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A Requirement Engineering Framework for Assessing Health Care Information Systems

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A Requirement Engineering Framework for Assessing Health Care Information Systems

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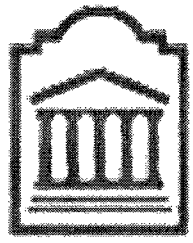

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Abstract

Health care is increasingly being provided by collaborative teams that involve multiple health care providers at multiple locations. To date, most of that collaboration is on an ad-hoc basis via phone calls, faxes, and paper based documentation. However, Internet and wireless technologies provide an opportunity to improve this situation via electronic data sharing. These new technologies make possible new ways of working and collaboration but it can be difficult for health care organizations to understand how to adopt new technologies while still ensuring that their policies and objectives are being met. It is also important to have a systematic approach to validate that e-health processes deliver the performance improvements that are expected. Using a case study of a palliative care patient receiving home care from a team of collaborating healthcare providers and organizations, we introduce a framework for assessing health care information systems based on requirements engineering. Key concerns and objectives were identified and modeled. Business processes which will use the new health care information system are modeled in terms of these concerns and objectives to assess their impact and ensure that electronic data sharing is well regulated and effective. The work in the thesis is design-oriented research to show the utility of our proposed requirement engineering framework compared to existing evaluation approaches for healthcare IT. The approach is evaluated based on a set of criteria drawn from our literature review and a gap analysis of our case study for palliative care.

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I would like to thank my supervisors, Liam Peyton and Craig Kuziemsky, for their guidance and comments. Finishing this work would have been an impossible task without their encouragement and support.

The thesis is dedicated to my dearest little one Catherine Y.B. Li.

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List of Acronyms

Acronym	Definition
B2B	Business-to-Business
BPM	Business Performance Management
CBA	Cost Benefit Analysis
EHR	Electronic Health Record
GRL	Goal-oriented Requirement Language
HCIS	Health Care Information System
ICT	Information & Communication Technology
ITU	International Telecommunications Union
KPI	Key Performance Indicator
LHIN	Local Health Integration Networks
PAL-IS	Palliative Care Information System
RE	Requirement Engineering
TAA	Technology Adoption Assessment
TAM	Technology Acceptance Model
UCM	Use Case Maps
UML	Unified Modeling Language
URN	User Requirements Notation

Chapter 1. Introduction

1.1. Problem Statement

The health care system must respond to all patients' needs at many different times and places, and care is be delivered by many different ways including in-person visits, telephone and Internet. The healthcare system should also try to proactively meet the needs and objectives of all parties in the system including patients' needs, rather than responding after the fact. Currently the healthcare system fails to fully deliver its potential benefits. There are many factors contributing to that situation.

First is that the public's healthcare needs have been changing. People are living longer, often with chronic diseases, including diabetes, heart disease, asthma, and cancers. However the current health care system in terms of human resources and funding still remains oriented toward dealing with acute care needs [Medicine01]. Providing care for chronic illness requires a movement from care delivery by a single provider and location to care delivery by multiple providers across multiple settings. However, our health care system is not designed to deliver team based care. Team based health care delivery is more complicated and needs more coordination than traditional one-to-one care delivery. With chronic care, the coordination problems among organizations are particularly apparent and important.

The second factor is the rate of change and development in medical science and technology over the past few decades. Compared to other domains such as banking, the health care delivery system is behind in applying new technology to promote safe,

efficient healthcare delivery. For example, the electronic health record (EHR) provides the means for electronic data collection and sharing among organizations, but there is still a need to support the underlying care delivery processes that take place. In fact, health care organizations including hospitals, clinics and physician groups are still operating separately, "acting without the benefit of complete information about the patient's medical history, services provided at other sites, or medications provided by other physicians." [Medicine01]. If health care does not adopt high-developed information systems and the new approaches for managing those information systems, it will continue to be inefficient.

1.2. Motivation and Objectives

Information systems have been used to support the delivery of quality health care. However, since there is a large variety of information technology on the market, it is a challenge for health care organizations to make choices regarding which technology to purchase.

The motivation for this work is to develop a framework that will help health care organizations to assess different information systems and to measure the extent by which the information systems improve the quality, efficiency and safety of health care services.

The main objective of the thesis is to provide health care organizations with such a framework that can be used to visually and quantitatively assess the impacts of health care information systems.

1.3. Thesis Contributions

The following contributions of this thesis are made:

1. A requirement engineering framework for modeling the impact of health care information systems on an organization's objectives.
2. Indentify the criteria for evaluating frameworks that assess the impacts of health care information systems.
3. Evaluate the URN language, which is an ITU standard, for implementing our framework.
4. Methodology for quantifying the impact of health care information systems on an organization's objectives by using indicators.

1.4. Thesis Methodology and Organization

The thesis methodology employed here is design-oriented research, which is "fundamentally a problem-solving paradigm" [Hevner04], to show the utility of our proposed requirement engineering framework. The five stages of design research methodology we have followed in our thesis work are "identification of problem relevance, framework design, framework evaluation, revaluation and improvement of framework, and communication and discussion of research" [Bell07]. Based on the research on current health care information systems (HCISs) and existing approaches to evaluate HCISs, we develop a framework by using existing requirement engineering language and tool for assessing health care information systems. We show the utility of the framework by applying it to the information system case study in palliative care and comparing it to other approaches.

In our work, the following steps were taken:

1. Identify and define the problem

2. Establish criteria for evaluation of the solutions

3. Select representative case study as an instance of the problem to be solved

4. Literature survey of the current approaches to problem

5. Gap analysis based on a case study

6. Develop our proposed requirement framework to address the gaps

7. Evaluate the proposed framework through the discussion of the case study

8. Iterate on steps 5 ~ 7 until the evaluation is satisfied

9. Summarize and publish results, and identify future work

The thesis is organized as follows: In Chapter 2, we provide the background on health care information systems (HCIS), current approaches of assessing information systems such as business performance management, cost-benefit analysis, and technology adoption assessment, and requirement engineering methodology. In Chapter 3, we propose a requirement engineering framework for assessing health care information systems. In that chapter, we first define the problem of the current approaches and indentify what we are going to solve. Secondly, we provide the criteria for evaluating frameworks that assess the impact of HCIS on an organization's objectives. Then, we

introduce our proposed requirement engineering framework. Finally, we discuss the methodology being used in the framework with details, such as models, metrics, tasks and continuous assessment. In Chapter 4, we explain how to apply our requirement engineering framework into practice through the case study of PAL-IS. In Chapter 5, we are going to evaluate the framework and compare it to current assessment approaches. Finally, in Chapter 6, we summarize our contributions and discuss possible future extensions that could be built on this thesis.

Chapter 2. Background

We present an overview of health care information systems in Section 2.1. In section 2.2, we introduce the business and technology assessment approaches that can be used to assess the impacts of HCIS. And in Section 2.3, we provide an overview of requirement engineering modeling.

2.1. Health Care Information Systems (HCIS)

2.1.1 Overview

The adoption of information technologies in health care has been slow compared to other industries such as finance or enterprise management.

We can take a look at the adoption process of electronic health records (EHR). EHR is a basis for most HCIS. EHR offers the possibility of enabling physicians to deliver more efficient health care in a shorter waiting time and improve patient safety by reducing medical errors. The Canadian federal government started to consider electronic health records 20 years ago; but only took action in 2000. The progress to date has been very slow. Every year, there are 322 million patients' visits, 94 per cent of which still result in handwritten paper records [CBC09]. Paper medical records stay in individual doctor's offices that do not allow electronic communications among health-care providers.

Why isn't there more adoption of information technologies in health care systems? There are two reasons: one is that the health care system is highly regulated and

very conservative, especially regarding patients' health risk; the second reason is that it is very hard for organizations to understand how new technology will impact organizational goals.

2.1.2 Legislation, accreditation and Guidelines

Health care is a highly regulated system. The adoption of any new information technology should need legislation, accreditation and guidelines involved.

Personal Health Information Privacy Act (PHIPA) specifies the legal responsibilities of health information custodians in terms of how they are to handle personal health information. PHIPA is legislation specific to healthcare in the Canadian province of Ontario within the framework of the federal Personal Information Protection and Electronic Documents (PIPEDA) act [GC09]. PIPEDA has been recognized by the European Commission as being compliant with the European Union's Data Protection [EUROPA09]. In the United States, there is similar legislation for healthcare in the form of the Health Insurance Portability and Accountability Act (HIPAA) [HIPPA09].

Ontario's Local Health Integration Networks (LHIN) created by the Ontario government in March 2006 is to plan, integrate and fund health care services. LHIN is managed under Local Health System Integration Act 2006. [ON06] The Ottawa Hospital (TOH) is a partner in the LHIN to deliver health care; but it is still governed under Applicable Law and Applicable Provincial Policies. [OttawaHospital08]

The Canadian Nurse Association (CNA) is a federation representing Canadian nurses. One of CNA's products, The *Code of Ethics for Registered Nurses*, "identifies

principles to govern the ethical practice of nursing across the country" and provides Canadian nurses "guidance for ethical relationships, responsibilities, behaviours and decision-making, and it is to be used in conjunction with the professional standards, laws and regulations that guide practice." [CNA08]

The Canadian Medical Association (CMA) is a national association of physicians to provide guidance to its members. Their practice should follow *The Act of Incorporation and Bylaws*. [CMA09] *CMA Code of Ethics* [CMA04] is also a guidance for professional conduct of Canadian physicians.

The Canadian Council on Health Services Accreditation (CCHSA) has developed a Core Set of Performance Measures to Support the Accreditation of Hospice Palliative and End-of-Life Care (HP/EOLC). This set of national standards is the basis for accreditation of hospice palliative and end-of-life care [AC] programs. They provide some of the key metrics for goals identified in our case study.

2.1.3 Data Sharing

It is expected that the number of individuals suffering from and living with chronic illness such as diabetes, heart disease and cancer will increase significantly in the forthcoming years [Medicine01]. Providing care for chronic illness requires a movement from care delivery by a single provider and location to care delivery by multiple providers across multiple settings. Team based care delivery is challenging for the fundamental reason that our healthcare system is not designed to deliver such care. [Coiera07] The electronic health record (EHR) provides the means for electronic data collection but there is still a need to support the underlying care delivery processes that

take place. Information access and sharing must be timely, accurate and secure or quality of care delivery can suffer. Poor information sharing in team based care delivery can be a source of medical errors [Alvarez06]. Thus if we are to support team base care delivery we must facilitate data sharing, but also support and monitor the underlying business processes that use the data. Stead et al. [Stead05] point to the need for an informatics infrastructure that details how to link information and business process needs to enable us to design technological solutions that provide care when and where needed, supporting processes that avoid error, and provide quality care while reducing administrative costs. The framework presented in this paper provides the basis for such an informatics infrastructure to support team based care delivery.

Currently, in spite of available information technology, health care providers still collect and share patient's information on an ad-hoc basis, by paper-based forms, faxes and phone. Although privacy and security are key concerns, there is also a resistance to technology and uncertainty that investment in technology will actually result in cost-effective improvements to health care delivery. The potential benefits of electronic healthcare data sharing is often overlooked. In the group of health care providers, nurses are the major persons who are responsible for collecting patient's data and entering into the electronic system. One study of information technology for palliative care showed that nurses were required to do "double entry" into electronic systems and paper charts for various reasons including medical legal issues [Kuziemsky04]. Such duplicate work creates the opportunity for medical errors and makes care providers (physicians, nurses etc.) hesitate to accept electronic records. Much of this duplicate work is motivated by studies showing electronic health care delivery to be problematic [Ash04] which raises

questions about the extent it can enhance care delivery. It is important in any switch to new technology to be able to monitor and document that quality of care is being maintained.

An ERP Web portal [Kuziemsky08], a common architecture of information systems, provides a solution of sharing data across multiple care settings. All users, such as nurses, doctors and patients, can access to a web portal interface, through which data can be updated and shared. Service Oriented Architecture (SOA) framework is another possible solution of sharing data in business-to-business (B2B) health care networks. It has been used in health care applications [Peyton07]. Policy-based Publish/Subscribe SOA Framework extends the traditional SOA solution to provide "platform independent data integration across an eHealth B2B network using web service protocols" [Eze09]. Health 2.0 technologies make use of Web 2.0 to create communities over internet in which health care providers, patients, and any other users can collaborate and share data [Hu09].

2.1.4 Palliative care

Palliative care is care provided to patients at end of life when curative therapies are not an option. Palliative care is an ideal domain to study team based care delivery across multiple settings as that is an integral part of palliative care delivery [Cummings98].

In such a domain, patients are usually staying at home to receive remote and long-term health care; nurses, physicians and other care providers deliver health care services to patients from different clinics or hospitals; case managers who are responsible for

administrating patients' overall care delivery often work from their office. How to collect, exchange and incorporate patients' data is the very first technical issue that needs to be addressed. Otherwise, such team based care delivery would not work efficiently and patients can not receive proper health care from home. The other issue related to the case of multiple physical locations is regulations and policies. To provide such health care delivery, different organizations are involved and different guidance, regulations and policies should be followed.

In this scenario, the health authority responsible for palliative care in a region of Ontario, Canada proposes to build a palliative care information system (PAL-IS). The intent is that PAL-IS will facilitate sharing of patient information among health care providers such as doctors, nurses and case managers as well as support the underlying processes of care delivery such as decision making and treatment dissemination.

2.2. Business and Technology Assessment

In this section, we describe three current approaches that can be used to assess the impacts of HCIS. They are Business Performance Management (BPM), Cost Benefit Analysis (CBA) and Technology Adoption Assessment (TAA).

2.2.1 Business Performance Management

Business performance management involves a series of analytic and management processes to define organizational strategy and then measure and manage performance business processes with respect to strategy in terms of key performance indicators (KPIs), with the help of technology. Based on the definition of BPM, "core BPM processes

include financial and operational planning, consolidation and reporting, business modeling, analysis, and monitoring of key performance indicators linked to strategy." [BPM10].

KPIs define how business strategy is quantified and measured. However, one of the challenges for Business Performance Management is to understand the relationship between operational business processes and the results that are measured with KPIs [Krishnipillai 2009]. Another challenge is the ability to understand how KPIs relate to the goals and objectives of the organization [Pourshahid09].

2.2.2 Cost Benefit Analysis

Cost-benefit analysis (CBA), which also refers to Benefit-Cost Analysis (BCA), is to help assess different alternatives by weighing the total expected costs over the total expected benefits. Cost-benefit calculations typically involve using time value of money formulas. This is usually done by converting the future expected streams of costs and benefits with a present value amount.

Cost–benefit analysis is heavily used in government to "evaluate the desirability of a given intervention" [Narrod07]. The public's willingness to pay for the benefits of an intervention and their willingness to pay to avoid the costs of the intervention are being taken [Narrod07]. Based on these values, the costs and benefits of the intervention are evaluated. The purpose of the measurement is to compare the efficiency of the intervention to the current situation.

2.2.3 Technology Adoption Assessment

Technology adoption assessment attempts to identify how likely it is that technology 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 [Rogers95] and the Technology Acceptance Model [Kukafka02]. The former is about technology adoption in general; the latter is a theory that is specific to information technology systems.

Technology Acceptance Model (TAM) models how users accept and use an IT system. It is an intention-based model that "focuses on the behavioral intentions of individuals to predict use" [Kukafka02]. TAM demonstrates that the behavior of an individual to use an IT system is determined by his intention to the system, which is in turn determined by his attitude to use. There are two factors that determine the attitude to use an IT system: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Davis defined PU as "the degree to which a person believes that using a particular system would enhance his or her job performance", and PEOU as "the degree to which a person believes that using a particular system would be free from effort" [Davis89].

2.3. Requirement Engineering Modeling

2.3.1 Requirements Engineering

Requirements engineering (RE) is "the branch of software engineering concerned with the real-world goals for, functions of, and constraints on software systems. It is also concerned with the relationship of these factors to precise specifications of software behavior, and to their evolution over time and across software families" [Zave97]. The

definition of RE first emphasizes the importance of goals that "represent the 'why' as well as the 'what' of a system" [Nuseibeh00], and then expresses the relationship between goals and software process activities like gathering requirements, developing systems to meet requirements and verifying requirements to be fulfilled.

The very first step in the RE process is to elicit requirements. The elicitation process includes identifying system boundaries, stakeholders and user classes, goals and tasks, and scenarios and use cases [Nuseibeh00].

Researchers have worked on applying requirement engineering concepts and tools to provide methodologies to ensure compliance and traceability between organizational goals and the business process that are supposed to achieve those goals. [Darimont06] describes how to apply one of the main goal-oriented requirements engineering methodologies (KAOS) to model regulations. They explain how to transform regulation documents into goal, objects and threat models incrementally and how to maintain a level of traceability from the source document to those models. [He06] introduced the Requirement-based Access Control Analysis and Policy Specification (ReCAPS) method to integrate access control analysis, improve software quality and develop policy and requirements-compliant systems. This method emphasizes compliance between different policy levels, requirements and system designs. In [Liu04], i*, a modeling language similar to Goal-oriented Requirement Language (GRL), was used to design information systems within a social context. In [Ghanavati07], User Requirements Notation (URN) was used as a basis for a framework to track legal compliance between health care processes and privacy legislation.

In the thesis, we focus on applying RE to evaluate the impact of health care information systems instead of the above purposes, such as development of a brand new system, business process modeling and optimization, and validation of legal compliance.

2.3.2 URN

We will use URN as a basis for our framework as well. URN was designed for modeling and analyzing requirements in the form of goals and scenarios prior to design [ITU-T02/03]. It can be used to model most kinds of reactive and distributed systems, as well as business processes [Weiss06]. URN combines two complementary notations: the Goal-oriented Requirement Language (GRL) and Use Case Maps (UCM) which are used for modeling goals and processes respectively. Figure 1 and figure 2 show a brief summary of the elements from these two notations that are used in this thesis.

URN is an ITU-T standard [ITU-T02/03] that combines goals and scenarios in order to help capture, model and analyze user requirements at the early stages of design. It can be applied to describe most kinds of reactive and distributed systems as well as business processes. URN is the only modeling language that can model goals and processes at the same time while providing traceability between them. URN integrates two notations, namely the Goal-oriented Requirement Language (GRL) and Use Case Maps (UCM). GRL is used to model, with AND/OR graphs, the relationships and strategies around how actors and tasks are organized to achieve goals and objectives. Figure 1 shows a subset of the main GRL elements.

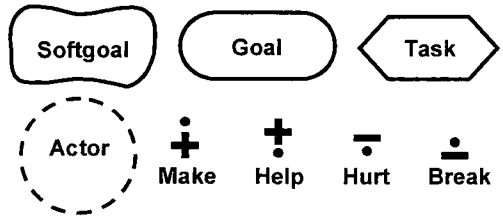

Figure 1 - Subset of GRL Notation

The UCM notation is used to model business processes and system behaviour in terms of related scenarios and use cases. Scenario paths connect start points (preconditions and triggering events), end points (post-conditions and resulting events), and responsibilities. Responsibilities indicate where actions, transformations, or processing are required. They can be performed in sequence, concurrently (using AND-forks and AND-joins) or as alternatives (with guarded OR-fork and OR-join). Complex processes can be defined at any level of abstraction and be decomposed with stubs, which act as containers for sub-maps. The subset of the UCM notation used in this chapter is shown in Figure 2.

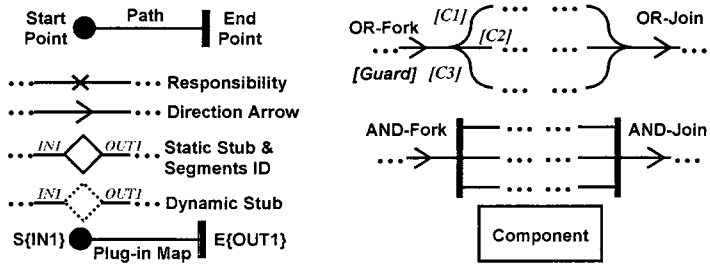

Figure 2 – Subset of UCM Notation

The UCM process view specifies the responsibilities to be performed (the what aspects) by whom, when, and where. The GRL goal view provides a rationale (why) for the business process elements, together with an explanation of why alternative solutions were chosen or not. More details on URN are provided in [Amyot03] [ITU-T02/03]. A

detailed analysis of the capabilities of URN in comparison with other well-known business process modeling languages is given in [Mussbacher07].

URN models are built using the Eclipse-based jUCMNav tool [Roy06]. 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 [Kealey06].

2.3.3 UML

The Unified Modeling Language (UML) is also a modeling language that "helps you specify, visualize, and document models of software systems, including their structure and design" [OMG10]. The UML standard was defined and is managed by Object Management Group. With UML, we can analyze project requirements, design system based on requirements and represent predicted results.

Now, UML 2.0 provides thirteen diagram types that are divided into three categories: structure diagrams, behaviour diagrams, and interaction diagrams. They are used in different modeling purposes in the different design stages.

Structure Diagrams are used to represent static structure and include six types, which are Class Diagram, Object Diagram, Component Diagram, Composite Structure Diagram, Package Diagram, and Deployment Diagram.

Behaviour Diagrams are used to represent behaviours and have three different diagram types, which are the Use Case Diagram, Activity Diagram and State Machine Diagram.

Interaction Diagrams are used to represent interactive processes and include four diagram types, which are the Sequence Diagram, Communication Diagram, Timing Diagram, and Interaction Overview Diagram.

As modeling languages, UML and URN are widely used to gather project requirements, model those requirements and design an application to meet them. They have similar features. They both have the features to support sequence flow, roles, activities, events, and process hierarchies for process modeling. URN has additional features like goal modeling, goal model evaluation, and traceability between business processes and goals; however, UML does not support these features.[Pourshahid09] Many researches are involved to address the issue. [Amyot00] presented how to use the concepts of UCM, one notation of URN, to extend UML for modeling complex reactive systems. And UML can also be extended for GRL through the definition of profiles, to make up its deficiency of modeling goals and non-functional requirements [Abid09].

Chapter 3. Framework

In this chapter, we propose a framework by using the language User Requirement Notation (URN) and the tool jUCMNav that supports URN. The framework is used for assessing health care information systems, by applying URN to model goals and business processes in order to quantify the impact of HCIS on organization goals.

In Section 3.1, we clearly define the problem that healthcare organizations have in choosing a health care information system, and give an overview of our approach. In Section 3.2, we identify a list of criteria for evaluating any framework for assessing the impact of HCIS. In Section 3.3, we describe our proposed framework and methodology. From Section 3.4 to Section 3.8, we analyze each point being used in our methodology. In Section 3.9, we summarize the chapter.

3.1. Overview

It is challenging for healthcare organizations to choose the right health care information system due to the rapid development of information technology and the changing context of healthcare delivery. There is increasing pressure on health care organizations not only to spend money wisely, but also to demonstrate it was wisely spent [Jeremy03]. One important perspective of evaluations is to assess how a health care information system satisfies organizational objectives.

The first issue in such an assessment is to identify what the organizational objectives are. We need to discover all relevant goals or requirements from all relevant stake holders. The second issue is how to measure organizational objectives. We need to

measure both quantitative and qualitative objectives. The third issue is how to manage organizational objectives. We need to have a way to explicitly tie objectives to outcomes that result from the operations and processes of the organization.

Current assessment approaches for health care information systems include business performance management, cost benefit analysis and technology adoption assessment. The commonality of these approaches is they all assume organizational objectives are known and measured. They have no ability to manage objectives in order to measure impact points for each objective and trace back how objectives are met.

The problem we are trying to address in the thesis is how can health care organizations choose the right information system? Our approach proposed in this chapter compensates for the deficiencies in existing assessment approaches identified above. In our framework, a goal model is first built to provide a graphical notation of organizational objectives, without assuming that they are all met. In the model, each goal is linked with indicators. Then, impact points, identified in terms of measurements, tasks, and processes, are used to manage and measure how each goal is met. And the concept of GRL strategies provides us with a way to analyze and compare alternative options. Finally, we show how continuous assessment can be done to maintain the model.

3.2. Criteria for the Framework

We need a set of criteria to evaluate any framework for assessing the impact of health care information systems. The aim of the criteria is to provide a check list to decision makers when they make comparisons among different frameworks in order to reach a reasonable decision on which framework to chose. We identified the following

criteria by analyzing the advantages and disadvantages of current assessment approaches in our literature survey from chapter 2, as well as drawing upon the knowledge we acquired with our case study described in chapter 4.

1. **Graphically model the impacts of HCIS on organizational goals:** to assess any HCIS, the first questions would be what the organization goals should be and how can they be satisfied. Documenting organizational goals and the processes that satisfy those goals can be challenging. However, it is even more complex to document the impacts an HCIS may have on organizational goals by identifying all the places that an HCIS will impact business processes. Therefore, it is important that any framework for assessing HCIS be able to graphically model the relations among organizational goals and processes and be able to graphically show how direct impacts on business processes are related to goals.

2. **Quantify the impacts of HCIS on organizational goals:** Although it is helpful if a framework can graphically model impacts on organization goals; it would be even better if those impacts can be quantified. Numbers would enable stakeholders or decision makers to understand the impact of a health care information system on organizational goals and make comparison among different HCISs. Any approach must be able to handle quantitative as well as qualitative goals.

3. **Assess business process impacts on organization goals:** there might be different underlying business processes to achieve the same organization goal,

and those processes have different impacts on the same goal. So, besides assessing organizational goals, a framework also needs to assess the impact of underlying business processes on organization goals from the view of implementation.

4. **Compare alternative technology choices for HCIS:** there are several of alternative technologies that a health care organization can choose from. A framework for assessing health care information systems should have the ability to compare different technology choices to help the decision maker in an organization select the right technology for their organization.

5. **Tool support for framework:** Healthcare organizations are complex. A paper-based methodology or framework for assessing HCIS would be hard to follow to the level of detail needed to fully assess the impact of a HCIS on a healthcare organization. Software tool support for any framework is crucial.

6. **Assess financial impacts of HCIS:** finance is a critical factor in evaluating HCISs; therefore, a framework should be able to or at least have potential possibility to show the financial impact.

7. **Assess the user adoption of HCIS:** evaluates user adoption, what users like and dislike. In our approach, we not only assess a framework from design and technical views, but also evaluate the acceptance level from the point of view of users.

8. **Continuous assessment of HCIS:** It is important to be able to continue to monitor the actual impact of an HCIS once one is chosen. As well, technology and organizations are constantly changing so the framework must support the ability to monitor and assess how goals are being met by an HCIS continuously as both technology and the organization (goals and processes) evolve.

3.3. Requirement Engineering Framework

To address the issue of assessing health care information systems, we developed a requirements engineering framework. The framework consists of a methodology, a requirements language and a tool that can support both the language and the methodology. Although there are a number of requirements languages and tools to choose from, we have focused our work on the User Requirements Notation (URN) language as supported by the jUCMNav tool. URN is the only requirements language that has been standardized by a standards body (International Telecommunications Union). The methodology is being discussed in detail from the section 3.3. to 3.8 using examples depicted in URN using the jUCMNav tool. Our case study in Chapter 4, provides a complete URN-based example. We evaluate both the strengths and weaknesses of URN in chapter 5.

Figure 3 depicts the conceptual structure of our framework as mapped to the sections in chapter 3.

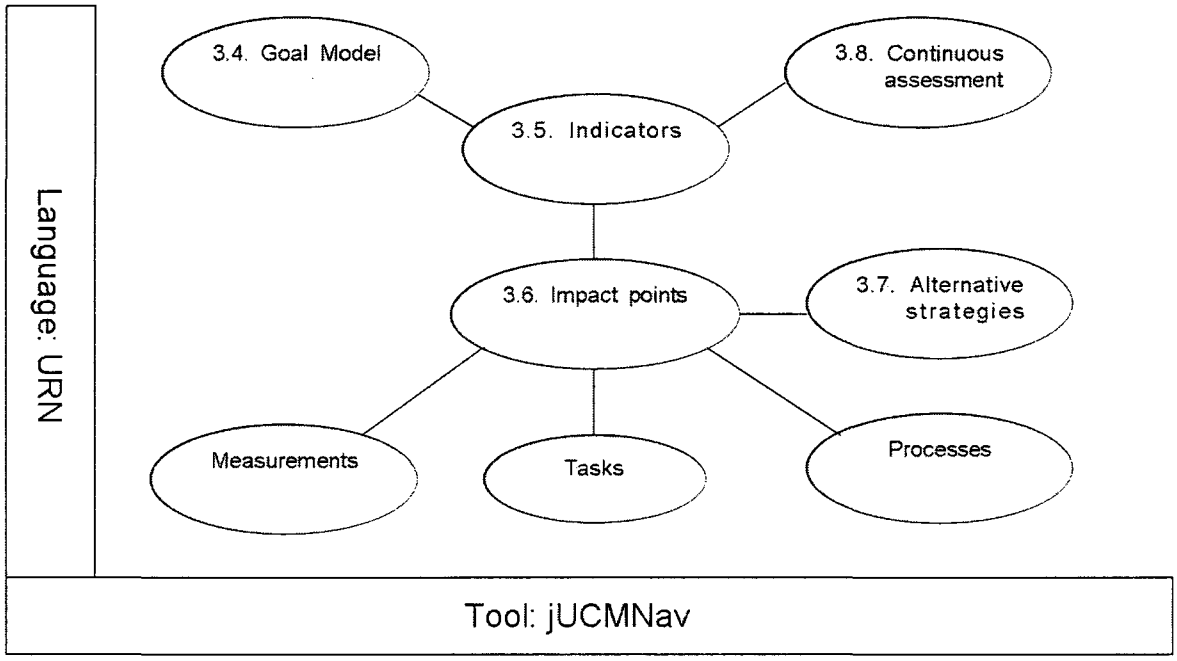

Figure 3 – The Structure of Requirement Engineering Framework

The methodology in our proposed framework contains the following elements and principles:

1. Goal model: a graphical notation that models the "why" aspect in terms of objectives, alternatives as well as decision rationales without much operational details.
2. Indicators: a measure of performance that can be linked to goals and used to evaluate how successfully the goal is fulfilled.
3. Impact points: the actual tasks, processes and specific measurements where the impact of the HCIS can be seen and measured and linked to goal models.
4. Alternative strategies: With impact points, we analyze and compare alternative strategies in terms of the way tasks and processes and

measurements are defined and implemented in order to compare different approaches to satisfying goals, often with different technologies.

5. Continuous assessment: how to manage and maintain the framework continuously after implementation.

3.4. Goal Model

A goal is a high level objective of the business, organization or system. Usually, there are two types of goals: one type is functional goals, which describe the functions a system should perform and have well-defined criteria that the system should satisfy; the second type is non-functional goals, which are hard to define and describe the system's quality and reliability. When a system is being built, the first thing to consider is to gather goals of the system. They can be conveyed by stakeholders, disclosed in requirements documents, gathered through the analysis of similar or current systems and elaborated from other goals. Identifying and managing goals is an integrated part in a method.

A goal model is a hierarchy structure of goals, connecting tasks and actors to business objectives and showing relationships among goals. It is used in early requirement engineering to identify problems and explore alternative strategies and solutions. Not all goals need be satisfied. Some goals in a goal model can be unsatisfied, which might help identify problems in design activities and provide criteria for evaluation. And sometimes, a goal model help indentify problems related to business structures, processes and their supporting systems [Kavakli05].

Building a goal model is the first step in our methodology. It plays an essential role in achieving the aims of the approach. We gather requirements of multiple

stakeholders involved in a health care information system. In the goal model, we give rationale for requirements and guide requirement elaboration. Through a graphic notation for the goal model, we can clearly see the goal relationships among all stakeholders, how goals and their sub soft goals contribute or impact each other. Based on the goal model, the later analysis of alternative strategies is going to show positive or negative influence among goals.

3.5. Indicators

Key Performance Indicators (KPIs) measure what is being achieved in business processes. They are typically the key values that an organization uses to measure how effective their business strategy is. A KPI can follow the **SMART** criteria, which means, Specific, Measurable, Attainable, Realistic and Time-sensitive [Shahin06].

In our goal model, we can represent KPIs as indicators and link them to the goals in order to relate these measurements to goals the organization is trying to achieve. In URN, "KPI evaluation and mapping to GRL initial evaluation levels is done through four value sets associated to each KPI: Target Value, Threshold Value, Worst Value and Evaluation Value. Target Value is the expected performance of the process under evaluation. Threshold Value is used to separate acceptable from unacceptable values, while Worst Value is used to specify the most serious condition from a users' perspective. These three values are adjustable as required. The Evaluation Value is the KPI's actual value retrieved from back-end business data sources at run-time or defined by users for test purposes at design time" [Roy06].

In our methodology, we try to identify at least one indicator for each goal. All low-level or leaf goals from our goal hierarchy must have indicators; we specify indicators for each goal of each stake holder. Indicators can be identified and specified when we are trying to find the critical factor(s) for each stakeholder to achieve his objective(s). We are using indicators to measure how successful the linked goal is achieved. Softgoals that are qualitative or non quantitative can also have indicators associated with them. For example, we can measure patient satisfactions by conducting a survey. The introduction of indicators makes our approach quantifiable and become complementary to other approaches.

3.6. Impact Points

Impact points in our approach include tasks and business processes that have impacts on goals in the goal model as well as measurements (the mechanisms by which indicators are collected for a goal).

A task is a solution to achieve goals and/or satisfy softgoals. A business process includes activities or tasks that result in a specific service for customers. We are using Use Case Maps (UCM) to represent how tasks or processes are involved in achieving associated goals. This is a scenario-based approach, which focuses on answering "what" questions. Measurements are a description of annotation for each indicator to indicate how they are calculated.

UCM combines goals and scenario for expressing and reasoning about functional and non-functional requirements. From the graphic scenario notation, we can easily see the relation between organizational goals and business processes/tasks, and make

comparison on different health care information systems through their impacts on the same goals.

3.7. Alternative Strategies

Strategies in our proposed framework represent different information technologies used in the HCIS, such as the adhoc system and PAL-IS. With different technologies, there could have totally different implementations related to a same task. For example, to collect patients' pain scores, nurses usually call or physically visit patients in the adhoc system; however, in the PAL-IS, patients would enter their pain scores into the system by themselves. In our framework, with GRL strategy, we evaluate alternative technologies by showing how they impact organization goals.

GRL strategy is a numerical interpretation of satisfaction levels by applying initial assessment values that are propagated to the rest of the model. It evaluates the impact of strategies on the operational and architectural aspects, using URN links, and allows comparing the results of intentional element evaluations. When comparing the adhoc system to PAL-IS, we give the initial assessment values to tasks, like "nurses collect pain scores" or "patients entry". The values are the subjectively expected impact of those tasks. By using the Scenario and Strategies view, GRL strategy will automatically calculate the predicted values for organization goals that are associated with those tasks.

GRL strategy provides us a quantifiable way to assess different health care information systems in our framework.

3.8. Continuous assessment

Our methodology includes the process of continuous assessment. The validation of the models, including indicators, impact points and alternative strategies, is not a onetime event. Continuous assessment is a means of ongoing evaluation.

There are two types of continuous assessment. One is to check the actual impacts after implementation and to identify the gap between predicted impacts and actual impacts. In our analysis of alternative strategies, we predicted what the expected impacts should be. The actual impacts should be evaluated continuously. The second type of continuous assessment is to manage GRL models as changes occur, such as organization objectives or business processes change. This kind of continuous assessment involves a cycle of evaluation, correction, and validation.

Health care is a complex system which not only involves many departments but also the needs of patients must be considered. Patient's needs or the organizational goals may change and, the framework for assessing different health care information systems should correspond to such changes properly and support those changes in a relatively long term. Continuous assessment gives organizations a good chance to see what and how they are doing and is a powerful tool to fill the gap between predicted results and actual results.

3.9. Summary

In this chapter, we presented the framework we proposed for assessing health care information systems. The framework includes our design based methodology, the existing requirement engineering language URN and tool jUCMNav. The methodology

consists of goal model, key performance indicator, impact points, alternative strategies and continuous assessment.

In chapter 4, we will apply our methodology to a case study to illustrate how the framework can be used to assess health care information systems. And in chapter 5, we are going to evaluate the framework based on our case study and compare it to other approaches.

Chapter 4. Case Study

In this chapter, we illustrate how to apply the framework developed in the previous chapter through a case study of an HCIS to support palliative care called Palliative Care Information System (PAL-IS). PAL-IS is an ideal example of a HCIS with multiple health care providers as users. The primary goal of PAL-IS is quality of health care delivery and adherence to accreditation standards instead of cost or user adoption.

After a brief introduction of the case study, we first define the goal model for the case of palliative care with GRL and indentify the indicators for each goal. Next, we set up the links between goals and impact points that are relevant business processes. Then, we use a model-based approach to analyze alternative strategies. Finally, we discuss continuous assessment.

4.1. Overview

4.1.1 Background of Case Study

The aim of the Champlain Local Health Information Network (LHIN) is to coordinate and fund health services in the health sectors among hospital, community care access centre, addictions and mental health agencies, community support services, community health centers, and long-term homes in the greater Ottawa region in Ontario, Canada. The LHIN does not provide services directly but ensures the services are well organized, appropriately funded and meet the needs of residents of all ages [LHIN09].

Palliative care, a priority service of the LHIN, is the care provided to patients at end of life when curative therapies are not an option. Palliative care is an ideal domain to study team based care delivery across multiple settings as that is an integral part of palliative care delivery [Davis89].

One problem relevant to palliative care is, in spite of current available information technology, the patient's information is still largely collected, exchanged and shared in an ad-hoc basis, by paper-based forms, faxes and phone calls. The ad-hoc based system is not efficient or effective. Not only can patients not get timely health care services but health care providers have a hard time getting complete patient information for them to make decisions about care provision. Furthermore, the ad-hoc based system is hard to provide timely operational information for the LHIN management sector to evaluate organization performance. Organizational performance is currently evaluated after the fact, which makes it difficult to address deficiencies in a timely manner.

The other problem is a lack of "coordinated, regional system of services with the ability to communicate patient information" [EUROPA09]. This causes the waste of precious health resources and care is provided with difficult mechanisms among providers. Integration becomes one "key goal of the Champlain LHIN." [GC09].

To address the problem, the Champlain LHIN launched a project called Aging at Home to better coordinate and provide services to patients at home. One of the aging at Home initiatives is a Palliative Care Information System (PAL-IS), which involves the development and implementation of an information system to facilitate communication among health service providers and across sectors and to support access to palliative care

services. The Champlain PAL-IS will provide the foundation for a regional palliative care system to enable accountability through communication and access to accurate information regardless of geographical location [PAL-IS08].

The intent is that PAL-IS will facilitate sharing of patient information among healthcare providers such as doctors, nurses and case managers as well as support the underlying processes of care delivery such as decision making and treatment dissemination. This goal for PAL-IS is consistent with the overall goal of palliative care, which is to improve the quality of life for patients who have life-threatening illness and their families and to provide equitable health care services based on patients' needs. Improving patients' access to healthcare services and delivery of healthcare services from providers are also important goals for PAL-IS. Technically, PAL-IS should ensure communication between patients and healthcare providers is efficient and timely. PAL-IS should also support and ensure patients can get timely access to their healthcare providers (i.e. nurses or physicians) whether at home or in other care facilities. Healthcare providers also need to be able to respond to patient's needs quickly. If care issues can be identified and managed efficiently then patient hospital stays can be shortened or avoided.

In this chapter, we are applying the framework developed in Chapter 3 to assess PAL-IS and validate and document the impact of PAL-IS on organizational goals. PAL-IS should improve the delivery of health care services over the existing adhoc system. Our framework will ensure that we have a systematic approach to measuring and verifying that impact.

4.1.2 Current HCIS Assessment Approaches

As discussed in section 2.2, current existing HCIS assessment approaches include business performance management, benefit-cost analysis and technology adoption assessment.

Business performance management (BPM) is an approach that first defines organizational strategies and then develops KPIs to measure and manage the performance of business processes in terms of the strategy. BPM can identify KPIs that the LHIN want to improve, which is useful. But we can not make judgment on which KPIs are useful or good to organization goals since there is no direct link between KPIs and goals, not to mention the link between KPIs and tasks or processes. In our case study, most of the KPIs used for business performance management by the LHIN, were also used as indicators. Our framework in some ways can be seen as an extension of BPM which uses integration of RE models for goals and processes with KPIs to give a more complete picture for assessment of HCIS.

Cost-benefit analysis (CBA) is a way to assess a proposal or a project weighing the total expected costs over the total expected benefits from the financial point of view. Although costs were a concern for the LHIN, financial benefits were not a significant motivation for the acquisition of an HCIS, and as such there were no real financial indicators the LHIN relevant to the case study. CBA could tell LHIN the cost of acquiring and implementing the PAL-IS. It could also give some indication of potential savings in that with PAL-IS, one might estimate that case workers could manage more cases, and one might estimate that fewer phycial visits might be required by nurses which

results in reducing costs. But those benefits were not a focus, and they were not needed to make PAL-IS worthwhile. Quality of care was the main objective in considering PAL-IS. Since even without these benefits, PAL-IS will help LHIN achieve the goal of delivering health care across multiple settings.

Technology adoption assessment (TAA) is used to evaluate systems based on usability and user acceptance. It can be conducted as the project is going along. In our case study, though, this was not a major focus since the LHIN assumed that web-based portal technology was familiar to the general population and would be readily used by patients and health care providers. Again, as a result, there were no indicators related to technology adoption that were relevant to our case study when it was discussed with the LHIN.

4.1.3 Proposed Framework for Assessing PAL-IS

In our case study, we followed the methodology described in Chapter 3 by applying the User Requirement Notation, supported by the jUCMNav tool, to model goals and business processes and quantify the impact of HCIS on organization goals.

With the framework, we were able to graphically model and quantify the impacts of health care information systems on organizational goals, assess the impact of underlying business processes on goals, compare alternative technology choices and make continuous assessment as well.

In the following sections, from 4.2 to 4.6, we apply the methodology proposed in the chapter 3 into our case study. We build the goal model by using GRL, indentify

indicators for each goal in the goal model, discuss impact points on goals in term of measurements, tasks and processes, compare alternative technology strategies, and make continuous assessment.

4.2. Goal Model

In this part, we will define the goal model for the palliative care case with GRL, and explain the relations among the goals and the measurements for each goal.

4.2.1 Modeling of Goals

The goal model for Palliative Care is described as a GRL model in figure 4. Note, although the goal model is developed based on the PAL-IS, the goal model is independent of PAL-IS. It is intended to apply to general palliative care no matter what business processes are underlying.

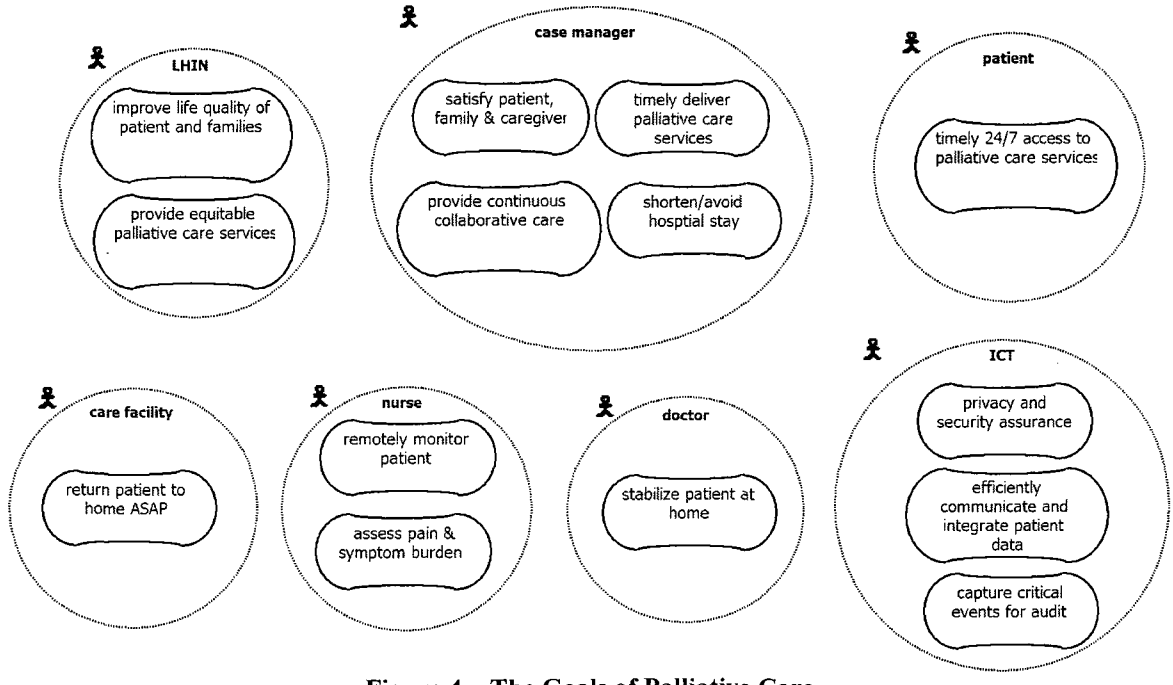

Figure 4 – The Goals of Palliative Care

In the above goal model, there are seven actors indicated: LHIN, case manager, patient, care facility, nurse, doctor and ICT. Because the LHIN "plans, coordinates and funds health services", we say, all goals belongs to LHIN. But each independent actor owns some goal(s) in the model.

The LHIN owns the two goals, "improve life quality of patient and families" and "provide equitable palliative care services".

As the primary coordinator in the case of palliative care, Case Manager owns the following goals: "timely deliver palliative care services", "shorten/avoid hospital stay", "satisfy family and caregiver", and "provide continuous collaborative care".

The receiver of palliative care, Patient, has only one goal, that is, "timely 24/7 access to palliative care services".

The palliative care team members each have their own goals. Care Facility has only one goal, "return patient to home ASAP"; Nurse has the goals of "remotely monitor patient" and "assess pain & symptom burden"; Doctor's goal is to "stabilize patient at home".

ICT owns three goals, "privacy and security assurance", "efficiently communicate and integrate patient data" and "capture critical events for audit". In practice, reliability and availability of ICT might be an issue; but they were not considered important by stakeholders in the case study because they could always fall back to adhoc system.

4.2.2 Goals Relation

The goals in Figure 4 are not completely independent; they affect, depend on or contribute to each other.

The relations among actors in the palliative care goal model are depicted in Figures 5 and 6.

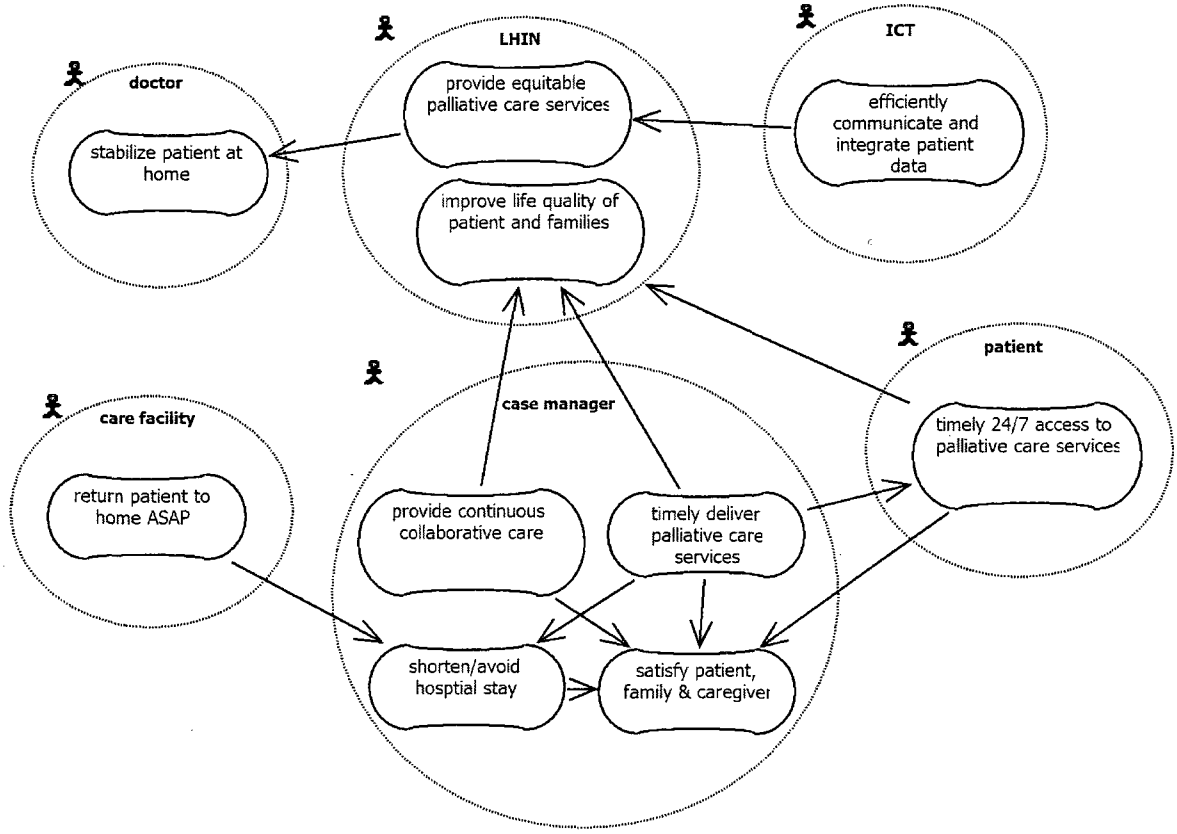

Figure 5 – The Goal Relation among Doctor, LHIN, ICT, Care Facility, Case Manager and Patient

In the relations among Doctor, LHIN, ICT, Care Facility, Case Manager and Patinet(Figure 5), ICT's "efficiently communicate and integrate patient data" goal contributes to the LHIN's "provide equitable palliative care services" goal, which

contributes to Doctor's "stabilize patient at home" goal. Three goals contribute the LHIN's "improve life quality of patient and families" goal; they are two goals owned by Case Manager, "provide continuous collaborative care" and "timely deliver palliative care services", and patient's only goal "timely 24/7 access to palliative care services". The relation between Patient and Case Manager is Case manager's "timely deliver palliative care services" contributing Patient's "timely 24/7 access to palliative care services", which contributes Case Manger's "satisfy patient, family & caregiver". The relation between Care Facility and Case Manager is "return patient to home ASAP" contributing "shorten/avoid hospital stay". The relations owned by Case Manager are also affecting each other. For example, "time deliver palliative care services" contributes two other goals "satisfy patient, family & caregiver" and "shorten/avoid hospital stay". And both "provide continuous collaborative care" and "shorten/avoid hospital stay" are contributing "satisfy patient, family & caregiver".

Figure 6 shows the relations among Doctor, Nurse, ICT and Case Manager. Case Manager is the coordinator among all actors and the bridge in the goal model.

The relations among Doctor, Nurse and Case Manger are as follows. Nurse's "assess pain & symptom burden" provides help to Doctor's only goal, "stabilize patient at home", which contributes Case Manager's "shorten/avoid hospital stay". And Nurse's "remotely monitor patient" contributes Case Manager's "timely deliver palliative care services".

Between the nurse and ICT, both the Nurse's "remotely monitor patient" goal and ICT's "efficiently communicate and integrate patient data" goal depend on ICT's

"privacy and security assurance" goal. Further the ICT's "capture critical events for audit" goal contributes to three other goals, its own "privacy and security assurance", and the nurse's two goals.

Between the case manager and ICT, ICT's "privacy and security assurance" goal contributes to the case manager's "timely deliver palliative care services" goal. Both of the ICT's "capture critical events for audit" and "efficiently integrate patient data" goals contribute to the case manager's "provide continuous collaborative care" goal.

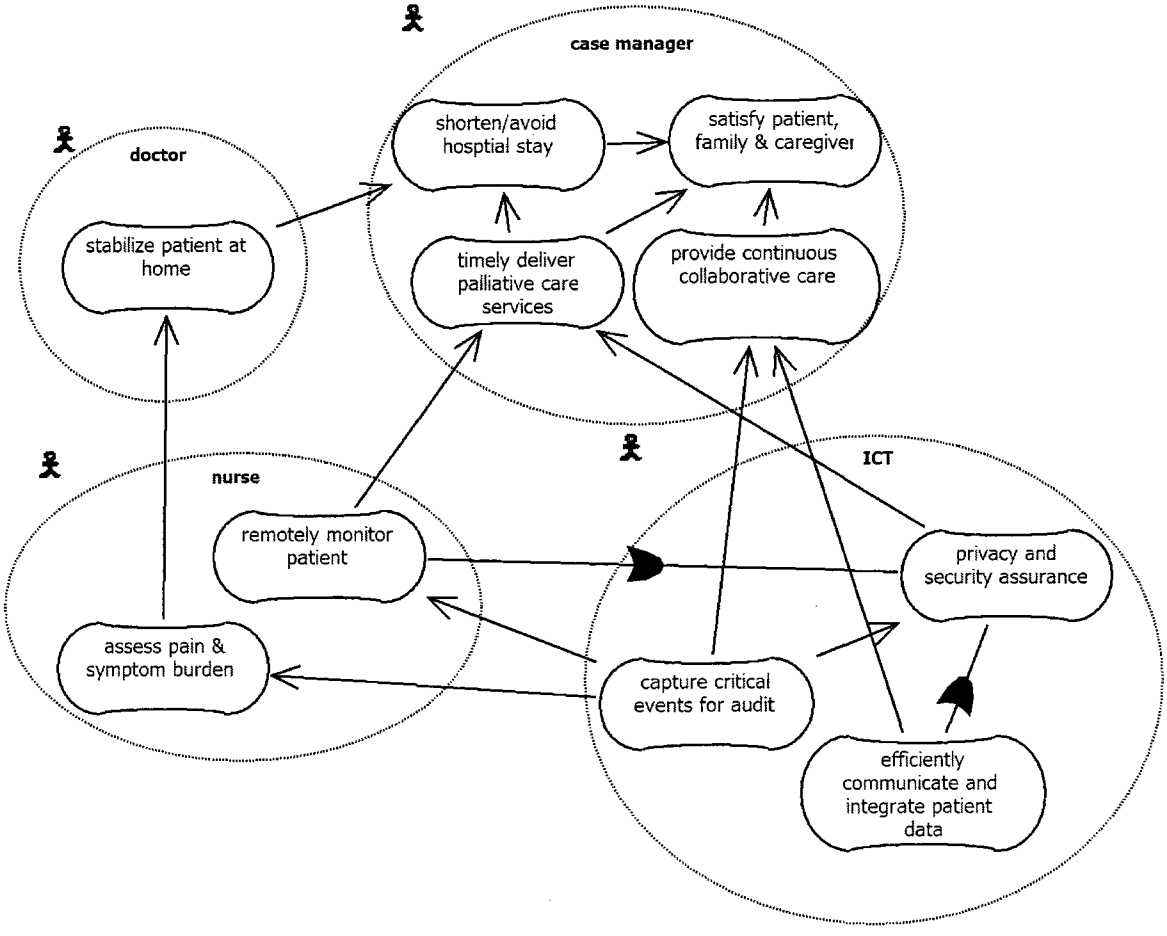

Figure 6 – The Goal Relation among Doctor, Nurse, ICT and Case Manger

4.3. Indicators

Key Performance Indicator (KPI) provides a way to model and monitor how well business processes meet goals.

The following figures depict the indicators for each goal to measure how well they are met. Figure 7 includes the indicators for the goals of LHIN, Care Facility, Case Manager, and Patient; and figure 8 includes the indicators for the goals of Doctor, Nurse and ICT.

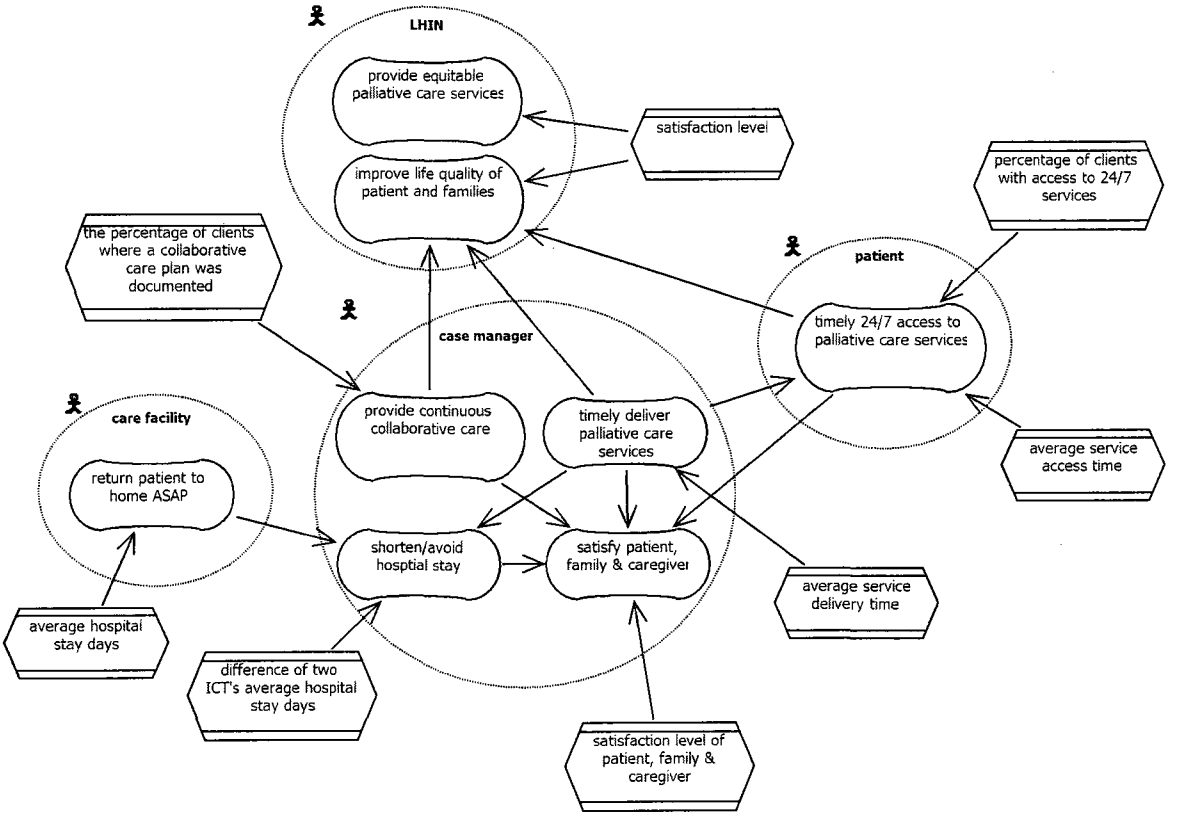

Figure 7 – Indicators for the Goals of LHIN, Care Facility, Case Manager, and Patient

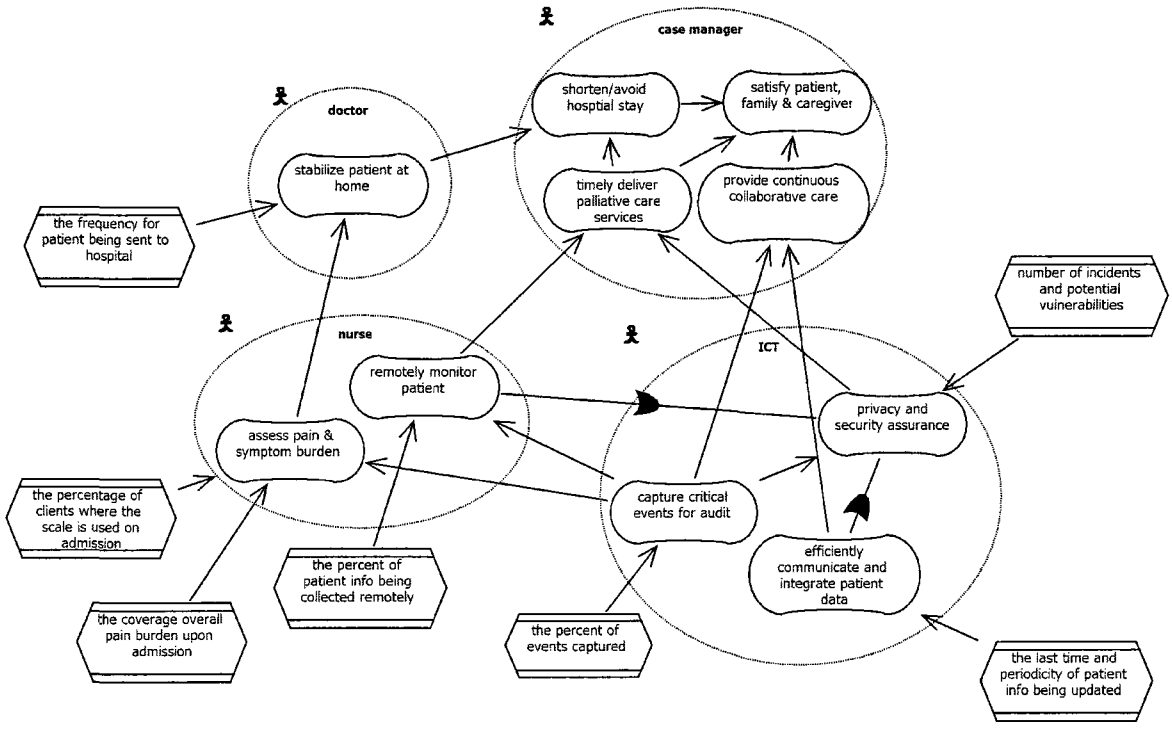

Figure 8 – Indicators for the Goals of Doctor, Nurse and ICT

Most of indicators come from the document of *Service Plan Submission for the Champlain LHIN's Aging at Home Project* [PAL-IS08], Champlain District End-of-Life Care Service Delivery Model Report [Champlain05] and CCHSA's Core Set of Performance Measures to Support the Accreditation of Hospice Palliative and End-of-Life Care (HP/EOLC) [AC]. Others come from the common knowledge in practice, for example, we set "satisfaction level" as the indicator for the LHIN's "provide equitable palliative care services" and "improve life quality of patient and families" goals, since it is a very common metric for assessment of service delivery like "provide equitable palliative care services" and "improve life quality of patient and families".

We now explain all indicators in detail, which are grouped by goals. Under each goal, we also include the possible related tasks or processes to show how we can get the values of those indicators.

The values of most indicators can be obtained directly or automatically from a calculation with the help of current advanced software technologies, such as "percentage of clients with access to 24/7 services" and "average service access time". However, some values like "satisfaction level" are still gotten from the survey conducted manually. Depended on the satisfaction level of what kind of goals to be measured, the contents of surveys can be designed to tailor the measurement needs. How to design surveys is out of the thesis scope.

1. ***Improve life quality of patient and families***

   - Owned by LHIN

   - The goal looks at the satisfaction level by collecting survey data among the patient and families who are receiving palliative care

   - Defined as the percentage of clients (patients and their families) who choose satisfied in the survey

   - Input data: the satisfaction levels include strongly satisfied, satisfied, some satisfied, some unsatisfied, unsatisfied, strongly unsatisfied (evaluation way: do the satisfaction survey once a month; and the date when survey is done.)

2. ***Provide equitable palliative care services***

- Owned by LHIN

- The goal looks at the satisfaction level by collecting survey among the patient and families who are receiving palliative care

- Defined as the percentage of clients who choose satisfied in the survey

- Input data: the satisfaction levels include strongly satisfied, satisfied, some satisfied, some unsatisfied, unsatisfied, strongly unsatisfied (evaluation approach: do the satisfaction survey once a month); and the date when survey is done.

3. ***Timely deliver palliative care services***

- Owned by Case Manager

- Defined as the average hours for a patient's request to be fulfilled

- Input data: amount of hours (evaluation way: for pain management, we define the hour from a patient sends out pain alert to he/she receives modified description as service delivery time. We collect this number once a month, and get the average service delivery time; we also record the date when the assessment is done.)

- Related process/task: ICT generate pain report; nurse sends pain alert; doctor modify prescription; ICT send updated prescription back to patient.

4. Timely 24/7 access to palliative care services

- Owned by Patient

- Defined as the percentage of clients with access to services 24 hours a day, seven days a week. For organizations not currently providing 24/7 access, access is measured as the per cent availability of services to clients (i.e. number of hours per week) [AC].

- Defined as the average hours for patient's request to be fulfilled

- Input data: the number of clients with access to 24/7 services, the total number of clients receiving palliative care services, amount of hours (evaluation way: (1) Collect the number of clients with access to 24/7 services and the number of clients receiving palliative care services; (2) for pain management, we define the hour from a patient sends out pain alert to he/she receive modified description as service access time. We collect this number over once a month, and get the average service access time; we also record the date when the assessment is done.)

- Related process/task: Access to ICT 24/7; patient enters pain score; pain alert raise; patient receives updated prescription.

5. Return patient to home ASAP

- Owned by Care Facility

- Defined as the average hospital stay day for patient stay in hospital to get recovered or get better

- Input data: the date on admission, the date being discharged (evaluation way: Count the days from the date when a patient on admission to the date when the patient being discharged. We collect the number once a month, and get the average hospital stay; we also record the date when the assessment is done.)

- Related process/task: Stabilize patient; integrate patient's data; discharge patient.

6. Shorten/avoid hospital stay

- Owned by Case Manager

- Defined as the difference of average hospital stay day for patient in two ICT systems

- Input data: the average hospital stay days in two ICT systems being compared (evaluation way: get average hospital stay days once a month in two ICT systems, and compare the difference; and also record the assessment date.)

• Related process/task: monitor patient remotely; stabilize patient at home; organize proper health care team.

7. Provide continuous collaborative care

• Owned by Case Manager

• Defined as the percentage of clients where a collaborative care plan was documented [AC].

• Input data: client amount (Evaluation way: Once a month, count the amount of clients whose collaborative care plans are document; and also record the assessment date.)

• Related process/task (underlying business processes): create and review and update collaborative care plan.

8. Satisfy patient, family and caregiver

• Owned by Case Manager

• Defined as the percentage of clients who choose satisfied in the survey

• Input data: the satisfaction levels include strong satisfied, satisfied, some satisfied, some unsatisfied, unsatisfied, strong unsatisfied (evaluation way: once a month, collect data by using the FAMCARE tool which looks at

satisfaction in a number of areas, e.g. availability of information [AC]; and also record the assessment date.)

9. Remotely monitor patient

- Owned by Nurse

- The measure is to evaluate if an ICT can remotely monitor patient properly.

- Defined as the percent of patient info (e.g., pain score) being collected remotely through ICT over a period of time

- Input data: times of pain scores being entered into ICT (evaluation way: patient enters pain score periodically; count the total amount of pain scores being collected by ICT over a month; get the percent of collected pain score by dividing the amount of pain scores that should be collected; and record the assessment date.)

- Related process/task: patient enters pain score; ICT generates pain report.

10. Assess pain and symptom burden

- Owned by Nurse

- Measured using the Edmonton Symptom Assessment Scale for its ability to explore multiple symptoms as well as quality of life [AC].

• Defined as the percentage of clients where the scale is used on admission; and, the coverage overall pain burden upon admission [AC].

• Input data: the number of clients on admission when the scale is being used or the number of clients on admission when the scale is not being used. (Evaluation way: measure patient's pain and symptom burden on admission; once a month count the number of clients being measured with such Scale; calculate the percent of clients done in 24 hours.)

11. Stabilize patient at home

• Owned by Doctor

• Defined as the frequency for patient being sent to care facility.

• Input data: the number of times that patient is being sent to a care facility in a month. (Evaluation way: Count the times for a patient who is not controlled through palliative care system and being sent to hospital in one month; and record the assessment date.)

• Related process/task (underlying business processes): based on the pain score reports or pain alert, doctor updates patient's description and help patient's pain being controlled.

12. Efficiently communicate and integrate patient data

• Owned by ICT

• Defined as how soon and how complete patient's info is being collected by ICT from different actors.

• Input data: the average time (e.g., days) for patient's info being transferred to ICT from external sources; the percent of patient's info being transferred to ICT in a month (Evaluation way: once a month, count the average days for patient's info being transferred from external to ICT; and record the assessment date.)

• Related process/task (underlying business processes): actors update patient info through ICT.

13. Privacy and Security assurance

• Owned by ICT

• Defined as number of incidents and potential vulnerabilities.

• Input data: times of incidents occurred in a month; the assessment date

• Related process/task: count the times of privacy and security related incidents occurred in a month.

14. Capture critical events for audit

• Owned by ICT

- Defined as number of critical events being captured, such as patients' failure to input data into ICT.

- Input data: the amount of events that are captured in a month; the assessment date.

- Related process/task: events are inserted into log table for trace.

4.4. Impact Points

In this section, we are going to discuss relevant business processes in palliative care using use case maps (UCM).

4.4.1 Scenario

We use UCM to model the scenario of pain management, which is one of the key business processes in the Palliative Care. We also link the processes to one or more goals in GRL model from the section 4.2, to show the relation between organizational goals and business processes.

The following is the scenario of pain management in PAL-IS.

A cancer patient is on two medications for his pain. A homecare nurse and a physician are monitoring the patient's symptoms through PAL-IS. One of the patient's daily jobs is to send his pain score to the nurse through PAL-IS. Pain scores range from 0-10 with zero being no pain and ten being the worst pain imaginable. There are four pain alerts with different priorities in the system, depending on the pain scores the patient sent. If the patient enters a low number for the pain score, the alert is set at a low priority. The

number will be recorded and the nurse will simply continue monitoring. But if the patient enters a high number (8, 9 or 10) for the pain score indicating severe pain, the alert would be set as a high priority and the nurse would contact the physician for appropriate action such as getting an updated prescription. Once a new prescription is issued, the nurse will send it to the patient.

Figure 9 depicts the sequencing tasks (sub-processes) involved in the scenario. They include: pain score collection, pain report generation, pain report sending (with low priority alert or high priority alert), and pain report analysis. The final output is either a changed prescription for pain control or no change. It represents the high-level painReport generation and painAlert sending process, which both the current paper-based system and PAL-IS are following.

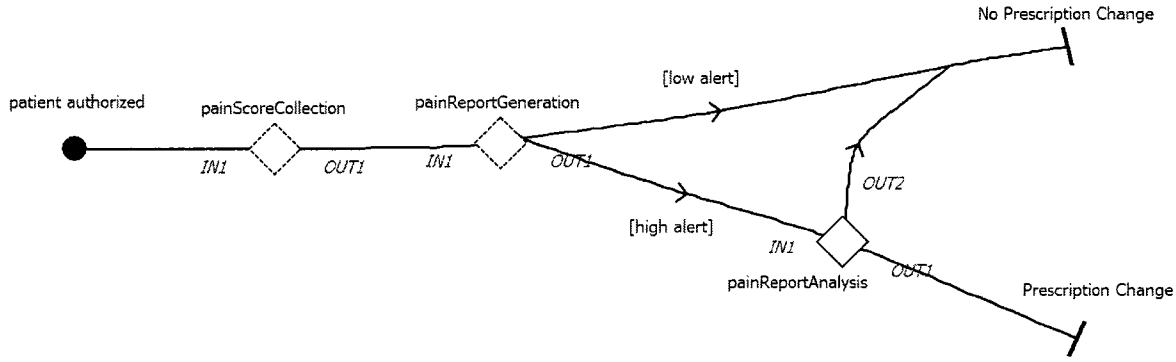

Figure 9 – High-level PainReport Generation and PainAlert Sending Processes

The dynamic stubs in Figure 9 offer alternative approaches for the same task. For example, for the stub of painScoreCollection, with PAL-IS, it is a patient who enters his pain score to a nurse through the information system; but for the same stub, without PAL-IS, it is the nurse who records the patient's pain score manually and periodically and must visit the patient in person, or contact them over the phone.

For the stub of painReportGeneration, with PAL-IS, the information system will generate the patient's pain report automatically based on the pain scores the patient enters and send out the pain alert with different priorities; without PAL-IS, with the paper based records, the nurse is responsible for analyzing the pain scores, generating a pain score report and making a judgment if a pain alert is a low priority or a high one. The nurse is also the person to send the pain alert to the corresponding doctor, again by making a phone call or faxing a paper-based document.

Figure 10 shows the details of the painReport generation and painAlert sending processes in PAL-IS, in which the involved parties (patient, PAL-IS, nurse and doctor) are associated with corresponding tasks.

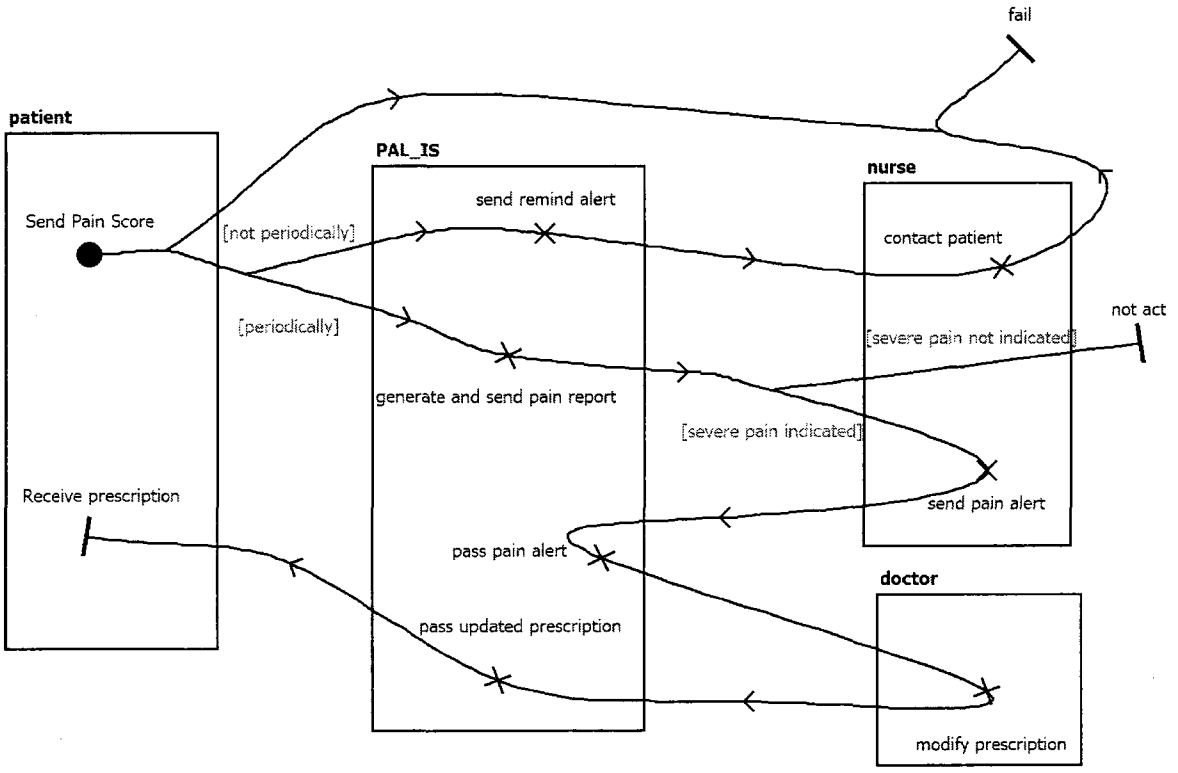

Figure 10 – PainReport Generation and PainAlert Sending Processes in PAL-IS

The above figure depicts the following scenarios: Patient stable at home & enter pain score periodically; Patient stable at home & forget to enter pain score from time to time; nurse and physician address the issue.

For comparison, Figure 11 depicts the details of current painReport generation and painAlert sending processes without PAL-IS system.

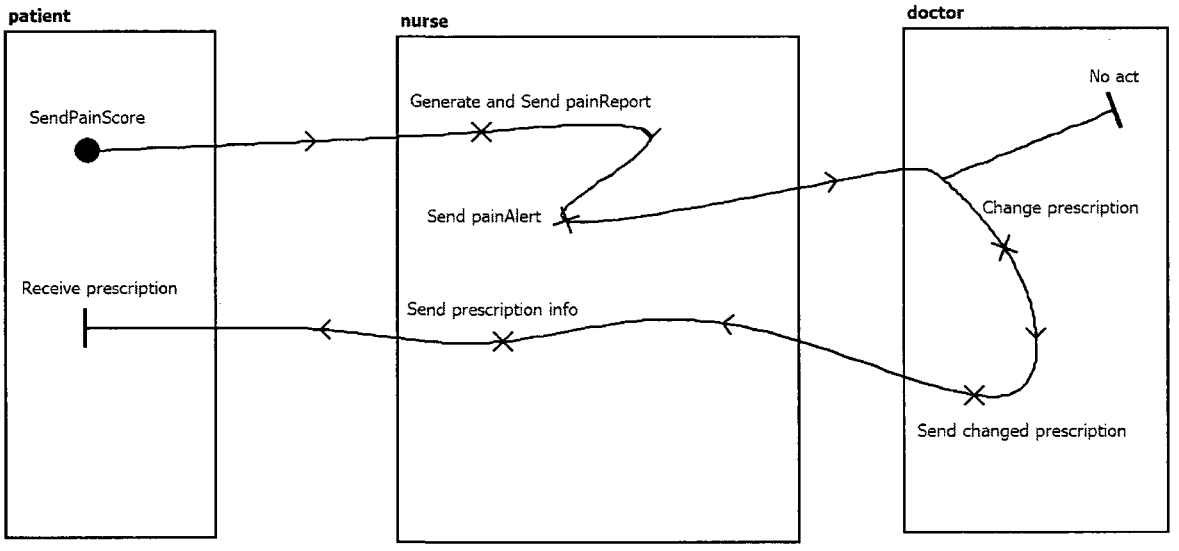

Figure 11 – PainReport Generation and PainAlert Sending Processes without PAL-IS

In the above manual process, there are a few measurements to make sure the patient is properly taken care of:

• The nurse should talk to the patient and take his/her pain score at least once every 8 hours.

• The nurse should analyze the patient's pain scores and update his/her pain score report at least once every 8 hours.

• Once a pain alert with a high priority is issued, the patient should receive his/her changed prescription within one hour.

All the steps are manual and time-consuming, especially for the nurse to analyze pain scores and generate a pain score report.

The process sharing healthcare data through PAL-IS is completely electronic. Also, there are some measurements to improve care, which are different from those in the manual process:

• To use PAL-IS, all users need to be identified for security purposes.

• The patient should enter a pain score at least once every 4 hours.

• If the information system did not receive the patient's two consecutive pain scores, a low priority alert would be raised and sent to the nurse. The nurse should contact the patient immediately by phone.

• If the patient entered a pain score greater than 7/10, a pain alert should be issued immediately from the information system to the nurse and then to the doctor. The patient should receive the changed prescription within one hour.

4.4.2 Associating the Processes with Goals

In this section, we depict how business processes affect goals based on the scenario of a patient who is stabilized at home with pain scores to be recorded periodically. First, we list the related tasks, with and without PAL-IS. And then, we compare their impacts on organization goals.

To be noted, not all goals in the goal model might be impacted in one single process. For those goals not being impacted, we set not applicable. For those goals being impacted, we define four levels: dissatisfied, partially satisfied, satisfied and undecided. Dissatisfied means a process impacts a goal negatively; satisfied means a process impacts a goal positively; and partially satisfied means a process might help a goal be fulfilled. Undecided means it is hard to predict how a process impacts a goal. We set these levels by borrowing the criteria of the goal evaluations [Amyot03] in GRL. The purpose of defining these levels is to show the different impacts of processes with and without PAL-IS on organization goals.

Scenario: Patient is stabilized at home and pain scores are recorded periodically.

- Related tasks without PAL-IS:

(1) Patient takes medicine as prescribed;

(2) Nurse visits patient physically or nurse calls patient to collect pain score;

(3) Nurse sends pain score to case manager by fax or phone;

(4) Case manager generates pain report and updates collaborative care plan;

(5) Case manager sends the report of collaborative care plan to LHIN.

- Related tasks with PAL-IS:

(1) Patient takes medicine as prescribed;

(2) Patient enters pain score periodically;

(3) Nurse monitors patient remotely;

(4) PAL-IS generates pain reports periodically and send to case manager;

(5) Case manager updates collaborative care plan and sends the report of collaborative care plan to LHIN.

From the above lists of related tasks, we can see PAL-IS saves time for nurses and the case manager. A nurse can focus on monitoring patient remotely instead of physically visiting or phoning patients. And with the help of PAL-IS, the case manager can focus more on care facilitation and delivery instead of generating pain reports and updating collaborative care plans from paper documents.

In Table 1, we compare how the processes, with and without PAL-IS, impact organization goals.

Table 1 – Comparison of Goal Satisfaction without and with PAL-IS

Goals	without PAL-IS	with PAL-IS
Improve life quality of patient and families	Partially satisfied.	Satisfied.
Timely deliver palliative care services	Dissatisfied.	Satisfied.
Timely 24/7 access to palliative care services	Dissatisfied.	Satisfied.
Return patient to home ASAP	Not applicable.	Not applicable.
Shorten/avoid hospital stay	Partially satisfied.	Satisfied.
Provide continuous collaborative care	Dissatisfied.	Satisfied.
Satisfy patient, family and caregiver	Partially satisfied.	Satisfied.
Remotely monitor patient	Dissatisfied.	Satisfied.
Assess pain and symptom burden	Satisfied.	Satisfied
Stabilize patient at home	Partially satisfied.	Satisfied.
Efficiently communicate and integrate patient data	Dissatisfied.	Satisfied.
Privacy and Security assurance	Undecided.	Partially satisfied.
Capture critical events for audit	Dissatisfied.	Satisfied
Provide equitable palliative care services	Undecided.	Satisfied.

We say, without PAL-IS, the goals of "improve life quality of patient and families" and "satisfy patient, family and caregiver" are partially satisfied since not matter how low the efficiency of the service delivery is, the whole care provider team is

dedicated to providing health care to patients as fast as possible to improve their life quality. With the help of PAL-IS, patients can get more efficient health care service and their life quality can be truly improved. The impacts on the two goals are satisfied.

In the case without PAL-IS, all tasks involved are manually done and time-consuming, such as the nurse visits patient physically or calls the patient to collect pain score, and then sends pain score to case manager by fax or phone; and the case manager generates a pain report and updates the collaborative care plan. So, we set the impact of the process on the "timely deliver palliative care services" goal as dissatisfied. On the other hand, with PAL-IS, we set the impact as satisfied. Since, with PAL-IS, most paper document jobs are done automatically and all actors focus on delivering care services, the efficiency is improved. This is the major function of PAL-IS in palliative care.

For the same reason as above, in the scenario, the goals of "timely 24/7 access to palliative care services", "provide continuous collaborative care", "remotely monitor patient", and "efficiently communicate and integrate patient data" are dissatisfied without PAL-IS and are satisfied with PAL-IS.

In the above case, since the patient stabilized at home without actually going to the hospital, the "return patient to home ASAP" is not impacted. We set the impact on the goal as not applicable, with and without PAL-IS.

However, in the scenario without PAL-IS, the service delivery time is long due to manual and time-consuming processes and thus it has the potential for patients to go to the hospital if they can't receive services in a timely manner. The goals of "shorten/avoid

hospital stay" and "stabilize patient at home" are partially satisfied. Conversely, the two goals are satisfied in the scenario with PAL-IS, because the possibility of patients' going to hospital is low since they can receive services in a timely manner.

In this case, nurse assesses and analyze pain and symptom burden based on patient's pain score; it is the same with or without PAL-IS. The impacts on the "assess pain and symptom burden" goal are satisfied.

For the impacts on the "privacy and security assurance", without PAL-IS, we say it is hard to predict, since there are many unpredictable factors in manually collecting and exchanging patients' data. With PAL-IS, the information system takes part of responsibility to ensure privacy and security, it can help to reduce some risks of human-related mistakes, like losing patients' documents, but can not avoid the network security issue. Compared to the undecided impact on the goal without PAL-IS, PAL-IS can partially satisfy the goal. Same reason here, PAL-IS can somehow overcome the mistakes that are related to human activities, it satisfies the "provide equitable palliative care services" goal. Without PAL-IS, the impact on the goal is undecided.

With the help of information technology like PAL-IS, critical events for audit can be easily captured and traced. Without PAL-IS, all paper document and analysis work are done by people; critical events to be captured depend on people's observation and experience. The goal "capture critical events for audit" is hard to be satisfied.

4.5. Alternative Strategies

The definition of Strategy in jUCMNav provides us a way to evaluate and compare the different approaches.

The propagation algorithm used in the thesis is called Forward Propagation [Amyot10], which has been implemented in the jUCMNav tool. There are four steps involved in our propagation: (1) set contribution levels and decomposition types among elements; (2) based on the selected strategy, initialized the satisfaction values to the intentional elements at the bottom; (3) calculate the evaluation values of higher-level elements by doing a forward propagation (the bottom-up way); (4) get the satisfaction value of target element on the top. The values of satisfaction levels and contribution levels are based on the expected values for indicators linked to goals.

For each contribution, the contribution level is represented by the corresponding factor: Make, Some Positive, Help, Unknown, Hurt, Some Negative and Break equal to 1, 0.75, 0.25, 0, -0.25, -0.75 and -1, respectively.

There are two decomposition types: AND and OR. For AND decomposition, the minimum value will be propagated to the above level; for OR decomposition, the maximum value will be propagated. And the contribution values will be converted to the corresponding factor.

The evaluation level is between -100 and 100, which represent Denied and Satisfied respectively.

In the case study, we developed two strategies: the adhoc strategy and the PAL-IS strategy, which are depicted in Figure 12 and Figure 13. We selected the "satisfy patient, family and caregiver" goal as an example to show the impacts of different technologies on it. The goal is on the top level in the graphics.

The goal model we built in section 4.2.1 shows four other goals that contribute to the "satisfy patient, family and caregiver" goal; the four goals are "provide continuous collaborative care", "shorten/avoid hospital stay", "timely deliver palliative care services" and "timely 24/7 access to palliative care services". They are on the second level in the graphics. We set the contribution level of the four goals to the "satisfy patient, family and caregiver" goal to Some Positive, Unknown, Some Positive and Help, with the contribution factors of 0.75, 0, 0.75 and 0.25, respectively. We set the contribution levels based on an estimation of how the goals contribute to other goals. For example, we set the contribution level of "shorten/avoid hospital stay" as Unknown because we are not sure how the goal will satisfy the goal of "satisfy patient, family & caregiver". The goal of "timely deliver palliative care services" will strongly satisfy the goal of "satisfy patient, family & caregiver" but there are other goals needed to make the latter goal fully satisfied; therefore we set its contribution level to Some Positive with the factor of 0.75. On the third level, we set the contribution level of "stabilize patient at home" to Make with the factor of 1 because it absolutely satisfies the goal "shorten/avoid hospital stay".

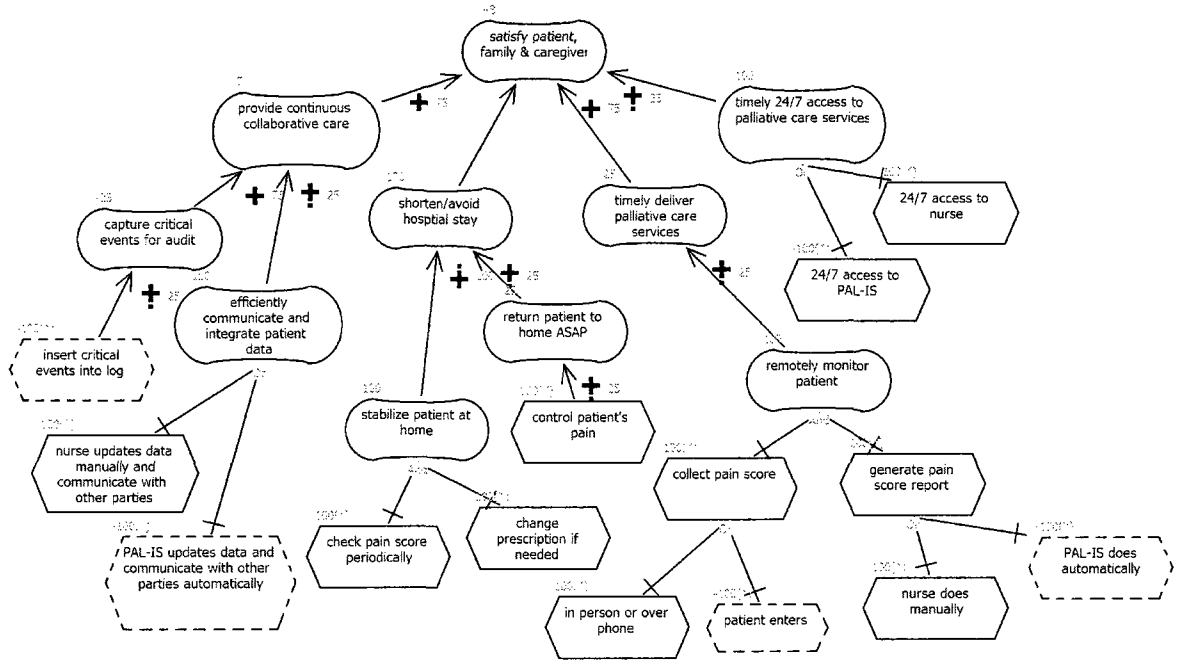

Figure 12 – the ADHOC Strategy

In the graphics, there are the third and fourth levels; they are either goals or tasks (hexagons in the graphics) that contribute or relate to the goals on the above level. For each goal that contributes to others, we set a contribution level, as we did on the second level. And for a goal or task that has other tasks related to, we set a AND or OR decomposition type. For example, for the "collect pain score" task, it can be done either by nurse or patient. The nurse collects pain scores in person or over the phone from patient is a regular task in the ADHOC system; however, in the PAL-IS system, patient enters pain scores by himself. So, under the "collect pain score" task, there are two tasks, "in person or over phone" and "patient enters"; they have an OR decomposition type. However, to satisfy the "stabilize patient at home" goal, two tasks are needed, patient's pain scores need to be checked periodically and when needed his/her prescription needs to be changed. That is why there are two tasks with an AND decomposition type under

the goal. After setting contribution levels and decomposition types, we derive the initial satisfaction values to the tasks at the bottom.

In the adhoc strategy, there is no PAL-IS; so, the values of tasks that are involved in PAL-IS (hexagons with dashed lines in Figure 12), such as, "insert critical events into log", "PAL-IS updates data and communicate with other parties automatically", "patient enters" and "PAL-IS does automatically" and "24/7 access to PAL-IS" are set to -100. The values of tasks that are involved in the ADHOC systems (hexagons with solid lines in Figure 12) are set to 100, like "nurse updates data manually and communicate with other parties", "check pain score periodically" and "change prescription if needed". With the initial values, decomposition types and contribution factors, jUCMNav calculates the satisfaction value of our target goal "satisfy patient, family and caregiver", that is, 48 for the ADHOC strategy.

We are evaluating the PAL-IS strategy in the same way. In the strategy, we set the values of paper-based tasks (hexagons with dashed lines in Figure 13), such as "nurse updates data manually and communicate with other parties", "in person or over phone" and "nurse does manually" to -100. The values of other PAL-IS related tasks (hexagons with solid lines in Figure 13) are set to 100. The satisfaction value of the target goal "satisfy patient, family and caregiver" is 75.

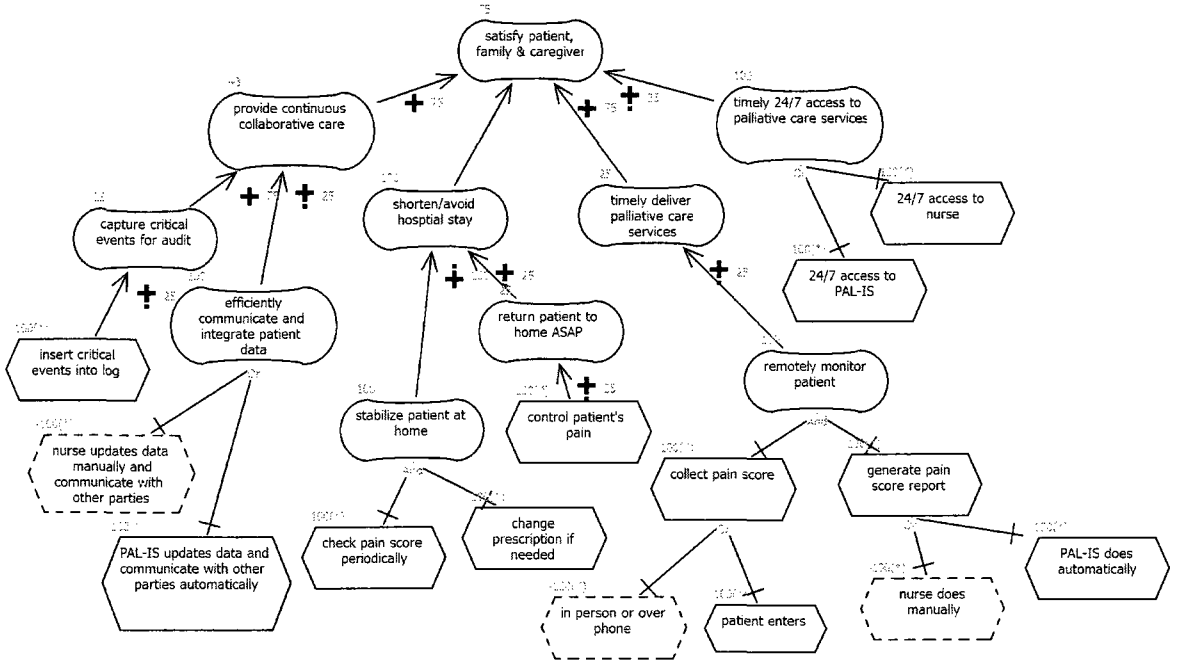

Figure 13 – the PAL-IS Strategy

The higher the satisfaction level is, the better the strategy is. From the above discussion of strategies, we say the PAL-IS strategy is better than the ADHOC strategy on fulfilling the specific goal "satisfy patient, family and caregiver" goal. The same evaluation way can be used to assess how PAL-IS and ADHOC satisfy other goals.

In the section, we showed the method to evaluate the impacts different technologies on organization goals.

4.6. Continuous Assessment

Continuous assessment is generally used to monitor impacts after implementation and identify the gap between predicted impacts and actual impacts after implementation. It also supports an ongoing cycle of evaluation, correction, and validation.

The work in the thesis is design-oriented research to show the utility of our proposed requirement engineering framework; our continuous assessment in the case study focuses on iteratively evaluating and modifying the built models. Such validation processes were done mostly through literature survey, such as PAL-IS proposal [PAL-IS08] and the accreditation introduced by Accreditation Canada [AC]. PAL-IS proposal was developed with cooperation of the LHIN; it represents the consensus of multiple stakeholders.

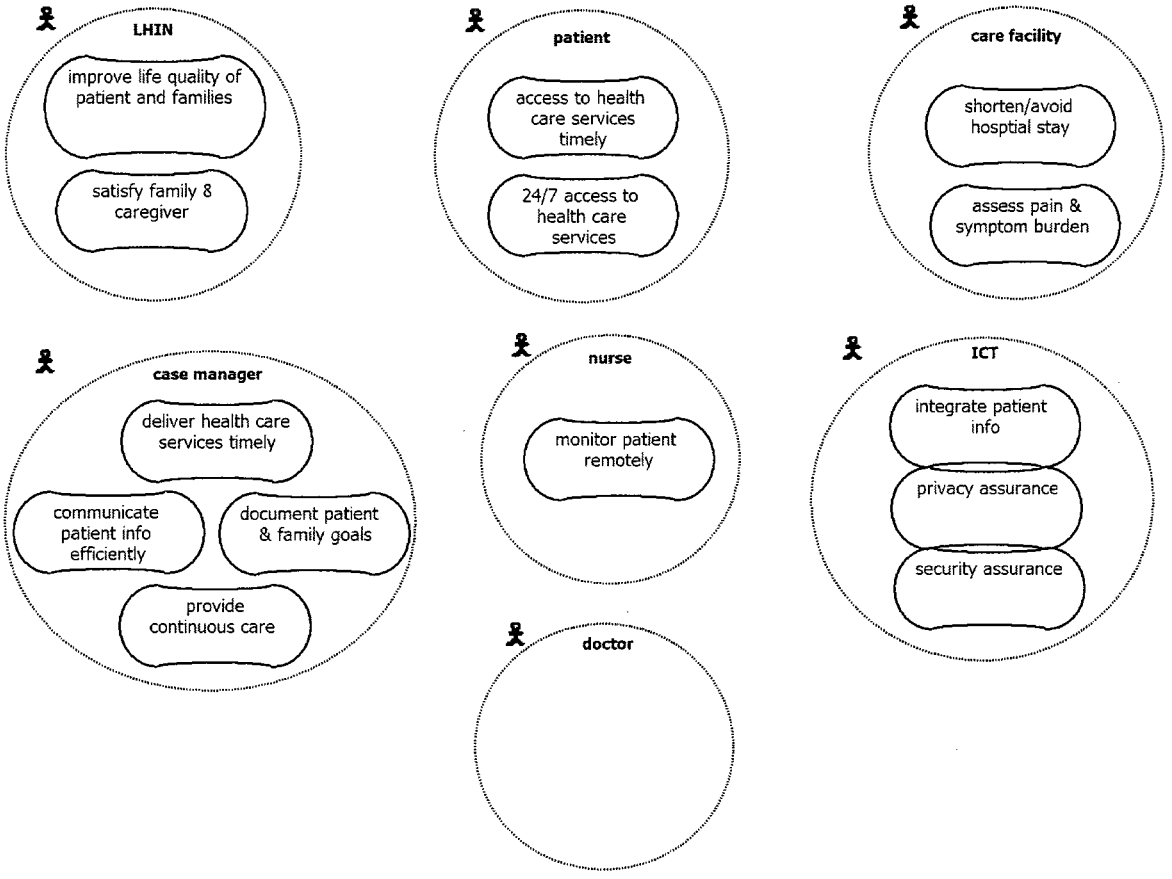

Figure 14 – The First Version of Goal Model

Figure 14 and Figure 15 shows the goal model and goal relationships in our first stage of the case study. They were based on the objectives from requirement documents and analysis of similar systems.

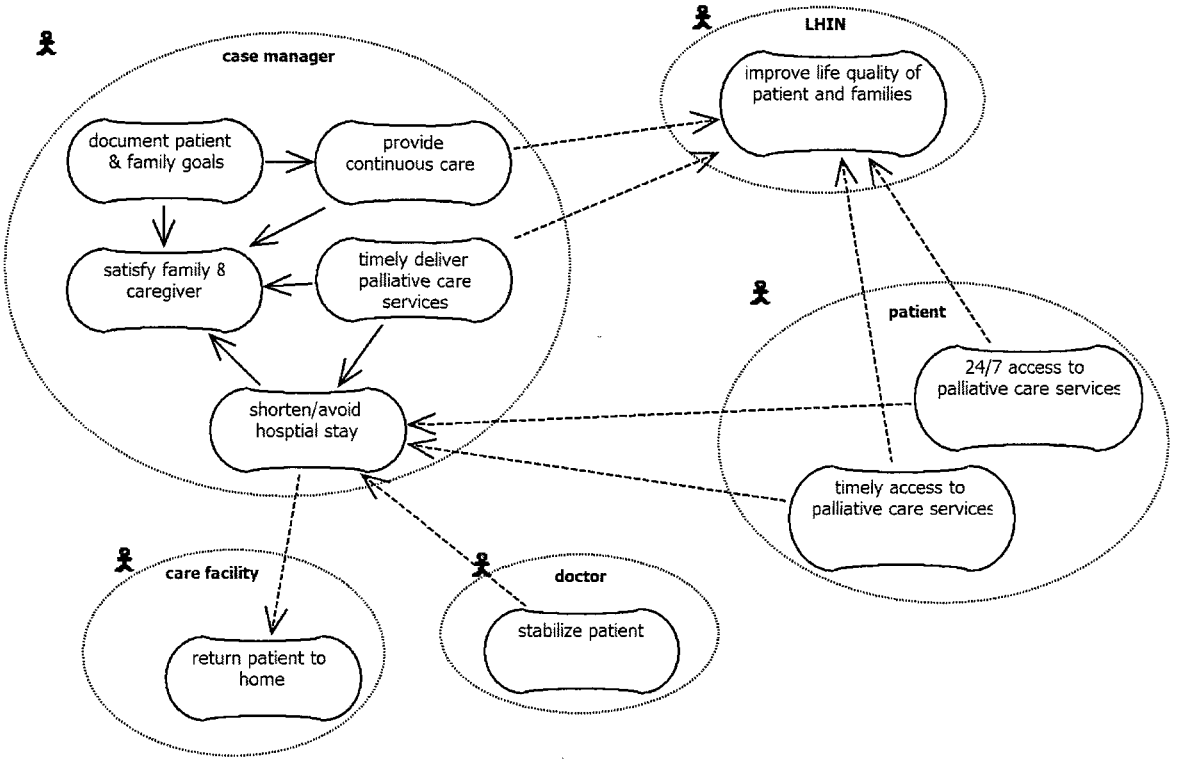

Figure 15 – The First Version of Goal Relationship Model

Two months later, the accreditation of Hospice Palliative and End-of-life care (HP/EOLC) was introduced by Accreditation Canada, which means, the organizational objectives and associated KPIs were changing. We added new goals into the original goal model to accommodate the necessary changes. For example, the "provide equitable palliative care services" and "assess pain and symptom burden" goals are added to LHIN and nurse respectively.

And with being more familiar with the responsibilities of all parties in the health care provider team, we realize it is more reasonable that the owner of the "satisfy patient, family and caregiver" goal is the case manager instead of the LHIN. So, the goal is moved from LHIN to case manager in the next version of goal model.

We updated the goal model first; and with the help of jUCMNav, the goal relationships were updated correspondingly. This resulted in the current goal model which we shown and analyzed in figures 5-14. The processes and strategies models might or might not need to be updated, depending on if their associated goals change.

Successive iterations are also used to evaluate and improve our proposed framework. At the beginning of the framework development, our methodology only included goal models, impact points, and alternative strategies. At the second stage, based on the gap analysis between the literature survey and case study, and the introduction of accreditation standards by Accreditation Canada, indicators were added to our methodology. Indicators are linked to goals and used to evaluate how successfully goals are fulfilled. We also realized that URN needs the ability to tie the goal satisfaction calculation to indicators. Continuous assessment was added to the methodology in the final stage, since we need a way to assess the predicted and actual impact of a HCIS over the long term. At the same time, we realized that URN also needs the ability to support continuous assessment.

The above discussion of case study shows our proposed RE Framework provides a systematic approach to assess the impact of HCIS on an organization's objectives. And

based on the measurement of alternative strategies, we can conclude that PAL-IS is better than AD-HOC system on satisfying LHIN's objectives.

Chapter 5. Evaluation

In chapter 4 we demonstrated our Requirement Engineering Framework (RE Framework) using a palliative care case study. In this chapter, we are evaluating our framework. The evaluation will look at criteria comparison, engineering effort and the application of URN.

In sections 5.1 and 5.2, we evaluate RE Framework, in comparison with Business Process Management (BPM), Cost Benefit Analysis (CBA) and Technology Adoption Assessement (TAA) by looking at criteria and engineering effort. In section 5.3, we evaluate URN as a requirements language applied in terms of how well it supports our RE Framework.

5.1. Comparison of Criteria

Based on the criteria defined in section 3.2, we are going to compare the RE Framework to three other assessment approaches: Business Performance Management (BPM), Cost-Benefit Analysis (CBA), and Technology Adoption Assessment (TAA).

Table 2 is the summary of the comparison. The sections from 5.1.1 to 5.1.8 are the detailed discussions of the comparison of RE Framework with BPM, CBA and TAA. Overall, RE Framework overcomes the shortcomings of existing approaches; it provides direct measurement of goals and graphically models and quantifies the impacts of HCIS on organization goals, which are discussed in the sections 5.1.1 and 5.1.2.

Table 2 – Comparison of Criteria

Criteria	BPM	CBA	TAA	RE Framework
Graphically model the impacts of HCIS on organization goals	No. It defines KPIs; but can not directly show the impact of HCIS on goals graphically.	No.	No.	Yes. The goal model graphically shows the relationships among organization goals and the impacts of HCIS on those goals.
Quantify the impacts of HCIS on organization goals	Indirectly. KPIs measures performance but the relationship with organization goals is not clear.	No.	No.	Yes. KPIs are linked to goals and used to evaluate how successful goals are fulfilled.
Assess business process impacts on organization goals	Indirectly. KPIs measure performance but the relationship with organization goals is not clear.	No.	No.	Yes. It defines impact points in term of measures, tasks and processes to show how they impact organization goals.
Compare alternative technology choices for HCIS	Not really. There is no direct link between operations KPIs and organization goals.	Yes. But strictly from the financial perspective (cost-benefit values are used.)	Yes. But strictly from the point of view of how likely an HCIS is to be used.	Yes. There is direct link between operations KPIs and organization goals.
Tool support for the decision on HCIS	Business intelligence tools.	CBA calculator.	Usability survey.	jUCMNav plus Business intelligence tools.
Assess financial impacts of HCIS	Indirectly; but one of its core processes is financial planning.	Yes. It calculates cost-benefit for involved processes.	No.	Potential, it is possible if we model relationship of financial indicators to goals.
Assess the user adoption of HCIS	No.	No.	Yes. It assesses the acceptance level by collecting statistics.	Potential, it is possible if we model relationship of user adoption indicators to goals.
Continuous assessment of HCIS	Indirectly. KPIs measure performance but the relationship with organization goals is not clear.	Not really. Only by redoing the assessment completely.	Not really. Only by redoing the assessment completely.	Yes. There is direct link between operations KPIs, and organization goals.

5.1.1 Graphically model the impacts of HCIS on organization goals

When an HCIS is being assessed, the first thing we need to evaluate is how the HCIS will impact the organizations goals. One of the key advantages the RE Framework provides is the means to model organization goals, which not only graphically models the relations among those goals, but also directly shows the impacts of HCIS on those goals.

Now, as health care service delivery moves towards team-based delivery instead of traditional one-to-one style, each involved organization has its own specific goals that affect other team members as well. We want to not only document each organization's goals but also monitor how they interact in order to reach the top goals as a whole team; especially we want to assess how HSIC impact the organization goals. A goal model provides us an easy and efficient way to do it.

Figure 16, is extracted from the goal model in figure 6. In figure 16, we focus on the relations between HCIS and others. There are four actors: nurse, case manager, LHIN and ICT. Each of them represents one independent organization in the whole health care service delivery team, with its own goals. Through the arrows, we can see how their goals depend on or contribute to others.

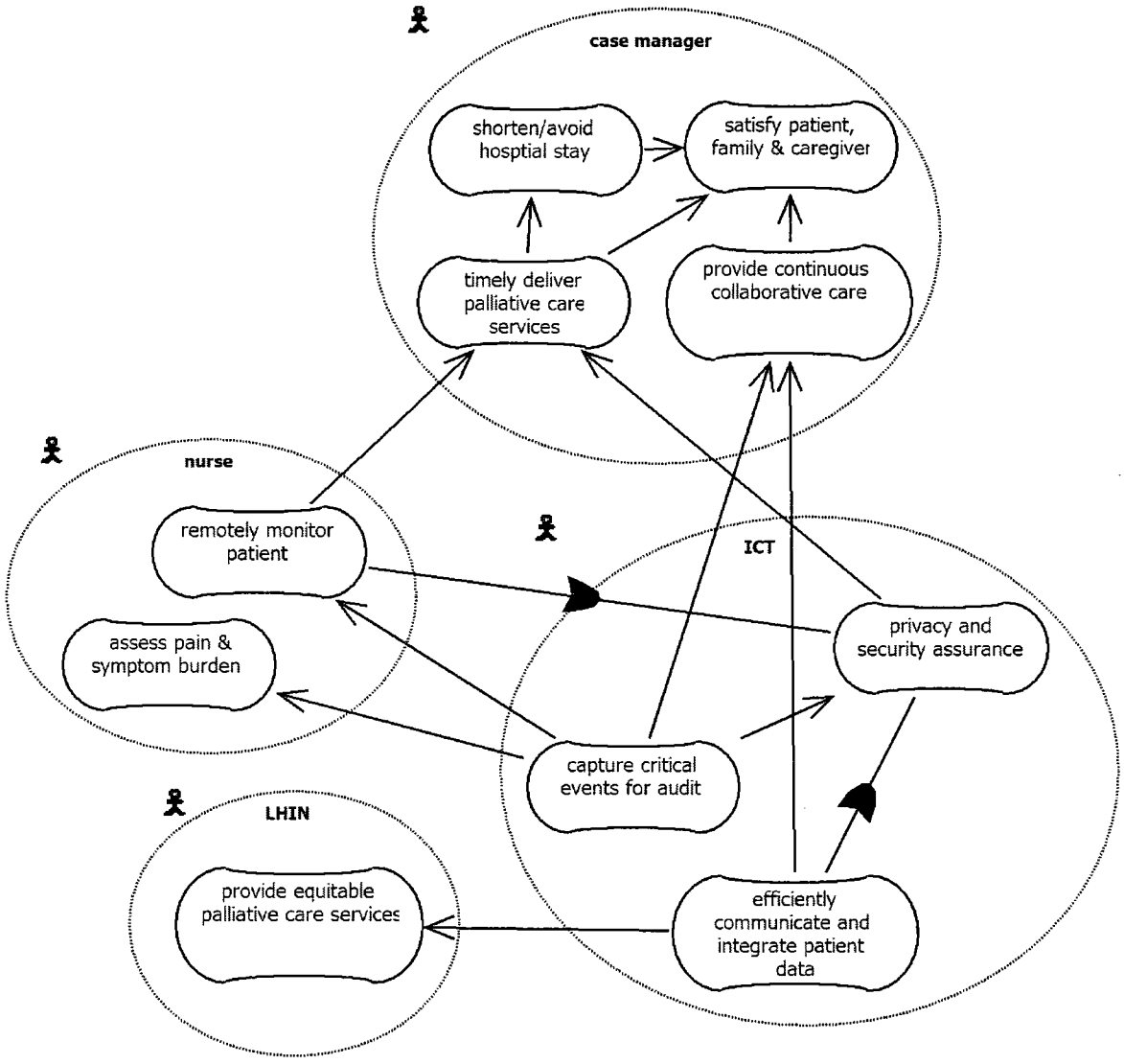

Figure 16 - Graphically model the Impacts of HCIS on Organization Goals

Figure 16 graphically models how the HSIC impacts other goals. For example, the goal of ICT, "efficiently communicate and integrate patient data" contributes to the LHIN's goal "provide equitable palliative care services"; and it also depends on one of its own goals "privacy and security assurance". The relations between HCIS and other actors are straightforwardly depicted through the arrows in the goal model. Compared to the RE Framework, other three approaches, BPM, CBA and TAA, the lack the ability to graphically model the impacts of HCIS on organization goals. BPM defines organization

goals but it doesn't model the goals to allow the measurement of performance. CBA and TAA don't define organization goals.

5.1.2 Quantify the impacts of HCIS on organization goals

RE Framework identifies KPIs for each goal and used them to evaluate how successfully the goals are fulfilled. Figure 17 is one part of figure 8 discussed in the case study in chapter 4. As figure 17 shows, when a HCIS is being assessed, each KPI linked to a goal will result in an actual value or number to show how the goal is satisfied.

For example, the KPI of the "privacy and security assurance" goal is set "number of incidents and potential vulnerabilities". The value can be gotten by counting how many times of incidents that relate to privacy and security in a period of time. It indicates a HCIS's the satisfaction level of ensuring privacy and security.

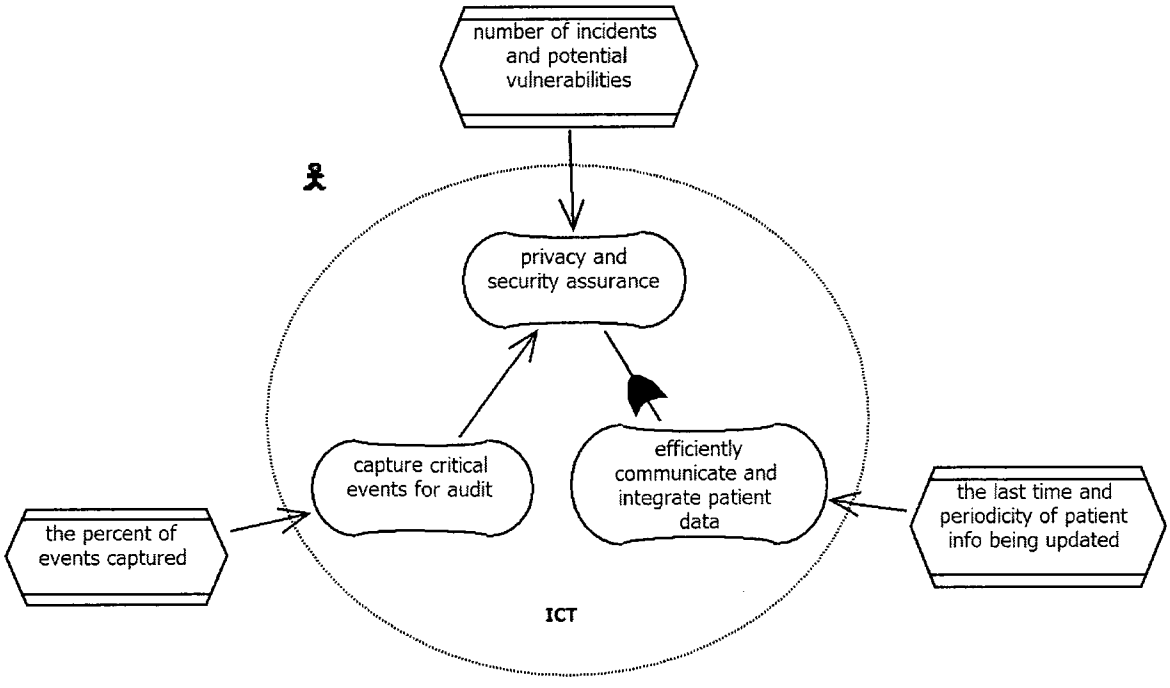

Figure 17 - KPIs of Goals

The concept of KPIs is also used in BPM to assess business performance; but it has no direct link to organization goals. CBA and TAA do not have the concept KPIs.

5.1.3 Assess business process impacts on organization goals

The RE Framework identifies impact points in term of measures, tasks and processes to show how they impact organization goals. If different HCISs are being assessed and compared, we identify the different measures, tasks and processes involved, as was done for PAL-IS in comparison to adhoc methods of communications as we discussed in the section 4.4. The RE Framework can model these impact points and evaluate their impacts on organization goals.

BPM provides an indirect way to assess business process impacts on organization goals through measuring and evaluating performance against goals. It does not have the ability to model and quantify the impacts of business processes on goals. CBA and TAA have no such ability to assess business process impacts on organization goals at all.

5.1.4 Compare alternative technology choices for HCIS

RE Framework, BPM, CBA and TAA can all evaluate and compare alternative technology choices for HCIS, but from different perspectives.

RE Framework assesses different technologies with the help of GRL strategies since there is direct link between implementation systems and organization goals. When different technologies are chosen, there would be different tasks or processes involved. In GRL strategies, satisfaction values of goals for different technologies are calculated through initializing related tasks or processes. The higher the satisfaction value is, the

better the information technology satisfies the organization goals. The decision on which information systems is chosen is based on those satisfaction values.

BPM considers the performance of alternative technology. For example, to compare the ADHOC system and PAL-IS, their KPIs would be identified and used to evaluate the performance of the two systems. However, since there is no direct link between operation system and organization goals, it can not show the impact of alternative technologies on goals.

CBA evaluates different technology choices strictly from the financial perspective, based on cost-benefit values. In our case study, the cost-benefit values of ADHOC and PAL-IS are calculated to provide a foundation for decision makers to make the choice on which information system would be used.

TAA compares alternative technologies strictly from the point of view of how likely an HCIS is to be used. In other words, to make choice on whichever the ADHOC system or PAL-IS is used, we can first calculate their acceptance levels through survey.

5.1.5 Tool Support

Using the approach of RE Framework, we first assume that the work of identifying indicators is done. And then, with jUCMNav, we build goal models with KPIs linked, use user case map to show the impacts of processes or tasks on organization goals, and make decision on HCIS through strategy analysis.

In BPM, manual efforts include setting up complete IT infrastructure and identifying key performance indicators. Business intelligence tools are used to gather,

analyze and present data from large unstructured data. Those reports reflect the efficiency and effectiveness of operations in a business or organization and help management make critical decisions.

A Cost-Benefit Calculator is commonly used in CBA. In this approach, we need make financial preparation such as collecting financial statements, balance sheet, and income statement.

In the approach of TAA, the Usability survey can be used, with the effort of preparing evaluation trials. Such usability surveys help management collect data and assess the adoption level of technologies based on statistics.

5.1.6 Assess Financial Impacts of HCIS

The RE Framework does have the potential to assess financial impacts of an HCIS. It becomes possible if we model financial impacts of HCIS on organization goals, like was done in figure 18. If we go back our case study in the chapter 4, in the ADHOC and PAL-IS systems, the responsibilities of nurse are very different. Since an HCIS can help efficiently communicate and integrate patient data among organizations, it would lower a nurse's workload or possibly reduce the number of nurses. Also, the case manager can deal with more cases in the same amount of time creating a more efficient workflow. All of those impacts could decrease health care service expenses.

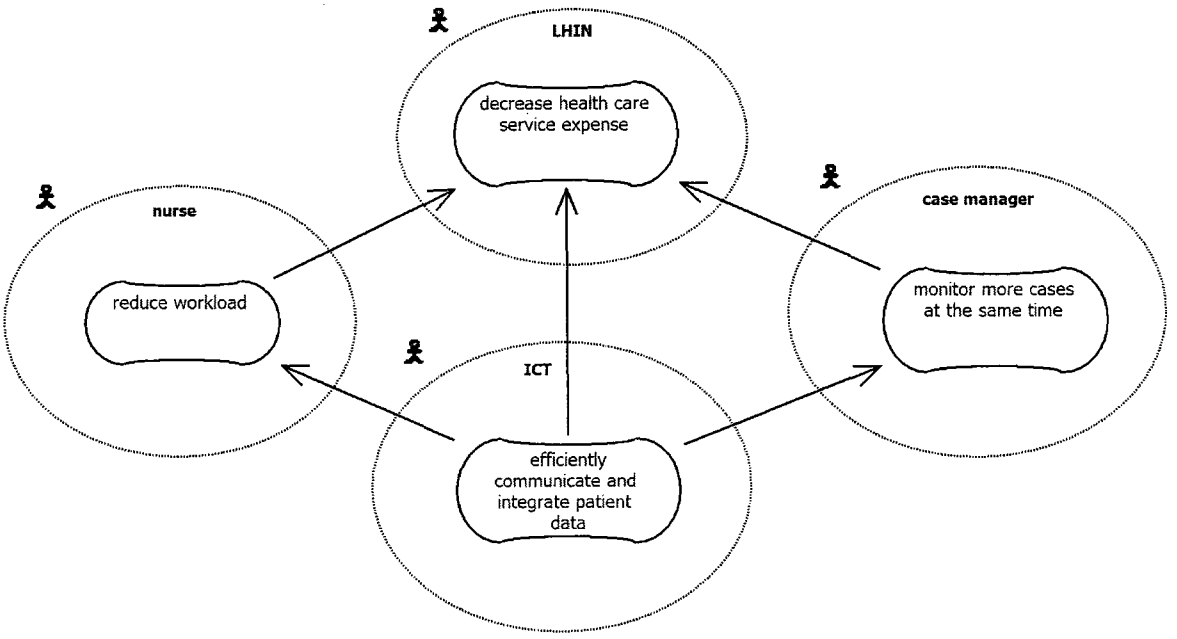

Figure 18 - KPIs to Asses Financial Impacts of HCIS

BPM has indirect abilities to assess financial impacts of HCIS. One of BPM processes is financial planning; but it helps to identify key performance indicators. It does not assess direct financial impacts of HCIS on a business.

In contrast, CBA is designed to assess financial impacts. Through the cost-benefit calculation, CBA assesses the direct financial impacts of HCIS on an organization. For example, we can compare the cost-benefit values with and without an information system to assess if the information system brings financial benefit for the organization.

TAA has no such ability to assess financial impacts of HCIS.

5.1.7 Assess the User Adoption of HCIS

The RE Framework has the potential ability to assess the user adoption of HCIS. In the following graphic (figure 19), we model the user adoption of HCIS by adding two

more KPIs. One is "number of nurses using PAL-IS" that is linked to the nurse's "monitor patient remotely" goal; the other is "number of case manager using PAL-IS" that is linked to the case manager's "send and receive patient data electronically" goal. By monitoring the numbers of nurses and case managers who are using information system as daily tool, we can assess the user adoption of HCIS.

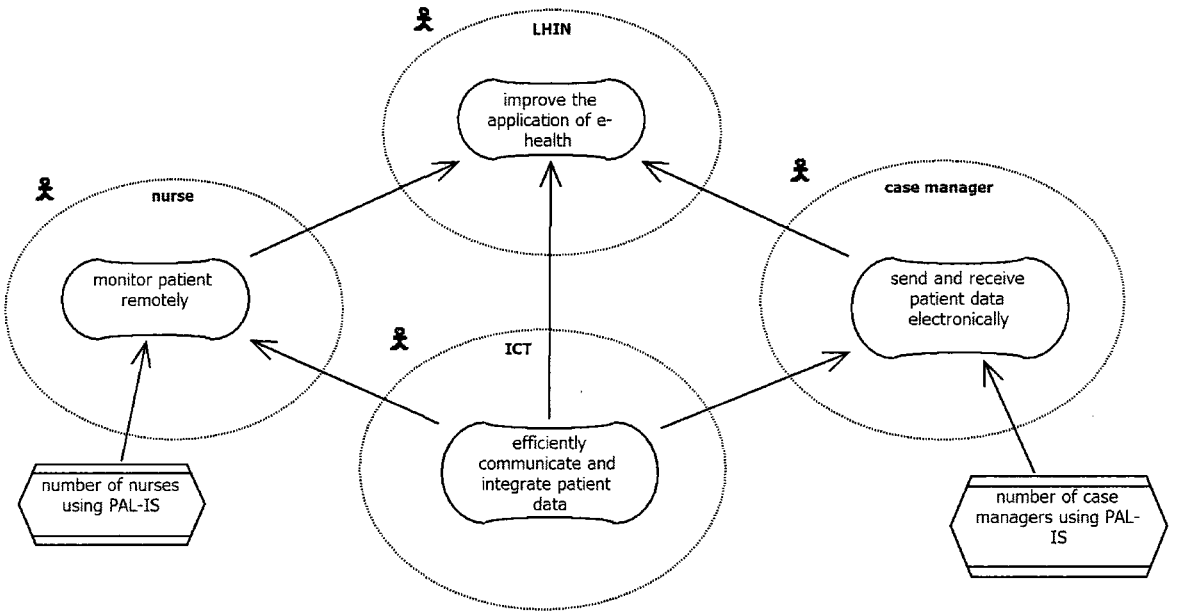

Figure 19 - KPIs to Assess the User Adoption of HCIS

The approach of ATT is designed for the purpose of assessing the user adoption. It assesses the user's acceptance level through collecting statistics. BPM and CBA have no such ability.

5.1.8 Continuous Assessment of HCIS

The RE Framework has the ability of continuous assessment of HCIS since there is direct link between operation KPIs and organization goals. When organization goals

change, measurements, tasks and processes would change correspondingly, and vice versa.

BPM provides indirect continuous assessment of HCIS. It measures and evaluates business performance against organization goals through KPIs. If organization goals change, we need re-identify KPIs and use them to re-measure business performance.

CBA and TAA have limited ability of continuous assessment. One is based on the narrow perspective of cost-benefit value; the other is based on the perspective of user adoption. If changes occur in HCIS, the value of cost-benefit would be re-calculated or the data of technology adoption would be re-collected.

5.2. Engineering Effort

In this section, we make a comparison of the four approaches: Business Performance Management, Cost-Benefit Analysis, Technology Adoption Assessment, and Requirement Engineering Framework, from the perspective of Engineering Effort.

5.2.1 Effort to set up

In the initial effort, BPM requires that a complete IT infrastructure be setup in order to create key performance indicators and collect large amounts of data. CBA needs financial preparation such as collecting financial statements, balance sheet, and income statement. Effort needs to be put in to preparing evaluation trials and collecting data through surveys in the approach of TAA. The RE Framework requires the almost same initial effort as BPM, in addition one also has to do complete goal analysis and business process analysis.

Table 3 – Comparison on Engineering Efforts

Feature	BPM	CBA	TAA	RE Framework
Effort to set up (initial effort)	Complete IT infrastructure + complete KPI analysis + data collection.	Financials.	Evaluation trials + data collection (survey).	BPM + complete goal analysis + process analysis.
Effort to maintain (continuous effort)	Maintain all above steps.	Update values or numbers.	Redo the whole trial.	It needs goal analysis plus all above steps.
Skill effort	IT support + business analysis + data analysis	Basic accounting.	MIS multivariate statistics	BPM + RE (goal model, UCM)
Infrastructure cost	Large.	Basic accounting that already exists there.	Set up a randomized trial.	Same as BPM.

5.2.2 Effort to maintain

The approaches of BPM and RE Framework need a little more continuous efforts; they need same efforts as that in the initial efforts plus required skills such as IT support, business analysis and data analysis. However, CBA only need update cost-benefit values or numbers and some effort in calculating financial figures. And TAA would need to redo the whole trial to collect data again.

5.2.3 Skill effort

BPM involves set up of IT infrastructure, and a series of analytic and management processes. Skill effort required include IT support, business analysis and data analysis. Data analysis is for financial and operational planning, consolidation and reporting. The only effort needed in CBA is basic accounting skill. For TAA, the knowledge of

multivariate statistics is required to understand the data collection from survey. Statistics are needed to analyze the data to interpret the results. The RE Framework requires not only the skills needed in BPM but also the knowledge of requirement engineering, including goal modelling, UCM, and GRL strategies.

5.2.4 Infrastructure cost

Regarding to infrastructure cost, BPM and RE Framework have large costs and thus such approaches are usually used in large organizations. The cost in CBA and TAA is much smaller. CBA only needs basic accounting that already exists in organizations; and all that is needed in TAA is to set up a qualitative or quantitative evaluation study.

From the above discussion of engineering efforts, we can see that efforts in BPM and RE Framework are pretty similar. The cost of RE Framework is the cost of BPM plus a little extra effort.

5.3. Evaluate URN

In the thesis, we are using URN as a basis for our framework. URN is the only modeling language that can model goals and processes at the same time while providing traceability between them. URN integrates two notations, namely the Goal-oriented Requirement Language (GRL) and Use Case Maps (UCM). The tool we use is jUCMNav, an open URN modeling, analysis and transformation tool based on the Eclipse platform. [Roy06]

Table 4 – Evaluation on URN

Criteria	URN	Tool Support
Graphically model the impact of HCIS on organization goals	Yes.	jUCMNav. Goal models can be built to graphically model the relations among organization goals and the impacts of HCIS on those goals
Quantify the impact of HCIS on organization goals	Yes, two ways. Indicators or subjective assessment of goal satisfaction.	jUCMNav. Only subjective assessment is well supported. Import of indicators is possible through import/export tool.
Assess business process impact on organization goals	Yes.	jUCMNav. It has the links between use case maps and goal models and provides support for goal satisfaction calculation. Unfortunately, the two are not combined, and goal satisfaction is subjective and does not involve indicators.
Compare alternative technology choices for HCIS	Yes. Business Strategies. Unfortunately, these are driven by subjective assessment of goal satisfaction instead by indicators.	jUCMNav. Supports GRL strategies and indicator import/export as well as tracking dependencies between goals and use case maps.
Assess financial impact of HCIS	Possible. If one has generically modeled indicators and goals related to financial impacts.	jUCMNav has no built-in financial impact specific support.
Assess the user adoption of HCIS	Possible. If one has generically modeled indicators and goals related to user adoption.	jUCMNav has no built-in user adoption specific support.
Continuous assessment of HCIS	Not really. There is some support for extending URN with links between models that might be used to help with continuous assessment and impact analysis.	jUCMNav has not specific support. Might be able to export and use change management tools.

One contribution of the thesis is evaluating URN as a requirement language for implementing our framework. The table 4 is the summary of our evaluation of URN, and its tool support using jUCMNav.

The two biggest advantages of URN in our work are visualizing and quantifying the impacts of HCIS on organization goals. We can use jUCMNav to build GRL goal models to graphically show the impact of HCIS on organization goals. URN has two ways to quantify the impact of HCIS on organization goals; one is the indicators and the other is assessment of goal satisfaction. jUCMNav well supports the assessment of goal satisfaction calculation through GRL strategies, although the assessment is subjective. Import of indicators is possible through import/export tool in jUCMNav.

URN can assess business process impact on organization goals. With jUCMNav, we can set up the links between use case maps and goal models to show the relations between business processes and organization goals. And, the goal satisfaction calculation is based on the relation between business processes and organization goals. Unfortunately, the goal satisfaction calculation is based on the users subjective assessment of how fulfilled a goal is and does not involve indicators (users could manually set the satisfaction value of a goal to correspond to the current value for an indicator, though).

URN uses the concept of business strategies to compare alternative technology choices for HCIS, although comparisons are based on subjective assessment of goal satisfaction instead of indicators. jUCMNav supports GRL strategies; we initially give

subjective satisfaction values to tasks, GRL strategies will do goal satisfaction calculation automatically.

URN has the potential to assess the financial impacts and the user adoption of HCIS. In sections of 5.2.6 and 5.2.7, we discussed such possibilities by modeling goals related to financial impacts and user adoption with indicators linked. jUCMNav does not have built-in financial impact and user adoption specific supports.

Finally, URN does not really have the ability to support continuous assessment of HCIS; but there is some support for extending URN with links between models that might be used to help with continuous assessment and impact analysis. And current jUCMNav does not have continuous assessment specific support. It can only keep different versions of models, and might be able to export and use change management tool to monitor changes.

Chapter 6. Conclusions

6.1. Summary of Contributions

We outlined four contributions of the thesis in the section 1.2. Here, we summarize the four contributions.

Contribution 1: A requirement engineering framework for modeling the impact of health care information systems on an organization's objectives.

Currently, there is no systematic approach to assess the impacts of health care information systems on organization objectives. The current approaches, such as BPM, CBA, and TAA, provide partial solutions from different assessment perspectives. In the paper, we applied requirements engineering for a new purpose; to evaluate the impact of HCIS on an organization's objectives. We proposed a requirement engineering framework that is more complete and systematic than other approaches.

The framework consists of three components: methodology, language and tool. The language we used to develop our framework was one of the existing requirement engineering languages, URN (supported by the jUCMNav tool). URN is the only modeling language that can model goals and processes at the same time while providing traceability between them. URN integrates two notations, namely the Goal-oriented Requirement Language (GRL) and Use Case Maps (UCM). We use GRL to build goal models and do alternative strategy analysis. UCM provides us a graphic way to show the impacts of HCIS on goals.

The five elements and principles in our methodology are goal model, key performance indicator, impact points in term of measurement, task and process, alternative strategy, and continuous assessment.

In the work, we show that the RE Framework provides a systematic approach on assessing the impact of HCIS on an organization's objectives by applying it into the information system case study of palliative care and by comparing it with current other assessment approaches.

Contribution 2: Indentify the criteria for evaluating any framework to assess the impact of health care information system.

The framework developed here aims to help decision makers compare alternative health care information systems. But is the framework good enough to help decision makers reach a wise decision? What advantages does the framework have, compared to the current approaches? We need an efficient assessment tool or solution to evaluation such a framework.

In the section 3, we identify the criteria in order to evaluate the proposed framework and compare it to current approaches for assessing the impacts of HCIS. The discussion of evaluation is in the section 5.1 and 5.2. The main categories are visualizing and quantifying the impacts of HCIS on organization goals, assessing business processes impacts on organization goals, and comparing alternative technology choices.

Contribution 3: Evaluate the URN language, which is an ITU standard, for implementing our framework.

URN is a draft ITU-T standard [ITU-T02/03] that combines goals and scenarios in order to help capture, model and analyze user requirements at the early stages of design. URN is the only modeling language that can model goals and processes at the same time while providing traceability between them. In the paper, we use URN and its core tool jUCMNav to implement our proposed framework. How does it work?

We evaluated the URN language for implementing our framework. From the discussion in section 5.4, we can conclude URN is an efficient tool to implement our proposed framework. It can satisfy most of our criteria, with only two possible satisfactions and one exception. Two biggest advantages of URN are graphically modeling and quantifying the impacts of HCIS on organization goals. Two possible satisfactions that URN has refer to URN's potential abilities to assess the financial impacts and the user adoption of HCIS on organization goals.

Two areas where additional work is needed (possibly just with tool support) are the ability to incorporate KPIs into goal satisfaction calculations and the ability to support continuous assessment.

Contribution 4: Methodology for quantifying the impact of health care information systems on an organization's objectives by using indicators.

Quantifying impacts of HCIS on objectives provides decision makers straightforward values to assess alternative technology choices. One contribution of our work is to develop a methodology for quantifying impact of HCIS on organization objectives by using indicators.

We discussed how to use key performance indicators to quantify the impacts of HCIS on organization goals in section 3.5. KPIs are measured and linked to goals for each stake holder. By modeling and monitoring KPIs, we can quantify impacts of HCIS and evaluate how organization goals are satisfied.

6.2. Future Work

6.2.1 Continuous Assessment

In the thesis, we propose a requirement engineering framework to assess HCIS and predict impacts of HCIS on organization goals. But there will always be a gap between predicted impacts and actual impacts after implementation. Continuous assessment is needed to watch the actual impacts of HCIS and evaluate the proposed framework. Furthermore, validation of models containing indicators, impact points, and strategies is not easy. Continuous assessment would serve as a good means to validate models, to see if the predicted impact or change in indicators is achieved. But in this master thesis, it is not practical to follow the case study long enough to do continuous assessment. A longer study with more follow up is needed on the current or similar case study.

6.2.2 URN Extension

URN is very helpful to graphically model the impacts of HCIS on organization goals, model business processes linked goals, and quantify the impacts of HCIS on organization goals. However, the biggest disadvantage of URN is it has no ability to base goal satisfaction calculations directly on the values of KPIs, predicted or actual. (Note, based on the recent communication with jUCMNav team, that feature is being added to

the tool.) It also needs the ability to support continuous assessment by, for example, tracking how indicators related to goals are trending over time. Furthermore, it lacks the abilities of assessing the financial impacts and user adoption of HCIS, as the approaches of CBA and TAA. If it can be extended to quantify financial impacts and the user adoption of a system, our framework would have more complete assessment abilities to evaluate HCIS.

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