

# **Activity-based Process Integration Framework to Improve User Satisfaction and Decision Support in Healthcare**

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# Abstract

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Requirements Engineering (RE) approaches are widely used in several domains such as telecommunications systems, information systems, and even regulatory compliance. However, they are rarely applied in healthcare beyond requirements elicitation. Healthcare is a multidisciplinary environment in which clinical processes are often performed across multiple units. Introducing a new Information Technology (IT) system or a new process in such an environment is a very challenging task, especially in the absence of recognized RE practices. Currently, many IT systems are not welcomed by caregivers and are considered to be failures because they change what caregivers are familiar with and bring new tasks that often consume additional time.

This thesis introduces a new RE-based approach aiming to evaluate and estimate the potential impact of new system integrations on current practices, organizational goals, and user satisfaction using goal modelling and process modelling techniques. This approach is validated with two case studies conducted in real hospitals and a usability study involving healthcare practitioners. The contributions of the thesis are:

- Major: a novel Activity-based Process Integration (AbPI) framework that enables the integration of a new process into existing practices incrementally, in a way that permits continuous analysis and evaluation. AbPI also provides several alternatives to a given integration to ensure effective flowing and minimal disturbance to current practices. AbPI has a Goal Integration Method to integrate new goals, an Integration Method to integrate new processes, and an Alternative Evaluation Method exploiting multi-criteria decision-making algorithms to select among strategies. The modelling concepts of AbPI are supported by a profile of the User Requirements Notation augmented with a new distance-based goal-oriented approach to alternative selection and a new data-quality-driven algorithm for the propagation of confidence levels in goal models.

- Minor: a usability study of AbPI to investigate the usefulness of the framework in a healthcare context. This usability study is part of the validation and is also a minor contribution due to: 1) the lack of usability studies when proposing requirements engineering frameworks, and 2) an intent to discover the potential usefulness of the framework in a context where recognized RE practices are seldom used.

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## **Realization**

“Nobody knew that healthcare was so complicated!”

Donald Trump, 2017

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# List of Acronyms

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<b>Acronym</b>	<b>Definition</b>
AbPI	Activity-based Process Integration
AHP	Analytic Hierarchy Process
AoURN	Aspect-oriented User Requirements Notation
BPM	Business Process Modelling
BPMN	Business Process Model and Notation
B-SCP	Business Strategy, Context, and Process
CIS	Clinical Information System
DIGM	Dissimilar Integrated Goal Model
DQbD	Data Quality by Design
EMR	Electronic Medical Record
EMRAM	Analytics Electronic Medical Record Adoption Model
ER	Emergency Room
GA	Genetic Algorithms
GQM	Goal, Question, Metric
GRL	Goal-oriented Requirement Language
IGM	Integrated Goal Model
IS	Information System
IT	Information Technology
ITU	International Telecommunication Union
ITU-T	ITU – Telecommunication Standardization Sector
KPI	Key Performance Indicator
MCDA	Multi-Criteria Decision Analysis
MHR	Medical Health Record
MLT	Medical Lab Technician
OCL	Object Constraint Language
O-MaSE	Organization-based Multi-agent System Engineering
OMG	Object Management Group
OR	Operating Room
PGM	Process Goal Model
PGModel	Process Goal Model (synonym of PGM)
PT	Path Traversal
RE	Requirements Engineering
RTTS	Real-Time Tracking Sample
SAR	Saudi Riyal
SIGM	Similar Integrated Goal Model
SOA	Service Oriented Architecture
SUS	System Usability Scale
TAT	Turn around time
TOPSIS	Technique of Order Preference Similarity to the Ideal Solution

UA	User Acceptance
UCM	Use Case Maps
UML	Unified Modeling Language
URN	User Requirements Notation
USE	UML-based Specification Environment
VRS	Voice Recognition System
WTES	Wait Time Estimation System

# Chapter 1 Introduction

---

This thesis presents a novel framework called *Activity-based Process Integration (AbPI)*, whose purpose is to support the incremental integration of a new process with existing processes, one activity at a time. AbPI focuses on healthcare-related processes and their goals and activities. AbPI includes a *Goal Integration Method*, an *Integration Method* and an *Alternative Evaluation Method*, which allow evaluating the fulfilment of user requirements and the achievement of organizational goals and performance objectives after each integration. This chapter discusses the problem context and motivations, as well as the research questions. It also presents the research methodology this thesis follows and highlights contributions.

## 1.1 Problem Context

Hospitals are facing many challenges such as long wait times, an aging population, and increasing pressures to deliver quality services in a timely fashion (Minister of Health and Long-Term Care, 2016). Hospitals try to improve their performance while controlling budgets. Governments also impose new rules and guidelines to ensure that hospitals provide better and more efficient health services to patients. For example, the Government of Ontario changed its purchasing system from using service-based payments to using *value-based* payments, which forces hospitals to question their practices and often restructure their processes to reach the desired performance levels (Burwitz et al., 2013). Redesigning processes or proposing new structures is not straightforward in healthcare, in part due to its multidisciplinary nature. A process may require multiple units (e.g., clinical services, clinics, and administration) to collaborate, while each unit has its own interests and objectives when participating to the process. The personnel involved in healthcare processes is usually very busy, and their actions can have severe consequences on the lives of patients.

Modelling is a common approach used to understand and combine different process views, as well as to define measurements and quality criteria to evaluate these views and



the way they interact (Jun et al., 2009). Still, process modelling is not widely used in healthcare. One more key opportunity to better cope with performance challenges is to consider technology-based solutions. Similarly, technology alone does not represent a perfect solution to healthcare problems due to disruption to current practices, users' resistance to change, and required deployment/integration/operations efforts.

*Requirements Engineering* (RE) regroups proven practices for the elicitation, modelling, analysis, specification, validation, and management of requirements. One of the main objectives of RE practices is to give a comprehensive view of different units/stakeholders along with their intentions and workflows, and to estimate the impact of alternatives during decision making, prior to system implementation. The absence of sufficient RE effort can lead to systems that result in unsatisfied users, time/effort lost, low performance, or ignorance about impactful changes. This could also lead (in a multidisciplinary environment) to situations where we miss engaging a party/unit in decision making opportunities or where we unconsciously force changes on others (Alahmadi et al., 2014). As the focus of electronic health (e-health) system development must move away from a single viewpoint to multiple views and user intentions, I see an opportunity to introduce better RE practices in healthcare along with intention-driven process modelling approaches.

The main objective of this study is to investigate the usefulness of model-based RE practices in improving technology-dependent healthcare processes by introducing a new *Activity-based Process Integration* (AbPI) approach. AbPI enables the modelling and assessment of alternative activity-based integrations of proposed processes into current practices while minimizing disturbances to work routines. AbPI can be used to estimate the impact of integrating the activities on the satisfaction of users and on performance and organizational goals.

## 1.2 Motivation

There are two major motivations of this thesis.

- 1) **Context-driven research:** Briand et al. (2017) and Briand (2012) argued that in a practical field such as Software Engineering, which relies intensively on customers and industry, studies shall be driven by industry needs tailored to a certain context.

Context-driven research makes clear assumptions and a well-defined context in addition to achievable objectives and attainable results. As I share the same beliefs, I had an internship (as a Requirements Analyst) at a Canadian hospital for six months before I established the work of my thesis. My mission was to meet physicians, identify the issues in a certain context, gather their requirements and needs, and map them to a set of off-the-shelf technologies. According to the mapping results and the analysis of the requirements/goals, I reported on the technologies that could be used in this context. During my work, I observed that there is little work done to gather and analyze requirements, especially user requirements, of all involved stakeholders/users in different units, which leads to users who are either strongly against proposed changes or strongly in favor of seeing them implemented. The main issue the premature discussions of solutions before identifying current issues and user needs. Also, the lack of an achievable vision, long-term values, and reasons for new changes did not help to negotiate the changes successfully with some groups. Resistance to change was a big obstacle due to the different computer literacy levels, urgent needs, and current goals of each unit. Accordingly, I built my thesis work around providing a flexible integration of new changes into current workflows/processes, where the current situation, processes, and goals/needs of different units are captured and modelled, resulting into integration alternatives. Each alternative would be evaluated against stakeholder goals, hospital goals/long-term values and performance objectives to find the best process integration alternative. I discussed the initial idea of the thesis topic with information technology (IT) managers and caregivers at the hospital. Both groups agreed with my approach because they want to be fully engaged in introducing changes and be able to see a holistic picture of the situation, including the interests of other units. In addition, I discussed this approach with some healthcare key informants, who occupied different positions in the administration, and I received encouraging and motivating feedback to start developing the approach.

- 2) **Challenges explored in the literature review:** When comes the time to introduce a new technology or e-system into a healthcare environment, there exist several grand challenges that are discussed but not entirely solved yet.

- Multiple views: a healthcare environment offers multiple views of processes that are performed across different units, including clinical pathways and administrative processes. E-systems are often handled, from development to implementation, as a distinct perspective and not as a part of these processes. As a result, e-systems or software artifacts are often seen as a nice (and at times even undesired) addition, but not as a mandatory part of the process (Landi-Lewis et al., 2015; Alkhalidi et al., 2014; Weber-Jahnke et al., 2013).
- Integration with current practices: many healthcare organizations *acquire* e-systems instead of developing them in-house. At the same time, caregivers already follow clinical/business workflows. In most cases, introducing a new e-system disturbs workflows caregivers are familiar with and brings undesirable changes (Holden 2011; Weber-Jahnke et al., 2013).
- Translating user requirements to technical requirements: there is a gap between what users need, what the context requires, and how a new e-system has to fulfill these needs and requirements (Vermeulen et al., 2014).
- User acceptance and long-term value: users frequently resist changes or try new solutions for many reasons. One of the main reasons is that users do not see the long-term value behind those changes. Currently, engaging users in early phases of designing or integrating e-systems into existing processes does not go beyond gathering their requirements (Holden 2011).
- Enhancing performance: one of the intended usages of e-health systems is to enhance the performance of healthcare personnel by performing tasks efficiently. However, most caregivers think that technology is time-consuming and prevents them from doing their real job (Holden, 2011).
- Usability: for caregivers, one major problem is that systems are often unusable and do not achieve what they are intended to be used for (Hardiker, 2010; Holden, 2011; Weber-Jahnke et al., 2013).
- Requirements engineering practices are standardized and regularly used in other areas such as telecommunication and automotive systems. The use of RE in healthcare is however not as mature as in these fields.

In this context, as seen observed the literature and in practice, the healthcare field is lacking solutions that combine different views of stakeholders' intentions, organizational goals, technology, and current practices to support better analysis and decision making at the level of requirements. Essentially, one needs to consider all these perspectives to ensure better user satisfaction, goals prioritization, effective integration with current workflows, and effective reasoning about trade-offs. The literature review presented in Chapter 2 illustrates the paucity of research on process-related requirements engineering practices in healthcare, and will highlight the gap between delivering new e-systems and meeting user and organizational goals in healthcare (Alkhaldi et al., 2014; Pagliari 2007; Vermeulen et al., 2014). Also, Chapter 2 discusses change management where the focus, mainly, is on capturing contextual concepts and capabilities to derive changes, and metrics/methods to guide and evaluate implementations of changes. Although, studies stated that some essential concepts such as organization values, stakeholder engagement, and considerations for current processes are important things to capture throughout the change management process, current practice does not systematically or formally address how to capture, analyze, trace and demonstrate the effect of one of those concepts on another or on the process to be improved. I hence observed an opportunity to introduce RE-based practices to the healthcare domain and to use them in combination with change management methods to provide comprehensive coverage/analysis of the context in which a change is introduced.

Another motivation is that, due to the lack of academic studies done in this field, there is little insight available on the usability of requirements engineering frameworks in healthcare. The more RE-based approaches are published without usability studies, the more the gap between industry and the RE field grows. In addition, there are no clear reasons why requirements engineering is not widely researched (and maybe even used) yet in healthcare when many studies emphasize the importance of RE in that domain.

### **1.3 Research Questions**

This thesis addresses two main research questions related to the use of a new RE-based process integration technique (AbPI) in healthcare:

**RQ1.** In healthcare, to what extent does the AbPI framework help:

- a) modelling and reasoning about how a new process can be integrated efficiently into current processes while providing integration alternatives?
- b) modelling and reasoning about goals, requirements, processes, and constraints of multiple stakeholders and units that are involved in the integration context?
- c) estimate the impact of the integration on user satisfaction and on the achievement of business and organizational goals?

**RQ2.** What is the usefulness and usability of the proposed AbPI framework as perceived by healthcare practitioners?

## 1.4 Methodology

In order to have efficiently-conducted research, an adequate research methodology that suits the problem context and the means of solving the problem should be followed. Due to the nature of this thesis, which involves business and organizational infrastructures and a novel, technology-oriented solution, the *Design Science Methodology in Information Systems (IS)* has been chosen as a basis this thesis' methodology.

The design science methodology in IS combines two complementary methodologies: *behavioural design* and *design science*. Whereas behavioural design focuses mainly on developing and verifying theories and methodologies, design science focuses on the originality and innovation of artifacts to extend knowledge (Hevner et al., 2004). This combination suits the IT field where an artifact should be produced with considerations to existing knowledge in the discipline and should be produced creatively to solve real-world problems. Each artifact produced and validated through the design science methodology should meet seven guidelines summarized in Figure 1. The framework of this methodology is highlighted in Figure 2.

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Figure 1 Design Science in IS guidelines (Hevner et al., 2004)

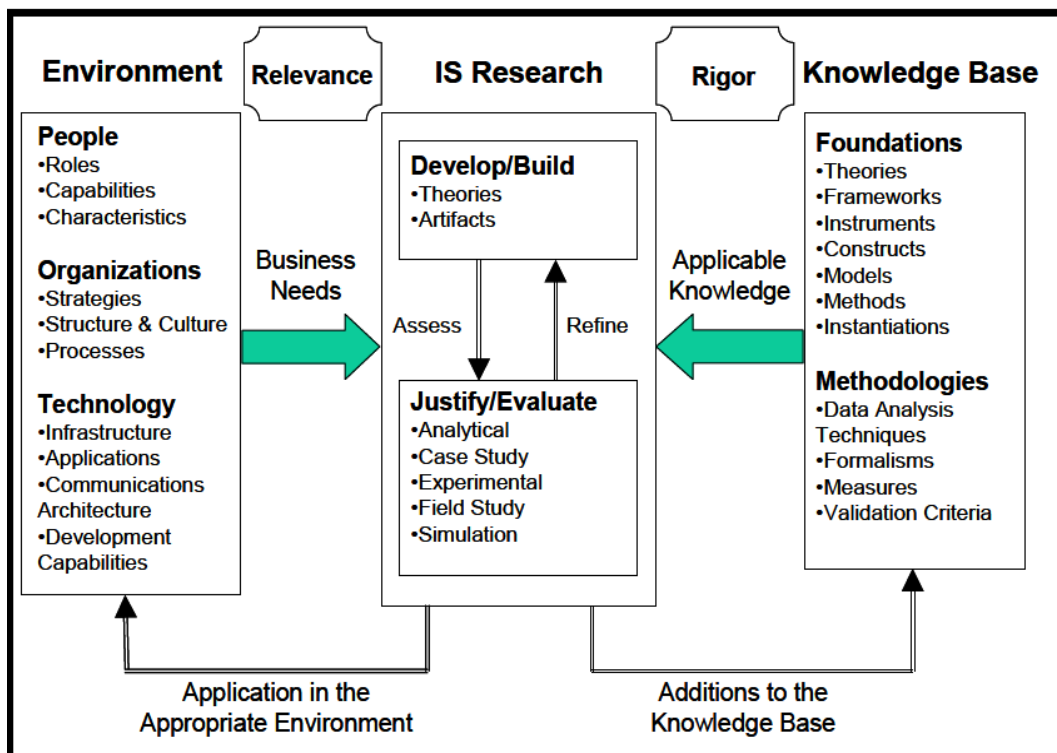
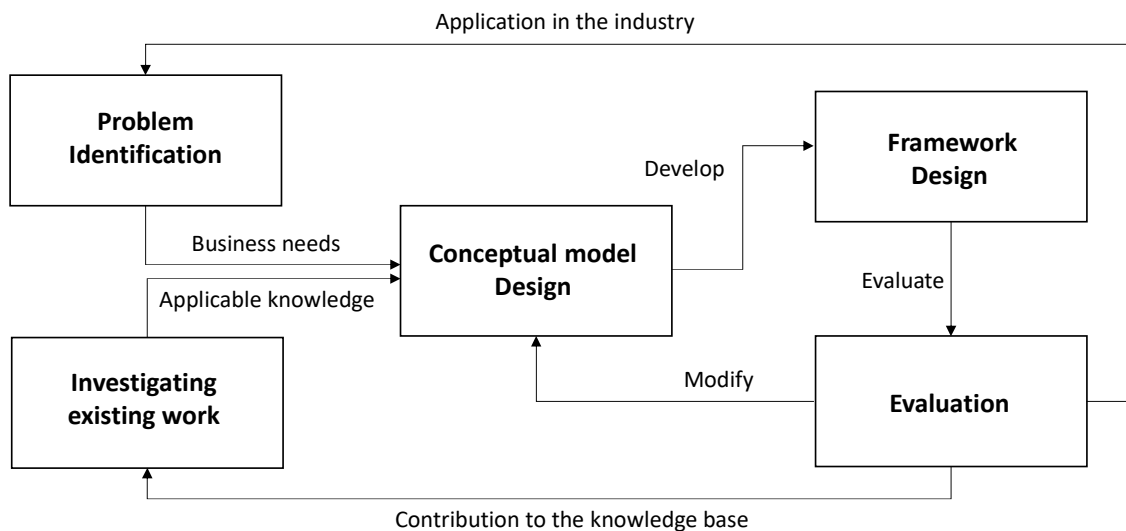


Figure 2 Design Science framework (Hevner et al., 2004)

As seen in Figure 2, there are two elements that feed the IS research component. The first one is the environment in which we find people, organizations, existing approaches, problems to solve, or performance to improve. The second component is a knowledge base composed of foundations and methodologies related to a potential artifact to improve or design. The IS research component represents the internal cycle of designing an artifact that has two overlapping phases: development and evaluation. It is essential in design science to develop an artifact that is relevant to the environment intending to adopt it and that is rigorously connected to the knowledge base in the same domain.

The thesis methodology has adapted the design science methodology as shown in Figure 3:



**Figure 3** Thesis methodology

As Figure 3 presents, there are five phases in the methodology used in this thesis:

- **Problem identification:** this is the first phase where the problem of lacking requirements engineering practices in healthcare and the associated consequences are identified. I spent six months (internship) working at a Canadian hospital to investigate the problem closely. One particular problem in that area, highlighted in Section 1.2, is the lack of rigor in the integration of new technology and their processes with the aim to improve existing healthcare processes. This phase corresponds to Guideline 2 in Figure 1. As for Guideline 1, the main design artifact targeted in this

thesis is a framework (AbPI, including methods and partial tool support) addressing this particular problem.

- **Investigating existing work:** in this phase, two literature reviews are done to explore existing work in the field of study and to highlight gaps to be filled. It is also important in this phase to gain an understanding of the requirements engineering process integration practices used in hospitals. In addition, existing change management approaches were studied too. This is in line with Guidelines 2 and 5 in Figure 1. The collected data and the knowledge gained in this phase and the previous phase (problem identification) were the input to the following phase.
- **Conceptual model design:** after completing the previous steps, the elements of the context of study should be identified along with their relationships and attributes. They are captured and formalized in a process integration conceptual model. This phase corresponds to Guideline 4 in Figure 1.
- **Framework design:** in this phase, we instantiate the conceptual model elements and relationships into the framework components, methods and expected input/output artifacts in a way that contributes to solving the identified problem (integrating new processes effectively into existing processes) and that improves on existing work. This phase also corresponds to Guideline 4 in Figure 1.
- **Evaluation:** this phase overlaps with the conceptual model design and framework design phases, in line with Guidelines 3 and 5 in Figure 1. They both have to be evaluated iteratively so evaluation results are to refine the conceptual model and the framework, as suggested by Guideline 6 in Figure 1. The evaluation has to test three aspects: the correctness of the conceptual model (which has to reflect real-world problems), the technical feasibility of the framework and its usefulness in solving the original problem, and the usability of the framework (would it be usable in a healthcare context). Table 1 illustrates the iterations between the evaluation and design steps, where each of the last three iterations builds on the previous ones.

The way in which the design science methodology in IS of Figure 2 is adapted here can be seen in the phases of the thesis methodology. The problem identification phase provides the first component of design science, i.e., the environment needs. The phase focusing on



the existing work investigation is related to studying the knowledge base component and use it in the design phase. Finally, the last three phases (conceptual model design, framework design, and evaluation) are equivalent to the IS research component, where the business needs and existing knowledge are used to build the conceptual model and the framework, and where the evaluation results in modifications to the designed artifact, contributions to existing knowledge, and applications in industry.

**Table 1** Iterations between the evaluation and design steps

Iterations	Description	Results
<b>Iteration 1</b>	Showing the initial framework and conceptual model to key healthcare informants.	Modifications and refinements to the framework and conceptual model.
<b>Iteration 2</b>	Evaluating the modified framework with a case study (lab sample monitoring).	Modifications and refinements to the framework. Limitations and technical challenges.
<b>Iteration 3</b>	Evaluating the modified framework with another case study (voice recognition system).	Modifications and refinements to the framework. Limitations and technical challenges.
<b>Iteration 4</b>	Evaluating the modified framework with a usability study.	Results of the usability study, limitations and technical challenges.

## 1.5 User Requirements Notation (URN)

AbPI makes use of the *User Requirement Notation* (URN) to formalize and provide a syntax for its concepts. This enables existing modelling and analysis tools to be reused.

URN is a modelling language used to model, elicit, analyze, specify, and validate requirements in the form of goals and processes. It was standardized by the International Telecommunication Union (ITU), first in 2008 and then with a revised version in 2012, which now includes indicators. URN represents requirements in a graphical, semi-formal form to facilitate understanding and communication with users and other stakeholders. In addition, it provides analysis techniques that help to resolve and highlight inconsistencies, incompleteness, or conflicts in requirements. URN has been used in many studies of goal and process modelling such as process improvements (Pourshahid et al., 2013) and pattern families that reuses domain knowledge captured by goals and processes (Behnam and Amyot, 2013).

URN combines two complementary sub-languages: the *Goal-oriented Requirement Language* (GRL) and the scenario-based *Use Case Map* (UCM) notation. GRL is used mainly to model actors and their intentions (including non-functional requirements) whereas UCM is used to specify operational and functional requirements as processes. They both can be used to reason about different design alternatives with regards to user, business, and organizational goals. In addition, GRL key performance indicators enable modellers to capture and reason about real-world values in a way that links them to goal satisfaction in the rest of the model (Pourshahid et al., 2012). URN also includes the concept of concern, where a concern can be a set of related GRL and/or UCM models.

There are other requirements and process modelling languages such as the Business Process Model and Notation (BPMN) and Unified Modeling Language (UML) activity diagrams (OMG, 2017), and goal modelling languages such as the *i\** framework. However, none of them provides both views of goals and processes in an integrated way. Pourshahid (2014) compared different approaches for goal and process modelling. URN was the most comprehensive one because of two reasons: 1) having both views of goals and processes standardized and linked to each other, which leads to more effective trade-off analysis between goals and processes; 2) URN indicators are a useful concept for measuring performance and for analyzing the impact of processes and decisions on business/organizational goals. These are the main motivations behind the use of URN to formalize the thesis' AbPI framework.

GRL provides a graphical representation of functional and non-functional requirements and shows trade-offs among stakeholder's intentions. GRL models can help answer *why* and *what* questions, for example: *what are the alternatives available to satisfy a set of goals?* and *why is this alternative better than the other?* In addition, the main objective of GRL models is to give a high-level perspective and understanding of user requirements, of business requirements, and of the context in which these requirements apply (see Appendix B for more details about the elements of a GRL model and GRL evaluation strategies).

UCM is a means to model processes reflecting the behavioural structure of functional and operational goals. UCM's graphical representation describes processes as responsibilities (tasks, activities, etc.) along paths, which can be allocated to components (including stakeholders, systems, and sub-systems). UCM processes can be formalized

(with data and conditions) in a way that enables validation based on the traversal of scenarios, as well as transformations to other representations (see Appendix C for more details about the elements of a UCM model and the traversal algorithm).

## 1.6 Thesis Contributions

There are two contributions in this thesis:

- Major contribution: an *Activity-based Process Integration (AbPI)* framework that introduces to the healthcare domain existing and new requirements engineering practices to solve a major problem related to *process integration*. The approach relies on a combination of different views (models of existing processes and practices from multiple units, stakeholder needs, organizational goals, performance objectives, and constrains/criteria) to lead to an effective integration of a new process (in a way that satisfies users/stakeholders and achieves organizational goals) and to enable rigorous decision support. This contribution consists of the following sub-contributions:
  1. A *Goal Integration Method* that integrates goal models of the organization and of the new technology/process to integrate, in order to reflect the global integration context.
  2. An *Integration Method* that enables an incremental integration of existing processes in the organization with a new process (accompanying a new technology), and that provides integration alternatives.
  3. An *Alternative Evaluation Method* to discover conflicts and perform trade-off analysis on the integration alternatives to support multi-criteria decision making.
  4. A *Distance-based GRL Approach* exploiting multi-criteria decision analysis algorithms to rank GRL strategies, which can be used to rank integration alternatives possibly leading to goal and process model modifications.
  5. A *Data Quality Tagging and Confidence Propagation Mechanism* to compute the confidence in the satisfaction levels of stakeholders and their goals according to the quality of the sources of data.

6. Formal descriptions of the proposed methods, including a conceptual model, a profile of the User Requirements Notation used as a concrete syntax, algorithms for the methods exploiting the models, and prototypes implementing these algorithms.
- **Minor contribution: *AbPI framework usability study*.** As will be demonstrated in Chapter 2, there are a few methodologies that combine both requirements engineering and process modelling, but none of them conducted a usability study of their work. The usability study provides insight on the following:
    1. The perceived usefulness and effectiveness of the AbPI framework.
    2. The usability of the AbPI methods measured according to the correct usage of the methods as well as perceived ease of use and efficiency.
    3. The expected value of AbPI for adopting new processes in practice in healthcare.
    4. Recommendations and pitfalls.

In line with Guideline 7 of the design science methodology in Figure 1, results of this research have already been communicated. So far, there are three publications directly extracted from this thesis, with others being planned (for the formalization, case studies, usability study, and confidence evaluation in goal models). I am first and most-contributing author of these papers.

- **Baslyman M.,** Almoaber B., Amyot D., and Bouattane E.M. (2017) Activity-based Process Integration in Healthcare with the User Requirements Notation. *E-Technologies: Embracing the Internet of Things (MCETECH 2017)*, LNBIP 289, 151–169, Springer (2017).
- **Baslyman M.** and Amyot D.: A Distance-based GRL Approach to Goal Model Refinement and Alternative Selection. In: *7th International Workshop on Model-Driven Requirements Engineering (MoDRE)*, REW2017, 16–20. IEEE CS (2017b).
- **Baslyman M.,** Amyot D., Almoaber B., and Bouattane, E.M.: Using Goals and Indicators for Activity-based Process Integration in Healthcare. In: *7th Int.*

*Conf. on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH 2017)*. Procedia Computer Science, Volume 113, 318–325, Elsevier (2017c).

In addition, I was invited to present the thesis work at Montfort Hospital:

- Presentation and discussion of the AbPI framework with the Lean project management team (April 2017).
- Presentation of the AbPI framework to administration and project management coordinators (November 2017).
- Presentation of the AbPI framework and results to the Montfort Knowledge Institute Vice-President and Directors (August 2018).

## 1.7 Thesis Outline

The rest of this thesis is organized as follows:

- **Chapter 2:** presents a two-part literature review about process-related requirements engineering in healthcare, and about requirements engineering and process modelling in general. Change management in healthcare is also discussed.
- **Chapter 3:** discusses the proposed AbPI conceptual model and framework. AbPI uses goal and process models as inputs and outputs. In addition, this chapter explains the goal integration, process integration, and evaluation methods, along with illustrative examples.
- **Chapter 4:** presents a new approach for computing and propagating goal satisfaction confidence in goal models, based on data quality. The chapter includes examples and a formal description of the approach, with tool support.
- **Chapter 5:** introduces a new Distance-based GRL approach to guide multi-criteria alternatives selection in goal models. Algorithms and illustrative examples are also provided.
- **Chapter 6:** presents an implementation of the framework using the User Requirements Notation, supported by the jUCMNav tool (Amyot et al., 2012).

- **Chapter 7:** explains the evaluation plan, composed of two case studies and a usability study.
- **Chapter 8:** presents the first case study: *Lab Sample Monitoring* in a Saudi hospital.
- **Chapter 9:** presents the second case study: *Voice Recognition System* in a Canadian hospital.
- **Chapter 10:** discuss the usability study conducted in a Canadian hospital to evaluate the usability and effectiveness of the proposed framework.
- **Chapter 11:** discusses some of research challenges and interesting observations, and threats to validity and limitations.
- **Chapter 12:** concludes the thesis, recalls contributions and discusses future work.

# Chapter 2 Literature Review

---

This chapter provides a literature review of three main topics. The first part of the review explores process-related requirements engineering approaches used in healthcare. The second part presents requirements engineering and business process integration and alignment approaches outside healthcare. The steps of these two first reviews are inspired from the systematic literature review guidelines of Kitchenham (2004); however, they are not systematic literature reviews. The initial review results were also refreshed in 2018. The third part recalls some of the main change management approaches in healthcare, including the Lean approach.

## 2.1 Process-Related Requirements Engineering in Healthcare

Five major phases (area of interest, criteria, query, filters, and results) were followed while conducting this first part of the literature review. There were several iterations involving these phases until the final results were obtained.

### 2.1.1 Review Methodology

#### **Area of interest**

This review investigates work being done in healthcare that combines the field of requirements engineering and the field of process modelling in the context of process integration.

This review is an attempt to answer the following questions:

*Q1: What work was done in healthcare that considered both requirements engineering practices and existing workflow/processes to solve a problem or introduce new processes, changes, or improvements?*

*Q2: In which contexts was such work proposed?*

## Criteria

The following criteria were inspired from the problem context that was discussed in Chapter 1. These criteria, which were used to evaluate the relevance level of studies to the two questions, are presented in Table 2.

**Table 2** First literature review's selection criteria

ID	Criteria
1	The work shall have used requirements engineering techniques along with process modelling to introduce a new process or e-system. There are sub-criteria here: 1.1, 1.2, 1.3, and 1.4.
1.1	The work shall have considered existing workflows or current practices
1.2	The work shall have been done in the context of process integration, process alignment, or process re-engineering.
1.3	The work shall have proposed new processes or services
1.4	The work shall have considered users/stakeholders requirements/needs, as well as business/performance, and organizational goals.
2	The work shall have been validated (by a user study, case study, or any other validation approach).
3	The work shall have proposed a methodology
4	The work shall have been done in a multidisciplinary environment or across multiple units.
5	The work shall have been done in healthcare.

The results of the search queries are grouped into three categories:

1. Relevant: if the work satisfied all criteria (1 to 5).
2. Partially relevant: if the work missed one or more but not all of the criteria (healthcare is mandatory)
3. Not relevant: if the work was not in the healthcare domain or was not considering both requirements engineering and current workflows, processes, or practices.

## Query

Two general queries on titles/abstracts/keywords were used to obtain the results:



1. TITLE-ABS-KEY("requirements engineering") AND TITLE-ABS-KEY("workflow" OR "process" OR "pathways") - limited to medicine
2. TITLE-ABS-KEY("requirements engineering") - limited to medicine

The two queries were performed on three general, large-scale databases, covering the scientific and medical literature: Scopus (largest database of peer-reviewed literature, including journals and conferences), PubMed (Medicine and Healthcare-specific database), and Web of Science (covers major journals in Engineering/Computer Science, Healthcare, and Management). No time limit was enforced. As the result of the first query on Scopus contained only 44 papers, it was decided to add a wider query (the second one) to cover all requirements engineering practices in healthcare. Then, manual filtering was performed based on the selection criteria in Table 2.

### **Filter**

This phase is composed of three sub-phases aiming to select the relevant papers resulting from the previous search queries.

- 1- Abstract: the filtering process starts by focusing on the abstracts. If a paper's abstract seems to be relevant or partially relevant, the paper is transferred to the second phase; otherwise, it is excluded.
- 2- Introduction and method: the introduction and the methods of papers transferred from the previous step were read. Relevant papers were transferred to the final step.
- 3- Full paper: in this step, all sections of the papers unfiltered by the previous steps were read. The relevant or partially relevant papers are presented in this chapter as a result.

### **Results**

Table 3 illustrates the returned results, from the selected databases, of the literature review process and the final number of papers that have satisfied the selection criteria. It is worth mentioning that the results of the second query 2 cover the results of query 1.

**Table 3** Summary of RE for process integration in healthcare-related work

<b>Query 1: TITLE-ABS-KEY("requirements engineering") AND TITLE-ABS-KEY("workflow" OR "process" OR "pathways") - limited to medicine</b>		
<b>Results</b>	<b>Relevant</b>	<b>Partially relevant</b>
75	4	5
<b>Query 2: TITLE-ABS-KEY("requirements engineering") - limited to medicine</b>		
<b>Results</b>	<b>Relevant</b>	<b>Partially relevant</b>
139	4	5

The second query did not result in additional papers compared to the first query. The four relevant papers are from Timpka et al. (1995), Teixeira et al. (2010), Hayes et al. (2011), and Weng et al. (2013). The nine relevant and partially relevant papers are discussed in Section 2.1.2.

### **2.1.2 Requirements Engineering and Process in Healthcare**

One of the very early attempts to consider requirements engineering in developing processes in healthcare is the work of Timpka et al. (1995), which aimed to design a hyper-media guidelines book in a Primary Healthcare Center in Sweden. There were three phases in this work: 1) The exploratory phase: gathering and generating requirements document by meeting and interviewing the medical personnel and requirements experts, and designing system mock-ups; 2) The experimental phase: integration of the current system into a workplace scenario and evaluation of the integration result against the previously collected information; 3) The evolutionary phase: decision made by the stakeholders on the current system to use as a basis for the system design and implementation. The results of the study showed that one of the challenges in designing systems in a multidisciplinary healthcare environment is that systems may challenge habitual routines and seem to break traditional organization boundaries.

More recent work from Teixeira et al. (2010) attempted to show how human and non-technology factors can be used to enhance requirements engineering in the design process of a web-based hemophilia information system. Teixeira et al. used both a user-centered design approach and grounded theory to gather user and organizational requirements about the context and the process. Then, they used three methods to complete the requirements: 1) use case development in UML, 2) task analysis, and 3) prototyping. UML use

case diagrams were used to model objects and their interactions in real-life situations. Then, they created a domain model to apply task analysis by walking users through some scenarios and tasks. Finally, they created a prototype interface to check user understanding. The results of the study showed that combining these approaches provided an opportunity to look at the process from different angles and decide on the critical requirements, but that this combination was time consuming. In addition, Teixeira et al. confirmed that it was hard for healthcare providers to express their needs and to understand abstract models in UML.

Hayes et al. (2011) proposed the use of a narrative networks representation to analyze the adaptation variability of new technologies. They claim that this approach is better than traditional process modelling such as Business Process Modelling (BPM) because it considers multiple views and provides a generic, but comprehensive, overview of the process. They applied these concepts to an electronic medical record (EMR) project at Uni-Hospital that aimed to develop one EMR across the hospital. The study was conducted in two phases: 1) gathering requirements and required data through interviews and observations; and 2) identifying and modelling exemplar processes with different point of views to explore narratives, actants, and actions. Hayes et al. had two case studies: patient scheduling, and records management & chart delivery. They reported that the approach is effective and they recommended using it with traditional process modelling approaches because it is only a representation means used to assist in analysis and decision making. The results also show how the surroundings (human behaviour or the context) could change due to new technology adaptation, but the authors did not assess the effect of these changes on the organizational goals or stakeholder satisfaction.

Weng et al. (2013) proposed multi-constraints user satisfaction rules and a resource optimization algorithm to coordinate patient care visits with clinical research visits. Hence, patient visits scheduling to the research center and clinics is automated to eliminate redundant visits or data. First, the authors collected data about current scheduling systems. Then, they defined the rules for scheduling optimal visits (for both users and clinics) and optimizing resources. The automated scheduling system was pulling required information from both a clinical research calendar and patients clinic visits scheduling. Weng et al. developed a prototype, which has schedule – reschedule – cancel as core features, to evaluate the

system with users. The evaluators were pleased at the result and at the system's ability to synthesize and organize visits information.

The next five papers are the ones identified as partially relevant in Table 3. Wilk et al. (2008) introduced a framework to support clinical decision named MET-A<sup>3</sup>Support. The Organization-based Multi-agent System Engineering (O-MaSE) process framework is used for requirements engineering, analysis, and design. These three tasks aim to develop a goal model, formalizing a domain model with possible agents and their interactions, and defining agent classes with protocols. They applied these three activities to develop MET-A<sup>3</sup>Support.

Similarly, in the context of decision support systems, Grando et al. (2012) proposed a framework that guides medical decisions based on medical guidelines, and identifies facilities that could help in the decision process (caregiver skills, for example). They modelled the workflow, tasks, goals, and roles using the COGENT system. The system suggests changes in the workflow to meet the medical goals of the context, and decide the role needed and available to accomplish better care quality. The prototype of the system showed positive results, however, one of the challenges was modelling goals (goals were still implicit and not prioritized).

The question that Hübner et al. (2012) studied was *“how to appropriately capture information and process requirements that are both generally applicable and practically useful”*. There are two contributions here: 1) collecting requirements and information about the current practices by conducting experts' interviews and Delphi surveys along with collecting medical guidelines about the topic from databases; and 2) modelling the collected information using UML. Prior to the modelling, the authors studied what approach among UML, BPM, and Event-driven Process Chains would be better given a group of criteria. They chose UML as it is well standardized and offers exports mechanisms to convert it to BPM.

Damas et al. (2003) focused on modelling different workflows of different units and pathologies based on non-functional requirements. They proposed two categories of logical operators: composition and decomposition. Composition operators are used to compose Message Sequence Charts (similar to UML sequence diagrams) for intersectional pro-

cesses and tasks; whereas, decomposition operators are used to separate irrelevant components from the charts in order to manage separation of concerns. Then, a labeled transition system logic is applied to demonstrate the transitions between activities.

Staccini et al. (2001) attempted to illustrate patient-centered processes. They intended to apply enterprise business processes to analyze current activities and understand a hospital's organization. The methodology they proposed consists of two phases. The first phase is requirements elicitation. They used existing processes and resources to extract the requirements of a new system and to define the relationships between the artefacts. In addition, they extracted dependencies, actors, and timing information. In the second phase, Staccini et al. used the gathered data and requirements to describe the system data types, structure, flow, users, and utilisation profiles.

## **2.2 Requirements Engineering and Business Processes**

Due to the limitations in the results found in the previous section, it was decided to search in general (i.e., not limited to healthcare) about the use of requirements engineering in integrating a new business/IT process into existing ones.

### **2.2.1 Review Methodology**

The strategy explained in Section 2.1.1 was also used here, only this time with only one large-scale database (Scopus, the most comprehensive source).

#### **Area of interest**

The intent here is to investigate work that combines the field of requirements engineering (and especially goal modelling) and the field of process modelling or process integration. This second part of the literature review is an attempt to answer the following questions:

*What work was done that considers both views of requirements engineering practices, goal modelling, and existing workflow/processes to solve a problem or introduce changes or improvements, and in which contexts was such work proposed?*

#### **Query**

One query is used (the Scopus syntax is used here):

```
( TITLE-ABS-KEY ( "requirements engineering" ) AND  
  TITLE-ABS-KEY ( "business process" OR "workflow" ) AND  
  TITLE-ABS-KEY ( "goal" ) )
```

AND

```
( LIMIT-TO ( LANGUAGE , "English" ) )
```

AND

```
( LIMIT-TO ( SRCTYPE , "p" ) OR LIMIT-TO ( SRCTYPE , "j" ) )
```

Note that on the last line about source types, the “p” stands for proceedings and the “j” for journals.

### **Criteria**

Four criteria were used for choosing the related work in this section:

1. The work shall have used requirements engineering techniques along with process modelling to introduce a new process or system. There are sub-criteria of this criterion:
  - a. The work shall have been done in the context of process integration, processes alignment, or re-engineering processes.
  - b. The work shall have considered existing processes and practices.
  - c. The work should have considered users/stakeholders requirements and satisfaction levels, business and organizational goals, and the impact on current performance levels.
3. The work shall have been validated (by a user study, a case study, or any other validation approach)
4. The work shall have proposed a methodology.

The results of the search queries are grouped under three categories:

1. Relevant: if the work satisfied all four criteria.
2. Partially relevant: if the work missed one or more of the criteria while still combining the two views of requirements engineering and process modelling.
3. Not relevant: if the work was not considering both requirements engineering and current workflow, process, or practices, or was not combining the two views of requirements engineering and process modelling.

## **Filter**

The same three-step filtering approach introduced in Section 2.1.1 was used here.

## **Results**

The query resulted in 105 papers of which 6 new ones were relevant (Santos et al., 2010; Ullah and Lai, 2011a; Kuziemyky et al., 2010; Bleistein et al., 2006; Decreus and Poels, 2010; Zlatev et al., 2005) and 4 new ones were partially relevant (Rungworawut et al., 2007; Pourshahid et al., 2013; Nagel et al., 2013; Ullah and Lai, 2011b). The results are grouped based on the context in which they were proposed: approaches for improving and (re)designing business processes, and approaches for aligning IT systems with business processes.

### **2.2.2 Approaches for Improving and (Re)Designing Business Processes**

Santos et al. (2010) proposed a variability analysis approach to update business strategies or transform them into software. The Business Process Model and Notation (BPMN) is used for specifying business strategies and goal-oriented modelling is used for capturing goals. First, the authors develop a goal model based on knowledge from existing business processes. The variability analysis approach starts with inquiring goals about variability concerns such as agents, time, and conditions. Then, it identifies the possible alternatives for configuring a business process using the result of the previous phase. Santos et al. also identify relationships between goals in alternatives that are dependencies or exclusions (i.e., achieving one goal will exclude the other). The analysis approach may go from the process alternatives to the goals (i.e., bottom-up), or go by selecting goals and searching for the alternatives that satisfy the goals (top-down). This approach was not validated, but it was demonstrated using examples. The authors mentioned that the study did not investigate the variability of requirements itself due to the complexity of this aspect.

Rungworawut et al. (2007) proposed the use of genetic algorithms (GA) to suggest the best requirements satisfying the design of business process components. The managerial goals they considered in this study are: cost, ease of assembly, customization, reusability, and maintainability; whereas the technical features of process components design are: intercomponent coupling, intercomponent cohesion, component size, complexity, and number of components. The previous goals and features are used to develop a BusCode

model that serves as a fitness function in GA. The optimal solution is the chromosome with the highest BusCode index value. The paper recommends the use of GA with BusCode as a supportive tool to find the optimal process components design because the design process is artistic and needs analysts and domain experts interacting to make better decisions.

Kuziemy et al. (2010) used the User Requirements Notation to show the possible impact of healthcare information systems (IS) on operational business processes and business goals. The proposed methodology consists of five steps: 1) develop the goal model and define dependencies and stakeholders; 2) assign key performance indicators to each goal in order to measure its satisfaction level; 3) develop use case models to illustrate scenarios that are used to identify the impact point of the new IS with regards to tasks, goals, and measures; 4) analyze two cases: the current situation with changes introduced by the new IS, and the current situation without the proposed system with respect to the tasks and goal; 5) assess the alternatives continuously. They applied the framework on a palliative care process and the results showed that the framework was effective in identifying and prioritizing indicators to decide whether to implement or resist the proposed changes.

As the industry is facing several challenges coping with rapid changes and updates in provided services, Zlatev et al. (2005) suggested the use of Information and Communication Technology to help organizations adjust to current needs. They proposed a framework that introduces the use of requirements engineering methods in the context of e-commerce business processes. The framework has three perspectives: economic value, business process, and application communication. Initially, the framework uses a set of business processes to extract patterns. Patterns are composed and validated or modified based on a tree of business and system goals. Then, a new business process is proposed (the framework uses UML activity diagrams to represent business processes). At the end, the three perspectives are used to analyze the outcomes. The aim of this approach is to provide process and communication patterns to discover a new business idea.

Another interesting work proposed by Pourshahid et al. (2013) defines a set of improvement patterns to identify improvement opportunities in business processes that may lead to more effective and efficient performance. The authors used GRL-URN to model performance and business goals, and UCM-URN to model business process. They designed the patterns using Mussbacher's Aspect-oriented URN (AoURN) language (Mussbacher,



2013). The main objective of this approach is to reason about trade-offs and alternatives to choose the ones that improve current business process the most. This is done by the use of key performance indicators (KPIs) that provide real-world values. The main drawback of this approach is the complexity of using AoURN and aspect-oriented modelling in general.

Nagel et al. (2013) suggested deriving business process models from business goals models designed with Kaos4SOA, which extends the KAOS framework (van Lamsweerde, 2001) and considers dependencies between goals and stakeholders to be used in generating business processes. The main idea is to extract constraints (in their Extended Process Pattern Specification Language) based on the dependencies between goals to verify the generated processes. They used a model-checking technique to validate the model against the generated constraints. They developed the Kaos4SOA Workbench to apply these concepts.

### **2.2.3 Approaches for Aligning IT Systems with Business Processes**

Bleistein et al. (2006) addressed the alignment of requirements with competitive business strategies. They proposed a *Business Strategy, Context, and Process* (B-SCP) framework that has three themes: business strategy (how to use IT to compete within its market?), context (what are the organizational/business structure?), and process (what are the business activities, role, entities, etc.). They used the *i\** goal modelling language (Yu, 1995) to represent business strategy as requirements, Jackson's context diagrams to represent the business context, and activity role diagrams to model process. They map activity role diagrams to goals models and context diagrams through cross-referencing mapping rules. Analysts can then check whether the business process belongs to the intended business context and meet its business goals. Bleistein et al. evaluated the approach using a case study, which highlights the complexity of their approach, especially with demonstrating business strategies.

Ullah and Lai (2011) demonstrated a business goal-driven requirements engineering approach to derive system requirements from business goals, in order to improve IT alignment with organizational objectives. The approach starts with modelling organizational values, objectives, actor responsibilities, and resources using three different modelling views: activity model, architecture model, and resource model. Then, one must create links between the business infrastructure and the IT infrastructure. Following this, conflicts

between business goals and extracted system requirements are resolved. At the end, two UML diagrams are developed: 1) a sequence diagram to specify valid system requirements; and 2) a statechart diagram to explain what the system exactly has to do. The study claims that the approach is very successful in aligning IT with business goals. To support this claim, Ullah and Lai evaluated the framework with a case study (a customer order management process in an automobile company). The case study revealed that the approach has many limitations such as having to model a complete business process before implementing the methodology. As a result, some business processes were not explained completely because managers were unable to do so due to a lack of IT knowledge.

Decreus and Poels (2010) contributed to aligning business processes with strategic requirements using a B-SCP metamodel (which illustrates objectives, requirements, activities, and rules of the problem context), an Eclipse-based B-SCP editor, and the automated generation of BPMN models. The proposed approach has four steps: users create B-SCP models, users add control flows to the created models, users transform the models to BPMN skeletons, and analysts ensure the validity and consistency of the transformed models. The main limitation of this study is the lack of validation.

Table 4 summarizes the work presented in the first two parts of the literature review and compares them according to the pre-defined criteria from Section 2.1.1. As seen in this table, in healthcare, there is a gap in process modelling and user/stakeholder needs, performance objectives, and organizational goals. In addition, goals are rarely considered as measures to estimate user/stakeholder satisfaction levels and performance. On the other hand, there is some work outside the healthcare sector that focuses on the alignment of IT systems with business processes. However, most of that work is either business process-oriented or business goal-oriented, but not both. These studies were often not conducted in a multidisciplinary environment and did not demonstrate the effect of a chosen strategy or design on the satisfaction of stakeholders, and the achievement of goals and performance objectives.

**Table 4** Literature review summary

Related work	(1.1) Considering current practices	(1.2) Process reengineering/ alignment/ integration	(1.3) Proposing new process	(1.4) Users / stakeholders' needs	(1.4) Performance objectives	(1.4) Organizational goals	(2) Evaluation	(3) Methodology	(4) Multidisciplinarity	Context
<b><i>In healthcare</i></b>										
Timpka et al. (1995)	Yes	No	No	No	No	Yes	No	No	Yes	Documenting hypermedia requirements
Teixere et al. (2010)	No	No	Yes	No	No	No	Yes	Yes	Yes	System requirements
Hayes et al. (2011)	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Process variability
Weng et al. (2013)	Yes	No	No	No	No	No	Yes	Yes	Yes	Scheduling system
Wilk et al. (2008)	No	Yes	No	No	No	Yes	No	Yes	Yes	Constructing clinical application at various medical conditions
Grando et al. (2012)	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Medical decisions support and facilities allocating system
Dames et al. (2003)	Yes	Yes	No	No	No	No	No	Yes	Yes	Decomposition and composition of process models' facets
Staccini et al. (2001)	Yes	No	No	No	No	No	Yes	Yes	Yes	User requirements elicitation using process-oriented analysis
<b><i>In general</i></b>										
Bleistein et al. (2006)	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	IT system alignment based on B-SCP
Santos et al. (2010)	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Process variability using a GRL subset and BPMN
Rungworawut et al. (2007)	Yes	No	No	No	No	Yes	Yes	Yes	No	Optimal process components design using GA
Ullah & Lai (2011)	Yes	No	Yes	No	No	Yes	Yes	Yes	No	IT system alignment with business goals
Kuziemsky et al. (2010)	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	IT system alignment with business process using URN
Zlatev et al. (2005)	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Analysis and redesign networked business systems
Decreus & Poels (2010)	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Business process alignment with strategical requirements
Pourshahid et al. (2013)	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Monitoring business performance and proposing improvement patterns using URN
Nagel et al. (2013)	No	No	Yes	No	No	Yes	Yes	Yes	No	Deriving business process from business goals to ensure consistency

## 2.3 Change Management in Healthcare

Change management shares common interests with requirements engineering, especially in the planning and design phases. One of the main aims of both fields is to support and provide rationales behind changes and decisions made. Both fields are essential and complementary to better introduce and manage changes.

One of the pillars of change management models is the *3-Step Model* of Lewin (1943). Lewin provided a model of change that consists of three sequential steps: unfreezing, moving, and refreezing. The unfreezing stage is about creating the urge for the change, meaning getting individuals to agree that the present situation is not valid anymore. Therefore, a change is a must to survive. The moving phase is about identifying what changes and strategies are needed. The last phase, refreezing, is all about stabilizing the change process, ensuring that a new behaviour is well adopted. Lewis also introduced three important theories, namely field theory, group dynamics, and action research, which are used to implement the 3-Step Model (Burnes, 2004).

Most of the fundamental work introduced in this field relates, in one way or another, to the work of Lewin, including Bullock and Batten's (1985) and Kotter's (1995) change management models. Bullock and Batten's model (with four phases: *Exploration, Planning, Action, and Integration*) looked at the change as a technical issue where it can be investigated and mapped to solutions. On the other hand, Kotter presented an 8-Step model that took the whole process of change management to another level of people engagement and analysis. Kotter's model introduced new powerful concepts such as communication and engagement, visions and short-term wins, and empowering others. This 8-Step model inspired many other studies, as will be discussed later in this section, and it is still appealing to some organizations. Other fundamental work, such as models from Kanter (2003), Hinings and Greenwood (1988), and Pettigrew (1989), brought more essential concepts to be considered in the context of change management, including transformational leadership, global and internal constraints, beliefs and interests, context, content, and process.

Moreover, there have been many studies investigating and applying change management in healthcare. In 1998, Moran and Brightman (1998) introduced their "T.R.Y" model. The model relies on the idea of trying new changes where "*maybe*" is an answer to the possibility of adopting the changes. While trying the new changes, there should be

always testing (T) and re-calibrating (R) of the introduced changes to cope with resistance, loss, and negative gaps. Later, Šuc et al. (2009) reported on a successful experience using Lewin's model and theories in a health informatics-related project at a German university hospital. The study reported that Lewin's model is still applicable and effective but some hospital's characteristics need to be considered as well. Recent studies shifted the focus from introducing new change management models or approaches in the healthcare sector, to identifying concepts and principals that are essential to be captured in this domain. For example, shared need and values, clinicians' engagement, and leadership support are emphasized in many studies and addressed as crucial factors for the change to happen (Nesse et al., 2010; Detwiller, 2014; Booker et al., 2016). Evans et al. (2016) proposed a conceptual framework (*Organizational Context and Capabilities for Integrating Care – OCCIC*) for change management. The framework was built based on conducting a literature review and doing interviews with healthcare workers in Ontario. The OCCIC framework consists of eighteen organizational factors in three groups: basic structures, people and value, and key process. The majority of most important factors are found in the people and value group: leadership approach, clinician engagement, patient-centeredness and engagement, organizational culture, and readiness for change. Relationships between organizational contextual factors and capabilities are identified as well. For example, the study showed that there is a direct relationship between organization culture and readiness for change; however, the negativity or positivity of the relationship varies from one context to another. The study concluded that, as those capabilities and factors change and evolve over time, it is necessary to re-examine them to deliver better integrated care.

Another concept that has been introduced recently to healthcare is *Thinking Lean* (Booker et al., 2016). Booker discussed the importance of evaluating and re-designing the *Model of Care* (MOC). The study identified the fundamental pillars for the MOC in order to obtain success and deliver the desired outcomes. Thinking Lean is addressed as one of the pillars with which the quality of care for patients can be improved through keeping value-added activities only and eliminating waste. It is well known that the Lean approach has been widely adopted in healthcare. Many studies agreed with the concept of the Lean approach being used in healthcare but did not agree to use it as is (Breuer, 2013; McIntosh et al., 2014). The Lean philosophy was derived from the Toyota Production System, in a

manufacturing context where cars are all similar (unlike hospital patients, who are all different). The main focus is to eliminate waste (reduce cost or minimize time, for example) without sacrificing productivity. The approach relies mainly on identifying customer values and mapping the process activities to those values, in order to increase quality of service. There are many approaches and tools to apply the Lean concept such as *Value Stream Mapping* (VSM). The main steps in the Lean approach start with identifying customer values. Then, non-added-value and added-value activities of the process are identified through mapping the process to the customer values, resulting in an improved process where waste is eliminated. As the nature of healthcare is different from manufacturing, Breuer (2013) proposed a framework adopted from Kotter's model to implement the Lean concept in healthcare. The steps of the Lean approach were mapped to the 8-Step model of Kotter. The work was an attempt to systemize the *Lean Thinking* philosophy. However, the study highlighted the need for empirical studies that share the best practices of adopting Lean in healthcare and recommendations for improvements.

The Lean concept received many criticisms and suggestions for adaptation in terms of using it in healthcare. Rossum et al. (2015) discussed the gap between strategy and execution in Lean healthcare. The study carried a quantitative case study supported with statistical evidence about the factors that, potentially, reduce the gap between strategy and implementation. The result showed that adopting Lean activities in the process of change management is insufficient to achieve successful and sustainable results. Transformational leadership and workforce flexibility are needed to support the implementation of Lean activities. Another study by Moraros et al. (2016) reported that there is no evidence of associating Lean with patient satisfaction or healthcare outcomes. McIntosh et al. (2013) addressed the limitations of Lean in healthcare in the study "*Illusion or delusion – Lean management in the health sector*". The complexity of healthcare, with all its unique elements such as demand on resources, human perceptions, technological development, and diverse patient satisfaction factors, makes it difficult to easily and clearly assess and improve processes, as Lean suggested. Another point is that "*value*" is difficult to identify as it depends on many factors, not only on the customer, who is the patient in healthcare. The risk of using Lean is that identified values are short-term, and solutions would not sustain the provision of true service values over a long-term period.

In general, as seen above, most of the change management models lack systematic approaches that define how models' concepts shall be captured and applied to achieve the desired changes. Many studies focused on bringing new elements and concepts that have not been discussed by previous work, especially in healthcare, where the environment is unique when compared with other domains. A few studies have attempted to draw relationships between those concepts; however, there has been no indication about how to apply and operationalize those concepts. In terms of analysis, some methods such as cost-benefit, risk, and conflict analysis have been around for a long time. The issue appears in capturing quality and user requirements, and relating them to goals, visions, and long-term values along with the expected implementation. The effect of each view on another is missing and the traceability (especially bottom-up) from identifying a problem to implementing a solution, and then sustaining the changes, needs to be further addressed.

The Lean approach provides more systematic methods to improve processes. However, the main pitfall of the Lean approach in healthcare is to focus only on the patient's goals but not on those of caregivers, among others. Caregivers in hospitals are a special type of employees, different from those of any other organization. They are intensively immersed in a dynamic context in which they treat end-users (patients) with many variables to consider, and multiple procedures to follow. It is essential to consider their needs and goals in any change management process. In Lean, the engagement of caregivers did not go beyond identifying the values for the patient and consulting caregivers about the validity of the improved processes.

All in all, change management cannot be used alone when introducing changes and improving processes, given the challenges mentioned above in healthcare. There is a gap in providing methods to capture and analyze the concepts in the process improvement context, and relating them to introduced changes and expected implementation. Bidirectional traceability is highly needed too (e.g., to trace back the rationale behind a specific implementation, moving from the implementation to the captured concepts/values). The AbPI is not a change-management-based framework. However, I believe that using RE-based methods with change management approaches would bring more value and a comprehensive coverage to the context of process improvement and integration.

## 2.4 Limitations

Two main reviews were presented in this chapter. The first one is about introducing changes in healthcare to investigate whether requirements engineering and process modelling techniques were used in this domain and whether there are specific needs associated with the healthcare's nature in the context of process integration. The second one is to survey the work done outside healthcare to introduce changes using requirements engineering and process modelling techniques. One obvious limitation is that the process of conducting the literature review was inspired by Kitchenham (2004) but it was not entirely systematic. Bias could be present in the summarization and conclusion of the review as it was conducted by one person only (the thesis author). To mitigate this bias, the literature review was checked by the thesis supervisor. No controlled vocabularies were used in the queries, which introduces another limitation as this approach could have led to additional relevant papers. Using appropriate terms in the context of goal modeling in healthcare was also challenging as the terms "goal" and "model" are used frequently and often differently in healthcare. Another important thing to mention is that a few papers were missing in the review because of accessibility issues, even after contacting the librarians.

It is worth mentioning that the change management section uses papers that were not part of the results obtained from the queries in Section 2.1.1. These papers were collected from multiple sources to bring a holistic, albeit incomplete, contextual view of change introduction in the healthcare sector.

## 2.5 Chapter Summary

This chapter highlighted two major issues: the lack of requirements engineering practices in healthcare, and the limitation of current approaches in providing a comprehensive method that considers both views of goal modelling (the satisfaction of users and of business and organizational goals) and of process modelling. Also, it revealed the lack of analysis methods to estimate the effect of changes on current processes and on the satisfaction of goals. The next chapter proposes a framework that attempts to fill that gap and contributes to solving that problem. In addition, the current chapter discussed change management



models in healthcare and highlighted where using change management models and RE-based methods could be beneficial to the organization.

## Chapter 3 Proposed AbPI Framework

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This chapter presents a conceptual model of the relevant entities and their relationships in the context under study. It also discusses the *Activity-based Process Integration* (AbPI) framework and explains its *Goal Integration Method*, its *Integration Method* for processes, and its *Alternative Evaluation Method*. Furthermore, the chapter provides an illustrative example and a discussion.

### 3.1 Conceptual Model

The concepts of a domain can be formalized using a UML class diagram.

#### 3.1.1 Elements and Relationships

The AbPI conceptual model consists of the following elements and relationships:

- **PGModel** (*Process Goal Model*, or simply *PGM*), the main concept of this conceptual model, which has sets of concerns, process models, goal models, and stakeholders.
- **Concern** consists of an isolated aspect of a process that has its own goals and a context in which it performs. It is a means of grouping processes and their goals that serve similar purposes.
- **GoalModel** is a set of related goals, including indicators.
- **Goal** is an objective to be achieved or satisfied. Each goal has an importance value for prioritization purposes. A goal can contribute to other goals. A goal may also be decomposed into a set of goals (parent – sub-goals relationship). A goal can be evaluated by a satisfaction level.
- **Indicator** is a type of goal with additional attributes. An indicator (also referred to as *Key Indicator Performance – KPI* – in a business context) measures the achievement of goals. An indicator has four attributes in addition to those of goals: the desired per-

formance value, the worst value possible, a threshold value, and the current (observable) value. Having indicators as a type of goal enables the former inherit the ability of having relationships (contributions and decompositions, in particular) with other goals.

- **ProcessModel** is a set of processes.
- **Process** is composed of a set of sequenced activities that are the start, the end, and in-between activities of the process. A process can be a sub-process of another process. In the context of process integration, a process can be *current*, *proposed* or *integrated*. A process *belongs to* a concern.
- **Activity** is an element of a process. An activity can relate to other activities through *ActivityRelation*. The relationships are defined (in *ActivityRelationType*) as: eliminate, replace, add, or combine. An activity may have a direct relationship to a set of goals. The relationships are *Contribution* and *Change*. An activity may have positive or negative *Contribution* in different levels to the satisfaction of the goals, or could change the current value of an indicator. Also, the activity can affect roles in the process through *ActivityRoleRelation*. The effect can be: eliminate, change, or add (in *ActivityRoleRelationType*).
- **Criterion** is a quality or performance measurement (such as time and cost) linked to a concern. The purpose of defining criteria is to eliminate process alternatives that do not satisfy qualities or performance sufficiently during the analysis phase (before the decision-making phase). Each concern has a set of criteria to satisfy. There are four types of criteria: long-term values, urgent needs, user acceptance, and maximized familiarity.
  - **LongTermValues** are meant to support and ensure the alignment of process integration alternatives with long-term values of a hospital.
  - **UrgentNeeds** are identified by caregivers as an important measure to guide the prioritization of alternative selection based on current needs.
  - **UserAcceptance** criteria may have a positive influence on healthcare workers to accepting new changes.
  - **MaxFamiliarity** is a concept borrowed from the software design patterns domain that is meant to maximize user familiarity with new software products to achieve better usability and minimize resistance and confusion. The maximized familiarity class of criteria can be used to evaluate process integration alternatives.

- **Constraint** is a situation that is imposed by stakeholders, policies, guidelines, or process properties, to be preserved during the generation of process alternatives. The purpose of defining a constraint is to eliminate process alternatives (at the design phase) that do not satisfy the constraint earlier to the analysis phase. Each process may have a set of constraints.
- **Stakeholder** represents a department, unit, personnel, or role that is involved in a particular context.

Figure 4 illustrates the elements of the AbPI conceptual model and their relationships, together with relevant attributes (e.g., for types, names, and identifiers). A formalization of this conceptual model, done with the USE environment (Gogolla et al., 2018), is available online (see Appendix F), with additional constraints discussed in Section 6.1.

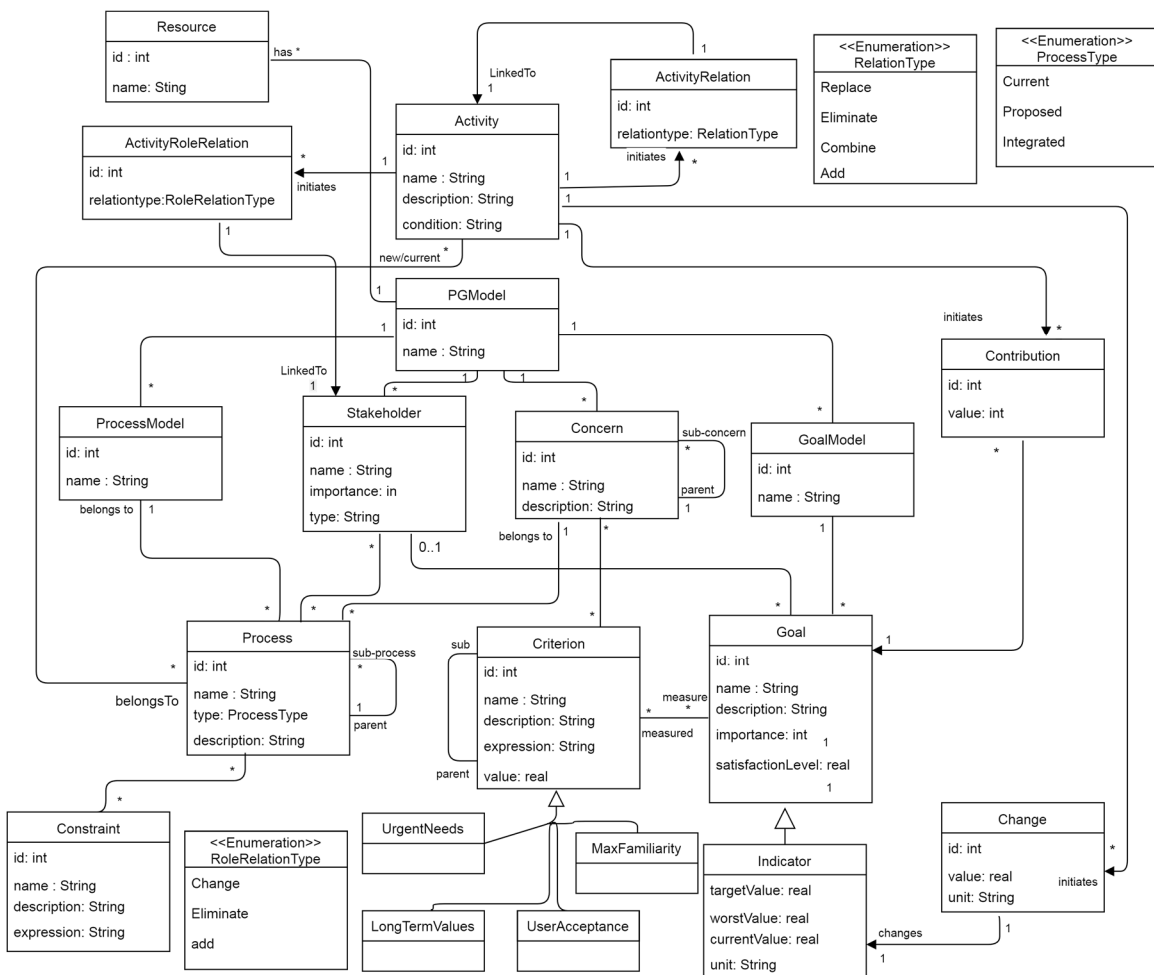


Figure 4 AbPI conceptual model

## 3.2 AbPI Framework

AbPI is a framework for activity-based process integration that uses the conceptual model to define inputs and outputs, and that provides methods for transforming the inputs into outputs. The framework can be implemented using various technologies, but examples in this chapter will use the User Requirements Notation to illustrate goals and processes.

### 3.2.1 High-Level Perspective

The framework consists of two major phases, as shown in Figure 5:

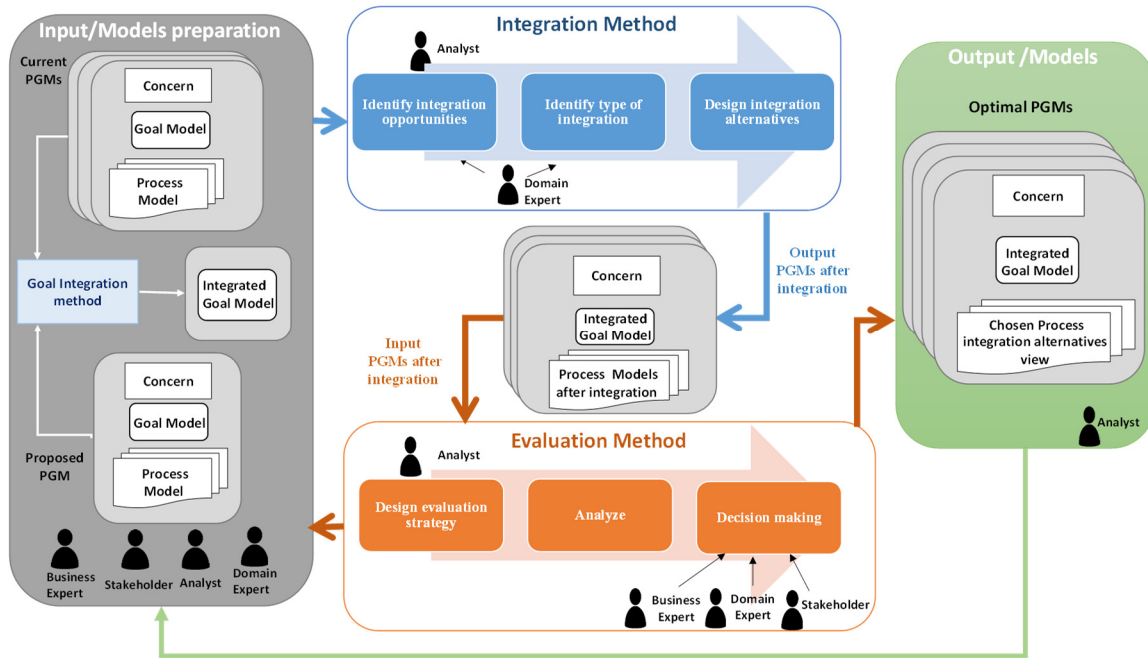


**Figure 5** High-level view of the AbPI framework

- **Modelling and Analysis:** in this phase, for a given organization, an analyst identifies current processes, roles/units, and goals. In addition, the analyst and one or many domain experts collaborate to model the *current PGMModels* (the identified elements, their relationships, and the impact of those relationships on the goals). They also model the *proposed PGMModel* for the new technology or process to be integrated.
- **Integration and Evaluation:** in this phase, the analyst and domain experts identify integration opportunities of the proposed process into the current ones. In addition, they identify the changes that might be introduced to the current processes, activities, and goals caused by the integration. Then, they analyze the impact of this integration on different levels of the PGMModel: activity, process, and goals in a concern. Lastly, the analyst, the domain experts, and other stakeholders collaborate to decide what to do based on the resulting integration alternatives. The output of this phase is a new PGMModel that consists of the alternatives that best achieve the desired outcomes.

### 3.2.2 Detailed-Level Perspective

This section presents the framework’s components, process, and roles. As shown in Figure 6, The AbPI framework has two main methods: integration and alternative evaluation. For each method, there are inputs, outputs, and roles. Inputs and outputs are composed of Process Goal Models (PGModel in Figure 4, also called PGM for short in Figure 6).



**Figure 6** Detailed AbPI framework

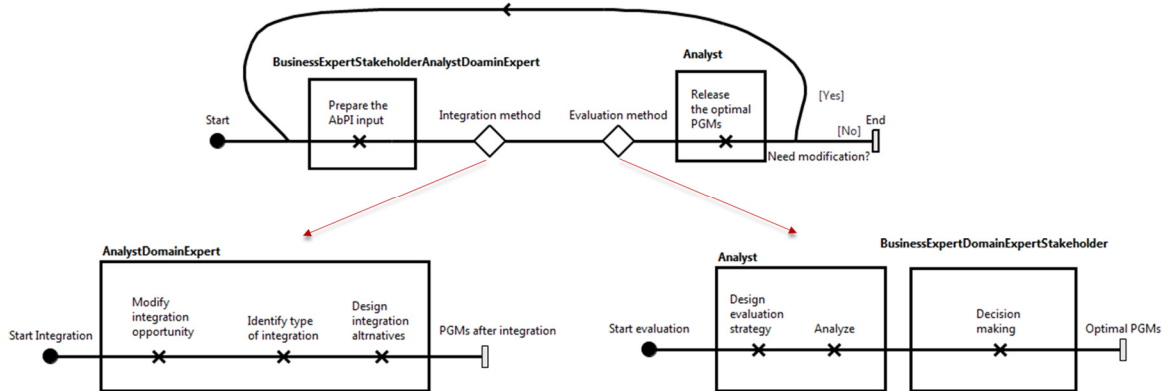
- Input (models preparation)***: The process integration method has two or more PGModels, composed of goal views and of process views, as inputs. One is the *proposed* PGModel (coming with the new technology to be introduced) and the others represent the *current* PGModels (documenting relevant goals and processes existing in the organization). The *goal view* of a PGModel consists of the organizational goals, user requirements, and stakeholders, along with their relationships (contributions), importance values, and current benefits they bring to the organization. The *process view* of a PGModel is composed of sequenced activities performed by roles. In a PGModel, activities contribute to the satisfaction of goals and criteria can be defined to evaluate the satisfaction levels and change the performance indicators values. Regarding the creation of PGModels, the *analyst* (who

models the PGModels and who manages the integration of processes) and the *domain experts* can collaborate to define the context in which a new process is proposed, which includes developing the current and proposed PGModels. The goal views of the proposed and current PGModels are integrated into one view that reflects the context in which processes need to be integrated. The ***Goal Integration method*** is used to merge the goal views to be used in the process integration method. If the current process is complex, it may be decomposed and refactored into an equivalent collection of sub-processes, each of which corresponding to a proposed process. The PGModels in the input will be used in the integration method.

- ***Process Integration method***: firstly, the analyst identifies the *integration opportunities* of the proposed process into the current process. Any integration of a new activity into the current process may lead to several changes. These changes differ in their levels of impact on a single activity or a part of the process, based on the type of the integration. In the end, the analyst designs new PGModels that consist of the integration alternatives of the proposed PGModel into the current PGModels.
- ***Alternative Evaluation method***: the input of this phase is the new PGModels. The analyst and the domain experts design strategies (i.e., initial contexts) to evaluate models. The evaluation focuses mainly on the levels of contribution to the goals brought by the activities after the integration. The contributions demonstrate to which extent the integration contributes to make or hurt the achievement of goals at different levels. The analyst, the domain experts, and stakeholders analyze the impact of the changes and then decide on the integration alternatives that achieve the desired outcomes. The integration and evaluation processes are done iteratively. The result from the alternative evaluation method might be the input of another integration. In addition, the result of the evaluation process may be used to refine the main models in the input or to do further evaluation.
- ***Output***: the output is the result of the alternative evaluation method. The output is composed of the PGModels that contain the alternatives that best achieve the intended objectives chosen by the analyst, the domain experts, and the stakeholders.

Each output of the alternative evaluation method can be a final output of the framework or a new input for another integration.

Figure 7 illustrates the typical process of preparing the input, applying the integration and evaluation methods, and release the optimal PGMs. The next three sections will further explain the three methods of the AbPI framework.



**Figure 7** Behavioural perspective of the AbPI framework

### 3.3 Goal Integration Method

In the context of process integration, it is essential that the process integration method ensures consistency, traceability to changes introduced, and the presence of rationales. Similarly, in the presence of different goal models provided by different groups, such as a service/system provider and a hospital, a formal integration method is needed to address how both goal models can be merged to reflect the goals of the process after integration and to represent new relationships/impacts that may occur accordingly.

Much work has been presented in the area of model merging, including the approaches of Sabetzadeh et al. (2006), Brunet et al. (2006), and Richards (2003). However, the focus was mainly on merging behavioural models (such as state machines) rather than structural models such as goal models (Nejati et al., 2006). The challenge faced in merging structural models is to ensure consistency of definitions and of relations of combined elements while capturing and preserving correct semantics.

The *goal integration method* proposed here is inspired by the three-way modelling approach of Sabetzadeh and Easterbrook (2006). In their work, they propose a framework

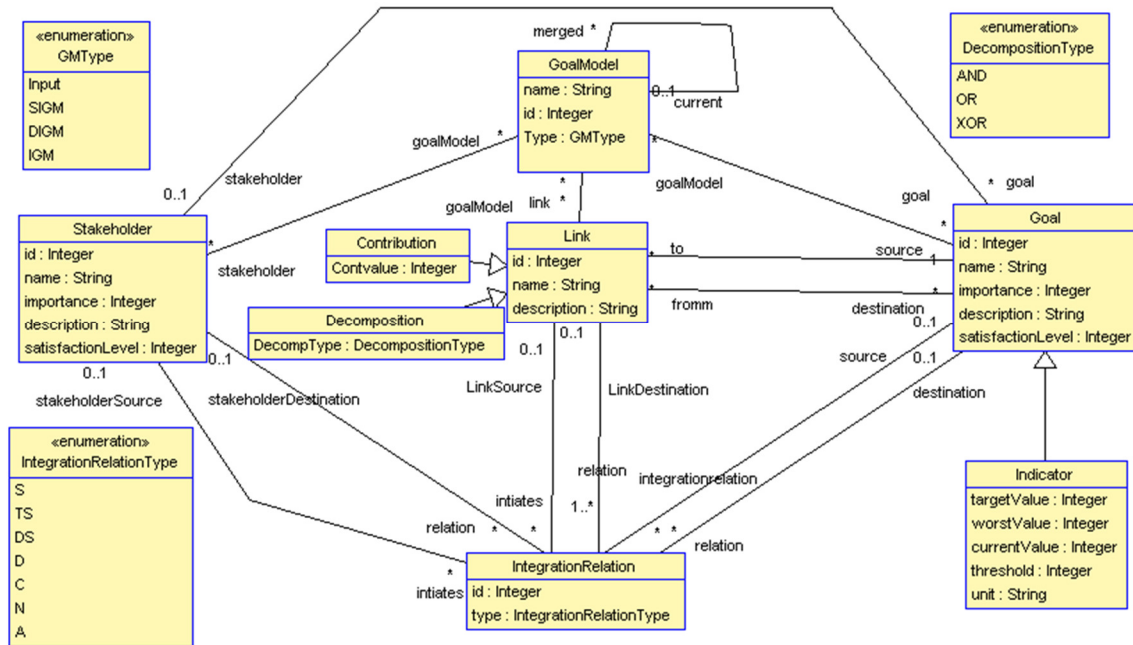


that highlights incompleteness and inconsistency occurring in different partial views, designed by different modellers, of one goal model. They treated multiple views of a goal model as structured objects to map them back and forth during the merging process. They also created an algebraic algorithm for merging views to increase scalability and adaptability.

One important concept that differentiates our method from the others is that I introduce relationships that go beyond the “similar” and “dissimilar” ones used by Sabetzadeh and Easterbrook’s work to denote inconsistency and incompleteness. The transitive similarity, conflict, different, new, and approved relationships in our goal integration methods help define finer levels of integration but require deeper stakeholder engagement to reason about introducing new elements/relations and resolve conflicts as part of requirements elicitation and validation.

### **3.3.1 Elements and Relationships**

The conceptual model of the goal integration extends the process integration conceptual model to form the complete AbPI conceptual model. The main addition is the *Integration-Relation* class that identifies the relationships between elements to be integrated in a goal model. In addition, the *Type* attribute was added to GoalModel class for model consistency checking. The goal integration method has seven main iterative steps: identify similarities of models to be integrated, identify dissimilarities of models to be integrated, highlight differences, resolve conflicts, refine combined models, validate results, and approve the integrated goal model. Table 5 explains the potential relationships that can be created between goal models to be integrated when applying the goal integration method, and the procedure to be followed in each case.



**Figure 8** AbPI conceptual model: additional elements and relationships supporting the goal model integration method

The goal integration method starts with the identification of similarities between the models to be merged, the addition of similar elements to a new *Similar Integrated Goal Model* (SIGM) and the mapping of each new element back to the original models through a *similar* relationship. Then, the method requires analysts to identify dissimilarities between the input models and to produce a new *Dissimilar Integrated Goal Model* (DIGM) with the dissimilar elements mapped back to the original models through *dissimilar* relationships.

Then, the method combines both the similar model and the dissimilar model into a new *Integrated Goal Model* (IGM), and then investigates the new model to identify different semantical or structural changes of the elements, which may exist or may be introduced, compared to the original models. All different or new elements have a relationship of type *different* or *new*, respectively. The method also highlights conflicts by tagging conflicting elements with *conflict*. All changes, different representations, and resolved conflicts shall be approved when validating the integrated goal model with stakeholders and tagged with *approved*. The table below illustrates the relationships that may exist between the elements of goal models during the integration process.

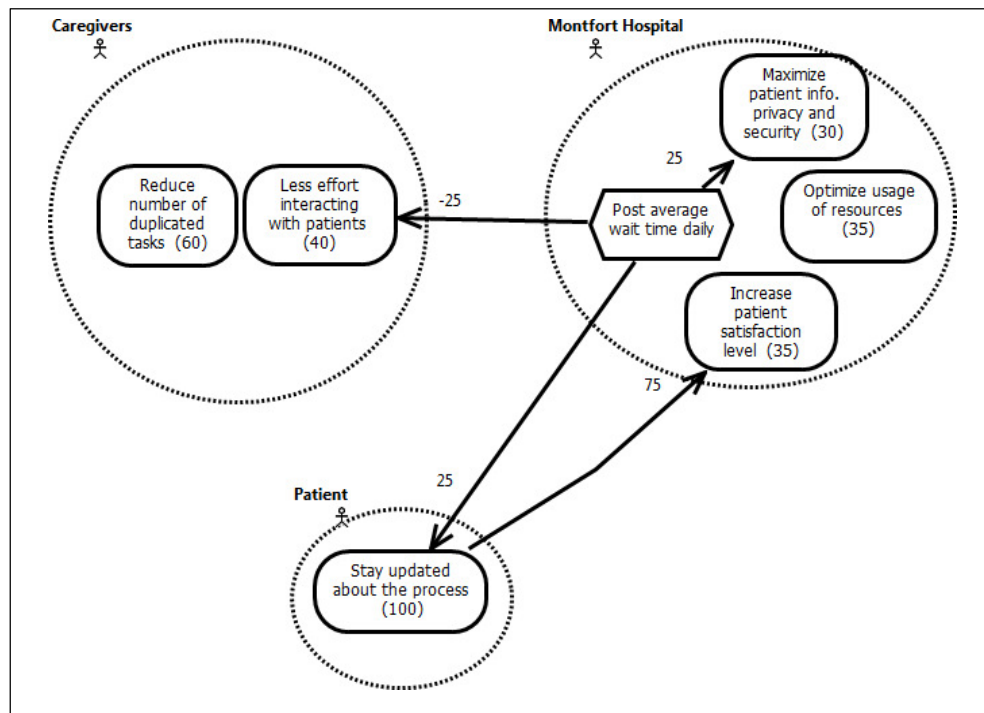
**Table 5** Relationships and mapping procedures of the goal integration method

Relationship	Elements	Mapping procedure	Conditions
S: Similar	<ul style="list-style-type: none"> <li>- Stakeholder to Stakeholder</li> <li>- Goal to Goal</li> <li>- Task to Task</li> <li>- Relation to Relation</li> </ul>	<ul style="list-style-type: none"> <li>- Similar elements in the input goal models (GM1 and GM2) will be added to a new <i>Similar Integrated Goal Model – SIGM</i></li> <li>- The SIGM model’s elements shall be mapped back to the input models to ensure coverage and consistency</li> </ul>	The elements shall be similar syntactically (structure) <b>and</b> semantically.
TS: Transitive similarity	<ul style="list-style-type: none"> <li>- Goal to Goal</li> <li>- Task to Task</li> <li>- Relation to Relation</li> </ul>	<ul style="list-style-type: none"> <li>- If the root elements, in GM1 and GM2, are similar, then sub-elements can be added into the SIGM too.</li> <li>- If two elements (goals/tasks), in GM1 and GM2 are similar, then all relations of one of the goals/tasks with other elements will add as well.</li> </ul>	The root elements element <b>shall</b> be similar first.
DS: Dissimilar	Elements that exist in one model but not in the other model: goal, task, stakeholder, or relation	<ul style="list-style-type: none"> <li>- Dissimilar elements will be added to a <i>Dissimilar Integrated Goal Model – DIGM</i>.</li> <li>- The DIGM model’s elements shall be mapped back to the input models to insure coverage and consistency</li> </ul>	The elements will be tagged with <b>DS</b> to be investigated for conflict or different representation.
C: Conflict	<ul style="list-style-type: none"> <li>- Goal to Goal</li> <li>- Task to Task</li> <li>- Relation to Relation</li> </ul>	After combining DIGM and SIGM into one integrated goal model (IGM), the goals and the relations shall be tagged by C to highlight the conflicting issue, if any. In case of goals and tasks, the domain modeller and the stakeholders shall resolve the issue. For contribution conflicts, the Analytic Hierarchy Process (AHP) method can be used.	<ul style="list-style-type: none"> <li>- Similar goals/tasks with different representation/relations</li> <li>- Opposing/invalid effect of goals/relations in IGM</li> </ul>
D: Different	<ul style="list-style-type: none"> <li>- Goal to Goal</li> <li>- Relation to Relation</li> <li>- Goals and Relations</li> </ul>	When representation of goals or relations are changed compared to original models, or when new elements are added. For example, change in the contribution level.	<ul style="list-style-type: none"> <li>- Result of resolving conflicts</li> <li>- Result of refining the model</li> </ul>

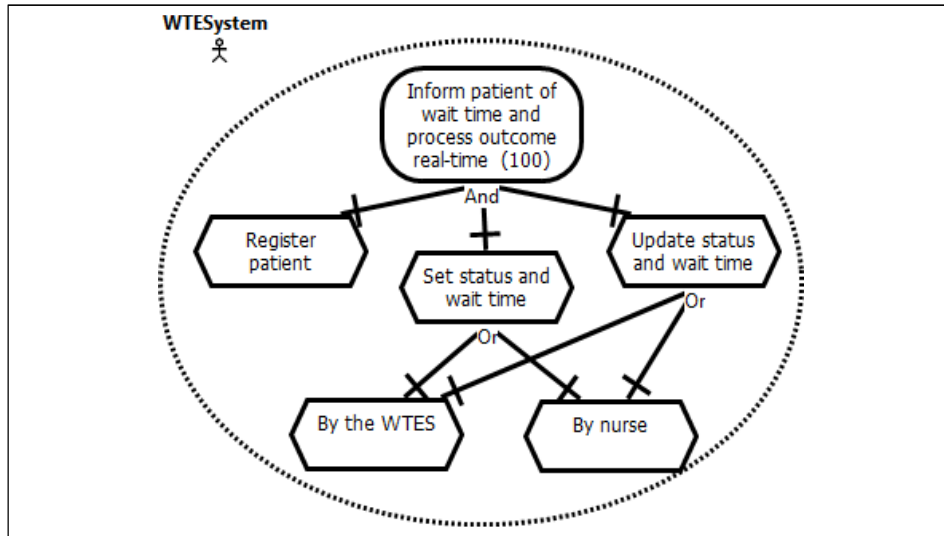
Relationship	Elements	Mapping procedure	Conditions
N: New	- New goal - New stakeholder - New relation	Adding new elements, which does not exist in the input models.	Does not exist in the input models
A: Approved	All elements tagged with DS, C, D, or N	Validating the IGM with stakeholders.	All elements are valid.

### 3.3.2 Illustrative Example

The example presented in this section illustrates the integration of two goal models in the context of managing patient anxiety at Montfort Hospital (Chapter 7 will cover this example in more details). The hospital intends to use a new *Wait Time Estimation System* (WTES) in the Emergency Room (ER) to inform patients about the admission process wait time, in real-time. The context goal model (Figure 9) shows current actors and their goals. The WTES goal model contains the goals and tasks of the system (Figure 10). Both goal models have to be merged to reflect the context of the process integration and to be used in the process integration method as explained in the previous section. Table 6 explains the iterations through which the goal models were merged.



**Figure 9** Context goal model (from the current PGModel)



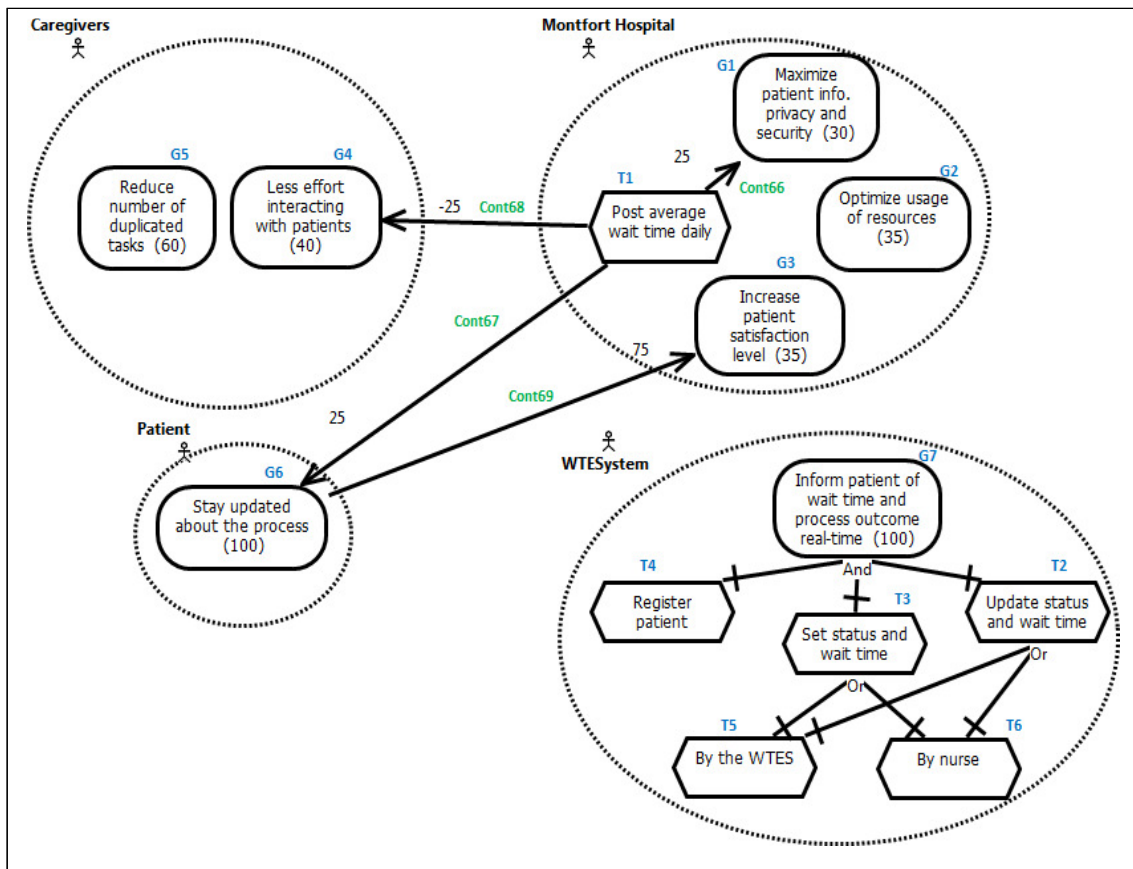
**Figure 10** WTES goal model (from the proposed PGModel)

**Table 6** Iterations used in merging the context (current) goal model with the WTES (proposed) goal model

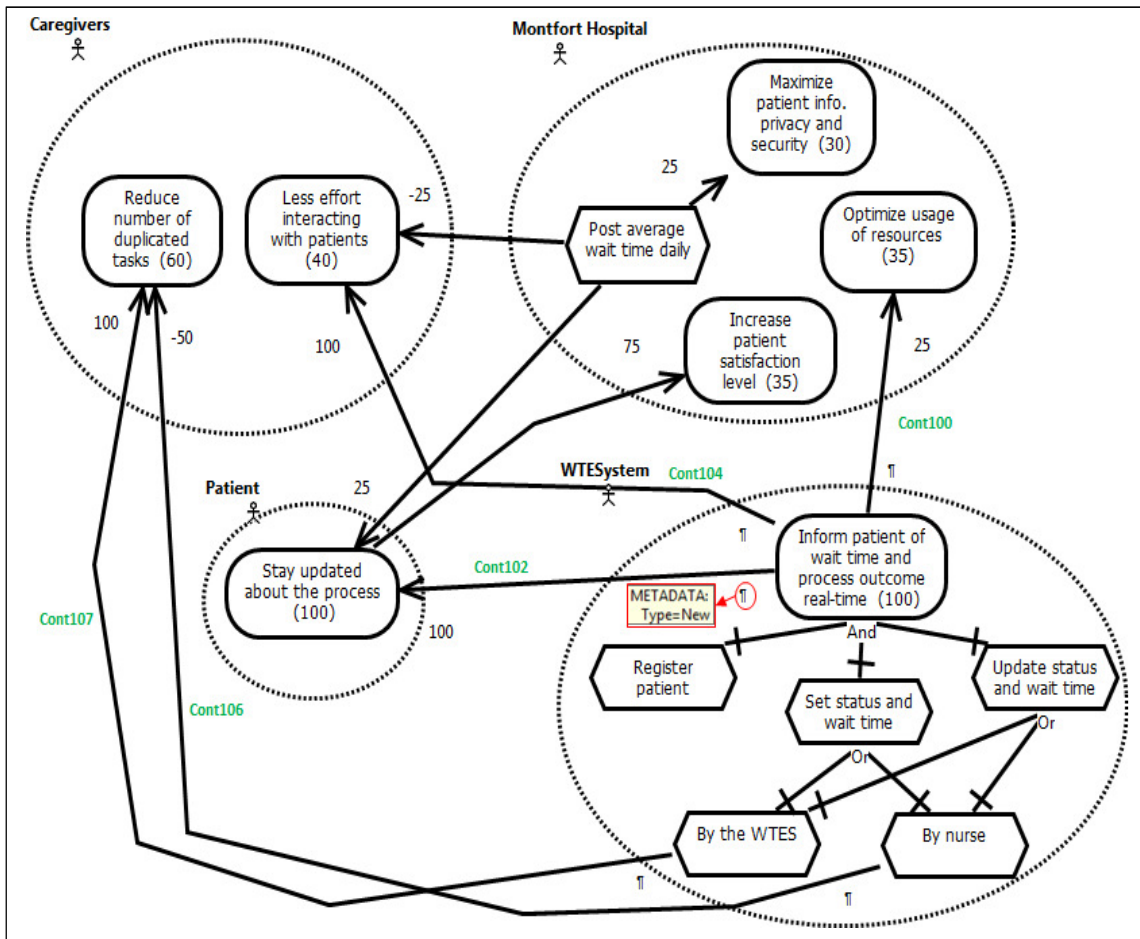
Relation type	Element ID	Explanation
<b>Iteration1: DIGM (Figure 11)</b>		
DS	DGIM contains all the elements of the context goal model and of the WTES goal model. The SIGM is empty.	All elements in both goal models are dissimilar.
<b>Iteration2: IGM-V1 (Figure 12)</b>		
New	Contribution100, Contribution102, Contribution104, Contribution106, Contribution107	Introduced in the IGM to capture the potential impact of the WTES goal model on the context goal model.
<b>Iteration3: IGM-V2 (Figure 13)</b>		
Approved	Contribution100, Contribution102, Contribution104	The changes have been approved.
New	KPI1 and KPI2	The KPIs are introduced to a more tangible illustration of the impact of the WTES on the Caregiver's Goal43. The KPIs replaced Contribution106 and Contribution107.
New	Contribution108 and Contribution 109	The contributions are introduced to capture the impact of KPI1 and KPI2 on the Caregiver's goal Goal43
<b>Iteration3: IGM-V3 (Figure 13)</b>		
Approved	KPI1, KPI2, Contribution108 and Contribution 109	The changes have been approved.

In the first iteration, as no similarities between the two goal models were found, all dissimilar elements (goals, actors, tasks, relationships) are grouped into a DIGM model. In this case, when a SIGM is absent, the IGM is equivalent to the DIGM. In iterations 2 and 3, new relationships are added between the merged goal models to reflect the impact of one on the other and reflect the context where processes (current and WTES) are integrated. In iteration 3, which is the last iteration, all new introduced elements were approved in order to obtain the merged goal model to be used by the AbPI methods (process integration and alternative evaluation).

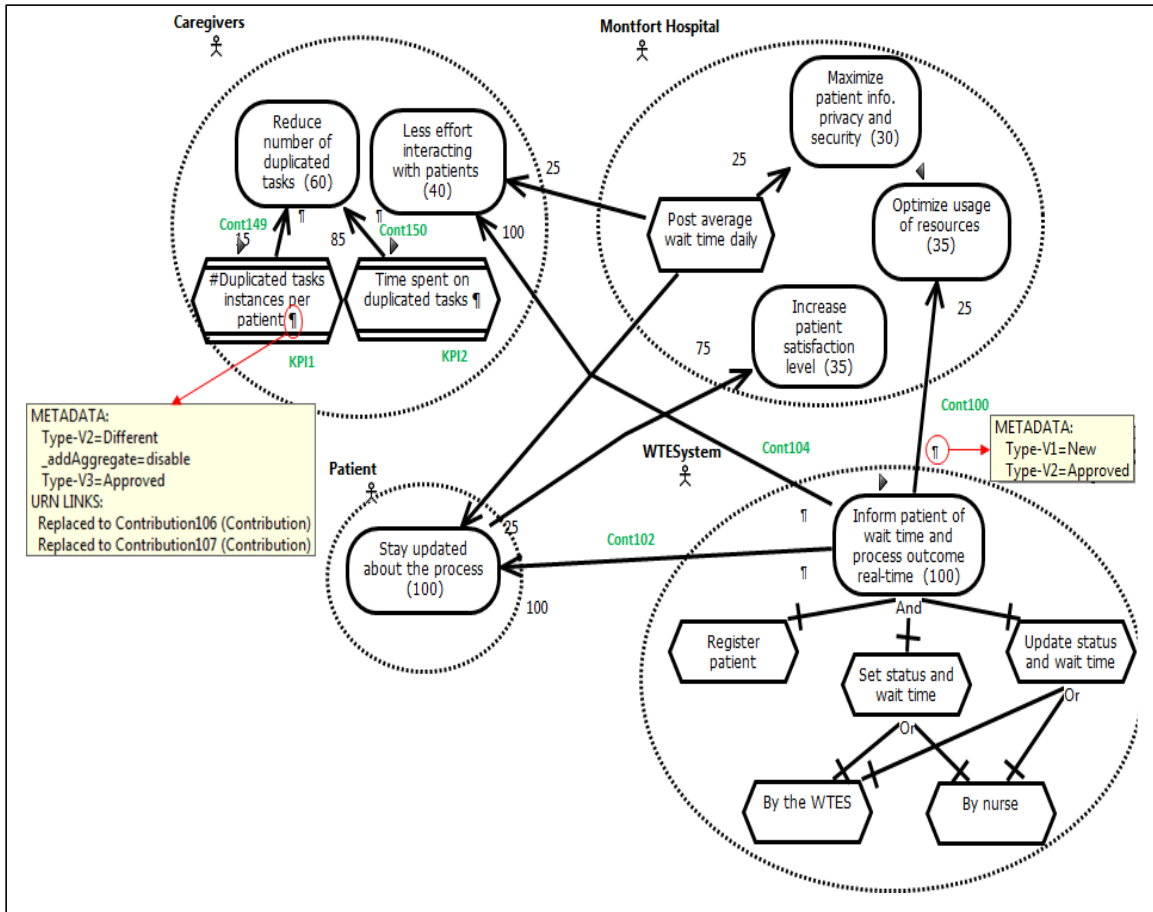
This goal integration method is formalized with an algorithm in Section 6.3.1 and used in the case studies, where the SIGM and DSGM models are different.



**Figure 11** Dissimilar integrated goal model (DSGM). The coloured labels beside the elements are their identifiers, which remain the same in the IGM.



**Figure 12** IGM-V1: new contributions are introduced. Each contribution was tagged with type *new*.



**Figure 13** Final IGM (V3): Cont100, Cont104 and Cont102 were approved in the second version of the IGM (iteration 2), while KPI1, KPI2, Cont149 and Cont150 were tagged as different in iteration 2 and approved in iteration 3.

### 3.4 Activity-based Process Integration Methods

AbPI is a model-driven, analysis-enabled process integration framework that supports the integration of activities from a proposed process into current processes. AbPI also supports the investigation of the potential effect of a single activity on entire processes, other activities, organizational goals, or stakeholders. It also shows the roles (i.e., who performs a certain activity) and the execution ordering of a group of activities when a single process cuts across multiple units or teams. AbPI aims to integrate the proposed process by maximizing the level of familiarity with the current process, which is an essential factor to gain user acceptance in healthcare.



When integrating an activity into a current/existing process, four types of relationships can be introduced.

### Activity Relationships

When integrating an activity into a current process, four types of relationships identified in the conceptual model might be introduced:

- **Activity-Process relationship:** this defines in which way an activity is connected to an existing process. An activity-process relationship would identify also the changes that may be introduced to the structure of a process. It is presented in the conceptual model as an association between the *Process* class and the *Activity* class.
- **Activity-Role relationship:** an activity can change, eliminate or add a role in an existing process. It is presented in the conceptual model as an intermediate class (*ActivityRoleRelation*) between the *Stakeholder* class and the *Activity* class.
- **Activity-Goal relationship:** this shows the impact of an activity on the satisfaction level of a goal or the performance indicator of a performance goal. In the conceptual model, the *Activity* class is linked to the *Goal* class through the *Contribution* class and is linked to the *Indicator* class via the *Change* class.
- **Activity-Activity relationship:** this is meant to show which activities will be affected by the integration of a new one and how. The relationship is presented in the conceptual model as an *ActivityRelation* class linked to the *Activity* class.

Table 7 explains these relationships.

**Table 7** Activity relationships

Type	Description
<b>Activity – Process relationship</b>	
<b>Current</b>	It means an activity is currently part of a process.
<b>New</b>	It means an activity is not existing yet in the process of context but there is a chance to be integrated into it.
<b>Integrated</b>	It means a new activity is integrated into the existing process.
<b>Activity – Role relationship</b>	
<b>Change</b>	An activity can change a role in a process to another (change a nurse role to a physician role, for example).
<b>Eliminate</b>	An activity can eliminate a role in the process.
<b>Add</b>	A new activity can introduce a new role to the process.

<b>Activity – Goal relationship</b>	
<b>Contribute</b>	An activity may contribute positively or negatively in different levels on goals.
<b>Change</b>	An activity may bring new KPI values (i.e., change the indicators' values).
<b>Activity – Activity relationship</b>	
<b>Replace</b>	A new activity replaces a set of other activities.
<b>Eliminate</b>	A new activity eliminates a set of other activities.
<b>Combine</b>	A new activity is combined with a set of current activities. There are five possible types of compositions: <ul style="list-style-type: none"> <li>• New ; Current // sequential composition, before</li> <li>• Current ; New // sequential composition, after</li> <li>• New OR Current // alternative composition</li> <li>• New PAR Current // parallel composition</li> <li>• Merged // new activity that is neither New nor Current</li> </ul>
<b>Add</b>	A new activity is added to current activities. There two types of possible additions: <ul style="list-style-type: none"> <li>• Before current activity</li> <li>• After current activity</li> </ul>

### 3.4.1 Integration Method

As illustrated in Figure 6, there are three major steps:

#### 1) Identify opportunities

An *integration opportunity* highlights a possible spot in the current process in which a proposed activity can be integrated in a way that preserves the current process flow properties and keeps it logically sound. A proposed activity can have multiple integration opportunities. In this step, the domain experts decide on the potential opportunities to integrate.

#### 2) Identify the type of activity-activity integration

For each potential opportunity resulting from the previous step, the relations between the proposed activity to be integrated and other current activities in the current process should be defined. There are four possible relations: replace, eliminate, combine, and add (see Table 7). If the relation is either replace or eliminate, dependencies (if any) between the current activity to be eliminated or replaced and other current activities in the current process should be defined. Then, the analyst and the domain experts investigate the possibility of transferring those dependencies to the new activity, or the new activity will eliminate those current activities as well. If the relation is combine, then the analyst and the domain

experts not only investigate the effect on an activity brought by another, but they also consider the possible change that may happen to the process structure such as changing roles or adding a new role. The add relation means that the proposed activity will be simply added to current activities where it is appropriate and logically correct. It is worth mentioning that proposed activities that are added to a current process may look like the proposed activities that are combined (*before or after*) with current activities in the processes model. However, the add relation is meant to show that the proposed activity is not related, semantically or in nature, to current activities but it is added before or after them, which is the different from the combine relationship where relevance to current activities exists.

### **3) Design a new process model**

In this step, the analyst models the alternatives discussed above. The analyst modifies the current process to reflect the changes introduced by each integration opportunity and its relation to other activities. The analyst and the domain experts modify the goals linked to the activities with new values for contributions. The developed integration alternatives model (PGModel) in this step will be the input of the alternative evaluation method.

#### **3.4.2 Alternative Evaluation Method**

The aim of the alternative evaluation method is to illustrate the impact of the alternative changes introduced by the integration on four levels:

- Goal level: the evaluation will show the impact of the new integration on the goal satisfaction levels that might have been affected by the contributions coming from activities. The evaluation helps decide keeping an integration if it is helping to achieve the organizational goals and performance objectives.
- Process level: the evaluation helps estimate the impact of the activity integration on the process performance, which contributes to the evaluation of the satisfaction levels of performance goals. In addition, the evaluation shows the impact of the newly brought changes on the process structure and roles.
- Concern level: for each concern, there is a set of criteria that measure the extent to which the concern reaches the desired results. For example, one of the criteria could be to reduce task duplication. In the evaluation at the level of concerns, the number of activities that were duplicated as a result of the integration will be counted. Then, the

impact of this duplication on another criterion such as time expected to perform a task is highlighted. The aim of the concern level evaluation is to highlight at a high level which concern consumes more time or raises costs, and whether this is caused by the integration or whether this is the nature of the concern in general.

- Stakeholder level: this evaluation targets the satisfaction levels of stakeholders, which could be defined at a department, unit, or personnel level, while considering their importance levels. As a result, this will help decide whether to keep, modify, or reject an integration to maximize the satisfaction level of an important stakeholder or to resolve conflicts between stakeholders. The satisfaction level of a stakeholder can be obtained by the importance of goals to stakeholders.

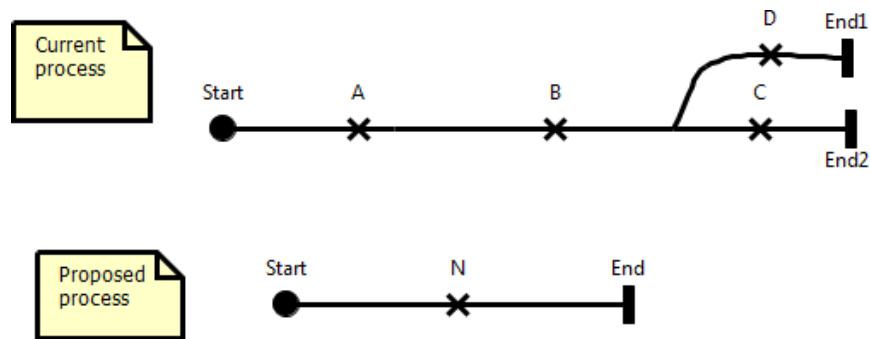
These four levels taken together give a comprehensive evaluation of the integration alternatives to reason about trade-offs and decision support in a holistic way. The alternative evaluation method has three main phases: Design evaluation strategy, Analyze, and Decision making (Figure 6). In the *Design evaluation strategy* phase, the analyst and the domain experts follow three steps:

1. Set the evaluation values and contribution levels of activities that will affect the goals.
2. Propagate satisfaction levels to goals and actors.
3. Validate the integrated models against predefined criteria and desired outcomes.

Then, the alternative evaluation method moves to the second phase (*Analyze*) where the integrated models will be validated against defined criteria and targets. Methods based on weights or distances could be used also to analyze and rank the process integration alternatives based on the pre-defined criteria and performance targets. The valid models will be transferred to the last phase (*Decision making*) where domain experts, stakeholders and analysts gather to reason on the alternatives and how they affect the goals, and choose the best one among them.

### 3.5 Illustrative Example (Process Integration Method)

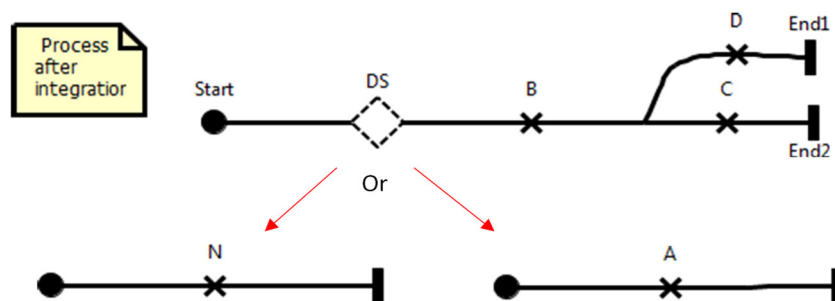
In this section, I illustrate some of the possible integration cases along with the changes they bring to the current process and its activities. I assume a sequential integration (no loops or conditional cases) where N, A, B, C, and D are activities. Figure 14 illustrates the current and proposed (or new) processes to be integrated.



**Figure 14** Current and proposed/new processes before the integration

#### Case 1: N replaces A

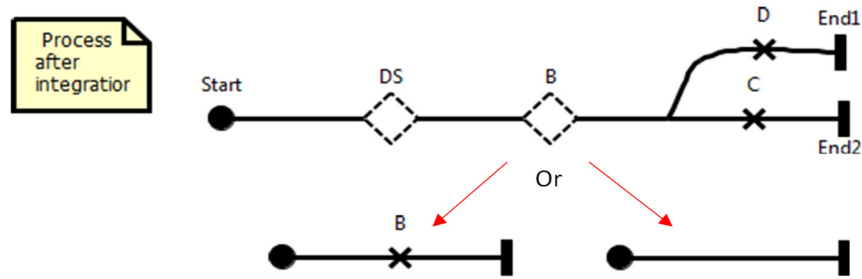
When the new activity N replaces the current activity A, the analyst has to check all dependencies between A and other activities (in case any existed). Then, the analyst shall consider the changes introduced by this replacement during the integration. The process after the integration will have two alternatives in performing the first activity, which are either to follow the old process and perform A, or go with the new activity and choose N (as shown in Figure 15). The reason for keeping the old activity A as an alternative and not deleting it from the model is that A may have better impact on the process than what N has, and to preserve the properties of the current process.



**Figure 15** Current process after the integration of proposed activity N; DS is a dynamic stub where the alternatives are found.

**Case 2: N eliminates B**

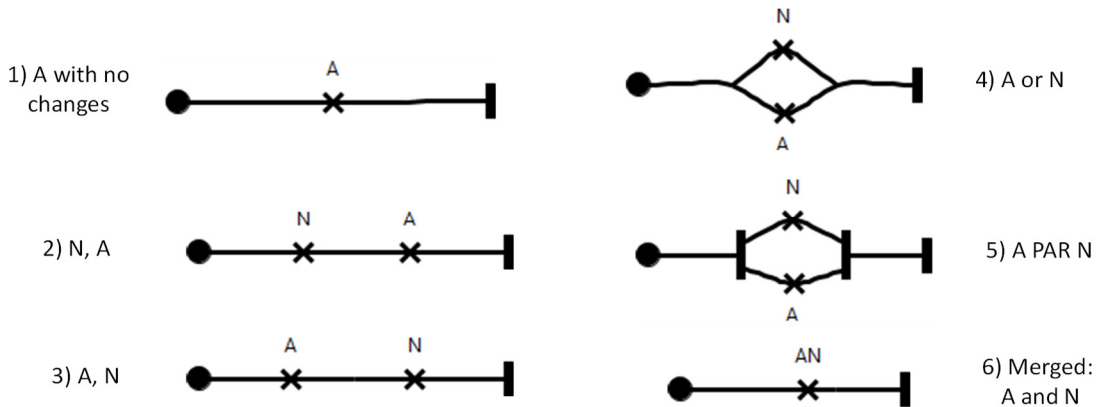
In the previous case, the next activity in the current process is B. The assumption here (as shown in Figure 16) is that choosing activity N, which has been integrated in the previous case (Figure 15), will eliminate activity B (B will be no longer needed).



**Figure 16** The B activity is eliminated by the integration of the N activity, which means that when evaluating the process with N, B’s values and contributions will be set to zero.

**Case 3: N combined with A**

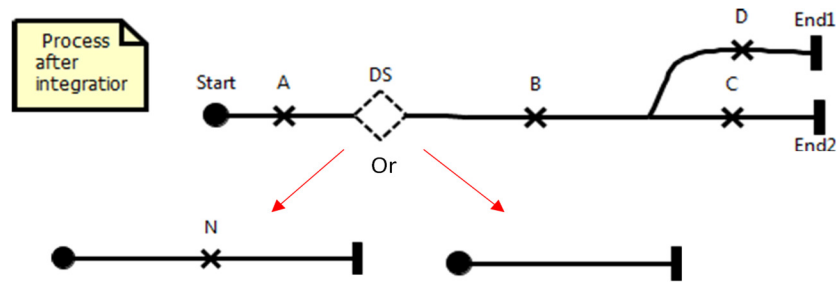
Figure 17 illustrates five options (2 to 6) for combining N with A, as mentioned in Table 7. These alternatives will be linked to the DS activity (stub in Figure 15) on the process after integration.



**Figure 17** Combining A and N alternatives

**Case 4: N added to the current process after A**

In this case, N is simply added to current process next to A leading to two integration alternatives: 1) N only, and 2) nothing changes in the current process (see Figure 18).



**Figure 18** Adding N to the current process

These are four basic integration possibilities. If the proposed or current process has loops or conditional paths, the domain expert and the analyst may need to decide whether to integrate them as-is or to integrate their activities separately. In the cases where many options are available, a domain expert's knowledge is needed to decide on a small group of alternatives to be evaluated. In this way, time and effort invested in the evaluation phase will be kept to a minimum.

### 3.6 Chapter Summary

This chapter introduced the AbPI framework, where the integration of an activity into a process in different ways results in multiple integration alternatives that can be evaluated and ranked. It also presented a conceptual model for AbPI and showed that the evaluation of an integration is not only limited to the level of processes, as it also covers goals, stakeholder satisfaction, concerns' criteria, and constraints. In addition, the chapter proposed a goal integration method to integrate the goal models in the input preparation phase of the AbPI framework.

Before formalizing AbPI and its methods with the help of a mapping to the User Requirements Notation (URN), the next two chapters introduce two new analysis techniques for goal models (and implemented for URN's Goal-oriented Requirement Language) as they will be important for the formalization of AbPI's alternative evaluation method

# Chapter 4 Data Quality and Confidence Propagation

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In this chapter, I propose a *Data Quality Tagging and Confidence Propagation Mechanism* to compute the confidence level of goal satisfaction based on the quality of data sources. The method uses the Goal-oriented Requirement Language to demonstrate the tagging approach and confidence propagation rules, and to illustrate examples. The availability of computed confidence levels as an additional piece of information can help decision makers i) modulate the satisfaction information returned by goal models and ii) make better informed decisions, including looking for higher-quality data when necessary.

## 4.1 On the Need to Consider Data Quality

Consider requirements analysis in a healthcare setting, where a hospital intends to use a real-time estimation system that informs patients of expected wait times. An analyst builds a goal model capturing design alternatives for the system-to-be. For the analysis, the analyst gathers data about manual effort, cost, number of tasks, and other metrics in order to decide what is the best solution among the alternatives. However, data, such as the average time it takes to carry out a task manually, are often unavailable, so they have to be estimated on the basis of data available from a similar context, or even guessed on the basis of first principles. The quality of the data used in the decision process influences the confidence the analyst and stakeholders have in the chosen solution for the problem at hand. In this chapter, I am interested in estimating that confidence during the goal analysis process.

Data availability for goal reasoning is a major challenge, especially in early phases of requirements and design analysis. New system design alternatives may not have been exposed to experimentation and performance testing. This results in uncertainty in the evaluation of these alternatives and, through propagation, in the satisfaction values of high-level goals. Moreover, ignoring the reliability level of sources from which data was collected may lead to uninformed decisions and inaccurate evaluations of high-level goals.



Letier et al. (2014) present a well-developed framework for decision making in the presence of uncertainty, which uses probability distribution techniques in the context of cost/benefit analysis. However, the framework is relatively complex and unaffordable in many situations where the data volume is low or where data and distributions are unavailable. As there are several similar proposed approaches that suffer from the same complexity issues, it is essential to provide solutions that are simpler and adoptable in situations where different data qualities are present, with general applicability to different goal modelling approaches. I argue that the *confidence level* of the satisfaction value of a certain goal can be computed simply using the data quality value of leaf goals in a goal model. For example, data collected from a pilot project operationalizing a leaf goal is sounder and of higher quality than purely estimated data acquired by front-end analysis. Accordingly, a higher or lower confidence in goal satisfaction values shall be assigned to leaf nodes, and then propagated to higher-level goals.

The main objective of this chapter is to propose a *Data Quality Tagging and Confidence Propagation Mechanism* that ensures the tagging of data with a certain quality level, and the propagation of the quality level to assign confidence values to the satisfaction values of higher-level goals. The data quality level varies based on the reliability of the source from which the data was collected. The approach qualifies the goal satisfaction levels by reflecting the data quality levels of leaf goals and their parents, leading to a more comprehensive view of goal evaluation in the presence of uncertainty. Of course, the propagated confidence level to top-level goals should influence decision making by trusting more high-confidence solutions, or by looking for additional evidence or better supporting data when confidence is insufficient.

Although the ideas introduced here can apply to many goal-oriented modelling languages, one specific language is used to present our proposal. I use the Goal-oriented Requirement Language (GRL) because GRL is part of an international standard (URN), enables the modelling of stakeholders and their goals, supports indicators for quantitative reasoning, supports contribution relationships, and supports evaluation strategies and propagation algorithms. GRL is also well supported by the jUCMNav tool (Amyot et al., 2010) for evaluating the satisfaction of goals and actors under selected strategies (Amyot et al., 2011).

## 4.2 Related Work

One important approach for managing uncertainty in goal models was proposed by Letier et al. (2014). Their proposal uses a statistical decision-theoretic technique to support decisions under uncertainty. Probability distributions are used to represent uncertainties of alternatives for a decision. In addition, the study used Monte-Carlo simulations to assess the impact of uncertainties on the goal models, as well as Pareto-based multi-objective optimization techniques to guide alternative selection. In a different approach, Cailliau and Lamsweerde extended a probabilistic goal/obstacle specification language to handle knowledge uncertainty (Cailliau and Lamsweerde, 2015). Their approach provides probability-based metrics and a method to identify uncertainties about goal satisfaction and to highlight the most impacting obstacles on the goal model. Similar work was done in this area by Sabetzadeh et al. (2011). Such approaches are mathematically sound but rely on many data points (uncertainty distributions) that are simply unavailable in the context of many real-life projects.

Bayesian Belief Networks (BBN) were used in many methods to estimate the confidence of an argument. Hobbs and Lloyd (2012) reported on the power and flexibility of BBN to represent the structured argument of an assurance case, where a claim is supported with multiple evidences characterized by different degrees of confidence. In a similar context, Guiochet et al. (2015) proposed an approach to identify and estimate confidence in a safety case. The safety case is modelled using the Goal Structuring Notation and the confidence of supporting arguments of a claim is estimated quantitatively and propagated using BBN. There exist several other proposals in the area of uncertainty and confidence reasoning in goal models, as well as other approaches such as the one of Hall et al. (2009), where goal modelling and data mining techniques are combined.

Many studies discussed data quality challenges in healthcare (Weiskopf and Weng, 2013; Kerr et al., 2008; Ferreira et al. 2015; Weber et al., 2015). The most recent work (Weber et al., 2015) presents *Data Quality by Design* (DQbQ), which is an architectural perspective of data quality that was introduced in the context of Clinical Information System (CIS) to tag data with a type that corresponds to a certain concern. The aim of this work is to promote the development of data quality standards based on fundamental theories and methods for engineering.

Note that the goal modelling languages used in the above approaches do not support contribution relationships, which are essential in a context such as AbPI's. Another key difference between the data quality proposed in this chapter and other studies proposed in healthcare is that our method for defining data quality concepts relies on the source from which data was collected whereas other studies focus on data anatomy and quality attributes such as completeness and correctness.

### 4.3 Mechanism

The method proposed in this chapter consists of two complementary sub-methods: *Data Quality Tagging* and *Confidence Propagation Mechanism*. In the former, the modeller tags the data of the goal model leaves with a certain data quality level, which is then converted to initial confidence levels. In the latter, an algorithm is used to propagate this information to the other goals through their links (decompositions, contributions, and dependencies) to compute the confidence levels of higher-level goal satisfactions. Both methods are explained in the following subsections.

#### 4.3.1 Data Quality Tagging

In our context, I propose different types of *data quality* based on the procedure followed to collect or obtain the data. I also propose a tagging mechanism that estimates the impact of the quality of collected data on goal satisfaction levels by giving it a *confidence value*. Table 8 defines the proposed types of quality and corresponding confidence levels.

*Valid (100)* and *Borrowed-Valid (100)* are the best data quality types because the data have been measured and validated, resulting in the highest confidence level. An example of data tagged with *Borrowed (75)* in a healthcare system context is data collected for patient information documentation in an Emergency Room but that will be reused in documenting patient information in a Surgery Room. *Estimated-Context (50)* is meant to be used when data is not available but can be estimated based on similar tasks. For example, one could estimate data for “write patient report after a surgery” based on data of a similar activity such as “write patient report for consultation”. In case data cannot be estimated

from similar activities, it could be estimated from the literature or studies of similar systems, and be tagged with *Estimated-Literature (25)*. *Unknown* is used to highlight missing evidence and its nullifying impact on the interpretation of goal satisfaction.

**Table 8** Data quality types

Quality type	Corresponding confidence value	Definition/condition
Valid	100	Data already measured and available for the design alternative, in the same context as the one under evaluation
Borrowed-valid	100	Data already measured and available for the design alternative, in a context similar to the one under evaluation
Borrowed	75	Data already measured and available for the design alternative, but in a different context
Estimated-Context	50	No data available, but it was estimated according to a similar design alternative in a different context
Estimated-Literature	25	No data available, but it was estimated based on the literature or previous studies
Unknown	0	No data will be used in the evaluation

In each evaluation strategy corresponding to a certain design alternative, the confidence of goal satisfaction will be calculated and propagated. The following section presents how the confidence of a satisfaction value is computed for different relationships between intentional elements.

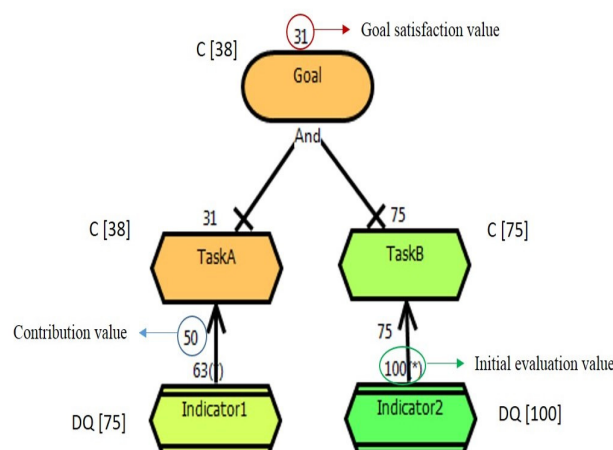
### 4.3.2 Confidence Propagation Method

GRL has four main types of links: AND-decomposition, XOR/OR-decomposition, contribution, and dependency. For each one of these types, the confidence level of the satisfaction of parent goals in a model will be calculated differently from the confidence of children goals. The algorithm for calculating confidence values is adapted from the *CalculateEvaluation* algorithm of standard GRL (URN, 2012). The confidence is computed in an integrated manner from the decomposition, contribution, and dependency relationships, in that order. Confidence is computed *independently* from the satisfaction values of goals; for example, a goal could have a high satisfaction with low confidence or a low satisfaction with a high confidence.

**AND-decomposition:** the confidence of a parent goal satisfaction is equal to the average confidence value of its sub-goals. Unlike satisfaction propagation (where the minimum satisfaction is propagated to the parent goal), the average is used for confidence because:

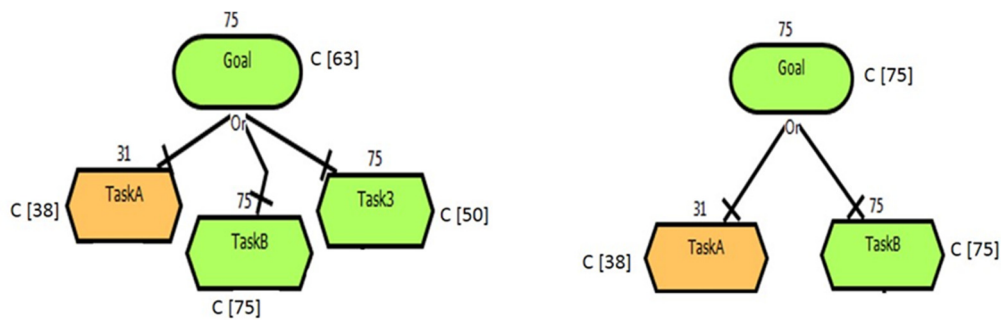
- The confidence of the sub-goal with minimum satisfaction value might be different from the minimum confidence among all sub-goals of the AND-decomposition.
- The confidence of the sub-goal with minimum satisfaction value might be much higher or lower than the confidence of the other sub-goals'. Yet, all sub-goals are taken into consideration during the propagation decision.

Since the satisfaction of the parent goal is computed based on the satisfaction levels of all of its child goals in the AND-decomposition, taking confidence levels of all child goals into consideration in an AND-decomposition context is hence a reasonable trade-off. Figure 19 illustrates how the confidence of the satisfaction of the goal is computed in the AND-decomposition relationship. The confidence is shown on a node using  $C[x]$  and data quality with  $DQ[x]$ , where  $x$  is a level between 0 and 100, inclusively. In the example, the average of 38 (for TaskA) and 75 (for TaskB) is 57, which is propagated to the top-level Goal. Note that GRL models also include other types of weights/results, including contribution values (between -100 and +100), initial satisfaction values in strategies (indicated with a \*), as well as computed satisfaction values (above the nodes). Note that for a model element tagged with  $DQ[x]$  (computed using Table 8), the confidence is also that value (i.e.,  $C[x] = DQ[x]$ ).



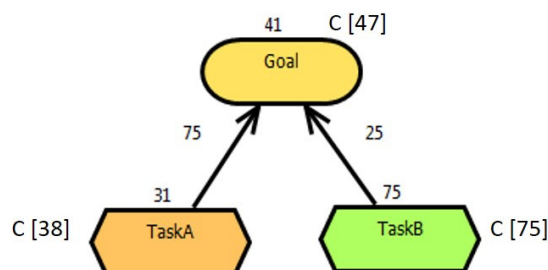
**Figure 19** Confidence of goal satisfaction in the case of an AND-decomposition; data inside circles already exist in standard GRL

**XOR/OR-decomposition:** the confidence of a parent goal satisfaction is equal to the confidence value of its maximally satisfied sub-goals. In case there are more than one sub-goal sharing the maximum satisfaction, the parent’s confidence level becomes the average confidence of the maximally satisfied sub-goals for the OR-decomposition because it is unknown which of these maximum alternatives will be selected (see Figure 20). For the XOR-decomposition, the maximum confidence among the maximally satisfied sub-goals is selected. As the OR-decomposition is about selecting one or many alternatives and the XOR-decomposition one alternative, only the confidence levels of the selected alternatives are considered by the propagation mechanism.



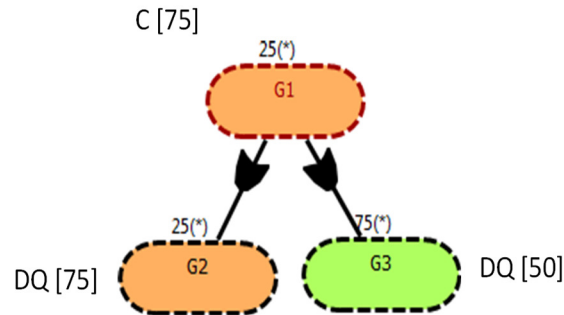
**Figure 20** Confidence of goal satisfaction in the case of an OR-decomposition. Left: average confidence of maximally satisfied sub-goals propagated to the parent goal. Right: confidence of maximally satisfied sub-goal propagated to the parent goal

**Contribution:** the confidence of a parent goal satisfaction is the sum of the product of contribution values of its sub-goals by their confidence values, divided by 100. In the example of Figure 21,  $(38*75 + 75*25)/100 = 47$ . If the sum of the contribution weights is larger than 100 (overcontribution), in order to avoid “confidence building”, the computed confidence level is normalized. This is a mechanism similar to the propagation of satisfaction values in GRL.



**Figure 21** Confidence of goal satisfaction in the case of a contribution

**Dependency:** the confidence of a depending goal is its current confidence level (if any) when the dependent sub-goals all have higher (or equal) satisfaction levels than that goal's satisfaction. However, if some dependent sub-goals have lower satisfaction levels, then the confidence is computed as the minimum between the current confidence level (if any) and the confidence levels of the sub-goals with the lowest satisfaction level. This is a conservative propagation of confidence.



**Figure 22** Confidence of goal satisfaction in the case of dependency;

Computing the confidence for the satisfaction of a goal that is the destination of multiple relationships is first done by handling decomposition confidence values, then contribution values (the confidence previously computed from the decomposition is considered as another contribution), and finally dependency values. In the latter case, the confidence of the destination goal's satisfaction is the average between the confidence of the dependency relationships and the contribution's confidence values.

#### 4.4 Confidence Propagation Formalization

Propagating the confidence of the satisfaction of intentional elements to other elements and to actors is new to the URN language. The leaf intentional elements (including indicators) of a GRL model are annotated (with metadata, see the URN metamodel in Appendix A) with initial confidence values computed from data quality information (see Table 8). The algorithm for propagating confidence values (*CalculateEvaluationAndConfidence*) extends the *CalculateEvaluation* algorithm of standard GRL. What is highlighted has been added to the standard algorithm, and the non-primitive data types are classes from the URN metamodel (Appendices A and B). The *CalculateEvaluationAndConfidence* algorithm generates a new confidence value (between 0 and 100) that can then be stored as a metadata

for the intentional element being evaluated. The algorithm invokes three sub-algorithms (*CalculateDecompositions*, *CalculateContributions*, and *CalculateDependencies*), which are also modified.

Once *CalculateEvaluationAndConfidence* has completed, the *ActorSatisfaction* algorithm (also modified) can be invoked to compute the satisfaction and confidence of an actor, and then the confidence can be stored again as metadata attached to that actor.

```

Algorithm CalculateEvaluationAndConfidence
Inputs element:GRLContainableElement, currentStrategy:EvaluationStrategy
Outputs satisfactionValue:EvaluationValue, confidenceValue:Integer
Assumption //the leaf intentional elements in the model each have an initial
              // confidence value (as a metadata annotation) coming from a data
              // quality assessment

decompValue:EvaluationValue    // intermediate result
contribValue:EvaluationValue    // intermediate result
decompConfValue:Integer        // intermediate result
contribConfValue: Integer      // intermediate result

if not(element in currentStrategy.evaluations.intElement) // is the elem. not initialized?
{
    // calculate based on decompositions, contributions, and dependencies
    decompValue, decompConfValue = CalculateDecompositions(element)
    contribValue, contribConfValue = CalculateContributions(element, decompValue,
                                                            contribConfValue)
    satisfactionValue, confidenceValue = CalculateDependencies(element,
                                                            contribValue, contribConfValue)
}

return satisfactionValue, confidenceValue

```



**Algorithm** CalculateDecompositions**Inputs** element:GRLContainableElement**Outputs** decompValue:Integer, decompConfValue:Integer

```
if (element.decompositionType = AND) {
    decompValue = min(element.linkDest.src.quantitativeVal)
    decompConfValue = average(element.linkDest.src.confidence)
}
else if (element.decompositionType = OR || element.decompositionType = XOR) {
    decompValue = max(element.linkDest.src.quantitativeVal)
    maxChildren:Set(IntentionalElement) =
        element.linkDest.src.subset(quantitativeVal = decompValue)
    decompConfValue = average(maxChildren.confidence)
}

return decompValue, decompConfValue
```

**Algorithm** CalculateContributions**Inputs** element:GRLContainableElement, decompValue:Integer,  
confDecompValue:Integer**Outputs** contribValue:Integer, confContribValue: Integer

```
oneCont:Integer           // one weighted contribution
totalCont:Integer = 0     // weighted sum of the contribution links
oneContConf:Integer      // one weighted contribution confidence
totalContConf:Integer = 0 // weighted sum of the contribution links' confidences
sumContribWeights:Integer // sum of contribution weights
```

```
// compute the weighted sum of contributions
```

```
for each link:Contribution in element.linksDest {
    oneCont = link.src.quantitativeVal × link.quantitativeContribution
    totalCont = totalCont + oneCont
    oneContConf = link.src.confidence × link.quantitativeContribution
    totalContConf = totalContConf + oneContConf
}
```

```
totalCont = totalCont / 100
```

```
contribValue = totalCont + decompValue
```

```
totalContConf = totalContConf / 100
```

```
confContribValue = totalContConf + confDecompValue
```

```
// contribution value cannot be outside [-100..100]
```

```
if (|contribValue| > 100)
```

```
    contribValue = 100 × (contribValue/|contribValue|)
```

```

// confidence cannot be built when the sum of contributions is above 100
sumContribWeights = sum(element.linksDest.quantitativeContribution)
if (sumContribWeights > 100)
    // normalize the confidence
    confContribValue = confContribValue / (sumContribWeights / 100)

return contribValue, confContribValue

```

**Algorithm** CalculateDependencies

**Inputs** element:GRLContainableElement, contribValue: Integer,

confContribValue: Integer

**Outputs** satisfactionValue:EvaluationValue, confidenceValue:Integer

dependValue: Integer // intermediate result

dependConfValue: Integer // intermediate result

dependValue = **min**(element.linkDest.src.quantitativeVal)

minChildren:Set(IntentionalElement) =

element.linkDest.src.subset(quantitativeVal = dependValue)

dependConfValue = average(minChildren.confidence)

satisfactionValue = **min**(dependValue, contribValue)

**if** (dependValue < contribValue) {

    // compute weighted average of confContribValue and dependConfValue

    confidenceValue = (dependConfValue × minChildren.size() + confContribValue)  
                           / (minChildren.size() + 1)

}

**else** confidenceValue = confContribValue

**return** satisfactionValue, confidenceValue

**Algorithm** ActorSatisfaction

**Inputs** actor:GRLContainableElement

**Outputs** satisfactionValue:EvaluationValue, confidenceValue:Integer

actorSatValue: Integer = 0 // intermediate result for sum of weighted satisfactions

actorImpValue: Integer = 0 // intermediate result for sum of quantitative importances

actorConfValue: Integer = 0 // intermediate result for sum of weighted confidences

**for each** elem: IntentionalElement **in** actor.elems {

    actorSatValue = actorSatValue +

        elem.quantitativeVal × elem.importanceQuantitative

    actorImpValue = actorImpValue + elem.importanceQuantitative

    actorConfValue = actorConfValue + elem.confidence × elem.importanceQuantitative

}

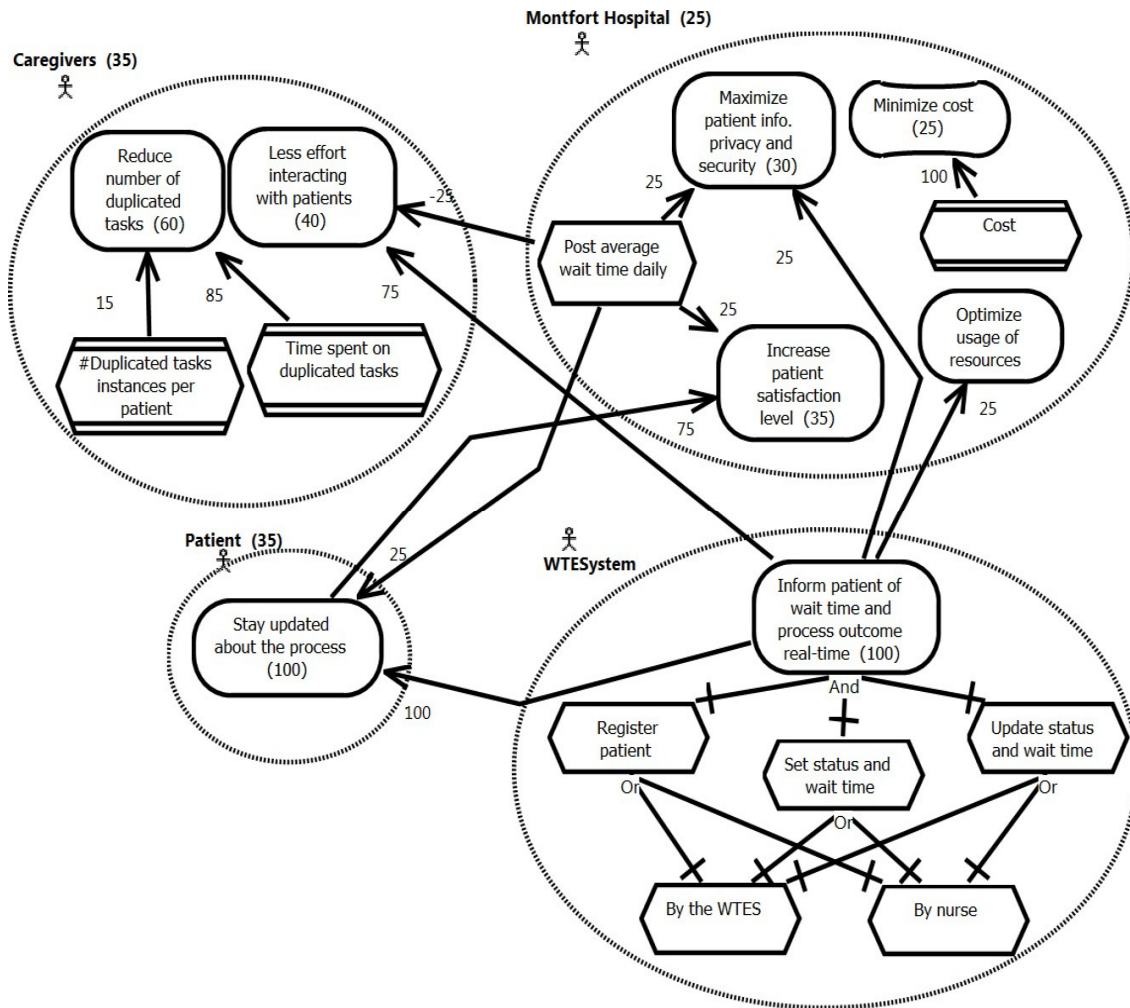
```
satisfactionValue = actorSatValue / actorImpValue
confidenceValue = actorConfValue / actorImpValue
return satisfactionValue, confidenceValue
```

## 4.5 Illustrative Example

This example revisits the one introduced in Section 3.3.2 (with a slightly different version), which is a simplification of a real problem faced by a Canadian hospital (Montfort). Synthetic data is being used here for illustrative purpose. In the emergency room (ER) of that hospital, expectations on wait times are manually posted on a board at different moments during the day. This procedure keeps patients updated on how long they may have to wait. The hospital considers introducing a new *Wait Time Estimation System* (WTES), with different design alternatives. Different stakeholders of WTES (caregivers, patients, and the hospital itself) have different goals, tasks, and indicators.

Using WTES, the current status and expected wait time shall be updated automatically for the patient at each step of the ER process. The design alternatives include: 1) WTES tasks being performed by the nurse; and 2) WTES tasks being performed automatically through bridging the WTES and the existing ER system. While the first alternative results in many duplicated tasks, the second increases the integration cost. Figure 23 presents the goal model of this context. The best alternative is the one that satisfies the model the best, given the weight of each actor and the importance of their goals (between parentheses in the figure).

Using the Data Quality Tagging and Confidence Propagation Mechanism, the indicators are first tagged with a certain level of data quality (Table 8) according to the above description (see Table 9), and then the confidence levels in the satisfaction of higher-level goals are propagated using the algorithms explained in Section 4.3.2. For leaf intentional elements other than indicators, initial confidence levels must also be provided. In particular, selected alternatives are given a confidence of 100 whereas unselected alternatives are given a confidence of 0.

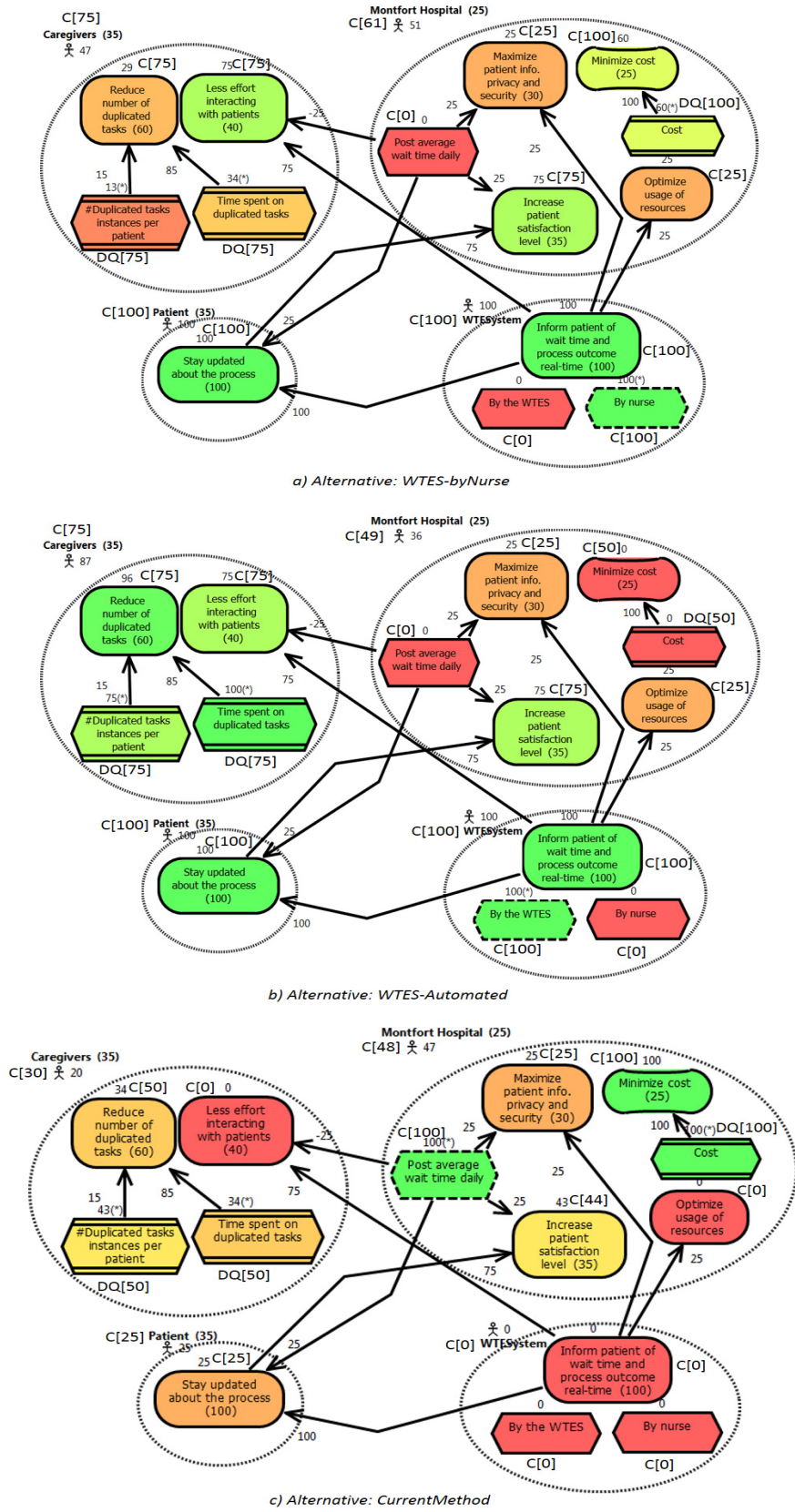


**Figure 23** Integrated goal model of the introduction of a WTES (with two alternatives) for informing patients of wait times in the ER.

**Table 9** Data quality of indicators for each evaluation strategy

Alternative	Number of duplicated tasks per patient	Time spent on duplicated tasks	Cost
<i>WTES-byNurse</i>	75 (Borrowed)	75 (Borrowed)	100 (Valid)
<i>WTES-Automated</i>	75 (Borrowed)	75 (Borrowed)	50 (Estimated-Context)
<i>CurrentMethod</i>	50 (Estimated-Context)	50 (Estimated-Context)	100 (Valid)

Looking at the evaluation of the WTES design alternatives (Figure 24), the WTES-Automated alternative seems to outperform the other alternative and the current method. However, considering the confidence of the top-level goals, it is noted that the indicators of duplicated tasks and the time share the same confidence value.



**Figure 24** GRL model evaluations of WTES alternatives, with confidence levels

In the WTES-byNurse alternative, the confidence of *Minimize cost* is valid (100). On the other hand, it is estimated (50) in the WTES-Automated alternative (where the cost indicator evaluation value is equal to the worst-case). There is no evidence to support the case. The cost could be even worse or, perhaps, better. Therefore, there are two potential conclusions 1) if the case of informing patients of ER process outcomes in real time is urgent, the hospital can choose, temporarily, the WTES-byNurse alternative until the cost of the other alternative is known, or 2) obtaining more valid data about the cost and re-evaluate the design alternatives.

Compared to the WTES alternatives, the CurrentMethod alternative contributes the least to the goals of patients and the hospital, and to the general satisfaction of caregivers, with the lowest confidence values in all goal satisfaction except for *Minimize cost*, where the confidence is 100. Note that the confidence propagated to top-level goals in each evaluation strategy (see Figure 24) reflects only the confidence of the chosen alternative.

## 4.6 Discussion

Although the mapping of quality types in Table 8 is simple, it has been informally validated by physicians of two hospitals. There is a good opportunity for this data quality approach to add a piece of information to a goal model that will help estimate confidence in a simple and practical way. Many studies have been proposed to support decision making in presence of uncertainty. However, they are often not practical in industry. For example, in the healthcare sector, data about patients, diagnoses and treatments, in most cases, are available. In this context, advanced methods, such as those based on probability distributions, can be used.

However, data about performance or cost (beyond acquisition) related to a new technology or system design are rarely available (Baslyman et al., 2017). The challenge increases when data is unavailable about the current technological solution being used in the hospital. In this case, the proposed mechanism would be beneficial to highlight data insufficiency and the need to collect more. As I am interested in healthcare RE research (Baslyman et al., 2017; 2017c), the approach has been discussed with healthcare IT workers with encouraging feedback. In addition to the potential benefits in practice (decision-making support, and coverage of goal contributions), this data quality approach could

likely be applied to other goal modelling languages beyond GRL (e.g.,  $i^*$ , KAOS, or the Goal Structuring Notation).

## 4.7 Limitations

There are also several limitations to the method that deserve attention. The major one is that data quality types could be improved based on other dimensions. The quality types presented in this chapter are generic and function well, to some extent, in the context of this thesis. However, more precise types may be needed in other contexts. For example, the classification of the data gathered through sensors in real time is not yet supported in the proposed approach. It is also worth mentioning that assigning quality types to data is not trivial. Currently, this is done based on an assessment of analysts and stakeholders involved in the context where, probably, many disagreements and conflicts arise. Therefore, it is important to systematize and formally describe the process of assigning quality types to data.

Some of the formulas used to propagate confidence levels could be further validated. Moreover, the approach should illustrate, more efficiently, the potential impact of other alternatives on goal confidence when only one alternative is effective at a time. The illustrative example may not reflect the complexity of real-world cases. However, the data quality approach is further tested in more advanced contexts in this thesis' case studies.

## 4.8 Chapter Summary

Data availability has always been a big challenge in industry. Yet, reasoning about system goals and alternatives in the presence of uncertainty related to data is important. In this chapter, I proposed a *Data Quality Tagging and Confidence Propagation Mechanism* that maps data quality to initial confidence levels and propagates this information to compute the confidence level of goal satisfaction. The approach improves upon related work by its simplicity and effectiveness (as illustrated in the example and informally reported by IT workers).

For future work, different data quality dimensions and the generalization to languages other than GRL could be explored. Further industrial validation is also required.

The next chapter presents a new and complementary analysis technique that computes the satisfaction level of an entire GRL model based on Multi-Criteria Decision Analysis techniques, in a way that enables the ranking of alternatives as well as improvements to the GRL model itself.



# Chapter 5 Distance-based GRL Approach

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The chapter proposes a distance-based evaluation approach for GRL models, to guide the selection of alternatives in the presence of multiple top-level objectives. The *Distance-based GRL Approach* (DbGRL) exploits the Analytic Hierarchy Process (AHP) technique and the Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) for building and analysing GRL models. This chapter presents DbGRL and its usage with a simple but realistic healthcare-related example where results are promising. DbGRL's expected benefits and limitations are also discussed. A preliminary version of this chapter was published in Baslyman and Amyot (2017b).

## 5.1 Introduction

Industry is changing rapidly to meet customers' needs and to cope with changes imposed by governments and competitors. Every day, many new alternatives are brought to the market or are suggested to accommodate those changes. *Multi-Criteria Decision Analysis* (MCDA) approaches have been used widely to guide the process of decision-making in multi-attribute selection problems (Ishizaka and Nemery, 2013). The main challenge in this change context is to choose the alternative that satisfies the intended goals and other criteria. Although modelling business goals (e.g., with the Goal-oriented Requirement Language or similar notations) is a common activity, little research has focused on the use of MCDA with goal-oriented modelling techniques to provide integrated decision support. Existing approaches usually rely on ranking the alternatives based on certain weighted criteria and goals. Yet, several questions often remain unanswered, such as: Is the highest-ranked alternative good enough to be the solution, or will it be chosen simply because it is the best alternative at hand? Is the goal model that supports decision-making good enough in the first place? To help answer such questions, I propose a new *Distance-based GRL* approach (DbGRL), discussed in this chapter in the context of business process integration. Small and medium organizations (e.g., a community hospital) often integrate technologies

and their supporting processes with those used in the organization because they seldom can afford developing custom technologies by themselves.

When using the AbPI methods, some challenges are faced such as the high number of integration alternatives from which stakeholders need to choose, and the many competing objectives of these stakeholders. MCDA and goal modelling are rich in methods that enable ranking the predicted performance of alternatives based on objectives and other selection criteria. However, I believe that ranking alone cannot be used blindly. It is important to question the goal models that affect the selection of appropriate alternatives (whether they are complete, consistent, and realistic) and whether the highly ranked alternatives are good enough to satisfy the goals. DbGRL uses GRL for modelling goal because GRL is a part of an international standard (URN), enables the modelling of stakeholders and their goals, supports Key Performance Indicators (KPIs) for quantitative reasoning, and supports evaluation strategies and propagation algorithms to evaluate the satisfaction of goals and actors under selected conditions. AbPI also uses GRL, but in combination with URN's Use Case Map notation, which is used to model business processes and their supporting components. DbGRL also uses the *Analytic Hierarchy Process* (AHP) (Saaty 2008) to determine the weight/importance of goals to their stakeholders and the *Technique of Order Preference Similarity to the Ideal Solution* (TOPSIS) (Behzadian et al., 2012) to rank the alternatives. The approach additionally uses TOPSIS to ensure that the highly-ranked alternatives are close enough to the ideal point, as otherwise additional elicitation/validation of requirements might be needed, which may impact the specification of the goal model and/or of the alternatives themselves.

## 5.2 Related Work

MCDA is an operations research discipline that evaluates multiple conflicting criteria in support of decision-making activities. MCDA has been used widely and in very different contexts, from aerospace (Zweber and Pendleton, 2007) to food chemistry (Sun et al., 2011). There are many MCDA approaches that were proposed to serve in a certain problem context (Ishizaka and Nemery, 2013) such as AHP (Saaty, 2008) and TOPSIS (Behzadian et al., 2012). AHP uses pairwise comparisons involving many stakeholders mainly to rank alternatives of an unstructured problem where selection criteria are not well defined and

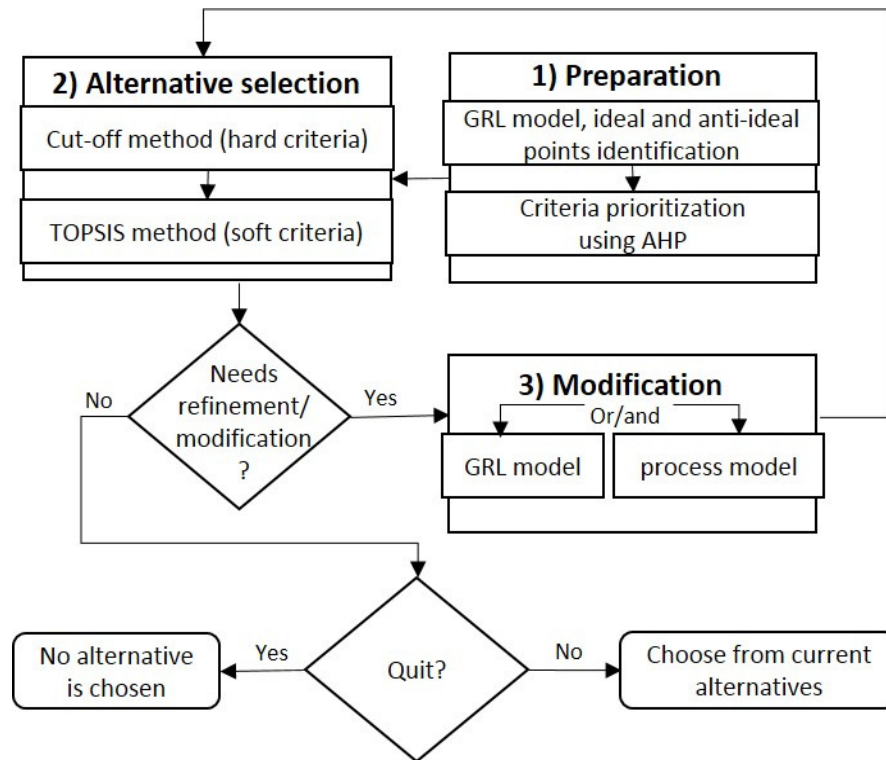
the importance scores of these criteria are unknown. AHP was introduced to goal modelling to prioritize criteria based on gathering weights (of contributions and of goals) from stakeholders (Akhigbe et al., 2014; Liaskos, 2012; Yamamoto and Saeki, 2008). It was also used to rank the alternatives (through additive weight and cut-off methods) with respect to a set of criteria (Ma and Kinderen, 2016; Zhao, 2015).

TOPSIS was used in a similar way, with criteria assumed to be monotonically increasing or decreasing, but where the ranking was based on the geometric distance from the *anti-ideal point* (i.e., the worse-case situation) and the *ideal point* (i.e., the best-case situation) (Luo and Li, 2011; Mairiza et al., 2014). The ideal and anti-ideal vectors are constructed from the available alternatives. TOPSIS hence not only looks for good solutions, but also for solutions that are far away from bad situations. Some studies introduced the use of AHP with TOPSIS where the former prioritizes the criteria and the later ranks the alternatives (Vinay et al., 2012; Sobczak, 2007). In terms of validation of GRL models themselves (beyond syntactic correctness), an approach based on stakeholder specific questionnaires was proposed by Hassine and Amyot (2016; 2017). DbGRL is complementary as it uses the evaluation of alternatives (e.g., analysis results) to highlight potential weaknesses in the goal model.

### 5.3 DbGRL Approach

The Distance-based GRL approach identifies an ideal point and an anti-ideal point, and then uses this information in addition to the evaluation of alternative solutions on a GRL model. DbGRL enables the analysis of the distance between the ideal point and the alternatives' performance on the GRL model and selection criteria. This can be used to reach desired outcomes and/or refine goal models and their alternative solutions (e.g., processes and integrations in AbPI). DbGRL consists of four main sequential phases: preparation, alternative selection, decision-making, and modification (see Figure 25). The approach's inputs are: a GRL model with alternative solutions captured via GRL evaluation strategies, an ideal vector (set of targets: satisfaction values of goals, and indicator values to be reached), and an anti-ideal vector (set of undesired satisfaction values of goals, and indicator values to be avoided). The outputs of DbGRL are the alternatives ranked from high to low, based on the defined preferences (goals and criteria), and optionally a new GRL model

and/or set of alternative solutions (if modifications are needed). The three phases are detailed below.



**Figure 25** DbGRL approach

### 5.3.1 Preparation

In this phase, criteria used to guide the selection of alternatives are defined. The criteria are goals, actors, or KPIs to be optimized. Some criteria can be defined as hard and others as soft. While hard criteria need to be satisfied completely in order for an alternative to be a potential solution, soft criteria are used to sort the alternatives based on stakeholders' preferences. The normalized weight of each criterion is defined using the AHP approach, which exploits pairwise comparisons of elements (in terms of importance) made by many stakeholders. Each weight is hence between 0 and 1 (inclusively) and the weights sum up to 1.

### 5.3.2 Selection of Alternatives

There are two steps in this phase. First, I select the alternatives that satisfy the hard criteria and eliminate the others. I use a simple cut-off method to perform this step. Second, I sort

the selected alternatives based on the ideal and anti-ideal points using the TOPSIS algorithm. Once the alternatives are sorted, there are several questions that need to be asked: Is the highest-ranked alternative the best, and is it far enough from the anti-ideal point? Is it close enough to the ideal point? Does it achieve the desired outcomes? If the answer is yes to each of these, then this highest-ranked alternative is the solution. Otherwise, more questions should be asked: Is there any other lower-ranked alternative that could be a candidate? What kind of modification, on the GRL model and/or the alternatives (e.g., the linked UCM process models in AbPI) should be done to acquire better results? These questions, and others if needed, are discussed with stakeholders and decision makers to determine whether to move to the modification step, while postponing the decision.

### **5.3.3 Modification**

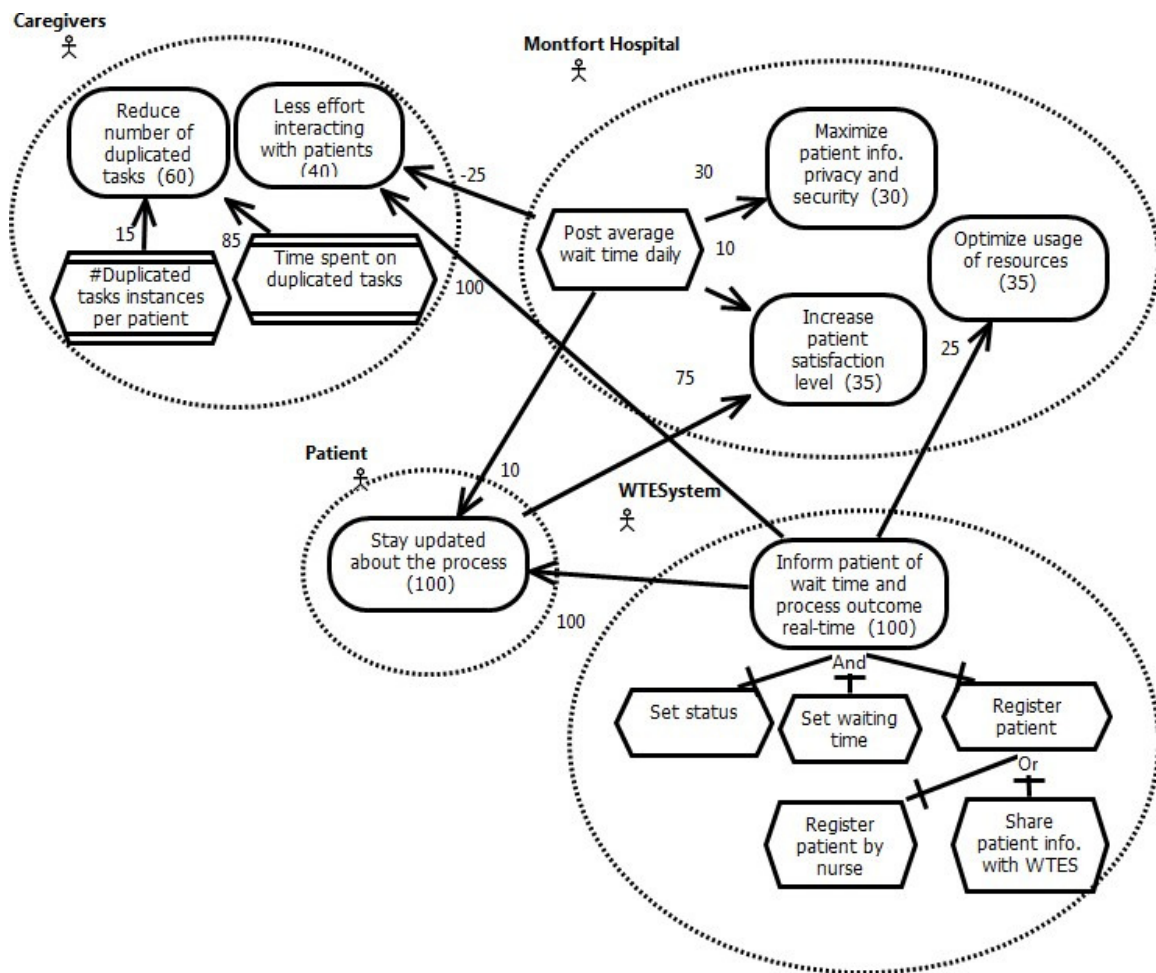
This phase is fairly unique to DbGRL, as it allows reassessing the models and values to check whether something needs to be fixed. Modifications can be done to the GRL model, ideal or anti-ideal vectors, or the alternatives. The GRL model can be modified to add/remove contributions, tasks, KPIs, actors, and goals. The GRL model can be modified also to accommodate changes proposed to the existing GRL elements (such as changing the importance value of a goal). The impact of changes made in the GRL model should appear in the alternatives' performance as well. In some cases, none of the alternatives might be close to the ideal point or far from the anti-ideal point because the values of these two vectors are not realistic or are incorrect. In that case, the ideal and anti-ideal vectors shall be questioned and validated with stakeholders again. Lastly, the alternatives themselves can be modified. More concretely, for the AbPI context, the process integration model can be changed by adding/deleting/replacing activities. The reason for changes at the solution level is to, possibly, realign the alternatives with the revised GRL model or ideal/anti-ideal points. The selection phase is then re-executed. DbGRL users keep iterating between the selection and modification phases until one of the alternatives is selected, or until users give up with no resulting decision. The following section describes the DbGRL elements and steps formally.

## 5.4 Illustrative Example

This section uses a variant of the example used in the two previous chapters, which is related to the introduction of a Wait Time Estimated System (WTES) at Montfort Hospital. The AbPI users identified three possible integrations of the WTES-dependent process into the current ER process. These are:

- Alternative 1: the WTES pulls the registration information automatically from the ER system.
- Alternative 2: nurses register patients to both the ER system and WTES in parallel.
- Alternative 3: no change will be made to the current process (status quo).

Figure 26 shows the main GRL model resulting from the integration of individual goal models of the current process and of the proposed process.



**Figure 26** Integrated GRL model for the DbGRL approach example

### 5.4.1 Phase 1: Preparation

The first phase of the DbGRL approach is to identify the selection criteria, their weights, and ideal and anti-ideal vectors. All values in the example were collected from stakeholders at the hospital. The criteria are: task duplication (number of task duplications per instance), time (time spent on duplicated tasks shall be less than 290 seconds), patient satisfaction, and security and privacy (maximizing the privacy and security of patient information). While task duplication shall be minimized, patient satisfaction as well as security and privacy shall be maximized. Time is identified as a hard criterion. The weights of these criteria were calculated using pairwise comparisons (as in AHP) based on stakeholder inputs (not shown here). Table 10 contains the criteria and their weights. Table 11 presents the performance of the alternatives against the criteria, as well as the ideal and anti-ideal vectors determined through stakeholder consensus. The stakeholders estimated the data about time and task duplication, and the satisfaction values of patient satisfaction and security and privacy goals were propagated using GRL evaluation strategies with the jUCMNav tool (Mussbacher and Amyot, 2009).

**Table 10** Criteria and assigned weights

Criteria	Weights
task duplication	0.1
time	0.1
patient satisfaction	0.4
security and privacy	0.4

**Table 11** Values of the alternatives and of the ideal and anti-ideal points for each criterion

Alternatives	Time (sec)	Task duplication	Patient satisfaction	Privacy and security
Alternative 1	60	2	100	0
Alternative 2	180	6	100	0
Alternative 3	300	2	10	30
Ideal	30	1	100	100
Anti-ideal	360	5	0	0

### 5.4.2 Phase 2: Alternative Selection

As discussed in the preparation phase, time is a hard criterion that will be used in the *cut-off* step (Figure 25) to eliminate the alternatives that are too weak. As the time value in

Alternative 3 is 300 seconds, this alternative is eliminated right away because it does not meet the required maximum of 290 seconds. Alternatives 1 and 2 hence pass to the next step, based on TOPSIS. TOPSIS has four computation steps (Ishizaka and Nemery, 2013):

- 1) Normalizing scores ( $r_{ai} = \frac{x_{ai}}{u_i}$ , where  $x$  is the performance of alternative  $a$  on criterion  $i$ ;  $u$  is the best performance on criterion  $i$  in the column);
- 2) Calculating the weighted normalized scores ( $v_{ai} = r_{ai} \cdot w_i$ , where the weights  $w_i$  result from applying AHP);
- 3) Calculating the (Euclidean) distances to the ideal point  $v^+$ : ( $d_a^+ = \sqrt{\sum_i (v_i^+ - v_{ai})^2}$ ) and the anti-ideal point  $v^-$ : ( $d_a^- = \sqrt{\sum_i (v_i^- - v_{ai})^2}$ );
- 4) Calculating the relative closeness (C) to the ideal point ( $C_a = d_a^- / (d_a^+ + d_a^-)$ ).

**Iteration 1:** the TOPSIS analysis leads to the results presented in Table 12 (iteration 1). For example, as the normalized ideal vector is  $v^+ = [0.1; 0.1; 0.4; 0.4]$ , the normalized anti-ideal vector is  $v^- = [1.2; 0.5; 0.0; 0.0]$ , and the weighted normalized Alternative 1 is  $v_{a1} = [0.2; 0.2; 0.4; 0.0]$ , the distance  $d_1^+$  becomes 0.42 and  $d_1^-$  is 1.1. Alternative 1 is closer, based on the calculated distances, to the ideal point than Alternative 2 (at 0.81). However, Alternative 1 is still 0.42 away from the ideal point, which was considered far by the stakeholders. In such a case, there is a good opportunity to investigate the GRL model itself and the solutions for any possible improvement that may enhance the performance of Alternative 1 against the criteria.

**Table 12** Results of the three iterations of alternative selection and modification phases, in terms of distances

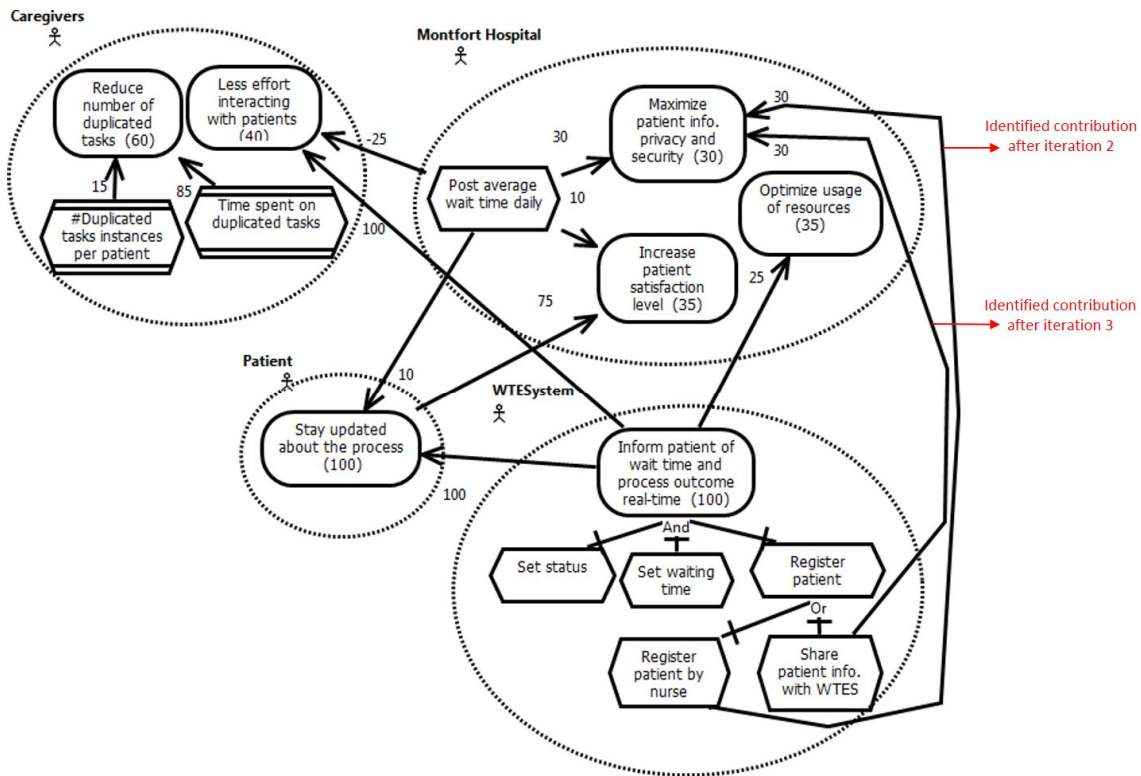
<b>Iteration 1</b>		
<b>Measures</b>	<b>Alternative 1</b>	<b>Alternative 2</b>
<b>d<sup>+</sup></b>	0.42	0.81
<b>d<sup>-</sup></b>	1.1	0.72
<b>C</b>	0.72	0.47
<b>Iteration 2</b>		
<b>d<sup>+</sup></b>	0.31	0.81
<b>d<sup>-</sup></b>	1.1	0.72
<b>C</b>	0.78	0.47
<b>Iteration 3</b>		
<b>d<sup>+</sup></b>	0.31	0.76
<b>d<sup>-</sup></b>	1.1	0.72
<b>C</b>	0.78	0.49



### 5.4.3 Phase 3: Modification

Looking at Table 11, the worst performance of Alternative 1 is on the security and privacy criterion, which leads to many questions: Could Alternative 1 perform better there? Is there any un-captured information or concerns at the GRL level? Is there any possible modification in the solution space (e.g., process model) that can contribute to the security and privacy goal? After discussing these questions with stakeholders, two possible solutions were identified: 1) the ER system shall push patient information to WTES (with no access from WTES to the ER system), and/or 2) an authentication mechanism is required. Applying any of these solutions to the process will contribute positively (30) to the security and privacy goal (new contribution from *Share patient info. with WTES*, see Figure 27). Table 11 hence needs to be updated with the new performance of Alternative 1 (+30) on the security and privacy criterion.

**Iteration 2:** The result of the modification step will be the new input of TOPSIS. As seen in Table 12 (iteration 2), Alternative 1 improved by 0.1 compared with iteration 1, and the relative closeness (C) value improved from 0.72 to 0.78. Now that the performance of Alternative 1 has improved, the same questions may be asked about Alternative 2 in order to investigate whether there is a room for improvement (Alternative 2 might over-perform Alternative 1) or not. In the GRL model, there is indeed a missing contribution link between the Register patient by nurse task and the security and privacy goal. If the nurse performs the task manually, it has the same effect on the privacy and security goal as posting the average wait time. Accordingly, the GRL model is refined with the newly discovered contribution (see Figure 27). Table 11 is again updated with the new performance of Alternative 2 (+30) on the security and privacy criterion.



**Figure 27** Refined version of the GRL model from Figure 26

**Iteration 3:** The result of the modification step (iteration 2) leads to new TOPSIS results in Table 12 (iteration 3). Alternative 2 is slightly better than before (from 0.47 to 0.49). However, the change is not significant. Alternative 1 still has a much higher C score and is hence selected in this example.

## 5.5 Discussion

Although the DbGRL approach is new, there is a good opportunity for it to bring better alternatives' performance by refining the GRL and solution models. Most TOPSIS applications construct the ideal and anti-ideal points *from the alternatives themselves*, while in our approach, the ideal and anti-ideal points are *identified with stakeholders* before TOPSIS starts. This idea was inspired by the culture at Montfort Hospital, where the Lean change management approach is used to improve current services (Womack et al., 2005). In the Lean approach, the target to be reached and the worst case are identified, ahead of exploring the solutions. I believe the DbGRL approach will work well in such context and can trigger discussions leading to the identification of missing/extra elements in the goal or solution

models. In the absence of explicit ideal and anti-ideal points, DbGRL can still fall back on a more conventional way of identifying them based on the alternatives themselves.

The DbGRL approach also improves upon related work, especially the one of Vinay et al. (2012), by using real values (numbers for goal initial satisfaction values and contribution weights) to evaluate goal models, instead of simpler qualitative values. In addition, our approach goes beyond using TOPSIS to select solutions from alternatives; DbGRL identifies the ideal and anti-ideal GRL models separately from the available alternatives, which enables identifying the gap between the alternatives and the ideal GRL model. As a result, deeper analysis and validation are permitted that could lead to modifications to the alternatives solutions (to reduce the distance to the ideal solution) and to the GRL model (changes in goals/contributions, etc.).

There are several limitations that deserve attention. The example may not reflect the complexity of real-world cases or how the approach could be beneficial in these cases. However, not all alternatives are candidates for the re-evaluation process (the iteration between the evaluation and modification phases). I think that the alternatives should be considered carefully and chosen based on a systematic method (involving some thresholds), which is not defined yet. In the example, DbGRL helps in capturing missing contributions for Alternatives 1 and 2. This is one of the main objectives of the approach. However, I am not certain that the approach can scale well to high numbers of criteria and/or alternatives. The usability of the approach related to the effort required for modelling, gathering of weights with AHP, identifying values for criteria and for the ideal/anti-ideal points, and deciding to update the model is yet to be determined. However, ad hoc discussions with two Lean teams suggest that this effort is not unlike what is done informally and manually during change management projects. In addition, DbGRL is used effectively in two case studies (Chapter 8 and Chapter 9) where the context is more complex, with more criteria to collect and measure.

## **5.6 Chapter Summary**

The selection of a solution among alternatives in the presence of multiple criteria has always been a challenging task, in part due to the poor identification of criteria or the com-

plexity of the search space. Combining the field of MCDA with goal modelling is synergistic, as both fields complement each other in capturing the performance of alternatives against goal-oriented criteria. DbGRL suggests benefits in combining MCDA approaches (cut-off, AHP, and TOPSIS) to go beyond the simple ranking of alternatives (e.g., based on weighted averages of actor satisfactions) by relying on two main principles: 1) identifying the ideal and anti-ideal points to evaluate how close current alternatives are from the desired outcome, and 2) using the alternatives' ranking results as an opportunity to investigate the GRL model for further refinement. Similarly, the alternatives (e.g., a UCM process model) linked to the GRL model can be modified to reach better performance and alignment. The feasibility of DbGRL was illustrated using an ER process integration example.

The next chapter will formalize the AbPI framework as a profile of the User Requirements Notation and provide algorithms for its methods, with implementations. The AbPI framework also takes advantage of the DbGRL approach introduced in this chapter, as well as of the data quality tagging and confidence propagation mechanism covered in the previous chapter.

# Chapter 6 Formalization and Implementation

---

This chapter discusses the formal representation of the AbPI conceptual model and its constraints. It also introduces an implementation of the framework by profiling the User Requirements Notation (URN), i.e., by mapping the URN language elements to the proposed conceptual model. It also presents the, PGMs and the framework methods.

## 6.1 AbPI Conceptual Model Formalization

The AbPI conceptual model introduced in Figure 4 is formalized in as a UML class diagram using the *UML-based Specification Environment* (USE) of Gogolla et al. (2018). USE is a formal modelling tool that enables the definition of class diagrams as well as of supplementary constraints in the *Object Constraint Language* (OCL) (OMG, 2014). The input of USE is a textual representation of the class diagram structure and constraints. The tool supports the creation of object diagrams (PGMs in the thesis context) to check whether models conform to the conceptual model (class diagram) and its constraints. This feature can also indirectly be used to validate the conceptual model itself, in terms of how well and sufficiently the goal and process model concepts are captured by the conceptual model's classes, attributes, and relationships.

The USE model of the AbPI conceptual model is available online (see Appendix F). In addition to the content of the class diagrams shown in Figure 4 and Figure 8, additional well-formedness constraints in OCL are included, and they are described in the next two sub-sections. The creation of the object diagrams (PGMs) and the conformance checking part is discussed in Section 6.4.4.

### 6.1.1 AbPI Conceptual Model Constraints for Goal Integration

There are several groups of constraints required to ensure coverage and consistency. The first group ensures that all elements of the Input, SIGM, and DIGM are covered by the integrated goal model (Figure 8). It is important to check this constraint, especially in the first version of the IGM, before making any decision about adding, removing, or changing

the elements in the later versions of the IGM. The following three OCL constraints ensure that all goal, link, and stakeholder elements belong to an integrated goal model. Violations of these constraints would indicate missing elements absent from the IGM but present in the SIGM or DIGM.

```
context Goal
inv GoalCoverage:
goalModel -> select(c : GoalModel | c.Type = GMTType::IGM )->size() >= 1
```

```
context Link
inv LinkCoverage:
goalModel -> select(c : GoalModel | c.Type = GMTType::IGM )->size() >= 1
```

```
context Stakeholder
inv StakeholderCoverage:
goalModel -> select(c : GoalModel | c.Type = GMTType::IGM )->size() >= 1
```

Another important group of constraints is needed to check that if there exist IntegrationRelation instances between two elements, one of these instances has to be of type A (Approved). This must be checked for goal, link, and stakeholder elements, as formalized below. Violations of these constraints would indicate integrate relations that remain to be approved by the analyst.

```
context Goal
inv GoalRelation:
self.integrationrelation.destination.relation->size() >= 1
implies
integrationrelation->select(c : IntegrationRelation | c.type = IntegrationRelationType::A )
->size() >= 1
```

```
context Link
inv LinkRelation:
self.integrationRelation.Linkdestination.relation->size() >= 1
implies
integrationRelation->select(c : IntegrationRelation | c.type = IntegrationRelationType::A )
->size() >= 1
```

```

context Stakeholder
inv StakeholderRelation:
  self.integrationRelation.Stakeholderdestination.relation->size() >= 1
implies
  integrationrelation->select(c : IntegrationRelation | c.type = IntegrationRelationType::A )
    ->size() >= 1

```

As will be presented in the case studies (Chapter 8 and Chapter 9), *Goal* elements can have *IntegrationRelation* with *Link* and/or *Stakeholder* elements. In this case, it is also essential to check that these are also approved, which is why the next two OCL constraints are also needed.

```

context Goal
inv GoalLinkIntegrationRelation:
  self.integrationrelation.LinkDestination.relation->size() >= 1
implies
  integrationrelation->select(c : IntegrationRelation | c.type = IntegrationRelationType::A )
    ->size() >= 1

```

```

context Goal
inv GoalStakeholderIntegrationRelation:
  self.integrationrelation.stakeholderDestination.relation->size() >= 1
implies
  integrationrelation->select(c : IntegrationRelation | c.type = IntegrationRelationType::A )
    ->size() >= 1

```

### 6.1.2 AbPI Conceptual Model Constraints for Process Integration

In the AbPI conceptual model (Figure 4), it is important to enforce a constraint ensuring that all activities of current and proposed processes are included in the integrated model. This is captured through the following OCL constraint. Violations of this constraint would indicate an activity missing from the integrated model but present in one of the source models.

```

context Activity
inv CurrentOrProposedActivityInIntegratedProcess:
  self.belongsTo.closure(parent).type -> includes(ProcessType::Integrated)

```

## 6.2 URN Profile

This section presents a URN profile for AbPI, which enables the use of URN as a concrete syntax to create process-goal models as instances of the AbPI conceptual model.

### 6.2.1 Design for Activity-based Process Integration Conceptual Model

As discussed in Chapter 3, the main elements of the AbPI conceptual model are: concerns, goal models, process models, roles, activities, internal relationships (between a group of elements that belong to one element type such as goal-to-goal relations), and external relationships (between elements that are not from the same type, such as activity-goal relations). URN already possesses many of these concepts, as well as mechanisms to extend the language with additional concepts (with *metadata*) and relationships (with *URN links*). See Appendix A for more information about the URN metamodel. Table 13 and Table 14 show how the mapping between each AbPI conceptual model’s element and link and the corresponding URN element.

**Table 13** Mapping between AbPI conceptual model elements and URN elements

Conceptual model elements	URN elements	Existence	Missing attributes
Concern	Concern	Exists	-
Stakeholder	Actor	Exists	-
Goal model	GRLgraph	Exists	Type
Goal	IntentionalElement (of type Goal)	Exists	-
Indicator	Indicator	Exists	-
Process Model	UCMspec	Exists	-
Process	UCMmap	Exists	type
Activity	Responsibility	Exists	-
Sub-processes	UCMmap (as plug-ins to a stub in a parent map)	Exists	-
Constraint	OCL expression	Exists	-
Criterion	IntentionalElement (of type Goal)	Exists	-

As shown in Table 13, almost all the conceptual model elements are covered by URN elements. The *Type* attribute of a goal model is captured as metadata on a GRLgraph in URN, where the metadata name is “Type” and the possible values are “Input”, “SIGM”, “DIGM”, or “IGM”. The *type* attribute of a process is captured as metadata on a UCMmap



in URN, where the metadata name is “ProcessType” and the possible values are “Current”, “Proposed”, or “Integrated”.

However, the case is different with the relationships (see Table 14) where goal to goal, activity to activity, activity to goal, and activity to role relationships are not supported out of the box. Typed URL links were used to capture the missing relationships.

**Table 14** Mapping between AbPI conceptual model relationships and URN relations

Conceptual model relationships	URN relations	Existence	Missing attributes/classes	Comments
Goal to goal	GRL Element-Link: Contribution, Dependency, and Decomposition	Exists	-	
Goal to/from activity	URN links	Does not exist	Change and Contribution classes	Captured through URN links of types: <i>contribute</i> and <i>change</i>
Activity to activity	URN links	Does not exist	Activity-Relation class	Captured through URN links of types: <i>replace</i> , <i>eliminate</i> , <i>combine</i> and <i>add</i>
Activity to role	URN links	Does not exist	Activity-RoleRelation class	Captured through URN links of types: <i>change</i> , <i>replace</i> , and <i>add</i>
Links	IntentionalElement (of type Links)	Exists	-	
Integration Relation (goal model integration)	URN links	Does not exist	Integration-Relation	Captured through URN links and intentional element’s metadata type: <i>Similar</i> , <i>Dissimilar</i> , <i>Different</i> , <i>Conflict</i> , <i>New</i> , and <i>Approved</i>

As seen in Table 14, some of the relations cannot be captured in URN. URN link is used to document activity to activity and activity to role relations. This helps in terms of changes and decisions made traceability, and with the navigation through introduced changes to ensure consistency and correctness of integrated models.

All relationships appeared between the goal model integration's elements are captured and mapped to URN relations through *URN links* and *intentional element's metadata*. None of types of relationships exists, fully or explicitly, in URN as URN does not support goal model integration. Therefore, the *IntegrationRelation* class is captured through URN links and the type of the relation is stored in the metadata of the URN links and, possibly, also the intentional elements' metadata. The reason for storing the *IntegrationRelation* type in additional metadata is that if *element1* replaces *element2*, initially, a URN link is used to capture the integration relation which is *Different*. However, once *element2* is deleted in some version of the integrated goal model, the URN link will be deleted as well and the integration relation will be lost. *Element1* is tagged, through its metadata, with the integration relations to keep track of all integration relations that happened so far until the integration gets finally *Approved*.

## 6.3 Algorithms

As an additional contribution to the formalization of the AbPI framework, this section presents algorithms for the framework's methods targeting goal integration, process integration, and alternative evaluation (see Figure 6). These algorithms exploit the AbPI conceptual model's elements. They have been applied manually in the case studies but several portions could be automated in the future. In these algorithms, the parts highlighted in grey are currently requiring human intervention.

### 6.3.1 Goal Integration Method

**Algorithm:** GoalIntegration

**Inputs:** GM1, GM2: GoalModel

**Output:** IGM: GoalModel

SIGM: GoalModel = **new** GoalModel // *new intermediate goal model*

DIGM: GoalModel = **new** GoalModel // *new intermediate goal model*

```

// identify similar goals in the input models. The order of the input models is irrelevant
for each G1:Goal in GM1 {
  for each G2:Goal in GM2 {
    // isSimilar() is a user-defined function of return type Boolean; the function
    // requires the analyst to decide whether G1 and G2 are semantically similar.

    if (G1.isSimilar(G2)) {
      // merge the similar goals into one goal to be added in the SIGM.
      // merge() is done by the analyst. Could be G1, or G2, or some hybrid.
      G:Goal = merge(G1,G2)
      SIGM.add(G)

      // create an IntegrationRelation of type Similar between the source (goal G
      // in the SIGM) and the destination (G1 in GM1)
      IG1: IntegrationRelation = new IntegrationRelation
      IG1.type = "S" // Similar
      IG1.source = G
      IG1.destination = G1

      // create an IntegrationRelation of type Similar between the source (goal G
      // in the SIGM) and the destination (G2 in GM2)

      IG2: IntegrationRelation = new IntegrationRelation
      IG2.type = "S" // Similar
      IG2.source = G
      IG2.destination = G2
    } // end if
  }
}

// add dissimilar goals to DIGM
for each GM:GoalModel in {GM1,GM2} {
  for each G:Goal in GM {
    if (!exists(G.relation.type = "S")) {
      Gds = new Goal
      Gds = G
      DIGM.add(G)
      IG1: IntegrationRelation = new IntegrationRelation
      IG1.type = "DS" // DisSimilar
      IG1.source = Gds
      IG1.destination = G
    }
  }
}

```

```

// identify similar stakeholders in the input models. The stakeholder order is irrelevant
for each S1:Stakeholder in GM1 {
  for each S2: Stakeholder in GM2 {

    // isSimilar() is a user-defined function of return type Boolean; the function
    // requires the analyst to decide whether S1 and S2 are semantically similar.

    if (S1.isSimilar(S2)) {
      // merge the similar stakeholders into one stakeholder to be added in the
      // SIGM. merge() is done by the analyst. Could be S1, or S2, or some hybrid.
      S:Stakeholder = merge(S1,S2)
      SIGM.add(S)

      // create an IntegrationRelation of type Similar between the source
      // (stakeholder S in the SIGM) and the destination (S1 in GM1)
      IG1: IntegrationRelation = new IntegrationRelation
      IG1.type = "S" // Similar
      IG1.stakeholderSource = S
      IG1.stakeholderDestination = S1

      // create an IntegrationRelation of type Similar between the source
      // (stakeholder S in the SIGM) and the destination (S2 in GM2)
      IG2: IntegrationRelation = new IntegrationRelation
      IG2.type = "S"
      IG2.stakeholderSource = S
      IG2.stakeholderDestination = S2
    }
  }
}

// add dissimilar stakeholders to DIGM
for each GM: GoalModel in {GM1,GM2} {
  for each S:Stakeholder in GM {
    if (!exists(S.relation.type = "S")) {
      Sds = new Stakeholder
      Sds = S
      DIGM.add(Sds)
      IG1: IntegrationRelation = new IntegrationRelation
      IG1.type = "DS" // DisSimilar
      IG1.stakeholderSource = Sds
      IG1.stakeholderDestination = S
    }
  }
}

```

```

// identify similar links in input model GM1. The links order is irrelevant
for each L:Link in GM1 {
    //checking if the source and destination of the link exist in the SIGM

    if (exists((L.source.integrationrelation.type="S" or L.source.relation.type="S"))
        and
        L.destination.integrationrelation.type="S" or L.destination.relation.type="S"))
    {
        // create an IntegrationRelation of type Similar between the source
        // (link Ls in the SIGM) and the destination (L in GM1)

        Ls = new Link
        Ls = L
        SIGM.add(Ls)
        IG1: IntegrationRelation = new IntegrationRelation
        IG1.type = "S" // Similar
        IG1.LinkSource = Ls
        IG1.LinkDestination = L
    }
}

// identify similar links in input model GM2. The links order is irrelevant
for each L:Link in GM2 {
    //checking if the source and destination of the link exist in the SIGM

    if (exists((L.source.integrationrelation.type="S" or L.source.relation.type="S"))
        and
        L.destination.integrationrelation.type="S" or L.destination.relation.type="S"))
    {
        // create an IntegrationRelation of type Similar between the source
        // (link Ls in the SIGM) and the destination (L in GM2)

        Ls = new Link
        Ls = L
        SIGM.add(Ls)
        IG1: IntegrationRelation = new IntegrationRelation
        IG1.type = "S" // Similar
        IG1.LinkSource = Ls
        IG1.LinkDestination = L
    }
}

```

```

// add dissimilar links to DIGM
for each GM: GoalModel in {GM1,GM2} {
  for each L:Link in GM {
    if (!exists(L.relation.type = "S")) {
      Lds = new Link
      Lds = L
      DIGM.add(Lds)
      IG1: IntegrationRelation = new IntegrationRelation
      IG1.type = "DS" // DisSimilar
      IG1.LinkSource = Lds
      IG1.LinkDestination = L
    }
  }
}

// create the IGM
for each E:{Goal | Link | Stakeholder} in SIGM {
  IGM = IGM.add(E)
}
for each E:{Goal | Link | Stakeholder} in DSGM {
  IGM = IGM.add(E)
}

// add missing elements (relations: contributions and decompositions) of the input
// models (GM1 and GM2) to the IGM
for each E:{Goal | Link | Stakeholder} in GM1 {
  if (!IGM.contains(E)) {
    IGM = IGM.add(E)
  }
}

for each E:{Goal | Link | Stakeholder} in GM2 {
  if (!IGM.contains(E)) {
    IGM = IGM.add(E)
  }
}

return IGM

```

### 6.3.2 Algorithms for the AbPI Methods (Integration and Evaluation)

```
Algorithm: AbPIIntegrationAndEvaluation  
Inputs: NP: PGM // New proposed process  
          CPset: Set of PGM // Current processes  
          IGM: GoalModel // Integrated goal model  
  
Outputs: OPset: Set of PGM // optimal PGMs after integration (one per current proc.)  
  
PAI: PGM // intermediate variable: integrated process with alternatives  
OP: PGM // optimal PGM after integration  
  
//Assumption: process models are available (or they can be constructed via interviews,  
existing documents, or possibly process mining for evidence-based process discovery),  
and people agree on them before the process integration method starts.  
  
for each CP: PGM in CPset {  
    PAI = Integration (NP, CP) // See algorithm details  
    AddGM(IGM, PAI) // Substitutes empty goal model with the integrated goal model  
    OP = AlternativeEvaluation (PAI) // See algorithm details  
    OPset = OPset.add(OP)  
}  
  
return OPset
```

```
Algorithm: Integration  
Input: NP, CP: PGM // PGM of new proposed process and current process model  
Output: PAI: PGM // PGM of process after integration with alternatives  
  
R: ActivityRelation // intermediate object  
AR: Set of ActivityRelation // intermediate object  
CA: Activity // intermediate object  
  
PAI = new PGM // initialize the output  
  
// Steps 1 and 2: Identifying integration opportunities and relationships  
for each CPP:ProcessModel in CP.processModel {  
    for each NPP:ProcessModel in NP.processModel {  
        for each NA:Activity in NPP.Activity {  
            CA = askUserOpportunity(NA); // user-defined function to identify integration  
                                       // opportunities; returns an activity  
  
            while (CA != null) {  
                R = new ActivityRelation  
                R.type = askUserRelation(); // user-defined function to identify the  
                                           // the integration type  
  
                AR.add(R);  
                CA = askUserOpportunity(NA);
```

```

    }
  }
}
}
// Step 3: Design alternatives
for each CPP:ProcessModel in CP.processModel {
  for each CP:Process in CPP.process {
    for each CA:Activity in CP.newcurrent {

      // Check if an ActivityRelation linked to the current activity exists
      Stub: Set of Process = new Set of Process // Intermediate variable
      while (AR.LinkedTo.contains(CA)) {
        SP:Process, Cnst:Constraint = createSubProcess() // user-defined function to
        // create the alternative that corresponds to the in-
        // tegration relation between current and new ac-
        // tivity; user identify a constraint to guard selec-
        // tion of the defined alternative

        Stub.addWithConstraint(SP, Cnst)
      }
      CP.add(Stub)
    }
    CPP.add(CP)
  }
  PAI.add(CPP)
}
// initialization to Alternative where one process of each stub will be chosen to
// represent an end-to-end alternative
for each Alternative:Process in PAI.processModel.process {
  boolean Done = false
  while (Done = false) {
    for each (Stub in PAI) {
      if (Stub != null) {
        P:Process = SelectSubProcess(Stub) // user defined function to select one of
        // the sub-processes of Stub

        Alternative.select(P)
        Stub.remove(P)
        Alternative.remove(Stub)
      }
    }
    PAI.add(Alternative)
    Done=AskUserToAddMoreAlternatives()// user-defined function to ask users if
    // they want to design another alternative
  }
}

return PAI

```



**Algorithm:** *AlternativeEvaluation*

**Input:** PAI: PGM // intermediate variable: integrated process with alternatives

**Output:** OP: PGM // optimal PGM after integration

// design evaluation strategy

```
for each Alternative:Process in PAI.processModel.process {  
    pairGoal: boolean = askUserToPairGoalwithActivity (Alternative, PAI.GoalModel);  
    // user-defined function to let user identify if there is an activity-goal relation  
    // in this case, only Contribution relations are identified.
```

```
    while (pairGoal != false) {  
        Ac:Activity = SelectActivity() // a user-defined function to select the activity  
        Cont:Contribution = Ac.initiates  
        Cont.contributes = SelectGoal() // a user-defined function to select the goal  
        Cont.value = SetContributionValue() // a user-defined function to let users set the  
            // contribution value  
        pairGoal = askUserToPairGoalwithActivity(Alternative, PAI.GoalModel);  
            //Ask user again if there is another activity-goal relation of type  
            Contribution to be identified is  
    }  
}
```

```
pairIndicator: boolean = askUserToPairIndicatorWithActivity (Alternative,  
    PAI.GoalModel);  
// user-defined function to let user identify whether there is an activity-goal relation;  
// in this case, only Change relations are identified.
```

```
while (pairIndicator != false) {  
    Ac:Activity = SelectActivity()  
    Chg:Change = Ac.initiates  
    Chgt.changes = SelectIndicator() // a user-defined function to select an indicator  
    Chg.value = SetChangeValue() // a user-defined function to let users set the  
        // change value  
    pairIndicator = askUserToPairIndicatorWithActivity(Alternative, PAI.GoalModel);  
}  
}
```

```
OP:PGM = SelectOptimalProcessAfterIntegration(PAI);  
// user-defined function to allow users to choose the best integration alternative; it is  
// recommended to use DbGRL and the Data Quality and Confidence Propagation  
// Method during the analysis
```

```
return OP
```

## 6.4 Implementation

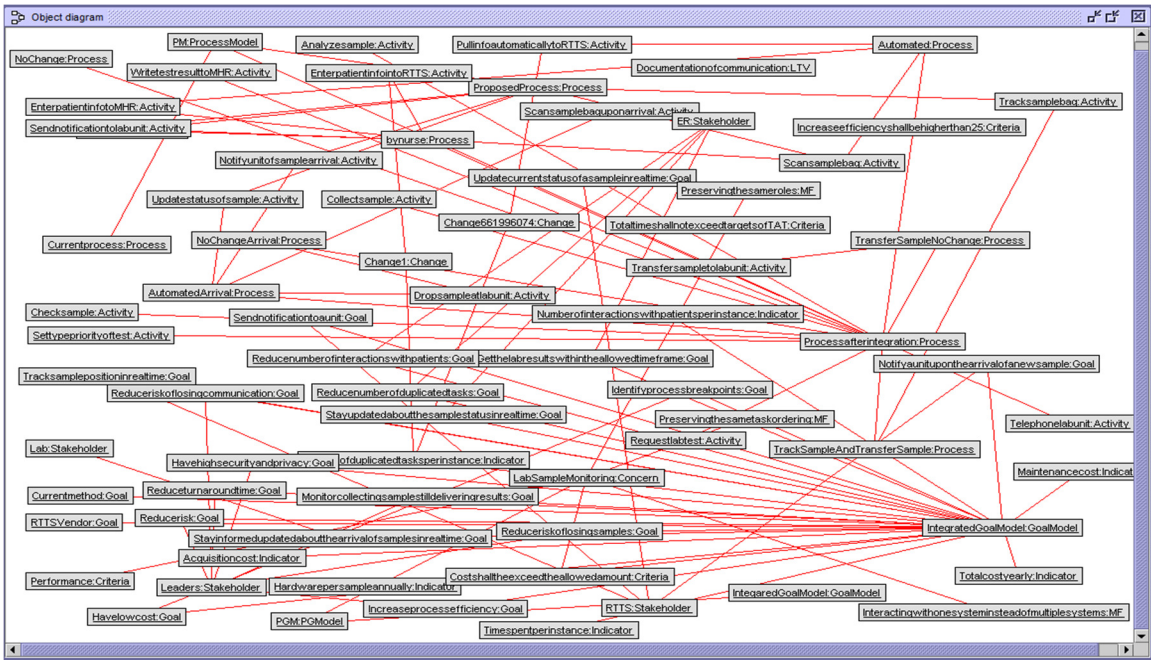
Several aspects of this formalization and of the work done in the two previous chapters were implemented.

### 6.4.1 Automated Transformation of Profiled URN Models to USE

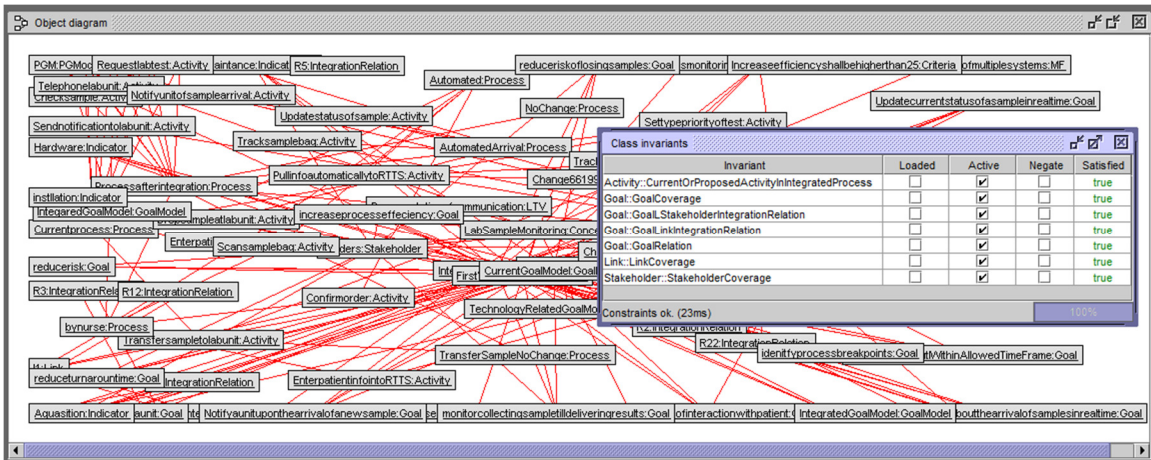
As explained in Section 6.1, the USE tool is used to check conformance with AbPI's conceptual model. However, as jUCMNav is used as the modelling environment, it becomes important to transform the PGM models created with the URN profile for AbPI to object models that can be consumed by USE and checked against the conceptual model and its OCL constraints.

Using the Java-based Eclipse framework, a new export filter was added to jUCMNav, where PGM models are generated in a syntax understood by USE. This *Export as USE file* transforms automatically a URN model profiled for AbPI into a sequence of objects and links (in a text file) instantiating the AbPI conceptual model (see Appendix F). This export is important because models are usually large and I need to avoid the typical errors and incompleteness issues caused by a manual transformation.

Figure 28 illustrates the first case study's PGMs (*Lab Samples Monitoring*, see Chapter 8) exported from jUCMNav as an object model for USE. The resulting object diagram, visualized with USE, is too complex to be readable. In USE, compliance with the conceptual model (classes, attributes, links, multiplicities, etc.) is checked when the object model is loaded. The well-formedness constraints described in Section 6.1 can also be checked for violations, as shown in Figure 29.



**Figure 28** Object model of the Lab Samples Monitoring example exported by jUCMNav and imported into USE



**Figure 29** Well-formedness OCL constraints evaluated to true on the object model of the Lab Samples Monitoring example

## 6.4.2 Confidence Propagation

The data quality tagging and confidence propagation mechanism described in Chapter 4 is implemented in jUCMNav as a revised version of the plug-in handling the standard quantitative propagation algorithm (ITU-T, 2012). The tagging step is performed with metadata

specifying the initial confidence values on goal leaves. The implemented confidence propagation algorithm computes the confidence of higher-level goals and actors and create/update their metadata along the way. The code of this plug-in is available online (via Appendix F).

### 6.4.3 DbGRL and TOPSIS

The Distance-based GRL approach presented in Chapter 5 was implemented outside of jUCMNav. In particular, the TOPSIS part was implemented using equations in Excel (template available online, see Appendix F). The evaluation strategies (criteria view) are exported as a CSV file (a feature that already exists in jUCMNav) and TOPSIS equations are applied to normalize and weight data, and compute the alternatives' distance to the ideal and anti-ideal vectors.

### 6.4.4 Well-formedness Constraints for the URN Profile

Section 6.1 introduced well-formedness constraints for the AbPI conceptual framework. However, such constraints are more useful to modellers when checked in the modelling environment, i.e., jUCMNav in the case of the URN profile for AbPI. Some of these OCL constraints can be lifted to the level of URN. For example, the constraint *CurrentOrProposedActivityInIntegratedProcess* from Section 6.1.2 is reformulated below in terms of URN elements profiled (with metadata) for AbPI.

```
context ucm::map::RespRef
inv: CurrentOrProposedActivityInIntegratedProcess
  ( diagram.oclAsType(ucm::map::UCMmap).getMetadata('ProcessType')='Current'
    or
    diagram.oclAsType(ucm::map::UCMmap).getMetadata('ProcessType')='Proposed')
implies
  respDef.respRefs->exists(ref | ref.diagram.oclAsType(ucm::map::UCMmap).
    getMetadata('ProcessType')='Integrated')
```

There exists a set of user-selectable rules predefined in jUCMNav<sup>1</sup> that can be used to further ensure semantic correctness and consistency. Table 15 contains the rules that should be checked before exporting the integrated PGM object diagrams. The first rule in this table

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<sup>1</sup> <http://jucmnav.softwareengineering.ca/foswiki/ProjetSEG/PredefinedSemanticsRulesOverview>

also has an equivalent constraint in the conceptual model whereas the last four are URN-specific assumptions on the input models. The second rule, *GRLintentionalElementInManyActors*, is already captured through the multiplicity between Goal and Stakeholder in the extended view of the AbPI conceptual model (Figure 8).

**Table 15** Relevant jUCMNav predefined semantic rules

Rule	Definition
GRLindicatorThresholdConsistency	Indicator threshold value must be between the target and worst values.
GRLintentionalElementInManyActors	GRL intentional element must not be bound to more than one actor
GRLactorNoCycle	GRL actor must not be part of a containment cycle
UCMcomponentNoCycle	UCM component must not be part of a containment cycle
UCMpluginNoOutBinding	UCM plugin bindings of this stub must all have out-bindings
UCMpluginNoInBinding	UCM plugin bindings of this stub must all have in-bindings

Equivalent OCL constraint for *GRLindicatorThresholdConsistency* in AbPI:

```

context Indicator
inv IndicatorThresholdConsistency:
  (threshold <= targetValue and threshold >= worstValue)
or
  (threshold >= targetValue and threshold <= worstValue)

```

## 6.5 Discussion

Although many parts of the AbPI framework were formalized and even provided tool support, there are several limitations to the current profile and implementation. For example, there might be additional constraints needed to ensure well-formedness at the AbPI level, and also at the URN profile level. The ones presented here resulted from lessons learned while doing the case studies.

For activity to activity, activity to goal, and activity to role relationships, their representation was not fully supported in standard URN, and they had to be captured through

typed URN links. This increases the complexity of analysis as current analysis tools do not consider such AbPI-specific links.

Another interesting extension could be to support the data quality tagging and confidence propagation mechanism natively in jUCMNav, or even in the URN standard. The *GRLLinkableElement* class (which is a superclass of *IntentionalElement*, *Indicator*, and *Actor*, see Figure 84) could be extended to have a *confidence* attribute. The confidence propagation algorithm could be also standardized and added to URN.

## 6.6 Chapter Summary

This chapter presented the formalization of the AbPI conceptual model with USE, including the OCL constraints used to ensure well-formedness of the integrated goal and PGM models. The constraints can be checked in the USE tool to assess correctness and conformance, and on jUCMNav to support modellers. The AbPI goal integration, (PGM) integration and evaluation methods were also described formally using algorithms. In addition, this chapter defined the URN profile for the AbPI framework, which enables modellers to create PGM models in a concrete syntax, with tool support (jUCMNav). The chapter further discusses the implementation of three artifacts for the data quality tagging and confidence propagation mechanism (a modified propagation algorithm in jUCMNav), DbGRL & TOPSIS (as an Excel template), and the automated generation of AbPI object models in the USE syntax (as a plug-in for jUCMNav).

The next chapter presents the thesis evaluation plan, which consists of case studies and a usability study. In addition, it assesses the feasibility of the AbPI framework using two illustrative examples.

# Chapter 7 Evaluation

---

The chapter discusses the methods used to evaluate the effectiveness of the AbPI framework. It also presents the objectives and the plan for the case studies. Two examples are also provided to assess the feasibility of the AbPI framework in the WTES context introduced in the previous chapters.

## 7.1 Evaluation Strategy

As mentioned in Chapter 1, there are several iterations used in the evaluation of the AbPI framework. Three evaluation phases are combined to provide a comprehensive evaluation that covers different angles of AbPI's feasibility, effectiveness, and usability.

1. **Feasibility assessment:** the aim of this phase is to illustrate and assess, with two examples, the feasibility of using the AbPI framework in a process integration context. This is also the first evaluation iteration. The first versions of the framework and its conceptual model, together with two examples, were shown to three key healthcare informants. Feedback was gathered in order to trigger improvements. The changes were not major in general, except for highlighting the need to have an explicit relationship (*ActivityRoleRelation*) between *Activity* and *Stakeholder*, which was not addressed clearly in the original version of the conceptual model.
2. **Case studies:** to help ensure that the AbPI framework meets its objectives, two real case studies, happening in two different hospitals, were conducted. Each one is a descriptive case study that focuses on a small group of instances to describe a certain situation and demonstrate how these instances interact given certain conditions. In the case studies, qualitative and quantitative data using different methods were collected to evaluate the capabilities (usefulness/effectiveness) and limitations of the AbPI framework. The case study protocol and the case studies are explained in Section 5.3.
3. **Usability study:** to answer the thesis' second research question "What is the usefulness and usability of the proposed AbPI framework as perceived by healthcare

practitioners?”, a usability study was conducted with a group of prospective end users of the AbPI framework at Montfort Hospital. The usability study content and design, together with current results, are presented in Chapter 10.

The following section presents the feasibility assessment with two examples. The first one was published in (Baslyman et al., 2017) and the second one in (Baslyman et al., 2017c).

## **7.2 Feasibility Assessment**

### **7.2.1 Example 1: Patient Satisfaction in an Emergency Room (ER)**

The section illustrates the AbPI framework (and its integration and alternative evaluation methods) with a realistic example from Montfort Hospital. The example has partially been introduced in Sections 3.3.2, 4.5, and 5.4. In the following section, the example context is explained in further details and its goal-process models (PGMs) are provided.

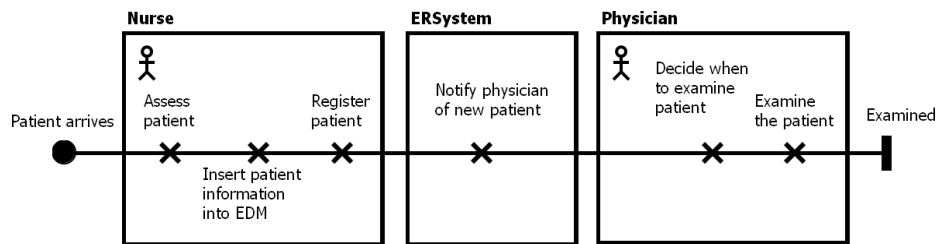
#### **7.2.2 Problem Definition**

The current workflow in an emergency room (ER) involves three main stages. First, the patient is triaged by a nurse to assess the acuity level. Once the acuity level is assigned, the patient is moved to the waiting area or examination room until seen by a physician. The physician at this stage may order some tests, or may request a specialist consultation. Once results are obtained, the patient is either discharged from the ER or admitted to the hospital for further treatment. One problem with the current flow is the lack of efficient information communication with patients regarding wait times or the arrival of lab test results.

The quality of care in value-based hospitals is measured through patient experience with the provided care. The lack of real-time information about wait times and intended plans during ER visits can increase anxiety in patients, and this reflects negatively on the satisfaction level of these patients. At Montfort Hospital, expectations on wait time are posted on a white board manually at different times during the day. There is no specific process to inform patients of updates in real time. Thus, patients in the ER complain mostly about being unaware of what is the current status of the process and how long it will take them to reach a specific step.

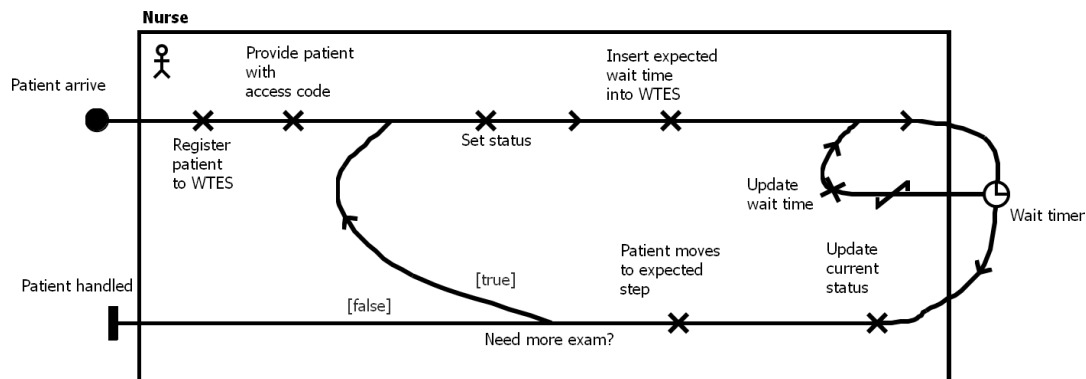


As explained in previous chapters, a new *Wait Time Estimation System* (WTES) is being considered. Caregivers would interact with WTES to insert and update the status and wait time of patients during their visits. In this example, our focus is on the interaction between caregivers and WTES and on activities that will be added to the current ER process. To simplify the integration, the example covers only the first and second steps in the ER process (triage and physician assessment), as Figure 30 illustrates with a UCM view of the current PGMModel. I used the jUCMNav tool to create the current and proposed models in this example.



**Figure 30** Current ER process with the triage (initial nurse assessment) and physician assessment tasks

Figure 31 presents the proposed process to interact with WTES. The process starts with a nurse registering the patient to WTES. Then, the nurse gives an access code to the patient to track the process in the system. This step is required to comply with privacy requirements. The nurse sets the current status and expected time to reach the next expected step (such as physician examination in the current process). The time starts and ends either by moving to the expected step or timeout. If further examination (such as lab test or imaging) is required, the nurse has to update the status and set the expected time again.



**Figure 31** Proposed process of WTES

Figure 32 shows the integrated goal model (resulting from the process described in Section 3.3), which includes Montfort Hospital, caregivers, and patient, in the context of keeping patients updated. The WTESystem actor shows the goals newly combined with the current goals of other stakeholders.

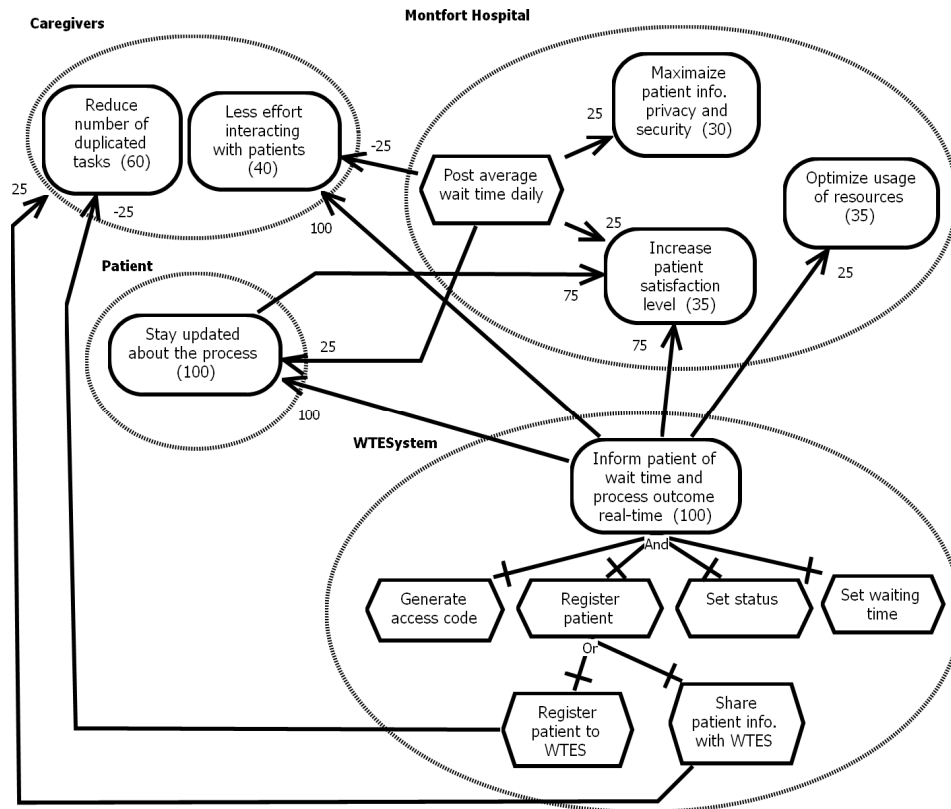


Figure 32 Integrated goal model combining the ER and WTES goal models, without KPIs

### 7.2.3 Integration Method

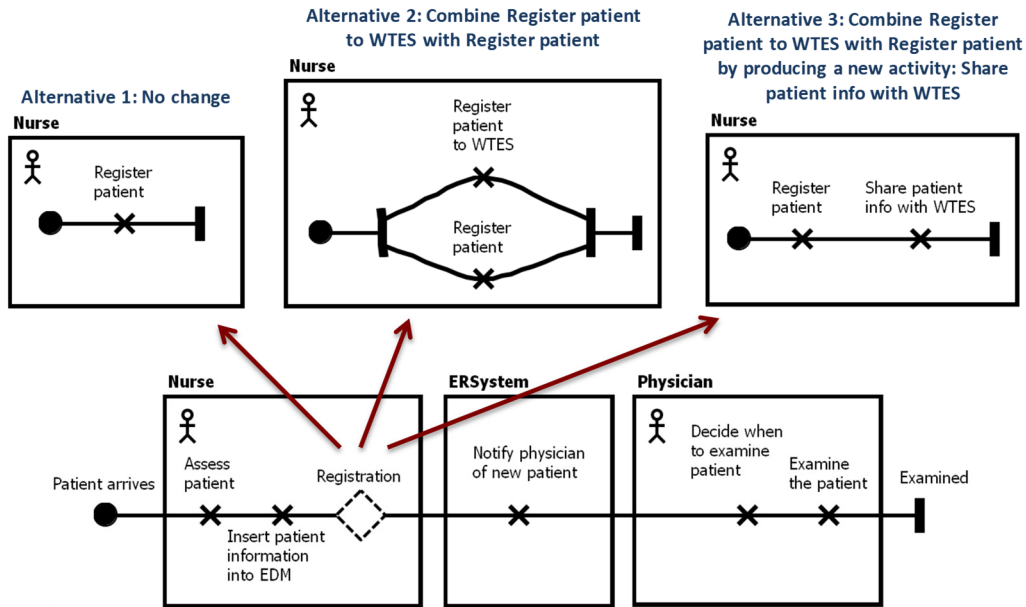
As mentioned in Section 3.4.1, each activity in the new process is integrated separately into current processes. However, one exception is when that activity cannot be separated from other activities, such as when they are in loops or guarded branches. The three steps of the integration method are discussed here (see Table 16 for the integration opportunities and activity relations).

**Table 16** First two steps in the process integration method: identifying integration opportunities and activity relationships

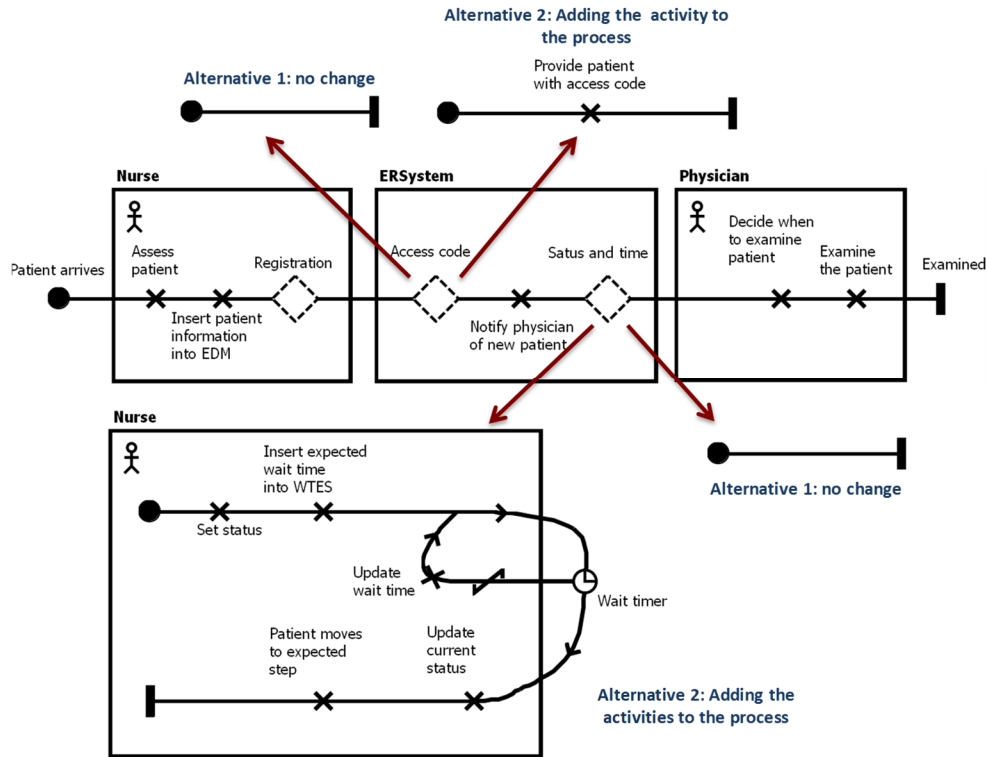
Activity to be integrated	Integration opportunity on current process	Activity-activity relation type	Activity-role relation type	Activity-goal relation type
Patient registration to WTES	Register patient	Combine, After or before	Same – by nurse	Contribute – Reduce number of duplicated tasks
	Register patient	Combine, merged	Change – by WTES	Contribute – Reduce number of duplicated tasks
Provide patient with access code	Notify physician of new patients	Add, before	Same – by nurse	Contribute – Reduce number of duplicated tasks
Loop: Set status, Insert expected wait time into WTES, Update wait time, Update current status, and Patient moves to expected step	Notify physician of new patients	Add, after	Same – by nurse	Contribute – Reduce number of duplicated tasks

1. **Identifying integration opportunities:** The first activity in the proposed process is *Patient registration to WTES*, which happens after the patient arrival to the ER. In the current process, there is ideally only one opportunity to integrate the activity that is either before or after the *Register patient* activity, because they both should be performed after the nurse assessment.
2. **Identifying type of activity-activity integration:** For the *Patient registration to WTES* activity, there are two possible relations: Combine (New ; Current) or Combine (Current ; New). This implies adding the new activity to *Register patient* where a caregiver will perform them both separately. The order here does not make much of a difference as the nurse should perform both activities to accomplish the registration. The second relation is Combine (Merged), producing a new activity *Share patient information with WTES*, where WTES pulls the data from the existing system automatically without the caregiver interfering after *Register patient* is done.

3. **Design a new process model:** Figure 33 shows the process models of the two relations mentioned in the previous step. The first relation is about adding the new activity to the process, which introduces a new role “Nurse”. This process also considers the scenario where no integration happens for the analysis purpose.



**Figure 33** Integration alternatives of *Register patient* with WTES from the proposed process to the current one



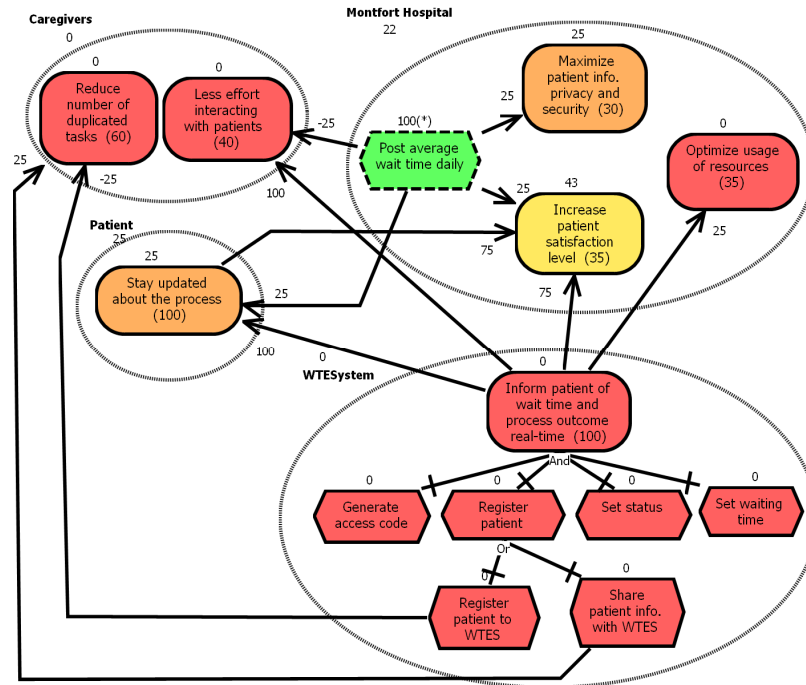
**Figure 34** Integration alternatives of the other activities in the proposed process after integrating them. Alternative 2 in the *Status and time* stub is a process that consists of dependent activities that cannot be separated

The other activities in the proposed process will be integrated following the same steps performed with the first integration. The produced relations between the proposed activities and the existing activities in the current process will be simply adding the activities as shown in Figure 34. There are also dependency relationships involved as some activities must be performed together or not at all.

### 7.2.4 Alternative Evaluation Method

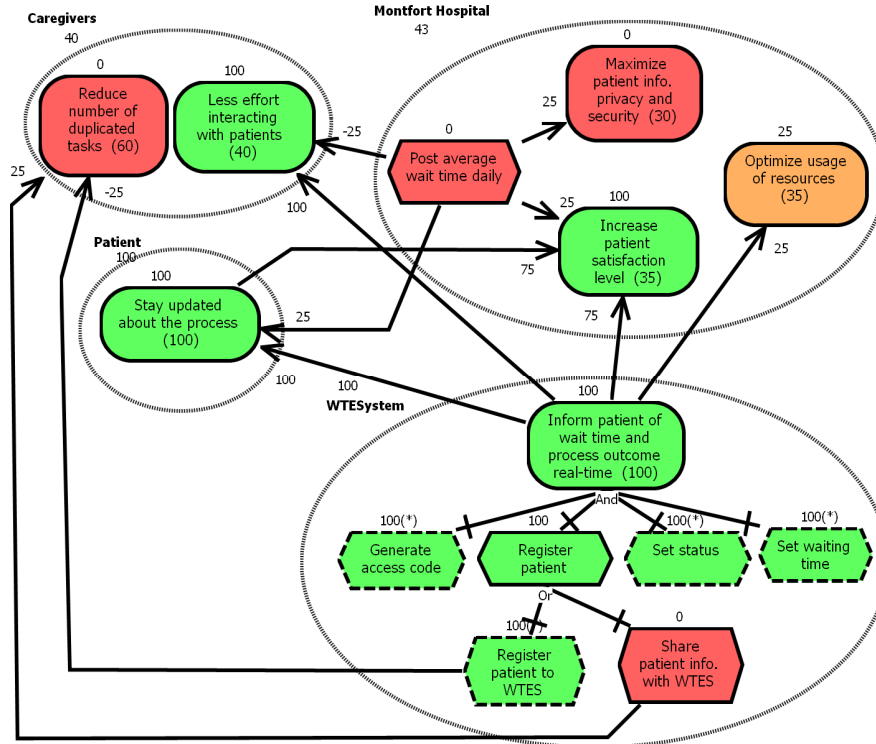
As mentioned in Section 3.4.2, I follow three steps: set up values and contributions, evaluate the trade-offs, and choose the best alternative that achieves the desired outcome. In the previous example, all activities are depended on *Register patient to WTES* and also on *Share patient info. with WTES*. Thus, there will be three main alternatives (processes) to evaluate based on the choice of the sub-process in the *Register patient* stub (Figure 33).

First integrated process: this is the current process with no changes. Figure 35 shows the satisfaction of the goals and stakeholders after applying the corresponding GRL evaluation strategy in jUCMNav. The WTES and the Caregivers (nurses) are not satisfied at all, and the Hospital and Patient actors have a very low satisfaction level.



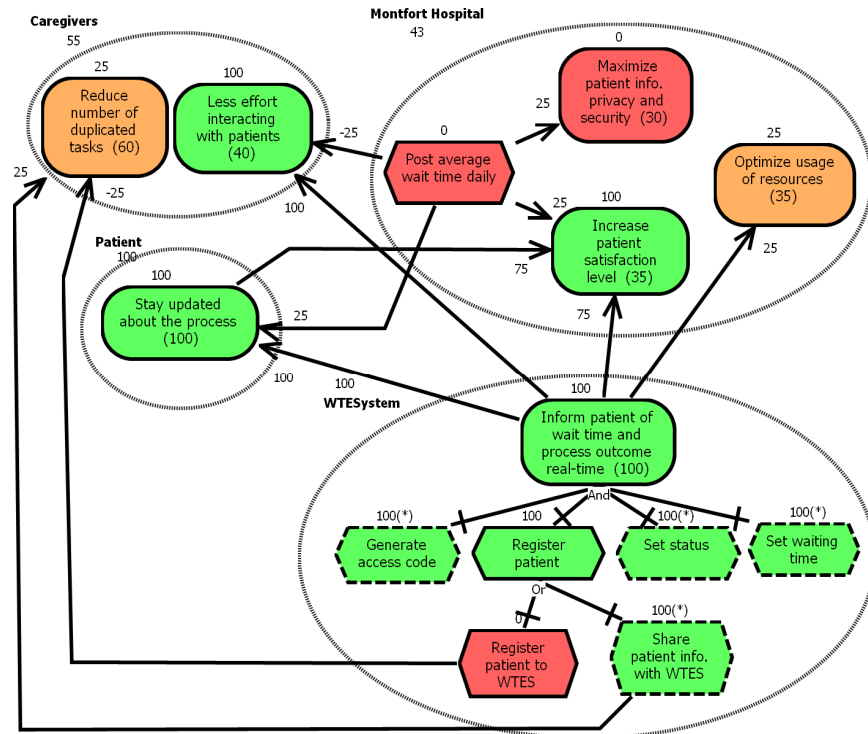
**Figure 35** Evaluation strategy results of the goal view with the current process (alternative 1)

Second integrated process: this one uses alternative 2 (Register patient to WTES) in Figure 33 and alternative 2 in the two stubs of Figure 34. The impact of an activity is represented in the tasks in the GRL model. If the activity is chosen, the evaluation value of the equivalent task is set to 100 (and 0 otherwise). Figure 35 shows that the Patient and WTES actors are satisfied, but that there is room for improvement for the other actors.



**Figure 36** Evaluation strategy results of the goal view with alternative 2 in the first integration

Third integrated process: this one corresponds to alternative 3 (Share patient info with WTES) in Figure 33 and to the two alternative-2 plug-ins in Figure 34. This integrated process is better than the second one because the Caregivers are more satisfied while the other actors have kept the same levels of satisfaction found for the second integrated process (see Figure 37).



**Figure 37** Evaluation strategy results of the goal view with alternative 3 in the first integration

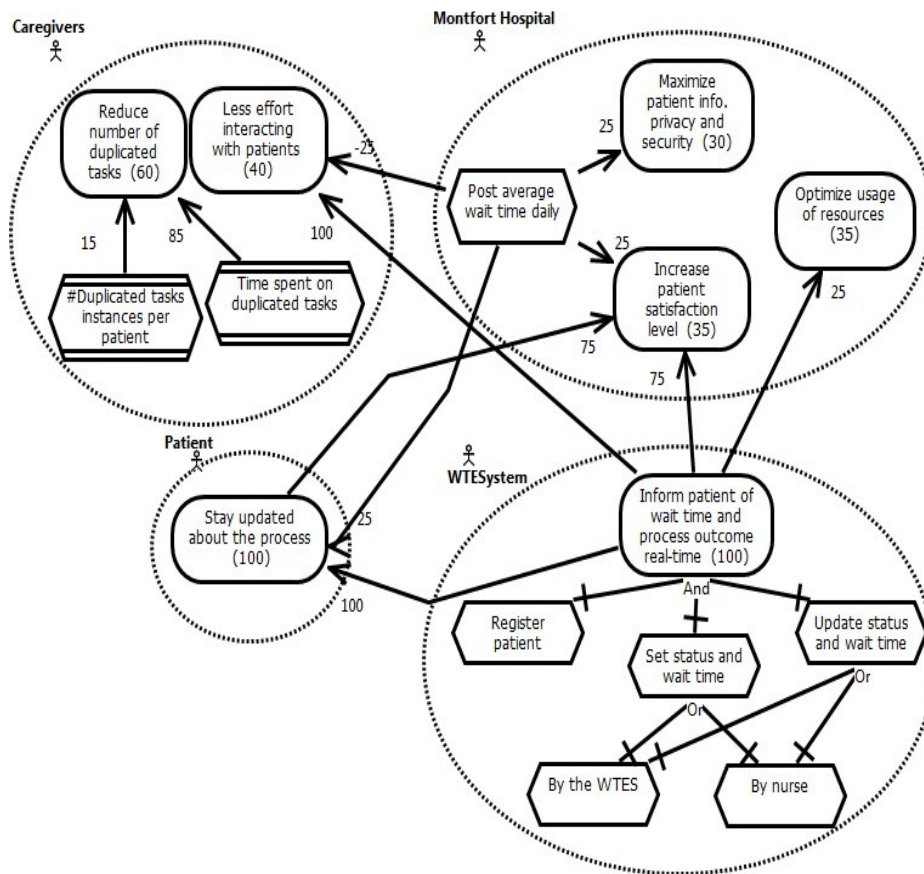
This analysis approach helps reason about trade-offs. As seen in the previous figures, the goal about maximizing patients' information privacy and security was better satisfied with the current process. On the other hand, nurses are more satisfied with sharing patients' information with WTES (automatically) than by inserting the information manually in the *Register patient to WTES* activity. Patients are fully satisfied, and so is the *Increasing patient satisfaction level* goal in Montfort Hospital. However, it is worth mentioning that even if the caregivers are more satisfied with the proposed process, the satisfaction level is only 55, so there is still room for improvement.

The analysis outcome should be presented to the hospital stakeholders to guide them on the best alternative to choose. Note that the results may not always be as clear as in this example. For example, one integration could lead to actor X being satisfied at level 80 and actor Y at 60, while another integration would lead to the opposite (X at 60 and Y at 80). In such cases, the DbGRL approach introduced in Chapter 5 can be used to better rank these alternative integrations.

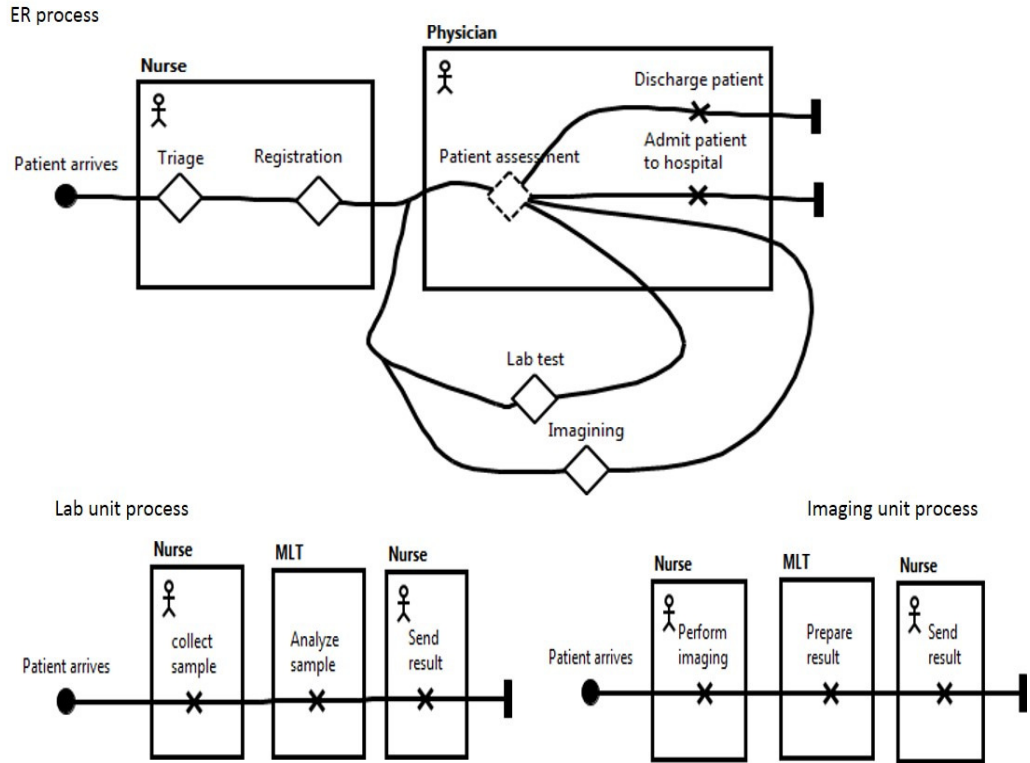


## 7.2.5 Example 2: Patient Satisfaction in an ER with KPIs

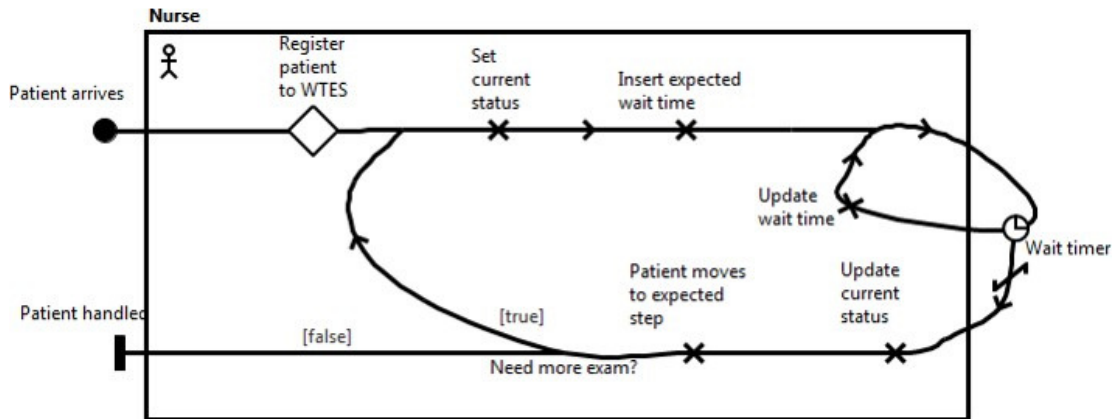
In this section, I illustrate the feasibility of the AbPI framework in modelling and analyzing the integration alternatives of the proposed Wait Time Estimation System into a current emergency process, and demonstrate the usefulness of using indicators (KPIs) to assess the impact of the integration alternatives on the satisfaction of the goals and actors. The integrated goal model in Figure 38 and the process models in Figure 39 and Figure 40 are the inputs (PGModels) of the integration process. In Figure 38, the WTES goal model was combined to the ER goal model, but this time both source models contained indicators.



**Figure 38** Integrated goal model combining the ER and WTES goal models, with KPIs



**Figure 39** ER, lab unit, and imaging unit process models, where the lab unit and imaging unit processes are different sub-processes of the ER process. MLT is the Medical Lab Technician



**Figure 40** WTES system, where nurses have to register patients to the system, and set status and time for each step in the ER process in real time

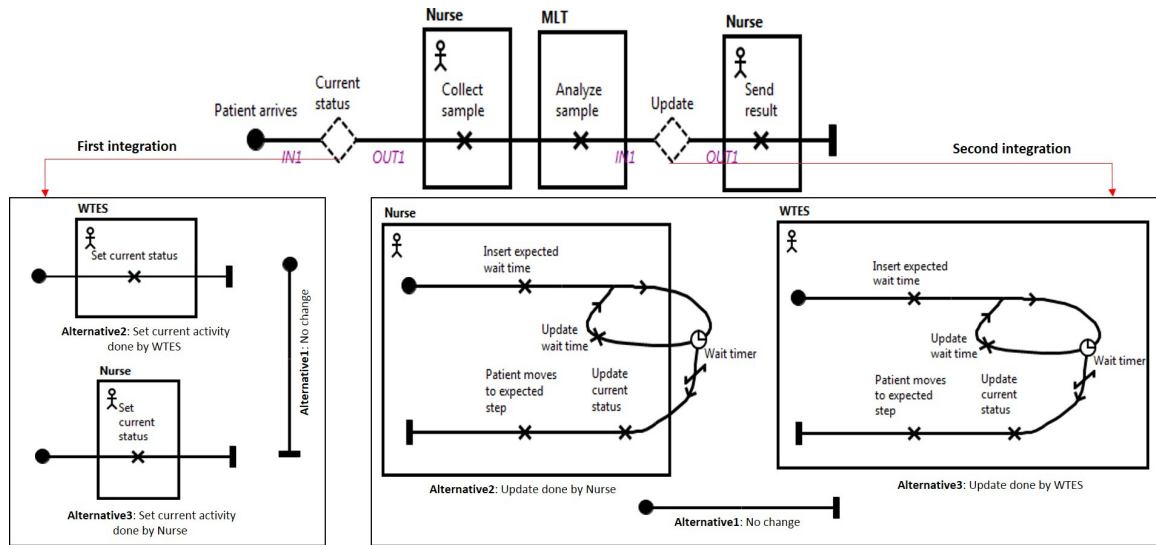
In this example, the focus is on integrating the activities *Set current status*, *Insert expected wait time*, *Update wait time*, and *Update current status* into the Lab unit process and the Imaging unit process. Table 17 presents the integration opportunities and activity relations.

**Table 17** First two steps in the process integration method: identifying integration opportunities and activity relationships

Activity to be integrated	Integration opportunity on current process	Activity-activity relation type	Activity-role relation type	Activity-goal relation type
Set current status	Collect sample	Add, before	Same – by nurse	Change – Reduce number of duplicated tasks, and time spent on duplicated task
	Collect sample	Add, before	Change – by WTES	Change – Reduce number of duplicated tasks, and time spent on duplicated task
Loop: Insert expected wait time into WTES, Update wait time, Update current status, and Patient moves to expected step	Analyze sample	Add, after	Same – by nurse	Change – Reduce number of duplicated tasks, and time spent on duplicated task
	Analyze sample	Add, after	Change – by WTES	Change – Reduce number of duplicated tasks, and time spent on duplicated task

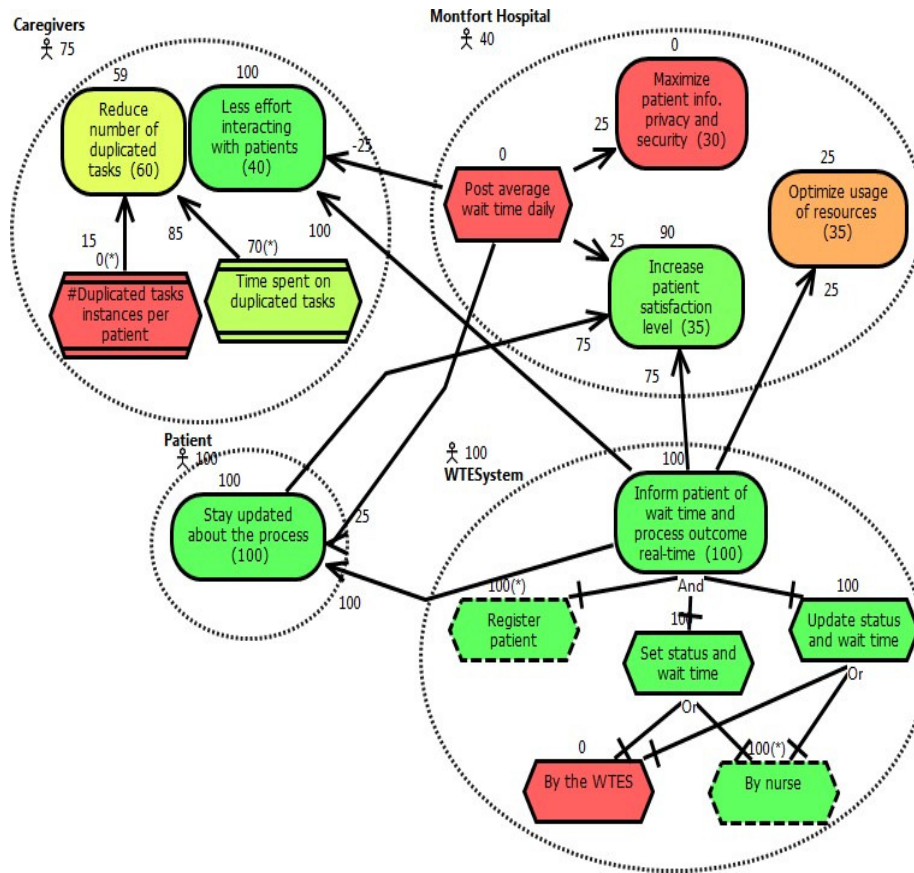
As AbPI’s integration method integrates the activities sequentially, the first activity to be integrated in the WTES process is *Set current status*. The integration method starts by identifying the integration opportunities of the *Set current status* activity into the current Lab unit process. There is one opportunity to integrate the activity, which is at the beginning of the process, before *collect sample*. The method identifies the impact of the integration on the process (structure, activities, and roles). The *Set current status* activity will be simply added to the current Lab unit process. Hence, as the ER has an electronic system, the *Set current status* activity can be automated where the WTES pulls the required information from the ER e-system. Thus, the integration model will have three alternatives: no change, *Set current status* done by the nurse, or *Set current status* done by the WTES, as shown in Figure 41 (bottom right). The second integration will follow steps similar to the ones in first integration. However, the activities *Insert expected wait time*, *Update wait time*, and *Update current status* are integrated together to preserve the semantic of executing the activities and the loop. Figure 41 (bottom left) illustrates the Lab unit process with

the two integration alternatives. The same integrations will be applied to the current Imaging unit process, resulting in the same alternatives.



**Figure 41** Integration alternatives of the WTES into the Lab unit process

Moving into the alternative evaluation method, the impact of each integration alternative is shown on the satisfaction levels of the goals and stakeholders. There are many possible combinations of the integration alternatives that affect the satisfaction levels of the goals and stakeholders differently. For the sake of simplicity, I only illustrate the impact of the scenario where a physician requires lab test and imaging; the nurse is responsible to deal with WTES activities (integration 1: alternative 3, and integration 2: alternative 2). As a result, the nurse will repeat activities *Set current status*, *Insert expected wait time*, and *Update current status* at least twice. The resulting number of individual duplications is 6. On the other hand, each activity, roughly, takes around 30 seconds to be completed. The number of duplicated tasks instances per patient and the time spent on each task are the current values of the KPIs in the goal model, which affect the satisfaction level of the *Reduce number of duplicated tasks* goal and the overall satisfaction level of the *Caregivers* actor, see Figure 42.



**Figure 42** Impact of the chosen integration alternatives on the satisfaction levels of goals and stakeholders (#Duplicated tasks instances per patient: current value = 6, threshold = 1, worst value = 5, and target value = 0; Time spent on duplicated tasks: current value = 120 sec, threshold = 300 sec, worst value = 600 sec, and target value = 0 sec)

In Figure 42, the number of duplicated tasks (which measures annoyance to the eyes of nurses) is insufficient without considering the time spent per tasks. The patient is fully satisfied and the caregivers are almost satisfied. All the remaining integration alternatives will be analyzed similarly to the previous example. Then, the analyst and the domain experts with the stakeholders can rank the integration alternatives and choose the one that achieves the desirable outcomes while satisfying the stakeholders and goals as much as possible. In Section 4.5 and Section 5.4, the *Data Quality and Confidence Propagation Mechanism* and the *DbGRL* methods are used in the same context to rank the alternatives and provide better decision support.

### 7.3 Case Study Plan

To help ensure formality and consistency of the evaluation procedure used in both case studies, a plan was prepared before starting the evaluation. The plan was inspired by the “*Guidelines for conducting and reporting case study research in software engineering*” of Runeson and Höst (2009). Table 18 contains the plan elements and explanation of each element.

**Table 18** Plan for case studies

<b>Objectives</b>	<ol style="list-style-type: none"> <li>1) Evaluate the comprehensiveness and completeness of the AbPI conceptual model to cover the process integration context (elements and relationships).</li> <li>2) Evaluate the capabilities of the AbPI methods to integrate processes and evaluate the generated alternatives.</li> <li>3) Discover the applicability of the AbPI framework in real-world cases.</li> </ol>
<b>Research questions</b>	<ol style="list-style-type: none"> <li>1) To what extent does the AbPI conceptual model capture the elements and relationships in the process integration context?</li> <li>2) To what extent is the AbPI integration method able to:             <ol style="list-style-type: none"> <li>a. Integrate goal models effectively?</li> <li>b. Integrate processes and generate correct and complete process integration alternatives?</li> </ol> </li> <li>3) To what extent is the AbPI evaluation method able to:             <ol style="list-style-type: none"> <li>a. Analyze the generated alternatives and evaluate them against pre-defined criteria?</li> <li>b. Suggest the best alternative and support the conclusion with evidence?</li> <li>c. Reflect the effect of data availability on the evaluation result?</li> </ol> </li> <li>4) What are the challenges/difficulties faced while using the AbPI framework?</li> </ol>
<b>Characteristics of case study</b>	Context where: <ol style="list-style-type: none"> <li>1) a new process will be integrated into current processes; and changes should be demonstrated and evaluated.</li> <li>2) a process is performed across multiple units.</li> <li>3) performance indicators are captured.</li> <li>4) multiple stakeholders have different needs and objectives.</li> </ol>
<b>Units under test</b>	The AbPI conceptual model and the integration and alternative evaluation methods.

<p><b>Data gathering</b></p>	<p>Interviews, discussions with stakeholders (whoever is involved in the context), and available documents.</p> <p>The interview questions are open/unstructured that focus on:</p> <ul style="list-style-type: none"> <li>a. stakeholder needs, objectives, fears, opinions about current processes and the new one</li> <li>b. organizational goals</li> <li>c. business objectives</li> <li>d. performance objectives</li> <li>e. long-term values</li> <li>f. importance of new changes</li> </ul>
<p><b>Implementation</b></p>	<p>Conducting the case study will happen through multiple iterations of: data gathering, applying a certain method/step of the AbPI framework, and validation. This cycle will be repeated many times until the desired result is reached.</p> <div data-bbox="695 772 1208 1276" style="text-align: center;"> <p>The diagram consists of three colored segments arranged in a circle, each with an arrow pointing to the next segment in a clockwise direction. The top-right segment is green and labeled 'Data gathering'. The bottom segment is red and labeled 'Applying a certain method/step of the AbPI'. The top-left segment is grey and labeled 'Validation'.</p> </div> <p><b>Figure 43</b> Case studies implementation phases</p>
<p><b>Reporting</b></p>	<p>The report on the result will focus on answering the research questions. It will report on undiscovered issues or needed medications.</p>

This case study plan was followed while conducting both case studies, presented in the next two chapters.

## 7.4 Chapter Summary

In this chapter, the approach used for evaluating the AbPI framework was explained. The evaluation approach includes a feasibility assessment, two case studies (in sequence, with

learning and framework improvements in between), and a usability study to evaluate the effectiveness of the framework in improving process integration outcomes. In addition, the chapter presented the plan designed to conduct the cases studies. The next chapter covers the first case study on *Lab Samples Monitoring* in Al-Rass Hospital.



## Chapter 8 Case Study 1: Lab Samples Monitoring

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This chapter assesses the effectiveness of the AbPI framework to integrate a proposed technology-related process to monitor the transferring of lab samples from the ER to the lab unit of a real hospital, and evaluate the usefulness of the analysis methods (alternative evaluation method, DbGRL method and data quality and confidence propagation mechanism) in guiding the decision and providing recommendations. In addition, the chapter presents some of the challenges faced while applying the AbPI methods.

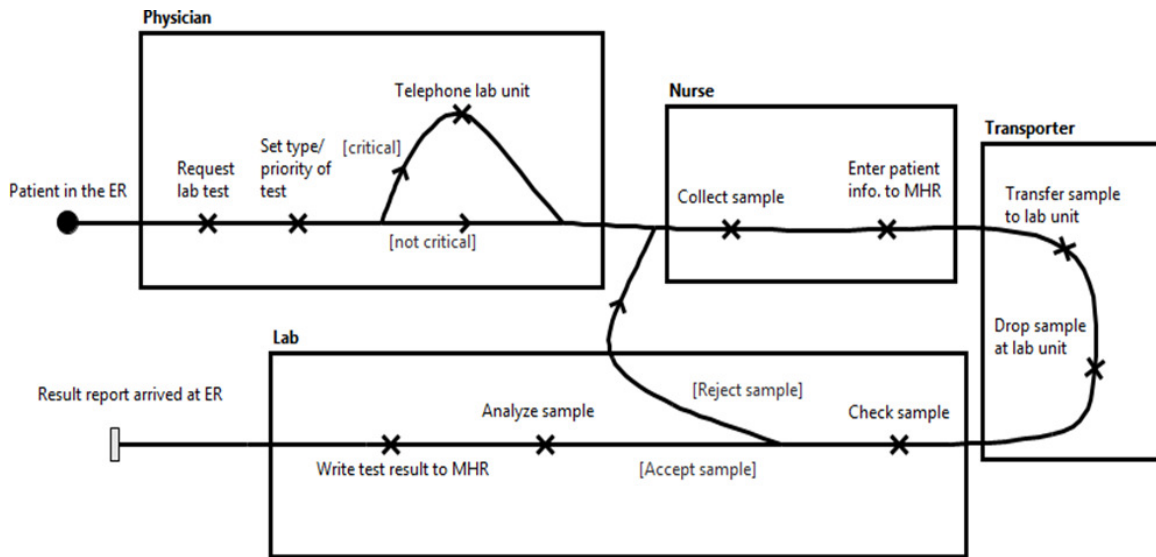
### 8.1 Introduction

This case study is about tracking the position of lab samples from the ER to the lab unit at Al-Rass Hospital in Saudi Arabia. The ER process, shown in Figure 44, is quite similar to the ER process that was presented in the illustration examples of the previous chapter. When a physician requests a lab test, the level of urgency (*Critical, Urgent, or Routine*) shall be set. A nurse collects the sample, and then registers the patient and the sample information into the *Medical Health Record* (MHR). Then, a transporter carries the sample to the lab unit and drops it into a box. Nurses in the lab unit check the box every 15 minutes for new samples because they do not receive notifications upon the arrival of new samples. Therefore, in most cases, there is a delay in delivering results of samples. In the case of *Critical* lab tests, the ER personnel calls the lab unit to inform them of the critical situation, as they expect the result of the collected sample to be available within an hour. If the sample result is not delivered within the allowed timeframe, the ER keeps checking on the status of the sample in the lab unit manually (e.g., with telephone calls or visits).

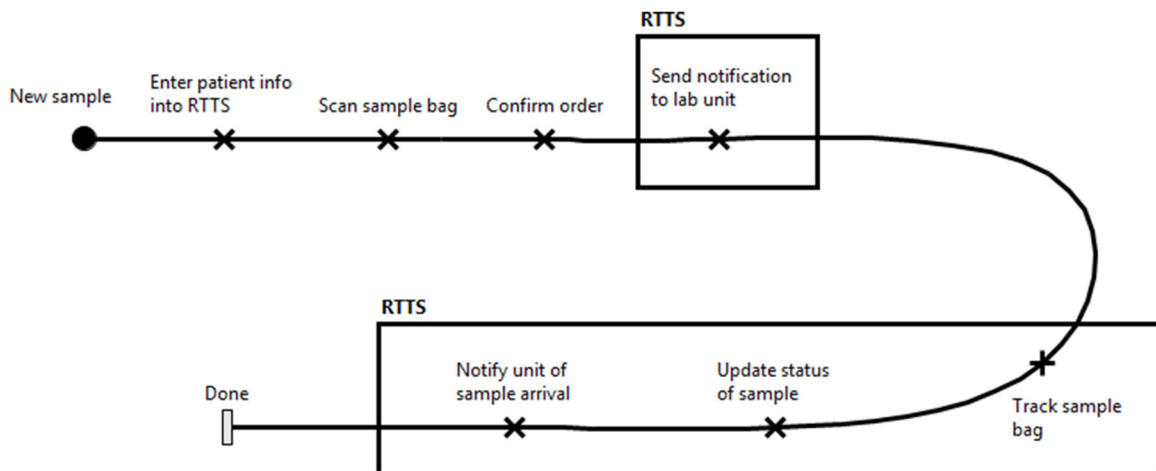
A customized *Real-Time Tracking Sample* system (RTTS) is being proposed to track samples in real time and report on the current position of samples while travelling from the ER to the lab. The samples are put into bags tagged with tracking chips that communicate wirelessly with the RTTS. Using the RTTS, the nurse shall add the sample into the bag, insert patient information into the RTTS, scan the bag, and confirm the request. The RTTS notifies the lab unit of the new lab test request. Then, the transporter carries the

sample bag to the lab unit. Once the sample bag arrives at the lab unit, the RTTS notifies the ER and the lab unit of the arrival of the new sample instantly (see Figure 45).

The aim of this case study is to help and support the decision that should be made, by the hospital, on whether to deploy the RTTS system or not. The RTTS system was developed by a programmer according to Al-Rass Hospital's needs.



**Figure 44** Current ER process at Al-Rass Hospital



**Figure 45** Proposed RTTS-related process

## 8.2 Preparing the AbPI Input

The first step is to identify the concern of the integration context in which a new process is introduced. The concern in this context is *lab samples monitoring*. Identifying the concern helps to focus on the goals, stakeholders, and processes of the integration context while excluding irrelevant information/data. Following this guideline, I started to collect data to prepare the input models using the AHP approach. The hospital does not have any existing goal or process models. It has the process of ordering, transferring, and analyzing lab samples described in written documents. To help understand the context, the *Quality Unit* of Al-Rass Hospital prepared simple flowcharts to describe the current process and the proposed RTTS process. Several iterations of meetings and interviews with stakeholders and domain experts took place to acquire the goal models for both the current and proposed processes, leading to two input PGMs.

### 8.2.1 Application of the Goal Integration Method

The goal models obtained reflect the proposed RTTS context and the current sample transferring context in the hospital, separately (Figure 46 and Figure 47). The goal integration method (described in Section 3.3) was applied to acquire one GRL model integrating both processes.

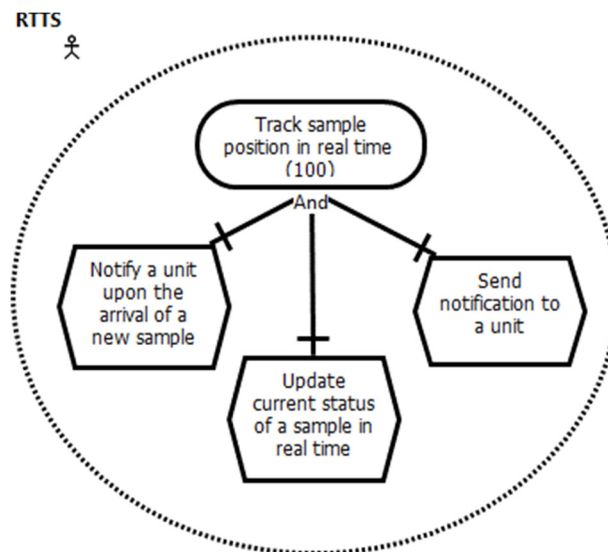
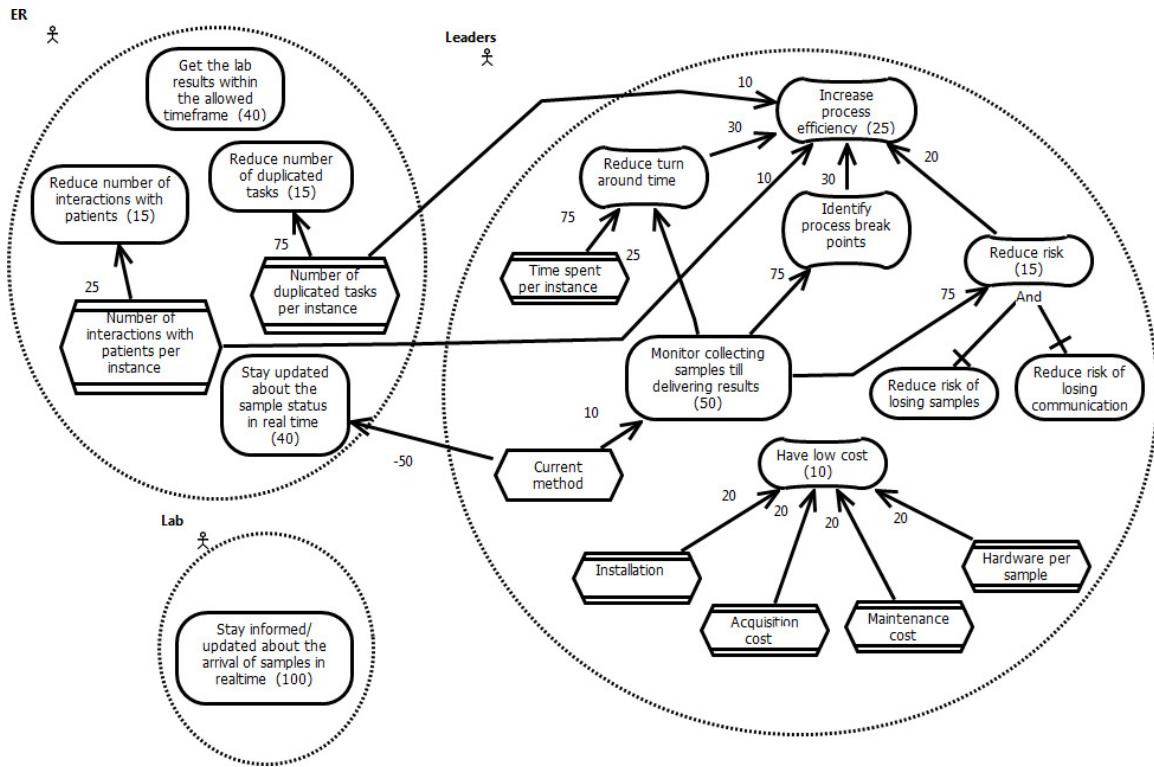
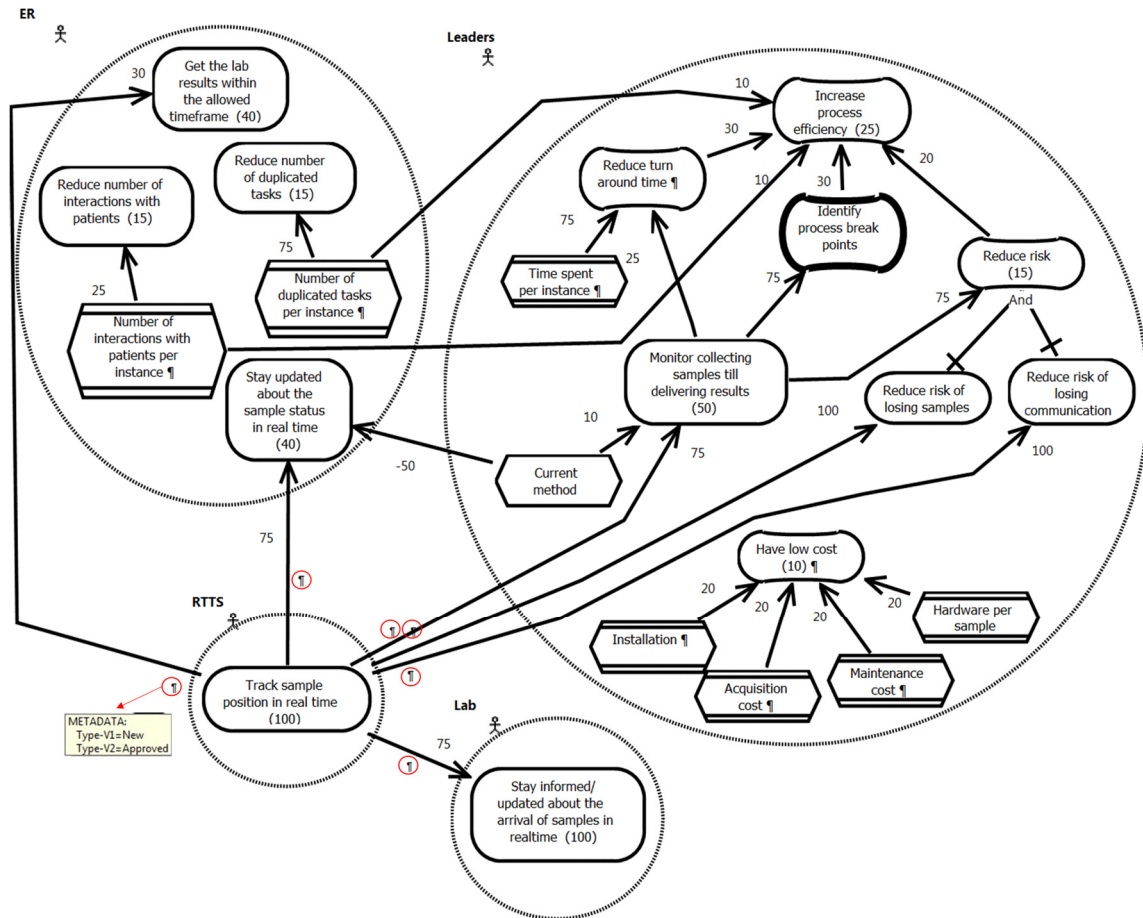


Figure 46 Proposed RTTS goal model



**Figure 47** Current goal model of the sample transferring context

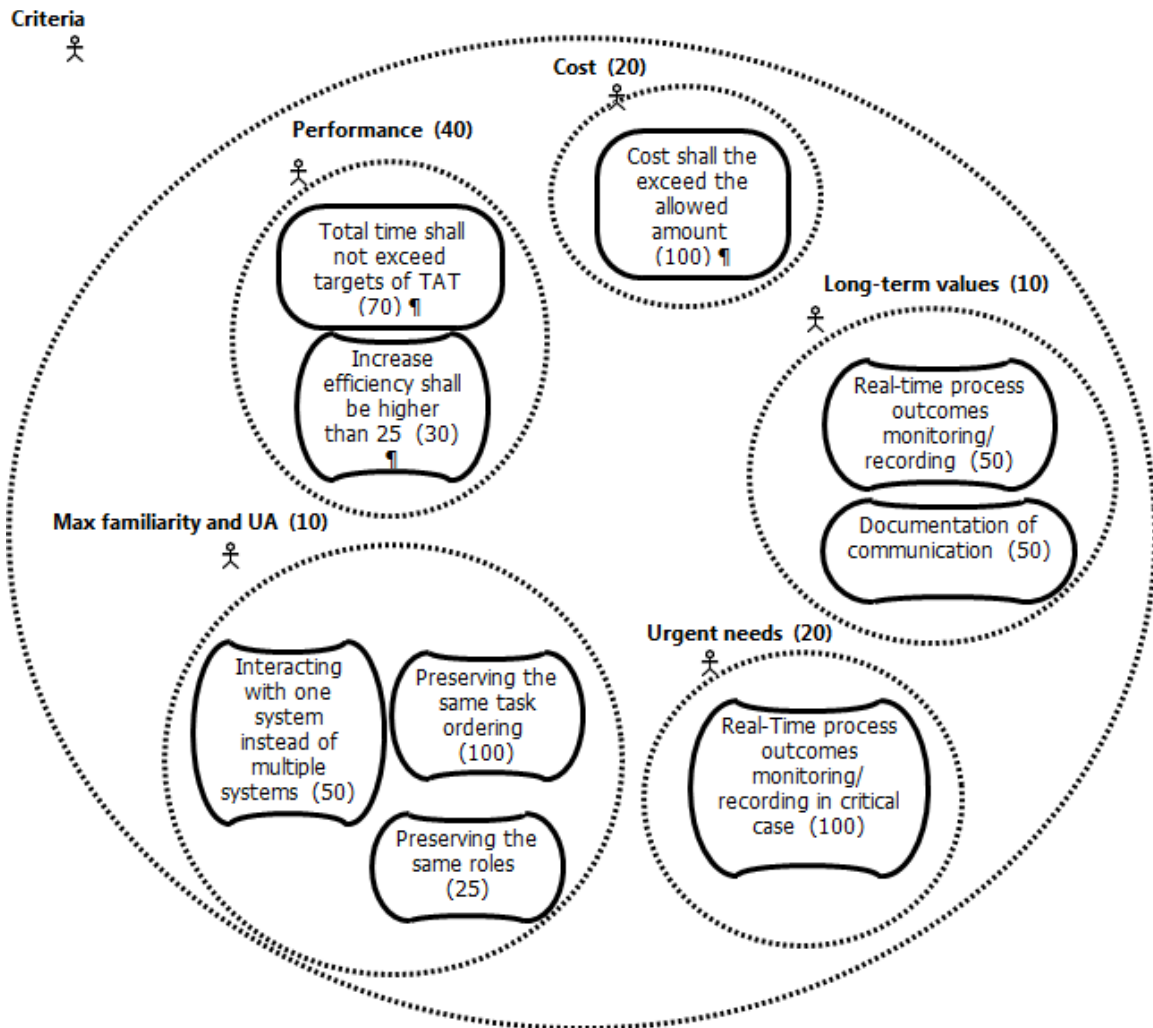
The current context and the context of the proposed RTTS system do not have anything in common. Hence, both models were added to the dissimilarity model, where no conflicts were raised. Then, relationships were introduced between the elements of RTTS and the current context to reflect how the RTTS system contributes to the sample transferring context's goals. All contributions were of a type "New" until they were validated and approved. After validation with stakeholders, the new elements were tagged with "Approved". The integrated goal model (IGM) in Figure 48 and the processes models in Figure 44 and Figure 45 are the inputs (PGMs) of the AbPI methods.



**Figure 48** Lab samples monitoring's Integrated Goal Model (IGM); the ¶ symbols in the red circles indicate the presence of metadata attached to the contributions. The metadata carries the type of relations of the contribution in each version (V1 and V2). The tasks of the RTTS goal model are kept in a separate view for simplicity.

## 8.2.2 Criteria

Pre-defined criteria were collected too. The criteria for choosing the best alternative were modelled, grouped, and added to the integrated goal model in a distinct view. The criteria will be used in the analysis phase to rank the process integration alternatives. There are five categories of criteria: Cost, Performance, Urgent Needs, Max familiarity and UA (user acceptance), and Long-term values. The criteria in the Max familiarity and UA group were identified by the caregivers in the ER (see Figure 49).



**Figure 49** Lab samples monitoring criteria

### 8.3 Application of the Integration Method

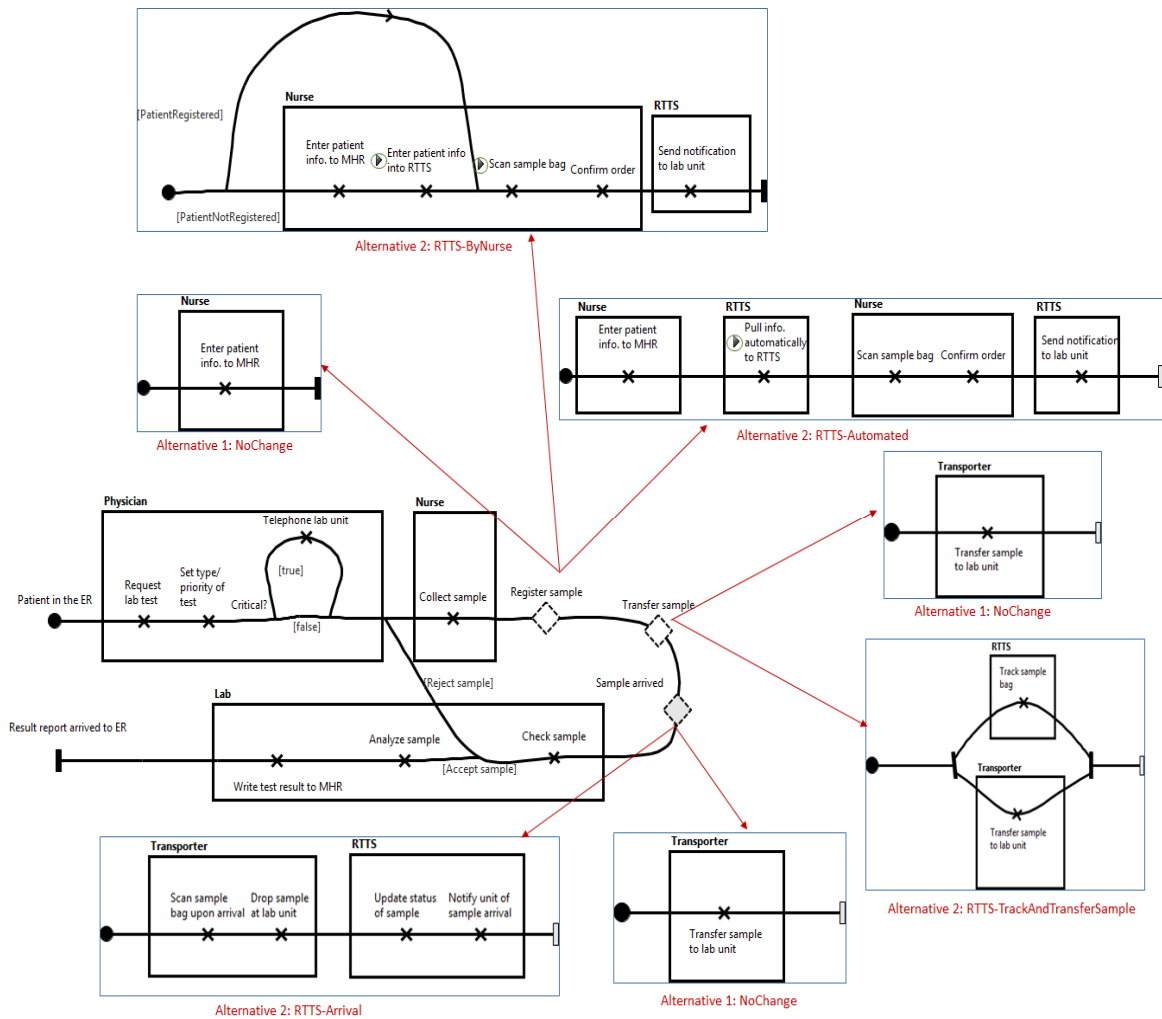
As explained in Chapter 3, the integration method has three phases: identifying integration opportunities, identifying the types of activity-activity relationships, and designing the integrated model. The first two phases had to be done with the domain expert to ensure correctness, consistency, and compliance to the policy and guidelines. There are two constraints that shall be held true, in this case study, during the integration method: 1) preserve the same ordering of activities found in the current process; and 2) in the proposed (RTTS) process, the activities *enter patient info. into RTTS*, *scan sample bag*, *confirm order*, and

*send notification to lab unit* shall be performed consecutively (to be integrated as a group). Table 19 specifies the identified integration opportunities in the current process and the type of activity-activity relationship for each opportunity.

**Table 19** First two steps in the process integration method: identifying integration opportunities and activity relationships

Activity to be integrated	Integration opportunity on current process	Activity-activity relation type	Activity-role relation type	Activity-goal relation type	Explanation
Inter patient info into RTTS	Enter patient info. into MHR	Combine, after	Same – by nurse	Change	The activity changes the current value of the indicator <i>Number of duplicated tasks per instance</i>
	Enter patient info. into MHR	Combine, after	Change – by RTTS	Change	The activity could be automated so that the RTTS pull patient information automatically from the MHR
Scan sample bag	After Inter patient info into RTTS	-	Add – by nurse	Change	The activity changes the current value of the indicator <i>Number of duplicated tasks per instance</i>
Confirm order			Add – by nurse	-	-
Send notification to lab unit				Add – by RTTS	-
Transfer sample to lab unit	Same	Same	Same – by transporter	-	-
Scan sample bag upon arrival	Drop sample at lab unit	Combine, before	Add – by transporter	-	-
Update status of sample	Drop sample at lab unit	Combine, after	Add – by RTTS	-	-
Notify unit of sample arrival	Drop sample at lab unit	Combine, after	Add – by RTTS	-	-

The identified integration opportunities and relationships were reviewed by another domain expert to ensure correctness and a logical flow of the process. The integration process alternatives model was then designed. The two main possible alternatives for integrating the RTTS-related process depend on the selection of one of the activities: 1) *enter patient info. into the RTTS* – by nurse, or 2) *pull patient info. from MHR* – by RTTS. Figure 50 shows the process integration alternatives model.



**Figure 50** Lab samples monitoring integrated process. In the ER process, the stub (diamond shape) contains the alternatives for performing the activity. The triangular (►) symbols in green circles beside the activities (*Enter patient info into RTTS*, *Scan sample bags* and *Pull info automatically to RTTS*) indicate URN links specifying activity-goal relations of type *Change*



## 8.4 Application of the Alternative Evaluation Method

The first phase of the alternative evaluation method is to design evaluation strategies for all potential process integration alternatives. The design of the evaluation strategies depends, to some extent, on the objectives and purpose of the evaluation from the stakeholder side. The main objectives in this context are to:

- 1- Evaluate the possibility of adopting and deploying the RTTS across the hospital (other monitoring purposes).
- 2- Investigate the performance of the integration alternatives on the predefined criteria for each level of urgency.

According to these objectives, I had to design three groups of evaluation strategies. Each group corresponds to a certain urgency level. In each group, there are three evaluation strategies that corresponds to the process integration alternatives (*current method*, *RTTS by nurse* and *automated RTTS*). There are hence nine strategies in total.

### 8.4.1 Indicators and Data Quality Method

In each evaluation strategy, initial evaluation values are assigned to some of the tasks and indicators. In a given group of evaluation strategies, the target value, the worst-case value and the threshold of an indicator do not change; however, the current value (evaluation value) changes according to the situation.

Each indicator was tagged with a data quality level that was assigned based on the source from which the indicator evaluation value was collected. Table 20 presents the indicators in this context and the data quality level assigned to each. The costs are calculated in Saudi Riyals (SAR). The data quality values of the cost indicators are set to 25 because the hospital was not certain about the costs and they provided estimated costs based on an initial discussion with the RTTS programmer. The data quality values of the *Number of interactions with patients per instance* and *Time spent per instance* indicators are set to 100 because the evaluation values were collected after conducting a pilot project, and hence they are reliable. Note that these last two indicators (like many indicators in general) cannot be computed directly by querying the structure of the UCM process definitions; their actual values are based on observations and evidence collected at the process instance level.

**Table 20** Lab sample monitoring indicators and data quality values

Indicators	Definition	Unit	Data quality
Total cost yearly	Summation of four other indicators: software installation cost, software acquisition cost, software maintenance cost, and the hardware cost per sample	SAR	Estimated-Literature 25
Installation cost	Software installation cost	SAR	Estimated-Literature 25
Acquisition cost	Software acquisition cost	SAR	Estimated-Literature 25
Maintenance cost	Software maintenance cost	SAR	Estimated-Literature 25
Hardware cost per sample	Cost of the tracking chip	SAR	Estimated-Literature 25
Number of interactions with patients per instance	Number of interactions between a nurse and a patient <i>inquiring about the lab sample result</i>	#	Valid 100
Number of duplicated tasks per instance	Number of duplicated tasks per instance in an alternative	#	Valid 100
Time spent per instance	Time from collecting the lab sample to its delivery to the lab unit	Second	Valid 100

In each evaluation strategy, the evaluation value of the task *Current method* and the tasks of the RTTS system were set either to 100 (when the task is selected) or to 0 (when another alternative is selected). The resulting evaluation strategies are the inputs of the DbGRL method, where they will be evaluated and ranked based on the predefined criteria.

#### 8.4.2 Application of DbGRL to the Ranking of Integration Alternatives

The DbGRL method is used to rank the alternatives in each situation based on the ideal and anti-ideal vectors provided by the hospital. The first step in the DbGRL (preparation) is already done in the *design evaluation strategies* phase. Table 21 contains the criteria and associated weights.

Turn Around Time (TAT) and Urgent needs are hard criteria. Using the cut-off method, none of the alternatives was excluded when evaluated against the hard criteria. In order to rank the alternatives using TOPSIS, the ideal and the anti-ideal vectors provided

by the hospital are used (Table 22). Note that the ideal and anti-ideal values of the total cost and of TAT vary between the three situations.

**Table 21** Lab samples monitoring: DbGRL criteria and weights (sum up to 1)

Criteria	Weight
Total cost	0.2
Turn Around Time (TAT)	0.3
Increase efficiency	0.1
Long-term values	0.1
Max familiarity and UA	0.1
Urgent needs	0.2

**Table 22** DbGRL ideal and anti-ideal vectors

Vectors	Total cost (SAR)	Total time of Turn Around Time (TAT) (s)	Increase efficiency	Long-term values	Max familiarity and UA	Urgent needs
<b><i>Critical situation</i></b>						
Ideal	50000	420	100	100	100	100
Anti-ideal	90000	1750	50	50	50	50
<b><i>Urgent situation</i></b>						
Ideal	70000	420	100	100	100	100
Anti-ideal	120000	1750	50	50	50	50
<b><i>Routine situation</i></b>						
Ideal	100000	1200	100	100	100	100
Anti-ideal	130000	1750	50	50	50	50

### First iteration

In the first iteration, the values of the cost in the ideal and anti-ideal vectors, in the critical situation, were not realistic (1000 SAR and 50000 SAR respectively). The performance of the alternatives on the cost criteria was very close to the anti-ideal value. Consequently, many discussions took place to understand the gap between the ideal cost value and the cost values of the alternatives. The hospital, then, changed the ideal and the anti-ideal values which were used in the second iteration.

## Second iteration

The cost values of the ideal and anti-ideal were changed to 50000 SAR and 90000 SAR respectively. The result of the ranking is illustrated in Table 23.

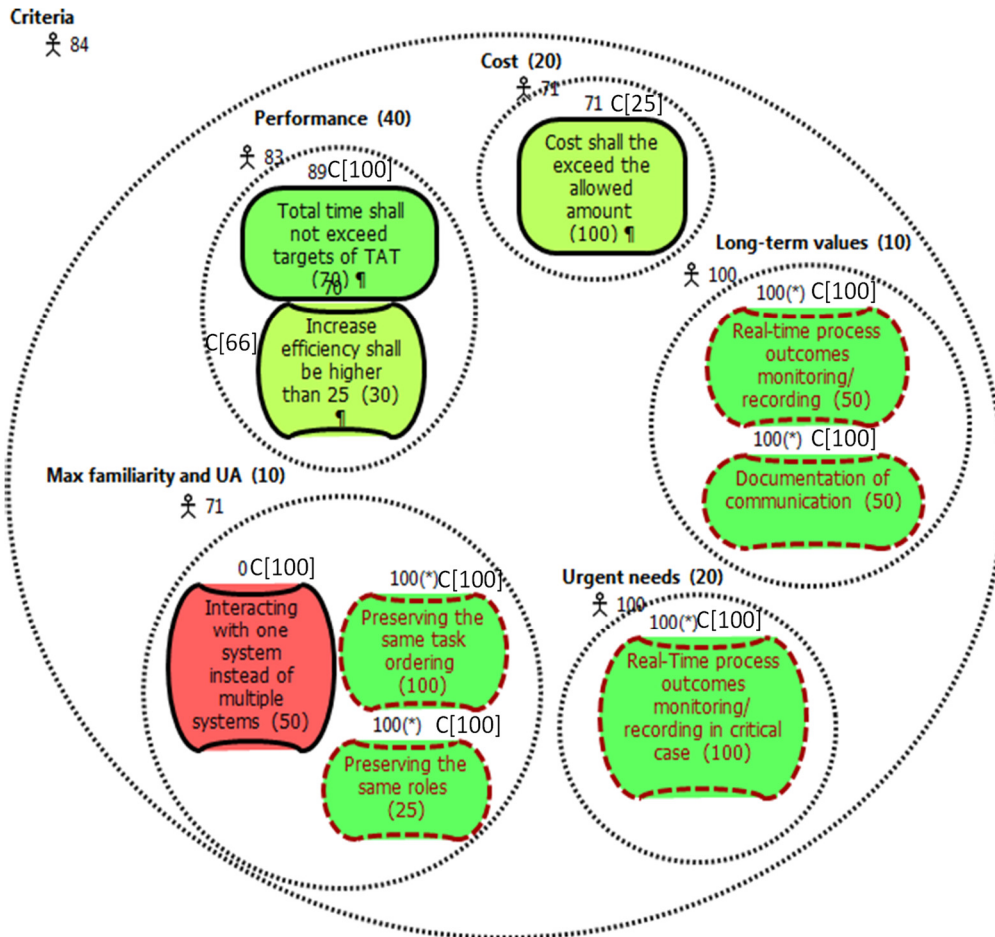
**Table 23** DbGRL: TOPSIS results for iteration 2

Alternative	d+	d-	C
<b>Critical</b>			
Current method	0.411	0.935	0.695
RTTSbyNurse	0.146	0.913	0.862
AutomatedRTTS	0.144	0.913	0.863
<b>Urgent</b>			
Current method	0.359	0.764	0.681
RTTSbyNurse	0.183	0.822	0.818
AutomatedRTTS	0.18	0.823	0.821
<b>Routine</b>			
Current method	0.26	0.275	0.514
RTTSbyNurse	0.954	0.929	0.493
AutomatedRTTS	0.954	0.931	0.494

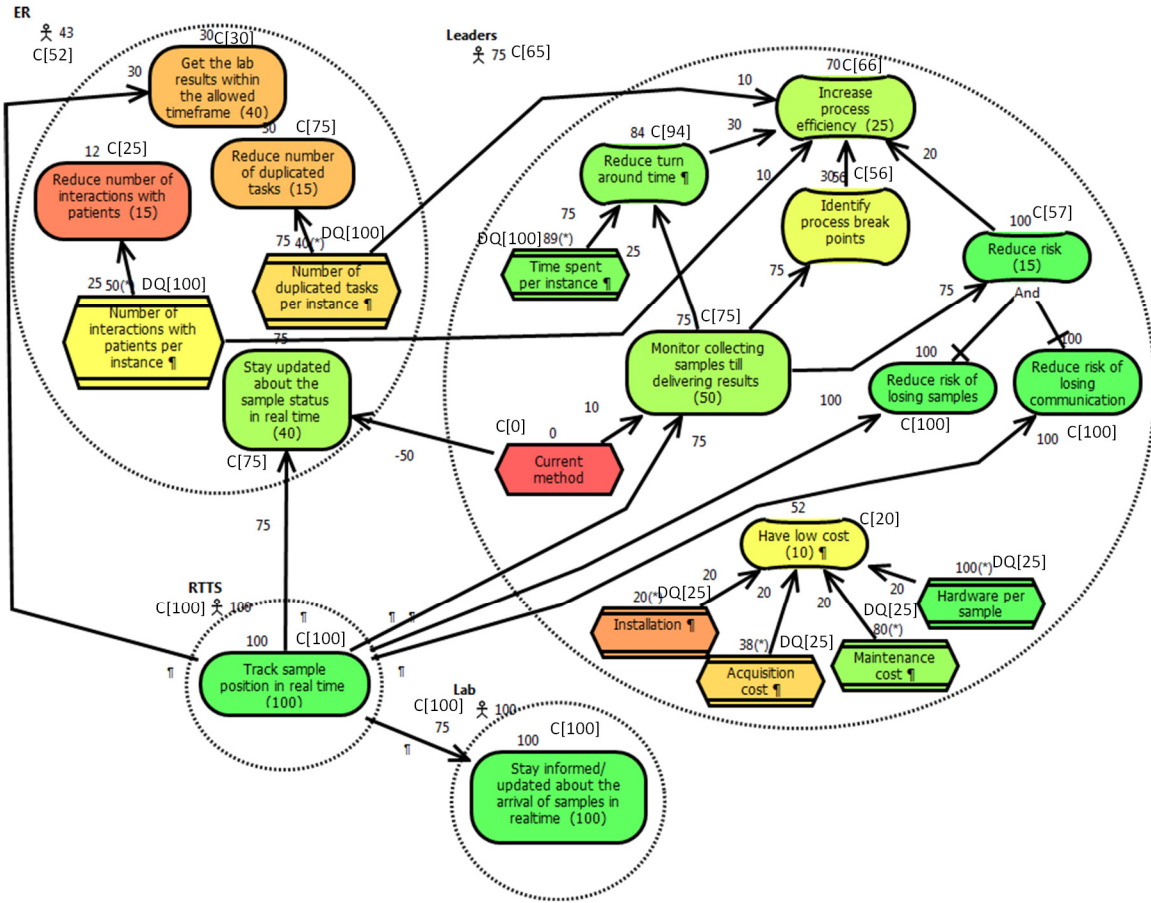
The results were presented and discussed with the hospital representative. The *Current method* alternative is better than the RTTS alternative mainly because of the cost. The hospital receives around 98550 urgent cases and 558450 routine cases yearly, which increases the cost of using an RTTS system dramatically. For critical situations, where they receive 49275 cases yearly, the cost is affordable. The hospital needs a real-time tracking system to track lab samples and other things; however, because the RTTS system was developed by a single programmer, not an official vendor, the hospital would not pay much for it at the moment. In addition, for the same reason, the RTTSbyNurse alternative was more welcomed than the AutomatedRTTS; nevertheless, the ER actor was less satisfied in the RTTSbyNurse compared to the AutomatedRTTS. There is an issue with the trust and a potential threat to data privacy and system security if they go with the AutomatedRTTS alternative because the programmer will bridge between the ER MHR system and the RTTS system. These new concerns need to be factored in the models.

The argument motivated the generation of iteration 3 where the concerns of data privacy and system security, as well as trusted vendor, are captured (see blue elements in Figure 57). It is important also to consider the confidence value of the cost estimates (20), which diminishes the soundness of the satisfaction value of the cost. The decision shall

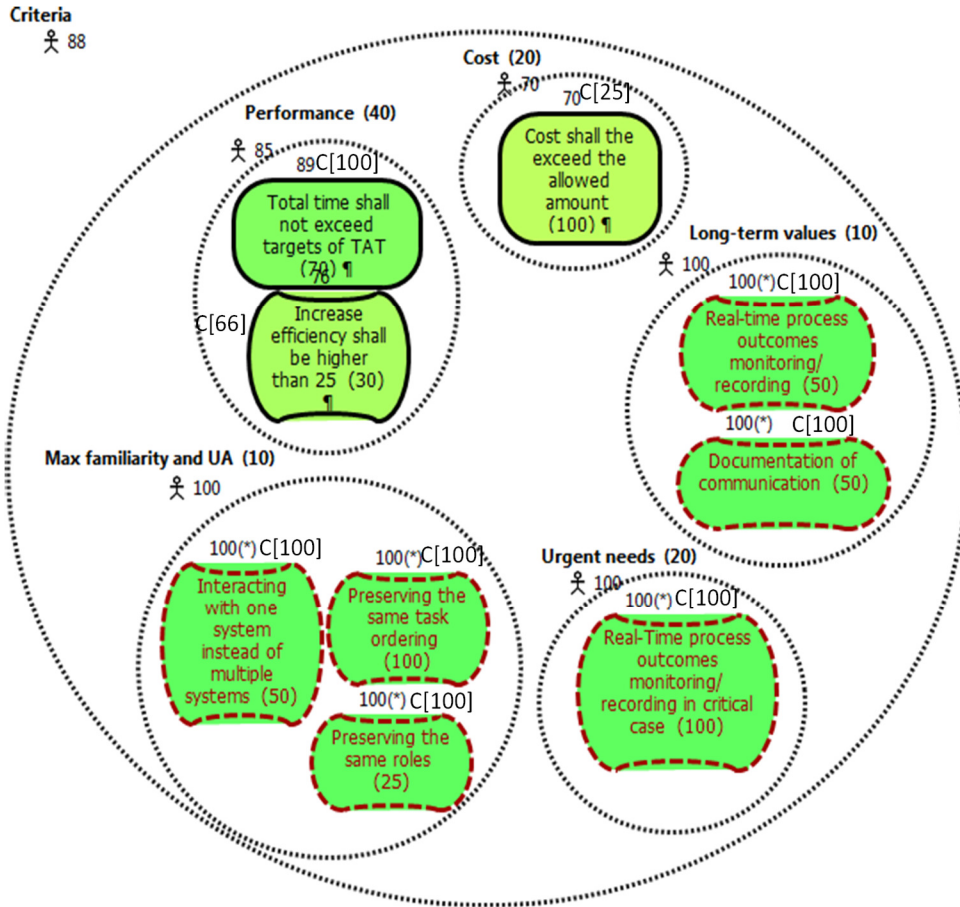
consider, mainly, the performance goals satisfaction, which have a confidence level of 100, and the urgent needs satisfaction.



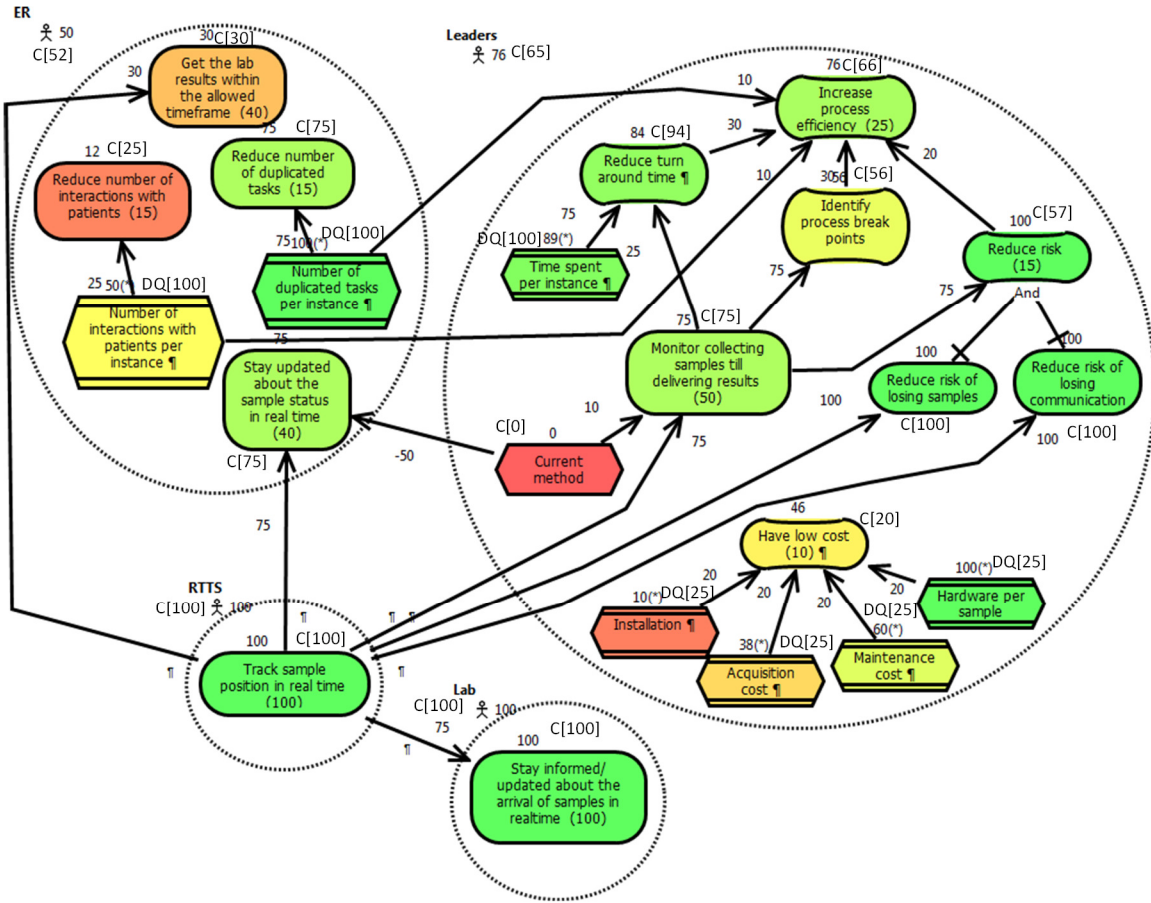
**Figure 51** Criteria evaluation results for the alternative *RTTSbyNurse* in the critical context



**Figure 52** Goal model evaluation results for the alternative *RTTSbyNurse* in the critical context, with propagated confidence values

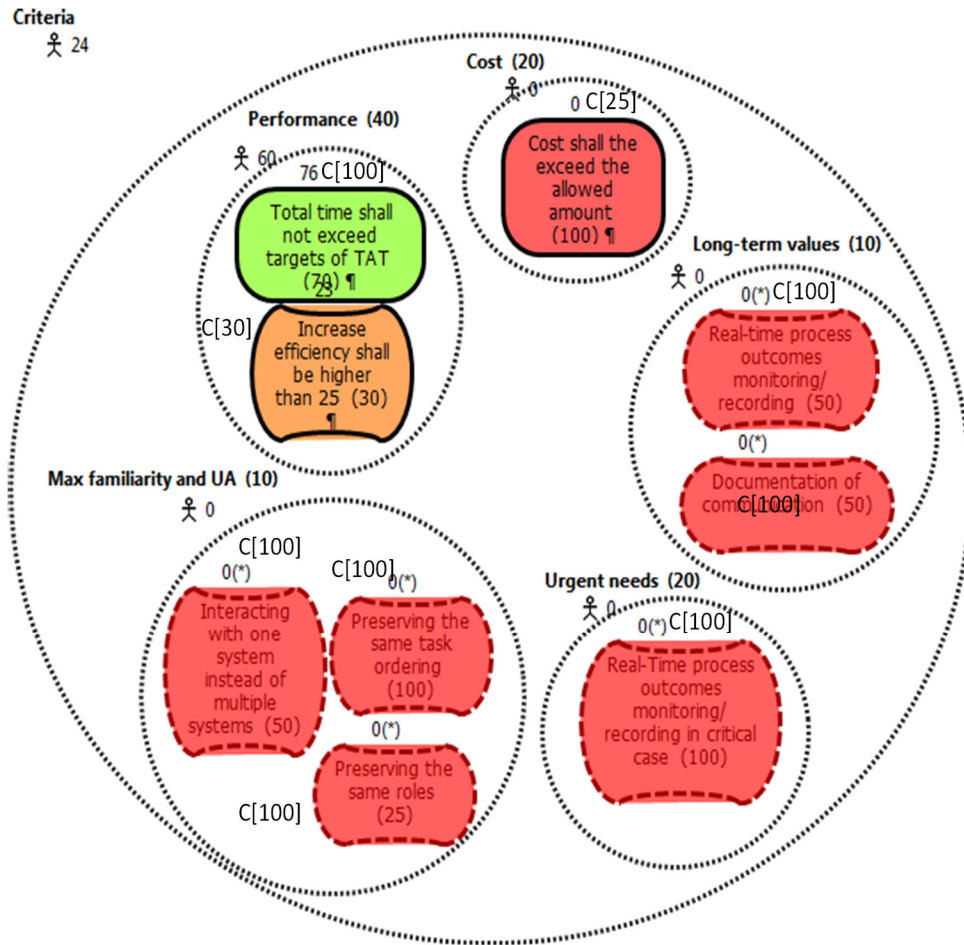


**Figure 53** Criteria evaluation results for the alternative *AutomatedRTTS* in the critical context



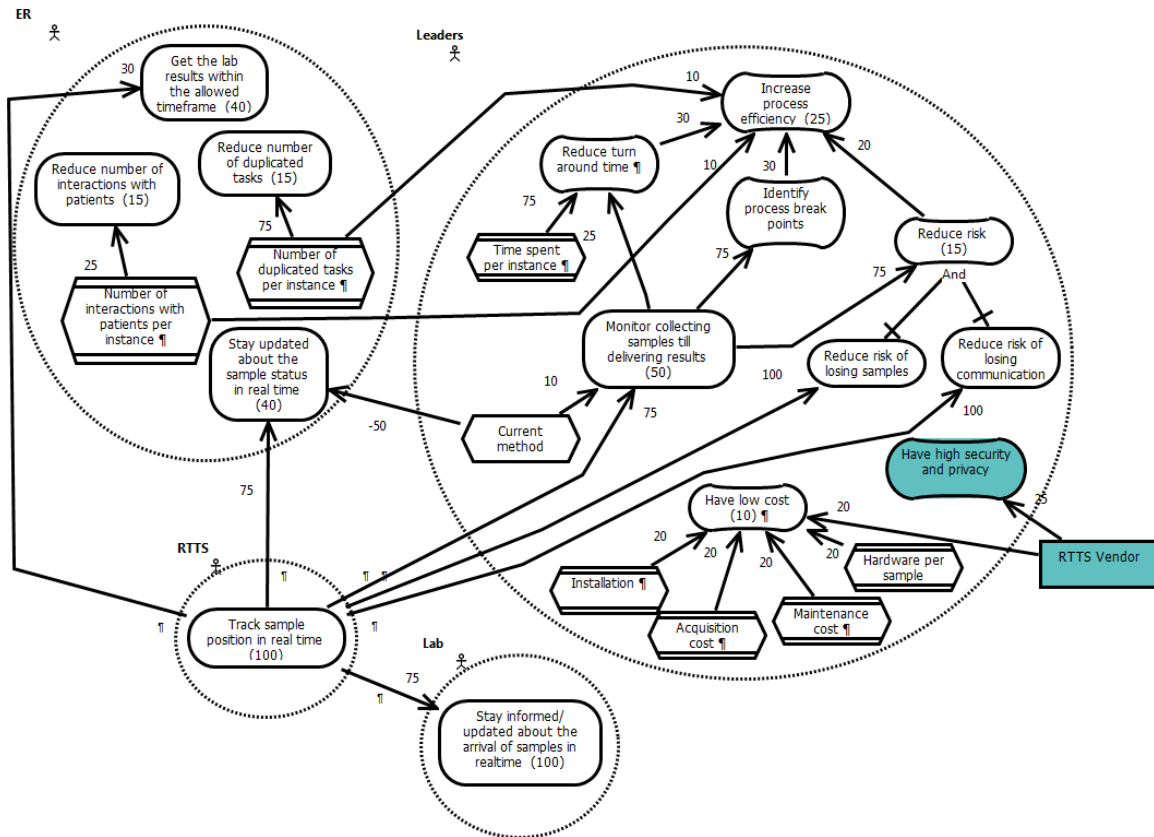
**Figure 54** Goal model evaluation results for the alternative *Automated RTTS* in the critical context, with propagated confidence values





**Figure 55** Criteria evaluation results for the alternative *CurrentMethod* in the critical context





**Figure 57** Refined goal model in DbGRL-iteration 3, where security and privacy, as well as RTTS vendor concerns, are captured

The results of the evaluation of the alternatives in the urgent and routine situations are similar to the ones in the critical situation. The big difference appears in the cost, as discussed above. In Figure 57, *Have high security and privacy* goal is not satisfied when using any of the RTTS alternatives and does not have an impact in the case where *CurrentMethod* is selected. Hence, evaluating the three strategies (*CurrentMethod*, *RTTSbyNurse*, and *AutomatedRTTS*) of each of the three situation groups (critical, urgent, and routine) leads to evaluations and conclusions similar to those of the second iteration. Note that the criteria view in Figure 49 could be updated with a security criterion in future process integrations.

### 8.4.3 Decision Making

The hospital representative delivered the analysis results to the administrative leaders, which support their argument of the suitability of using the RTTS as a temporary solution to fulfill the urgent needs in the critical situation, a situation that was shown by the analysis

to be affordable. However, they will keep the current method in the other situations (with higher load) until they find a trusted vendor.

## 8.5 Discussion

In terms of the research questions in Table 18, the case study assessed the capabilities of the AbPI framework to capture the context of the integration. The goal models were integrated adequately using the goal integration method. In addition, the AbPI methods were used effectively to integrate processes and evaluate the integration alternatives where the best alternative is highlighted. The main challenge faced in this case study is the data availability. The Quality Unit in the hospital established the project without sufficient consideration to the organizational or user goals. For example, one of the major issues was the cost. Data about the cost was estimated and was never trustable, even though the estimation went through many iterations to be as realistic as possible. This is an example where the data quality method plays a pivotal role by highlighting the low confidence of the cost goal satisfaction compared to other goals. The DbGRL method also contributed to help the hospital set realistic ideal and anti-ideal vectors and to capture hidden concerns of stakeholders regarding the RTTS (security and privacy, and cost relation to the vendor). Moreover, the *Urgent needs* criterion was first introduced in this case study. After discussions with representatives from Al-Rass hospital and other hospitals workers, it was decided to extend the AbPI conceptual model with an *Urgent needs* sub-class of criteria as it was emphasized and needed in many cases.

## 8.6 Chapter Summary

This chapter presented a case study used to assess the effectiveness of the AbPI methods to guide and support decision making in the case of an RTTS-related process integration in Al-Rass Hospital. It also presented the steps, the iterations and interesting points discovered while applying the AbPI methods to acquire the best alternative. In addition, the DbGRL method was used effectively and helped to refine the goal model and capture missing concerns. The data quality and confidence propagation mechanism also contributed to

attract the attention of stakeholders to missing data and confidence in the alternatives performance on the criteria.

In next chapter, the effectiveness of the AbPI is further assessed with a second case study related to the introduction of a *Voice Recognition System* at Montfort Hospital.

# Chapter 9 Case Study 2: Voice Recognition System

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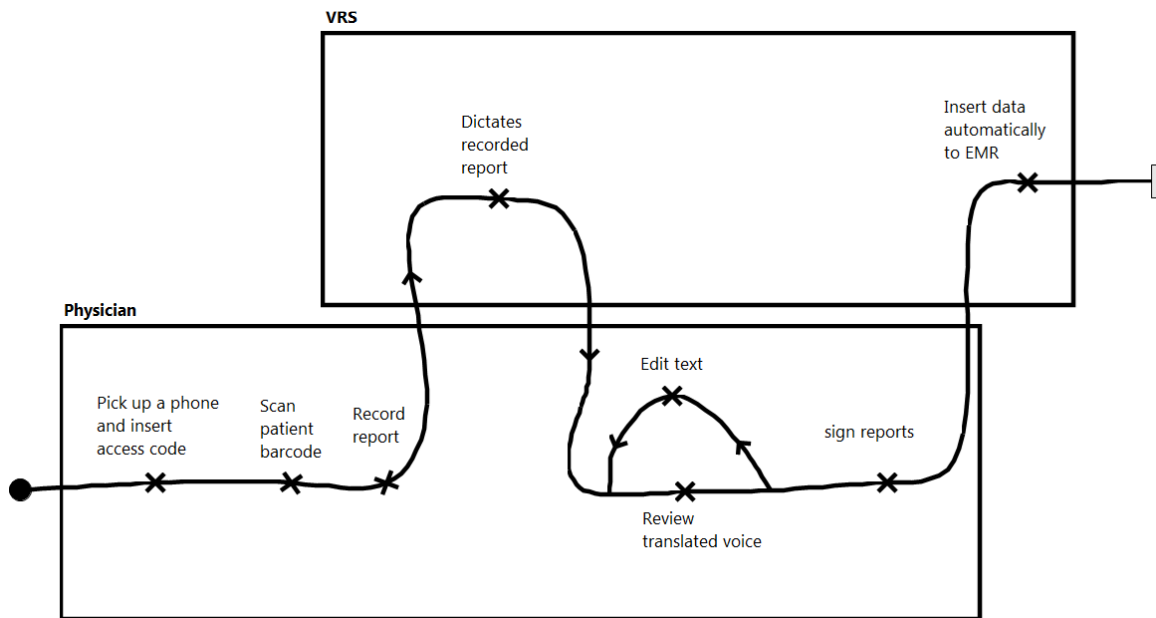
This chapter presents the second case study where the AbPI framework is used in a real context, namely *Patient Report Documentation* in a hospital. The case study illustrates how the AbPI methods are used to construct the models, integrate the proposed technology-related process (of a voice recognition system) into two different processes belonging to two different units, and evaluate the output to choose the best alternative that achieves the desired outcomes at the moment and on a long-term basis.

## 9.1 Introduction

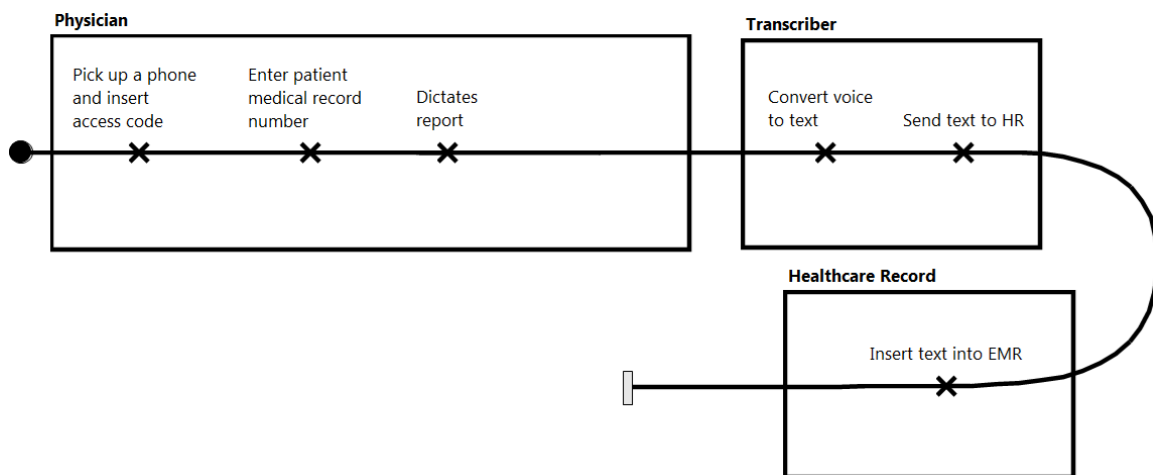
This project is an intermediate phase towards a full *computer-based entry* in a hospital. Montfort Hospital is, currently, at level 4 of the *Analytics Electronic Medical Record Adoption Model* (EMRAM), an “eight-stage (0-7) model that measures the adoption and utilization of electronic medical record (EMR) functions” (HIMSS Analytics, 2017). Montfort Hospital’s administration intends to deploy a new *Voice Recognition System* (VRS) to replace paper-based documentation/registration of patient information. Caregivers will record their notes using computers instead of writing or typing them. The VRS will recognize speech and present it as text for the caregiver to verify and sign electronically. Then, the recorded information will be fed automatically to the patient medical record in the information system (MediTech), as shown in Figure 58. The administrative leaders expect the VRS to be beneficial for caregivers who prefer not to type directly into MediTech. Currently, there are three alternatives for documenting patient report/information: writing on paper, typing directly into MediTech, and using a voice recording system. In the last alternative, a physician records a patient report, the system converts the recorded speech to text, and transcribers, a third party, review the result of the speech recognition. Then, they either edit the text, if needed, or send it to the *Healthcare Record* department at Montfort to insert it into the patient healthcare record in MediTech (see Figure 59). If the transcribers edit the

text, the hospital pays a certain amount of money per minute, in addition to the software license itself.

As I previously collaborated with Montfort Hospital in managing patient anxiety during the AbPI feasibility study, Montfort leaders were motivated to use AbPI in the patient report documentation context. Their objective is to evaluate performance of each alternative on goal achievement and needs fulfilment, in order to choose the best one. Through using AbPI, they attempt to get units/stakeholders to participate in the decision-making process, so that they select the best alternative and support deploying it effectively.

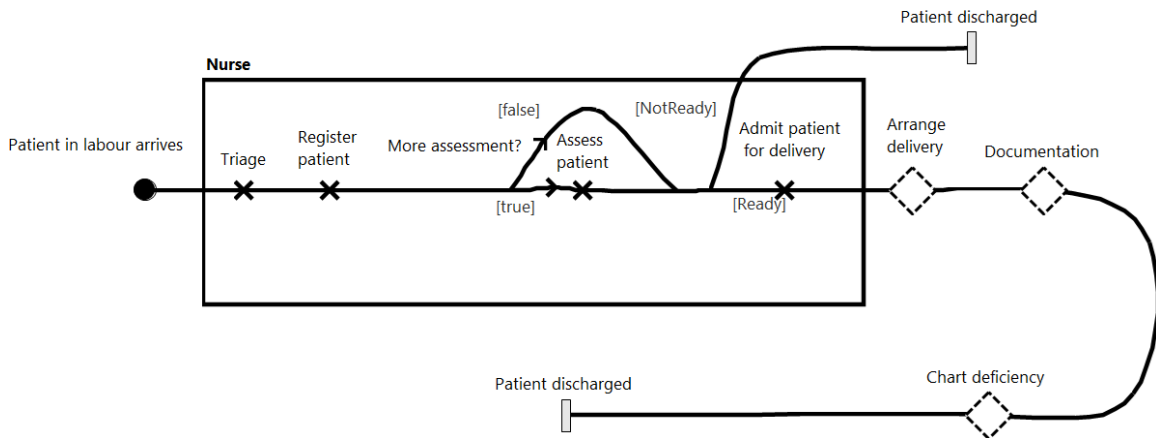


**Figure 58** Proposed VRS-related process



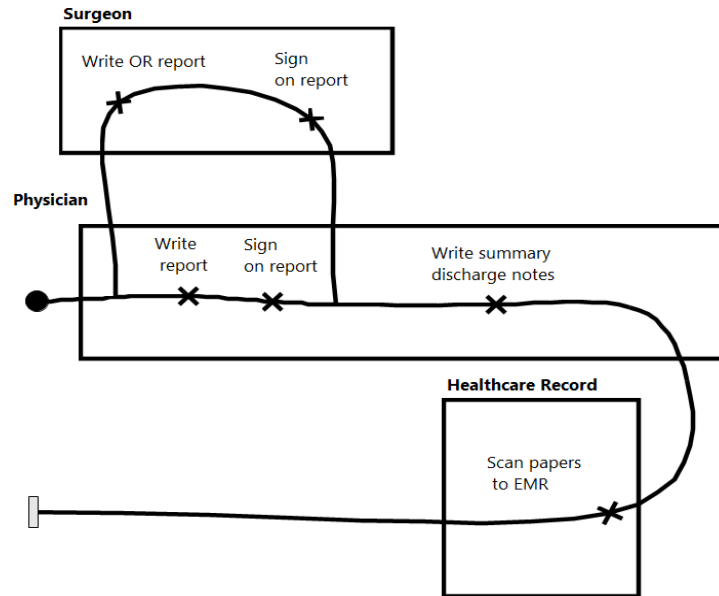
**Figure 59** Current VoiceRecording process

In this case study, the integration of the proposed Voice Recognition System happens in two different units: the ER (Figure 39) and the Obstetrics unit (Figure 60). In the Obstetrics unit, once a patient arrives, she is assessed to determine whether she is ready to deliver the baby or not. If she is ready, she gets admitted and the baby delivery process is arranged. The delivery process is either normal or one that uses C-Section. In the case of a C-Section surgery, the surgeon has to write an Operating Room (OR) report. If the delivery was normal, the physician has to write a patient report. The Health Record unit scans the documents if the report was written on paper. At the end, if some patient information is missing, the physicians are called in the *Chart Deficiency* workspace to fill the missing information. Figure 61, the sub-process of the Documentation stub in Figure 60, illustrates the process of documenting patient information in both types of delivery.



**Figure 60** Current obstetrics process





**Figure 61** Patient report documentation in the Obstetrics unit (sub-process in the Documentation stub of Figure 60)

## 9.2 Preparing the AbPI Input

Similar to the previous case study, the hospital does not have existing goal or process models. Several interviews and meetings were conducted to gather stakeholder/user (physicians and administrative leaders) goals, organizational goals, performance objectives, and long-term values (using pairwise comparisons). Current processes and alternatives for documenting patient information were captured too. In addition, during those meetings, the VRS goal and process models were constructed.

The concern in this context is *documenting patient report*. Therefore, any unrelated information was discarded. The goal integration method was applied to acquire one integrated goal model for the AbPI framework. The following sections discuss the goal integration method and the criteria. The basic process of documenting a patient report was modelled to be used as baseline in the analysis phase and as a reference to ensure that the process integration alternatives are correct and complete (Figure 62). The process of documenting patient information in the Obstetrics unit (Figure 61) and the ER (Figure 63) were modelled too.

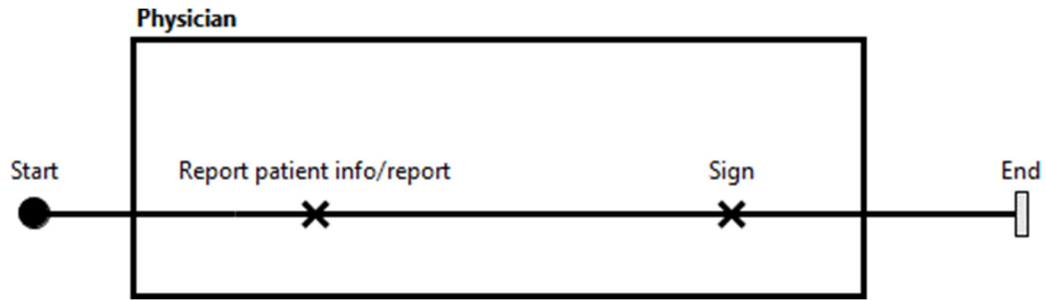


Figure 62 Basic patient report documentation (technology independent)

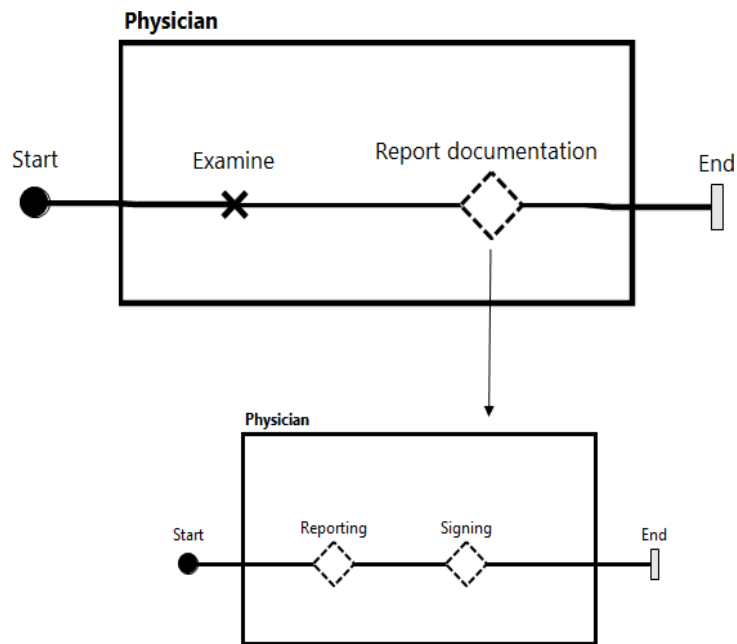
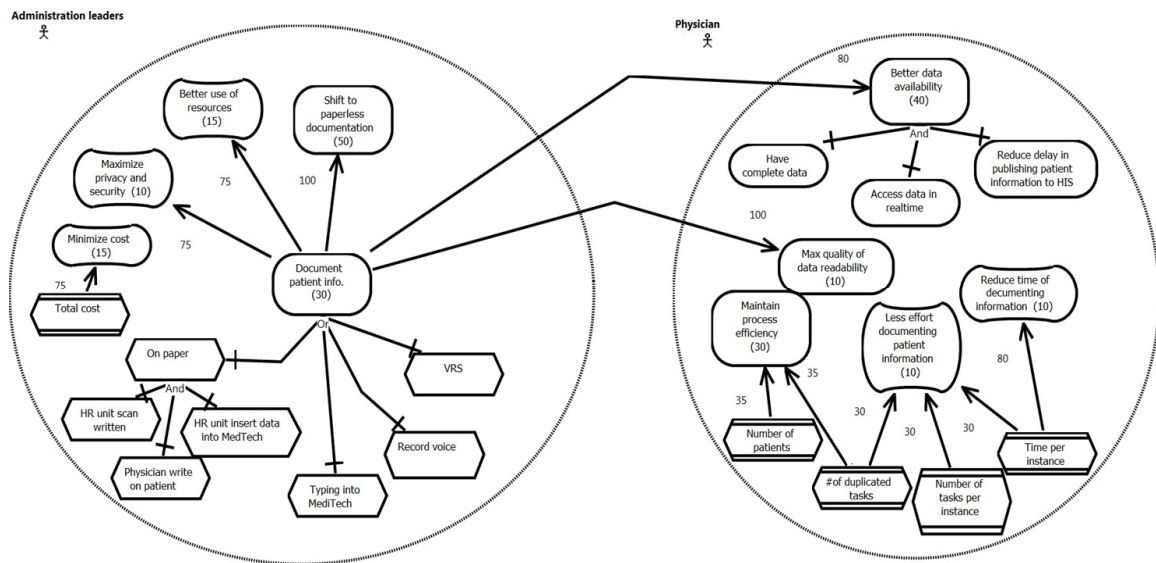


Figure 63 Patient report documentation in the ER

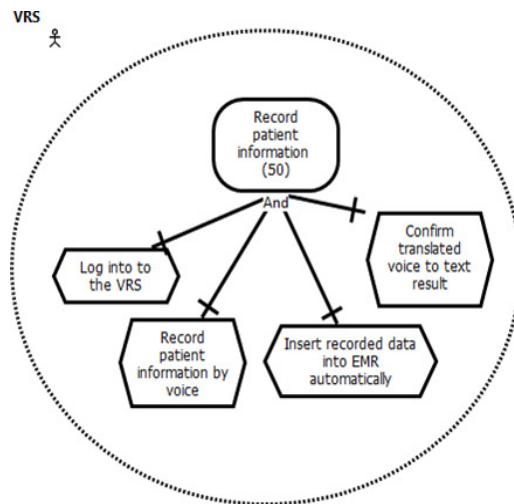
### 9.2.1 Application of the Goal Integration Method

Figure 64 and Figure 65 contain the goal models of the current situation and the proposed VRS before applying the goal integration method. The first step in the goal integration method is to identify similarities between the two goal models and combine the similar elements in the similarity model (SIGM). The goals “*Document patient information*” in the hospital actor and “*Record patient information*” in the VRS actor are similar. Both are about documenting patient information; however, the *Record patient information* goal is more specified in terms of the technology used to document patient information. Therefore, in the similarity model, the *Document patient information* goal is used to represent both goals. *Similarity* relationships are added between the two goals in the original models and

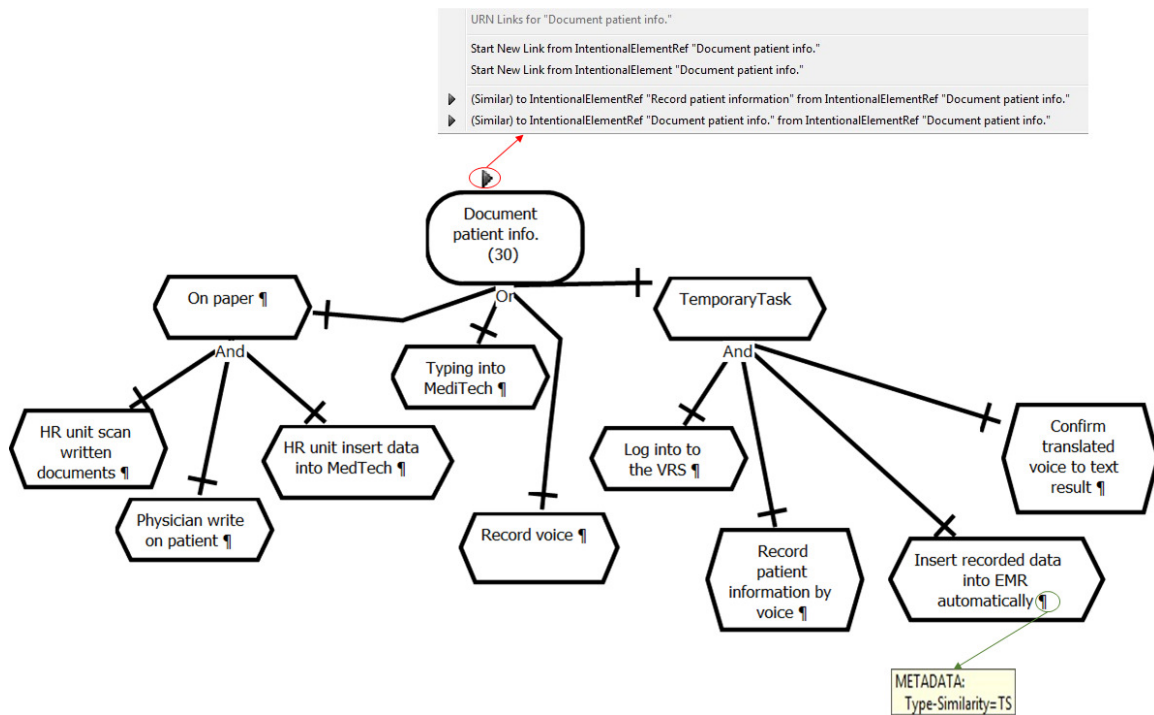
the *Document patient information* goal in the new similarity model. The tasks of the two goals in the hospital actor and the VRS actor are added to the similarity model too, with TS (transitive similarity) relationships to the source elements. Figure 66 illustrates the similarity model. In the similarity model, the structural *TemporaryTask* is used to hold the AND-decomposition of the subtasks added from the VRS goal model because it cannot be combined with the subtasks added from the current goal model, which has a different type of decomposition (OR) with the goal “*Document patient information*”. *TemporaryTask* plays a temporary structural role until it gets replaced with another task that is more related to the context of the integration, which cannot be done in the similarity model.



**Figure 64** Current patient report documentation goal model



**Figure 65** Proposed VRS goal model

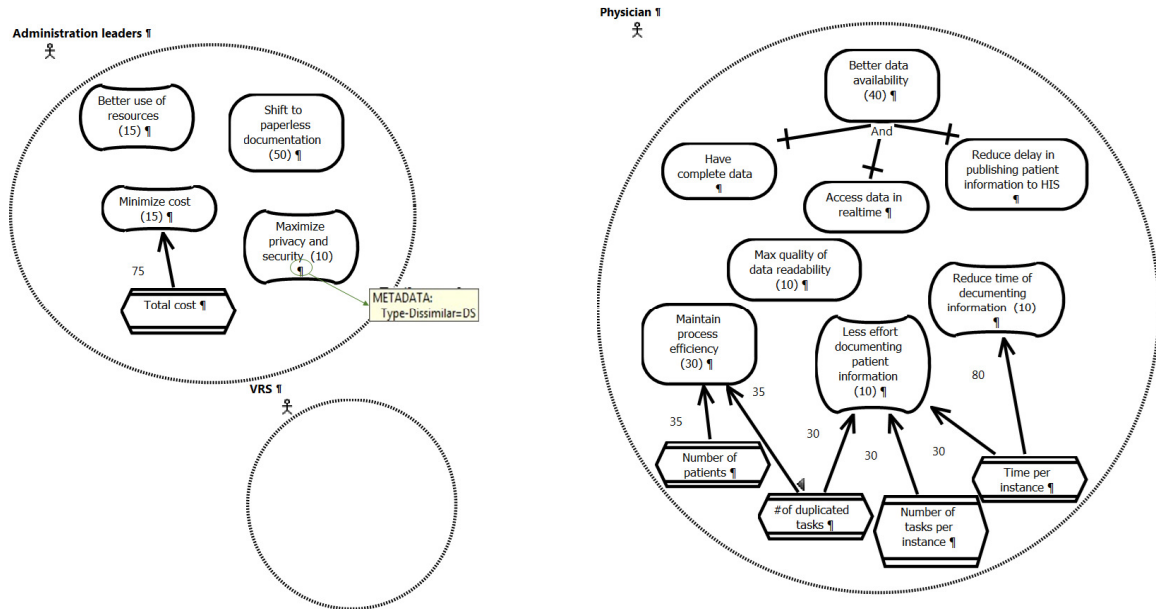


**Figure 66** Similarity model (SIGM): the triangle in the red circle indicates the presence of a Similar relation from *Document patient info.* to the *Document patient info.* in the current goal model and *Record patient information* in the VRS goal model. The transitive similarity (TS) metadata is also attached to all tasks

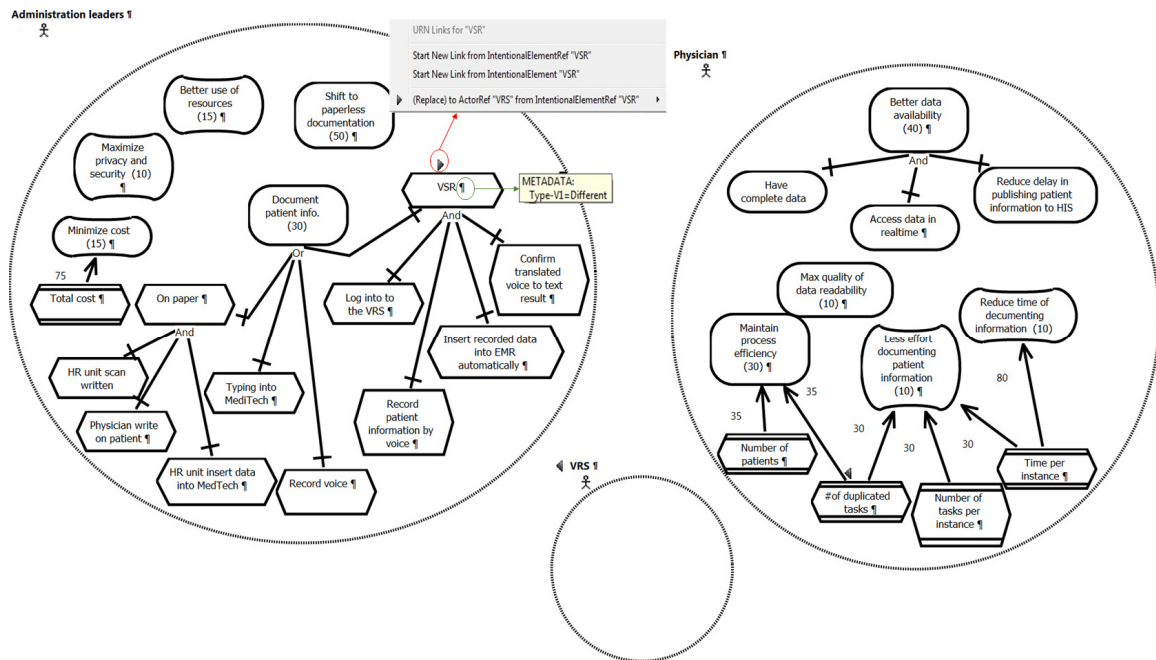
The second step in the goal integration method is to create the dissimilarity model (DSGM). In this case, the actor VRS from the proposed VRS goal model and all elements in the current situation goal model, which are not in the similarity model, are added to the dissimilarity model (see Figure 67). Following this, the similarity and dissimilarity models are merged in the integrated goal model (IGM). In the IGM, the actor VRS does not have any goal. In fact, in the process integration context, the VRS is one of the alternatives for documenting patient information. Therefore, the VRS is modelled as a task and a *different* relationship is initiated between the VRS task and the VRS actor (IGM-V1, Figure 68). In addition, the VRS task replaces the TemporaryTask, which is not needed anymore.

After ensuring that there are no conflicts between the merged models in the IGM, the relationships from the original models (current situation and proposed VRS) are added to the IGM-V1 resulting in IGM-V2 (Figure 69). For all added relationships in IGM-V2, the representation of the VRS actor as a task is *approved*. The added relationships are not different from the relationships in the original models so no conflict or different situation

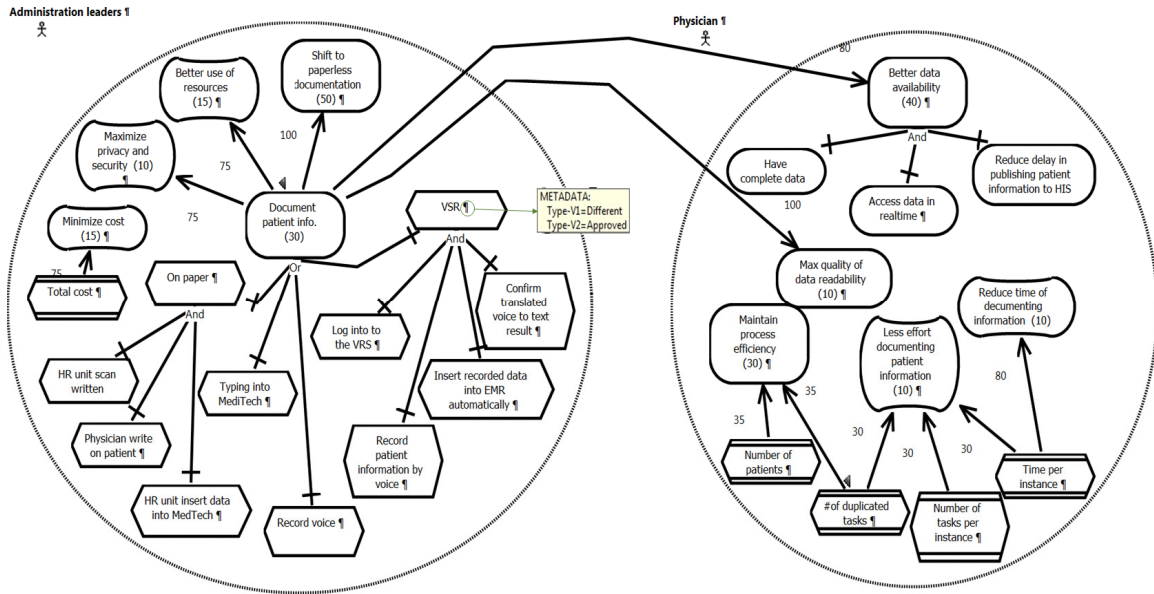
has occurred. The IGM-V2 was validated with the stakeholders where no issue was raised. Accordingly, the IGM-V2 is the approved goal model to be used as input by the AbPI process integration and alternative integration methods.



**Figure 67** Dissimilarity model (DSGM): all elements were tagged with the DS (dissimilar) type



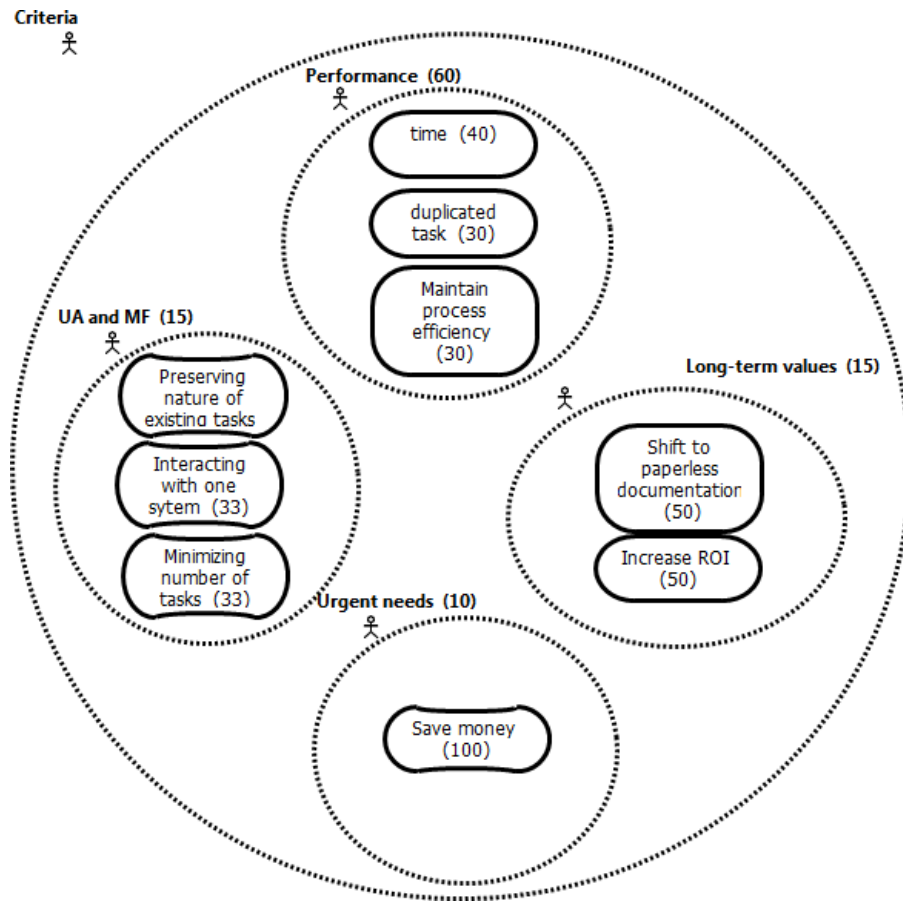
**Figure 68** First version of the integrated goal model, where the VRS is represented as a task to replace the VRS actor (IGM-V1)



**Figure 69** Second version of the integrated goal model (IGM-V2), where all types of relations have been approved.

### 9.2.2 Criteria

Predefined-criteria were modelled and added to the integrated goal model in a distinct diagram. The criteria will be used in the DbGRL model to rank the process integration alternatives based on the distance to the ideal and anti-ideal performance vectors. In this context, there are four categories of criteria: Performance, Urgent needs, which includes the cost, Long-term values, and Maximize familiarity and UA (user acceptance). Figure 70 illustrates the view of the criteria. The importance of each actor is equivalent to the weight assigned to each group of criteria, which will be used in the DbGRL method.



**Figure 70** Patient report documentation criteria

### 9.3 Application of the Integration Method

In the integration method, there is a constraint that the activities of the proposed VRS-related process shall be performed sequentially. To satisfy the constraint, the domain expert helped in grouping and ordering the activities. The decision was to integrate the activities *Pick up the phone and insert access code*, *Scan patient barcode* and *record report* as an unseparated group; and *Review translated voice*, *Edit text*, and *Sign report* as another unseparated group. Table 24 contains the integration opportunities and the activity-activity and activity-role relations, and Table 25 explains the activity-goal relations. It is worth mentioning that both contexts (obstetrics and ER) share the same integration opportunities and activity relations because the processes of documenting patient reports in both contexts are identical.



**Table 24** Patient report documentation integration opportunities and activity relations

Activity ID	Activity to be integrated	Integration opportunity on current process	Activity-activity relation type	Activity-role relation type	Explanation
1	Pick up the phone and insert access code	Write OR report	Replace	Same	
		Write report	Replace	Same	
2	Scan patient barcode	-	Add, after	Same	Added after activity 1
3	Record report	-	Add, after	Same	Added after activity 2
4	Dictates recorded report	-	Add, after	New – VRS	Added after activity 3
5	Review translated voice	Sign on report	Add, before	Same	
		Sign on report	Add, before	Same	
6	Edit text	-	Add, after	Same	Added after activity 5
7	Sign report	Sign on report	Replace	Same	
		Sign on report	Replace	Same	
8	Insert data automatically to EMR	Scan papers to EMR	Replace	Change – Healthcare record to VRS	The activity will be changed to suites the context and current EMR being used at Montfort Hospital: Insert data automatically to MediTech

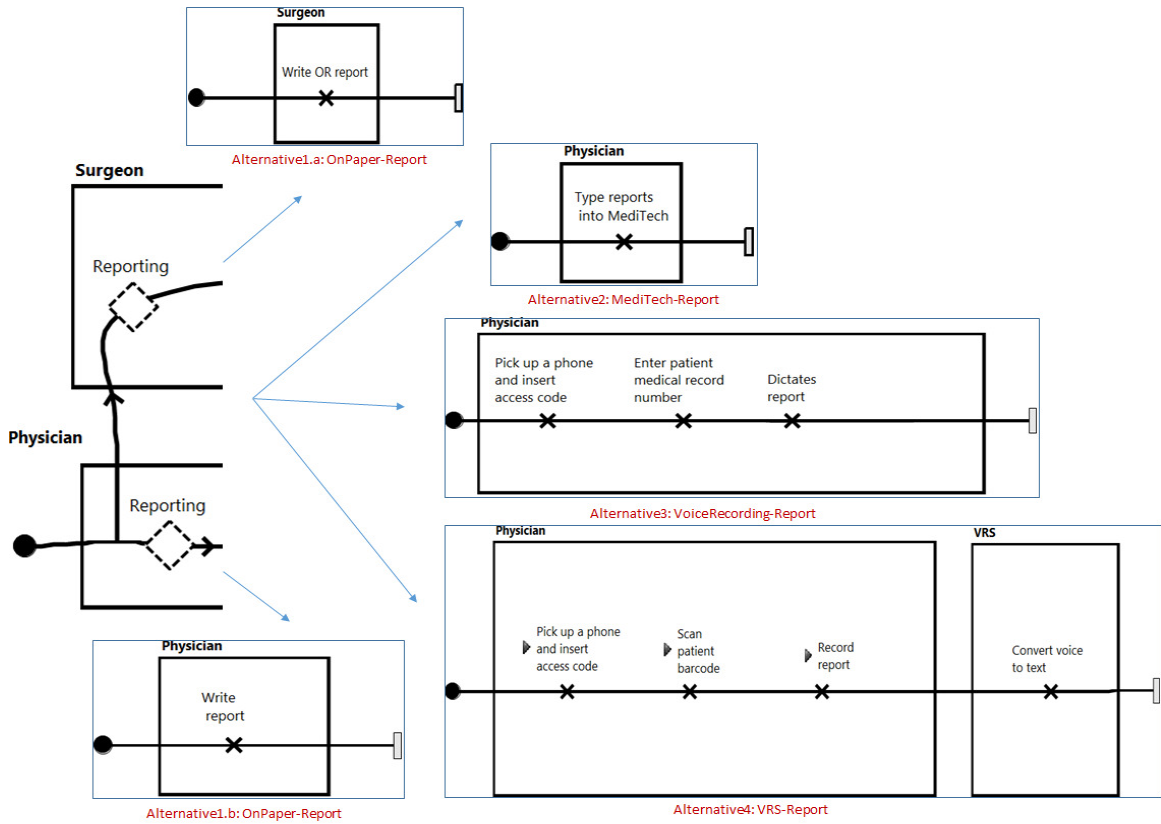
In the activity-goal relations (Table 25), while all mentioned activities change the current value (evaluation value) of the indicators, the contributions of the *Review translated voice* and *Edit text* tasks to the time goal are not computed in the alternative evaluation method. The contribution relationships were added to highlight the elicited impact of the two activities on the time goal as expressed by physicians. The *Reduce time of documenting information* goal was measured through the overall *Time spent per instance* indicator, regardless of the breakdown of time per activity.



**Table 25** Patient report documentation: activity-goal relations

ID	Activity	Goal	Type	Explanation
1	Pick up the phone and insert access code	Number of tasks per instance	Change	The activity will be added to the number of tasks to be performed
2	Scan patient barcode	Number of tasks per instance	Change	The activity will be added to the number of tasks to be performed
3	Record report	Number of tasks per instance	Change	The activity will be added to the number of tasks to be performed
5	Review translated voice	Number of tasks per instance, and Number of duplicated tasks per instance	Change	The activity will be added to the number of tasks to be performed
		Reduce time of documenting information	Contribute	It contributes negatively to reducing the time
6	Edit text	Number of duplicated tasks per instance	Change	The activity will be added to the number of tasks to be performed
		Reduce time of documenting information	Contribute	It contributes negatively to reducing the time
7	Sign report	Number of tasks per instance	Change	

The identified integration opportunities and relations were designed and modelled as illustrated in Figure 71, Figure 72, and Figure 73. For simplicity, the patient report documentation process in the Obstetrics unit (Figure 61) was divided into three parts (figures) where each part contains one activity with the corresponding integration alternatives.



**Figure 71** Report-process integration alternatives

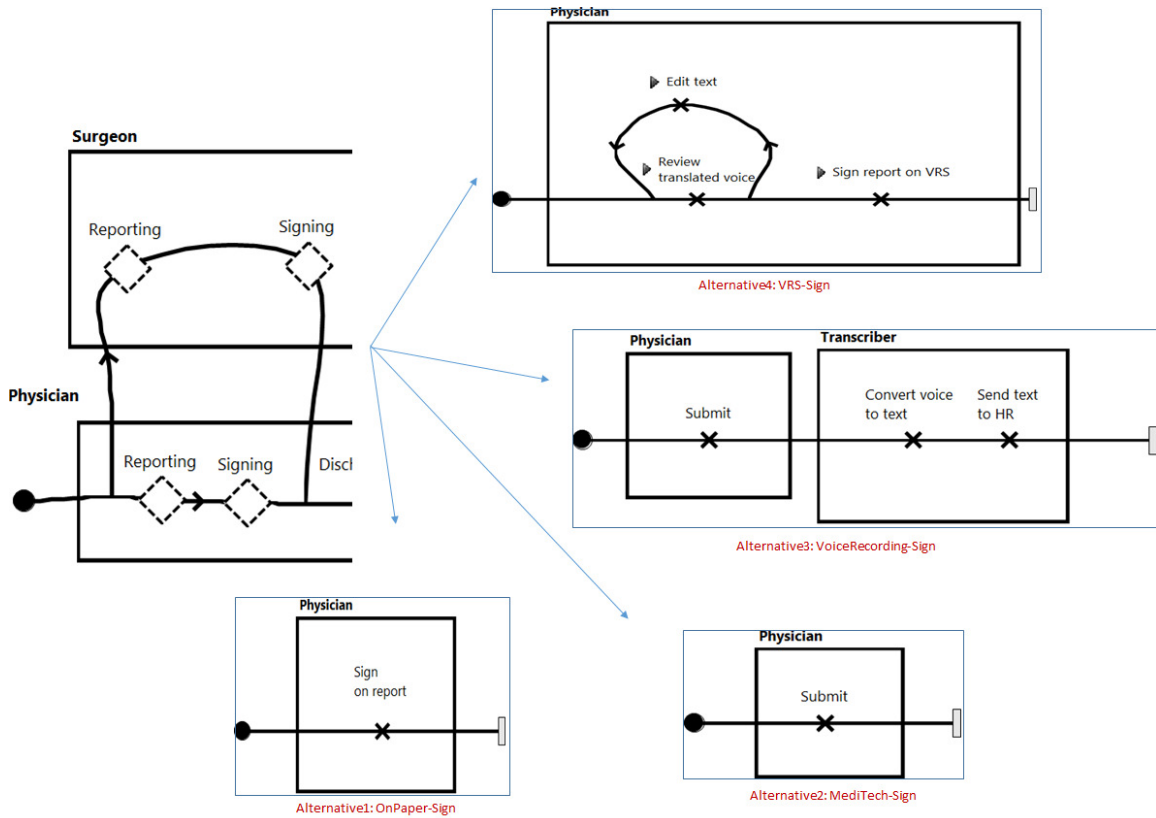


Figure 72 Sign-process integration alternatives

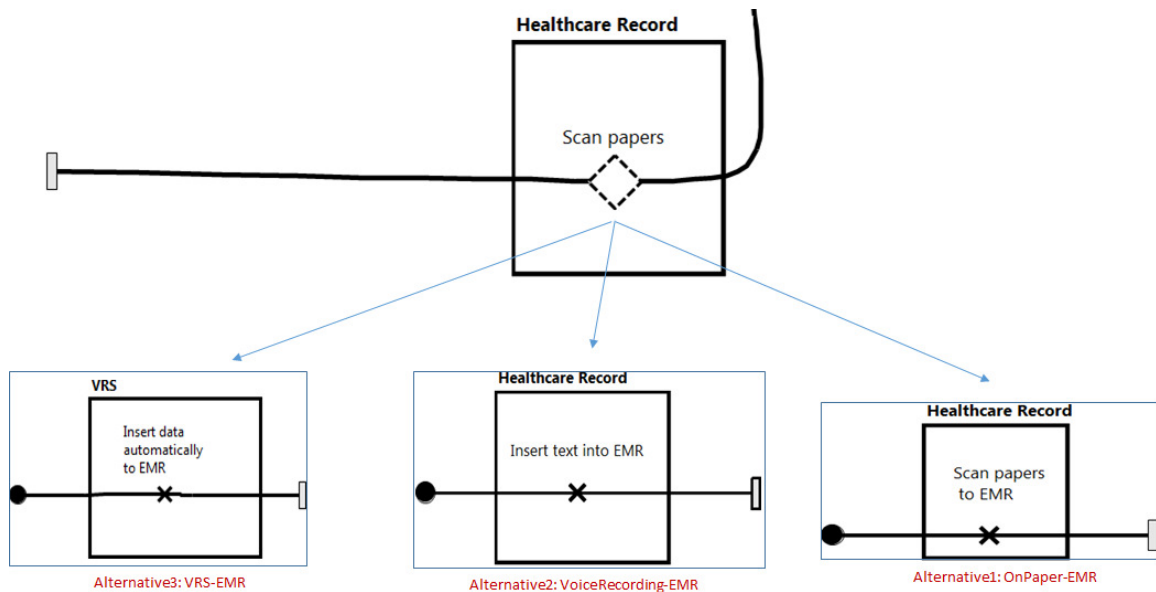
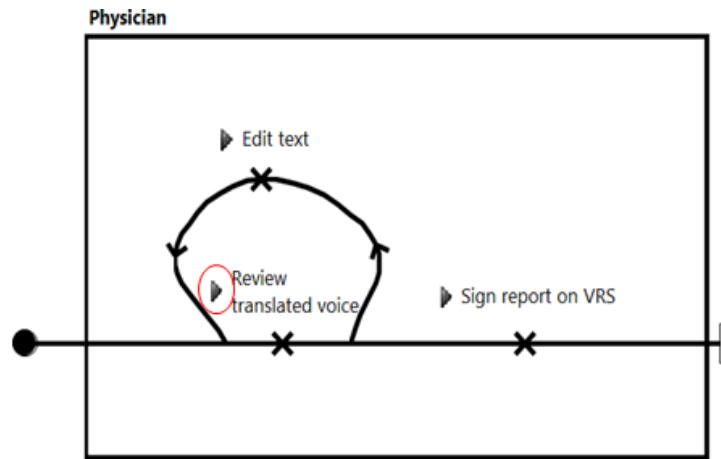


Figure 73 EMR-process integration alternatives



URN Links for "Review translated voice"	
▶	Start New Link from RespRef "Review translated voice"
▶	Start New Link from Responsibility "Review translated voice"
▶	End New Link from RespRef "Edit text" to RespRef
▶	End New Link from RespRef "Edit text" to Responsibility
▶	(Change) to IntentionalElementRef "#of duplicated tasks" from RespRef "Review translated voice" ▶
▶	(Change) to IntentionalElementRef "Number of tasks per instance" from RespRef "Review translated voice" ▶
▶	(Contribute) to IntentionalElementRef "Reduce time of documenting information" from RespRef "Review translated voice" ▶

**Figure 74** Snapshot of the URN links that illustrate the relations between the activity *Review translated voice* and the goals

## 9.4 Application of the Alternative Evaluation Method

As the main objective of this case study is to evaluate the performance of the process integration alternatives against certain criteria and stakeholder goals in two different units (ER and Obstetrics unit), two groups of evaluation strategies were created for each unit. Each group contains four alternatives for documenting patient reports: *on paper*, using *MediTech* (the EMR) directly, using *Voice Recording*, and using the proposed *Voice Recognition System*.

It is worth noting that not only do the evaluation values of the indicators and the tasks change from the evaluation strategy of an alternative to another, but the contribution values were also overridden to reflect the opposing impacts of process alternatives on some goals. For example, in the integrated goal model, the *Document patient information* goal contributes positively (100) to the satisfaction of the *Max. quality of data readability* goal. However, this is not the case when the alternative chosen to achieve the *Document patient*

*information* goal is on paper. The on-paper option contributes negatively (-100) on the *Max. quality of data readability* goal. In the on-paper evaluation strategy, the contribution (100) between the two goals was overridden with -100. The User Requirements Notation (ITU, 2012) and the jUCMNav tool support the concept of *contribution overrides*, a simple mechanism to explore different collection of modifications to the weights of some contributions in a goal model during analysis (e.g., to assess model variations, or check the impact of divergent opinions from stakeholders on the nature of contribution weights). Similarly, the contributions from the *Document patient information* goal to the *Long-term values* and *Maximize familiarity and UA* sub-criteria were overridden based on the alternative under evaluation. The next section discusses the indicators used in this context and the data quality types set to each indicator's evaluation value.

#### **9.4.1 Indicators and Data Quality**

Similar to the previous case study, the indicator parameters were gathered and the evaluation values were tagged with certain data quality types, converted to confidence values according to the mapping in Table 8. The initial evaluation value of each alternative (task) was set to either 0 or 100 depending on the context under evaluation. For example, if the alternative *on paper* was selected for the evaluation, the evaluation value of the task *on paper* is set to 100 while the evaluation values of the other tasks of the *Document patient information* goal are set to 0.

Table 26 illustrates the indicators definition and the data quality value of each indicator. The data quality is 100 for the alternatives being used currently (on paper, Meditech, and Voice Recording) because they are already measured. However, the data quality values are different in the VRS alternative because it has been deployed, temporarily, in the ER but not the Obstetrics unit. The difference in confidence appears in the *time per instance* and *number of duplicated tasks* indicators. The *time per instance* data quality value was set to Estimated-Context (50) in the Obstetrics unit because the nature of the process there is quite different from the dynamic and busy nature of the process in the ER. In addition, the *number of duplicated tasks* data quality value was set to Estimated-Literature (25) for both contexts because it depends on several factors such as the clarity of the recorded speech, which in turn depends on physicians.

**Table 26** Indicators definitions and data quality values in the VRS alternative

Indicators	Definition	Unit	Data quality in ER	Data quality in Obstetrics unit
Total cost yearly	The amount of money paid for each software or other materials	CAD	Valid – 100	Valid – 100
Number of patients	Number of patients were assessed compared to the actual number of patients who should have been assessed	#	Valid – 100	Valid – 100
Time per instance	The time spent documenting patient reports per instance	Second	Valid – 100	Borrowed – 75
Number of tasks	Number of tasks in an alternative performed to document patient report	#	Valid – 100	Valid – 100
Number of duplicated tasks	Number of duplicated tasks (review and edit) per instance.	#	Estimated – 25	Estimated – 25

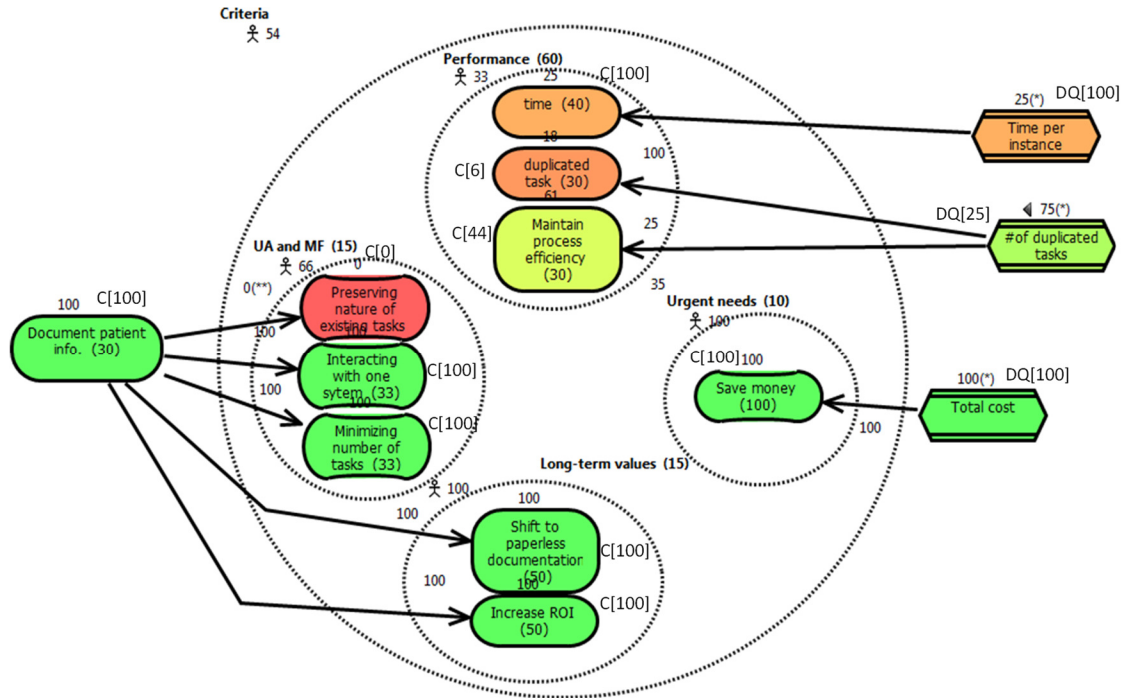
Interestingly, the definition of the cost indicator has gone through many iterations. The leaders provided the cost for each alternative (on paper: 100,000 CAD; MediTech 1M CAD; Voice Recording: 450,000CAD; and Voice Recognition: 286,000 CAD). The first iteration was about the cost of the software license and paper materials. However, considering the software license only is insufficient and, in the end, invalid. The goal of the administrative leaders is to cut the cost to half from 1M CAD (worst-case value) to 0.5M CAD (target value), keeping in mind that replacing MediTech, which costs 1M CAD, is not an option. MediTech is the main EMR system the hospital is using and most other information systems at the hospital are built on the top of or interact with MediTech. The hospital is already paying the cost of MediTech; therefore, it was not realistic to compare the cost of MediTech to other alternatives, or to the target and worst-case values. Hence, the indicator definition has to be changed to reflect the context correctly.

In the second iteration, the cost was supposed to be captured through the equation:  $\text{Cost} = (\text{number of documenting patient report instances} \times \text{number of hours performing the documentation task} \times \text{cost/hours}) + \text{cost of other software} + \text{cost of materials}$ . Here, the evaluation better reflects the context as the MediTech cost is included in each alternative

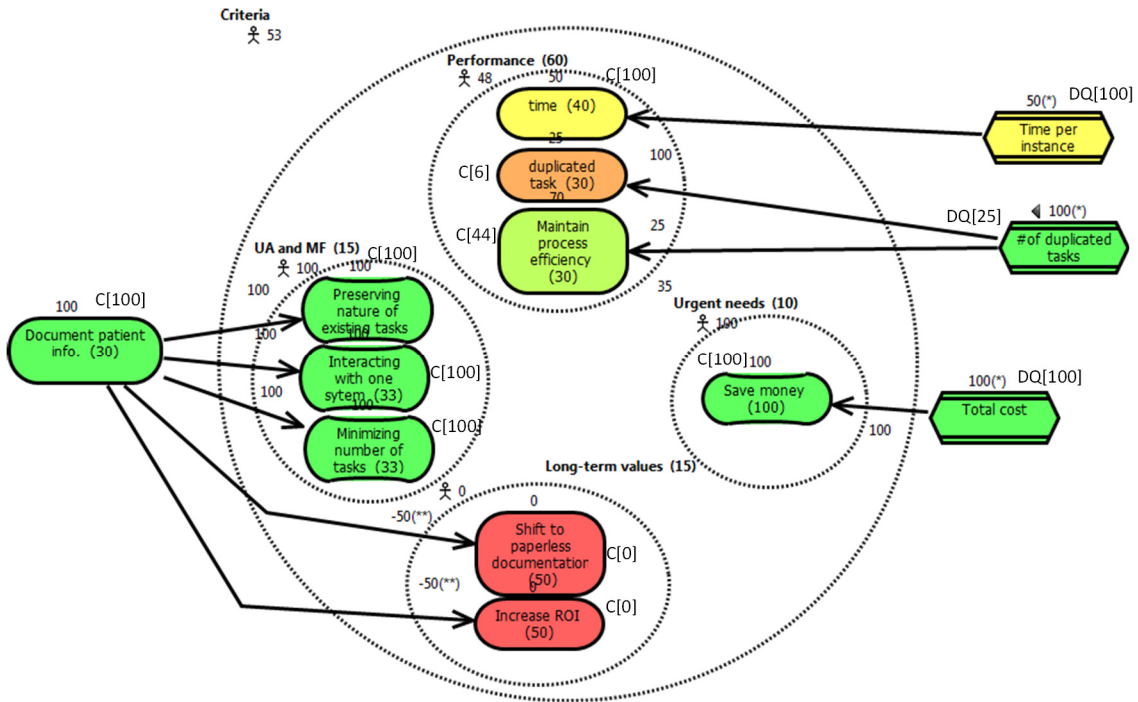
and the cost goes beyond the acquisition cost. The leaders agreed on this equation. However, the data was not available to compute the cost for each alternative.

In the last iteration of the cost indicator definition, after many discussions with the leaders, it was revealed that cutting the cost to a half was about the *additional* software, other than MediTech, and the additional material. Accordingly, the first definition was used but the cost of MediTech itself was set to zero.

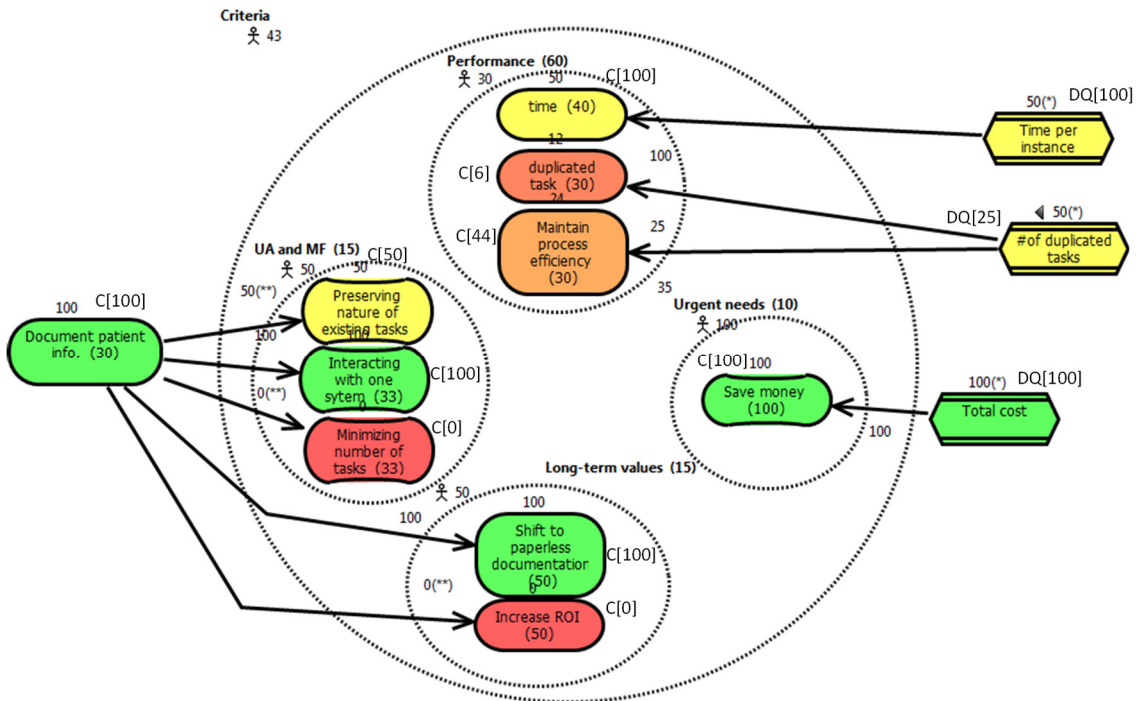
The evaluation strategies created in this step are used as the input to the DbGRL method. Figure 75 to Figure 82 illustrate the criteria evaluation results of the process integration alternatives in the ER and the Obstetrics units. These results will be used in the next section for ranking these eight alternatives.



**Figure 75** Criteria evaluation in the alternative *MediTech* in the ER, with propagated confidence values; the contribution from the *Document patient info.* goal to *Preserving nature of tasks* was overridden (0)

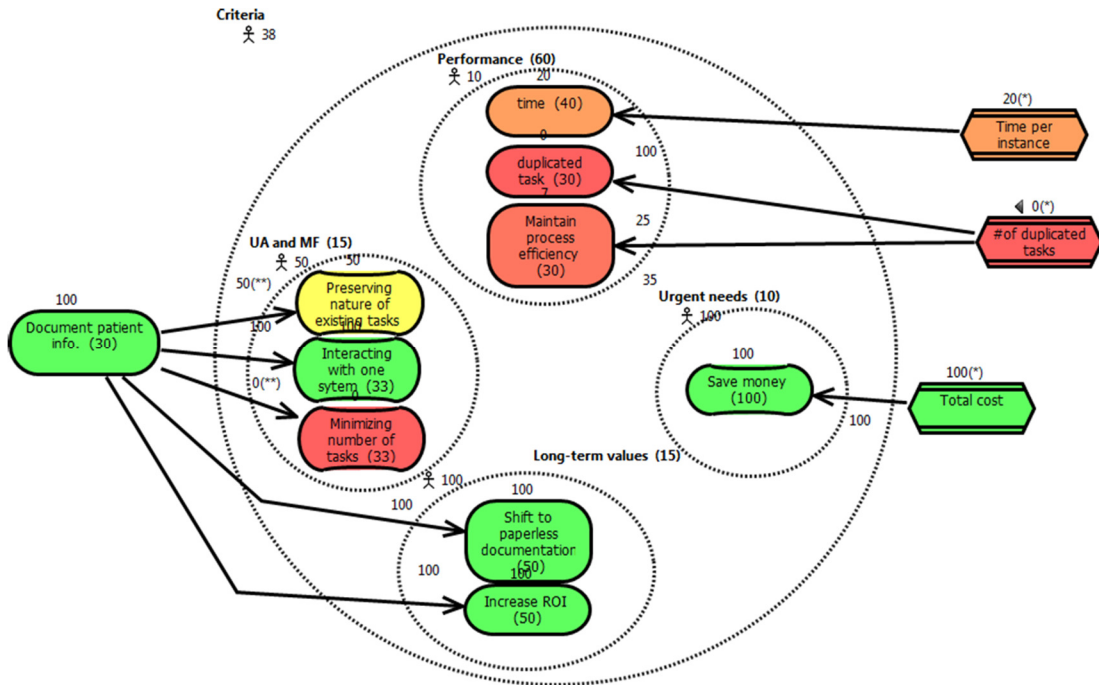


**Figure 76** Criteria evaluation in the alternative *OnPaper* in the ER, with propagated confidence values; the contributions from the *Document patient info.* goal to the *Long-term values* goals were overridden (-50)

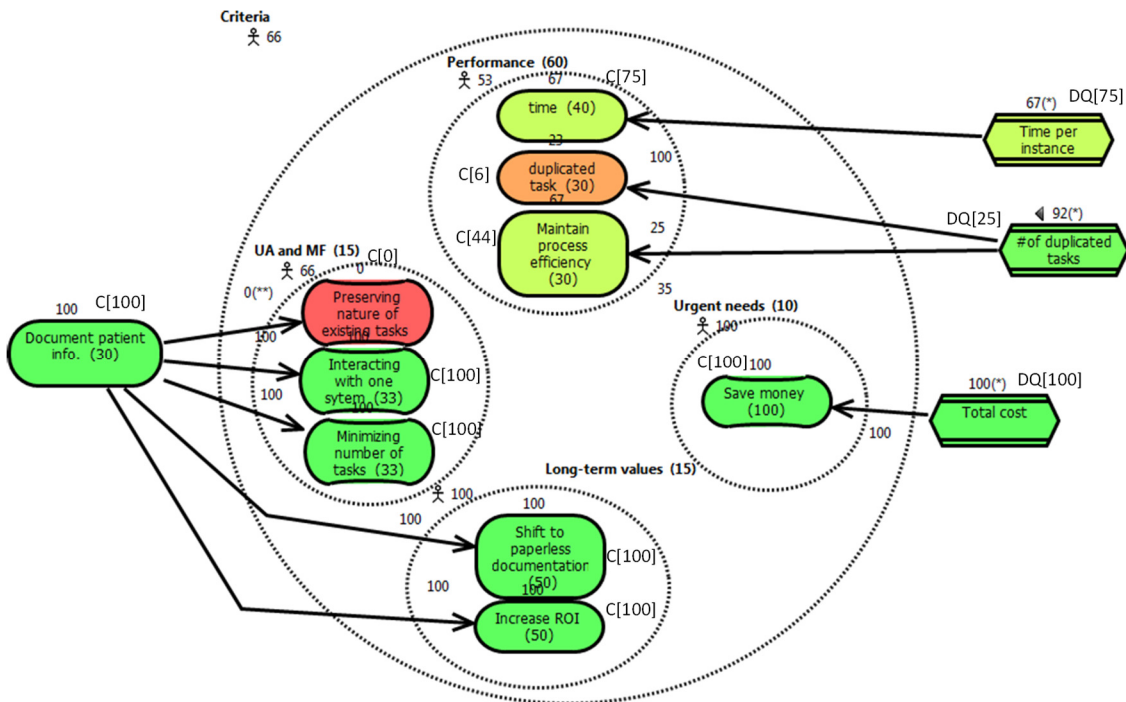


**Figure 77** Criteria evaluation in the alternative *VoiceRecording* in the ER, with propagated confidence values; the contributions from the *Document patient info.* goal to *Preserving nature of tasks* and *Increase ROI* were overridden (50 and 0 respectively).

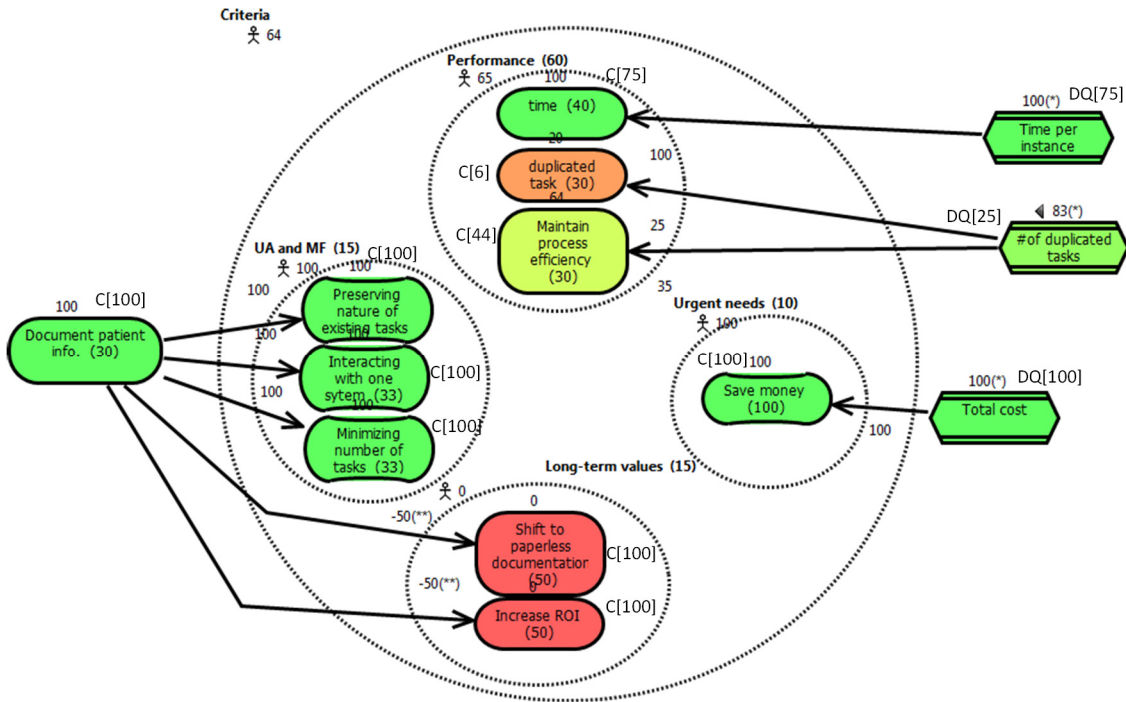




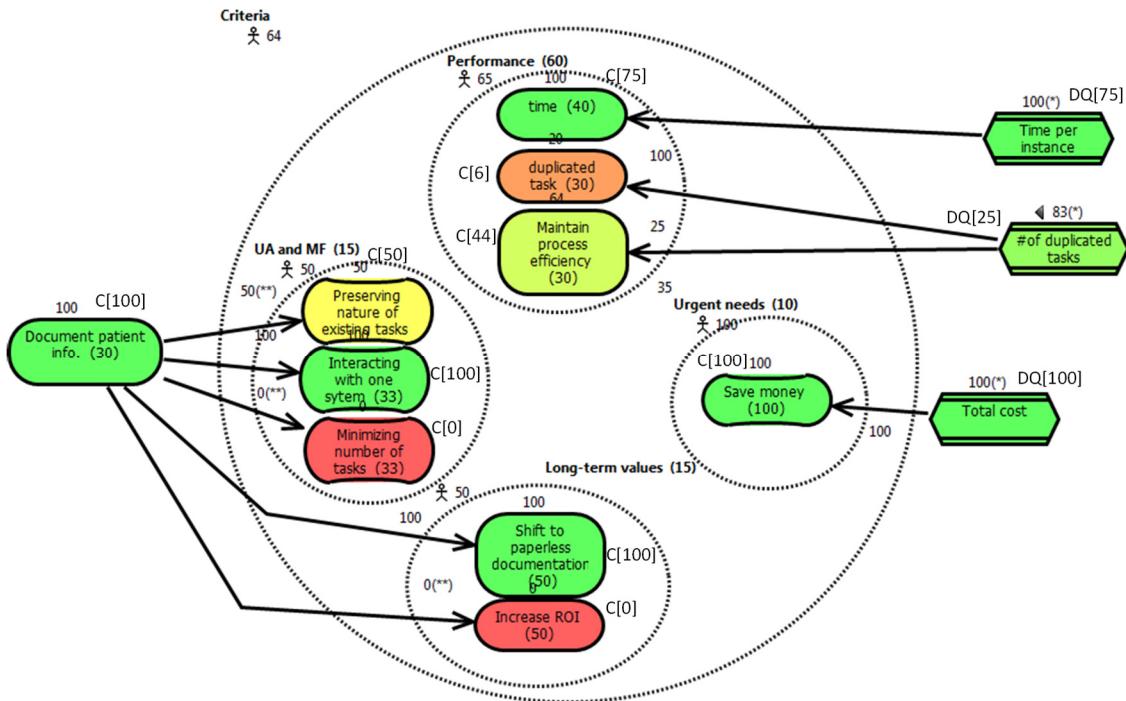
**Figure 78** Criteria evaluation in the alternative *VRS* in the ER, with propagated confidence values; the contributions from the *Document patient info.* goal to the *Preserving nature of tasks* and *Minimizing number of tasks* goals were overridden (50 and 0 respectively).



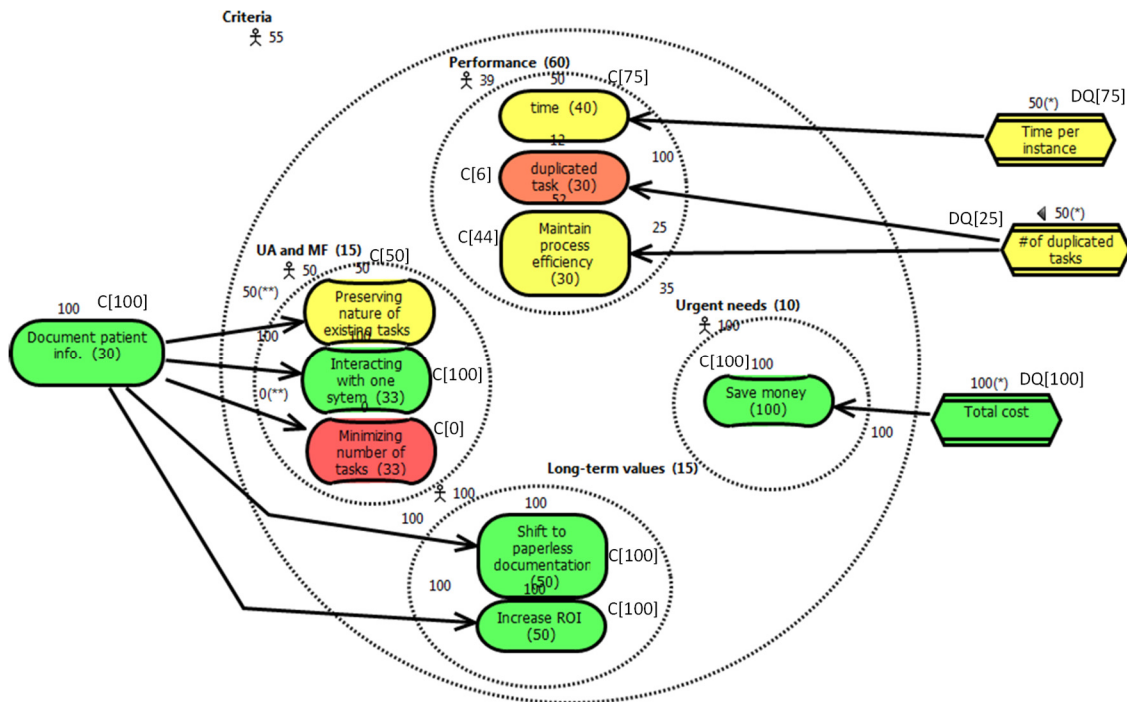
**Figure 79** Criteria evaluation in the alternative *MediTech* in the Obstetrics unit, with propagated confidence values; the contribution from the *Document patient info.* goal to *Preserving nature of tasks* was overridden (0)



**Figure 80** Criteria evaluation in the alternative *OnPaper* in the Obstetrics unit, with propagated confidence values; the contributions from the *Document patient info.* goal to the *Long-term values* goals were overridden (-50)



**Figure 81** Criteria evaluation in the alternative *VoiceRecording* in the Obstetrics unit, with propagated confidence values; the contributions from the *Document patient info.* goal to *Preserving nature of tasks* and *Increase ROI* were overridden (50 and 0 respectively).



**Figure 82** Criteria evaluation in the alternative VRS in the Obstetrics unit, with propagated confidence values; the contributions from the *Document patient info.* goal to the *Preserving nature of tasks* and *Minimizing number of tasks* goals were overridden (50 and 0 respectively).

**Table 27** Goals and assigned confidence values based on the data quality of the indicators

Goal	Confidence value in the ER	Confidence value in the Obstetrics unit
Save money	100	100
Maintain process efficiency	44	44
Number of duplicated tasks	25	25
Time	100	75
Less effort documenting patient info.	68	61

Table 27 illustrates the confidence values of the satisfaction values of the goals propagated from the data quality values of the indicators. The table shows that there is more confidence in the *Save money* and *Time* goals satisfaction than in the others. Moreover, it shows that the satisfaction of the goals *Maintain Process efficiency* and *Number of duplicated tasks* are not strong enough to make a firm decision upon them; however, they could be useful to support the decision making.

#### 9.4.2 Application of DbGRL to the Ranking of Integration Alternatives

In the DbGRL approach, the evaluation strategies designed in the previous step are evaluated against a set of criteria. The criteria were gathered from stakeholders and defined as mentioned in Section 9.2.2, and were used in the models of the eight previous figures. Table 28 lists the criteria and their associated weights.

**Table 28** Patient report documentation: criteria and weights (sum up to 1)

Criteria	Weight
<b>Performance</b>	
Time	0.2
Number of duplicated tasks	0.2
Maintain process efficiency	0.2
<b>Maximize familiarity and UA</b>	
Preserving nature of existing tasks	0.05
Interacting with one system	0.05
Minimizing number of tasks	0.05
<b>Long-term values</b>	
Shift to paperless documentation	0.075
Increase ROI	0.075
<b>Urgent needs</b>	
Save money	0.1

The urgent needs criterion (Save money) is hard in both contexts of the ER and the Obstetrics unit. Given the dynamic and demanding environment in the ER, *Time* and *Number of duplicated tasks* are also identified as hard criteria. On the other hand, in the Obstetrics unit, the work nature is more stable and under control, which makes those criteria important but not hard. In order to rank the process integration alternatives according to their performances on the criteria, the ideal and anti-ideal vectors were identified in both departments (Table 29).

The process integration alternatives (on paper, MediTech, VRS, and Voice Recording) passed the hard criteria in both contexts. Among all criteria, the number of duplicated tasks was the one that most affected the ranking in TOPSIS. Table 30 illustrates the ranking results of the process integration alternatives.

**Table 29** Ideal and anti-ideal vectors in the ER and Obstetrics units

Vector	Time	Duplicated tasks	Process efficiency	UA and MF	Long-term values	Urgent needs
<b>ER</b>						
ideal	2	0	100	100	100	500000
Anti-ideal	10	8	50	0	0	1000000
<b>Obstetrics unit</b>						
Ideal	5	0	100	100	100	500000
Anti-ideal	15	12	50	0	0	1000000

**Table 30** DbGRL: TOPSIS ranking results

Alternatives	d+	d-	C
<b>ER</b>			
MediTech	0.082	0.22	0.73
On paper	0.103	0.193	0.651
VRS	0.117	0.165	0.586
Voice Recording	0.138	0.177	0.562
<b>Obstetrics unit</b>			
MediTech	0.082	0.239	0.745
On paper	0.105	0.219	0.677
VRS	0.114	0.17	0.599
Voice Recording	0.089	0.198	0.691

In the above table, the MediTech alternative is the best in both contexts. The MediTech alternative performed better than the others in all criteria, especially on *Duplicated tasks* and *Cost*. The on-paper alternative is ranked the second best in the ER and the third best in the Obstetrics unit; however, using this alternative is not acceptable to the administrative leaders and some physicians because it does not contribute to many essential goals such as *Shift to paperless documentation* and *Max quality of data readability*. Moreover, the on-paper alternative was ranked higher in the ER than the Obstetrics unit because of the *Maintain process efficiency* criterion. This criterion is measured by two indicators: number of assessed patients and number of duplicated tasks. While the number of duplicated tasks is the same in both alternatives in both contexts, the number of assessed patients is different. In the ER, it is essential to assess all patients, even though the number of patients is not

static and keeps increasing, which makes the on-paper alternative a better option to document the patient report quickly. It was reported that using the voice recording system (VRS) in the ER lowered the number of assessed patients by around 25%. On the other hand, in the Obstetrics unit, the number of patients to be assessed daily is fixed and cannot be affected by the alternatives used to document patient reports. Another point is that the Voice Recording alternative is better than the on-paper alternative in the Obstetrics unit because it contributes more to the long-term values. The VRS was ranked the last in both contexts because, mainly, of the number of duplicated tasks, which increases compared to the other alternatives when the physician needs to edit the generated texts (see Figure 58).

### **9.4.3 Decision Making**

Even though the DbGRL method ranked the alternatives effectively, it is essential to interpret the ranking result considering the source from which criteria and data were gathered. For example, the MediTech was ranked the highest because the data was gathered from physicians who use MediTech. A similar situation occurs with other physicians for the on-paper alternative. Both groups of physicians (in favor of technology and in favor of paper) shall be involved in making the decision. The administrative leaders support, strongly, the MediTech alternative. Other alternatives (VRS and Voice Recording system) were introduced to support making patient report available on MediTech when physicians prefer not to type into the system directly.

After discussing the alternative evaluation method results with some physicians, they suggested, in case it is necessary to use MediTech, to have a smooth transition from paper use to MediTech by providing educational sessions and speed typing workshops. It was also said in other departments, but not in the ER, that physicians do not mind using the VRS even if the number of duplicated tasks is higher than the other alternatives as long as it provides better data availability and readability, and they will not need to type into Meditech directly. For now, MediTech is the best alternative for physicians who are already using it as supported with high confidence in the performance goals satisfaction. For the obstetric unit, VRS could be a temporary solution, as the cost of VRS does not exceed the target cost (with 100 level of confidence). Having VRS, a Voice Recording system and on-paper alternatives selected all together requires way more than the target cost, which is the

case now at the hospital. The argument is supported with the highest confidence in the *Save money* goal satisfaction.

## 9.5 Discussion

Similar to the first lab sample monitoring case study, this second case study answered the research questions sufficiently (Table 18). The AbPI framework was used effectively to capture and analyze the integration context, and to suggest the best alternative given a set of criteria. The AbPI conceptual model was also extended with the *Long-term values* subclass of *Criteria*, as was suggested by the hospital representatives in many occasions. The DbGRL was used adequately to rank the alternatives and the data quality and confidence propagation mechanism effectively highlighted the data validity issue.

Beside the data availability challenge mentioned in the previous case study, there were more technical challenges faced in this one. The intensity of manual work was high. All related/sub-processes to the integration context had to be modelled. In addition, if any of the main processes changed, many related/sub-processes had to be changed as well. Checking the correctness and completeness of the models was intensive and error-prone. This takes us to the second point, which is the lack of tool support. With the current tool, representing opposing opinions in the goal models and with regard to a single alternative was possible (e.g., using GRL contribution overrides) but inefficient. Therefore, I could not represent the two groups of physicians (in favor and against technology) with same goals in the goal model. Identifying the goals and the main process in isolation to the patient report documentation tool was a challenge too. Each unit was describing the main process from the perspective of documenting patient report. It was needed to read and bring information about the main processes and goals in the ER and Obstetrics units to prepare the input models. In such cases, more supporting material, from the hospital, and better tool support to handle the integration are needed.

## 9.6 Chapter Summary

In this chapter, the feasibility and effectiveness of using the AbPI framework to integrate a new proposed process into *multiple* processes (ER and Obstetrics unit) at once, in a real

context, were demonstrated. In addition, the chapter presented how the AbPI methods were beneficial to understand the conflicting needs of stakeholders and evaluate the integration alternatives against pre-defined criteria (urgent needs, long-term values, performance, and maximum familiarity and user acceptance).



# Chapter 10 AbPI Usability Study

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The chapter presents the usability study of the AbPI framework's methods. It discusses the study objectives and plan. In addition, it shows how the study was conducted along with acquired results.

## 10.1 AbPI Usability Study Motivation

Usability studies have been used widely and for many decades to evaluate software and products against grounded principles or with end users. However, in requirements engineering, despite the fact that RE methods are meant to be used in practice, few studies carried out usability studies to evaluate proposed RE-based artifacts or methods. The literature review conducted in Chapter 2 (Section 2.1 on process-related requirements engineering in healthcare) shows that several RE methods were evaluated in healthcare, although none of the studies conducted a usability evaluation. The evaluation methods used in these studies were case studies, illustrative examples, or simulations (Hayes et al., 2011; Teixeira et al., 2012; Weng et al., 2013).

The situation is slightly different outside the healthcare domain. Ivarsson and Gorschek (2008) conducted a literature review assessing the support available in transferring RE technologies to industry. The study investigated many interesting and important questions related to the state of RE technology evaluation, of evaluation contexts, as well as of the scale and the realism of the evaluations. The results show that the evaluation approach that was most-often used is the conceptual analysis, where the subject is, mainly, the researcher and the context is mixed between industry and academia. Interestingly, out of 34 cases of evaluation, only eight were carried out in real setting with industry practitioners (one case in laboratory experiment, and the other seven cases in case studies or conceptual analysis methods). Evaluating RE-based artifacts using usability methods while engaging the industry is still neglected, even though it is essential to investigate usability when developing any new approach or method in a real context (Moody et al., 2010; Ivarsson and Gorschek, 2008).

Having a combination of evaluation methods (case studies and usability study) and real practitioners involved in both types of studies would increase the concreteness and reliability of the results (Ivarsson and Gorschek, 2008). In the evaluation of the AbPI framework, both evaluation methods are used. Practitioners are involved in forming the case studies, as recommended by Ambreen et al. (2018), and they are the subject of a usability study.

I also believe that it is crucial to evaluate RE methods with real stakeholders to ensure that proposed RE-based approaches are applicable in a real context. As this thesis was motivated by healthcare industry needs, I evaluated the AbPI framework's methods and its output (ranked alternatives) with a usability study to investigate the potential for AbPI to be used in practice, and to explore the hidden usability issues of and other barriers to using AbPI in the real world. In addition, a broad goal of conducting a usability study is that there is no work done in terms of evaluating the perceived usability and usefulness of RE-based approaches with the intended customers in healthcare. The usability study is intended to explore the needs and limitation of the AbPI framework to be effectively used in healthcare.

## 10.2 Related Work

There is some work done in evaluating the usability of goal-oriented RE tools and notations using different methods. In terms of the front-end analysis methods, Moody et al. (2010) evaluated the cognitive effectiveness of  $i^*$ 's visual syntax using a set of principles of cognitively designing visual notations. The result of the analysis reveals major issues, such as shape inconsistency, associated with the  $i^*$  visual syntax. The problem was not only with the  $i^*$  modelling framework, but also with all RE modelling notation (including UML), as mentioned in the study. Often, such notations are not practical because of some design issues, which widen the gap between academic contributions and industry needs. In addition, Horkoff and Yu (2013) compared three different tools that support seven similar goal satisfaction analysis procedures. The result of the comparison showed that different procedures could lead to different results. Accordingly, the study recommended to use satisfaction analysis as heuristics for decision making.

Moving into experiment-based methods, while Grubb and Chechik (2017) conducted an experiment to evaluate the *modelling tool* GrowingLeaf, Dahan et al. (2012) used the experiment to compare quality and the comprehension of models using OO-DFD (Object-Oriented DFD) and the use case *modelling methods*. In addition, Ferrari et al. (2010) investigated the differences in requirements elicited with and without the presence of a system architecture. They conducted a controlled experiment to discover the main differences. It is worth noting that the participants in the abovementioned studies are all belonging to academia.

Another important and encouraging study is “*Usability Insights for Requirements Engineering Tools: a User Study with Practitioners in Aeronautics*”. Gaspard-Boulin and Conversy (2017) conducted interviews and designed mock-ups to explore the RE tasks, performed by requirements engineers, and support tools. The study involved 15 practitioners from four aeronautics companies. It was reported that the usability of the RE tools hurts time, effort, and satisfaction of users.

### **10.3 Usability Study of the AbPI Framework’s Methods**

The usability evaluation design was guided by the Goal, Question, Metric (GQM) framework of Basili (1992). For each identified goal, there is a set of questions reflecting the goals and a set of measures to assess the achievement of the goals. The main goals of the usability study are to:

- G1:** Evaluate the usefulness and effectiveness, and the usability of the AbPI methods.
- G2:** Evaluate the applicability of the process integration alternatives to be used in real practices.

The following subsection explains the study design and other components such as data collection methods, ethics approval, and participants.

#### **10.3.1 Design Iterations**

The usability study has three main parts: an educational session (Section 10.3.6), process integration tasks (Section 10.3.3), and a survey (Section 10.3.5). The content of the educational material and the process integration tasks have been developed through many iterations. I conducted a pilot study with students to evaluate the content after each iteration so

the entire usability session could be done in one hour (time budget allocated by Montfort partners). Table 31 shows the changes made in each iteration.

**Table 31** Usability study design iterations

Usability parts	Content	Participants	Improvements
<b>Iteration 1</b>			
<i>Educational session</i>	<i>Goal modelling</i> (GRL notation) <i>Process modelling</i> (UCM notation) <i>AbPI methods</i> (integration and analysis)	Graduate students who do not have a background on RE or URN	-More details about the GRL notation -More examples in the AbPI part. -Some improvements regarding the wording of questions
<i>Tasks</i>	Two integration tasks of three sub tasks: identify integration opportunities and relations, draw integration models, and choose the best integration alternative.		-Clarifications about how to follow/apply the AbPI methods -Simplifying the tasks
<b>Iteration 2</b>			
<i>Educational session</i>	<i>Goal modelling</i> (GRL notation) – more details <i>Process modelling</i> (UCM notation) <i>AbPI methods</i> (integration and analysis) – with illustrative example	Graduate students with a background on RE	- Remove the GRL part - Add textual goals - Change the context of the AbPI illustrative example to match the context of the integration tasks
<i>Tasks</i>	Two integration tasks of three sub tasks: identify integration opportunities and relation (in tables), draw integration models, and choose the best integration (highlight the goals)		- Remove the integration opportunity and relation tables - Simplify drawing process integration models - Provide a checklist: list of stakeholders and goals

<b>Iteration 3</b>			
<i>Educational session</i>	<i>Process modelling</i> (UCM notation) <i>AbPI methods</i> (integration and analysis) – with illustrative example	Graduate students (mixed of the above-mentioned groups)	-
<i>Tasks</i>	Two integration tasks of three sub tasks: Identifying integration opportunities and relation, and Identifying the alternatives using a textual representation. Checklist to choose the best alternative.		- Reduce the number of tasks to one.

As seen in the table, the content of the educational material and the integration tasks was intensive and wide in scope in iterations 1 and 2; then, it became narrower and more focused, yet, comprehensive to achieve the goals while fitting in one hour. The participants in the pilot studies were a mix of experienced and non-experienced students in RE and URN. The reason for having the participants with an RE background is to assess how deep the usability study has gone into RE or whether removing some parts (such as GRL) would affect the study or not, and how to mitigate such effect if present.

In the last iteration, I gave participants versions 1 and 2 of the usability study to compare and ensure that the applied improvements have essentially improved the study. Some observations were noted. For example, participants did not relate the best process integration alternative to the GRL model. Therefore, it was decided to remove the GRL part and highlight the goals in the text itself and in a checklist in the analysis part. Another point is that modelling the integration alternatives took more time than expected. The participants reported that the modelling step was the most challenging one. As a result, the modelling task was replaced with identifying the integration alternative in a textual representation. The last version of the usability test is in Appendix E: Usability Study.

### 10.3.2 Goals and Measures

In this part, goals G1 and G2 are evaluated. Table 32 illustrates the measures of G1 and G2.

**Table 32** G1 and G2 measures

Goal	Measure
<b><i>G1: Evaluate the usefulness and effectiveness, and the usability of the AbPI methods</i></b>	
Usefulness and effectiveness	User perception
Usability	User perception
	Time spent on tasks and tasks completion
<b><i>G2: Evaluate the applicability of the process integration alternatives to be used in real practices</i></b>	
Usability in real practices	User perception

The user perception will be used to assess the achievement of both goals. Participants will be asked to answer a set of questions in the survey (Appendix E: Usability Study) after completing all tasks. Most of the questions are about user perceptions while the rest is about comments and possible improvements participants may suggest.

The usability of the AbPI methods is assessed by two measures: *time spent on each task* (less than 15 minutes or not) and *tasks completion*. The task completion has 3 main categories: successfully completed tasks, partially completed, and uncompleted.

### 10.3.3 Tasks

There are two main processes integration tasks that participants should do. The context of the tasks is the integration of the WTES process that was presented in Section 7.2.1 (Example 1: Patient Satisfaction in an Emergency Room (ER)) and Section 7.2.5 (Example 2: Patient Satisfaction in an ER with KPIs). After each task, participants have to:

1. Identify the integration opportunities of integrating the WTES-related process into the ER process. Mark the integration opportunities on the ER process.
2. Write the activities to be integrated from the WTES process beside its identified integration opportunity on the ER process, including integration alternatives if any.
3. Write/mark the sequence of activities that form the best process integration alternative to be deployed in the ER unit.

4. Answer: What are the difficulties/challenges faced while using the AbPI integration method?

### 10.3.4 Data Collection

The plan is to collect data through three methods: observation, survey, and discussion.

- **Observation:** while performing the usability tasks, participants are observed to collect interesting comments and take notes about challenges they may face and time spent per task.
- **Survey:** participants are asked to answer some questions about challenges or difficulties they face while performing the tasks, and answer a set of Likert questions to measure the perceived usefulness and ease of use of the AbPI methods.
- **Discussion:** participants are asked, at the end of the session, whether they have further comments, suggestions, or concerns about using the AbPI framework.

### 10.3.5 Survey

The survey has two parts, *evaluating the AbPI effectiveness and usefulness* and *evaluating the usability of the process integration alternatives in real practices*, in order to assess how usable the AbPI framework is and, more importantly, the chances for AbPI to be used in practice. The questions are mostly Likert-scale type of questions, with a few open-ended questions to collect feedback, comments, and improvements.

The System Usability Scale tool (SUS) from Brooke (1986) was used to write the survey questions. I had to modify the questions slightly, in some places, to suit the nature of the unit under test, which are the AbPI methods instead of a system or an end-product as the tool suggested. The questions of the survey were checked also with experts in the usability domain to ensure reliability and suitability.

### 10.3.6 Educational Material

The basics of the UCM notation is taught to participants. The context where the UCM concepts are presented is the ER process at Montfort Hospital. After presenting the UCM educational material, participants have to answer a set of questions that assess their understanding of the UCM process notation before proceeding to the tasks.

A brief introduction is given about process integration, in general, in healthcare. Following this, the AbPI methods are presented in the context of the *Patient Report Documentation* at Montfort Hospital. In the integration method, identifying integration opportunities, activity-activity relations, providing alternatives, reasoning about the best integration alternative with regard to stakeholder's goals are presented.

After completion of the tasks, the AbPI alternative evaluation method (goal model, propagation algorithm, and DbGRL) is presented to the participants. This is for them to gain a better overview of the AbPI framework, and to overcome the simplicity of the context they worked on in the integration tasks.

### **10.3.7 Ethics Approval**

Ethics approvals from the University of Ottawa's Research Ethics Board and from Montfort Hospital's Ethics Board were acquired to conduct the usability study. Both certificates are included in Appendix D: Ethics Approvals.

### **10.3.8 Participants**

The aim of this usability study is to evaluate the effectiveness and usability of the AbPI methods in the industry with real practitioners. Therefore, there are two inclusion criteria for participants, who have to:

- 1- Work in the healthcare sector.
- 2- Have a background on requirements engineering, change management, process improvement, process re-engineering, or business analysis (or similar areas where changes are introduced and decisions are made).

Potential participants were contacted via an email invitation letter. The time and place of the usability exercise was determined according to the availability of the people who accepted the invitation.

## **10.4 Results**

The study was carried out at Montfort Hospital with 6 participants. All participants belong to a non-clinical healthcare occupation except for one who occupies both non-clinical and



clinical occupations (nursing). All participants have been involved in process improvement projects and Lean projects. Participants came from different backgrounds and have different roles in research, health administration, nursing, transformation, and engineering. In terms of education level, four participants possessed university graduate degrees, one has a university undergraduate degree, and one has a high school/technical/collage type of degree. Five participants reported that they have used Visio to model processes. One of the participants, who has an engineering background, used BPMN, UML and Petri nets.

Giving the small size of the study participants, a descriptive analysis is used to report on the study results. The following section presents the results of the educational session, the process integration tasks, and the survey.

#### **10.4.1 Educational Session**

Before presenting the education material about the UCM notation, participants were given two consent forms to sign (one for them and one for us). After presenting the educational material (5 minutes), the participants were asked to answer a set of question about the ER process (5 minutes), described with a UCM model. The participants answered all questions related to the process modelling notations successfully. They managed to identify correctly the start point, activities, and conditional directions. Only two participants could not answer correctly a question regarding the conditional loop (used to examine patients and request imaging/lab tests). These results made us confident that the participants have understood the UCM models used in later tasks.

#### **10.4.2 Process Integration Task**

Before performing the process integration tasks, the AbPI methods were presented (10 minutes). The participants were asked to do two process integration tasks. However, because of the time constraint (some participants were late), only the first task ended up being performed (15 minutes). The measures in this part are the time spent to do the task and the task completion rate.

### 10.4.3 Time

The time budgeted for the task was 15 minutes. Four participants finished on time, while two participants could not to complete the task in time and needed three more minutes.

### 10.4.4 Task Completion

In the process integration task (task 1), the participants had to complete three sub-tasks: identify integration opportunities and activity-activity relations, write activities to be integrated (i.e., providing alternatives), and choose the best integration alternative. Table 33 presents the sub-tasks of task 1's completion results. Only two participants performed all tasks completely and correctly. Some participants managed to identify the integration opportunities and activity-activity relations correctly; however, they integrated the WTES as is without considering the two alternatives of registering patient to the WTES (automatically or by nurse) resulting in one process integration alternative. Two participants did not complete the last part about choosing the best integration alternative even though they had completed previous tasks. At the end of the tasks, participants were asked to write the challenges/difficulties faced while doing the integration. Two comments were left in this part which were about the uncertainty whether *insert expected time* reflects the whole process estimated wait time or that of each individual activity.

**Table 33** Task completion results

Tasks	Completed tasks	Partially completed tasks	Uncompleted tasks
Identify integration opportunities and relations	4	2	
Provide alternatives	2	4	
Choose the best alternative	2	2	2

### 10.4.5 Perceived Usefulness and Effectiveness

After completing task 1, participants were asked to answer the survey, which consists of two parts. The first part is about the perceived usefulness and effectiveness of the AbPI methods. As Table 34 presents, all participants, except one who did not answer the question, agreed that they would use and recommend using the AbPI methods in their organization. Two participants disagreed that the AbPI methods are complex; however, the rest

was neutral. In terms of efficiency, most participants agreed that using the AbPI methods would reduce time and effort in choosing the best alternative among many. In terms of reliability and learnability, most participants either agreed or stayed neutral. The reason for this, as participants commented, is that the scalability of the approach is unknown. They need to use it on a case bigger than task 1 to assess scalability. Another point is that some participants suggested that if they had more time, they would learn and apply the AbPI methods more easily. Most participant stayed neutral about having better integration/analysis methods in their organization. Again, they could not decide because they did not use the AbPI methods in real situations.

**Table 34** Perceived usefulness and effectiveness results

<b>Subject</b>	<b>Strongly agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>Strongly disagree</b>
<b>Usefulness</b> Use and recommend the AbPI		5			
<b>Complexity</b> Unnecessary complex			3	1	1
Easy to apply		1	4	1	
<b>Learnability</b> ease to learn		3	2		
<b>Reliability</b> Confidence in the best integration alternative		2	3	2	
<b>Efficiency</b> Reduce time and effort to find the best integration opportunity		5	1		
Better available methods			4	1	

There were other questions such as using the AbPI framework with different process modelling languages/tools, and the utility of the AbPI methods to help setting goals and performance objectives, and to address stakeholders' needs. For the former, four participants agreed to use AbPI methods with different tools such as Lean tools, as suggested, and two participants remained neutral. For the later, all participants agreed that the AbPI methods would help set and evaluate targets of goals and performance objectives.

Finally, participants answered questions about negative points in the use of AbPI, about the main benefit and drawbacks of AbPI, about potential modifications, and about the unit or department that should use the AbPI methods. The main negative point identified by four participants is that the AbPI methods require much training and learning to be

used. The second negative point, raised by two participants, is that processes, goals, and data are not easily available. One participant identified the required manual work and another one mentioned the complexity of the process modelling notation. Table 35 presents the participant's answers to the rest of questions.

**Table 35** Participants' answers to open-ended questions

<b>Subject</b>	<b>Answers</b>
<i>Benefits</i>	<ul style="list-style-type: none"> <li>- "chance of choosing the best solution"</li> <li>- "get a visual and get different options to satisfy all partners involved"</li> <li>- "holistic vision of the problem"</li> <li>- "find the best approach to integrate processes"</li> <li>- "weighted goals achieved for alternatives, alternatives are interesting in moving away from status quo, especially, when showing goals/KPIs of all stakeholders"</li> </ul>
<i>Drawbacks</i>	"a lot of relations" , "difficult to use"
<i>Unit / department</i>	"project management, lean office", "Lean office", "Clinical department", "business analyst", "admission   Accueil", "used by all departments"
<i>Modifications</i>	"use healthcare wording as symbols to make sense of it all"

## 10.5 Perceived Applicability in Practice

This part is about assessing the likelihood of using the AbPI methods in practice. For the three factors that assess AbPI's applicability in practice, the answers provided by the participants were divided between agree or neutral (see Table 36).

**Table 36** Perceived applicability in practice

<b>Factor</b>	<b>Strongly agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>Strongly disagree</b>
<b>Flexibility</b> Provide flexible solutions		2	3		
<b>Comprehensiveness</b> Provide comprehensive solutions		3	2		
<b>Applicability</b> Apply the AbPI but with modifications		1	4		

Some remained neutral mainly because of the missing information about scalability and applicability in real cases at the hospital. Two participants left comments to improve the AbPI to be used in practice: "use notation similar to Lean, make the methods shorter", and

“link the holistic approach to metrics (as in the end)”. The last comment refers to the use of goal modelling because the goal models (with indicators) and the complete alternative evaluation method were only presented at the end of the session.

## **10.6 Discussion**

The usability study was designed and conducted to evaluate the usefulness, effectiveness, and usability of the AbPI methods. The participants were healthcare workers who are involved directly in process improvements projects. In this section, interesting points and observations are discussed, in addition to limitations and challenges.

### **10.6.1 Study Design**

As mentioned in Section 10.3.1, I conducted a pilot study to evaluate the context and design of the usability study. The pilot study resulted in many iterations. It was essential to have a mixed group of participants, with some who had an RE and usability background and some who did not. Participants with an RE background/usability helped to keep the study small and to the point while ensuring that it achieves its goals. They had good comments on what to keep, what to replace and what to eliminate without missing the essence of the study. Having the other group of participants (without prior knowledge of RE/usability) was important too to simulate the group of likely participants in healthcare.

The two big challenges were how to simplify the educational material while making others apply the AbPI methods. For the former, I chose the ER context with which everyone is intuitively familiar; then, the process modelling notation (UCM) was introduced incrementally (step by step, from a start point to an end point). For the AbPI methods, given the time constraints and the absence of knowledge about goal modelling, the best option to identify the integration alternatives was to use text instead of models. Interestingly, three participants drew the process integration model. Another big challenge was the time constraint. The study was designed to be offered in one hour-long session (ideally repeated with different groups). I ended up with one usability session that was 40 minutes long because some participants arrived late (this in turn eliminated task 2 from the session).

Essentially, I planned to conduct an experiment and a usability study (see Appendix E). In the experiment, I planned to have two groups (controlled and experimental) to discover the differences between using the AbPI methods and current methods for process integration at Montfort Hospital. Giving the fact that it was impossible to afford two sessions and to gather more than 10 participants, I conducted the usability study only. However, the material is available for conducting the comparative experiment.

### **10.6.2 Participants**

Although 9 participants had confirmed their presence, only six participants showed up to the session. The participants' expertise and current roles were however very relevant to the subject of the study; even though they have different educational background. This diversity actually contributes to the positive results of the study. Participants were also excited to explore how the AbPI methods could be combined with Lean tools. In addition, they were interested in learning more about the “*weighted goals*” and they valued having goals linked to the process integration alternatives, as mentioned in some participants' comments.

### **10.6.3 Process Integration Tasks**

For the integration method, where participants are asked to model the integration alternatives, most of participants integrated the WTES-related process as modelled without considering the design alternatives mentioned in the text, which indicates that inserting patient information into the WTES could be done by a nurse or automatically by the WTES. The reason for this is because I have not presented any similar case in the educational material and the process alternatives in the presented examples were all modelled and not explained in the text.

### **10.6.4 Limitations and Threats to Validity**

Although, the study results seem to be promising and encouraging, there are several limitations and threats to validity that are worth mentioning. One of the limitations is the small number of participants. It is always difficult to conduct usability studies with real practitioners from industry, who have severe availability constraints. Luckily, the study had six

participants with relevant and diverse occupation roles in one session. However, six participants are insufficient to derive statistically significant conclusions. Indeed, more participants and experts in healthcare are needed to improve the confidence in the results.

Another point is that the study was designed and conducted mainly by the thesis author. To mitigate the perception of bias, in designing the study, especially the survey questions, the SUS tool (Brooke, 1986) was used and the questions were reviewed by usability experts. Regarding how the study was conducted, I had my supervisor and a colleague ensure that the usability session and the presented material were as neutral as possible, in order to avoid influencing the participants. Participants' answers to open-ended questions were reported as-is to mitigate biases I could introduced while reporting on the results.

It was also not possible to compare the results of AbPI with a baseline coming from current practice, or to use participants from many different organizations.

## **10.7 Chapter Summary**

In this chapter, the usability study design and components were presented. This usability study was conducted at Montfort Hospital with six healthcare workers who are involved in process improvements projects. In general, the participants were able to understand the models and perform some positions of a non-trivial integration task, with little training. They also had a positive perception of AbPI. No major issues were discovered, and the results are generally promising and encouraging. This chapter also contributes a usability study of an RE approach in healthcare, in a world where such studies are far too rare.

# Chapter 11 Discussion and Limitations

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This chapter provides a brief comparison that highlights how the AbPI framework improves upon the related work against relevant criteria. In addition, it discusses the challenges faced while developing and applying the AbPI framework. Lastly, this chapter discusses the main threats to validity to and limitations of this thesis, which supplement previous limitations identified for the data quality and confidence propagation mechanism (Section 4.7), DbGRL (Section 5.5), the URN profile for AbPI (Section 6.2), and the usability study (Section 10.6).

## 11.1 Criteria-Based Comparison

In this section, the AbPI framework is compared to the related work discussed in Chapter 2 to show how it improved upon the *coverage of the comparison criteria* and how the research gap is filled. In Table 4, the gap in healthcare was identified in terms of considerations for current practices, process integration, users/stakeholders' needs, performance objectives, and organizational goals. Outside healthcare, the summary table shows that studies were either business process-oriented or business goal-oriented. The last line of Table 37 shows how the AbPI framework introduced in this thesis improves upon them by providing a comprehensive model-driven and analysis-based framework that captures processes, stakeholder/user goals and performance objectives, and analyzes the relationships to recommend the best process alternative that achieves the desired outcomes. Moreover, one key point that distinguishes the AbPI framework from other work is that the development and evaluation of AbPI's methods were driven by the needs of healthcare collaborators who were intensively engaged in this work.



**Table 37** AbPI compared to the literature against the criteria identified in Table 2

Related work	(1.1) Considering current practices	(1.2) Process reengineering/ alignment/ integration	(1.3) Proposing new process	(1.4) Users / stakeholders' needs	(1.4) Performance objectives	(1.4) Organizational goals	(2) Evaluation	(3) Methodology	(4) Multidisciplinarity	Context
<b><i>In healthcare</i></b>										
Timpka et al. (1995)	Yes	No	No	No	No	Yes	No	No	Yes	Documenting hypermedia requirements
Teixere et al. (2010)	No	No	Yes	No	No	No	Yes	Yes	Yes	System requirements
Hayes et al. (2011)	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Process variability
Weng et al. (2013)	Yes	No	No	No	No	No	Yes	Yes	Yes	Scheduling system
Wilk et al. (2008)	No	Yes	No	No	No	Yes	No	Yes	Yes	Constructing clinical application at various medical conditions
Grando et al. (2012)	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Medical decisions support and facilities allocating system
Dames et al. (2003)	Yes	Yes	No	No	No	No	No	Yes	Yes	Decomposition and composition of process models' facets
Staccini et al. (2001)	Yes	No	No	No	No	No	Yes	Yes	Yes	User requirements elicitation using process-oriented analysis
<b><i>In general</i></b>										
Bleistein et al. (2006)	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	IT system alignment based on B-SCP
Santos et al. (2010)	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Process variability using a GRL subset and BPMN
Rungworawut et al. (2007)	Yes	No	No	No	No	Yes	Yes	Yes	No	Optimal process components design using GA
Ullah and Lai (2011)	Yes	No	Yes	No	No	Yes	Yes	Yes	No	IT system alignment with business goals
Kuziemy et al. (2010)	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	IT system alignment with business process using URN
Zlatev et al. (2005)	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Analysis and redesign networked business systems
Decreus and Poels (2010)	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Business process alignment with strategical requirements
Pourshahid et al. (2013)	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Monitoring business performance and proposing improvement patterns using URN
Nagel et al. (2013)	No	No	Yes	No	No	Yes	Yes	Yes	No	Deriving business process from business goals to ensure consistency
<i>This thesis</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>	<i>RE-based framework to integrate processes in healthcare</i>

## 11.2 Challenges

The weak presence of RE in healthcare raises many questions. From a research perspective, it is obvious that more studies and focus on this area are needed (Alahmadi et al., 2014; Vermeulen et al., 2014), especially on open questions such as: Are current RE practices too weak or complicated to be applied in healthcare? Does the healthcare domain require specific approaches to match unique concepts of the domain and, if so, what are these concepts? I intended to partially answer such questions for process integration by conducting case studies and a usability study to assess the effectiveness and usability of AbPI. However, there are important challenges and risks associated with this research:

**Acceptance:** the AbPI framework introduces changes to current processes incrementally. Its methods are aligned with the Lean approach currently used in Canada's healthcare sector to evaluate existing processes. The motivation behind Lean management is to eliminate waste, particularly when working with limited resources, so all steps along the value stream (process) create value (Womack et al., 2004). Using Lean management principles in healthcare means leaders must specify a shared goal/value that unites the interests and activities of all stakeholders, which also means, in the case of value-based healthcare, increasing outcomes quality and reducing costs. Then, leaders must evaluate healthcare processes by identifying every step in the process and eliminating non-value-adding steps (Womack et al., 2004). The AbPI approach is designed to capture the shared values/goals of different units/stakeholders and provide integration alternatives for each step (activity) of the new process into the current ones. It also enables the analysis of the integration impact on different levels (goals, performance, users, and stakeholders). Our assumption is that the nature of AbPI is not foreign to healthcare practitioners. The usability study showed that the AbPI is acceptable by the participants from diverse disciplines and backgrounds but who were involved in Lean projects at Montfort Hospital. However, the number of participants was small and there is no evidence that AbPI will be acceptable by non-Lean projects members.

**Data availability:** the most challenging data to collect in AbPI are KPI definitions/values as well as contribution levels in goal models. The KPIs are needed to evaluate the current performance and to estimate the impact of the integration on the future perfor-

mance. Contribution and importance levels can be obtained from stakeholders using consensus-building techniques such as the Analytical Hierarchy Process (AHP). Also, processes, goals, stakeholders, and their relationships must be modelled, which requires data collection and validation effort. Data availability remains a challenge, but the thesis provides a simple mechanism to illustrate the impact of the input data quality/completeness on the confidence of the goal evaluation results. Confidence values can also impact decision making.

**Scalability and effort:** one process may cut across multiple units of an organization, or even across different organizations (e.g., hospitals and clinics). Each unit has its own processes, roles, goals, and quality criteria. At times, I expect to have larger PGMs than the ones used in the case studies. Although large URN models were created and analyzed in the past, the AbPI framework may not scale well at modelling and analyzing multiple large processes across the organization or across organizations. In addition, AbPI can be used manually when there are few alternatives (as demonstrated in the usability study), but automation will be required for large set of processes or integration opportunities (potential alternative compositions). Considerable amounts of time and effort were spent on the two case studies, especially for preparing the input models where many elicitation and validation iterations happened. Roughly, it took about two months to build and prepare the PGMs for the integration, to integrate the PGMs, and to select and discuss the best alternative with decision makers. Note that I had to build my own domain expertise along the way, in addition to developing and refining the framework, which also slowed down the work.

**Tool support:** it is challenging to use current tools for the AbPI framework. The relationships between activities and goals could not be illustrated efficiently, meaning that the existence of activity-goal relation, in jUCMNav for example, could only be captured through URN links, which require many interactions and are not entirely visible on diagrams. In addition, the impact of an activity (change or contribute) on a goal was done manually or through a task, which corresponds to the activity, in the goal model. As a prototype based on a URN profile, jUCMNav was good. Nevertheless, there is a need for *usable* AbPI-specific tools that provide appropriate support in the context of the integra-

tion. The tools shall automate the automatable steps of the AbPI methods such as the generation of alternatives when the integration opportunities and activity to other elements relationships are identified. However, I do not expect the tools to provide full automation of the methods, as human interaction and judgment is essential in some steps, especially the ones **highlighted** in the algorithms of Section 6.3.

## **11.3 Threats to Validity**

To mitigate bias that may be introduced by the evaluation studies, several potential threats to validity are identified, in addition to the ones that have been already discussed in previous chapters.

### **11.3.1 Construct Validity**

Construct validity aims to assess the extent to which the tests actually measure what our hypothesis/framework claims to be doing. An important threat here is that the chosen case studies may not reflect the full complexity of real environments. Another important issue here is data availability to be used by the models (specially for KPIs). To mitigate the data availability threat, I proposed the data quality tagging and confidence propagation mechanism. However, the data quality types may not be applicable in a wider context with more data quality levels, or with automated data sources (e.g., sensors). Furthermore, pairwise comparisons and AHP were used to build the goals models to help ensure that goals and relationships reflect the context as-is, in a consensual way.

### **11.3.2 Internal Validity**

Internal validity estimates the degree to which conclusions about causal relationships can be made based on the test settings and measures obtained. One obvious threat here is that bias might be introduced by having the thesis author perform the evaluation, collect the raw data, and analyze the results. A similar issue pertains to the literature review, mainly done by one person. This was mitigated partly by having a second person (my supervisor) involved in several steps of the work. This could be further mitigated in the future by studying how other people use the AbPI framework.

### 11.3.3 External Validity

External validity is concerned with whether results of the evaluation can be generalized to other cases or contexts. Generalization from case studies is already limited by definition. However, to partially mitigate the effect of this threat, the two case studies came from two different hospitals in two different countries. The second case study also targeted the integration of a proposed process to many current processes at once (i.e., in the ER and the Obstetrics unit). Other case studies are still needed, including some that would involve multiple organizations (with similar or cross-cutting processes). In terms of the usability study, this threat strongly appears because of the small number of participants, especially as all belong to one hospital. Finally, supporting approaches such as the *Data Quality and Confidence Propagation Mechanism* and the *Distance-based GRL* approach are very likely applicable to GRL modelling contexts outside healthcare and even to other goal modelling languages, but there is currently no evidence supporting such generalization at this time. Note also that the AbPI conceptual model (Figure 4) could be used outside healthcare by customizing the Criterion's sub-classes to suit the domain needs, or by having a more generic mechanism to define criteria dynamically.

# Chapter 12 Conclusions and Future Work

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The chapter recalls the thesis contributions and answers the research questions. In addition, it discusses some research opportunities and future directions on process integration and requirements engineering in healthcare.

## 12.1 Contributions

In the context of healthcare, more hospitals are shifting from a service-based to a value-based paradigm, which requires hospitals to question current practices and re-engineer some of them. One huge opportunity for hospitals is to use available technology to improve the quality of the outcomes of their processes and enhance caregiver's performance. However, in healthcare, technology and e-systems are often failing due to poor acceptance by users and disturbances to existing practices. The thesis partially addresses this problem through:

- 1- The AbPI framework, which combines goal and process views through using requirements engineering and process modelling approaches in an activity integration context. The benefits of AbPI include:
  - Rigorous and effective integration: by providing multiple process integration alternatives and relationships to goals using the *Goal Integration Method* and the (process) *Integration Method* (Chapter 3).
  - Comprehensive evaluation of the fulfillment of organizational and business goals, and stakeholders' satisfaction using the *Alternative Evaluation Method* (Chapter 3).
  - A conceptual model enabling AbPI users to capture relevant elements goals and processes in an integration context (Chapter 3), with a visual syntax and partial tool support provided by a URN profile and jUCMNav, respectively (Chapter 6).

- Rigorous support for decision making, alternatives ranking/selection, and opportunity identification for refining goal and process models using the tool-supported *Distance-based GRL* approach (Chapter 5).
  - Consideration for data quality and confidence in the satisfaction of stakeholders and their goals using the tool-supported *Data Quality and Confidence Propagation Mechanism*, with impact on decision making (Chapter 4).
- 2- AbPI framework usability study (Chapter 10): as shown from the literature review, there was no user study conducted about the combined use of requirements engineering and process integration approaches in healthcare. The thesis contributed to investigating the use of AbPI in the healthcare industry, with relevant limitations and recommendations, through assessing:
- The perceived usefulness and effectiveness of the AbPI framework.
  - The usability of the AbPI methods measured according to the correct usage of the methods as well as perceived ease of use and efficiency.
  - The expected value of AbPI for adopting new processes in practice in healthcare.

## 12.2 Research Questions

This thesis addresses two main research questions related to the use of AbPI (a new RE-based process integration technique) in healthcare:

**RQ1.** In healthcare, to what extent does the AbPI framework help

- a) illustrate how a new process can be integrated efficiently into current processes providing integration alternatives?
- b) illustrate goals, requirements, processes and constraints of multiple stakeholders and units that are involved in the integration context?
- c) estimate the impact of the integration on users' satisfactions and the achievement of business and organizational goals?

**Answer:** the case studies and the illustrative examples demonstrate that the AbPI framework can be used to integrate processes, provide integration alternatives, and analyze the impact of each alternative on users/organizational goals and pre-defined criteria. In addition, it was shown that supporting approaches (*Data Quality and Confidence Propagation Mechanism* and *DbGRL*) lead to more concrete decisions, more realistic performance targets, and goal model refinements than with the conventional use of GRL. It is worth mentioning that the results of the case studies were beneficial to both hospitals reporting on the best solution to obtain, with a certain level of confidence, and for supporting current and future decisions, as the hospitals' leaders mentioned.

**RQ2.** What is the usefulness and usability of the proposed AbPI framework as perceived by healthcare practitioners?

**Answer:** to answer this question, a usability study was carried out with healthcare practitioners. The result of the study was positive. The participants saw potential in adopting the AbPI methods in their current practice. In addition, the participants agreed about the usefulness and effectiveness of the AbPI methods in the context of process integration, with suggestions regarding a combined use with the Lean approach.

### 12.3 Future Directions

There are many opportunities to follow up on the thesis work, including these four directions.

- **Combining the AbPI framework and Lean tools:** As all the participants in the usability study mentioned that they would use the AbPI methods with Lean tools, and as I see the opportunity for them to be combined, it is encouraging to investigate this subject. The research question would be *to which extent combining the AbPI methods and Lean tools is beneficial for healthcare organizations?* The subject should be studied through collaborations with hospitals that have Lean project teams to gain real, practical knowledge and validation.
- **AbPI tool support:** the current implementation of the AbPI methods requires much manual work, and takes time and effort. Tool support is needed to facilitate applying



the AbPI methods efficiently and effectively. Omitting human interactions is not a realistic option at this point. However, the tool shall automate identifying integration opportunities, designing alternatives, and evaluating alternatives as much as possible. The tool shall also go beyond jUCMNav's capabilities in manipulating relationships unique to AbPI and absent from URN. The healthcare industry could use such tool and experience applying the AbPI methods on real cases, and further develop the AbPI methods to suit their specific needs.

- **Further evaluation of AbPI:** The usability study could be conducted again with more participants, in several hospitals. In addition, it would be useful to conduct the experiment mentioned in Chapter 10. After working with practitioners and conducting this thesis in collaboration with hospitals, I highly recommend studying the impact of the RE modelling languages (such as URN) on the perceived ease of use and acceptance of RE practices by industry practitioners. In addition, additional case studies would help improve the generality of the framework, especially in situations not yet covered by this thesis (e.g., integration of a proposed process across hospitals).
- **Generalization of AbPI:** The AbPI conceptual model (Figure 4) contains some concepts that are specific to healthcare and to the case studies used here (i.e., the four sub-classes of Criterion). Most of the concepts and processes of AbPI could likely be reused as is in domains other than healthcare by removing these predefined sub-classes and having criteria being user-defined. This would also allow for unanticipated criteria to be added dynamically in healthcare and other domains, as in the first case study (Section 8.4.2) where security suddenly became a new concern (and hence an evaluation criterion).
- **Requirements engineering in healthcare:** in a broader context, it is essential for both researchers and practitioners to continue investigating the paucity of requirements engineering practices in healthcare, the gap between current practices and desired outcomes, and needed tools for the RE to be an effective part of healthcare practices.

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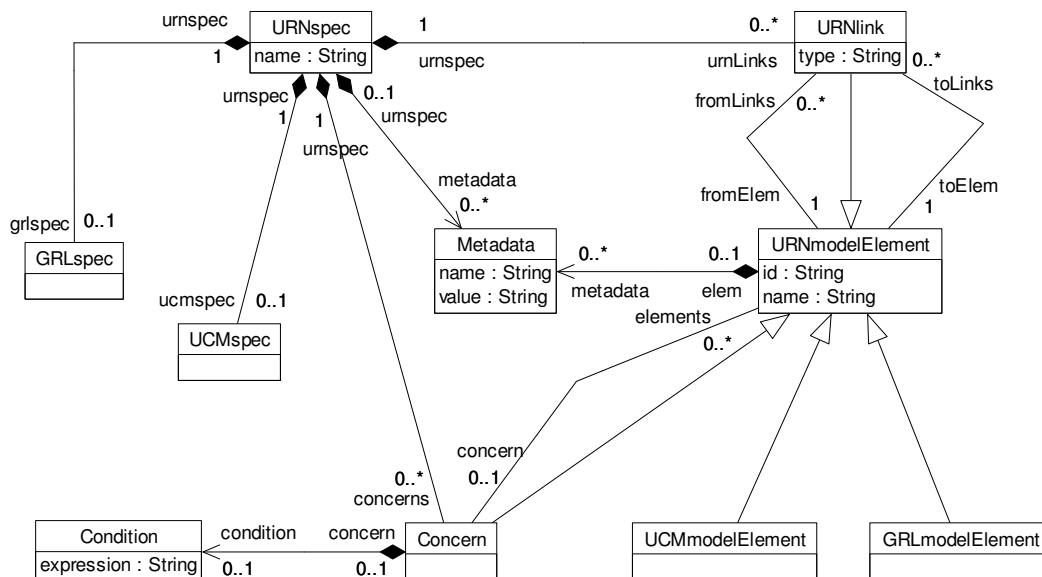
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# Appendix A: URN Metamodel

Figure 83 illustrates the elements of the URN metamodel. URNspec is composed of GRLspec, UCMSpec, URNlinks, Metadata, and Concern. All GRL and UCM model elements are subclasses of URNmodelElement, and hence can be linked (with URNlink), annotated (with Metadata), and grouped (with Concern). Links, metadata, and concerns are useful concepts for supporting traceability and language extensions.



**Figure 83** Extract of the URN metamodel (ITU-T, 2012)



- *Indicators*: elements whose qualitative/quantitative satisfaction levels are computed by comparing observable measures (in real-life units) with target, threshold, and worst-case values.
- *Element links*: used to connect model elements and express relationships between them. The types of the links are: contributions, dependencies, and decompositions (AND, OR, or XOR). An element can contribute to the achievement of another element at different qualitative levels: break, hurt, some negative, some positive, unknown, help, make, and equal.

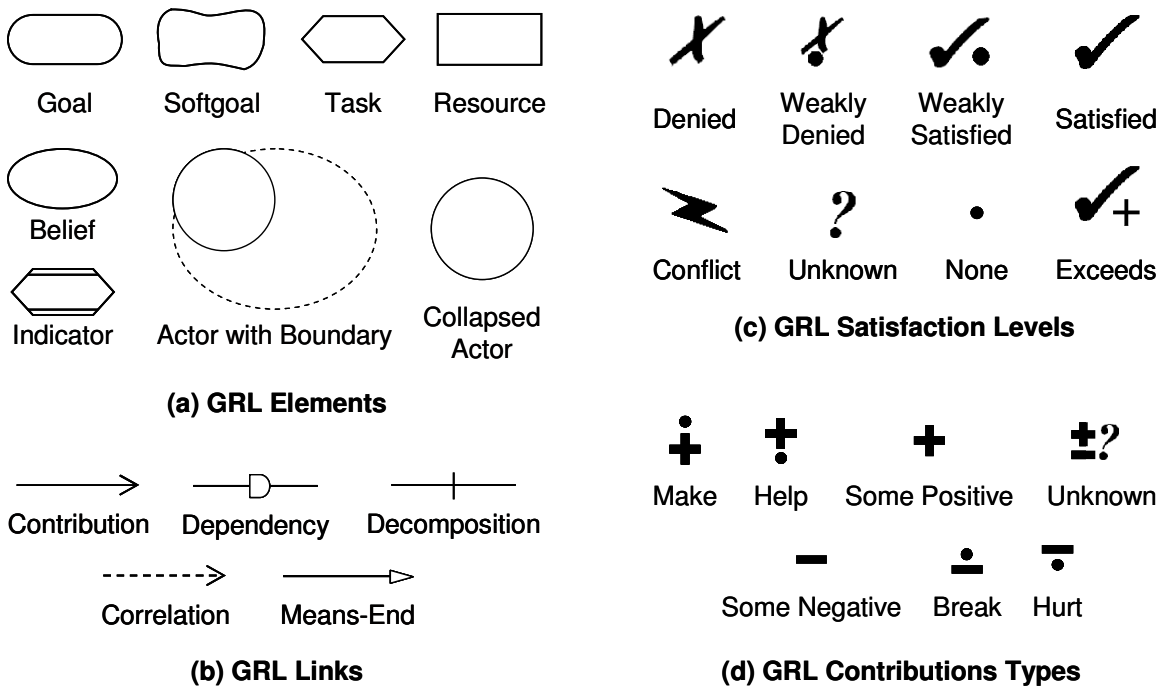


Figure 85 Syntax of GRL's modelling elements (ITU-T, 2012)

### GRL model evaluation strategy

For each GRL model, modellers can define multiple evaluation strategies. An evaluation strategy contains initial values for some of the elements of the model (satisfaction of some intentional elements and/or observable values for indicators). Each evaluation strategy reflects a unique state of the model with respect to the decisions made about the importance and contributions of intentional elements. A *propagation algorithm* works as follows:

- Compute the satisfaction value of indicators based on the strategy's observable value.

- Propagate these values and the other satisfaction values from of the strategy to the other intentional elements associated through their links. For each element whose satisfactions for all input links are known, use decompositions first, then contributions, and finally dependencies.
- Compute each actor's satisfaction according to the normalized sum of products between importance levels and satisfaction levels for each intentional element with a non-zero importance inside the actor.

GRL supports many propagation algorithms, for example: fully qualitative, fully quantitative, or hybrid.





- *Paths* are casual sequences of responsibilities, possibly allocated to components. A path begins with a *start point* and ends with an *end point*.
- *Responsibilities* are actions to take or tasks to perform.
- *Components* capture structural aspects of the system and its environment.
- *Conditions* guard alternatives in OR-forks, waiting places, concerns, and stubs. They also capture preconditions in start points and post-conditions in end points.
- *Stubs* link (contain) sub-scenario (plug-in) maps to the parent map.

Figure 87 illustrates the symbols of the UCM notation:

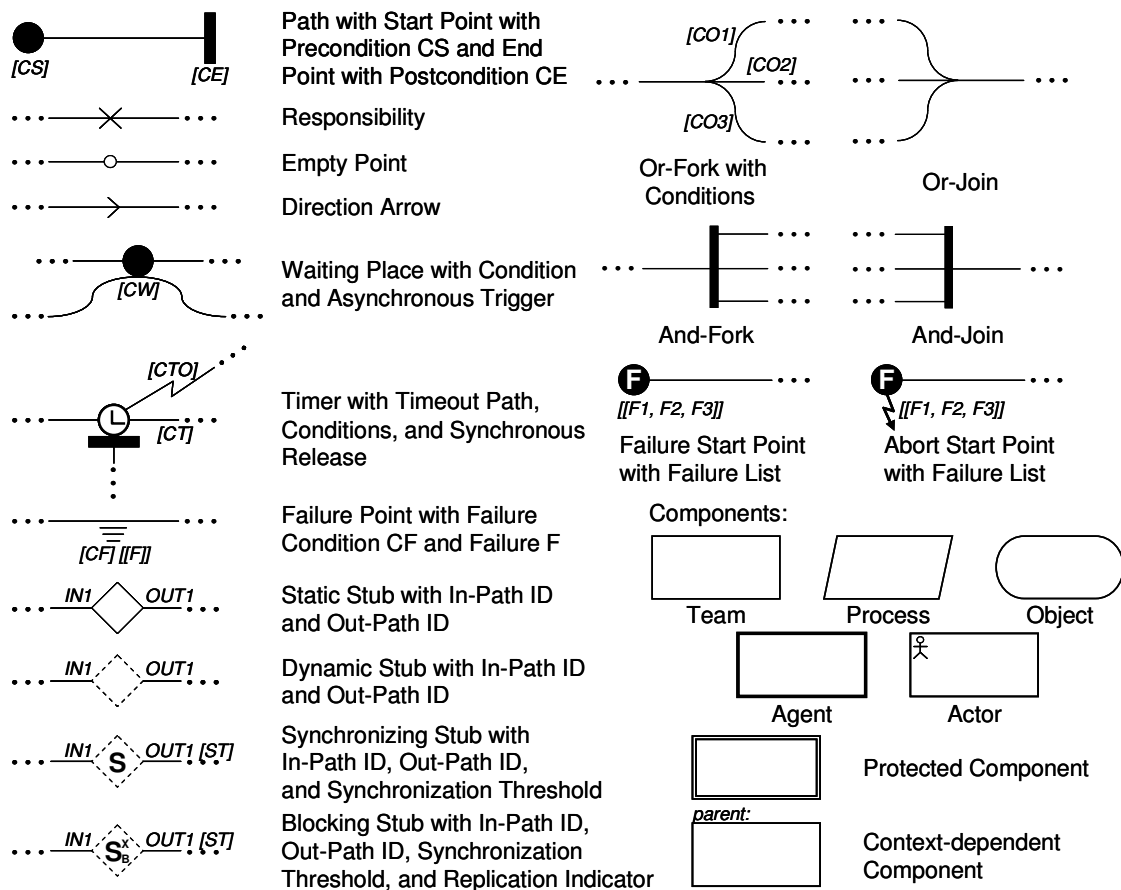


Figure 87 Syntax of UCM's modelling elements (ITU-T, 2012)

## Path traversal algorithm

The UCM path traversal (PT) algorithm evaluates the validity of path elements and the transitions between them, and tests the behaviour of the system under specific conditions

defined by initialized variables and triggered start points (in a scenario definition). PT simulates the progression along the paths triggered in the scenario definition while selecting conditions met by the initialized variables. The output is a partial order (an execution trace with responsibilities in sequence/parallel) that can be highlighted on the UCM model or transformed into another representation (e.g., UML sequence diagrams).

# Appendix D: Ethics Approvals

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File Number: H02-18-03

Date (mm/dd/yyyy): 03/09/2018



**Université d'Ottawa**  
Bureau d'éthique et d'intégrité de la recherche

**University of Ottawa**  
Office of Research Ethics and Integrity

## Ethics Approval Notice Health Sciences and Science REB

### Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

<u>First Name</u>	<u>Last Name</u>	<u>Affiliation</u>	<u>Role</u>
Daniel	Amyot	Engineering / Others	Supervisor
Malak	Baslyman	Engineering / Electrical Engineering	Student Researcher

**File Number:** H02-18-03

**Type of Project:** PhD Thesis

**Title:** Usability Study of Activity-based Process Integration Approach in Healthcare

<b>Approval Date (mm/dd/yyyy)</b>	<b>Expiry Date (mm/dd/yyyy)</b>	<b>Approval Type</b>
03/09/2018	03/08/2019	Approval

**Special Conditions / Comments:**  
N/A

**Figure 88** University of Ottawa ethics approval



Hôpital Montfort REB's approval certificate  
745-A, chemin Montréal road, Suite 102, Ottawa (Ontario) K1K 0T1

May 15, 2018

**Principal investigator**

Malak Baslyman  
Ph. D Student, Computer Science  
University of Ottawa

**Supervisor**

Daniel Amyot  
Professor  
University of Ottawa

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**Project title:** « Usability Study of Activity-based Process Integration Approach in Healthcare »

**File number:** 18-19-04-001

**Start date:** May 15, 2018

**End date:** May 14, 2019

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In accordance with the latest edition of Tri-Council Policy Statement - Ethical Conduct for Research Involving Humans Subjects (TCPS 2), I confirm that the Hôpital Montfort Research Ethics Board (REB) has evaluated and **approved the research project** and the following documents for the start and end dates mentioned above:

- **Appendix A1:** Usability study questions experimental group
- **Appendix A2:** Usability study questions control group
- **Annexe B:** Informed consent form (EN), version 1 dated April 26, 2018
- **Annexe C:** Invitation letter to participate in the study (FR & EN), version 1 dated April 26, 2018

The Hôpital Montfort REB is established and operates in a manner consistent with the National Standard of Canada for the Monitoring of Research Ethics Conducting Biomedical Clinical Trials of the Canadian General Standards Board, Clinical Practice Guidelines: Consolidated Guidelines of the International Council for the Harmonization of Technical Requirements for the Registration of Pharmaceuticals for Human Use (ICH-BPC E6), Part C, Title 5 of the Food and Drug Regulations, and The applicable regulations, Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations, the "Code of Federal Regulations" of the United States, the Ontario Personal Health Information Protection Act, 2004, and the laws and regulations applicable in Ontario.

The protocol of the study cannot be amended without prior approval of the REB unless there is an immediate safety issue for the participants. You must notify the REB immediately of any changes, adverse event or new information that may increase the risk of the study, changing the course of the study or reach the safety of participants. The changes to the project and recruitment tools must be submitted to the REB.

Please send us **four weeks before the due date of the notice of approval**, a final report to close the file or to request the renewal of the certificate of ethical approval for the study.

## Figure 89 Montfort Hospital ethics approval

# Appendix E: Usability Study Material

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## The usability study of *Activity-based Process Integration (AbPI)* approach in healthcare

### Demographic information:

- Your main healthcare occupation/work experience (circle one or more):
  - Clinical (physician, nurse, etc.),
  - Non-clinical (management, administration, information technology, etc.)
  - Other:
- Highest level of education (circle one):
  - High school / Technical / College
  - University undergrad
  - University graduate (Master, PhD, MD, ...)
- Area of study:
- Current occupation:
- Technical skills:
  1. Have you been involved in any of the following activities? Please circle the ones you have done:
    - a) Process modelling task
    - b) Process improvements project
    - c) Software design task
    - d) Lean project
  2. Have you used any of the following languages/tools/frameworks? If yes, please name them:
    - a) Process modelling language (such as Business Process Model and Notation/ BPMN or UML activity diagrams)?  
If yes, please name them:
    - b) Process modelling tool (such as IBM BPM or Visio)?  
If yes, please name them:
    - c) Process improvement framework/approach (such as Lean or six-sigma)?  
If yes, please name them:

**Part 1: Education and Training**

- Considering the presented material and the ER main process model (fig1), answer the following questions:

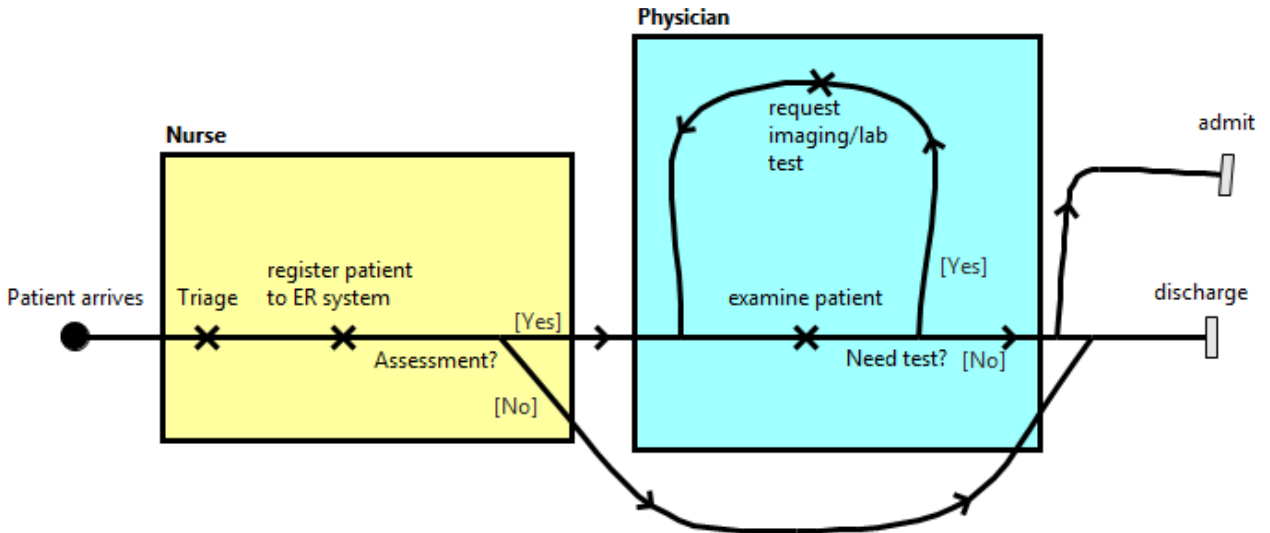


Fig 1. The ER main process model

**Process Model**

1. Answer the following questions:

- What is the start point of the ER process? .....
- How many activities are in the ER process? .....
- Name two responsibilities that are performed by two different roles:  
.....
- What are the expected end points of the ER process?  
.....
- True or false:
  - After registering the patient to the ER system, imaging or lab test must be required ( )
  - Physicians are the only ones that can decide to admit a patient to the hospital ( )
  - After requesting imaging/lab test, patients can be discharged immediately ( )

## Part 2: Evaluate usefulness and effectiveness, and usability of the AbPI approach

### **Task1:**

In the ER at Montfort Hospital, expectations on wait time are posted manually on a white board at different times during the day. **Patients** want to *stay updated about the process outcomes in real time*. The hospital considers using *Wait Time Estimation System (WTES)* to satisfy patients. WTES provides patients with an up-to-date view of their status and wait time in the ER process. Note that it is very important for **Montfort hospital** to *increase patient satisfaction*. **Caregivers** share the same value of satisfying patients; however, they want to *avoid task duplication*.

WTES consists of four main tasks: Register patient to WTES, Provide patient with access code, Insert expected wait time, and Update current status. *Register patient to WTES* task could be done **by a nurse** or, alternatively, **automatically** through publishing the patient information in the ER system to the WTES. The WTES-related process is modelled in the following figure:

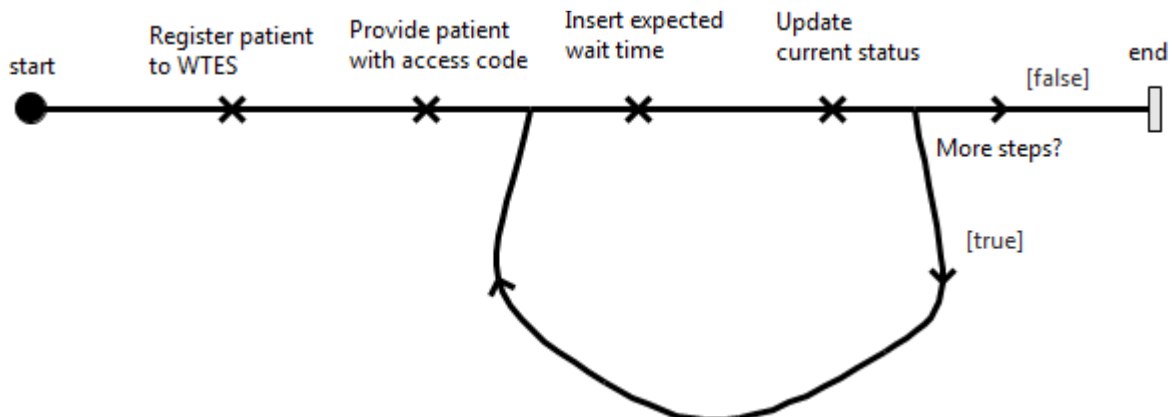


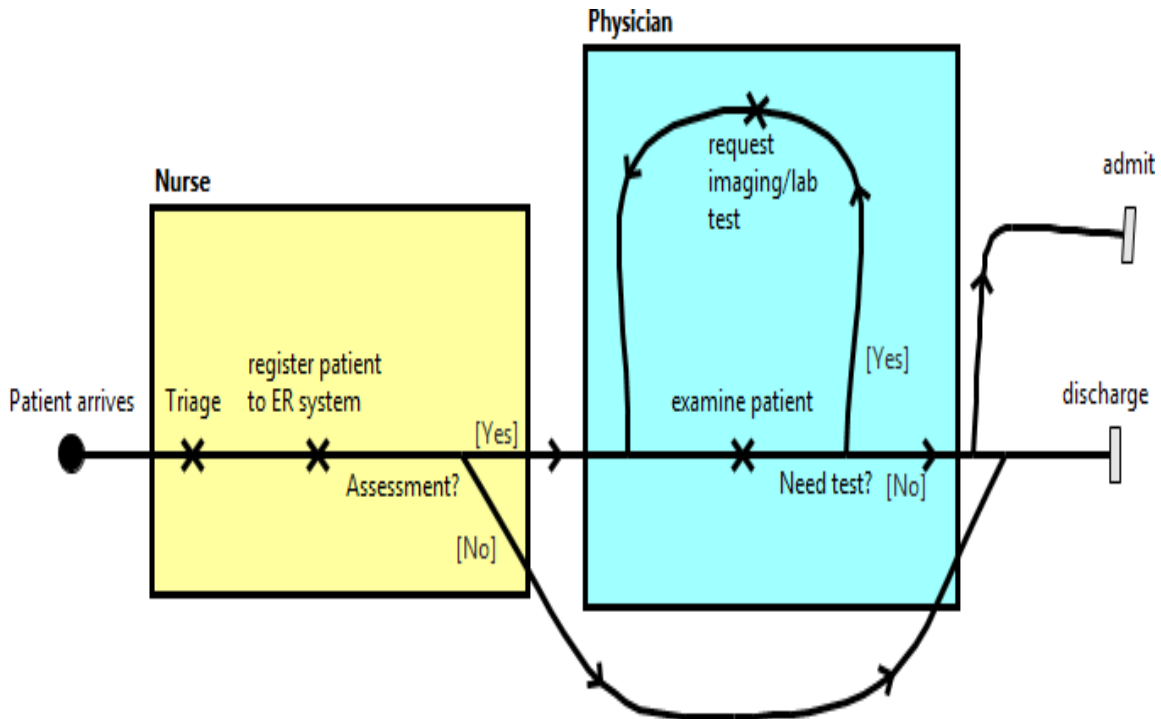
Fig 2. WTES-related process

The WTES-related process shall be integrated into the current ER process (fig 1). Using the AbPI integration method presented previously:

1. Identify the integration opportunities of integrating the WTES-related process into the ER process. Mark the integration opportunities on the ER process.
2. Write the activity(s) to be integrated from the WTES process beside its identified integration opportunity on the ER process, including integration alternatives if any.
3. Write/mark the sequence of activities that form the best process integration alternative to be deployed in the ER unit?
4. What are the difficulties/challenges faced while using AbPI integration method?

**Task 1 answer:**

**1 & 2) Identify integration opportunities and write activities to be integrated beside each integration opportunity.**



**3) The best integration alternative is (sequence of activities):**

**Checklist:**

The best process integration alternative:                      satisfies    partially satisfies    dissatisfies

- Montfort Hospital: Increase patient satisfaction
- Caregivers: Reduce number of duplicated tasks
- Patient: Stay updated about the process flow



## Task2

In the ER, a physician may request a lab test. The lab unit process starts upon the arrival of the patient (Fig 3). The process has three main tasks: Collect sample, Analyze sample, and Send result. Patients want to stay updated of the wait time from the moment they arrive to the lab and during analysing the sample.

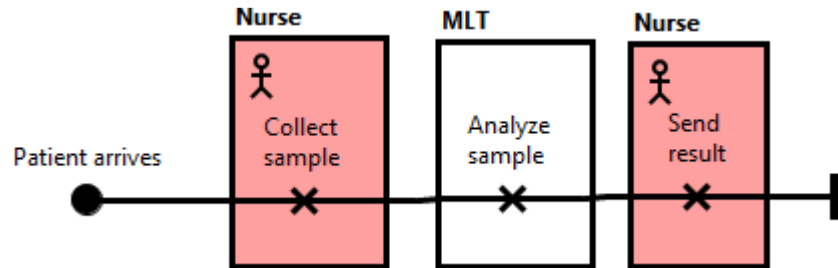


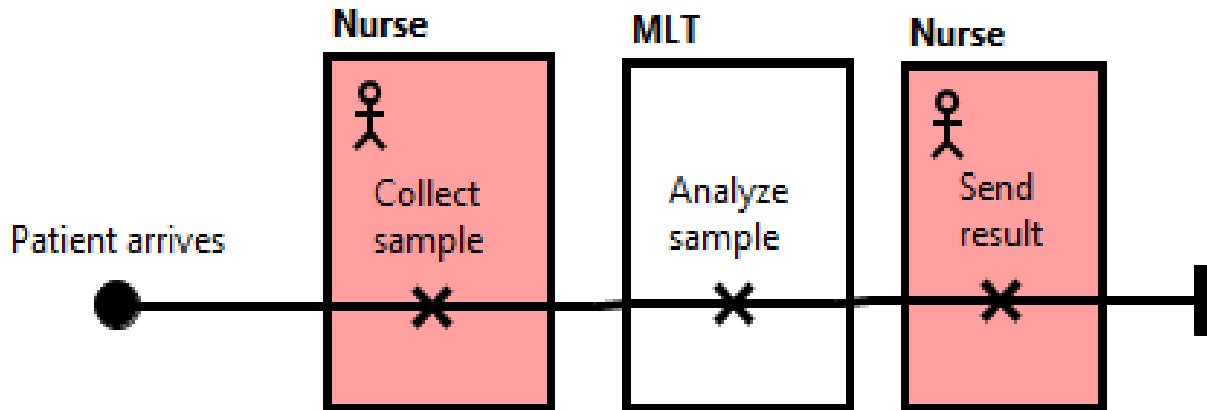
Fig 3. Lab unit process

The WTES-related process (Fig 2) shall be integrated into the lab unit process. Note that the activities *Register patient to WTES*, and *Provide patient with access code* are performed **once** and already integrated in Task 1. Using the AbPI integration method presented previously:

1. Identify the integration opportunities of integrating the WTES-related process into the ER process. Mark the integration opportunities on the ER process.
2. Write the activity(s) to be integrated from the WTES process beside its identified integration opportunity on the ER process, including integration alternatives if any.
3. Write/mark the sequence of activities that form the best process integration alternative to be deployed in the ER unit?
4. What are the difficulties/challenges faced while using AbPI integration method?

**Task 1:**

**1 & 2) Identify integration opportunities and write activities to be integrated beside each integration opportunity.**



**3) The best integration alternative is (sequence of activities):**

**Checklist:**

The best process integration alternative:                    satisfies   partially satisfies   dissatisfies

- Montfort Hospital: Increase patient satisfaction
- Caregivers: Reduce number of duplicated tasks
- Patient: Stay updated about the process flow

**Part 3: Evaluating the AbPI effectiveness and usefulness:**

Choose the answer that reflects, the most, your opinion:

1. I would like the AbPI approach to be used in my organization:  
Strongly agree, agree, neutral, disagree, strongly disagree
2. I found the AbPI approach unnecessarily complex:  
Strongly agree, agree, neutral, disagree, strongly disagree
3. It was easy to apply AbPI in the example:  
Strongly agree, agree, neutral, disagree, strongly disagree  
**The reason(s):**

4. I think AbPI provides a comprehensive approach to integrate processes, however, we need to learn a lot of things before using it:  
Strongly agree, agree, neutral, disagree, strongly disagree
5. It was easy to learn AbPI  
Strongly agree, agree, neutral, disagree, strongly disagree  
**The reason(s):**

6. I would use AbPI but with my own tools/modelling languages:  
Strongly agree, agree, neutral, disagree, strongly disagree  
**The reasons(s):**

7. I feel confident about the best integration alternative provided by the AbPI approach  
Strongly agree, agree, neutral, disagree, strongly disagree

8. I think the AbPI approach is useful in terms of reducing time and effort finding the best process integration alternative  
Strongly agree, agree, neutral, disagree, strongly disagree

9. I think the alternatives evaluation method helps to set/evaluate the targets of goals and performance objectives  
Strongly agree, agree, neutral, disagree, strongly disagree

10. I would recommend using the AbPI approach but with modifications:  
Strongly agree, agree, neutral, disagree, strongly disagree  
**If you agree with the previous sentence, type the suggested modifications:**
11. We have analysis/integration methods better than the AbPI methods  
Strongly agree, agree, neutral, disagree, strongly disagree  
**If you agree with the previous sentence, name the analysis method being used in your organization:**
12. Choose the negative points, if any, of using AbPI:  
Requires a lot of training and learning, takes time to use, there is lot of manual work, processes are not easily available, goals and data are not easily available, the notations are too complicated, others .....
13. What is(are) the main benefit(s) of AbPI?
14. What is(are) the main drawback(s) of AbPI?
15. What is the unit/department that should use AbPI to integrate processes?

Comments: including modifications, any missing perspective in the context of the process integration, etc.:




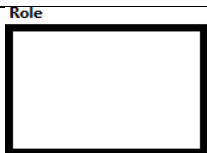

**Part 4: Evaluating the usability of the process integration alternatives in real practices.**

1. I will use / recommend to use the process integration alternatives (the output of the integration method) to provide more flexible solutions  
Strongly agree, agree, neutral, disagree, strongly disagree
2. I will use / I will recommend to use the process integration alternatives (the output of the integration method) to provide more comprehensive solutions  
Strongly agree, agree, neutral, disagree, strongly disagree
3. I think the process integration alternatives need some modifications to be used in real practices:  
Strongly agree, agree, neutral, disagree, strongly disagree  
What kind of modifications?
4. I will never use/recommend the process integration alternatives  
Strongly agree, agree, neutral, disagree, strongly disagree
5. Ranks the reasons if you agree with the previous sentence (number 4):  
(.....) They are complicated  
(.....) It takes time and effort to understand them  
(.....) It takes time and effort to integrate them into our current practices  
(.....) We do not need integration alternatives, one process for all is enough  
Others:

Thank you for your participation! ☺

## Educational material

### Process modelling notation

Element	Explanation	Graphical shape
Start point	Start point of a process	
End point	End point of a process	
Activity	A task to be performed by a role	
Role	A role that performs an activity(s)	
Conditional branch	Possible directions of a process according to the status of a condition	

### The integration method steps:

- 1) **Identifying integration opportunities:** a possible spot(s) in the current process in which a new activity can be integrated.
- 2) **Identifying the type of activity-activity relationship:**

Type	Description
<b>Activity – Activity relation</b>	
<b>Replace</b>	A new activity replaces another activity.
<b>Eliminate</b>	A new activity eliminates another activity or a set of activities.
<b>Add</b>	A new activity is added to a set of current activities. T

Table1: Activity to activity relations

- 3) **Modify the process model:** put a circle around the integration opportunity on the current process (ER in task 1 and lab in task 2). Write the activity to be integrated next to its integration opportunity and the activity-activity relationship. Optionally, add a name to the alternative (alternative 1 or AutomatedOption, for example).

### The analysis method:

- The best alternative is the one that achieves the desired outcomes
- It also has the best positive impact on goals and stakeholders' satisfaction.
- Check the *checklist* to ensure that the best process integration alternative is chosen.

## Appendix F: Online Material

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Many of the artefacts developed in this thesis (Table 38) are available online at this location: <http://www.eecs.uottawa.ca/~damyot/pub/Baslyman/>

**Table 38** Artifacts developed in this thesis

Artifact	File name	Tool	Explanation
AbPI conceptual model (Section 6.1)	AbPIConceptual Model.use	USE	The file has the AbPI conceptual model that combines Figure 4 and Figure 8 in Chapter 3.
Lab sample monitoring PGMs – object model (Section 6.4.1)	CaseStudy1. usecmd	USE	The file contains the object model exported from jUCMNav for model conformance and consistency checking with USE
Lab sample monitoring PGMs – URN model (Section 6.2)	CaseStudy1. jucm	jUCMNav	The file has the goal and process models presented in Chapter 8
Voice Recognition System – object model (Section 6.4.1)	CaseStudy2. usecmd	USE	The file contains the object model exported from jUCMNav for model conformance and consistency checking with USE
Voice Recognition System PGMs – URN model (Section 6.2)	CaseStudy2. jucm	jUCMNav	The file has the goal and process models presented in Chapter 9
Data Quality and Confidence Propagation Mechanism (Section 4.4)	Quantitative GRLStrategy Algorithm.java	Eclipse and jUCMNav	The implementation of the confidence method extending the quantitative GRL strategy algorithm, seen in Section 6.4.2
Export as USE file (Section 6.4.1)	Export AsUSE.java	Eclipse and jUCMNav	The implementation of the jUCMNav plug-in for automated generation of AbPI object models in USE format from URN models
TOPSIS equations (Section 6.4.3)	TOPSIS.xlsx	Excel	The implementation of TOPSIS equations explained in Section 5.4.2