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ORIGINAL ARTICLE

Model-Based Management of Strategic Initiatives

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Abstract In order to adapt to a continuously changing environment, organizations are evolving their business objectives, processes, and operations through various strategic initiatives. In this context, it is imperative for organizations to continuously monitor their performance and adjust when there is a need or an opportunity to do so. The cluster of technologies that delivers this monitoring capability is called business intelligence (BI), and over the years it has come to play a central role in business operations and governance. Unfortunately, there is a huge cognitive gap between a requirements view of a strategic initiative articulated in terms of business goals, processes, and performance on one hand, and an implementation view of BI monitoring articulated in terms of databases, networks, and computational processing. In this paper, we present a model-based performance management framework for managing strategic initiatives across their complete lifecycle of analysis, modeling, implementation, and evaluation to bridge this cognitive gap. We demonstrate its usefulness through a case study at a major teaching hospital, which is implementing a strategic initiative to reduce antibiotic-resistant infections.

Keywords Business intelligence · Goal modeling · Database integration · Organizational transformation · Strategic initiative

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1 Introduction

Modern organizations are continuously evolving their business objectives, processes, and operations through an ongoing process of transformation and renewal that includes strategic initiatives. A strategic initiative is an endeavor intended to achieve an objective highly beneficial to key stakeholders, often through the transformation of an organization or of its business processes. A variety of methodologies, techniques, and performance management frameworks exist that are intended to manage strategic initiatives along the different phases of their lifecycle [51]. For instance, strategies can be defined in the modeling phase using strategic maps or goal models [2]. Typically, strategic initiatives identify opportunities and enact change through a continuous process of monitoring and measurement to align operational performance with strategic targets. A tool-supported methodology that can integrate goals, processes, and performance is essential to help management implement such initiatives by automating or semi-automating some of the implementation

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tasks [45]. In current practice, key performance indicators (KPIs) play a bridging role by integrating data from a variety of sources inside and outside an organization to measure how well strategic targets are being met [33].

Unfortunately, there is a huge cognitive gap between a requirements view of a strategic initiative articulated in terms of business goals, processes, and performance on one hand, and an implementation view of BI monitoring articulated in terms of databases, networks, and computational processing. The implementation is intended to offer a monitoring function for key performance indicators that determine how the organization is doing with respect to its strategic initiatives. Take for example an initiative to reduce antibiotic-resistant infections. The requirements of such initiative are to create awareness amongst clinicians about the effect and proper utilization of antibiotic prescriptions, define medical guidelines, and track the number of antibiotic prescriptions. From the BI monitoring perspective, there is a need to report on the number of antibiotic prescriptions, the percentage of prescriptions that included antibiotics, as well as the average duration of antibiotic prescriptions. A modeling approach is needed that can represent both a requirements view of the strategic initiative and an implementation view of the BI monitoring, along with computational mappings that bridge the gap between the two levels and deliver ongoing monitoring and transformation.

In this paper, we present a model-based performance management framework for managing strategic initiatives across their complete lifecycle of analysis, modeling, implementation, and evaluation to bridge this cognitive gap. The key elements of the framework involve novel conceptual modeling techniques:

- A business intelligence model (BIM) that represents a requirements view of strategic initiatives and their associated plans in terms of goals, processes, situations, and indicators.
- A conceptual integration model (CIM) that represents an implementation view of organizational data integrated to create focused dashboards for reporting indicators used to monitor strategic initiatives.
- A mapping framework between BIM and CIM, along with corporate dashboards that link the two levels for purposes of monitoring and reporting.

The use of a patchwork for managing an initiative's lifecycle can lead to poor results for organizations that must deal with strong competitors in their market. BIM and CIM are integrated into a single model-based performance management framework for controlling an initiative during the early phases of its lifecycle and in cooperating with current business intelligence solutions for the evaluation of the initiative's impact.

A real-world case study is used to demonstrate the workings of our proposed framework. It involves a large teaching hospital in Ontario, Canada, that decides to implement strategic initiatives to reduce antibiotic resistant infections.

This paper extends our initial work [6] in a number of ways by providing

- A refined definition of the performance management framework exploiting the new BIM and CIM modeling technologies.
- A refined case study that follows a more rigorous methodological approach and whose description illustrates the various steps of the performance management framework.
- Tool support for the BIM modeling and analysis part [17].
- A prototype antibiotic management and infection control BI portal exploiting the models.
- A more complete evaluation and better comparison with related work.

Section 2 of this paper includes a brief introduction to BIM and CIM concepts, as well as an overview of managing organizational transformation and BI. Section 3 presents our research methodology, adapted from design science. Section 4 introduces our proposed model-based process for managing the lifecycle of a strategic initiative. Section 5 gives an overview of the healthcare case study related to antibiotics management. Section 6 illustrates the lifecycle phases of an initiative from the initial analysis to BIM modeling, CIM implementation and data mapping, BI-based evaluation, and further problem analysis. Section 7 discusses related work, while Sect. 8 provides an evaluation of our approach. Section 9 presents our conclusions and plans for future research.

2 Background

We give a brief overview of organizational transformation and business intelligence, as well as the foundations of our business intelligence model (BIM) and conceptual integration model (CIM). Then, we give an overview of performance management frameworks to set the context for our proposed framework, which integrates BIM and CIM.

2.1 Organizational Transformation and Business Intelligence

Organizational transformation [21,39] is a process through which low-performance organizations change state and become strategically healthy. As described by Burgin and Koss [12], "strategically healthy organizations respond efficiently to change, anticipate change in a beneficial way, and lead change within their industries". Negash [42] observes that business intelligence can be a powerful enabler for such

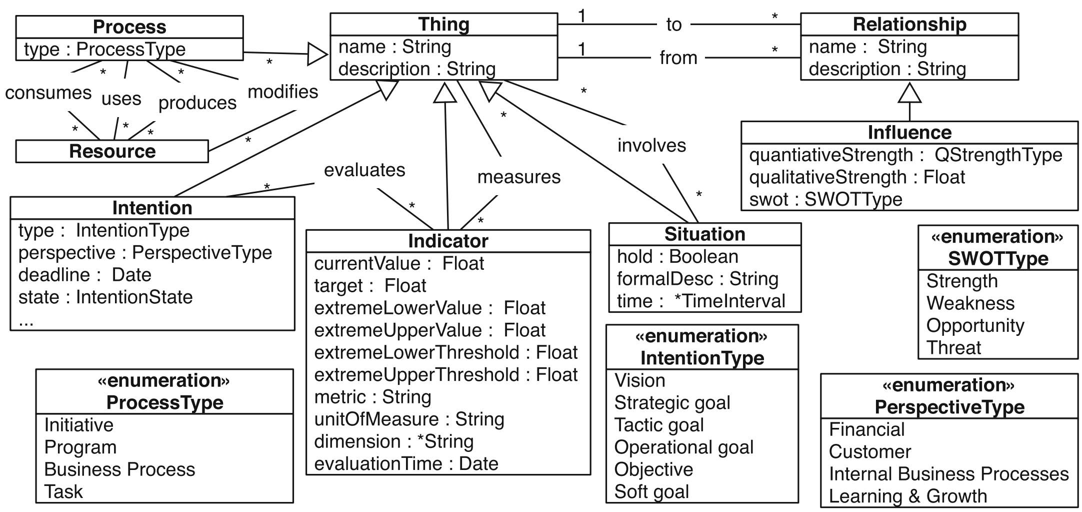

Fig. 1 A fragment of the BIM metamodel

a strategic transformation to produce a high-performance organization. In particular, BI systems combine operational data with analytical tools to present complex and competitive information to planners and decision makers. In fact, as described by Watson and Wixom [52], BI is a process that includes two primary activities: getting data in and getting data out. The former involves moving data from a set of sources into an integrated data warehouse; the latter consists of business users and applications accessing data from the data warehouse (often via intermediate data marts) to perform enterprise reporting, online analytical processing (OLAP) querying, and predictive analysis. BIM supports getting data in activities by defining clear requirements that make explicit the information needed to evaluate strategies, and getting data out activities by presenting to the user an abstract view of their business (in terms of goals, processes, resources, and other concepts) and its performance. On the other hand, CIM collects and integrates an organization's data sources (therefore, it supports getting data in activities) and makes them available to BIM and, in turn, to the business users.

2.2 The Business Intelligence Model

The business intelligence model [5] allows business users to conceptualize their business operations and strategies using concepts that are familiar to them, including actor, directive, intention, event, situation, indicator, influence, and process. Figure 1 shows the fragment of BIM used in this paper (see [5] for details). BIM is drawn upon well-established concepts and practices in the business community, such as the Balanced Scorecard and Strategy Maps [30,31], as well as techniques from conceptual modeling and enterprise modeling, such as metamodeling and goal modeling techniques.

BIM can be used by business users to build a model of their strategies, operations, and performance measures. Users can, therefore, query this model using familiar business concepts, to perform analysis on enterprise data, to track decisions and their impacts, or to explore alternate strategies for addressing problems [24]. The queries are translated through mappings into queries defined over databases and data warehouses, and the answers are translated back into business concepts. BIM works together with CIM to address such an issue and, in this paper, we show how such a connection is performed (in particular) for indicators.

2.3 The Conceptual Integration Model

A data warehouse is a repository of data that has been materialized for statistical and analytical purposes. Data warehouses are organized in multidimensional fashion, i.e., the basic data stored in fact tables are linked to various hierarchical views or dimensions that help analyze the data in multiple ways. As in the relational model [38], there is an impedance mismatch between (business intelligence) applications accessing the data and data's physical storage. The problem is exacerbated by the fact that the underlying multidimensional data is physically organized for data access performance rather than to reflect the models that the data and business analysts have in mind.

To raise the level of abstraction and bridge the ever increasing gap existing between physical data warehouse schemas and conceptual multidimensional models, the conceptual integration modeling (CIM) framework was proposed [46]. The CIM framework offers both design time and run time environments based on a CIM visual model (CVM), which provides two different views of a data warehouse: a conceptual model of the data (called CVL—conceptual visual language) and a physical model of the data (called SVL—store visual language). In other words, the CVL provides an abstract, high-level view of the data stored in the physi-

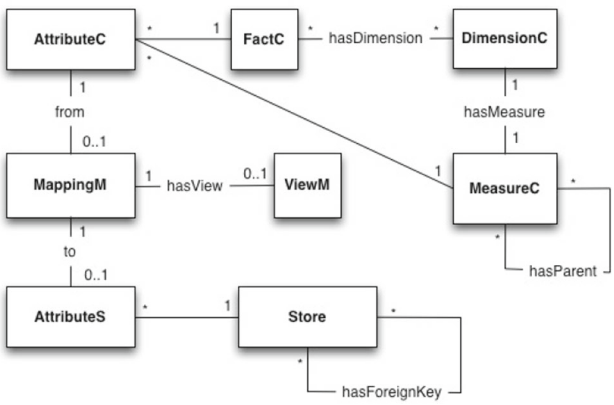

Fig. 2 A fragment of the CIM metamodel

cal tables of the SVL. The representational gap between the CVL (conceptual) and the SVL (physical) models is filled by the mapping visual language (MVL) consisting of correspondences between attributes of entities in the CVL and the SVL models, with optional value conditions. A CIM tool can then compile these simple correspondences (captured in XML) into complex views over the physical model that can be used to efficiently evaluate queries posed on the conceptual model.

Figure 2 shows a fragment of the CIM metamodel, without the attributes to keep it simple. In essence, CIM regroups three levels:

1. (C) a conceptual schema that consists of facts (FactC), each of which with zero or more dimensions (DimensionC). Each dimension has zero or more measures (MeasureC), which in turn may have parent measures. Both facts and measures may have attributes (AttributeC). This part of the metamodel represents the conceptual level in an ER-like language that extends the MultyDim conceptual language of Malinowski and Zimányis [35]. This is the part that can be visualized with CVL.
2. (S) a physical data warehouse schema that consists of stores (Store), some storing fact data, others dimension data. Stores may also have attributes (AttributeS). This part can be visualized with SVL.
3. (M) mappings between the first two levels (MappingM), each possibly with a view (ViewM). Mappings can be visualized using MVL.

2.4 Performance Management Frameworks

Business performance management is used by an organization to define measures, called key performance indicators, that quantify how well an organization is performing in terms of its strategic goals [11]. Typically, it requires two components: an underlying enterprise data architecture that delivers data used in computing measures (from data bases and data warehouses), and a performance management framework. Otley [43] identified five main capabilities that a performance management framework should provide:

1. Identify organizational goals and the strategies being pursued to fulfill them.
2. Identify processes that are enacted in pursuit of a strategy and define how to measure their performance.
3. Set appropriate targets that need to be reached to fulfill goals.
4. Set appropriate rewards or penalties for managers (and other employees) as incentives.
5. Provide feedback mechanisms that enable the organization to see where strategies fall short or need adjustment.

The agility of a performance management framework is critical to accommodate change [10]. Krishnapillai [32] surveyed existing performance management frameworks and identified the inability to represent relationships between strategies, goals, measures, and processes and track the impact of changes as a major weakness. For any organization, the ability to ensure that measurement systems are reviewed and modified as requirements and strategies change is critical [19].

Examples of performance management frameworks are Balanced Scorecard [30], Performance Prism [41], and the Excellence Model™ [44]. The latter is defined by the European Foundation for Quality Management and is based on principles from Total Quality Management [16]. A recent development in Balanced Scorecard is the definition of a Strategy Map for visualizing cause-and-effect relationships between strategic objectives and KPIs [31]. However, there is no provision in the framework to link key performance indicators to operational business processes to model what determines a KPI. Performance Prism focuses on identifying the needs of organization stakeholders in addition to strategies, processes, and capabilities [41]. It provides feedback through measures of stakeholder satisfaction, again without any link to operational business processes. The Excellence Model™ provides a holistic system perspective on performance using nine criteria that reflect industry standards in the form of benchmarks. They help an organization to understand their current performance in relationship to the benchmark and work on improvements when necessary [53], but again there is no link to operational business processes. The key to linking with operational business processes is understanding the mapping from operational business process through the enterprise data architecture, which stores data related to them and aggregates that data to calculate key performance indicators [32].

3 Research Methodology

Our methodology is based on design science research as described by Hevner et al. [23]. We followed five steps, as suggested by Bell et al. [9]:

1. *Identification of problem* As discussed in the previous section, there is a need for modeling and linking strategic goals, business process tasks, and KPIs together with data sources from which KPIs are computed to improve the support for strategic initiatives in organizations.
2. *Framework design* This is the topic of Sect. 4, where we develop a performance management framework for managing the strategic initiative lifecycle.
3. *Framework evaluation* This part is based on a healthcare case study, introduced in Sect. 5, further detailed in Sect. 6, and evaluated in Sect. 8.
4. *Revaluation and improvement of framework* This paper focuses on the application of the framework to the most recent iteration of the case study, and on its last evaluation in Sect. 8. One previous evaluation/improvement iteration was done that is not discussed here. The framework (and especially the BIM part) is also based on earlier work focusing on the modeling of goals, tasks, and KPIs for initiatives related to various healthcare processes [45], but with a different language [29] and less emphasis on managing the strategic initiative lifecycle.
5. *Communication and discussion of research* This is achieved through training of our industrial partners and through publications such as this paper.

The focus of our research is to identify gaps in current practice and then search and develop possible solutions that can address those gaps. Example scenarios, case studies and other approaches are used to illustrate the potential utility of our framework in addressing perceived gap. This is early research that still needs much work to elaborate and validate with more systematic comprehensive trials.

4 Managing the Strategic Initiative Lifecycle

Enacting organizational transformation through the implementation of strategic initiatives is a well-understood process that is taught in business schools. Changes to organizational intentions, processes, and resources are implemented and monitored to address a particular problem or opportunity. Nadler et al. [39] as well as Kaplan and Norton [30,31] have studied this process and proposed several tools to help manage it. However, in these classical approaches, there is very little emphasis on models that capture the organization goals, their relationships, how they are measured, and their mapping to concrete data sources. In addition, current management of strategic initiatives requires organizations to integrate many techniques and tools themselves to really support continuous management. Ideally, a model-based approach to managing strategic initiatives would not only guide an organization through the different stages of an iniative's lifecycle but would also help integrate the disparate tools and techniques involved.

Figure 3 shows how the key elements of our performance management framework integrate with and support the iterative lifecycle of a strategic initiative. Following an initial analysis of a problem to solve or of an opportunity to consider, the lifecycle becomes iterative because the organizational changes enacted by the initiative are refined and updated based on the feedback provided by indicators. The mapping

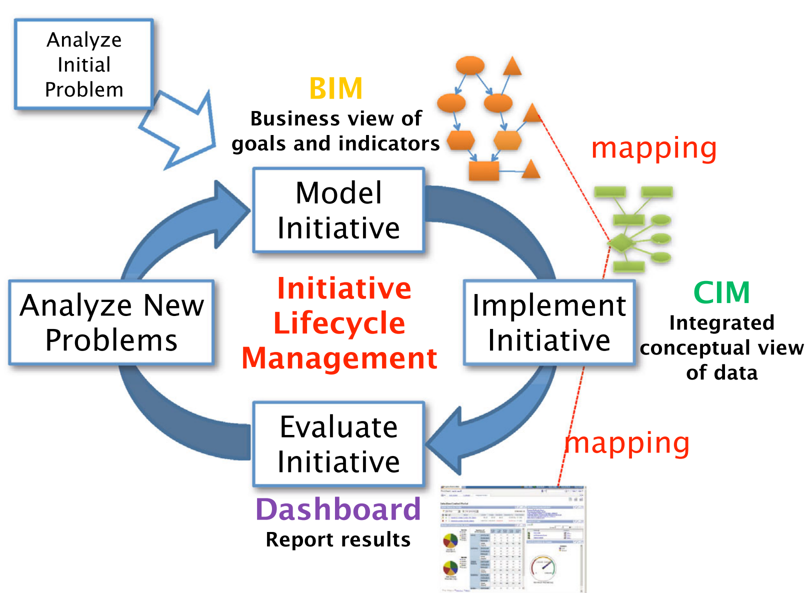

Fig. 3 Model-based management of strategic initiatives

framework from BIM to CIM and from CIM to BI dashboards facilitates the implementation and maintenance of the initiative throughout its lifecycle, as well as incremental considerations for new initiatives.

4.1 Analyze Initial Problem

An initial analysis of an important organizational problem is performed, often based on ad hoc evidence and in the absence of a performance management environment. An initial strategic initiative is proposed, frequently by senior managers or business analysts. This initial initiative usually consists in creating a first model of the organization (including goals, tasks, and indicators) accompanied by suitable reports to formally assess the current performance of the organization regarding the problem at hand.

4.2 Model Initiative

An initiative is modeled by the business analyst in all its aspects through the use of BIM. Strategic goals are defined and decomposed hierarchically until operational goals are reached. Business processes are described along with the resources they use, consume, and produce to achieve the hierarchy of goals. To evaluate the performance of the initiative, indicators are created to measure key aspects of performance and associated with strategic goals, business processes, resources, actors, etc.

4.3 Implement Initiative

The initiative is implemented within the organization where business processes are executed and performed by employees, policies are enforced, resources are consumed and produced, and so on. In this phase, data are collected and integrated from a variety of applications, systems, and documents into a data mart or a data warehouse with a particular focus on providing the data needed to calculate indicators. To enable such an integrated view, CIM is used to provide a corresponding conceptual representation that, in turn, is directly linked and integrated with the BIM model and the indicators that are defined there.

4.4 Evaluate Initiative

Indicators are calculated from the collected data to measure performance against the defined targets associated with the initiative's goals and objectives. Dashboards [50] are used to report such evaluations to the business users allowing for insight to reveal whether an actual value for a goal deviates too far from a predefined target or not. Past trends and predictions can be also visualized.

4.5 Analyze New Problems

Further analysis is performed on critical areas identified in the previous phase to understand why an organization may or may not be on track to meet a specific target or goal. In this phase, operational information collected via monitoring is used to identify the causes of faults and errors as they occur, as well as to forecast performance levels and threats to operational stability. Discoveries made during analysis should help the management in planning next steps, set new (or adjust existing) expectations as measured by indicators, and predict what may happen based on the organization's decisions.

The organizational transformation cycle allows for a continuous improvement process in which feedback from the measurement system provides managers with the necessary information to make changes or adjustments to an initiative. This lifecycle is in line with the "RADAR" view of the Excellence Model™[44], but with more emphasis on models connecting goals, tasks, and indicators, and on the formal integration with data sources. The details of the framework are explained and demonstrated through the use of a case study in the next sections.

5 Case Study Overview: Reducing Antibiotic-Resistant Infections

We explain and illustrate our model-based performance management framework for managing organizational change using examples drawn from a strategic initiative currently underway at a large teaching hospital to reduce antibiotic-resistant infections (RARI) by changing the way antibiotics are used. Increasingly, hospitals have been plagued with outbreaks of micro-organisms that are resistant to antibiotics, including *Clostridium difficile* (*C. difficile*), methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant enterococcus (VRE). One reason for these outbreaks is the overuse of antibiotics, which selectively allows these organisms to thrive in an environment [37]. Antibiotics are also very expensive; according to Salama et al. [47], they account for about 30 % of a typical hospital's pharmacy budget. Thus, overuse of antibiotics leads to increased morbidity in patients and excess cost.

The ultimate goal of the RARI initiative is to reduce the number of incidents of antibiotic-resistant infections, but in the initial analysis phase for the initiative it is determined that the initial focus of the initiative is to limit the amount and number of prescriptions for antibiotics deemed to be high risk. An education campaign for physicians will be created to minimize antibiotic prescriptions. Correct medication guidelines will be defined for antibiotic usage, and this will be monitored through various reports. The hospitals anticipate cost savings both from fewer antibiotics used and through a lower rate of incidents.

Enacting such a strategic initiative is a complex task. In particular, it is important in the modeling phase to precisely define the indicators that will be used to monitor whether the goals of the initiative are being met and map this definition accurately and efficiently to the collection and reporting of the data used to measure the indicators. In the implementation phase, the data needed for the indicators must be integrated from many different data sources including the pharmacy records, administrative records that indicate where patients were located (bed, unit, campus) when the prescription was made, and for what service the prescribing physician was working. As well, individual departments within the hospital each have their own clinical information systems to classify which antibiotics in what amounts are appropriate for what diagnoses.

An infection control dashboard was created for infection control analysts to monitor indicators and evaluate the effectiveness of the strategic initiative. In the evaluation phase, it is used to present a dimensional view of indicators relevant to the initiative. The dimensional view allowed prescription usage to be broken down by time (hour, day, month, year), drug (drug category, drug type, drug brand), location (bed, nursing unit, campus), and by organization (physician, service, department). The indicators tracked were the number of antibiotic prescriptions, the percentage of antibiotic prescriptions (over all prescriptions), the average duration of antibiotic prescription (measured in hours), and the average and total amount of antibiotic prescription(s) (measured in milligrams for the entire duration of the prescription).

The analysis phase of the first lifecycle for the strategic initiative led to a situation where further enhancements such as an antimicrobial stewardship program can be considered in subsequent iterations of the lifecycle.

6 Illustration of the Strategic Initiatives Lifecycle Steps

In this section, the five phases of the strategic initiatives lifecycle illustrated in Fig. 3 are applied in detail to the case study introduced in Sect. 5.

6.1 Phase Zero: Analyze Initial Problem

An initial analysis was done at the hospital based on ad hoc evidence from operational systems, from scientific literature, and from reports from the provincial government. The analysis team believes that the overuse or misuse of antibiotics at the teaching hospital is resulting in unnecessarily high costs and in an unnecessarily high rate of antibiotic resistance infections. This negatively affects the ability of the hospital to offer treatments that are both safe for the patients and of high quality.

Senior managers decided to implement a strategic initiative named RARI to change the way antibiotics are used. The following are identified as priorities for the initiative:

- Create an education campaign for physicians to promote change in the type, amount and number (or percentage) of antibiotic prescriptions.
- Define medication guidelines for antibiotic usage, which will be monitored with monthly and annual reporting of prescription rates (percentage, number, total amount, and duration) by service, location, physician, and antibiotic type.
- Track the amount and number of prescriptions for antibiotics deemed to be high risk using a BI dashboard application that can report antibiotics usage at the hospital.

It is expected that there will be cost savings to the hospital both from fewer antibiotics used, and through a lower rate of incidents.

6.2 Phase One: Model Strategic Initiative

In this phase, the initiative and its organizational context are modeled using the business intelligence model. The set of primitives provided by BIM allows a business user to model the RARI initiative undertaken by the hospital. The initiative is modeled in terms of strategic goals, processes, and resources and is monitored by indicators to understand whether or not goals are met or to identify possible sources of problems. Such a model also provides visibility to the project and a basis for understanding and common agreement. A complete description of how such models are built can be found in [8]. In this section, only a portion of the model to define and monitor the RARI initiative is shown.

6.2.1 Strategic Goals Definition

Figure 4 illustrates the high-level strategic goals for the hospital and the RARI initiative. The term Strategic goal is one of the values that can be assumed by the type attribute associated with the Intention primitive (see Fig. 1). The BIM Intention primitive is used to represent the hospital's strategic goals, while the Situation primitive is used to represent those partial states of the world that can positively or negatively influence such goals. For example, the situation Overuse of antibiotics in the hospital undermines or weakens the hospital's goal to reduce the use of antibiotics. In the figure, the meaning of the Weakness label is derived from SWOT analysis [18] and represents an internal factor to the hospital that is harmful to achieving the goals (whereas a Threat would be an external factor or condition that could damage the goals). To

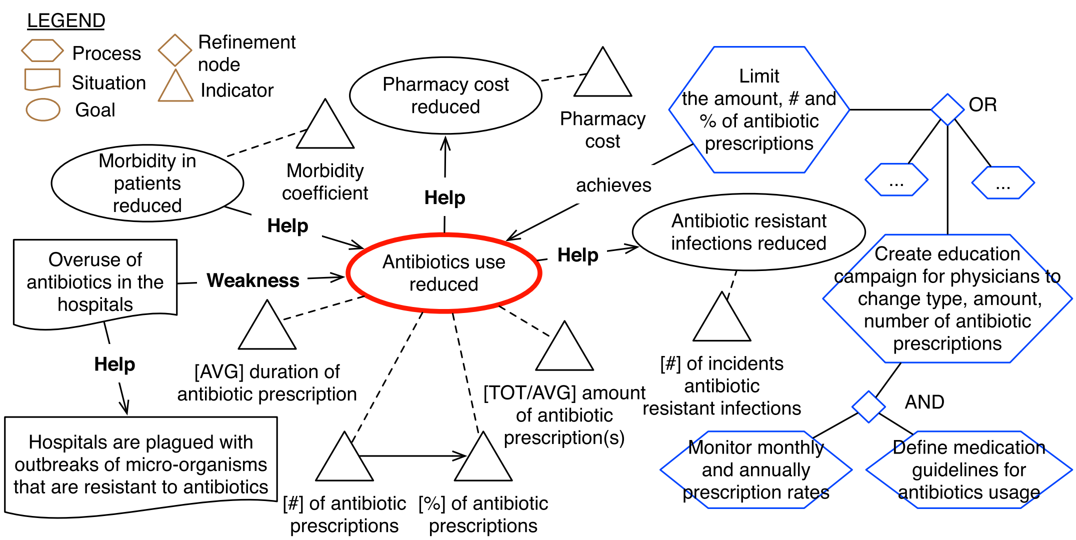

Fig. 4 BIM model for RARI: strategic goals

reason in the presence goals and situations, we use a qualitative contribution scale to characterize Influence relationships among goals and situations, as is supported in User Requirements Notation (URN) models [2]. For example, the help label in Fig. 4 should be read as a reduced use of antibiotics helps to reduce pharmacy cost (see Sect. 5) while a situation in which antibiotics are overused can favor (help) outbreaks of micro-organisms that are resistant to antibiotics.

Figure 4 also shows the RARI initiative and its decomposition. In this partial view of the overall model, only one alternative is shown for its refinement, i.e., the education campaign creation. However, more actions can be planned to reduce antibiotic-resistant infections. The figure also shows a set of Indicators that are defined to monitor the impact of the initiative on the strategic goals. For simplicity, in the rest of the paper we will focus the analysis on the Antibiotics use reduced goal, but a similar analysis can be done for all the strategic goals in the figure, including Antibiotic-resistant infections reduced.

6.2.2 The Drug Treatment Process

Figure 5 describes the drug treatment process where antibiotics are prescribed. We can see that it is decomposed into the Medication prescription and Medication administration activities.

In BIM, Resources can be classified according to their nature; for example, we have information resources, human resources, capability/skill resources, etc. Moreover, BIM provides four relationships among processes (or activities) and resources, namely uses(p,r), consumes(p,r), modifies(p,r), and produces(p,r). An in-depth description of resource classification and their relationships with processes can be found in [5,8]. In Fig. 5, a prescription is produced by the Medication process by (i) using information on patients and on the drugs available in the hospital, and (ii) using and consuming, respectively, skills, and time of a doctor (this is the meaning of the use/consume relationship associated to a human resource in the figure).

Notice how BIM supports the definition of indicators on processes and resources to monitor their performance with respect to intentions. Indeed, BIM helps to motivate why an indicator is needed (e.g, to evaluate antibiotics use reduction) and identify what an indicator must measure (e.g., the amount of antibiotic in a prescription). For example, in Fig. 5, with respect to the RARI initiative, we need to concentrate on those indicators associated with the prescription resource since they monitor the doctor behavior the initiative aims to modify. In fact, the term prescription is commonly used to mean an order (from a doctor to a patient) to take certain medications, while we use the term drug dose to identify the actual medication's dose a nurse administrates to a patient.

While a BIM model shows how indicators relate to goals, resources, processes, and even other indicators, defining valid indicators remains a difficult exercise. Indicator validity can be achieved through the use of approaches such as Basili's Goal-Question-Metric (GQM) technique [48]. Over the years, GQM was extended and tailored to multiple domains and recently to the healthcare sector by Villar [49].

We also developed an Eclipse-based modeling tool to support the design and early analysis of BIM models [17]. This tool, shown in Fig. 6, allows business analysts to create a BIM model as well as to explore or simulate various scenarios based on hypothetical or observed values for the indicators [4,24]. Such analysis can help determine if an initiative has the potential to make a difference at the organizational level. It can also help set reasonable requirements and expectations for the implementation of the initiative.

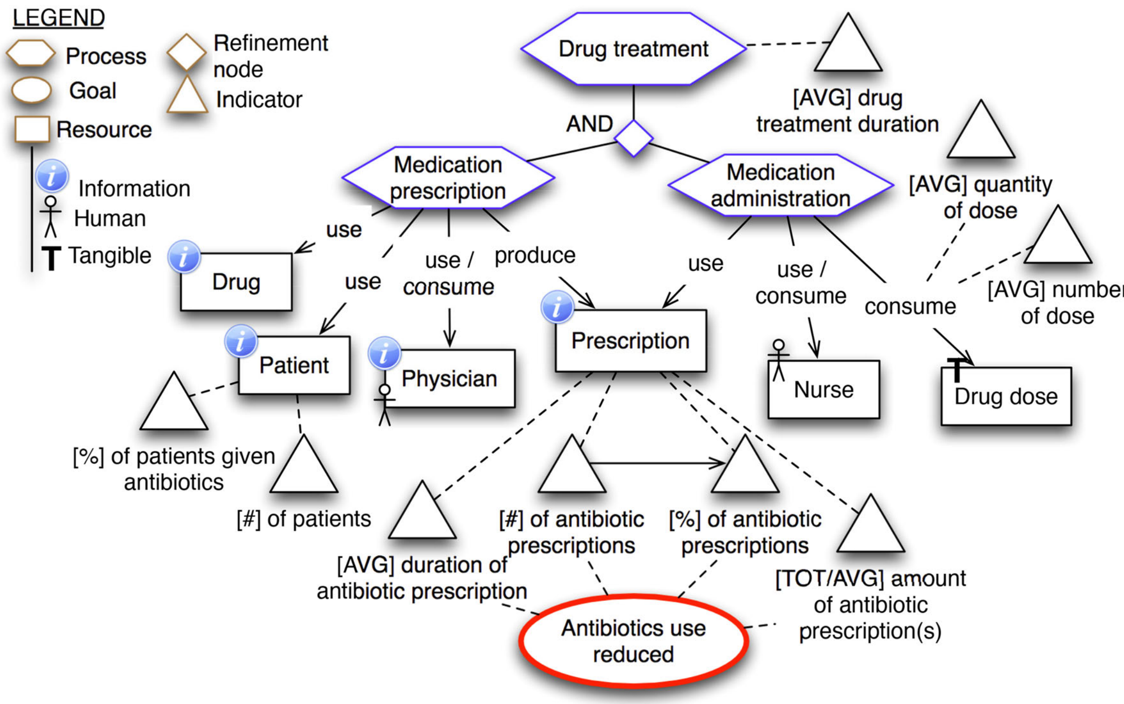

Fig. 5 BIM model for RARI: the drug treatment process

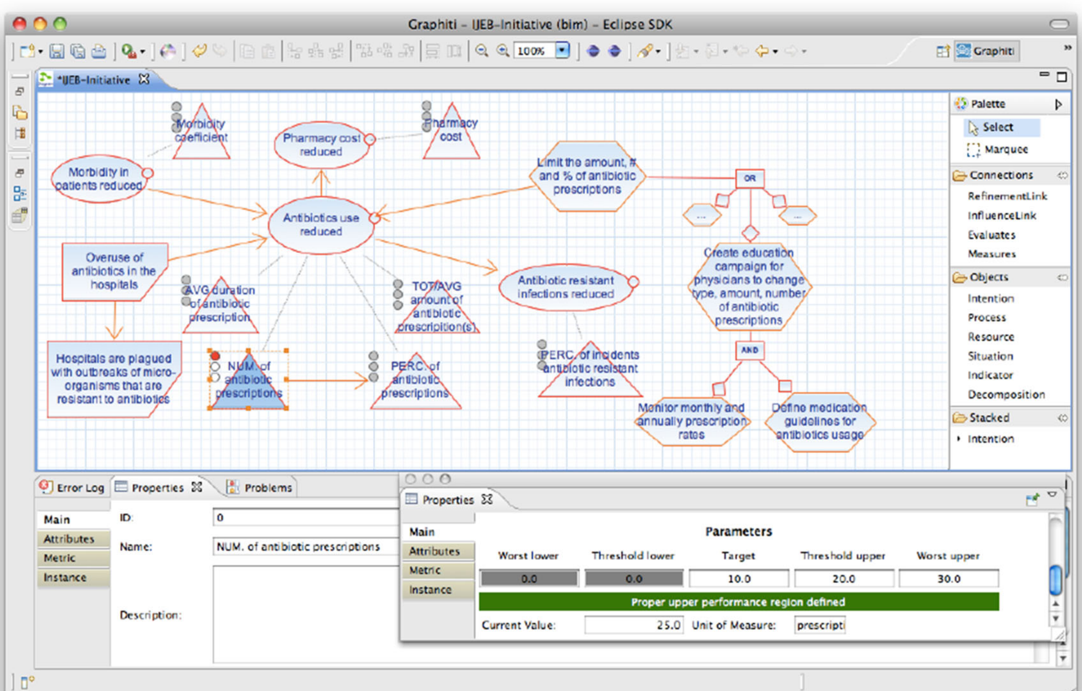

Fig. 6 Eclipse-based tool for BIM modeling and analysis

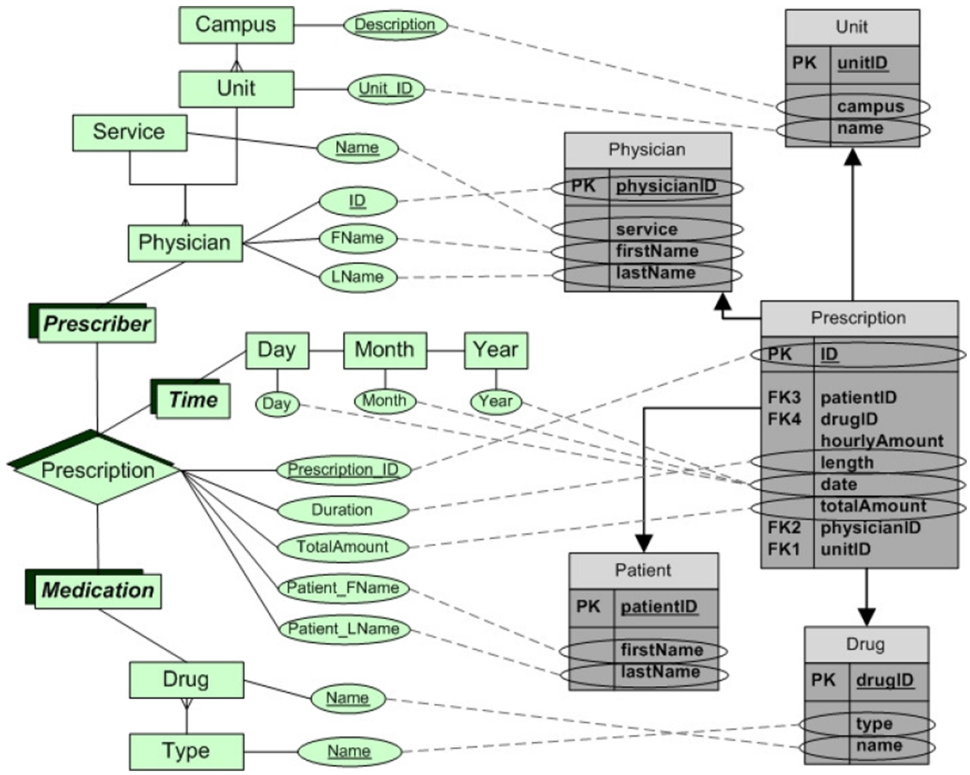

Fig. 7 CIM visual model for the medication prescription activity: CVL (*left*), SVL (*right*) and MVL (*left–right dashed lines*)

In the following section, we show how BIM can be supported by CIM to feed indicators with data.

6.3 Phase Two: Implement Initiative

In this phase, the initiative is implemented by the organization. This requires dealing with large amounts of information from complex multidimensional data warehouses to collect and deliver the data needed to compute performance indicators. Those implementing initiatives such as RARI need to use this data without having to become sophisticated data analysts. The conceptual integration model bridges the gap between the BIM requirements model and the data bases used in the implementation of business intelligence monitoring. CIM is used to model the data available in different information systems and data warehouses to enable the computation of indicators as well as provide answers to general queries related to the BIM model produced in Phase One. The CIM model structures the organization data along various dimensions and is then mapped to the BIM model.

Figure 7 shows a CIM model consisting of a CVL (on the left) and an SVL (on the right). Medication and Prescriber (shadowed rectangles) are CVL dimensions describing measures in the Prescription fact relationship (shadowed diamond). Non-shadowed rectangles (e.g., Drug and Physician) represent CVL levels in the dimensions. These levels are organized into hierarchies by parent–child relationships, which are drawn as edges between levels. For instance, the Prescriber hierarchy indicates that all physicians roll up to Unit, Campus and Service. The SVL is a UML-like representation of the relational data warehouse schema, containing relational table definitions, keys, and referential integrity constraints. The dashed lines are part of the MVL and represent the correspondences between the CVL and SVL models. For instance, the CVL Prescription fact relationship is physically stored in two different data warehouse tables: the SVL Prescription and Patient.

The CVL specification corresponds to what is increasingly called the semantic layer in industry. Such a layer liberates users from the low-level multidimensional intricacies and allows them to focus on a higher level of abstraction. For example, the SVL model in the figure has normalized tables, which is not necessarily the best way to represent multidimensional entities in the conceptual view.

It is important to note that the only model that contains materialized data is the SVL; the CVL can access SVL data only through mappings. Interestingly, the user-defined correspondences that appear in the MVL are not sufficient for exchanging data from the SVL to the CVL—some data dependencies are lost by such simple attribute-to-attribute mappings. For data exchange, the CVL and SVL models are related by more complex mappings [34].

However, it is not practical for a high-level data analyst accustomed to deal only with the conceptual view of the data to come up with such complex view definitions in terms of the tables of the physical data warehouse. That is the reason

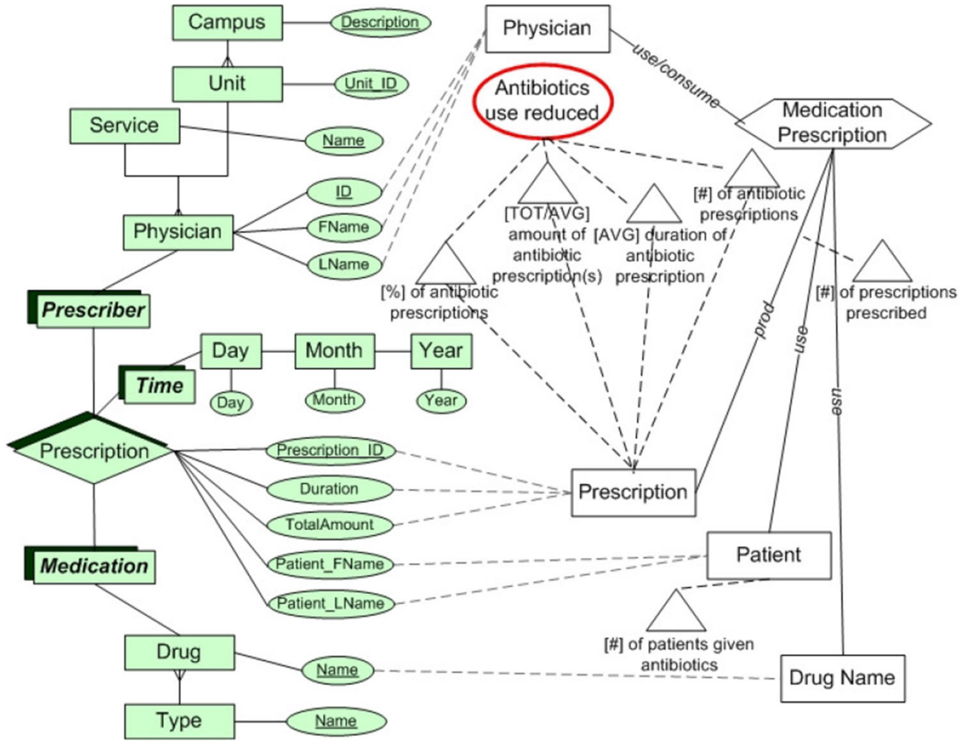

Fig. 8 BIM + CIM visual model for the medication prescription activity: CVL (*left*), BIM (*right*) and mappings (*left–right dashed lines*)

why CIM requires from the user only very simple correspondences between attributes. Then, the CIM tool takes care of transparently compiling the user-defined correspondences into complex, fully fledged, multidimensional mappings that can be used for query evaluation [40]. This is similar to the approach followed by EDM [38] for the relational setting.

A similar situation arises when trying to map a BIM model to an existing data warehouse with SVL, CVL, and MVL already defined. In that situation, BIM entities can be related to a query expression (view) over the CVL, much in the same way CVL entities are mapped to views over the SVL. Such expressions can be complex multidimensional queries with aggregations and roll up functions. Again, writing these complex expressions is not practical for a business user. Instead, the business user draws simple correspondences between the models at hand, this time between BIM and CVL, and the BIM tool is expected to generate the multidimensional CVL views representing the user's data requirements expressed in the correspondences.

Consider Fig. 8. The CVL model on the left-hand side is the one from Fig. 7. The BIM model on the right-hand side corresponds to the Medication Prescription activity of Fig. 5. BIM entities have attributes that are not represented in the figure for simplicity—they happen to have the same names as the CVL attributes they are mapped to. For instance, there are four correspondences from the BIM: Prescription resource to four attributes in the CVL Prescription fact relationship, i.e., Prescription_ID, Duration, Date and TotalAmount, which are also the names of the Prescription resource attributes. Moreover, for Indicators, we have (hidden) information such as target, threshold, current value, etc., but also, more important for the mapping task, dimensions and levels to represent hierarchy. The possible dimensions (and levels) available for an indicator are elicited by the CVL fact table with which it is associated, e.g., the dimensions for [#] of antibiotic prescriptions are Prescriber, Medication and Time.

The BIM mapping compilation takes these correspondences and creates views over the CVL. For instance, BIM Prescription is mapped to a CVL view defined as V1 = Prescription (Prescription_ID, Duration, Date, TotalAmount), which is essentially a SELECT query in SQL. Every time the Prescription resource needs to pull data from CIM, view V1 is used.

Some other views involve roll up queries with aggregations, i.e., the views to feed BIM indicators. For instance, for the following BIM indicators from our case study, we have

- *[#] of antibiotic prescriptions* The actual value for the indicator is obtained by a query that aggregates the number of instances that appear in the CVL Prescription fact table which have a value equal to antibiotic for the Type.Name attribute in the Medication dimension.
- *[%] of antibiotic prescriptions* The actual value for the indicator is obtained by the value of the number of antibiotic prescriptions divided by a query that aggregates the number of instances that appear in the CVL Prescription fact table, all multiplied by 100.

– *[TOT/AVG] amount of antibiotic prescription(s)* The actual value for the indicator is obtained by a query that aggregates the amounts that appear in the CVL attribute Prescription.TotalAmount for all those corresponding to Type.Name="antibiotic" on the Medication dimension. If the average is requested, the above value is divided by the number of antibiotic prescriptions.
– *[AVG] duration of antibiotic prescription* The actual value for the indicator is obtained by a query that aggregates the durations that appear in the CVL attribute Prescription. Duration for all those corresponding to Type.Name="antibiotic" on the Medication dimension and divides it by the number of antibiotic prescriptions.

As explained above, the current values for these indicators can be drilled down using dimensions and levels defined in the BIM Indicators. Indeed, when a drill-down action is performed, a corresponding query is performed on the CVL. For example, a BIM user can desire to have the number of antibiotic prescriptions prescribed by a Physician named "John Smith". In such a case the above, query is reformulated considering the Prescriber dimension with Physician.FName="John" and Physician.LName="Smith".

6.4 Phase Three: Evaluate Initiative

In this phase, the efficiency of the strategic initiative can be assessed in terms of how well targets are being met, as measured by indicators associated with the goals for the initiative. This analysis is done with the help of a dashboard that provides visualization of the data collected through the CIM model and used to compute indicators and goal satisfaction in terms of the BIN model. The dashboard can also be used to interactively query all aspects of the data collected and organized by the CIM model, presented in terms of the view defined by the BIM model. In particular, one can drill down/up along various goal refinements and data dimensions.

One such dashboard was prototyped using the IBM Cognos BI tool (note that for privacy and confidentiality reasons, only simulated data and results are reported here). Figure 9 gives a partial view of an infection control dashboard that reports on the goals, indicators, and data specified in the BIM model and fed through the CIM model. In particular, there is detailed report (labeled "antibiotics tracking" that gives a detailed breakdown of the "number of Prescriptions" indicator. It shows what number of prescriptions there were for each major antibiotic drug type (Antibacterial, Antifungal, RetroViral, etc.) and for each service within the hospital

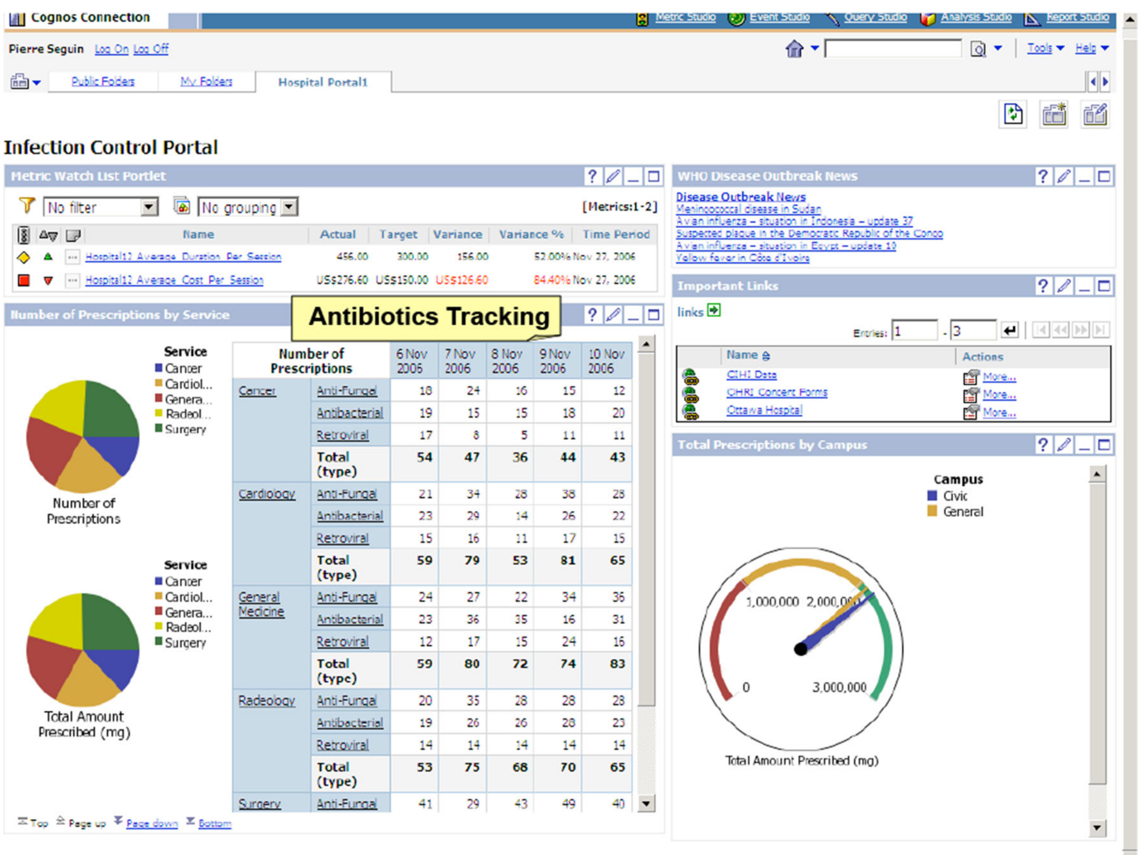

Fig. 9 Infection control dashboard

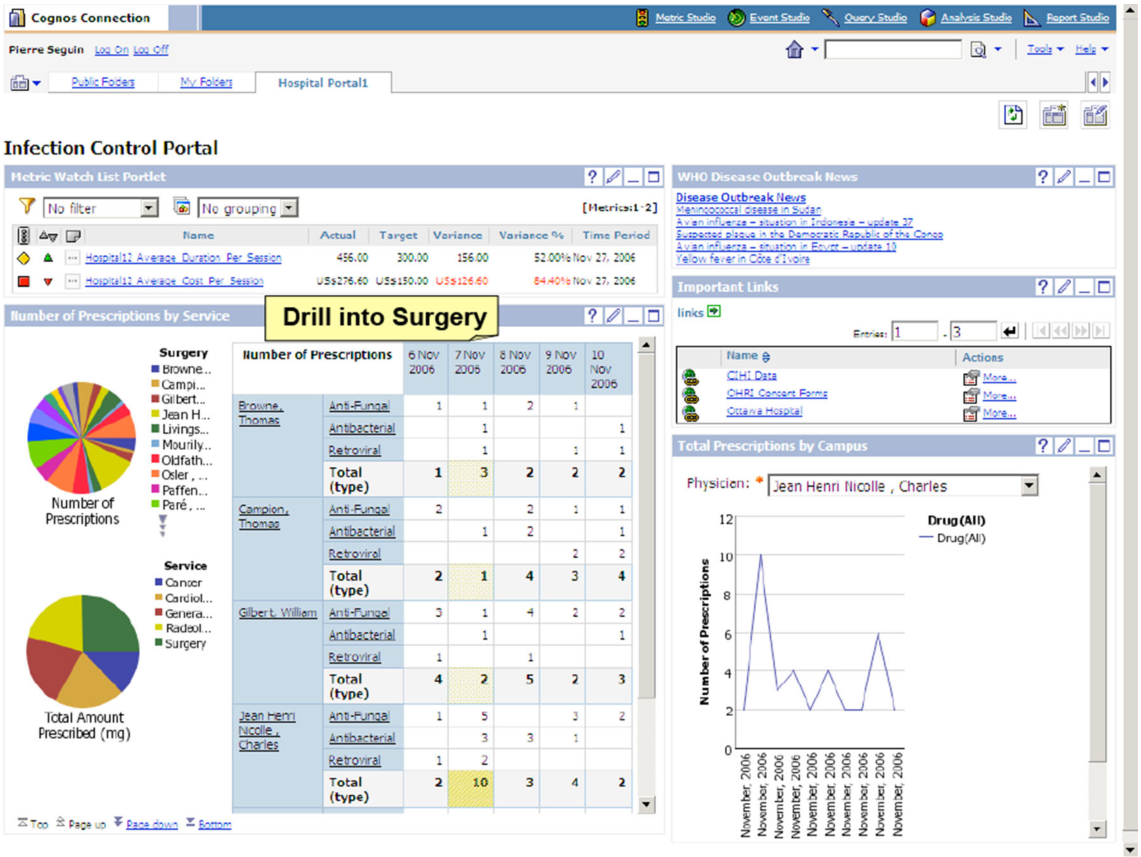

Fig. 10 Drilling down into surgery and most prescriptions

(Cancer, Cardiology, General Medicine, Radiology, Surgery, etc.) on a day-by-day basis.

This dashboard is built based on the multi-dimensional CIM model, which supports drill up and drill down along those three dimensions (Physician/Service, Drug/Drug Type, Day/Month/Year). Figure 10 illustrates the ability to drill down through those dimensions specified in the CIM model. In this case, the graph in the bottom left (Drill into Surgery) is shown when we click on the Surgery service in Fig. 9 to drill down to see the number of prescriptions for each individual physician. We could have also clicked on a particular drug type (e.g. antibacterial) and seen the number of prescriptions for each individual drug. Additionally, we could have right-clicked on an individual day to drill up to see the totals for the month or for the year.

Referring back to Fig. 7, one can see how this relates to the BIM model as supported by CIM. Physicians in the BIM model are organized in the CIM model into a hierarchy based on Service to support drilling up and down. Drug names in the BIM model are organized in the CIM model into a hierarchy of Drugs within drug Type to support drilling up and down. Moreover, # of antibiotic prescriptions is one of the indicators defined in the BIM model to measure Antibiotics use reduced. It corresponds to Number of Prescriptions in our dashboard, as implemented by the Prescription fact table in the CIM model.

Note that since the creation of the prototype shown here, the teaching hospital redesigned and deployed their own corporate version of an antibiotic management and infection control portal, also implemented with the Cognos BI technology.

6.5 Phase Four: Analyze New Problems

In this phase, based on the feedback of the analysis in Phase Three, the strategic initiative can be adjusted and new ones created to better meet targets, leading to a new iteration along the strategic initiative management lifecycle.

The existence of dashboards and of the underlying measurement infrastructure also becomes an opportunity to explore new strategic initiatives that are data intensive. In the context of our RARI case study, an education campaign for physicians with medication guidelines and the monitoring of monthly prescription rates was a necessary initiative (which justified the creation of dashboards), but it is not sufficient to achieve the hospital goals in terms of reduced costs and morbidity caused by antibiotic overuse. It was expected that the education campaign combined with the dashboard publicizing antibiotics usage (down to the level of individual physician) would be enough to result in a change in prescription behavior by doctors. However, only a minimal change in the amount and types of antibiotics prescribed was observed and no statistically significant change was observed in the rate of antibiotic-resistant infections.

One common issue is that physicians prescribe wide-spectrum antibiotics to new patients as a precaution while asking for various test results to be performed on the patient. However, once the test results are available, few physicians will change the antibiotics prescription to another one that would be more focused (and hence help reduce resistance to antibiotics) or less expensive, or that would allow for the patient to be sent home earlier (e.g., by using oral medication instead of intravenous ones), again leading to cost savings. One way to monitor such context and to intervene at the appropriate moment is to implement an antimicrobial stewardship program [28]. In such program, a specialized team of healthcare professionals (infectious diseases physician, pharmacist, microbiologist, epidemiologist, etc.) review prescriptions for appropriateness at various point in the flow of care (e.g., when a prescription is done or when test results arrive) and make recommendations to physicians when needed. A recent study by Galipeau et al. [20] suggests that antimicrobial stewardship programs are often cost effective. A new strategic initiative regarding the implementation of such a program can hence be proposed, and a new iteration of the initiative management lifecycle (Fig. 3) can be started accordingly.

7 Related Work

In the literature, different approaches from goal-oriented requirements engineering combine intentional and social concepts to model organization strategies and their elements (e.g., actors, resources, and processes). Other works have also extended *i** [54] and related frameworks (e.g., URN, standardized by the International Telecommunication Union [29]) towards enterprise models, e.g., the approach of Andersson et al. [3]. The recent addition of indicators to the URN standard, based on the work of Pourshahid et al. [45], does not address the question of how to link them to databases and BI monitoring. The BIM aims to unify various modeling concepts into a coherent framework with reasoning support and connection to enterprise data, built upon a firm conceptual modeling foundation. In particular, with respect to the above works, BIM includes (among others) the notion of influence, which is adopted from influence diagrams [26], a well-known and accepted decision analysis technique; SWOT analysis concepts [18] (strengths, weaknesses, opportunities, and threats) and others that are adopted from OMG's business motivation model standard [13]; and support for Balanced Scorecard and Strategy Maps [30,31].

Moreover, BIM's concepts are formalized through meta-modeling in terms of abstract concepts such as Thing, Object, Proposition, Entity, and Relationship, taking inspiration from the DOLCE ontology [22]. Further formalization based on Description Logics is on its way [25].

A number of conceptual multidimensional schemas for warehouse modeling have been proposed over the years (see [36] and references therein). Such approaches are mainly proposals for modeling languages that are part of data warehouse design methodologies. By contrast, CIM provides a run-time environment that allows a user to pose queries and do analysis integration across databases at conceptual level with mappings to BIM [46].

On the industry side, two major vendors of business analytics solutions (namely SAP Business Objects and IBM Cognos) provide proprietary conceptual levels that they call "semantic layers". SAP Business Objects' semantic layer [27], called a Universe, is a conceptual level representation of an organization's data assets (i.e., data warehouse as well as transactional databases). IBM Cognos' semantic layer, Framework Manager [50], is similar to SAP's Universes and works according to the same principles.

In contrast to these approaches, the EDM framework [1] provides a querying and programming platform that raises the level of abstraction from the logical relational data level to Chen's entity-relationship (ER) conceptual level [14]. EDM consists of a conceptual model, a relational database schema, mappings between them and a query language (entity SQL–eSQL), over the conceptual model. A compiler generates the mapping information in the form of eSQL views that express ER constructs in terms of relational tables. Unlike CIM, which deals with the multidimensional data model, EDM deals with the classical relational data model.

8 Evaluation

The case study that we used to illustrate our model-based approach for managing strategic initiatives was developed over a 2-year period at a major teaching hospital. The RARI initiative is a real initiative that is still active and has gone through at least two complete lifecycle iterations of analysis, modeling, implementation, and evaluation. The dashboard shown in this paper was a research prototype only that was developed during the first lifecycle iteration. It has since been replaced by a corporate dashboard that is in active use in the hospital.

During the case study, members of our research team were able to participate in meetings as guest members of the hospital initiative team and participate in the implementation. Our models were presented in those meetings and helped inform the management of the initiative. We also had research meetings that focused on the development of our model-based approach in which hospital personnel participated and gave us feedback.

The consensus of the feedback was that they found our approach informative and useful as a means of guiding their thinking and informing their use of technology throughout the process. It was particularly useful to focus on quantifying performance in terms of indicators linked to goals and leveraging those indicators to drive the implementation of an appropriate data model and dashboard to evaluate the initiative.

However, while they found the models useful, there was a skill gap that restricted their ability to create and work with the models directly. This was partially due to the fact that the models and tool support for the models were changing and being developed during the case study. A more significant factor is that modeling in this fashion was new to them, and the tool support for the models was too generic and abstract. BIM and CIM are general modeling tools and there was no interface specifically customized and optimized for initiative management.

In general, the model-based approach to strategic initiative management was useful to them because it helped structure and systematize the manner in which they leveraged data to quantify and monitor progress on their initiative. The cyclic approach of model, implement, evaluate, analyze is not new. It is a classical approach to managing strategic initiatives that is taught in business schools, and is carried out by organizations around the world. However, the gaps between a requirements view of the strategic initiative, the implementation view of the BI monitoring, and the results reported in dashboards can be quite large and often must be bridged largely in a manual, ad hoc fashion. Our approach uses models to structure, systematize, and automate the process, and provided analysts at the hospital with novel tools that they did not currently have.

- A structured representation of the requirements view of a strategic initiative, which links goals to tasks that accomplish them and indicators that measure them.
- A conceptual view of data that collects the required data from disparate sources across the organization in order to compute the indicators and report on them in a dashboard.
- A systematic approach to mapping from requirements view to conceptual view to dashboard.
- An opportunity for tool-based support for analysts to design, implement, and manage strategic initiatives.
- Formal mappings that ensure that changes to goals, indicators, dashboards, and data sources can be flexibly accommodated, facilitating maintenance.
- Better support in the cognitive gaps between requirements and implementation views, which allows savings in terms of time, accuracy, and other qualities during the implementation phase.

9 Conclusions and Future Work

We have presented a model-based performance management framework for bridging the requirements and implementation views within organizations. The workings of the framework are demonstrated through a case study that involves managing the strategic initiative lifecycle at a teaching hospital implementing an initiative intended to reduce antibiotic-resistant infections (RARI). The case study demonstrates how the framework works, but also how it can help bridge cognitive gaps and reduce the need for manual processing.

Our plans for future work include fleshing out the framework and supporting it with tools that automate or semi-automate some of the implementation tasks. With this aim, the concepts of flexibility and adaptability defined in [15] will be investigated and applied to our approach to (i) satisfy the changing data analysis requirements of business users, and (ii) cope with changes in local data sources. This will allow for the delivery of timely and accurate BI to business users.

We will use and further refine our approach in the implementation of a new strategic initiative related to an antimicrobial stewardship program at the teaching hospital, hence going through another iteration in the initiative management lifecycle. Along the way, we plan to extend the capabilities of our tools to better support analysis not only at the BIM level (see [4] for examples), but also at the CIM level. In parallel, one of us started using the framework on a new healthcare strategic initiative targeting Emergency Department Patient Flow (in another hospital), also with encouraging results [7].

We finally propose to study how the framework can be used to support other managerial and governance processes within different organizations such as governments as well as small and medium enterprises.

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