Leveraging Goal Models and Performance Indicators to Assess Health Care Information Systems

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Abstract— **Health care delivery teams are increasingly adopting healthcare information systems (HCIS) to improve the efficiency and quality of care. Methods for assessing candidate HCIS exist, but are inadequate. Enhanced approaches to HCIS assessment are needed which focus on quality of care goals and compliance with accreditation standards. Performance indicators are often used to measure how well goals are met, but on their own are not sufficient. We presents a five-step framework for modeling the impact of candidate HCIS using User Requirements Notation based on impact points where the effects on operational business processes are measured and linked to organizational goals. A case study illustrates the framework and evaluates its potential.**

Keywords- Requirements Engineering; User Requirements Notation; health care information system; goal models; performance indicators; quality of care

I. INTRODUCTION

The 2001 Institute of Medicine Study called for the healthcare system to be reengineered to support team based care and the sharing the of data and work processes [15]. However, in spite of available Healthcare Information Systems (HCIS), many health care providers still collect and share patient's information in an ad-hoc basis, by paper-based forms, faxes and phone. Resistance to using HCIS often stems from uncertainty that investment in technology will actually result in improvements to either the efficiency or quality of care [3]. One study of HCIS showed that nurses were required to do "double entry" into electronic systems and paper charts for various reasons including legal issues [18]. Such duplicate work creates the opportunity for medical errors and makes health care providers hesitate to accept HCIS. There is increasing pressure to demonstrate that money is wisely spent [30], but existing HCIS assessment tends to be either too narrow in focus or lack the specificity needed to assess day to day processes. Health care providers need to be able to assess the impact of HCIS in a systematic way that links daily processes to organizational goals related to quality of care and regulatory oversight. This paper presents a requirement engineering framework that models organizational goals linked to business processes. It integrates performance indicators to quantify the impact of an HCIS and compare alternatives.

II. BACKGROUND

In this section we review existing approaches for assessing HCIS, as well as the role of accreditation and other legal requirements. We also provide an overview of requirements engineering and the URN language.

A. Assessment Approaches for HCIS

Business performance management (BPM) is a common approach in which key performance indicators (KPIs) are used to define how organizational objectives are quantified and measured. The Balanced Scorecard is perhaps the most well known and has been applied successfully to the management of healthcare organizations [14]. However, one of the challenges for BPM is to understand the relationship between operational business processes and results measured with KPIs [17] as well as the constraints imposed by legal requirements. Recent research indicates that URN can be used to address both business process issues [24] and legal constraints [10].

BPM has the potential to be used as an HCIS assessment tool but the gap between KPIs and operational business processes limits its effect. Typically more narrowly focused measures are used. Cost-benefit analysis (CBA) assesses different alternatives by weighing the total expected costs over the total expected benefits measured strictly in terms of financial impact. In healthcare, though, quality of care and regulatory compliance is paramount, which limits the effectiveness of CBA for truly understanding the impact of an HCIS [7].

Technological adoption models (TAM) are an alternative as they evaluate how likely it is that an HCIS will actually be used if provided, and to identify what factors influence adoption (positively or negatively). There are several technology adoption assessment models such as Roger's Diffusion of Innovation Model [25] and Technology Acceptance Model [5]. However, TAM does not evaluate how the HCIS impacts organizational goals such as quality of care or regulatory compliance. Ash et al. showed that HCIS can have impacts that extend beyond the technology itself [2].

B. Accreditation and Other Legal Requirements

Accreditation is affirmed as a process designed to improve the quality, efficiency and effectiveness of a healthcare organization, including its structures, processes and outcomes [20]. It is reasoned that an effective accreditation research program will not only identify poor performing areas but will be sufficiently sensitive to predict poor performance and thus help avert clinical or administrative failure [4]. The benefits of accreditation include an acceptable level of quality amongst

healthcare providers [19], improved communication between providers, and continuous self analysis of performance [21].

The case study used in this research was an HCIS to support palliative health care within the jurisdiction of Ontario, Canada, for which Accreditation Canada specifies process guidelines and KPIs [1]. Privacy is also regulated by the Personal Health Information Privacy Act [22] within the framework of the federal Personal Information Protection and Electronic Documents (PIPEDA) act [23]. PIPEDA has been recognized by the European Commission as being compliant with the European Union's Directive on Privacy and Electronic Communications [8]. In the United States, there is similar legislation for healthcare in the form of the Health Insurance Portability and Accountability Act (HIPAA) [13].

C. Requirements Engineering with URN

For any information system, understanding and analyzing its purpose is important [9]. Goal oriented approaches to requirements engineering [26] address why an information system is needed in addition to what and how the system works. The purpose of requirements engineering [11] is to understand both the need and the justification of an information system in terms of the organization which will use it. The ability to measure how well these goals are met by an information system by combining goals with BPM is an emerging focus for requirements engineering research [24, 28] as is the ability to address legal compliance [6, 10].

URN is a requirements engineering language, recently adopted by the ITU as a standard [16] that combines goal models and use case maps in order to model information system requirements. Goal models show how actor (stakeholder) goals are structured and how they are measured by indicators. An example of a goal model is shown in figure 2 and explained in detail for our case study in section V. Use case maps model scenarios that depict behavior which can be linked to goals. In particular, they can be used to model organizational business processes [24]. Scenario paths connect start points, end points, and responsibilities. Responsibilities indicate where actions, transformations, or processing are required. An example of a UCM diagram is shown in figure 3 and explained in detail for our case study in section V.

URN models can be built using the Eclipse-based jUCMNav tool [27]. jUCMNav supports an extensible meta-model for extending the set of diagrams, model elements and links the tool can work with as well as a data exchange layer for integration with other tools and systems. It provides integrated support for KPIs as an extension to the URN standard [24].

III. RESEARCH METHODOLOGY

The methodology used was design-oriented research that consisted of five stages [12]: problem definition, framework design, framework evaluation, re-evaluation and improvement of framework, and communication and discussion of results. The problem definition stage included a carefully selected case study, a literature survey of existing approaches and a gap analysis of how effective existing approaches were for addressing the problem. An initial set of criteria for evaluating our framework was established during this stage based on the literature survey and our interaction with key stakeholders n the case study who were responsible for HCIS assessment. During framework evaluation and re-evaluation this set of criteria was refined through our interaction with stakeholders who participated in the evaluation.

The following criteria were used to evaluate our proposed framework. To a large degree, many of the criteria are generally assumed to be satisfied by Business Performance Management approaches such as the Balanced Scorecard, but are not due to the inability of the Balanced Scored to directly capture how the changes an HCIS creates in business processes are related to the results measured with KPIs.

- **Graphically model impact on organization goals:** Quality of care goals and regulatory oversight make the context for HCIS assessment complex. It is important to graphically model the key stakeholders, their goals, the relationships between them, and the impact on them in order that decision makers can visualize all aspects of the situation.
- **Quantify impact on organization goals:** Quantifying impact enables stakeholders and decision makers to understand the impact of a HCIS in a manner that can be measured objectively, compared, and used for planning. KPIs are the usual mechanism for measuring business performance. Ideally, the impact of an HCIS would be quantitatively understood in terms of the impact on KPIs.
- **Correlate KPIs, goals and business processes:** The impact of an HCIS is most clearly seen in how it is intended to change existing business processes. An HCIS assessment is not complete unless it explicitly shows the relationship between changed business processes and the KPIs that measure business performance in terms of organizational goals.
- **Compare Alternatives:** There are choices in how business processes can change with an HCIS. There are even technology options to be chosen from in the implementation of an HCIS. It must be possible to compare alternatives during HCIS assessment.
- **Continuous Assessment:** It is important to be able to monitor the impact of an HCIS over time as goals, processes, and technology change. Ideally, one would want to continue to assess after the HCIS is implemented in order to validate that its actual impact is in line with its expected impact. .
- **Tool support:** Because of the complexity of HCIS assessment, as well as the requirement to compare alternatives and perform continuous assessment, software tool support is crucial.
- **Assess financial impact:** Existing approaches like CBA should be supported.
- **Assess user adoption:** Existing approaches like TAM should be supported.

IV. URN FRAMEWORK

The framework, with jUCMNav tool support for URN and key extensions to integrate KPIs, is shown in figure 1.

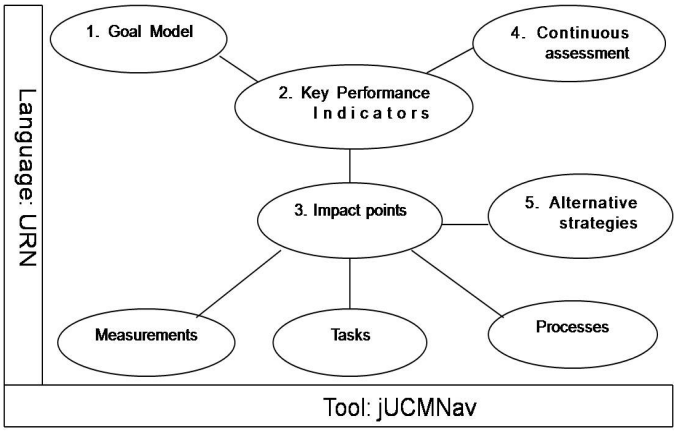

Figure 1. URN Framework

1. **Goal model:** A goal model structures the goals and captures dependencies and interactions between goals. It identifies the key stakeholders or actors responsible for goals. The goal model depicts what the organization is trying to achieve with a particular focus on those goals and stakeholders where the HCIS is intended to have an impact.

2. **Key Performance Indicators:** For each goal, there should be at least one KPI that measures to what degree the organization is achieving the goal. Without KPIs there is no ability to measure the impact of HCIS adoption (or any other change in the way the organization operates). KPIs are added to the goal model and linked to the goal(s) for which they measure impact (positively or negatively).

3. **Impact points:** Each KPI is reviewed and assessed to understand what impact, if any, is expected from the proposed HCIS. If an impact is expected, further analysis is done to identify precisely what task, process or measurement should be changed by the HCIS. These impact points are analyzed in detail in order to quantify the expected impact. Use Case Maps are used to model particular scenarios to illustrate how organizational processes will change with the new HCIS.

4. **Alternative strategies**: This step pulls together a complete view of the HCIS quantifying the impact in terms of two strategies to choose from: adopting the HCIS versus the status quo. At each impact point, we modeled how tasks, processes and measurements would impact KPIs with and without the proposed HCIS.

5. **Continuous assessment:** Initial assessment predicts what impact indicators will measure when an HCIS is implemented. Follow up assessments should be performed on a regular basis after implementation to ensure that the HCIS is having the desired impact.

V. CASE STUDY

Palliative care is the care provided to patients at end of life when curative therapies are not an option. Typically it is provided as team based care delivery across multiple settings. [29]. In our case study, we worked with a health care provider in Ontario, Canada to assess an HCIS called PAL-IS (palliative care information system) which was a web portal intended to facilitate sharing of patient information among doctors, nurses and case managers to support decision making and treatment.

Figure 2 shows a subset of the high level goal model and some important KPIs from the case study. It is basically a snapshot of the goal model after the first two steps of the methodology have been completed (1.Goal model and 2.Key Performance Indicators). The goal model was initially built based on an analysis of internal documents from the palliative care team and accreditation documents that specified process guidelines and quality of care KPIs. It was then refined iteratively based on feedback from the palliative care team.

KPIs are indicated by hexagon figures, goals are indicated by “squashed” ellipses. The dotted line circles indicate the four main actors for palliative care: doctor, nurse, case manager and ICT (Information Computing Technology). PAL-IS was being proposed to replace ad hoc ICT such as faxes and emails. The case manager owns the goals: “timely deliver palliative care services”, “shorten/avoid hospital stay”, “satisfy family and caregiver”, and “provide continuous collaborative care”. The nurse has goals “remotely monitor patient” and “assess pain & symptom burden”, while the doctor’s goal is to “stabilize patient at home”. The ICT has three goals, “privacy and security assurance”, “efficiently communicate and integrate patient data” and “capture critical events for audit”.

The KPIs came from meetings with stakeholders and Accreditation Canada’s palliative care guidelines [1]. Each KPI is linked to the goal it measures. For example, “the percent of patient info being collected remotely” measures “remotely monitor patient”, and “the last time and periodicity of patient info being updated” measures “efficiently communicate and integrate patient data”. The arrows in the diagram indicate a positive contribution towards a goal, except for the round-headed arrows which indicate that “remotely monitor patients” and “efficiently communicate and integrate patient data” potentially compromise “privacy and security assurance”.

The critical step in applying the methodology was the identification and analysis of impact points. (3.Impact Points). For each KPI, discussions with the palliative care team identified what business processes provided the data measured by the KPI. These were then reviewed to determine the impact points where PAL-IS might be expected to have an impact that would be measurable by a KPI. Use case maps were then used to model the key operational business processes related to these impact points, in order to predict and quantify the impact.

The main impact of PAL-IS was anticipated to be around the goal of “remote monitoring” for the nurse and “efficiently communicate and integrate patient data” for the ICT. In palliative care, the most critical operational business process is pain assessment and management, which is directly related to those goals. In the exiting “Ad Hoc” approach to ICT, without PAL-IS, business process remote monitoring and communication was were currently being achieved by an ad hoc combination of faxes, phone calls, emails, and in person visits by the nurse.

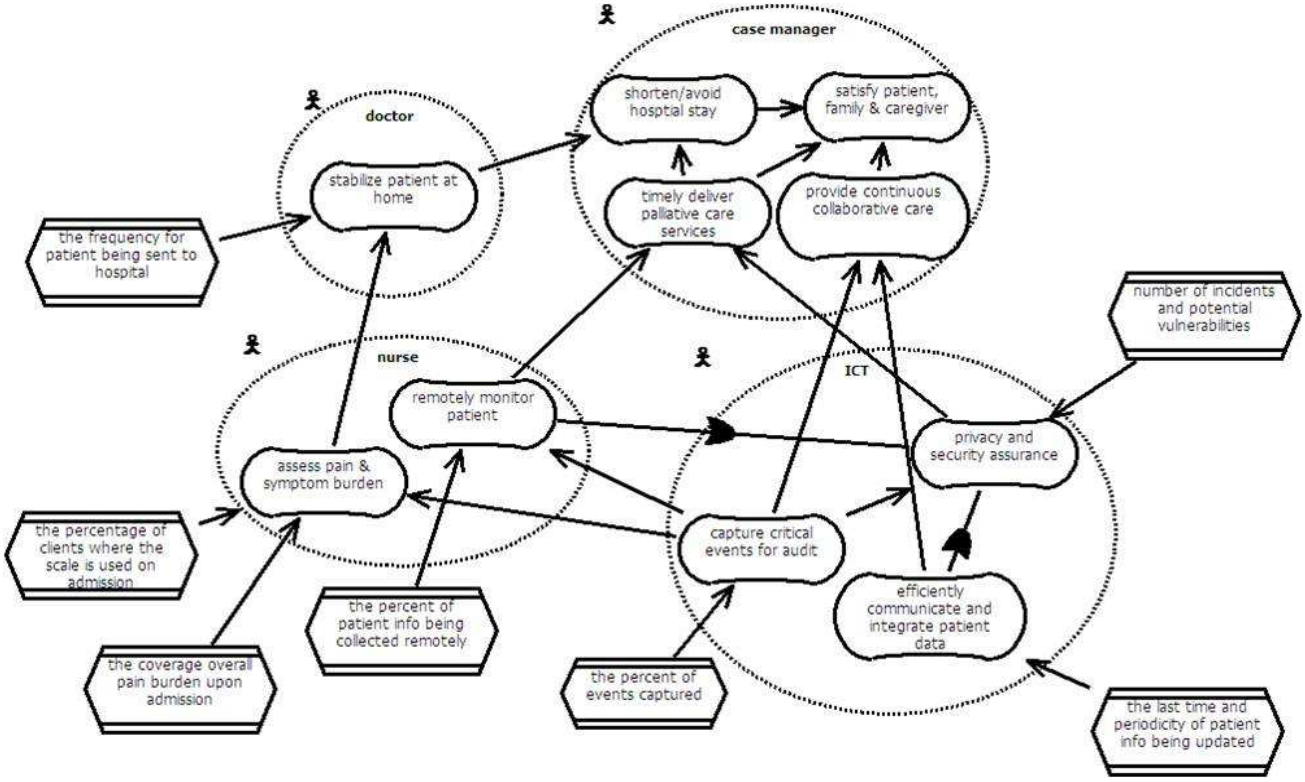

Figure 2. Goal Model and KPIs

Figure 3 is a use case map that shows process flow for one scenario. Each actor (Patient, Nurse, and Doctor) has a rectangular box for their individual responsibilities. The process start is indicated by the large dot when the Patient does "SendPainScore". The process flows in the direction indicated by arrows. Each "X" indicates another task. The Nurse "Generates and sends a painReport" based on the pain scores sent by the Patient. If the pain score exceeds a certain threshold then the Nurse "Sends PainAlert" causing the doctor to "ChangePrescription", and then the Nurse "Send prescription info" as needed in order that the Patient "Receive Prescription".

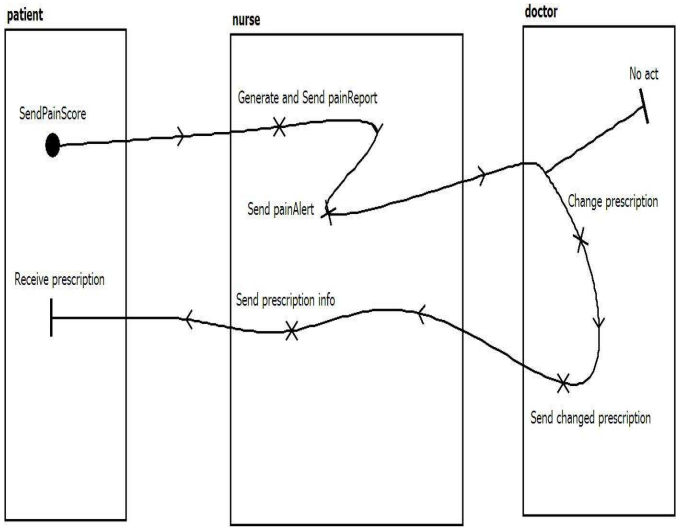

Figure 3. Palliative Pain Management Scenario

The next step in the process (4.Alternate Strategies) was to formally model the difference between the existing "Ad Hoc" ICT, and the proposed "PAL-IS" ICT. This was done, using jUCMNav's support for comparing alternative strategies. In Figure 2, one could associate two alternative tasks with the goal "efficiently communicate and integrate patient data": one with the Nurse updating data manually and communicating with other parties, the other with PAL-IS updating data and automatically communicating.

In the existing "Ad Hoc" approach to ICT, without PAL-IS, there can be significant delays before messages are received and acted upon. Often the nurse must visit the patient in person to collect pain scores. Using PAL-IS, patients could submit their PainScore to the web portal and pain alerts and changed prescriptions could be delivered to doctors and nurses automatically in a single standard interface. This increases the patient info collected remotely and increases the periodicity of patient info updated. The turnaround for our scenario was expected to drop from a period measured in days to one measured in hours.

The final step in our methodology is to support continuous asssessment as PAL-IS is implemented. In our case study, the model went through three versions before it was finalized, and we are planning for regular ongoing assessment. At each point, where a new model or a new reassesment is done, one needs to save a completely different version of the model. Comparisons between versions and tracking and analysis of trends must be done manually.

There is support in jUCMNav for linking KPIs in the goal model to a business performance management system

[24]. This would allow one to automatically link the actual values for KPIs once PAL-IS is implemented, in order to compare with the predicted ones entered during assessment. It is also possible to use external change management tools to track changes as goals, KPIs, and business processes evolve over time. However, better and more integrated tool support is needed be able to monitor assessment in a continuous fashion (e.g. monthly snapshots, comparisons between model versions etc.).

VI. EVALUATION

The case study illustrated how our URN-based framework flexibly correlates goal models with impact points in business processes while integrating KPIs and alternate strategy analysis. This, of course, supports a more comprehensive approach to HCIS assessment then "narrow" techniques like CBA (Cost Benefit Analysis) and TAM (Technology Adoption Models). However, our characterization of CBA and TAM as being "narrow" simply reflects that they are focused on a smaller set of particular KPIs, where our URN-based framework would incorporate all KPIs impacted by the HCIS that are relevant to organizational goals. So, a more interesting evaluation would be to compare our URN-based approach to a more comprehensive BPM (Business Performance Management) Methodology like the Balanced Scorecard.

In Table 1, we evaluate and compare the two approaches with respect to the evaluation criteria that we identified as part of our research methodology in section 3.

Table 1. Evaluation of URN Framework

Criteria	**Balanced Scorecard**	**URN**
Graphically model impact on organization goals	Not really. KPIs in a strategy map but hard to directly correlate with HCIS.	Yes. Goal models linked to impact points: HCIS, Actors, Tasks, Processes & Measurements.
Quantify impact on organization goals	Not really. KPIs quantify but hard to directly correlate with HCIS.	Yes. jUCMNav extends the URN standard with support for KPIs.
Correlate KPIs, goals & business processes	No.	Yes.
Compare alternatives	Not really. Only KPI, not HCIS.	Yes
Tool support	KPI infrastructure	jUCMNav plus KPIs
Assess financial impact	Somewhat. If financial KPIs exist.	Yes, if financial KPIs exist.
Assess user adoption	Somewhat. If adoption KPIs exist.	Yes, if adoption KPIs exist.
Continuous assessment	Somewhat for KPIs.	Mostly through export to external tools.

In theory, Balance Scorecard (with Strategy Maps) should enable us to graphically model, quantify impact, and compare alternatives on a continuous basis through the use of KPIs with good tool support. But in practice, it is not effective for assessing the impact of HCIS because of the lack of support for directly correlating organizational goals with business process impacts linked to KPIs. To the degree that stakeholders intuitively feel or "know" which KPIs are related to the HCIS, they could express their understanding of the impact an HCIS will have on organizational goals, but it is an approximate or intuitive assessment at best

At this point, it should be emphasized that only a single small, case study has been done as design-oriented research in order to demonstrate the potential of our proposed framework, while Balance Scorecard is a well established methodology that has been used commercially for over a decade now. As well, our framework to a large degree was created specifically to address well known limitations of current technology support for Balance Scorecard. As such Table 1, should be understood simply as an evaluation of the degree to which, in a single case study, we were able to demonstrate the benefits of using URN to complement the Balance Scorecard approach.

Our URN-based framework does much better, largely because it can be thought of as an extension or complement to BPM approaches like Balanced Scorecard. URN models are used to provide the direct correlation between goals, impact points, and KPIs that is missing in BPM approaches. It does require significant more in depth analysis, in order to identify impact points, quantify them and link them to goals and KPIs. It should be noted that support for KPIs is not currently in the URN specification, but is provided by jUCMNav using the URN language features that support extensions. That extension is effective, because there is also tool support for integrating the UCM models in jUCMNav with the performance management infrastructure that provides actual values for KPIs.

VII. CONCLUSIONS

When an HCIS is being assessed, the first thing we need to evaluate is how it will impact organizations goals. One advantage of our URN-based framework is that it provides the means to model organization goals, relationships between goals, and links to scenarios where the impacts of HCIS can be directly modeled. The other key advantage is the extensions to URN supported by jUCMNav which enable support for KPIs to be integrated with the goal model. This enables the impact on goals to be quantified in terms of whatever business performance management framework has been put in place. In our case study, a key aspect of accreditation is the ability to quantify quality of care goals with KPIs. Work should be done on the next version of the standard to make support for KPIs an integral part of URN.

The URN-based framework provides a more comprehensive approach in which to assess the impact of HCIS on organizational goals, by extending traditional business performance management with the ability to correlate KPIs to both strategic goals and operational

business processes. Compared to more traditional approaches such as CBA and TAM, it is able to assess the overall impact of an HCIS along all dimensions for all stakeholders, rather than from the more narrow point of view of financial impact or user adoption. In our case study, we found that our approach provided a systematic mechanism for identifying and prioritizing the indicators most relevant to the assessment of whether or not to implement an HCIS. It also identified areas, where indicators were missing or needed better data collection methods in order to provide data needed for managing the organization. More case studies are needed.

Finally, our framework has highlighted another fruitful area of application for the integration of BPM with requirements engineering. This continues to be an active area of research. Support for continuous assessment and management of goals, KPIs and business processes to ensure HCIS are aligned with organizational objects could still be better served with more integrated tool support.

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