A Framework for a Business Intelligence-Enabled Adaptive Enterprise Architecture

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Abstract. The environments in which businesses currently operate are dynamic and constantly changing, with influence from external and internal factors. When businesses evolve, leading to changes in business objectives, it is hard to determine and visualize what direct Information System responses are needed to respond to these changes. This paper introduces an enterprise architecture framework which allows for anticipating and supporting proactively, adaptation in enterprise architectures as and when the business evolves. This adaptive framework exploits and models relationships between *business objectives* of important stakeholders, *decisions* related to these objectives, and *Information Systems* that support these decisions. This framework exploits goal modeling in a Business Intelligence context. The tool-supported framework was assessed against different levels and types of changes in a real enterprise architecture of a Canadian government department, with encouraging results.

Keywords: Adaptive Enterprise Architecture, Business Intelligence, Decisions, Goal Modeling, Information Systems, User Requirements Notation.

1 Introduction

Aligning business objectives with Information Systems (IS) to facilitate collecting, processing, storing, retrieving and presenting the different types of information organizations require has always represented a challenge. It has been observed that IS tend to be hard to use, are inflexible to the needs of the business, and fail to support or reflect the businesses they were designed to support; "*most information systems are technical successes but organizational failures*" [16]. Needless to say, CIOs of most companies agree that making IS simple and closely aligned to the business they support remains their uppermost priority today [21, 26].

The fundamental premise of an Enterprise Architecture (EA) is the alignment of the organization's business objectives with the IS that support them. Frameworks for EA design that enable alignment have been used for over 30 years [7], including the Zachman Framework for Enterprise Architecture, The Open Group Architectural Framework (TOGAF), the Federal Enterprise Architecture, and the Gartner Methodology [25]. Such frameworks and their companion methodologies, although used in

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over 90% of EA designs and implementations, do not seem to fully address the misalignment of IS to business objectives, especially from a decision-making viewpoint. These frameworks suggest that business objectives should be at the center of EA because these objectives define the information used to make decisions. However, the question of how the centrality of objectives allows organizations to adapt their architectures in the current dynamic business environment needs to be further explored. We recommend an adaptive architecture for the enterprise that links IS to business objectives, thus allowing for seamless co-evolution of the information structure. In such an architecture, the decisions made to achieve organizational business objectives should take priority in the design and implementation of IS structures. This is because these decisions influence the sourcing and subsequent use of information.

This paper introduces and illustrates a framework that links decisions regularly made by managers in achieving organization's business objectives to the IS providing the information utilized. This *Business Intelligence - Enabled Adaptive Enterprise Architecture* (BI-EAEA) framework consists of a model, a methodology and tool support [1]. The framework exploits goal, process, and indicator modeling and analysis in establishing links between an organization's business objectives and IS. It relies on the User Requirements Notation (URN) [4, 12] and jUCMNav [5] (a free Eclipse-based tool for analyzing and managing URN models), to model business scenarios, the stakeholders involved, their intentions in terms of organizational objectives, tasks they perform, and the IS that support these objectives. Processes and indicators measuring their performance (often obtained through Business Intelligence tools – BI) are captured, modeled and evaluated to anticipate and support architectural changes.

The rest of the paper is structured as follows: Section 2 provides the background on adaptive EA and highlights the need for the proposed framework. Section 3 discusses the methodology, types of changes that occur, and levels within the enterprise where adaptation is required. It also addresses tool support within jUCMNav for the framework. Section 4 presents the proposed model and illustrates its applicability. Section 5 discusses and evaluates the framework in a real-life case study. The paper concludes in Section 6 with a summary, limitations and future work directions.

2 Background

Information technology (IT) has transformed the way organizations deal with information used to make decisions, giving rise also to the use of different kinds of IS. Nonetheless, organizations still face the challenge of continually adapting to remain relevant in the face of changing business environments. The reality is that organizations are open systems that evolve through interaction with the environment around them [15]. To survive, some form of adaptation is often required (not necessarily automated). As the business adapts, the IS must also adapt and evolve its artifacts to meet new business demands either through a modification, deletion or an addition.

In providing a holistic view of the business, an EA should allow for maximal flexibility and adaptability [10]. In reality however, within the different domains of EA, there are different architectural practices and ways of addressing domain concerns.

These practices are characterized by varying degrees of maturity and different methods or techniques for handling the architecture. When changes in business objectives do occur, the resulting adaptive responses tend to be disparate, leading to local adaptations rather than to adaptations that serve the organization as a whole. This results from the heterogonous methods and techniques currently used in EA. Also is the lack of well-defined alignment between services delivered at every level of the organization, and of support for cross-organizational interaction [20, 30].

Current adaptive EA frameworks do not address these limitations. These frameworks focus on strategic assessment and adoption or decommissioning of technology in response to constantly changing business needs [9], while attempting to enable more adaptive IS, which in turn leads to organizational adaptability [29]. Others focus on the use of Service Oriented (SO) paradigms [20]. These SO approaches, while useful, do not directly solve the need to take a more holistic view where business objectives of stakeholders, decisions made by decision-makers, IS supporting processes and the relationships between them can be exploited for adaptability.

We propose an adaptive EA framework that enables a coherent view across the domains of the EA, while facilitating alignment of an organization's business objectives to daily operations and required information sources. This framework is modeled on a BI theme where information about business objectives and IS artifacts is continually gathered and delivered to decision makers for use in deciding on architectural changes. In its simplest form, BI is about getting data into a system to enable decision-making. BI helps organizations derive meaning from information and is especially useful in dynamic environments [19, 30] to support decisions (Fig. 1).

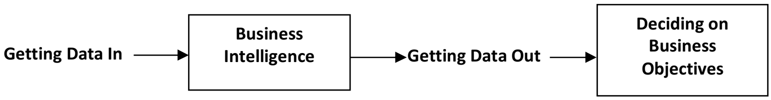

Fig. 1. Relationship between Business Intelligence and business objectives

The BI theme, therefore, refers to instrumenting of data used to make decisions. In this paper, the instrumentation relies on the use of URN and jUCMNav to better inform decision makers about the business objective, decisions to be made, the IS linkages, and the changes required as objectives and decision requirements evolve. The link from IS serving as information sources, to decisions made with 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 businesses evolve [19].

With this opportunity to trace, monitor and address change, the principles of business process modeling can be applied to show the relationships between the IS, decision makers, and objectives they achieve, as well as to show the changes and resulting responses (adaptation). URN is a modeling language that supports processes with Use Case Maps (UCM) [22, 28], goals and indicators with the Goal-oriented Requirement Language (GRL) [12], as well as goal evaluations based on strategies, i.e., initial satisfaction values of some elements in a goal model, including indicators potentially fed by external sources of information such as BI systems [3]. URN can also be tailored or profiled to a particular domain [2] through the use of metadata (name-value pairs for stereotyping or annotating model elements), URN typed links (between a pair of elements), and constraints in UML's Object Constraints Language (OCL) [27]. This set of characteristics of URN is quite unique among goal and business process modeling languages and it informs our choice of URN. In our BI/EA context, the use of URN enables one to model the relationships discussed above and observe and manage adaptation in terms of satisfaction levels of the IS, decisions, and business objectives.

3 BI-EAEA Approach

This section introduces the *Business Intelligence - Enabled Adaptive Enterprise Architecture* (BI-EAEA) framework, with its methodology, types of changes, and levels within the enterprise where adaptation is required. We also discuss tool support.

3.1 Phases and Steps of the Methodology

The BI-EAEA methodology consists of two phases ("As Is Scenario" and "To Be Scenario") and four steps (Fig. 2) and is iterative between the phases and their steps, as the business and architectural needs become clearer. The steps 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.

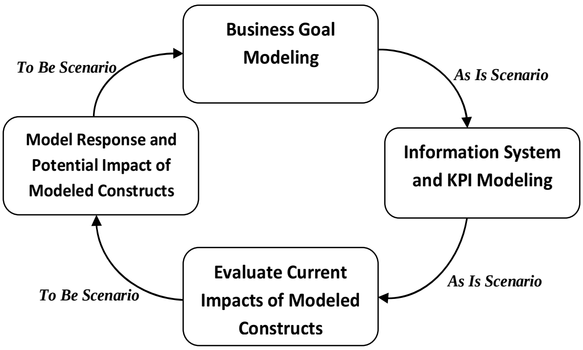

Fig. 2. Phases and steps of the BI-EAEA methodology

The first step (**Business Goal Modeling**) is to build the organization's business goals showing, with GRL, stakeholders and decision makers as actors (◯) with their goals (▭), softgoals (▭), tasks (⬡, for decisions), and resources (□) utilized to meet business objectives. GRL links are also documented. In the second step (**Information System and KPI Modeling**), each IS that provides the information supporting decisions about the goals is modeled with a GRL resource. KPIs (⬡) are used to model characteristics that indicate the performance level of the IS in alignment with business objectives of the organization. These KPIs are integrated with the GRL model of the IS. Evaluation strategies are developed to set context for evaluating KPIs.

In the thirds step (**Evaluate Current Impacts of Modeled Constructs**), each modeled IS is linked to the business goals using contributions (→), indicating the extent to which the IS support business goals. This gives a depiction of the EA with links from business objectives to actions of decision makers to information utilized to meet the objectives. Each link is assessed to see the level of contribution or influence the source element has on the target. The satisfactions levels in GRL strategies are also checked to determine whether they are reflecting the "As Is Scenario" of the EA. Color feedback is used to assess satisfaction at a glance (the greener, the better).

In the fourth step of the methodology (**Model Response and Potential Impact of Modeled Constructs**), the anticipated "what-if" 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 satisfaction of other modeled entities, thereby indicating and informing the methodology users (typically an enterprise architect) of the anticipated changes in the EA, which allows for support as required.

3.2 Types of Changes and Enterprise Levels

The reasons for adaptation generally include responding to change in ways that make the new state more suitable for the revised/new use or purpose. In its application to EA, adaptation represents how the enterprise and architecture in place respond to various forms of changes (see below), which make the new EA more suitable:

- **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.

We observe that instances of modifications, deletions, or additions occur in three levels within the organization, regardless of abstractions and consistent with the *goal-decision-information* (GDI) literature [24]. They are: in the business objectives of the organization (which we refer to as the *High level*), within actions of decision makers required to achieve these objectives (the *Decisions*), and lastly, in the IS that provide the information utilized in achieving these objectives (the *IS)*. This representation can also accommodate many levels of abstractions for goals within the enterprise, an important consideration in performance analysis of EAs [6].

3.3 Tool Support: Pairwise Comparison of Business Objectives and IS

In addition to the complexity of processes within enterprises, we find techno-social and political paradigms to consider. 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 organizations. These conflicts, which relate to concerns about things such as context, interest, cost, relations, or structures, influence the importance and priority attributed to business objectives, decision, IS, and their relationships within the organization. The BI-EAEA framework uses the Analytic Hierarchy Process (AHP), in which factors are arranged in a hierarchical structure [24], to evaluate and identify the importance of levels and priorities. This approach helps accommodate and resolve the aforementioned concerns at play in enterprises by eliciting and aggregating quantitative measures for them. Although AHP has recently been used on goal models in other languages [14, 17], to our knowledge, this is the first use in GRL models, which support quantitative measures for contribution levels, indicator definitions, and actor importance levels. Different business objectives, decisions of actors, IS in place, as well as their priorities or influences, are compared against each other using AHP's pairwise comparison technique to get importance and contribution levels from stakeholders (e.g., architects), thus giving an agreeable representation of all concerns.

3.4 Tool Support: Well-Formedness Constrains

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 that go beyond URN's basic syntax. These rules are constraints for GRL models designed in OCL and checked by jUCMNav [2]. BI-EAEA defines nine new OCL well-formedness rules in addition to a selection of 19 currently existing URN rules supported by jUCMNav. Examples of rules include "The elements of the Information System must not receive contributions from other actors" and "The sum of the importance values of the intentional elements of an actor must not be higher than 100". These 28 rules are part of a URN profile for Adaptive EA. Once models are created with the methodology from Section 3.1, they are checked against these rules to ensure conformity to the style expected for the analysis. jUCMNav reports violating model elements, if any.

4 Illustrative Example

To illustrate the BI-EAEA framework, we apply the approach to a business unit involved in administering grants within a large government organization. This is a highly dynamic business unit influenced by continually changing policies and a frequently evolving Information Technology landscape as new IS technologies emerge.

4.1 The As Is Scenario

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.

In the **first step** of the methodology (Business Goal Modeling), 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. In modeling the business goals of the organization, the extensive work that exists on modeling organizations using GRL and UCM (e.g., [22, 28]) provides a strong basis. From the process identified, the organization's business analysts model goals, softgoals, tasks and resources along with their links, current importance levels and priorities, for each selected process. The AHP pairwise comparison approach described in Section 3.3 is used for quantifying contribution levels and importance values of elements in actors.

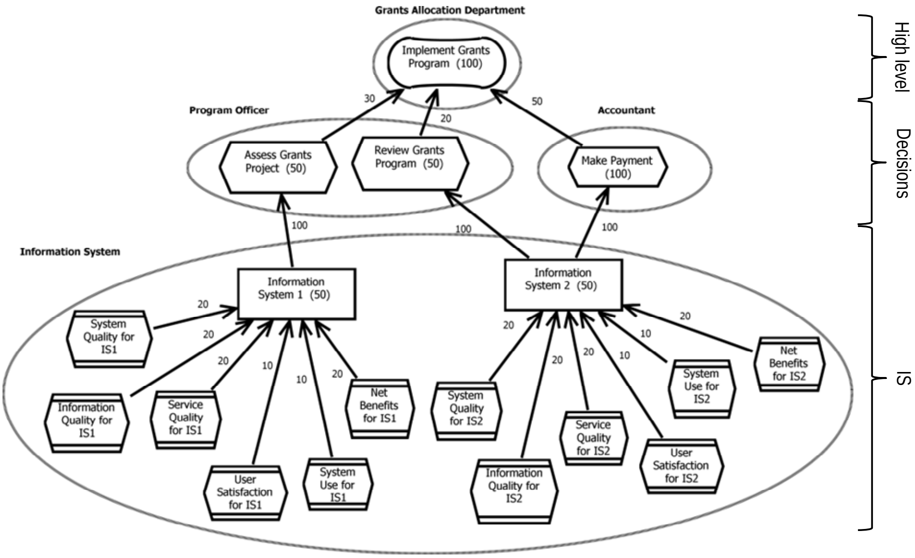

Fig. 3. GRL model example of a Grants Implementation Program

The top half of Fig. 3 illustrates a partial GRL model of the department's 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 *Decisions level*. Both actors have different tasks that they act upon utilizing different resources, to be defined in the next step. The tasks each have an importance level, summing up to 100 for each actor, in conformity to OCL rules as discussed in Section 3.4. Respective contribution weights are also illustrated, and they too sum up to 100 for each target intentional element.

The **second step** of the methodology is the modeling of the Information Systems (IS) themselves, including their KPIs. Ideally, the modeling procedure utilized in the previous step [22, 28] should be sufficient. However, the representation of IS in goal-modeling notations such as URN is mainly about the individual functions of an IS and its effects; they are not represented as whole entities, i.e., an accumulation of all functions with their resultant effects. We introduce a different 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*". Using the AHP pairwise comparison approach again, stakeholders can agree and model the individual IS as a whole and not based on their functions, in ways they agree the IS performance is in alignment to the organization's business objectives.

We use the performance characteristics that IS possess to do this. The former also indicate how IS are considered and judged to be of benefit by organizations. We therefore represent IS as GRL *resources* with *indicators* inside a single Information System actor. In providing information that is utilized to achieve goals, they act as resources. Indicators are used to quantify IS characteristics. With such indicators, we can show how well organizations perceive the IS to be performing and, in doing so, how they are meeting desired business objectives, 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. For each information system, we use as indicators the six characteristics for measuring IS success described by DeLone and McLean [8].

As illustrated at the bottom of Fig. 3, the IS actor has two resources: Information System 1 and Information System 2. They provide information utilized to achieve the business objective Implement Grants Program through tasks of the actors Program Officer and Accountant. This figure also shows the six characteristics of each IS, which measures the IS performance level via weighted contributions. AHP is used to determine these weights, as well as the definitions of each indicator (i.e., their target, threshold, and worst case values).

The **third step** in the methodology is the evaluation or assessment of the current state of the modeled EA. Such assessment shows the satisfaction levels of the modeled business objectives, decisions of decision makers, and IS performing in line with business objectives.

First, the model is checked against the OCL rules described in Section 3.4 to ensure it was built correctly. Then, GRL strategies are used to evaluate the degree of satisfaction or dissatisfaction of the model elements. 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 decisions and high level's intentional elements in order to compute their satisfaction levels, using a bottom-up quantitative propagation algorithm [3]. Fig. 4 illustrates the evaluated GRL model (indicating *IS*, *Decision*, and *High levels*) for the as-is situation, with values propagated from the KPI. It indicates the current satisfaction level of the organization and its IS, on a 0-100 scale.

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 evaluation values can be entered for the KPIs in jUCMNav manually, imported through an Excel sheet (e.g., based on survey results), or derived and fed in from BI tools assessing the specific characteristics by the organization to generate a satisfaction value. Each indicator uses linear interpolation to compute a satisfaction level from an evaluation

(100 for target or better, 50 for the threshold, and 0 for the worst value or even worse). For example, if the target system use is 250 hours per month (hpm), with a threshold of 200hpm and a worst-case situation of 50hpm, then a measured usage of 225 hpm will result in a satisfaction of 75 (midway between the target and threshold) whereas a measured usage of 45 hpm will result in a satisfaction of 0 (below the worst value).

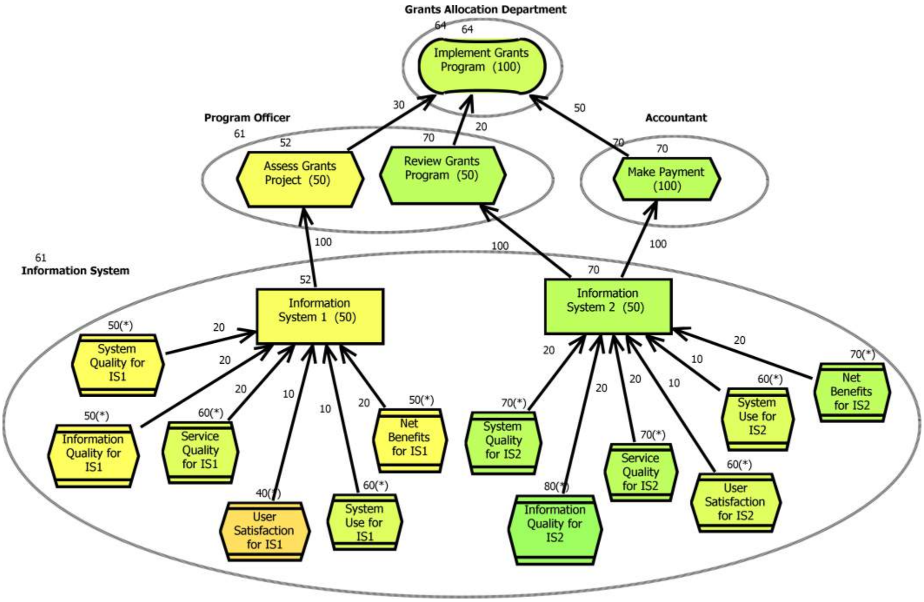

Fig. 4. Sample model showing current satisfaction levels of the IS, Decision Maker's and High Level

4.2 The To Be Scenario

The second phase of the methodology 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. As described in Section 3.2, these adaptations are observed as modifications, deletions or additions in the three levels within the enterprise: the organization's business objectives (*High level*), actions of decision makers in achieving these objectives (*Decision level*), and the IS providing the information utilized (*IS level*).

Table 1, as part of the BI-EAEA methodology, provides a summary of identified changes and the steps the model takes to adapt to them, as well as corresponding responses based on automation in jUCMNav. Some of the automation steps take advantage of advanced jUCMNav features such as strategy differences, a constraint-oriented propagation algorithm, and contribution overrides [5]. For example, from Fig. 4, a decrease (modification) of the current evaluation value of the System Quality for IS2 KPI, contributing to Information System 2, will result in an update of its satisfaction value (say, from 70 to 30). This change in turn affects Information System 2 and its ability to support the Review Grants Program task of the Program Officer and the Make Payment task of the Accountant towards achieving the Grants and Allocation

Department's Implement Grants Program objective. By executing the As Is Strategy with values indicative of this change as fed by the BI system or entered manually, the BI-EAEA model shows the resultant impacts of the change on the EA. If the satisfaction of these actors becomes too low, this might trigger a reassessment of the suitability of Information System 2 and perhaps the analysis of an update or a replacement. Such options can again be modeled as modifications (the "To Be" system), with evaluations assessed and compared through what-if scenarios.

Table 1. Summary of types of adaptation and automated responses

Change Need	Adaptation	Automation in jUCMNav
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 levels. 4) Execute As Is Strategy.	2) Pairwise comparison to compute new levels [3, 5]. 3) OCL rule checks violation [2]. 4) jUCMNav evaluations to indicate impact [3].
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 [5]. 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 [22]. 2) jUCMNav evaluations (quantitative GRL algorithm [3]) 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 intentional element (their importance and satisfaction levels as well).	1) Locate goal, decision or IS. 2) Remove goal, decision or IS from model (in a *copy* 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 levels. 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 *copy* 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.

5 Case Study

We have used the BI-EAEA framework to model a real-life Enterprise Architecture, namely the "Grants and Contributions Program" of a large department of the Government of Canada. Based on discussions with personnel of the department responsible for their enterprise architecture, on program descriptions, and on existing business process descriptions, and using the AHP-based approach described in Section 3.3, we developed the "As Is Scenario" model composed of the business goals, decisions, IS, and KPIs. We also collected realistic data to provide the model with an "As Is" strategy, enabling its evaluation. The jUCMNav size metrics indicate that the model, which represents the head and provincial offices involved in the program, is non-trivial. It is composed of 4 diagrams, 8 actors, 40 intentional elements (12 goals, 9 softgoals, 8 tasks, and 11 resources), 30 indicators, and 102 links. The model proved to conform to our 28 OCL rules. We then investigated one particular and likely "To Be Scenario", mainly based on a deletion, with the potential impact on the modeled constructs.

With the domain of adaptive EA relatively emerging, the work of Yu et al. [30], which proposes twelve key characteristics of an adaptive enterprise to gauge feasibility and effectiveness adaptive EA models should meet, was used to evaluate our methodology. To empirically measure and evaluate the BI-EAEA model, these twelve characteristics were operationalized as questions with a *Likert scale* styled response ranging from "All" to "None". The questions were administered to the personnel at the department (four senior enterprise architects) who were exposed to the model and the methodology. Their responses, summarized in Table 2 for all phases and steps of the methodology and the model's performance, are encouraging and show no apparent major weakness. Informal but very positive observations on our BI-EAEA framework were also provided by these senior enterprise architects:

- They liked the presence of the three levels; from experience, much time is spent working at the Decisions 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 "magic happens", as they mentioned. The links between the three levels is where the real value of this framework rests.
- With the increasing need for numbers and quantities in organizations, the KPIs and satisfaction values could likely help accommodate this.
- There is a risk to spend much time documenting the "As Is" enterprise architecture in many approaches, and little value is seen in this from their experience. They liked BI-EAEA because investment in the modeling is minimal.
- The granularity of the IS could be changed too (and BI-EAEA 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. This would also enable to better specify the links between particular IS functionalities and decisions, although at the cost of higher modeling effort.
- They liked that the URN-based modeling used 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 can also enable people to "disagree sooner", which can help avoid disappointments and failures in the long run.

- The models, with GRL strategies, could also be used as documentation trail for analysis and decisions.

Table 2. Evaluation of BI-EAEA characteristics (Yu et al. [30]) by enterprise architects

CHARACTERISTICS	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 Syst., Boundaries, 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

6 Summary, Limitations and Future Work Directions

This paper discussed the Business Intelligence-Enabled Adaptive Enterprise Architecture (BI-EAEA) framework, which enables anticipation and support of architectural changes. The 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 IS serving as sources of the information utilized by the decision makers, and indicators measuring six common performance aspects of these IS. 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 evaluated to further aid decision making in organizations. BI tools can be used both as means to feed the indicators enabling model analysis and as means to further visualize and distribute the analysis results.

Our BI-EAEA approach represents a significant step towards achieving adaptive EAs. BI-EAEA also stands out compared to common adaptive EA approaches [9, 20, 29] by a focus on goal and decision modeling, the systematic handling of various adaptations (caused by modifications, additions, and deletions at three levels of abstraction), and tool support for automating part of the adaptation analysis. BI-EAEA also conforms in part to the elements of the ISO/IEC/IEEE 42010 standard [14] required in the architecture viewpoints and the architecture description language (ADL).

However, several limitations were encountered along the way. We did not consider what triggers decisions as organizations decide about business objectives, but rather captured and treated decision as scenarios of “the business evolving”. These scenarios were subsequently modeled adequately as adaptations. The construction of the questions used to evaluate the model did not have a comparison point for the result obtained. While we could have compared our results with an assessment of their current practices, informal discussions confirmed we presented a more rigorous and useful assessment compared to what they currently use.

For future work, since we covered only one case study, more enterprise architectures of different sizes and domains should be modeled and assessed, for generalization and to better understand the business situations that the framework can and cannot support. The department model explored here also did not take into consideration cost issues related to decisions, so a research question is whether cost aspects should be included in the model or handled separately. Although GRL was used here, some aspects of the framework could be transposable to other modeling languages, especially the Business Intelligence Model (BIM) [11] as it also covers actors, goals, indicators, and (limited) strategies. Better tool support in jUCMNav for automating pair-wise comparisons and AHP analysis (e.g., through generation of online comparison surveys) is something that would greatly enhance the usability of the methodology.

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