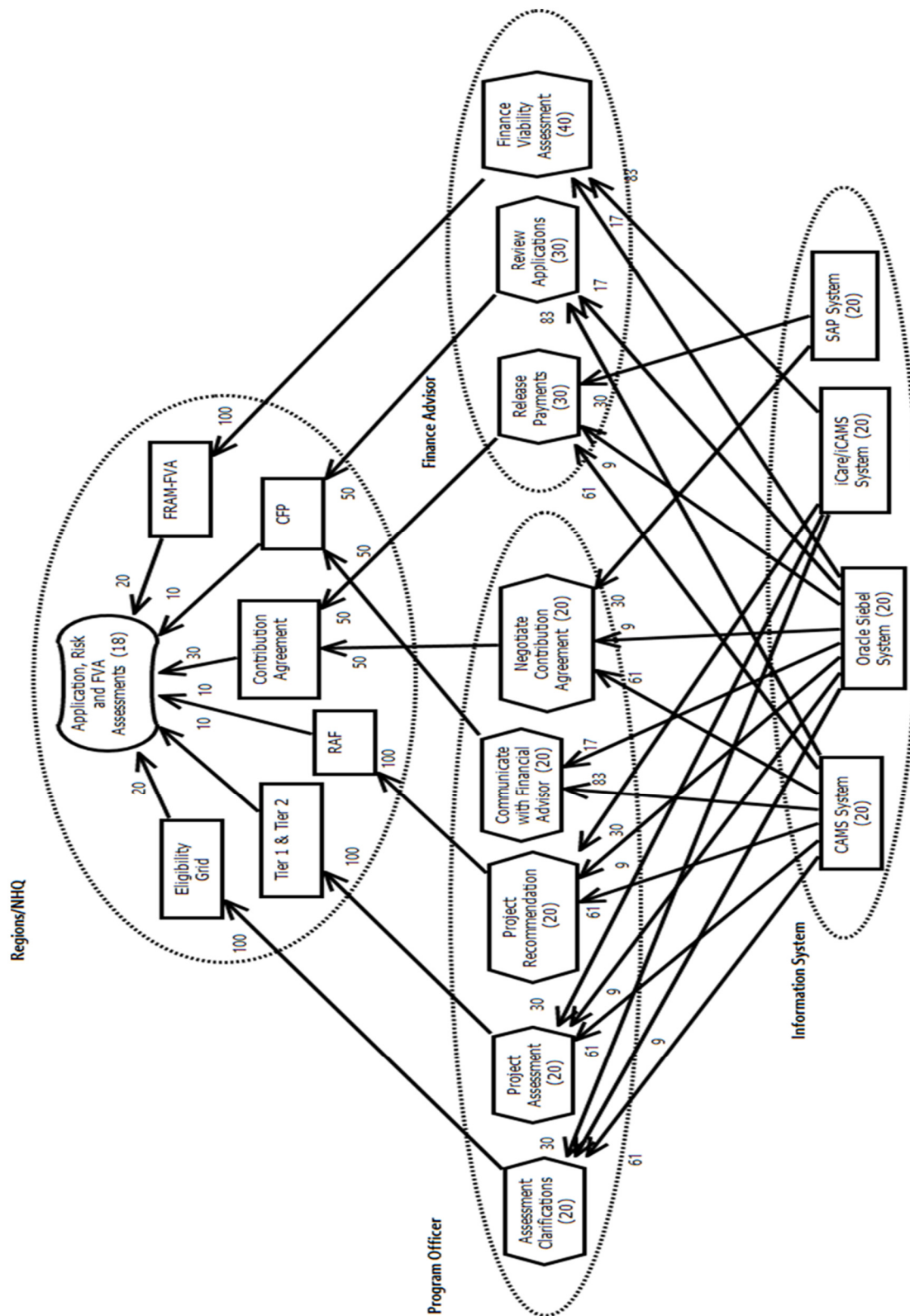


Figure 47: Application, Risk and FVA Assessments goal model.

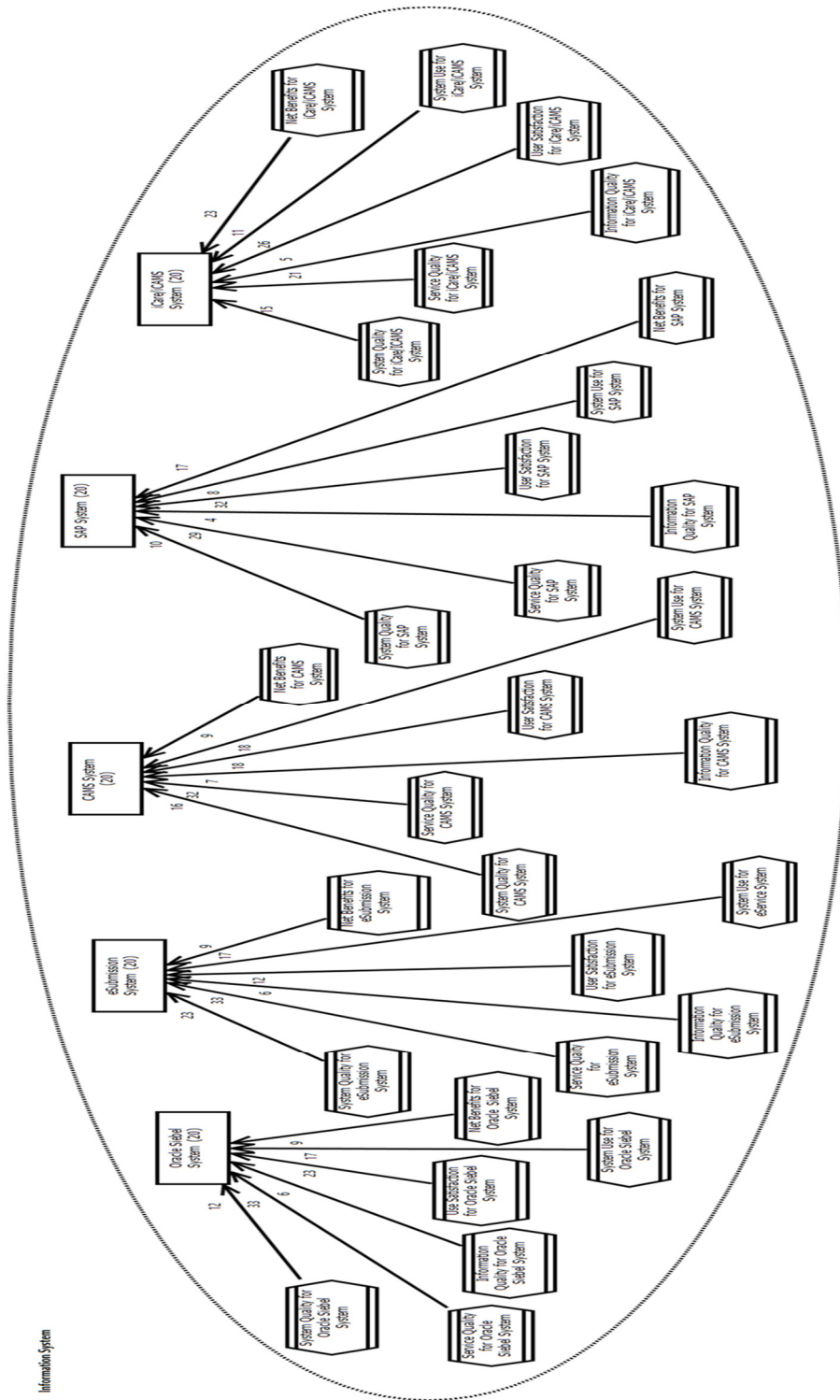


Figure 48: IS and KPI Model.

Note that Figure 46 uses correlations to indicate the presence of an influence relationship resulting from transitive contributions with weights defined elsewhere in the model (e.g., in Figure 48). These correlations have no weight because weights are already handled by the intermediate contribution links, and hence the weights should not be counted twice. The resources in Figure 47 are activities that contribute to the “Application, Risk and FVA Assessments” with information from tasks of the actors “Program Officer” and “Financial Advisor”. These tasks utilize information from four of the five IS resources of the actor “Information System”: “CAMS System”, “Oracle Siebel System”, “iCare/iCAMS System” and “SAP System”.

5.2. As Is Scenario – IS and KPI Modeling

We identified five different types of IS used to provide information utilized in the proof of concept process for the Grants and Contributions Program (Figure 48): “eSubmission System”, “Oracle Siebel System”, “CAMS System”, “SAP System” and “iCare/iCAMS System”. With the set of questionnaires in Appendix E and using the pairwise comparison technique described in Section 3.3.1, the contribution weights for the six characteristics of each IS resource, which measure each IS performance level, was computed as shown with a sample of the “eSubmission System” in Figure 49.

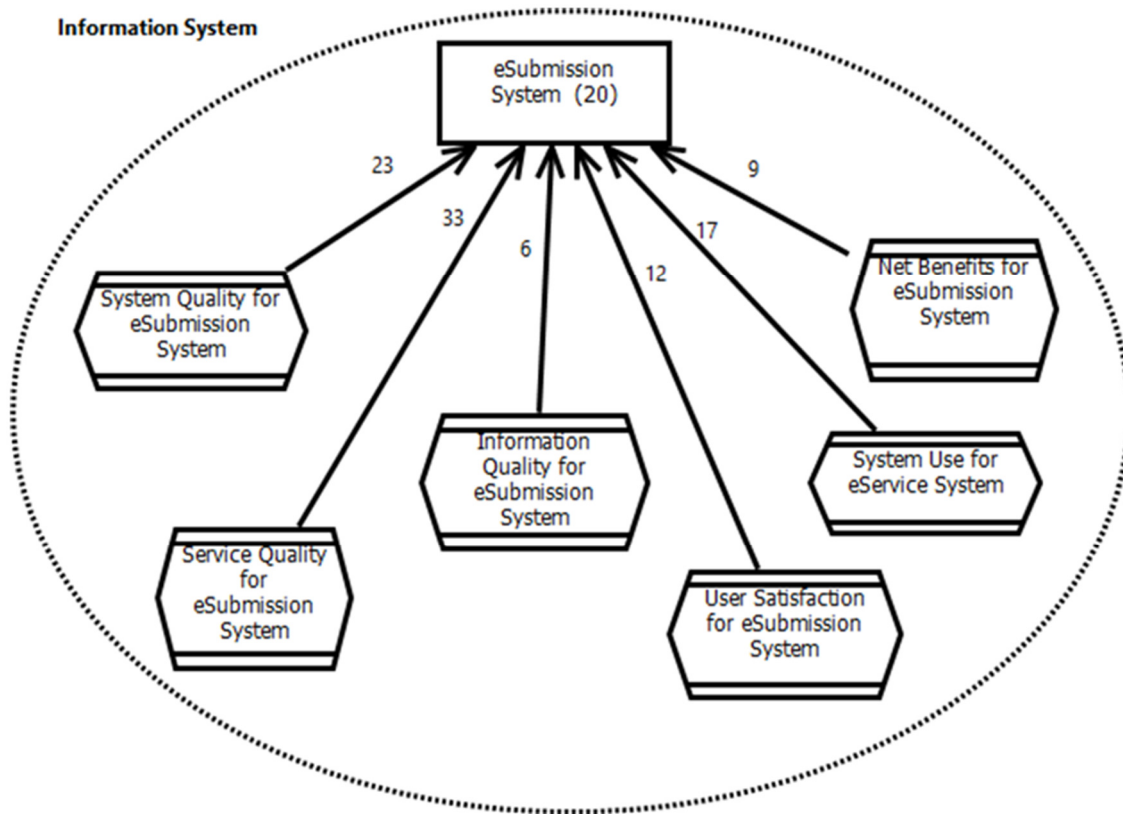


Figure 49: Goal model of the 'eSubmission IS resource' and contribution weights of its KPIs

5.3. As Is Scenario – Evaluation of Modeled Constructs

After modeling the proof of concept (composed of stakeholders, objectives, decisions, IS, their importance levels and priorities), the model was then checked against the OCL rules of our profile, as described in Section 3.3.2, to ensure it was built properly before doing any analysis. The model proved to conform to the defined well-formedness rules, as illustrated in Figure 50. Using jUCMNav's size metrics, this model is characterized as follows: 4 diagrams, 8 actors, 40 intentional elements (12 goals, 9 softgoals, 8 tasks, and 11 resources), 30 indicators, and 102 links.

Table 12: KPI values for eSubmission System

	Target Value	Threshold Value	Worst Value	Evaluation Value
System Quality	90	70	50	72.5
Information Quality	90	70	50	80
Service Quality	90	70	50	90
User Satisfaction	90	70	50	65
System Use	90	70	50	80
Net Benefits	90	70	50	75

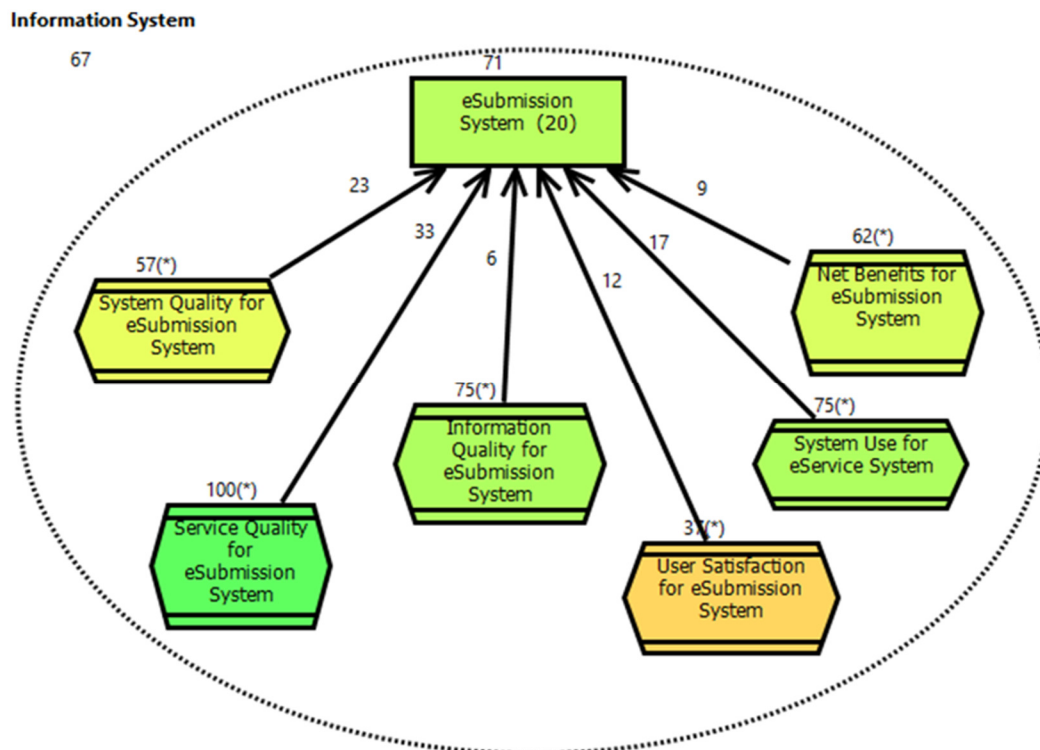


Figure 51: Evaluated IS eSubmission System and its KPIs.

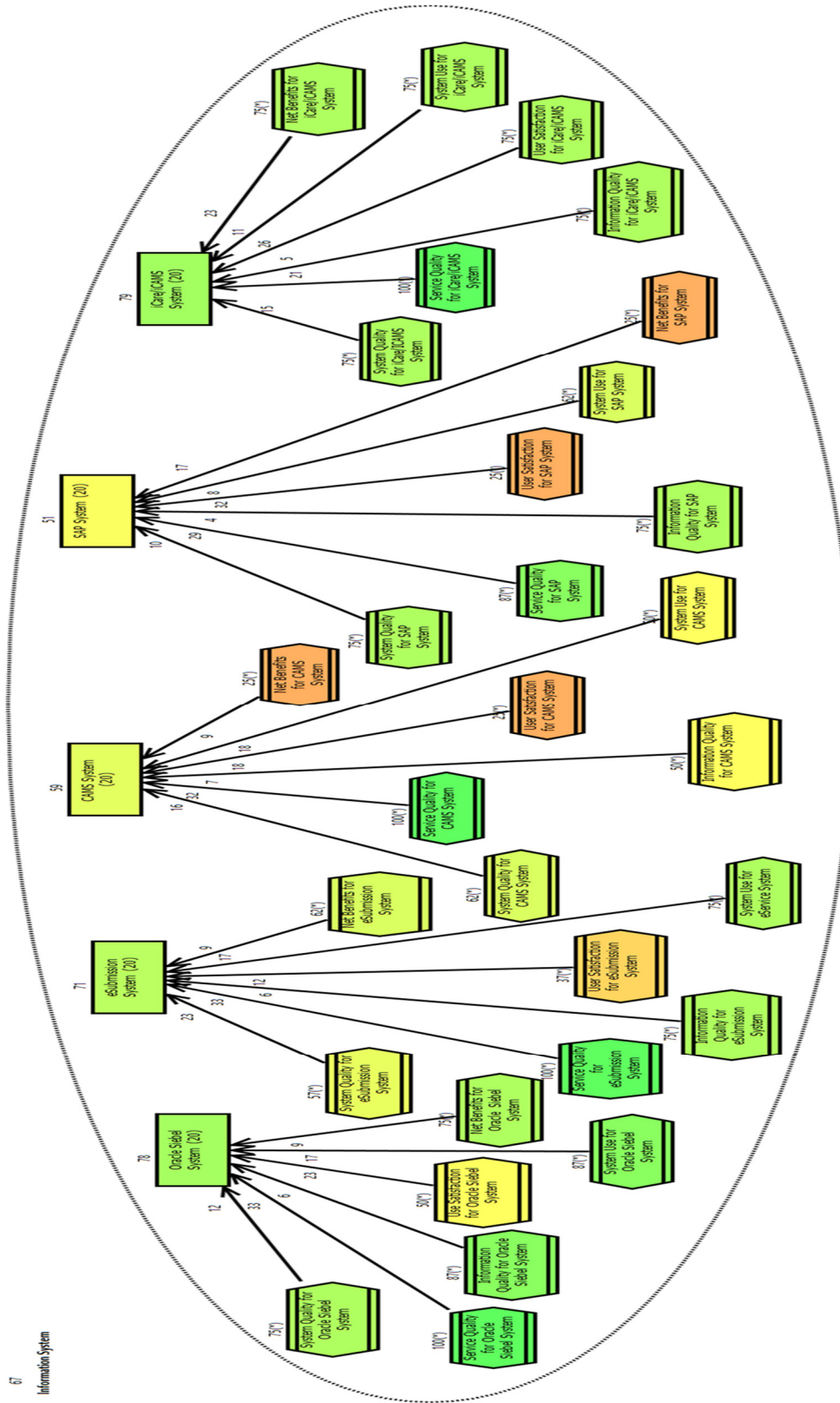


Figure 52: Evaluated IS and KPI model.

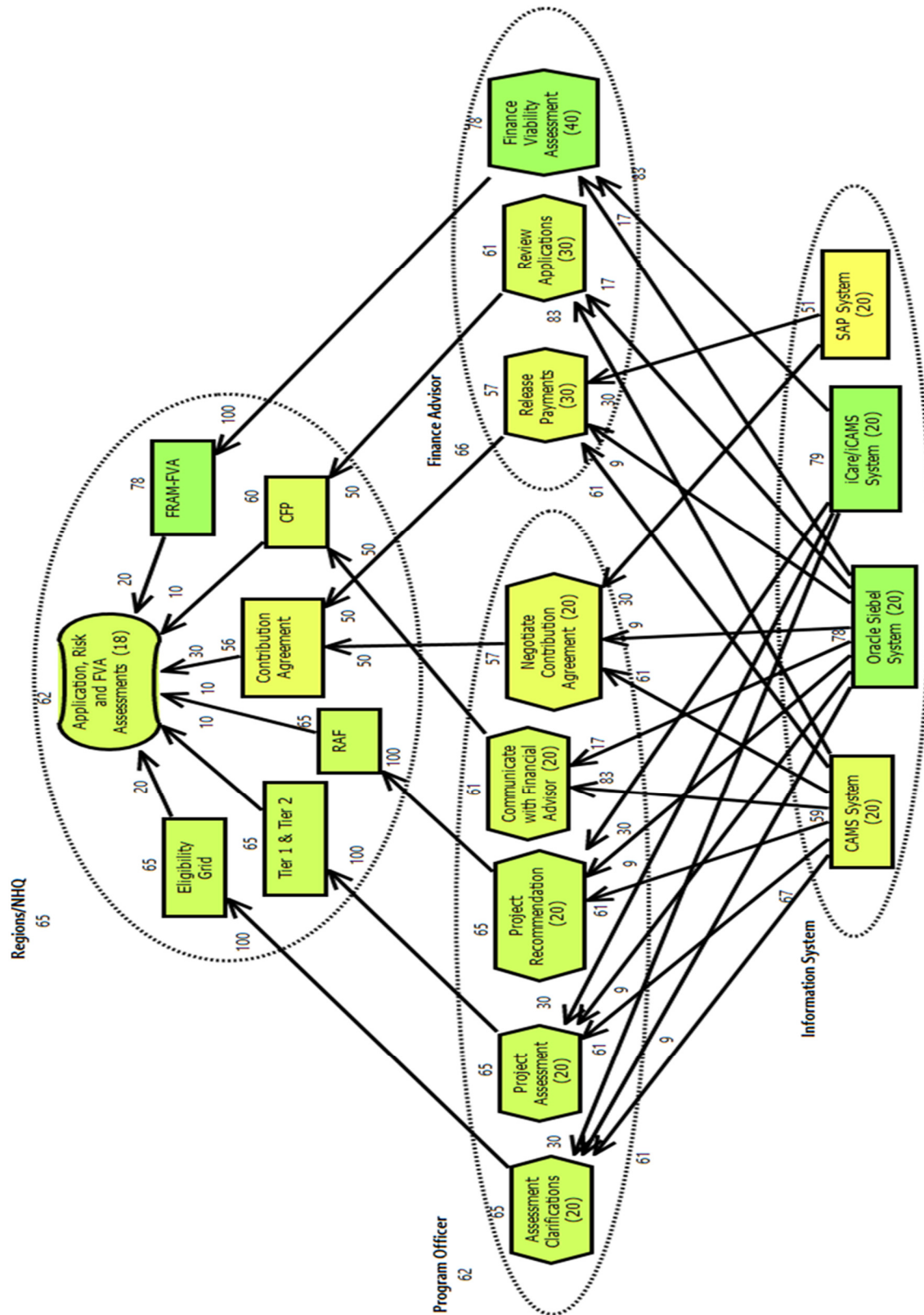


Figure 53: Evaluated Application, Risk and FVA Assessments goal model.

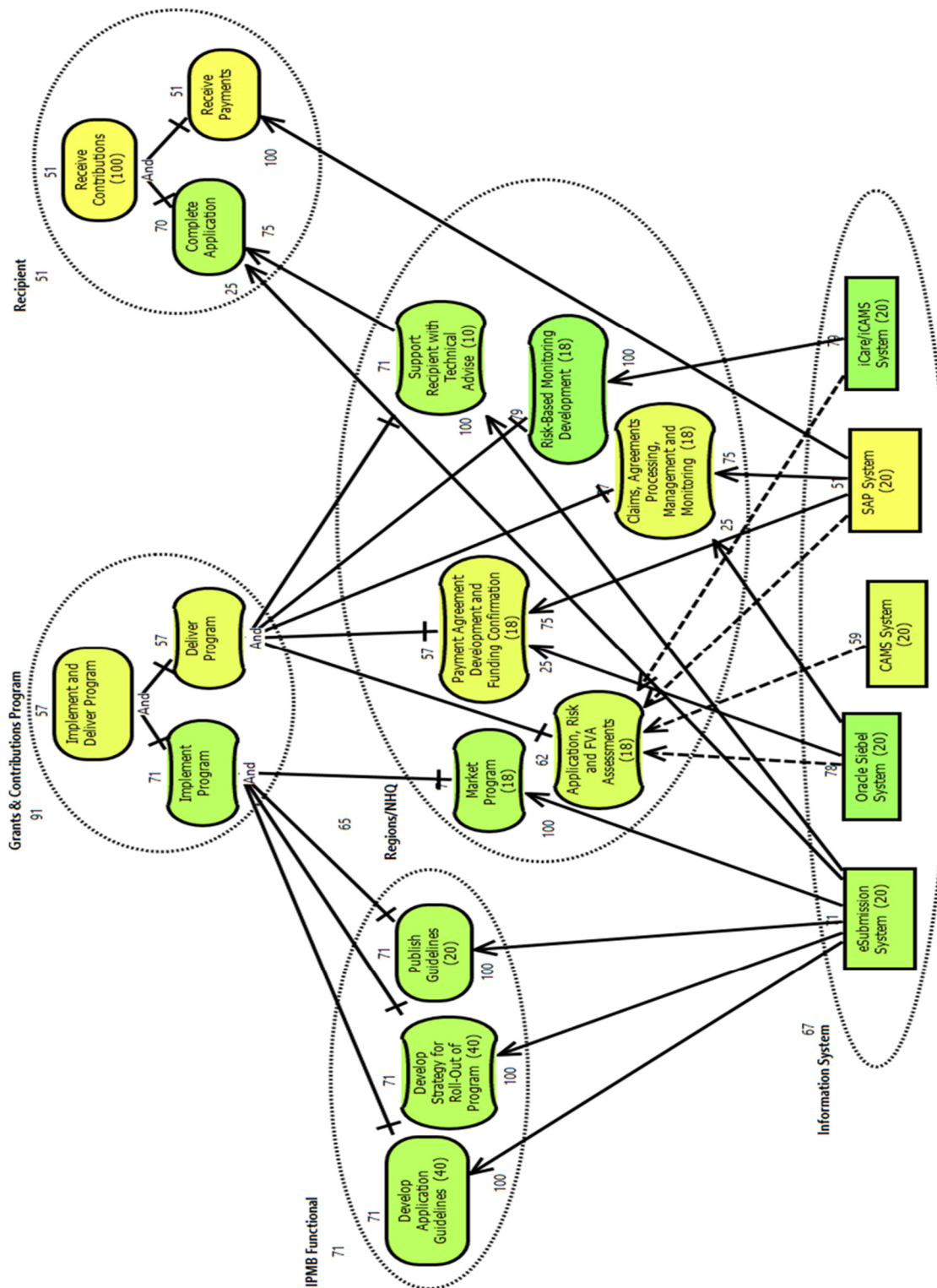


Figure 54: Evaluated Implement and Deliver Program goal model.

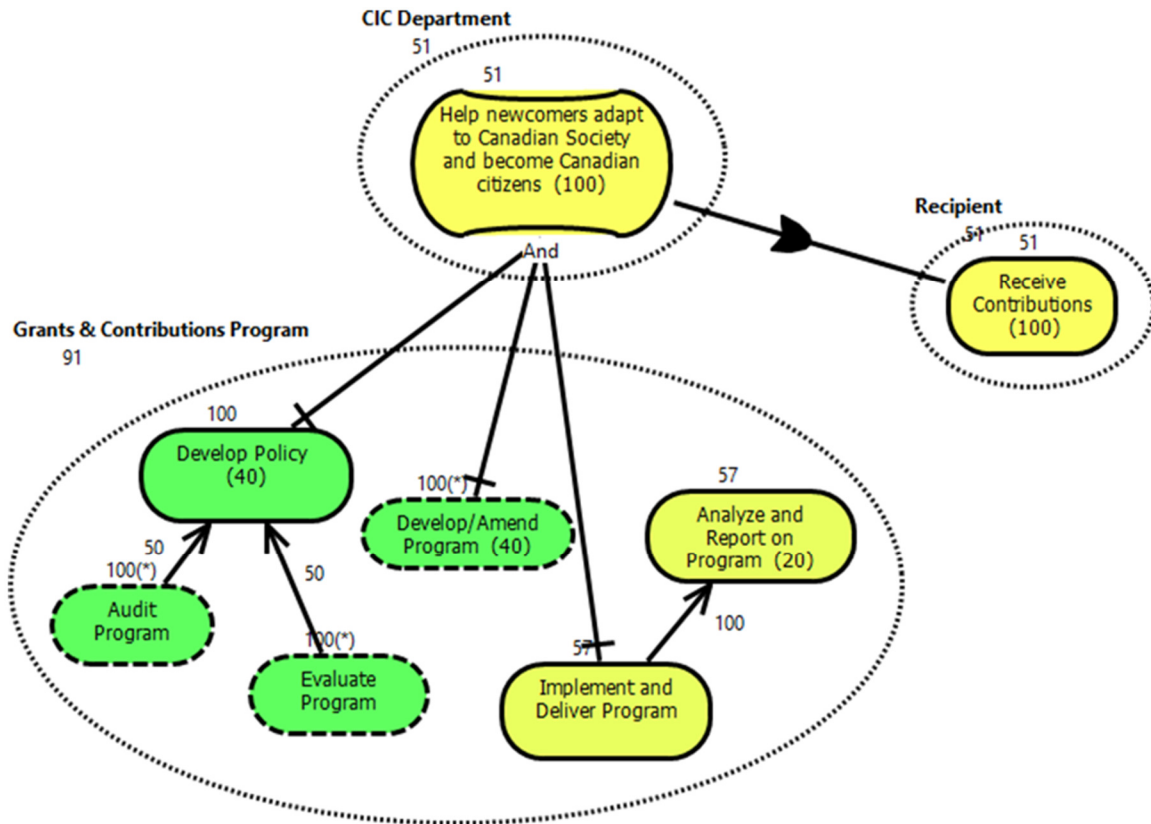


Figure 55: Evaluated Grants and Contributions Program High level model.

The proof of concept only involves the “Implement and Deliver Program” goal. Therefore, to evaluate the model, the “Develop/Amend Program”, “Audit Program” and “Evaluate Program” goals were initialized as fully satisfied (Figure 55). Note that in this As Is scenario, the CIC Department is lukewarm in terms of satisfaction, mainly because of its dependency to the Recipient. Hence, the Recipient’s satisfaction needs to be improved.

5.4. To Be Scenario – Potential Impact of a Deletion.

With the anticipated needs for adaptation within the Grants and Contributions Program as listed in Section 5.1, the model was evaluated against the different adaptation needs described in Section 4.2. The model’s adaptation and impact of the planned decommissioning of the “CAMS System” and increase of contribution levels for the “Oracle Siebel System” (which will now be used as a source of information for other existing tasks) is illustrated in Figure 56, Figure 57, Figure 58, and Figure 59. For the decommissioning, the “CAMS System” is deleted, together with its KPIs and contributions.

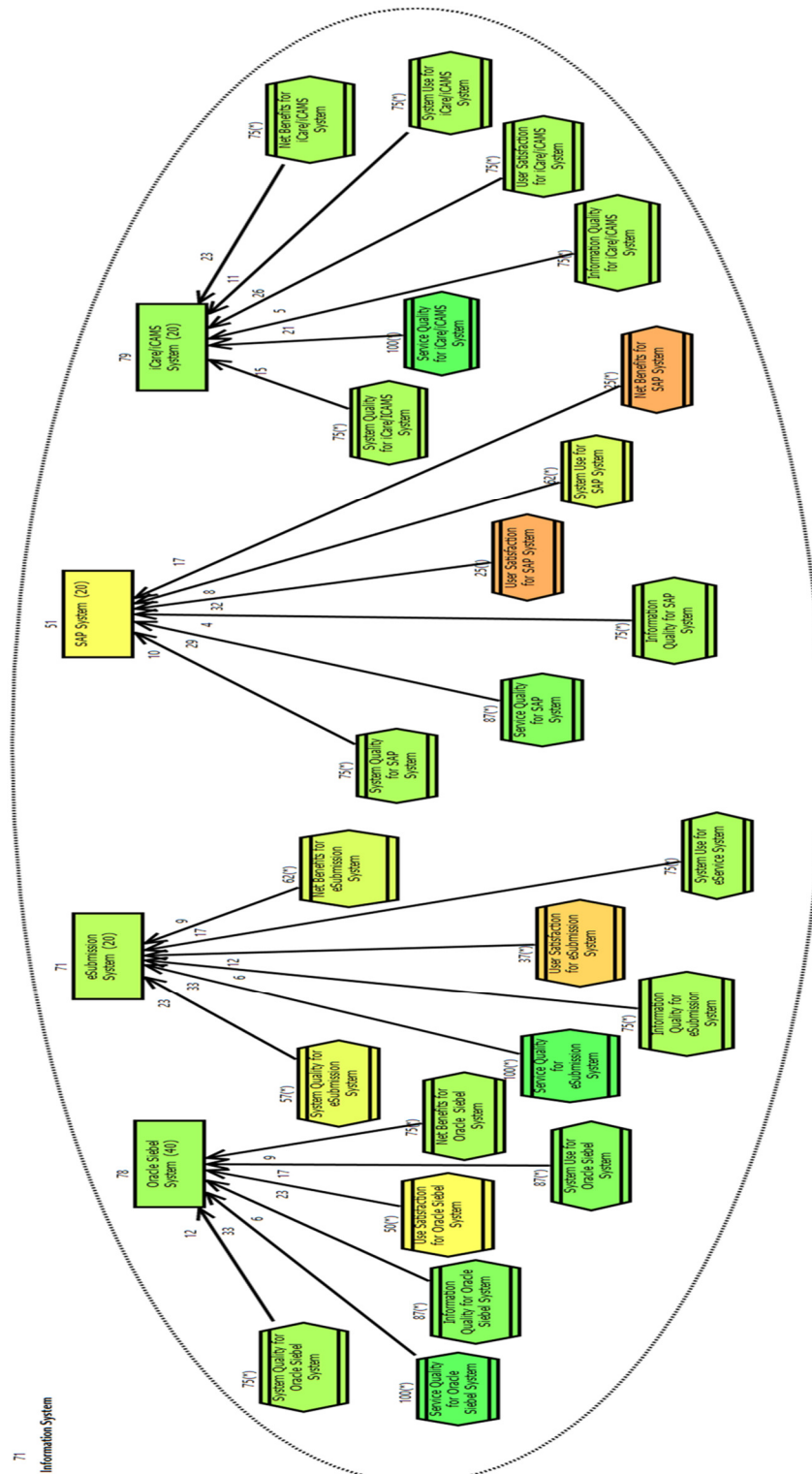


Figure 56: Evaluated IS level model after decommissioning the CAMS system.

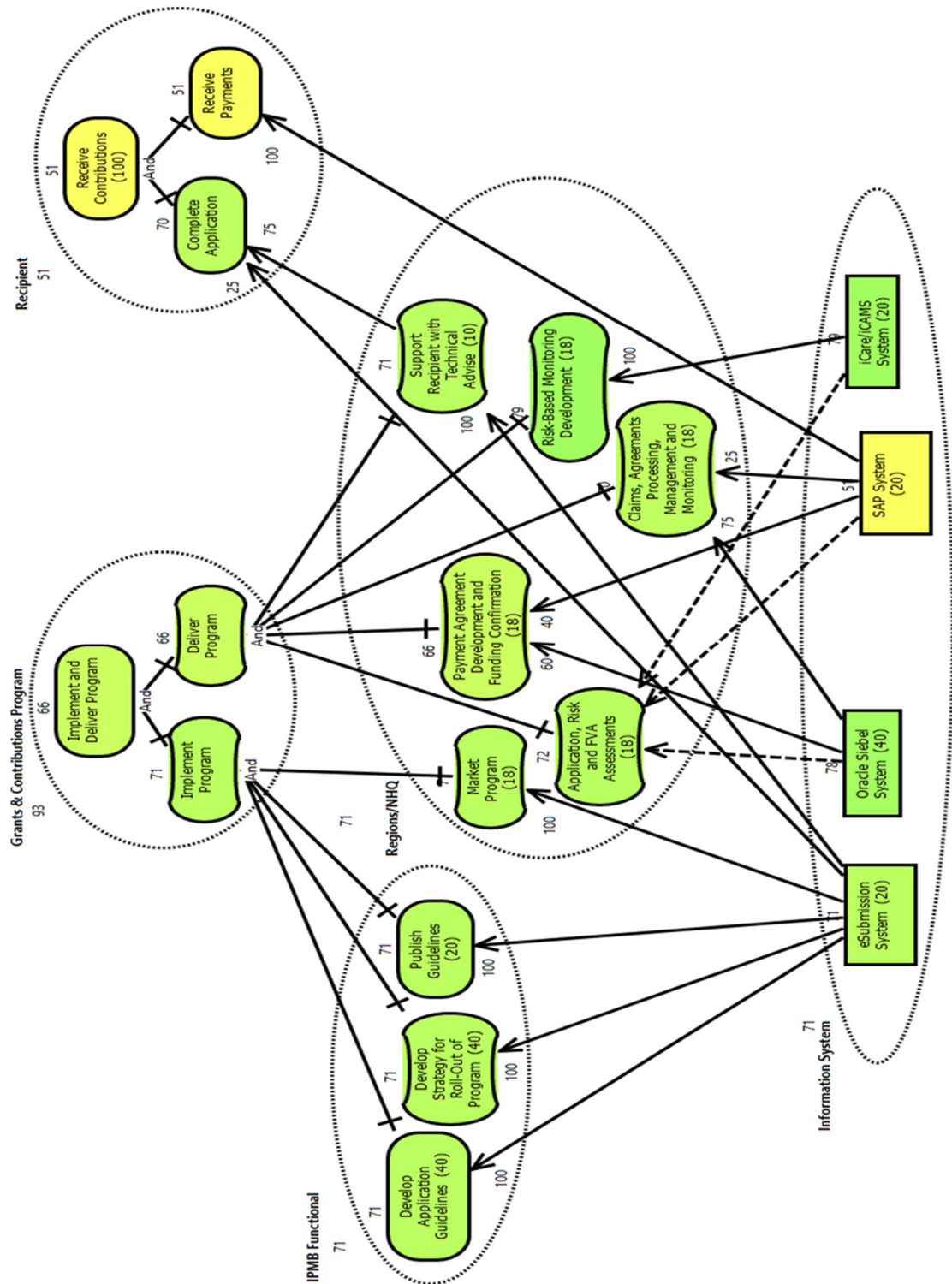


Figure 58: Evaluated Implement and Deliver Program goal model after decommissioning the CAMS system and computing new importance levels and contribution weights.

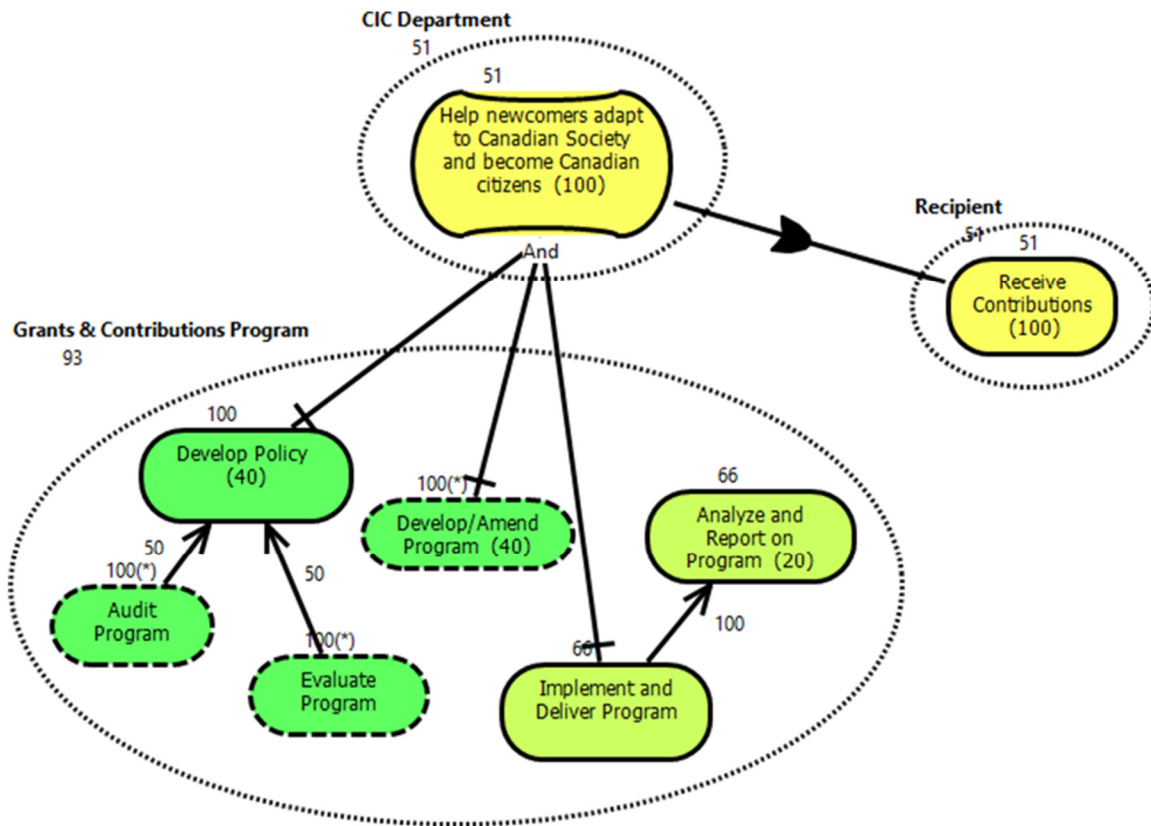


Figure 59: Evaluated Grants and Contributions Program High level model after decommissioning the CAMS system and computing new importance levels and contribution weights.

With the decommissioning of the “CAMS system” and computation of the CIC’s proposed new importance levels and contributions weights (as one other IS, Oracle Siebel, is taking over the support of most processes), we observed that there will be an increase in the satisfaction of different modeled intentional elements in the *High level*, *Decision level* and *IS level* of the Grants and Contributions Program. They include:

IS Level

There will be an increase from 67 to 71 in the satisfaction level of the “Information System” actor.

Decision Level

The “Application, Risk and FVA Assessments” will have a satisfaction level of 72 coming from 62, the “Program Officer” goes from 62 to 75 and the “Financial Advisor” increases to 75 from 66. The “Regions/NHQ” will have its satisfaction level increased from 65 to 79 while there will be no effects on the satisfaction

levels of “IPMB Functional” or “Recipient” since they are not supported by either the decommissioned “CAMS System” or “Oracle Siebel System”

High Level

The “Grants & Contributions Program” satisfaction level will increase from 91 to 93 while the “Recipient” and “CIC Department” remains the same.

With this information, the CIC is aware of the impact of the decommissioning of the “CAMS System” and adaptation response of the EA. The model comparison illustrated in Figure 60, further informs of what exact items in the model changed as a result of the decommissioning. Of note also is that while the “Grants and Contributions” department had its satisfaction level increased, there was no change in the satisfaction level of the “CIC Department”. This is because its softgoal “Help newcomers adapt to Canadian Society and become Canadian citizens” is dependent on the “Recipient” goal “Receive Contributions”, which is supported by the “SAP System”. A possible solutions to having it satisfied further could be by using the “Oracle Siebel System” to support the “Receive Contributions” goal as illustrated in Figure 61 and Figure 62 or increasing the performance of the “SAP System” as illustrated in Figure 63, Figure 64, Figure 65, Figure 66 and Figure 67.

In choosing the former, we notice that using the “Oracle Siebel System”, to support the “Recipient” actor’s goal only increases its satisfaction levels in the “Implement and Deliver Program goal model” and the “Grants and Contributions High level goals”. The “Recipient” satisfaction levels increases from 51 to 70 resulting in the “CIC Department” satisfaction level increasing from 51 to 66. If we choose the latter, we observe that increasing the performance level of the “SAP System” affects all abstractions of the model, the “Information System Model”, “Application Risk and FVA Assessments softgoal model”, “Implement and Deliver Program goal model” and the “Grants and Contributions High level goals” with the “Recipient” and “CIC Department” satisfaction levels both increasing from 51 to 68. With this information, the stakeholders of the CIC are also informed of the impact of some possible options to responding to the impacts of decommissioning the “CAMS System”.

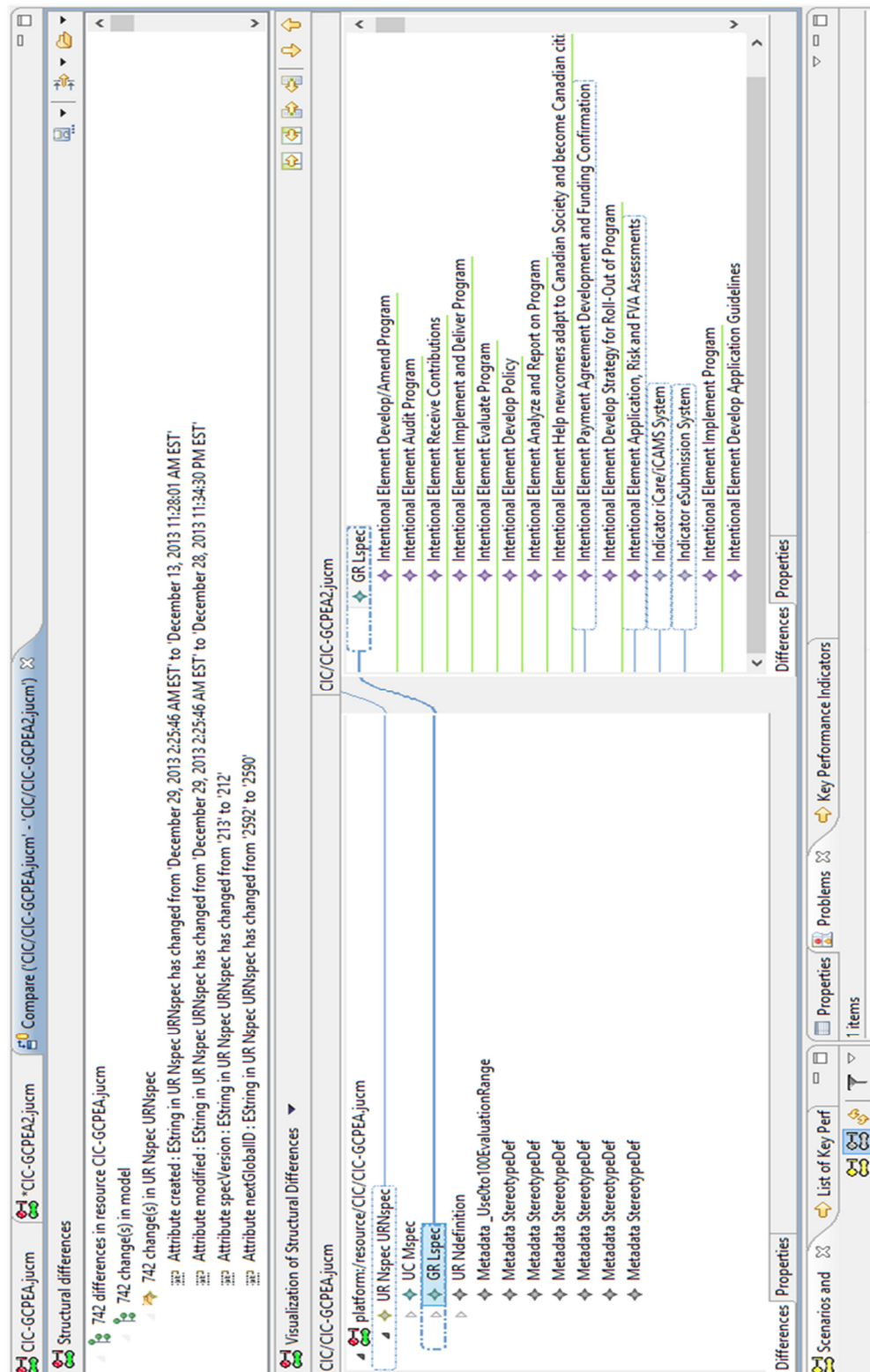


Figure 60: Model comparison showing the time and number of changes as a result of the decommissioning the CAMS system and computing new importance levels and contribution weights.

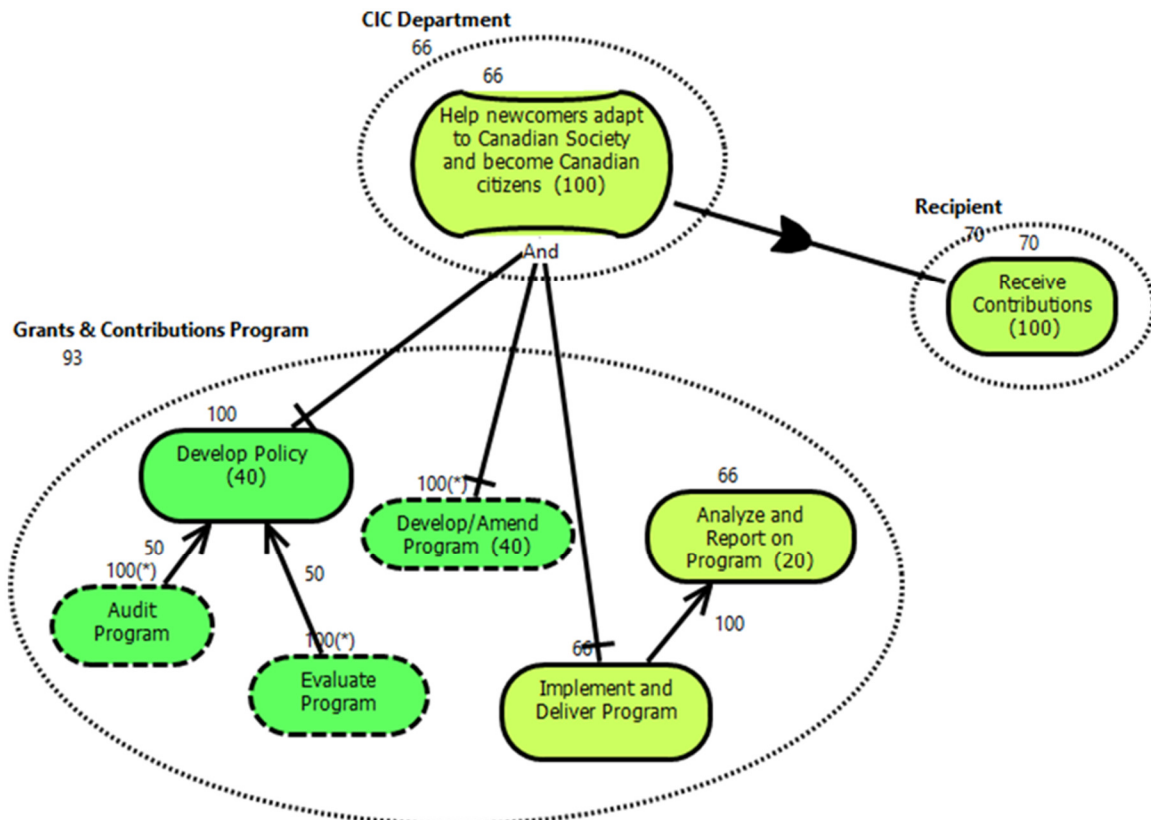


Figure 62: Evaluated Grants and Contributions Program High level model with the Oracle Siebel System supporting the Recipient goals.

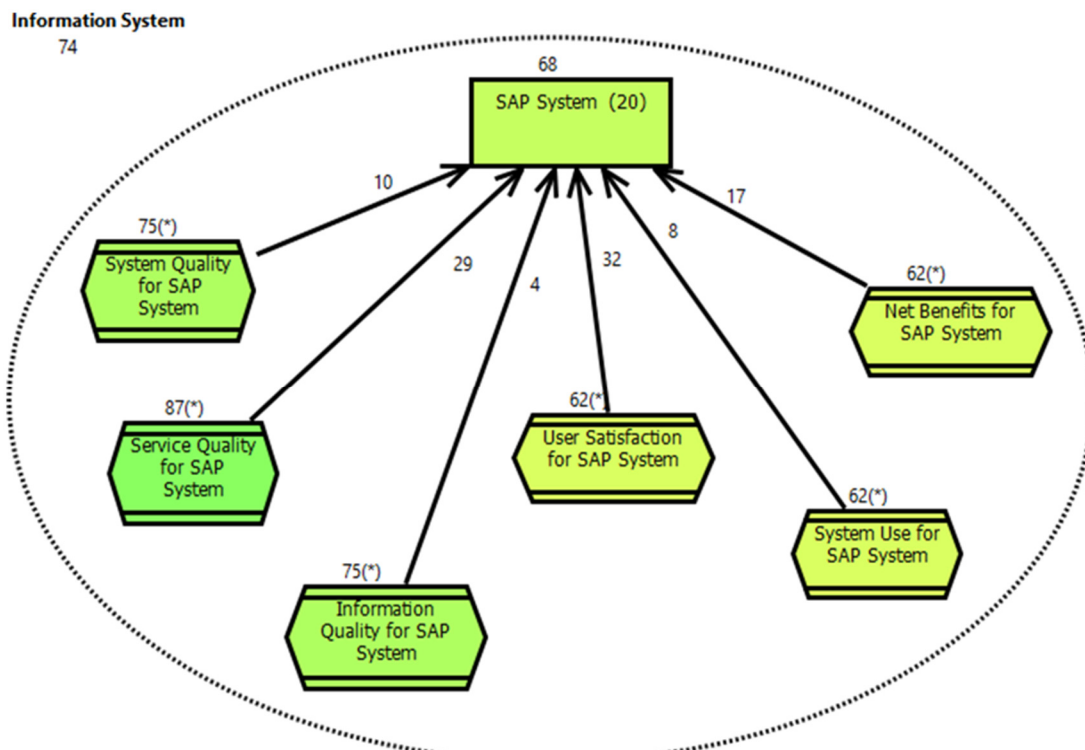


Figure 63: Increased satisfaction levels for the SAP System's KPIs.

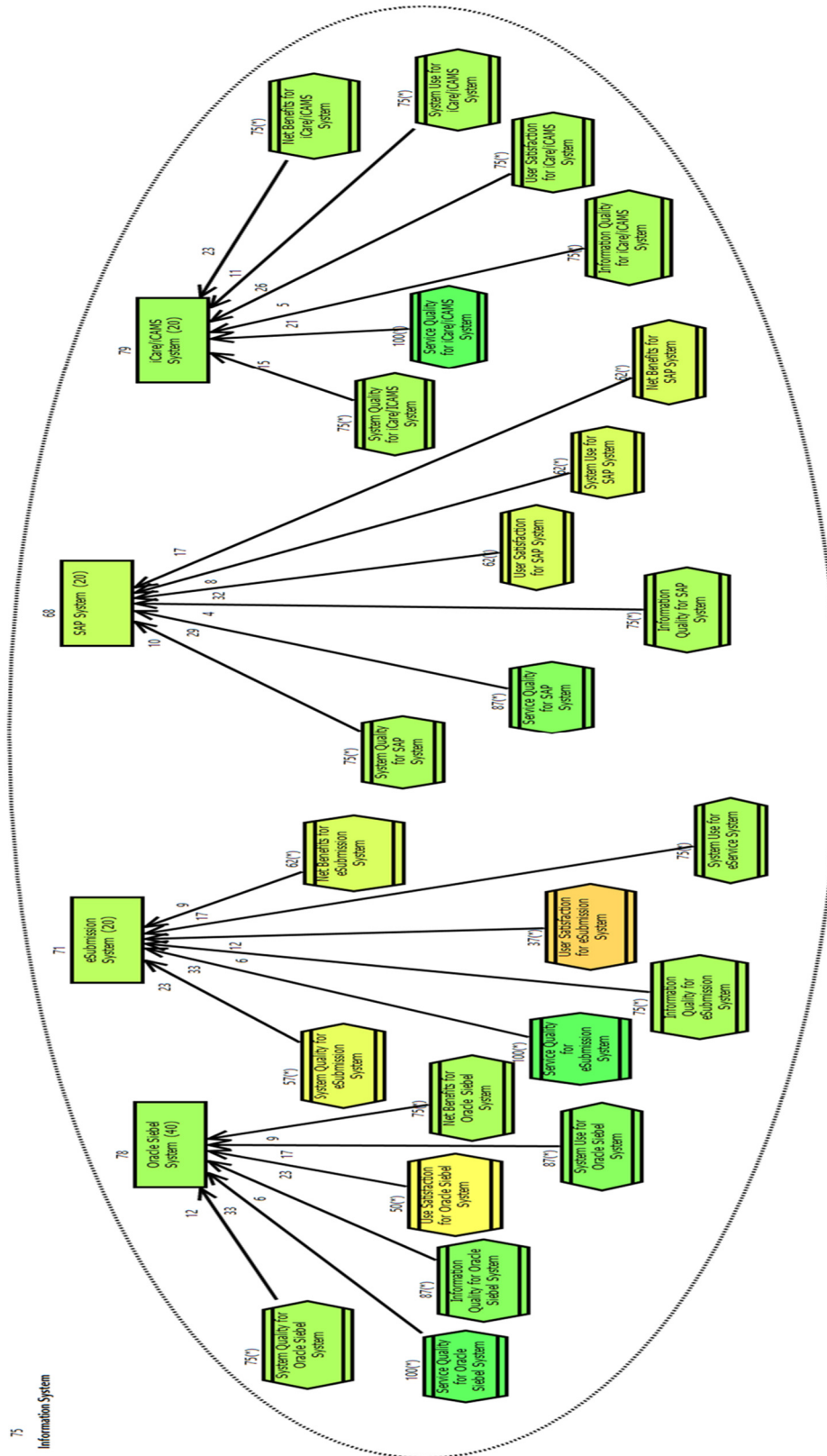


Figure 64: Evaluated IS level model after increased satisfaction levels for the SAP System's KPIs.

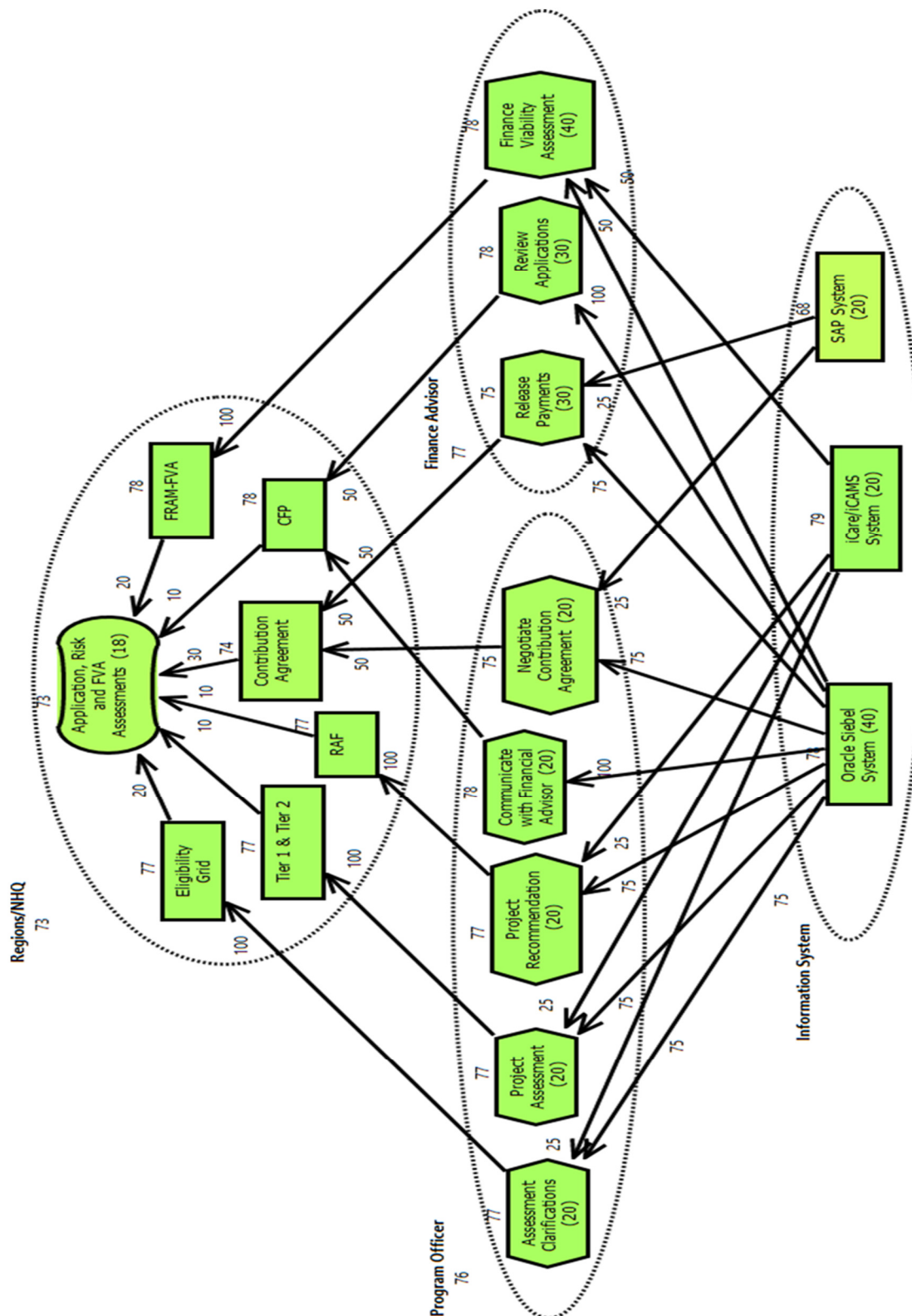


Figure 65: Evaluated Application, Risk and FVA Assessments goal model after increased satisfaction levels for the SAP System's KPIs.

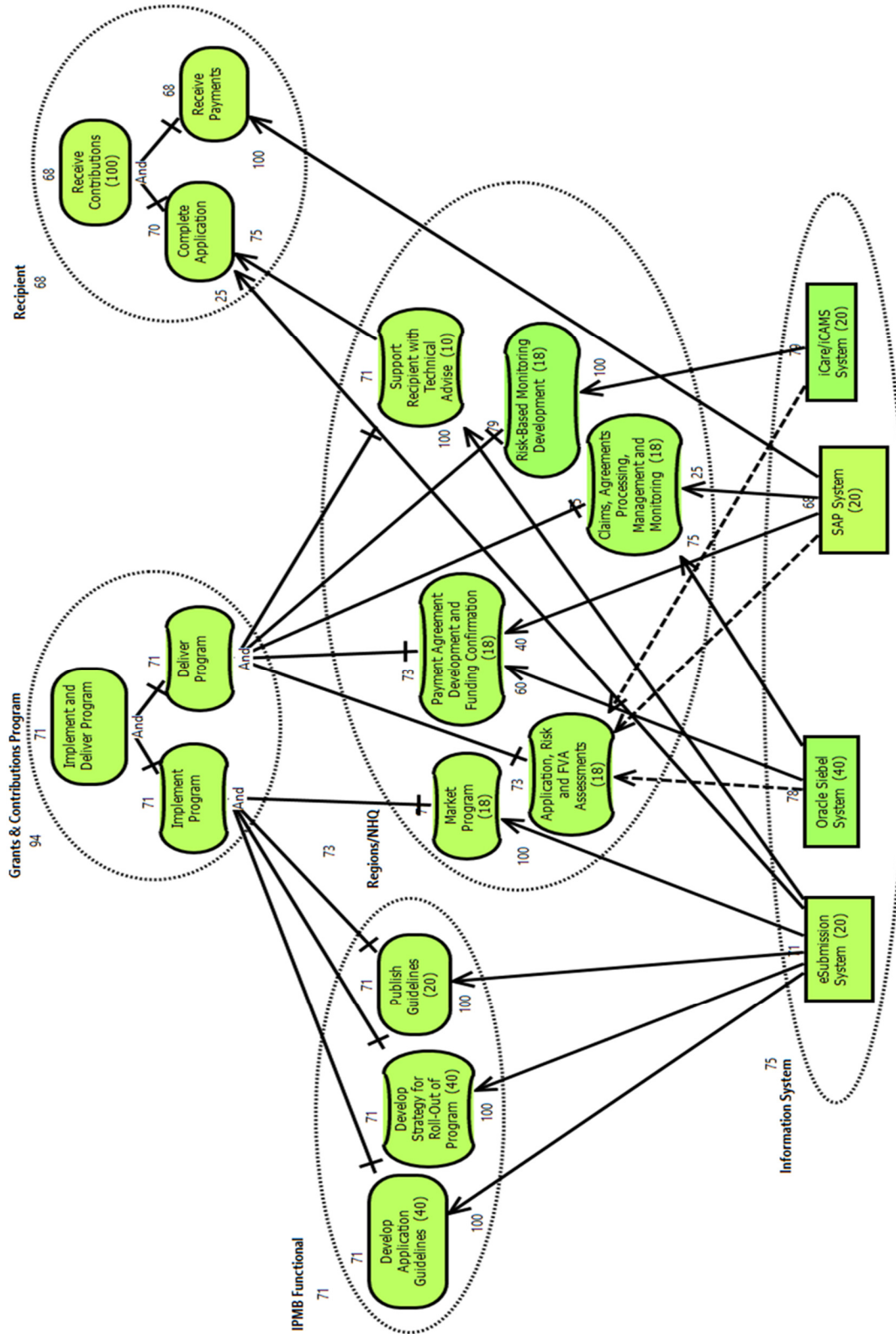


Figure 66: Evaluated Implement and Deliver Program goal model after increased satisfaction levels of the SAP System's KPIs

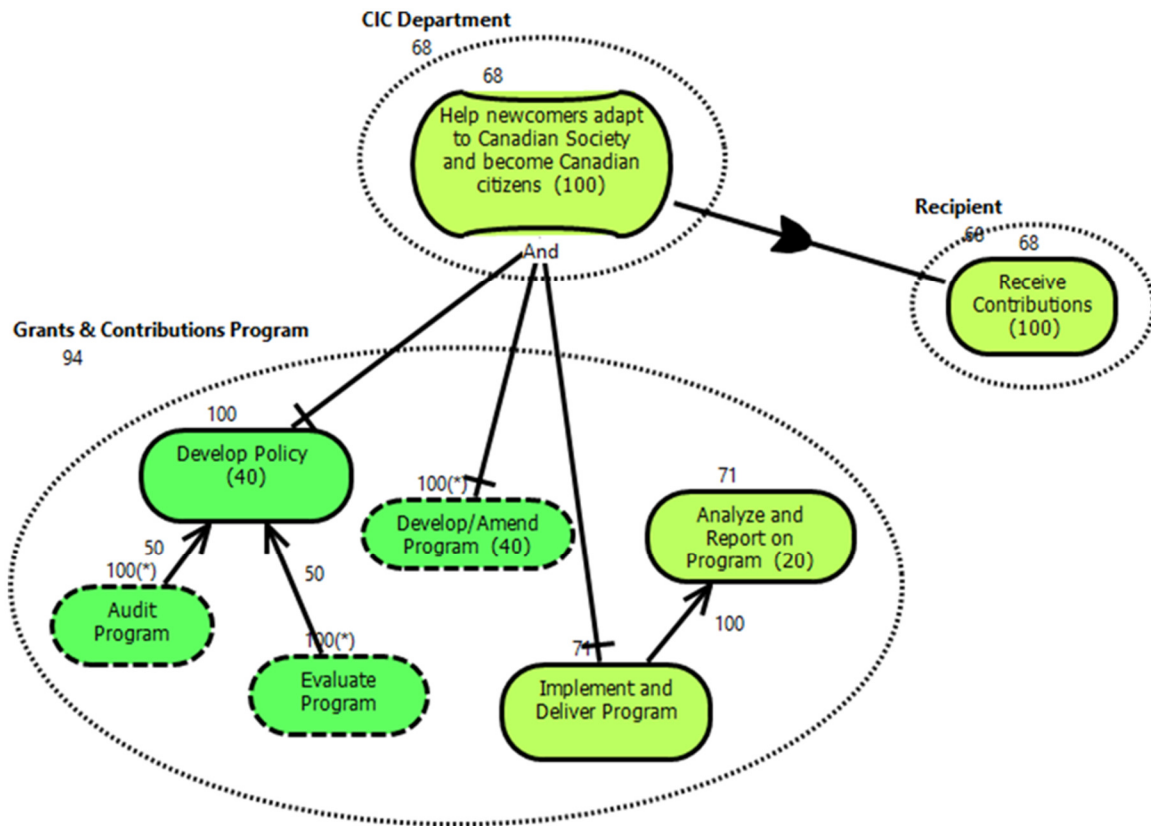


Figure 67: Evaluated Grants and Contributions Program High level model after increased satisfaction levels for the SAP System's KPIs.

5.5. Summary

In this chapter, we demonstrated the application of the *Business Intelligence-Enabled Adaptive Enterprise Architecture* framework using a validation scenario, the Grants and Contributions Program of the Department of Citizenship and Immigration Canada. We illustrated the steps of the methodology and the model's response to scenarios requiring adaptation, to validate the applicability of our approach and URN-based tool support in jUCMNav.

This model of the Grants and Contributions Program EA was shown in the *High level, Decision level and IS level*. The *Decision level* had two abstractions of the CIC's Grants and Contributions Program, which the model was able to show within jUCMNav with the use of contribution and correlation links. Such views address the need of representing many levels of abstractions for goals in enterprise goal modeling as a considera-

tion for performance analysis in EA (Cardoso, 2013). Finally we illustrated adaption to the decommissioning (an instance of deletion) of an IS at the CIC, using the methodology to show response, impacts and possible ways of adaptation.

The next chapter evaluates the application of the methodology at the CIC against the evaluation approach outlined in Section 3.4.

Chapter 6. Evaluation

This chapter presents the evaluation of the *Business Intelligence - Enabled Adaptive Enterprise Architecture*. This evaluation, as discussed in Section 3.4, is based on anonymous responses to the characteristics of an adaptive enterprise as prescribed by Yu et al. (2012), by the CIC's senior personnel who were exposed to the model.

6.1. Presentation of Evaluation Results

The characteristics used to evaluate the adaptive EA in this thesis are not easily accommodated in conventionally EA frameworks. Importantly, as discussed in Yu et al. (2012), they address what an EA framework for the adaptive EA should do and what issues the framework should encompass. Based on these characteristics, questions with quantitative values ranging from “All (76% - 100%)”, “Most (51% - 75%)”, “Some (26% - 50%)”, “Few (1% - 25%)” to “None (0)” were created for each characteristic. These questions (see Appendix B) were administered to four personnel at CIC, to whom the models were presented and made available. The questions and responses obtained are discussed.

6.1.1 Diversity and Variability

This characteristic addresses the model's ability to recognize and support change along all variables and diverse dimensions relevant to the enterprise. The question asked for this characteristic was:

How much change across all different modeled aspects of the organization is the model diverse in recognizing and supporting?

Of the four respondents asked, three responded that the model is diverse in recognizing and supporting change in most (51% - 75%) of the different modeled aspects of the organization, while one respondent said it did in some (26% to 50%).

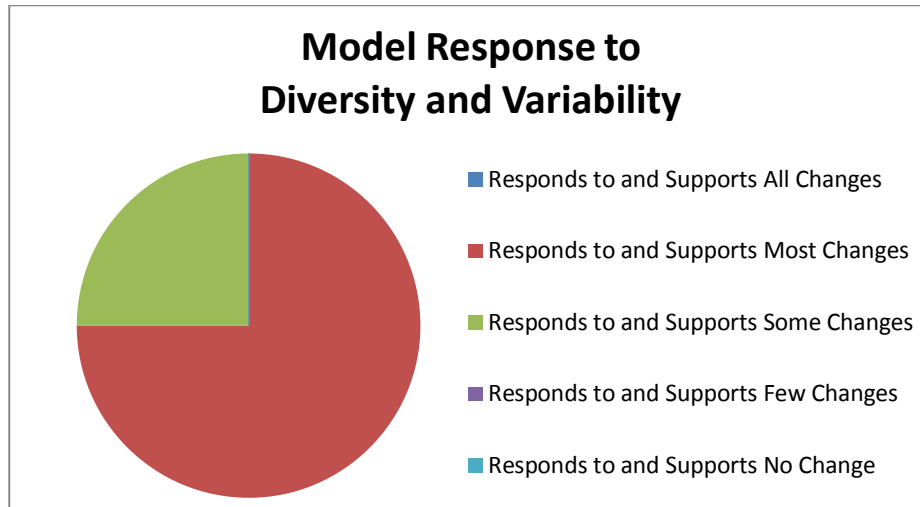


Figure 68: Model's response to the Diversity and Variability characteristic of the Adaptive Enterprise.

6.1.2 Uncertainty and Commitment

This characteristic addresses the model's consistency to anticipate specific kinds of changes in order to have built-in provisions, which allows for changes if and when they materialize. Two questions asked for this characteristic were:

How much known change does the model have provision to anticipate and support when they occur?

How much unknown change does the model have provision to anticipate and support when they occur?

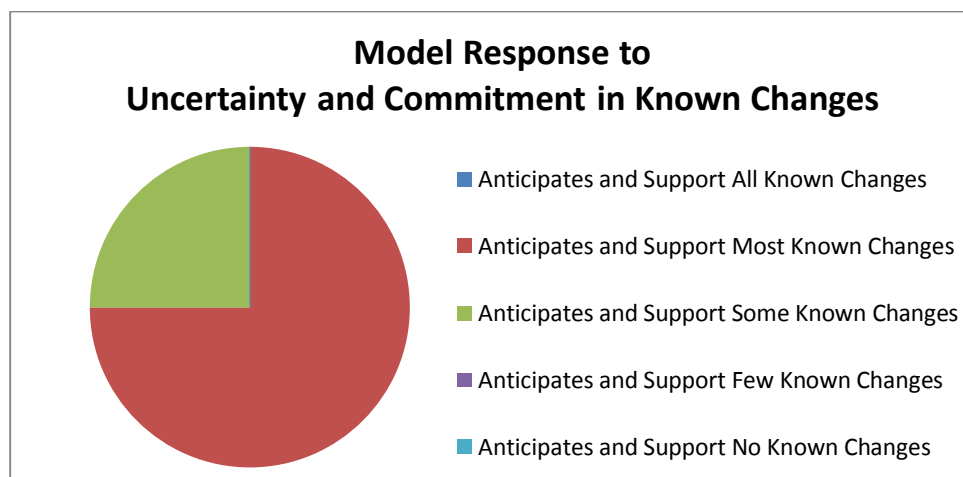


Figure 69: Model's response to Uncertainty and Commitment characteristic of the Adaptive Enterprise 1.

Of the four respondents asked, three responded that the model had provision to anticipate and support most (51% to 75%) changes with one respondent saying it can anticipate and support some (26% - 50%).

On anticipating and supporting unknown changes, two respondents said the model did most (51% to 75%) and the other two said it did some (26% - 50%).

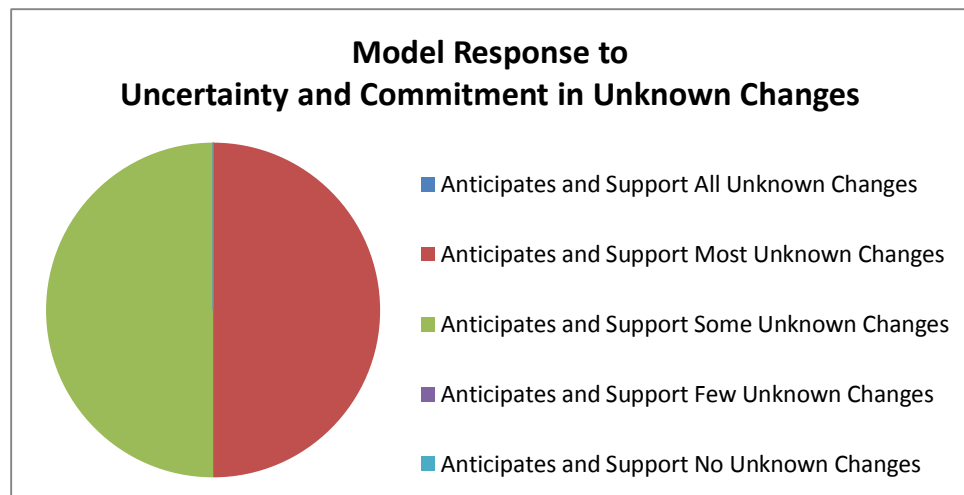


Figure 70: Model's response to Uncertainty and Commitment characteristic of the Adaptive Enterprise 2.

6.1.3 Sensing and Effecting Change

This characteristic addresses the model's ability to quickly and effectively respond to different types of changes. Two questions were also asked for this characteristic:

The model quickly and effectively responds to how much known changes when they occur?

The model quickly and effectively responds to new or unknown changes when they occur?

Of the four respondents asked, two said the model quickly and effectively responds to most (51% - 75%) known changes when they occur while the other two said it quickly and effectively responds to some (26% - 50%). On quickly and effectively responding to unknown or new changes when occur, one respondent said it did respond effectively to

all (76% - 100%) unknown or new changes, while the other three said it did to most (51% - 75%).

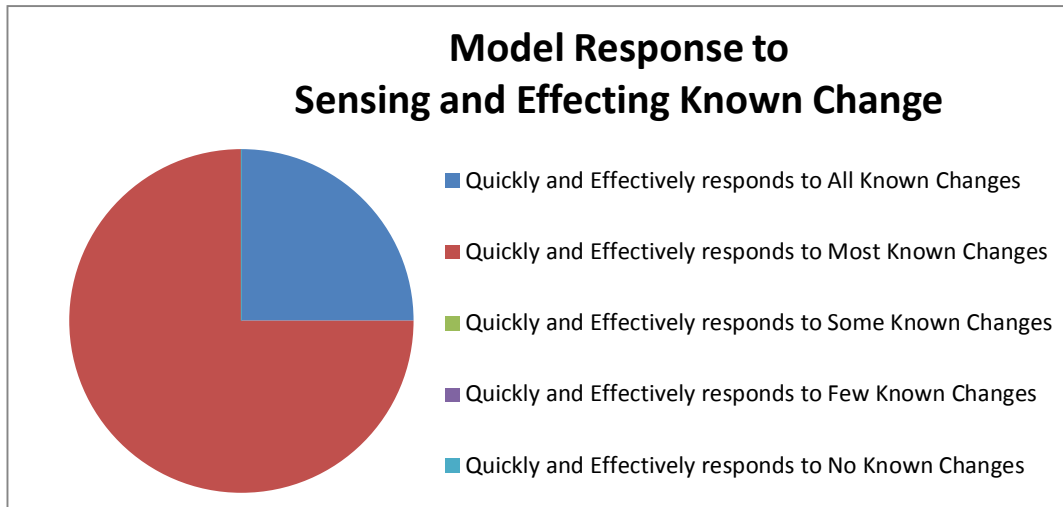


Figure 71: Model's response to Sensing and Effecting Change characteristic of the Adaptive Enterprise 1.

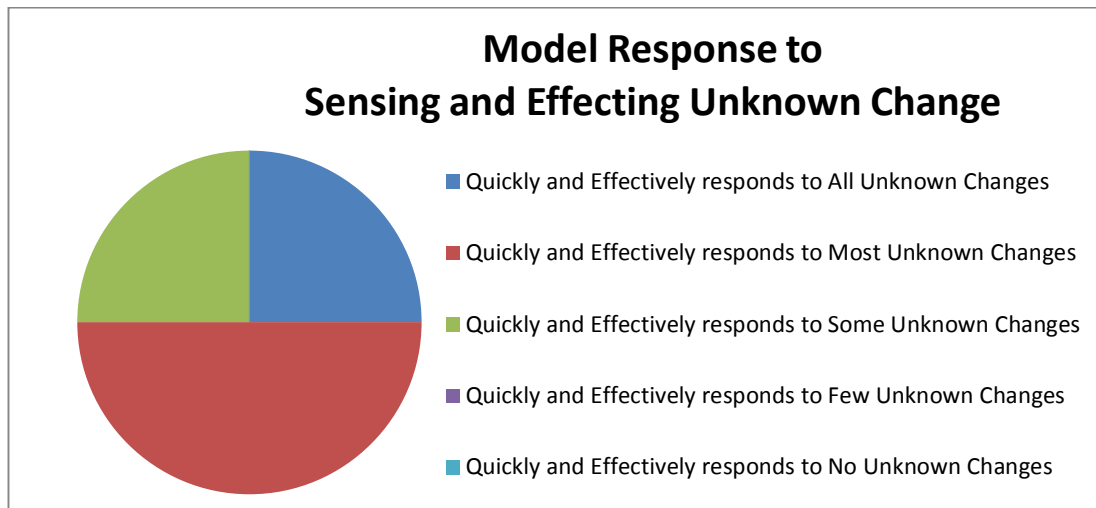


Figure 72: Model's response to Sensing and Effecting Change characteristic of the Adaptive Enterprise 2.

6.1.4 Barrier to Change

This characteristic addresses how aware the model is to barrier and resistance to change, social, political or technical in nature. The question asked for this characteristic was:

How much related aspects within the organization and their scope prone to changes, does the model show?

Of the four respondents asked, three responded that the model shows most (51% - 75%) related aspects within the organization and their scopes prone to changes while one respondent said it showed some (26% to 50%).

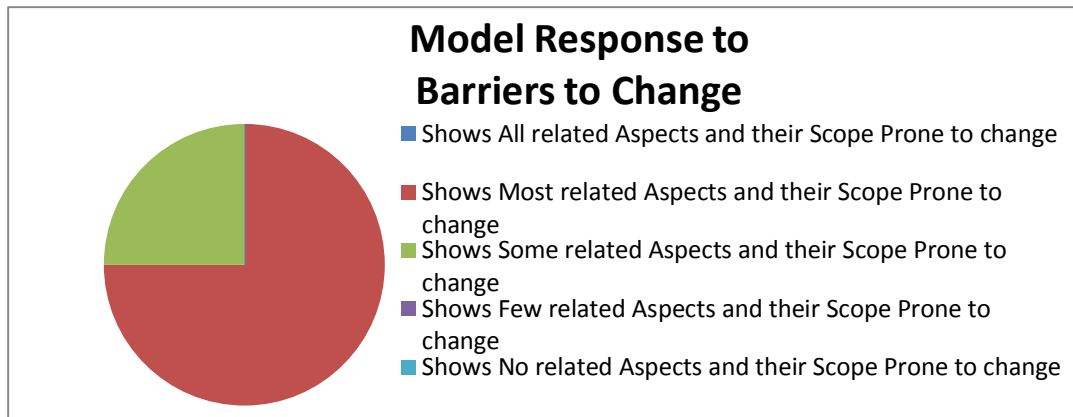


Figure 73: Model's response to Barrier to Change characteristic of the Adaptive Enterprise.

6.1.5 Multiple Levels of Dynamics

This characteristic addresses the model's recognition of different types and rates of changes, their characteristics and cycle times to provide appropriate adaptation support. Two questions were also asked for this characteristic:

How much kinds of change, their impact and means of response do the model document?

How much of the documented change do you find easy and effective to use?

Of the four respondents asked, three responded that the model documents most (51% - 75%) kinds of change, their impact and means of response while one respondent said it documented some (26% to 50%).

On how much of the documented change they found easy and effective to use, all of the respondents said they found most (51% - 75%) of the documented changes easy and effective to use.

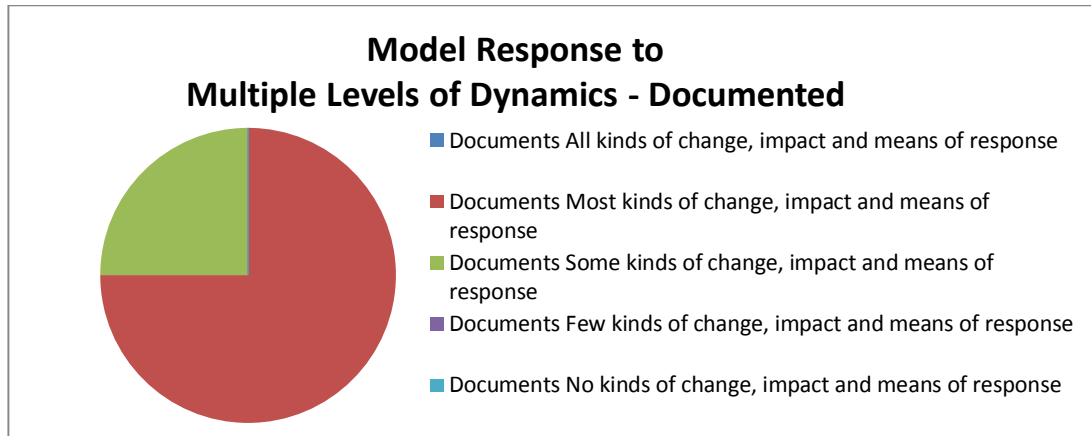


Figure 74: Model's response to Multiple Level of Dynamics characteristic of the Adaptive Enterprise 1.

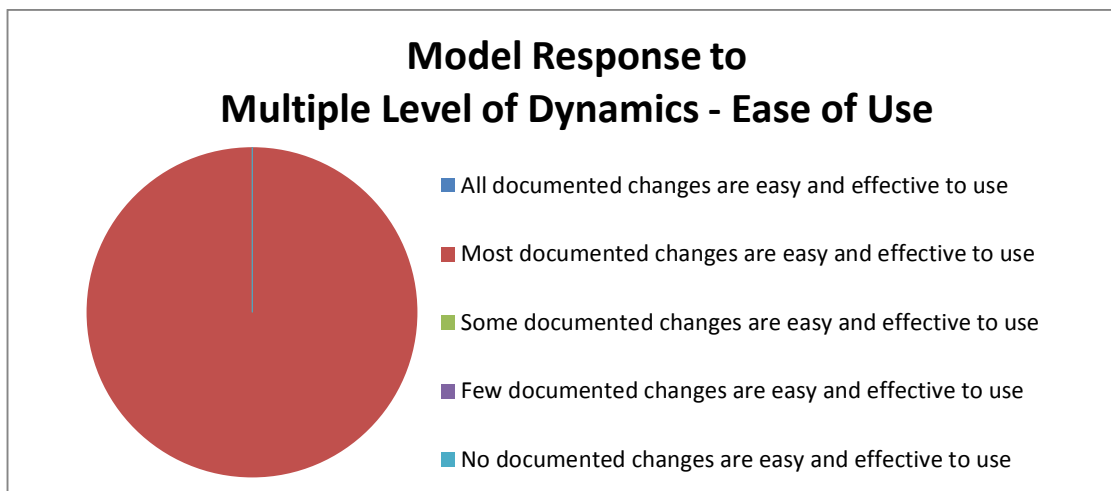


Figure 75: Model's response to Multiple Level of Dynamics characteristic of the Adaptive Enterprise 2.

6.1.6 Dynamic Systems, Boundaries and Closure

This characteristic addresses the model's support for the perception of an enterprise being a collection of interrelated bounded dynamic systems. The question asked for this characteristic was:

Of the agreed-on aspects of the organization, how many aspects and their dynamic interconnections does the model clearly show?

Of the four respondents asked, all responded that the model shows most (51% - 75%) agreed-on aspects of the organization and their dynamic interconnections.

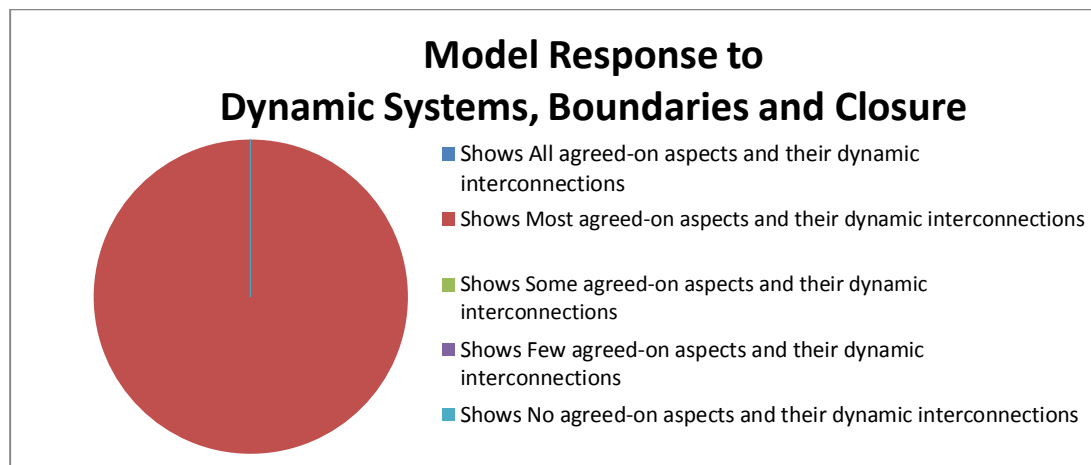


Figure 76: Model's response to Multiple Level of Dynamics characteristic of the Adaptive Enterprise 2.

6.1.7 Actor Autonomy and Alignment

This characteristic addresses whether the model shows the alignment of interests between the idealized dynamic system and participating actor with their goals. The question asked for this characteristic was:

How much elements of the model such as IT Systems (resources), stakeholders (actors), goals, softgoals or decisions (task) of the modeled scenarios can you clearly identify?

Of the four respondents asked, one respondent said the model clearly identifies all (76% - 100%) elements of the model, two respondents said it clearly identified most (51% - 75%) elements of the model while one respondent said it model some (26% to 50%) of the elements of the model.

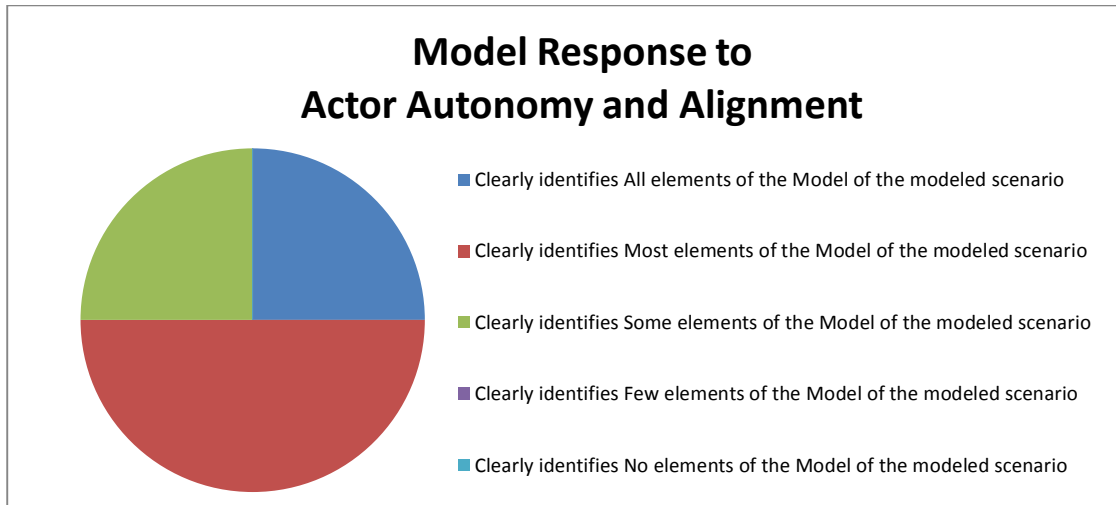


Figure 77: Model's response to Actor Autonomy and Alignment characteristic of the Adaptive Enterprise.

6.1.8 Business-IT Alignment

This characteristic addresses whether the model accommodates and supports a distributed view of business-IT alignment and the different mechanisms that contribute to it. The question asked for this characteristic was:

How much view and support of the business objectives by the Information System does the model show and address?

Of the four respondents asked, one respondent said the model shows all (76% -100%) views and support of the business objectives by the IS. Two respondents said it shows most (51% - 75%) views and support of the business objective by the IS while one respondent said it model some (26% to 50%) of the views and support of the business objectives by the IS.

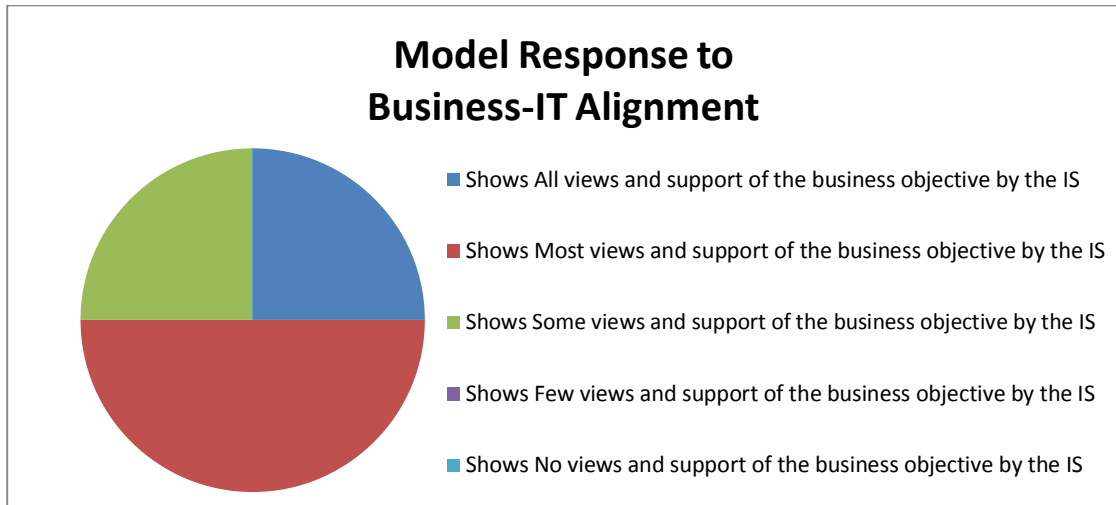


Figure 78: Model's response to Business-IT Alignment characteristic of the Adaptive Enterprise.

6.1.9 Adaptiveness as a Business Requirement

This characteristic addresses whether the model adopts techniques from requirements engineering in viewing adaptive requirements as goals within scenarios.

How much change in the modeled aspects does the model accommodate as business requirements?

Of the four respondents asked, one responded that all (76% - 100%) changes in the modeled aspects are accommodated as business requirements.

One respondent said that most (51% - 75%) changes in the modeled aspects are accommodated as business requirements while two respondents said some (26% to 50%) changes in the modeled aspects are accommodated as business requirements.

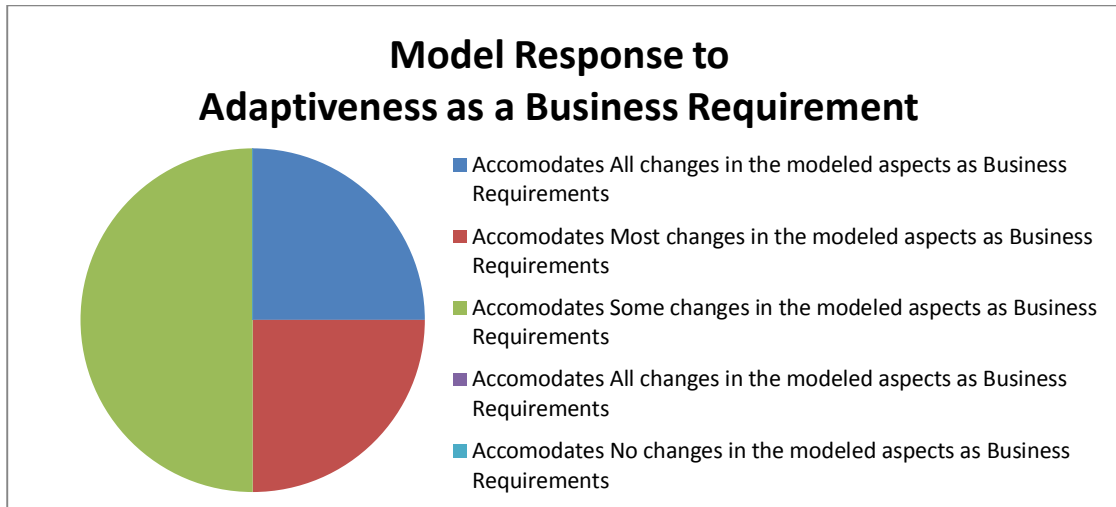


Figure 79: Model's response to Adaptiveness as a Business Requirement characteristic of the Adaptive Enterprise.

6.2. Discussion of Evaluation Results

Table 13 shows a summary of the responses by the CIC's senior personnel on the performance of the model in supporting adaptive enterprise architectures as described in Yu et al. (2012). To obtain the average values used, we assign the following weights for each response:

All (76% - 100%)	=	5
Most (51% - 75%)	=	4
Some (26% - 50%)	=	3
Few (1% - 25%)	=	2
None (0%)	=	1

We observe that the model's response after use at the CIC's 'Grants and Contributions' program are encouraging, showing no apparent major weakness. With average responses for all characteristics ranging from "some" to "all", the model responds strongest to sensing and effecting almost "all" known changes. Strong responses are also observed for "most" of, sensing and effecting unknown changes, multiple levels of dynamics for ease of use of documented change, dynamic systems boundaries and closure, actor autonomy

and alignment as well as for business-IT alignment. Diversity and variability, uncertainty and commitment for known changes, barrier to change, multiple dynamics for documented change and adaptiveness as a business requirement show relatively strong responses with about “most”. The weakest response was for uncertainty and commitment for more than “some” unknown changes.

Table 13: Summary of the model’s responses to characteristics outlined in Yu et al. (2012)

CHARACTERISTIC	MODEL RESPONSE					Weighted Average (Max: 5)
	All (76% - 100%)	Most (51% - 75%)	Some (26% - 50%)	Few (1% - 25%)	None (0)	
Diversity and Variability		3	1			3.75
Uncertainty and Commitment for known changes		3	1			3.75
Uncertainty and Commitment for unknown changes		2	2			3.50
Sensing and Effecting Change (known changes)	1	3				4.25
Sensing and Effecting Change (unknown changes)	1	2	1			4.00
Barrier to Change		3	1			3.75
Multiple Levels of Dynamics for documented change		3	1			3.75
Multiple Levels of Dynamics for ease of use of documented change		4				4.00
Dynamic Systems, Boundaries and Closure		4				4.00
Actor Autonomy and Alignment	1	2	1			4.00
Business-IT Alignment	1	2	1			4.00
Adaptiveness as a Business Requirement	1	1	2			3.75

The reasons for these variations and identified strong performance could be as a result of the validation scenario chosen being one of a known change – the proposed decommissioning of the “CAMS System.

Informal but very positive observations on our BI-EAEA framework were also provided by the CIC personnel:

- They liked the presence of the three levels. From experience, they said they spend much working at the Decision level, to adapt to changes in (and negotiate with) the High level and the IS level. The importance of the Decision level is often underestimated, yet this is where “the magic happens”. The links between the three levels is where the real value of this framework is found.
- There is a risk to spend much time documenting the As Is enterprise architecture (and inventories) in many approaches, and little value is seen in this from their experience. They liked the URN-based approach because the investment in the modeling aspects is minimal.
- The granularity of the IS could be changed too (and we could represent one or several functionalities or modules of a complex IS instead of the IS as a whole). The framework seems to accommodate this as well.
- They liked the fact that the URN-based modeling used here reflects what is done informally right now. The framework can likely make this happen faster or more systematically, while providing a rationale for decisions. An earlier availability of EA models also enable people to *disagree sooner*, which can help avoid disappointments and failures in the long run.
- There is an increasing need for numbers and quantities in the organizations, and the KPIs and satisfaction values could likely help accommodate this.
- The models, with GRL strategies, could also be used as documentation trail for analysis and decisions.

6.3. Summary

In this chapter, we presented and discussed responses on the model’s performance against the validation scenario for characteristics of an adaptive enterprise architecture as report-

ed by personnel of the CIC who were exposed to the model. The answers and informal feedback are positive and encouraging.

The next chapter highlights the contributions of this work, limitations during the research as well as recommendation for future works.

Chapter 7. Conclusions

This chapter summarizes the framework introduced in this thesis, compares it to closely-related work, reviews the contributions, discusses limitations, and makes recommendations for future work and research possibilities.

7.1. Summary of Contributions

In this thesis, we answered the research question “*Can the modeling of organizational information needs based on concepts from the User Requirement Notation (URN) allow for adaptive architecture design and if so, to what extent?*” by the affirmative with a new framework for achieving adaptiveness in EA, with limitations discussed in the next section.

The Business Intelligence-Enabled Adaptive Enterprise Architecture (BI-EAEA) framework consists of a modeling language implemented as a profile of URN, a methodology, and tool support based on jUCMNav. The framework helps enterprises model the relationships between business objectives of important stakeholders, the decisions made by decision-makers in achieving these business objectives, the Information Systems serving as sources of the information utilized by the decision makers, and indicators measuring six common performance aspects of these Information Systems. Using GRL goal modeling and evaluation strategies within jUCMNav, these concepts and their relationships can be modeled and analyzed with the response and impacts of adaptation (caused by modifications, additions, and deletions at any level) evaluated to further aid decision making in organizations. Business Intelligence can be used both as means to feed the indicators enabling model analysis and as means to further visualize and distribute the analysis results.

The BI-EAEA also conforms in part to the elements of the ISO/IEC/IEEE 42010 standard (ISO/IEC/IEEE 42010, 2011) seen in Section 2.1 required in the architecture viewpoints and the architecture description language (ADL), as illustrated in Table 14. This standard provides a core ontology for the description of architectures and can be used to assess conformance of an archi-

tecture description, of an architecture framework, of an architecture description language, or of an architecture viewpoint to its provisions.

Table 14: *Conformity of the BI-EAEA to the ISO/IEC/IEEE 42010 Standard*

	ISO/IEC/IEEE 42010 Standard	BI-EAEA
Architecture viewpoint	- Concerns framed by the viewpoint - Stakeholders for the concerns. - One or more model kinds used in the viewpoint. - For each model kind, languages, notations etc. used on models of this kind.	- Adaptive EA scenarios the BI-EAEA models. - Modeled in GRL as actors. - GRL models used to describe the EA and adaptive scenarios. - URN/GRL
Architecture description language (ADL)	- Concerns to be expressed by the ADL. - Stakeholders having these concerns. - Model kinds implemented by the ADL framing these concerns. - Any architecture viewpoints.	- Adaptive EA scenarios the BI-EAEA models. - Modeled in GRL as actors. - GRL models used to describe the EA and adaptive scenarios

A comparison of BI-EAEA and other approaches described in Section 2.2.4 shows that our approach provides an elaborate means of addressing adaptation. It does this not only by identifying how adaption is presented and the levels within the enterprise where they are presented, but also by allowing for anticipation and support by showing the relationships between all actors and scenarios involved in adaption. Our approach also provides tool support. Table 15 shows a comparison summarizing the other approaches to adaptive EAs and the Business Intelligence-Enabled Adaptive Enterprise Architecture. It extends Table 1 with an additional column covering our BI-EAEA framework, as well as three more rows adding further relevant points of comparison (in yellow background).

Table 15: Comparison of reviewed adaptive EA frameworks and the BI-Enabled Adaptive EA Framework

	Gill Framework	HP Adaptive EA	KARSA Framework	BI-EAEA Framework
Objective	Enabling enterprise service system adaptation.	Builds processes and applications over an IT infrastructure that is adaptive.	Leverages services as key elements in addressing adaptation.	Models goals, decisions, IS, indicators and their links within the EA where adaptation can be explored and addressed.
Approach	Use of sets of integrated adaptive disciplines for developing and managing EA adaptation.	Use of an architecture that brings together hardware, software and services to drive towards a data centre that operates more efficiently, delivers on more stringent SLAs and responds faster to business needs.	Use of ITIL Service Operation and Service Computing Taxonomy to address EA and Service Oriented issues	Use of a profiled GRL to model and evaluate responses to adaptation and evaluation of their impacts.
Elements	Inner Layer: Defining, Operating, Managing, Supporting. Outer Layer: Context, Rationalisation, Assessment, Realization, Unrealization	A model composed of strategic objectives, KPIs and operational performance measures.	SO Lifecycle, Classification Schema, meta-model and Life History Model	Methodology, modeling language and tool with support for analysis
How is adaption presented in the enterprise?	None	None	None	Modifications, Deletions and Additions.
Where is adaptation presented in the enterprise?	None	None	None	In the business objectives, decisions of stakeholders and IS, as well as their relationships
Shows levels of abstraction goals are represented within the enterprise	None	None	None	Yes

	Gill Framework	HP Adaptive EA	KARSA Framework	BI-EAEA Framework
Tool Support	None	HP Virtual Server Environment and HP BladeSystem Infrastructure.	None	jUCMNav
Based on	TOGAF	HP	SO, ITIL	URN

Through the implementation and validation of the framework, the following contributions were also made in this thesis:

- Systematic handling of changes (modification, deletion and addition of objectives, decisions, IS, their attributes and relationships) to support adaptation.

In identifying the ways adaptations are presented in the enterprise and the levels within the enterprises in which they occur, goal modeling using URN can be applied to model, respond to, and evaluate adaptations in terms of modifications, deletions or additions within changing business objectives, decisions or IS. This is best summarized by Table 11.

- *A modeling style for URN, which exploits existing tool support (jUCMNav), to which well-formedness rules were added as selectable OCL constraints. This style also uses KPIs potentially fed by BI systems.*

The framework builds on URN but also profiles it to the particular domain of EA. We also created 9 new OCL rules for jUCMNav for addressing adaptive Enterprise Architecture concerns (Section 3.3.2 and Appendix A).

- *A new methodology based on Analytical Hierarchy Process to compute contribution levels in GRL models.*

In Section 3.3.1 and Appendices C and D, BI-EAEA's methodology exploits pairwise comparisons and AHP in GRL models. This goes beyond recent proposals for using AHP to compute contribution levels in different languages such as Liaskos et al. (2012) for i^* , Kassab (2013) for the Non-Functional Requirements framework, and Vinay et al. (2012) for their own goal modeling language. Not only are contributions

handled in a standardized language for the first time (GRL), but so are importance levels in actors, and KPI contributions.

- *Further debate/dialog on the influence of decision makers' actions, and on organization's business objectives and IS that support them, as an important consideration in adaptive EA.*

The response from the validation of the framework at the CIC (Chapter 6) highlights the importance of the often underestimated Decision level, which addresses decision maker's actions.

By creating goal models showing links between business objectives and IS that support them, as conversations on adaptive EAs continues, decision makers have models they can use as rationales to reason about responses and impacts of adaptation. Since the models reflect what is currently done informally, they can be applied more systematically, with traceability, and hopefully in a faster way (although this last part requires further investigation).

7.2. Limitations

This work is an applied research involving the introduction and use of IT artifacts to address adaptiveness in enterprise architectures. To this end, consideration of possible risks involved in the design and execution of these artifacts, also called experimental validity threats, is necessary. Wright et al. (2010) argue that for any experiment to make convincing arguments, it must possess a high degree of validity. This indicates that experimental threats and measures put in place to address them should be an important consideration. These experimental threats include:

- **Conclusion Validity Threats:** threats concerned with the relationship between the treatment and outcome.
- **Internal Validity Threats:** threats that could indicate the relationship is not casual but a result of factors the research is controlling.
- **Construct Validity Threat:** threats concerned with the relations between the theory and observation in the research.

- **External Validity Threats:** threats concerned with the generalization of the observed result to a larger population outside the sample instance used in the experiment.

Of note, the author is aware that within any implementation of IS, real people exist. These are people who represent the techno-social-political paradigm, and they co-exist with the IS involved in an adaptive enterprise. This is because adaptability is not just in terms of the IS in place, since IS are not just communicating with themselves, but with the people involved. To address this concern, this research focused on information needs, when and how they change, to enable creation of the scenarios of adaptation we addressed. Also, the various concerns of the techno-social-political paradigm were addressed using the pairwise comparison technique with AHP discussed in Section 3.3.1. In addition to this, the construction of the questionnaires used to evaluate the model (see Appendix B) did not have a comparison point for the result we obtained. While we could have compared our result with an assessment of their current practice, informal discussions confirmed that we presented a more rigorous and useful assessment compared to what they current use.

Again in terms of construct validity, for simplicity of the process, this thesis did not consider what triggers decisions as organizations decide about business objectives, but rather captured and treated decisions as scenarios of “the business evolving”. These scenarios were subsequently modeled adequately as adaptation. Again, whilst decisions can be used as some indication that a new information source is required, we were aware that the CIC like most organizations, do not generally have a repository of decisions. However since they register goals, within a certain goal structure, the need for adaptation can be observed. This can be when the available decisions calls for scale or addition of new resources; either more people need to make more decisions or the same person need to make more decisions within the context of the goal. If a new goal is registered, it is normally indicated in the business plan or the budget, as new goals have to be funded.

In terms of internal validity, the thesis author created the goal model himself, as well as the strategies. Although these artifacts were inspected by his advisors, some bias might have been introduced along the way, to avoid certain types of problems. To mitigate this aspect, the model was validated by two employees of CIC. However, it would have been better to have the employees of the target organization create the models themselves (and avoid bias), but this was

impossible due to their insufficient training at the time, and their lack of availability. Another related threat is the use of artificial examples, which was mitigated to a large extent by taking a real-life example involving real IS and real enterprise architects.

Finally, in terms of external validity, inasmuch as the CIC was chosen because it reflects a typical organization that constantly deals with changes in its diverse ranges of business decisions, we recognize that the representation and application of the methodology and model described deals with only one representation of one organization. The results and conclusion therefore, could be limited to that particular case. Also the way the CIC operates, including its business processes and the IS in places, may not be a true representation of every organization. Additional case studies would help mitigate this threat and improve generalization, and also help better assess the scalability, usability, and performance of the framework.

7.3. Recommendations for Future Work

Our approach towards addressing adaptive EA presents a significant step towards achieving adaptive EAs as well as the use of URN in modeling EA. However, several new research questions were raised along the way.

In terms of generalization of the framework, since we covered only one case study in this thesis, more enterprise architectures of different sizes and domains should be modeled and assessed, not only against the 12 questions we used here, but also in terms of the validity of the insights and the potential gains in performance (perceived or real) when architectural decisions are made.

The CIC model explored here did not take into consideration cost issues related to decisions. One research question is whether cost aspects should be included in the model, or be handled separately.

Future work should also address the use of the “Constraint-Oriented GRL Algorithm” discussed in Section 4.2.1. Solving the scalability issues in the existing prototype would enable top-down and inside-out evaluations of GRL models, and provide more possible solutions while analysing changes at either the High level or Decision level of the model. It will also support more abstractions of the enterprise. Better tool support in jUCMNav for automating pair-wise comparison and AHP analysis (e.g., through the generation of online comparison surveys and collection of answers) is something that would greatly enhance the usability of the methodology.

Another area of focus would be to further explore the complementary use of Use Case Maps (UCM) for adaptive EA. This would provide a means of modeling, for adaptive EA, scenarios at play within business processes along with the GRL models this work showed.

Although GRL was used here, some aspects of the framework could be transposable to other modeling languages, especially the Business Intelligence Model (Barone et al., 2010; Horkoff et al., 2012) as it also covers actors, goals and indicators (but not yet strategies).

With the influence decision makers' actions have on the enterprise coming to light in consideration for adaptive EAs, future work can bring to the fore the need to capture these decisions that influence business objectives and IS, i.e., the "Managerial Process", as an important consideration for BI 2.0.

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Appendix A: URN Measured OCL Rules

This appendix formalizes in OCL the well-formedness rules adapted for adaptive EA discussed in Section 3.3.2. These constraints are available in the jUCMNav tool and make use of jUCMNav's library of predefined OCL functions².

Rule 1: The Information System actor must only contain resources and KPIs/Indicators.

context grl::IntentionalElementRef

inv IShasOnlyResourcesAndKPIs :

```
( getDef().type<>grl::IntentionalElementType::Ressource
  and
  getDef().type<>grl::IntentionalElementType::Indicator )
implies
self.contRef.contDef.oclAsType(grl::Actor).name.toLower()<>'information system'
```

Rule 2: The elements of the Information System must not receive contributions from other actors.

context grl::LinkRef

inv NoContributionsToIS :

```
self.link.oclIsTypeOf(grl::Contribution)
implies
( source.contRef.contDef.oclAsType(grl::Actor).name.toLower()<>'information system'
  implies
  target.contRef.contDef.oclAsType(grl::Actor).name.toLower()<>'information system' )
```

² <http://jucmnav.softwareengineering.ca/ucm/pub/ProjetSEG/SemanticVerification/library.ocl>

Rule 3: Contributions to an intentional element should not sum up to a value higher than 100.

context grl::IntentionalElement

inv GRLtotalIncomingContribNotMoreThan100 :

```
    self.linksDest
        -> select(link | link.oclIsTypeOf(grl::Contribution))
        -> collect(link | link.oclAsType(grl::Contribution)).quantitativeContribution
        -> sum() <= 100
```

Rule 4: Contributions to an intentional element should not sum up to a value less than 100.

context grl::IntentionalElement

inv GRLtotalIncomingContribNotLessThan100 :

```
    self.linksDest
        -> select(link | link.oclIsTypeOf(grl::Contribution)) -> notEmpty()
    implies
    self.linksDest -> select(link | link.oclIsTypeOf(grl::Contribution))
        -> collect(link | link.oclAsType(grl::Contribution)).quantitativeContribution
        -> sum() >= 100
```

Rule 5: A contribution change should not make the sum of contributions to an intentional element be more than 100.

context grl::ContributionContext

inv GRLcontributionContextSumMoreThan100 :

```
    self.grlspec.urnspec.getAllIntentionalElements() ->
    forall (ie | ie.linksDest
        -> select(link | link.oclIsTypeOf(grl::Contribution))
        -> collect(link | link.oclAsType(grl::Contribution))
        -> collect(c |
            if ( changes.contribution->includes(c) )
            then ( self.changes -> select (ch | ch.contribution = c) ->
                first().newQuantitativeContribution )
            else c.quantitativeContribution
            endif )
        -> sum() <= 100
    )
```

Rule 6: A contribution change should not make the sum of contributions to an intentional element be less than 100.

context grl::ContributionContext

inv GRLcontributionContextSumLessThan100 :

```

    self.grlspec.urnspec.getAllIntentionalElements() ->
    forAll (ie | ie.linksDest
    -> select(link | link.oclIsTypeOf(grl::Contribution))
    -> collect(link | link.oclAsType(grl::Contribution))
    -> collect(c |
        if ( changes.contribution->includes(c) )
        then ( self.changes -> select (ch | ch.contribution = c) ->
            first().newQuantitativeContribution )
        else c.quantitativeContribution
        endif )
    -> sum() >= 100
    )

```

Rule 7: The sum of the importance values of the intentional elements of an actor must not be higher than 100.

context grl::ActorRef

inv GRLtotalImportanceNotMoreThan100 :

```

    let
        ierefs : Set(grl::IntentionalElementRef) =
            self.contDef.contRefs.nodes
            -> asSet()
            -> select(n | n.oclIsTypeOf(grl::IntentionalElementRef))
            -> collect(n | n.oclAsType(grl::IntentionalElementRef))
            -> asSet()
    in
        self.diagram.urndefinition.urnspec.grlspec.intElements
            -> asSet()
            -> select(ie | ie.refs -> intersection(ierefs) -> notEmpty())
            -> collect(importanceQuantitative)
            -> sum() <= 100

```

Rules 8: The sum of the importance values of the intentional elements of an actor must not be lower than 100.

context grl::ActorRef

inv GRLtotalImportanceNotLessThan100 :

let

```
ierefs : Set(grl::IntentionalElementRef) =  
    self.contDef.contRefs.nodes  
    -> asSet()  
    -> select(n | n.oclIsTypeOf(grl::IntentionalElementRef))  
    -> collect(n | n.oclAsType(grl::IntentionalElementRef))  
    -> asSet()
```

in

```
self.diagram.urndefinition.urnspec.grlspec.intElements  
    -> asSet()  
    -> select(ie | ie.refs -> intersection(ierefs) -> notEmpty())  
    -> collect(importanceQuantitative)  
    -> sum() >= 100
```

Rule 9: An Intentional Element (e.g., goal or resource) should have links.

context grl::IntentionalElementRef

inv GRLintentionalElementWithoutLink :

```
self.getDef().linksSrc->notEmpty()  
or  
self.getDef().linksDest->notEmpty()
```

Appendix B: Questionnaire on Evaluation Strategy

Where All = 76% - 100% Most = 51% - 75% Some = 26% - 50% Few = 1% - 25%
None = 0

- 1) How much change across all different modeled aspects of the organization is the model diverse in recognizing and supporting?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 2) How much *known* change does the model have provision to anticipate and support when they occur?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 3) How much *new or unknown* change does the model have provision to anticipate and support when they occur?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 4) The model quickly and effectively responds to how much *known* changes when they occur?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 5) The model quickly and effectively responds to how much *new or unknown* change when they occur?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 6) How much related aspects within the organization and their scope prone to changes do the model show?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 7) How much kinds of change, their impact and means of response do the model document?
☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 8) How much of the documented change do you find easy and effective to use?
☐ All ☐ Most ☐ Some ☐ Few ☐ None

- 9) Of the agreed-on aspects of the organization, how much aspect and their dynamic inter-connections does the model clearly show?
- ☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 10) How much elements of the model such as IT Systems (resources), stakeholders (actors), goals, softgoals or decisions (asks) of the modeled scenarios can you clearly identify?
- ☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 11) How much view and support of the business objectives by the Information Systems does the model show and address?
- ☐ All ☐ Most ☐ Some ☐ Few ☐ None
- 12) How much change in the modeled aspects does the model accommodate as business requirements?
- ☐ All ☐ Most ☐ Some ☐ Few ☐ None

Appendix C: Pairwise Comparison for Indicators

PAIRWISE CONTRIBUTION CHART FOR INFORMATION SYSTEM

Please select the importance level of the following characteristics against each other for the respective Information System where:

- << : is much less than
 < : is less than
 = : is equal to
 >> : is much greater than
 > : is greater than

1) SYSTEM A

System Quality	<<	<	=	>	>>	Service Quality
Service Quality	<<	<	=	>	>>	Information Quality
Information Quality	<<	<	=	>	>>	User Satisfaction
User Satisfaction	<<	<	=	>	>>	System Use
System Use	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Information Quality
Service Quality	<<	<	=	>	>>	User Satisfaction
Information Quality	<<	<	=	>	>>	System Use
User Satisfaction	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	User Satisfaction
Service Quality	<<	<	=	>	>>	System Use
Information Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	System Use
Service Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Net Benefit

2) **SYSTEM B**

System Quality	<<	<	=	>	>>	Service Quality
Service Quality	<<	<	=	>	>>	Information Quality
Information Quality	<<	<	=	>	>>	User Satisfaction
User Satisfaction	<<	<	=	>	>>	System Use
System Use	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Information Quality
Service Quality	<<	<	=	>	>>	User Satisfaction
Information Quality	<<	<	=	>	>>	System Use
User Satisfaction	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	User Satisfaction
Service Quality	<<	<	=	>	>>	System Use
Information Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	System Use
Service Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Net Benefit

3) **SYSTEM C**

System Quality	<<	<	=	>	>>	Service Quality
Service Quality	<<	<	=	>	>>	Information Quality
Information Quality	<<	<	=	>	>>	User Satisfaction
User Satisfaction	<<	<	=	>	>>	System Use
System Use	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Information Quality
Service Quality	<<	<	=	>	>>	User Satisfaction
Information Quality	<<	<	=	>	>>	System Use
User Satisfaction	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	User Satisfaction
Service Quality	<<	<	=	>	>>	System Use
Information Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	System Use

Service Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Net Benefit

4) **SYSTEM D**

System Quality	<<	<	=	>	>>	Service Quality
Service Quality	<<	<	=	>	>>	Information Quality
Information Quality	<<	<	=	>	>>	User Satisfaction
User Satisfaction	<<	<	=	>	>>	System Use
System Use	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Information Quality
Service Quality	<<	<	=	>	>>	User Satisfaction
Information Quality	<<	<	=	>	>>	System Use
User Satisfaction	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	User Satisfaction
Service Quality	<<	<	=	>	>>	System Use
Information Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	System Use
Service Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Net Benefit

5) **SYSTEM E**

System Quality	<<	<	=	>	>>	Service Quality
Service Quality	<<	<	=	>	>>	Information Quality
Information Quality	<<	<	=	>	>>	User Satisfaction
User Satisfaction	<<	<	=	>	>>	System Use
System Use	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Information Quality
Service Quality	<<	<	=	>	>>	User Satisfaction
Information Quality	<<	<	=	>	>>	System Use
User Satisfaction	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	User Satisfaction

Service Quality	<<	<	=	>	>>	System Use
Information Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	System Use
Service Quality	<<	<	=	>	>>	Net Benefit
System Quality	<<	<	=	>	>>	Net Benefit

Appendix D: Pairwise Comparison for Other Elements

PAIRWISE CONTRIBUTION CHART FOR BUSINESS OBJECTIVES AND (OR) INFORMATION SYSTEMS

Please select the importance level of the following characteristics against each other for the respective Information System where:

- << : is much less than
< : is less than
= : is equal to
>> : is much greater than
> : is greater than

A) ORGANIZATION'S OBJECTIVE OR DECISION MAKER'S ACTIONS

Goals

Goal 1	<<	<	=	>	>>	Goal 2
Goal 1	<<	<	=	>	>>	Goal 3
Goal 2	<<	<	=	>	>>	Goal 3

Softgoals

Softgoal 1	<<	<	=	>	>>	Softgoal 2
Softgoal 1	<<	<	=	>	>>	Softgoal 3
Softgoal 2	<<	<	=	>	>>	Softgoal 3

Tasks

Task 1	<<	<	=	>	>>	Task 2
Task 1	<<	<	=	>	>>	Task 3
Task 2	<<	<	=	>	>>	Task 3

Resource

Resource 1	<<	<	=	>	>>	Resource 2
Resource 1	<<	<	=	>	>>	Resource 3
Resource 2	<<	<	=	>	>>	Resource 3

B) INFORMATION SYSTEMS

IS Resource

IS Resource 1	<<	<	=	>	>>	IS Resource 2
IS Resource 1	<<	<	=	>	>>	IS Resource 3
IS Resource 2	<<	<	=	>	>>	IS Resource 3

Appendix E: KPI Evaluation Values

INFORMATION SYSTEM PERFORMANCE CHART

Please rank the performance of the Grants and Contributions' Information Systems currently in use on a scale of "0 – 100" with 10 being worse performance and 100 being best performance, against the following:

- a) **System Quality**: exhibits desirable characteristics such as reliability, flexibility, ease of learning, sophistication, feature of intuitiveness, etc.
- b) **Information Quality**: exhibits desirable characteristics of the Information System output such as relevance, understandability, accuracy, completeness, usability, etc.
- c) **Service Quality**: the quality of support the system users receive from IT personnel is responsive, accurate, reliable, with empathy, etc.
- d) **System Use**: the degree and manner all stakeholders utilize the capabilities of the information system in terms of amount of usage, frequency of use, nature of use, appropriateness of use, extent of use, purpose of use, etc.
- e) **User Satisfaction**: user's level of satisfaction with reports, websites, data, etc. they get from the information system.
- f) **Net Benefits**: the extent to which the Information System contributes to the success of individuals, groups, and organizations who use it in terms of improved decision-making, improved productivity, increased sales, cost reduction, etc.

Where

- Target Value:** Identifies the maximum value of satisfaction for an Information System performance.
- Threshold Value:** Identifies the least acceptable value of satisfaction for an Information System performance, any value lower is considered unacceptable.
- Worst Value:** Identifies the maximum value of dissatisfaction for an Information System performance.

Evaluation Value: Identifies the current actual value the Information system is performing.

1.) SYSTEM QUALITY

System	Target Value	Threshold Value	Worst Value	Evaluation Value
System A				
System B				
System C				
System D				
System E				

2.) INFORMATION QUALITY

System	Target Value	Threshold Value	Worst Value	Evaluation Value
System A				
System B				
System C				
System D				
System E				

3.) SERVICE QUALITY

System	Target Value	Threshold Value	Worst Value	Evaluation Value
System A				
System B				
System C				
System D				
System E				

4.) SYSTEM USE

System	Target Value	Threshold Value	Worst Value	Evaluation Value
System A				
System B				
System C				
System D				
System E				

5.) USER SATISFACTION

System	Target Value	Threshold Value	Worst Value	Evaluation Value
System A				
System B				
System C				
System D				
System E				

6.) NET BENEFITS

System	Target Value	Threshold Value	Worst Value	Evaluation Value
System A				
System B				
System C				
System D				
System E				