Toward a Care Process Metamodel

For Business Intelligence Healthcare Monitoring Solutions

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***Abstract*—Improving care processes in healthcare institutions relies on effectively monitoring and making timely decisions for improving patient experience. Business Intelligence solutions have proven to be effective for monitoring processes in other industries. However, healthcare organizations face three challenges for implementing Business Intelligence solutions that effectively monitor care processes. First, the great variation of processes in this domain makes it difficult to model them. Second, there is a gap between abstract administrative indicators and fine-grained operation-level measures of healthcare processes. Finally, it is difficult to reuse the underlying healthcare processes used for other successful solutions. In this paper, we present a Care Process Metamodel, which is geared toward modeling healthcare processes. This metamodel (a) provides a uniform platform for creating care processes, (b) enables hierarchical care processes for modeling complexity as well as bridging the gap between abstract performance indicators and operation-level measures of healthcare processes, and (c) facilitates reusing the processes and the data structure needed for monitoring them. This metamodel thus addresses some of the challenges for implementing a successful Business Intelligence care process monitoring solution. We also show how the Care Process Metamodel-based processes fit into an architecture, where data collected about encounters of patients can be used by stakeholders for improving the process and its execution. We use samples of cardiac-related processes to illustrate our approach.**

***Index Terms*— Care Process Metamodel, Care Process Model, Healthcare Process Monitoring, Business Intelligence Solution, Performance Indicators.**

I. Introduction

Managing and improving processes in any organization are not possible without capturing the knowledge about the models and also collecting measures about processes and compiling them into performance indicators at different levels of granularity. In healthcare domain, similar to other domains, (i) collecting measures and (ii) pulling them together in the form of performance indicators are critical elements for drawing the overall picture representing states of care processes. The status of indicators can then be used for improving the effectiveness and efficiency of care processes.

Delivering satisfactory healthcare services relies on effective and efficient care processes. Achieving and maintaining such qualities depend on continuously measuring the performance of processes. Business Intelligence (BI) solutions have been used successfully for monitoring the performance of processes in other industries [5]. In order to implement BI solutions and reap their advantage, organizations need to clearly define its business processes. Furthermore, success of BI solutions for monitoring processes depends on capturing data about metrics of the underlying processes which ultimately expose areas that need attention. The great variation of healthcare processes and their complexity makes it difficult to create such needed business processes that are used as the foundation of successful BI solution.

However, implementing successful BI solutions for monitoring healthcare process is challenging. First, there is a disconnection between operational-level measures and high level indicators that are being used for administrative accreditation and performance validation of the care processes. In other words, overall performance indicators, sometime mandated by regulations, lack the details necessary for identifying root problems or improvement opportunities. The often-used indicators in healthcare domain are too abstract, making it difficult to identify what lead the measures to be undesirable (or desirable). For example, there may be an accreditation guideline that wait times for cardiac patients in the emergency room should be less than one hour. However, in cases where longer waits are evident, it is difficult to identify the operational-level elements of care process that caused the longer wait times for patients. Making decisions that improve the effectiveness and efficiency of processes ultimately relies on the measures at the detailed level of granularity. Therefore, it is necessary to breakdown high-level care and performance indicators into contributing fine-grained measures.

In addition to bridging the gap between high-level indicators and fine-grained measures, improving the patient care relies on making the right decisions about the care processes at the right time. Healthcare institutes can reap the advantage of monitoring processes only if they can use its outcome in real time to make decisions. This in turn requires the performance indicators along with related fine-grained measures to be made available to relevant actors in real time. Currently, these measures and indicators are not delivered in real-time, which adversely affect the decisions of process administrators. For instance, lack of real-time access to measures about wait times may cause the emergency room administrations to miss the opportunity to allocate extra resources (i.e. nurses or physicians) or change the priorities in patient flow at the right time before it is too late.

Finally, care processes are usually described informally. They are frequently complex and can be composed of numerous steps. These processes involve a variety of care providing actors; these actors provide different care services to patients. Frequent transfer of responsibilities amongst the actors blurs the boundary lines of patient states, which are required to calculate basic measures such as wait time. Take the example of a cardiac patient whose wait time exceeded the regulatory limit of one hour. To identify the root cause of the excessive delay, fine-grained data about the patient, the current care process, and the involved actors must be aggregated into a more abstract and meaningful measures that can be used by care administrators. The informal representation of complex cardiac processes make it very difficult to know, with reasonable certainty, the exact steps of the process that are contributing to longer wait times.

We have previously showed a metamodel can be used as a platform for capturing the domain knowledge in the form of reusable patterns composed of business goals and business processes [1][2]. The suggested metamodel is used for modeling the knowledge in patient safety [3] and aviation security [4] domains. However the suggested metamodel is geared for reusing the captured domain knowledge for creating business process models.

In order to address the abovementioned challenges, this paper presents Care Process Metamodel for modeling care processes. This provides a uniform platform that specifically addresses the requirements of healthcare stakeholders for designing and maintaining care processes. Using CPM for modeling care processes facilitates bridging the gap between abstract and concrete indicators, thus, enabling the reasoning about the root causes of undesirable results for indicators such as wait time. This approach supports near-real time dashboards by focusing on relevant indicators and measures. At the same time, this metamodel provides the flexibility that is required for accommodating the changes of healthcare processes as well as the instantiation different encounters by reusing the care processes as building blocks.

The rest of this paper is organized as follows. Section II presents background information on Business Intelligence solutions. Then, Section III provides Care Process Metamodel. Section IV presents an architecture for monitoring healthcare process with the aid of BI solutions. Section V follows with a discussion of related works and Section VI presents our conclusions and future work.

II. Background

Business Intelligence (BI) solutions enable stakeholders of organizations to analyze available data that is already being captured within the operational databases. Healthcare organization conventionally collect large amount of *facts*, i.e. the data about patients and their states during their encounters within the healthcare organizations. Administrations of healthcare organizations can benefit from BI solutions as means of analyzing these facts. BI solutions enable healthcare administrators to visualize the performance of care processes across different *dimensions*. Dimensions are key contexts of a domain against which the facts can be analyzed. The time that patients spend while receiving healthcare services or waiting for those services are facts collected during the encounters. It can then help administrative analyze the care processes from different perspectives. Figure 1 illustrates a simplified sample report in which all the wait time of patients during their encounter is aggregated over the time dimension. This highlights a potential problem during the month of October where the average of actual waiting time is much higher than the expect wait time in comparison with other months.

Month (2012)	***Average Waiting Time of Cardiac Patients***	
	Actual (Hours)	***Expected(Hours)***
Sep	58	48
Oct	74	48
Nov	51	48
Dec	62	60

Figure 1 Sample report on actual and expected waiting of cardiac patients

BI solutions provide enable healthcare stakeholders to *drill down* by which they can start from summarized high level reports and investigate the areas of interest gradually accessing more detailed information. In the abovementioned example, drilling down enables stakeholders to understand the exact portion of the healthcare process that caused the higher than average waiting times for the month of October. This is done by drilling down to weeks or days on one hand and drilling down to specific departments or specific service on the other hand.

Although successful BI solution are proven to be beneficial for stakeholders, their implementation involves difficult and time consuming activities and is shown to fail frequently [5]. Barone et al. in [6] highlights that amongst the prominent risks in development of successful BI solutions is bridging the gap between abstract performance indicators and relevant concrete measures which involves both business domain expertise and software professionals. In the following section, we provide a metamodel as platform for modeling care process and important metrics of the processes.

III. Care Process Metamodel

Clinical pathways are processes that improving the well-being of patients during their encounter with healthcare institutes. Healthcare domain contains many different clinical pathways. Models that represent conceptual business processes and key measures for the stakeholders are prerequisite of developing successful BI solutions [6]. The great number of clinical pathways and their variation is an obstacle for creating such models. To address this issue, we provide are Process Metamodel (CPM) that can be used as a blueprint for representing different processes and capturing the key measures in the healthcare institutes.

In the metamodel, shown in Figure 2 , *Healthcare Entity* represents an entity within a healthcare organization which is in charge of clinical pathways represented by *Care Processes*. For example, cardiology department is one instance of *Healthcare Entity*. Care Process can be composed of other Care Processes. This hierarchical relationship amongst Care Processes is

essential for modeling the complexity of healthcare processes. As a result, this metamodel is able to capture complex clinical pathways such as chemotherapy treatments which is composed of more detailed steps. These steps are also instances of Care Processes representing finer-grained processes. *Care Provider* represents those individuals who either are in charge of a process or involved in delivering such a process. Physicians and nurses are typical instances of a Care Provider. *Patient* captures the patients that the care processes are delivered to them. Resources that are necessary for delivering a Care Process to patients are captured as *Care Resources*. Several Care Provider, Care Resource, and Care Process together compose a Healthcare Entity.

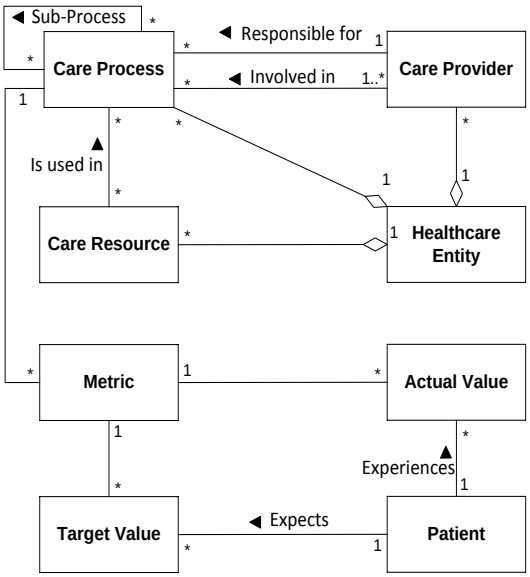

Figure 2 A Class diagram representing the Care Process Metamodel

This metamodel is geared towards the requirements for building conceptual healthcare processes required for BI solutions. Aligned with this goal, *Metrics* enable capturing the important indicators used by healthcare administrators to investigate the performance and compliance of healthcare processes. Waiting time for receiving a typical service, i.e. delivery of a Care Process, is an instance of Metric. The provided architecture captures both *Actual Value* and *Expected Value* of a Metric during the patients' encounters within the healthcare institute. Capturing both Actual and Expected Values of an instance of Metric are used by BI solutions for creating reports that clearly highlight the current status of a Care Process in comparison with the targets of that particular process. This metamodel has two advantages for investigating the undesired results. First, it is possible to drill down within the hierarchy of Care Processes to find the one with the main share in the undesired results. Second, it is possible for the administrators to find the patients who are affected the most by the undesirable results. In the next section we will show how the suggested metamodel can represent specific care processes. We also show how instances of these specific processes can represent encounters of individual patients and facilitate data collection about the measures that can be used in BI solution.

IV. Care Process Monitoring

A. Architecture of Care Process Metamodel-Based Care Monitoring

The metamodel presented in the previous section is the blueprint for creating conceptual business processes. Using CPM-based models benefits healthcare stakeholders who engineer the care processes in their organizations, and software professional who aim to develop BI solution for monitoring care processes. CPM-based models empower the stakeholder designing the care process with a platform tailored for capturing their knowledge about care processes. This is important because when BI solutions highlight the need for changes in some areas of process, the current system can be improved while maintaining the learned lessons about care processes accumulated during the previous iterations. Furthermore, using CPM-based models facilitate reusing of the processes that have been successfully deployed in BI solution within different departments of one particular hospital as well as across different healthcare institutes.

Figure 3 illustrates the architecture of a CPM-based care process monitoring solution. The premise of CPM for providing a uniform platform for modeling care process is essential for reusing the data collection strategies adopted by healthcare organizations. Moreover this platform enables the structure of the data warehouse in successful BI care monitoring solution be reused. This structure is then uses the captured data about metrics for providing reports and dashboards on performance of care process. The example in the middle gray portion of Figure 3 is a CPM-based care process that represents the care process applied on a typical cardiac patient admitted in the emergency department. During their encounter, the cardiac patients receive service through three care processes: (i) Emergency Admission, (ii) Cardiac Procedure, and (iii) Discharge. Emergency Admission is an example of a Care process composed of other care processes. Triage and Physician Consultation are Care Processes that construct Emergency Admission. This attribute of CPM models enables healthcare process designers to encapsulate the details of a complex process such as Emergency Admission and provide simple way of communication across the hospital and for decision makers. The details of process would be captured in constructing care processes, i.e. Triage and Physician Consultation. Care process can be further decomposed into more detailed process which leads to creating a hierarchical care process models.

While receiving care services, patients flow through different care process. As seen in the Figure 3 different types of events may trigger the flow of patients through different steps of care processes. For instance, a filled form by a physician approving the patient to be discharged can trigger Discharge. There has been some research such as [7] and [13] on utilizing Radio Frequency Identification (RFID) tags for geo-locating patients and care providers and using the location information as the source of events. However the means of discovering the events are transparent to CPM-models and accompanying BI solutions. Data collection takes place whenever the care processes are applied on patients for providing services. During

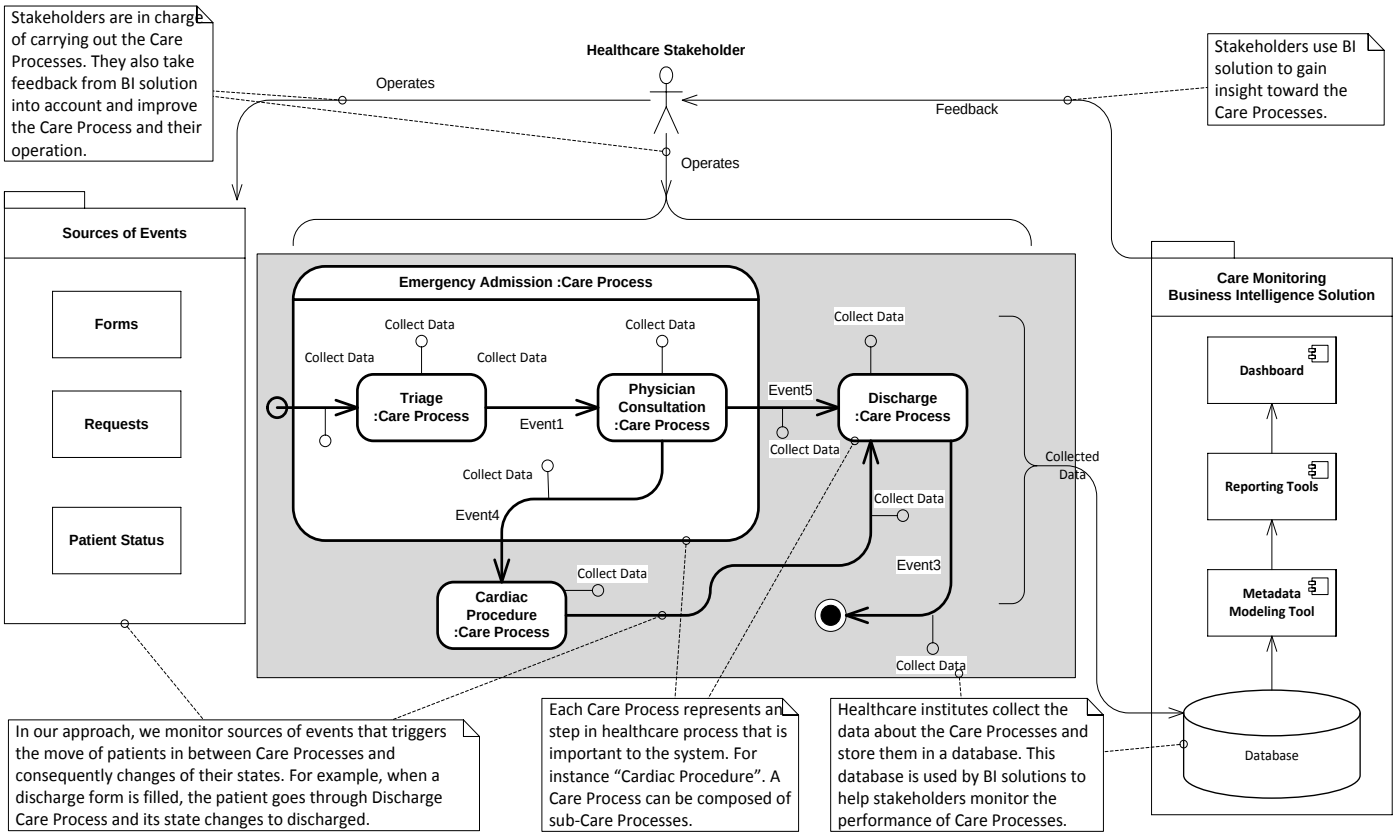

Figure 3 Architecture of a CPM-based BI Care Monitoring solution

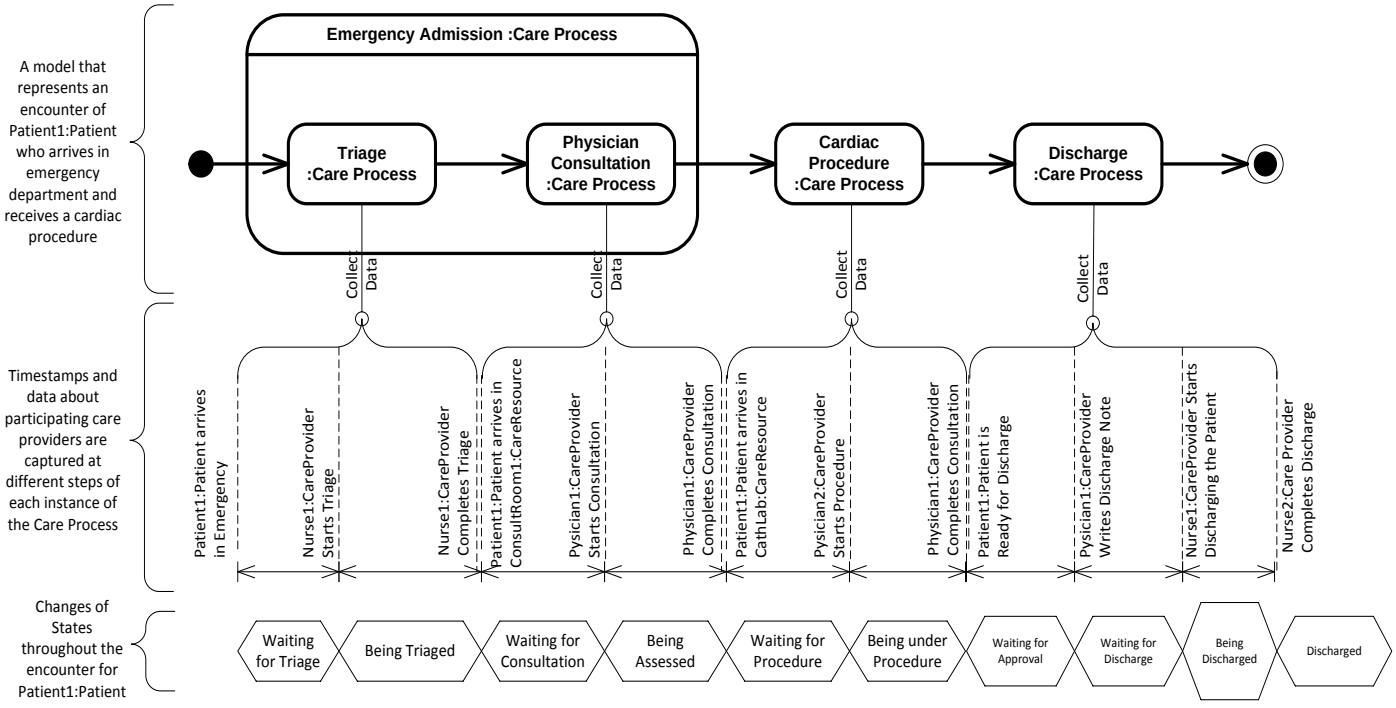

Figure 4 Use of care process metrics for determining patient states and wait times

the patients' encounters data are collected about different elements of CPM-based models such as care providers or care processes. The collected data determines the value of metrics that are significant for managing each monitored care process.

The stakeholders in Figure 3 use the feedback from BI solutions in two different ways. First, the stakeholder at the operational-level will use the reports on the fly in order to improve the quality care being provided to current encounters. Next, the feedback can also be used for highlighting the required improvement of care process.

B. Applying Care Process Metamodel-based Models

Typical healthcare organizations provide care to many patients with different underlying clinical conditions. Each patient encounter begins with the patient arriving in the hospital, continues with a series of services being provided through applying care processes, and ends when the patient is discharged. These encounters are potentially different because patients require different care services provided through different set of care processes. The CPM-based models are able to represent these encounters. This is made possible by using different instances of CPM-based care processes and composing them as building blocks of specific encounters of individual patients. For example, in the care process presented in Figure 3 a patient may be discharged after consultation or they may receive a cardiac procedure before being ready for discharge. Figure 4 is an instance of the mentioned care process for a particular encounter of an individual patient that was admitted to emergency department. In this encounter after arriving in the emergency department, the patient then is triaged and visited by a physician for a consultation. During the consultation, the physician determines the need for a cardiac procedure. As a result the patient is discharged only after receiving a needed cardiac procedure.

Figure 4 also shows that timestamps and data about care providers are collected during any encounters. The captured data during each encounter are stored in a BI care monitoring database where they are used to determine the metrics of care processes. These metrics are used by BI care monitoring solution for rendering near real-time reports. The advantage of using CPM-based models for instantiating patient encounters and collecting data is twofold. First, the administrative stakeholders can monitor the performance of care process for their compliance with the healthcare policies of the organization. In case of undesirable performance, they can further investigate the issues by drilling down into details for finding the root causes, i.e. those steps of process, which has the major share leading to unaccepted results. For example when the waiting time for patients is higher than usual, drilling down can reveal that longer cardiac procedure times keeps the patients from proceeding faster during their encounters. Consequently, administrators may assign more care providers to improve the patient flow through the cardiac procedures. Second, stakeholders at the operational-level also benefit from monitoring the care processes propelled by data collection during the CPM-based encounters. The near real-time monitoring of care process metrics determine the states of patients and can easily highlight the patients and relevant areas of care processes that require immediate attention. For instance, a visualizing report on current waiting time of patients who are in the emergency department draws the attention of nurses for immediate attention to a patient who is experiencing an unusually long waiting time.

The UML timing diagram in the bottom part of Figure 4 illustrates how the data collected about care processes determines the states of a patient as well as the points of time where changes of states occur. This information can be used by administrator for improving the care processes and by operation-level stakeholders for providing better care for improving current patient encounters.

The fact that CPM-based care processes can be instantiated and used as building blocks of encounter of individual patients facilitate the success of the accompanying BI solutions. This is because the CPM-based care monitoring recognized the need for variation of care processes and inevitable differences amongst the patient encounters yet its uniform platform makes it possible to benefit from a common data structure and from reusing the best practices of BI care monitoring solutions. This reuse of knowledge may happen across different departments of one hospital or across different healthcare organizations.

By using CPM-based hierarchical care process, collected metrics of care processes at the concrete level preserve the operational details of processes applied on the patients while more abstract level of model are linked to those metrics that represent the care process performance indicators. Usually the healthcare administrators use the high-level indicators to validate and accredit the healthcare process while operational-level healthcare stakeholders use the detailed-level indicators for near real-time management of patient flow and improvement of services provided to patients. Hierarchical care process models can bridges the infamous gap between the performance indicators and those at the operational-level. This is done by linking the metrics at one level to the contributing metrics of care processes at the other level.

It should be mentioned that although this model is designed based on the observations of processes in real world hospitals in Canada, they are simplified for the purpose of brevity. In the real world examples, a patient flows through more care processes and the hierarchy of care process that are composed of other care processes are deeper than in the mentioned example. However as it shown, CPM is flexible for supporting care process models and relevant encounters that have more complex realistic characteristics.

C. Care Process Monitoring Approach

Our approach for modeling and applying CMP-based care processes enables a BI solution to build upon the data structure of the databases that stores the data collected at different stages of patients' encounters. In order to show the feasibility of creating BI care monitoring solutions, we have created a data warehouse metadata that stages the data collected during encounters of cardiac patient in the form of a *star schema* (Figure 5-a). The star schema is an effective way of staging data for the purpose of creating reports. Moreover, such metadata hide the detail of database which enables the authors to use BI tools such as IBM Cognos BI tool (see Figure 5-b) and simply create the required reports on the fly.

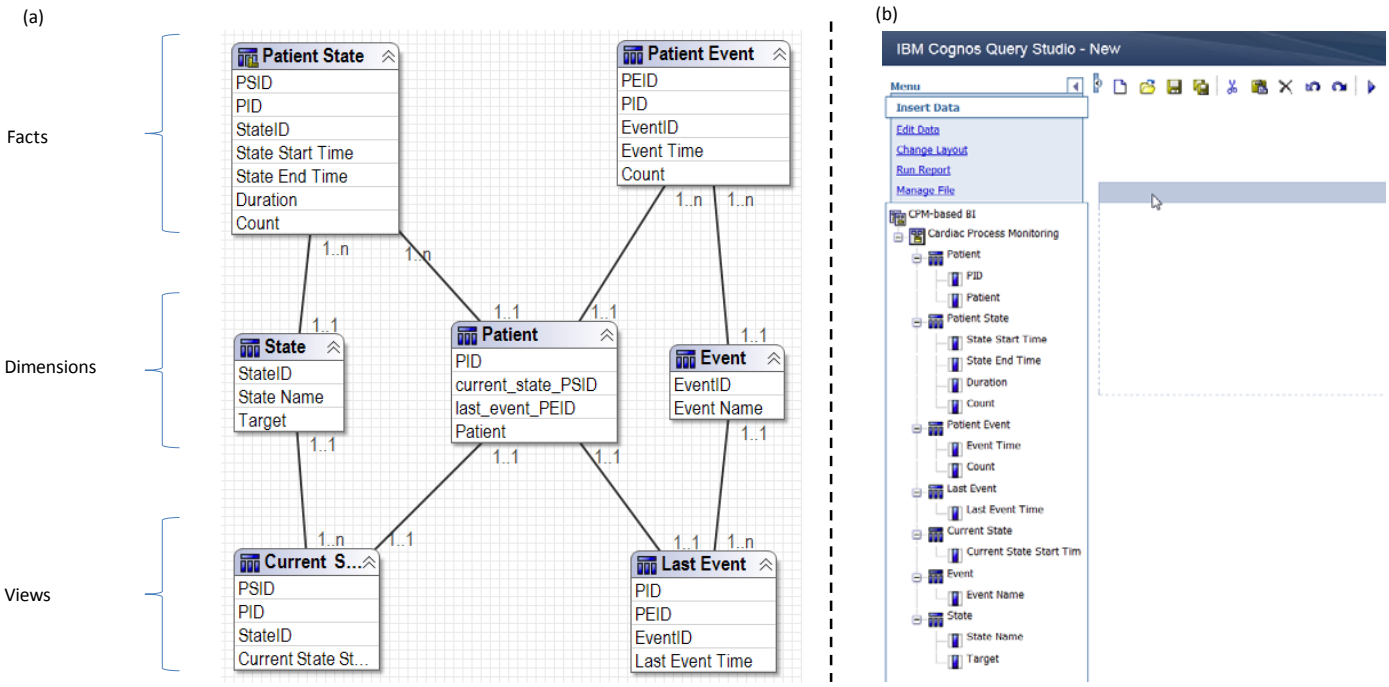

Figure 5 (a) A star schema for staging collected data during encounters of cardiac patients. (b) An environment that used published schema for reporting

V. Related Work

The use of metamodels is a common technical practice. Meta-models are particularly useful when there is a need to define a set of acceptable models, or when there is a need to explicitly define a set of acceptable standards. For example, Object Management Group (OMG) publishes and maintains all UML meta-models [8]. In the healthcare domain, meta-models are also growing in popularity.

Winter et al. [9] has proposed a Hospital Information Systems metamodel that has the objective of supporting architects and information managers in their work. Their model is comprised of three layers and is designed to support operations at hospitals in general. Our metamodel focuses on supporting Business Intelligent solutions.

Supporting inter-operability of standards is another area where metamodels have been used in health care [10]. Such metamodels focus is to support system integration and interoperability.

Cimellaro et al. [14] presented a metamodel focusing on assessing performance in emergency departments. Their metamodel is made general to support different hospital configurations. Their main performance metric is wait time. This approach is similar to our approach. The main difference is that our metamodel focuses on explicitly defining all data needed for designing BI reports and dashboards, while Paolo's main concern is measuring performance using wait time as the key measure.

Analytics is one area where healthcare institutions can utilize existing data to analyze practice and performance. Corrales [11] proposes an approach where goal models are used to aggregate small measures and enables stakeholders to reason about service performance at varying levels of granularity. [12] proposes an approach that also utilizes existing data. This approach aims at supporting the continuous monitoring of performance and quality of care processes. This work first identifies the requirements of continuous monitoring of healthcare processes, and integrates common streaming events data model with agent-based surveillance.

[13] identifies some of the limitations of applying analytics in the health care domain. The authors identify the lack of driving integration in health care as a key limitation.

VI. Conclusions and Future Work

Monitoring processes in the healthcare domain is challenging because (i) great variation of healthcare processes and their complexity makes it difficult to model them, (ii) links between indicators used by administrative and operation-level stakeholders are unclear, and (iii) it is difficult to reuse the knowledge about the processes as well as the data structure used for storing captured data about them. In order to address these challenges, we introduced CPM; a metamodel that provides a platform for modeling and presenting healthcare processes. We showed that CPM-based modeling can benefit healthcare domain in three ways: First, this metamodel provides a platform for creating conceptual business process models. These models are based on consistent underlying terminology CPM and represent processes that are specific to particular healthcare organizations and their requirements. Second, CPM-based care processes can capture hierarchical composition of health care processes. Therefore, CPM is a good candidate for modeling the healthcare processes which are usually hierarchical and complex. This ability to capture the hierarchy facilitates bridging the gap between high level abstract indicators and concrete operational-level care

processes. This, in turn, addresses the linkage of performance indicators to operational-level measures. Finally, using CPM makes it possible to reuse the knowledge captured about the care processes within and across the healthcare organizations. Using CPM-based care process models as building blocks provides the flexibility that is required for accommodating the changes of healthcare processes as well as the instantiation of different encounters. Consequently, the data structure for capturing the measures of processes and pieces of BI care monitoring solutions such as staging metadata and reports can be reused.

For the future work we are planning to examine more healthcare processes potentially from different healthcare organizations. Furthermore, we are also planning to implement reports based on the provided star schema for further assessment of CPM-based BI solutions.

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