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A Method for Improving Healthcare Management Using Enterprise Ontology

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Abstract

The global healthcare spending has constantly increased in the last decades, and there is data showing inefficiency in resource consumption that is not reflected in healthcare improvement. The need to introduce new ways to do the same at a lower cost is rational. To address this, we propose a method based on Enterprise Ontology to find non value-added transactions that must be redesigned to improve the healthcare management. This methodology was chosen as a basis for our solution because it provides a better understanding of the dynamics of an organization, and allows a good alignment between the enterprise design and operation. Demonstrations were accomplished within National Health System, making it possible to find transactions that can be refined or improved. Evaluation was carried out by means of interviews, the Four Principles from Österle et al., the Moody and Shanks Quality Framework, the framework from Pries-Heje et al., and the feedback from the scientific community. Results prove that the method yields an adequate and clear process view and is reliable when it comes to improving healthcare operational processes.

Keywords: Enterprise Engineering, Operational Processes, Enterprise Ontology, Design and Engineering Methodology for Organizations, Continuous Improvement, and National Health System.

Resumo

O crescimento da despesa com a saúde tem aumentado ao longo das últimas décadas, e existem dados que demonstram ineficiência na utilização de recursos, pois o excedente não se reflecte na melhoria dos serviços prestados. A necessidade de introduzir melhorias na saúde é fundamental. Para atingir esse objectivo, propomos um método baseado na teoria de Ontologia Empresarial para encontrar transacções sem valor acrescentado que possam ser redesenhadas para melhorar a gestão da saúde. Esta metodologia foi escolhida para integrar a proposta de solução pois permite uma melhor compreensão sobre a dinâmica das organizações e permite um bom alinhamento entre o desenho e a operação das organizações. Foram levadas a cabo demonstrações em organizações do Sistema Nacional de Saúde, que permitiram encontrar transacções que podiam ser melhoradas. Para avaliar a proposta realizámos entrevistas com profissionais, aplicámos os Princípios de Österle et al., a metodologia de referência de Moody and Shanks, a metodologia de referência de Pries-Heje et al., e ainda o *feedback* da comunidade científica. Os resultados demonstram que o método produz modelos que transmitem uma visão clara e adequada dos processos de saúde, e torna-se relevante para identificar melhorias para os processos operacionais de saúde.

Palavras-chave: Engenharia Organizacional, Processos Operacionais, Ontologia Empresarial, DEMO, Melhoria Contínua, Sistema Nacional de Saúde.

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List of Acronyms

AM	Action Model
ATD	Actor Transaction Diagram
BPMN	Business Process Modeling Notation
BPR	Business Process Reengineering
C-acts/C-facts	Coordination acts / Coordination facts
CM	Construction Model
DEMO	Design and Engineering Methodology for Organizations
DMAIC	Define, Measure, Analyze, Improve and Control
DSRM	Design Science Research Methodology
EA	Enterprise Architecture
ED	Emergency Department
EO	Enterprise Ontology
GDP	Gross Domestic Product
IQ	Information Quality
IT	Information Technology
NHS	National Health System
OE	Organizational Engineering
P-acts/P-facts	Production acts / Production facts
PDCA	Plan-Do-Check-Act (Lean Operating Framework)
PHC	Primary Healthcare (in Portuguese: *Centro de Saúde* or *Cuidados Primários*)
PSD	Process Structure Diagram
PM	Process Model
ROI	Return on Investment
SM	State Model
TQM	Total Quality Management

Chapter 1

Introduction

In a world of growing business dynamics, high rates of organizational changes and technological breakthroughs, most organizations need to be effectively and continuously redesigned and reengineered in order to achieve strategic and operational success. The inefficiency of processes and the lack of innovation are some of the main reasons for strategic failures, entailing serious consequences for business and its competitiveness (Kotter, 1996; Henriques, Tribolet and Hoogervorst, 2010).

These strong external forces and the need for innovation also challenge the healthcare system. Its organizations need to improve treatments, eliminate non value-added activities, reduce waiting time and expenses, treat more patients, and implement new technological services. Besides these challenges, the healthcare system suffers from operational management problems, and its processes are considered inefficient (Christensen, Grossman and Hwang, 2009; Kaplan and Porter, 2011).

A frightening factor is that its expenditure accounts for 10% of the Gross Domestic Product (GDP) in developed countries, and there is an increasing trend. Other than that, there is data indicating that service cost and quality are not correlated by showing inefficiency in resource consumption, which is not reflected in improved quality of care. Consequently, quality of life may be affected because of a knock-on effect on the economy, increase in tax rates and insurance contributions, disinvestment in other public services, and increased difficulties to afford healthcare (Walshe and Smith, 2010; Kaplan and Porter, 2011). Hence, this research stems from the assumption that many healthcare processes have become inefficient and unsustainable, which affects the management of the healthcare system.

Although the problem is identified as a need for organization redesign and reengineering, some authors argue that there is not a strong and reliable method to solve this problem (Dietz and Hoogervorst, 2008). It is estimated that over 70% of strategic initiatives such as Total Quality Management (TQM), Business Process Reengineering (BPR), and Six Sigma, among others, tend to fail (Mintzberg, 1994; Lifvergren et al., 2010). In this context, three main reasons are addressed: 1)

The lack of integration among the various enterprise elements at the design level; 2) The inability to deal with the enterprise dynamics at the operational level due to weak enterprise construction models; and 3) The need to encourage management practices that advocates the development of self-awareness within the organization (Aveiro, 2009; Henriques, Tribolet and Hoogervorst, 2010).

Following this, our research proposes an approach based on the theories of Enterprise Ontology (EO) and the modeling language proposed by DEMO – Design and Engineering Methodology for Organizations. We chose this approach as foundation for our proposal, because it is deemed able to provide a better understanding of an organization's dynamics, has a strong and well-formed theory, allows a good alignment between the enterprise design and operation, and it also enables a unified reengineering strategy (Reijswoud, Mulder and Dietz, 1999; Dietz, 2006). Therefore, our research main objective is to provide a method based on EO to find non value-added transactions, and redesign them to improve the healthcare management.

The research was conducted by using the Design Science Research Methodology (DSRM) that aims at creating and evaluating artifacts to solve relevant organizational problems (Henver et al., 2004). The obtained artifact is a method that provides guidance on how to find improvements through a set of steps divided in two phases. It starts with the Modeling Phase, which uses EO for modeling and understanding the essence of the organization and its processes. Then, the Innovation Phase based on some Lean steps, identifies possible improvements from models, prioritizes them in terms of impact and feasibility, and finally the organization is redesigned to include the most relevant improvements.

In order to demonstrate the use of the proposal, we are applying it within medical organizations, such as an Emergency Department (ED), a Primary Healthcare Center (PHC), and a Pharmacy. Besides the possible improvements in each organization, we are also interested in analyzing the interactions between them so that we can conclude how they can improve inter-organizational cooperation.

To evaluate the proposed artifact and its results we used: 1) The framework proposed in (Pries-Heje, Baskerville and Venable, 2004); 2) Demonstrations of the utility of the method; 3) Interviews with practitioners; 4) The Four Principles of (Österle et al., 2011) to evaluate the artifact; 5) The Moody and Shanks Quality Framework to assess the quality of produced models (Moody and Shanks, 2003); and 6) The feedback from the scientific community through the submission and presentation of papers.

1.1 Problem and Motivation

This section corresponds to the *problem identification and motivation* step of DSRM, which defines the specific research problem and justifies the value of a solution. Healthcare organizations face several challenges such as providing services efficiently, achieving strategic and operational success, and improving their business processes. They are forced to make these improvements not only to compete and prosper, but also to merely survive strong external forces, such as technological breakthroughs, rapidly evolving customer needs, globalization trends and political or economic factors (Kotter, 1996). Consequently, healthcare organizations need to improve treatments, eliminate non value-added tasks, reduce waiting time and expenses, treat more patients, and implement new technological services (Christensen, Grossman and Hwang, 2009).

Hampering these transformation challenges, the healthcare system suffers from a serious and growing problem of unsustainability, since its expenditure accounts for a large percentage of the GDP in developed countries, and there is an increasing trend (Christensen, Grossman and Hwang, 2009; Walshe and Smith, 2010). As illustrated in Figure 1, its cost exceeded almost 10% of the GDP in an average of forty countries, the expenditure in function of the GDP doubled in fifty years, and there are no signs of a slowdown. The greatest increases have been reported in the United States, Netherlands and Portugal (Walshe and Smith, 2010).

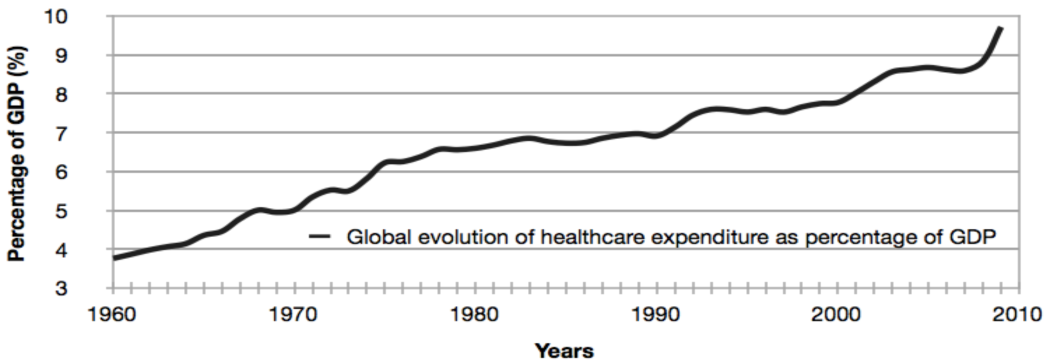

Figure 1: Evolution of healthcare expenditure as GDP percentage, adapted from (OECD, 2012)

Some of the most common explanations for this “cost crisis” are the growing demand for healthcare, population ageing, increasing incidence of chronic diseases, technological advances, and the development of new treatments. Other than that, third-party payers (insurance companies and governments) lead to a rising consumerism, and patients bear little responsibility for the cost of the services they demand (Walshe and Smith, 2010; Kaplan and Porter, 2011).

This situation is even worse when there is data indicating that cost and quality are not correlated, because some lower cost healthcare systems produce higher quality care, there are still long lines for specialty services and technologically advanced care, and some estimates indicate that a staggering 50% of healthcare consumed seems to be driven by physician and hospital supply, not patient need or demand (Christensen, Grossman and Hwang, 2009; Kaplan and Porter, 2011).

Therefore, several authors and entities are questioning the efficiency of healthcare services and reviewing some of the management practices commonly used. For example, the Portuguese Court of Auditors (*Tribunal de Contas*) accounted for inefficiencies in the order of 750 million euros (0.5% of GDP) related to the excessive use of human resources, medicines, complementary means of diagnosis, models of financing, and contractual agreements (Tribunal de Contas, 2011). Kaplan and

Porter identified the lack of understanding of how much it costs to deliver patient care, making it difficult to take decisions about investments, human resources, and elimination of activities (Kaplan and Porter, 2011). The European Commission underlines the importance of a systematic approach to implement strategies to avoid inefficiencies from different viewpoints, such as funders, providers and patients (Comission of the European Communities, 2007; Public Health Evaluation and Impact Assessment Consortium, 2011).

The reported inefficiency and unsustainability have impact on the quality of life because it may create a knock-on effect on economy, leading to the potential misallocation of resources and a reduction in purchasing power. Unless funding for other public services is denied or taxes are raised to extreme levels, there will be serious difficulties in financing healthcare services for retired or poorest people, affecting the productivity and the public health conditions (Christensen, Grossman and Hwang, 2009).

Moreover, this situation may also affect competitiveness at the macroeconomic level by diverting resources away from other, potentially more productive, sectors of the economy. Furthermore, countries with a larger expenditure will become less competitive than the others, especially when there is a discrepant difference with countries spending 17% of GDP in healthcare, while others are below 6%, as depicted in Figure 2.

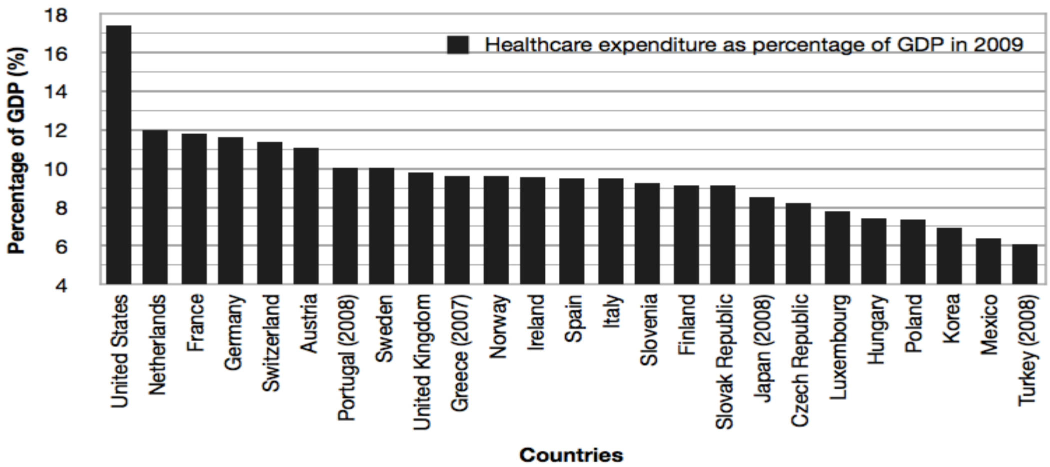

Figure 2: Healthcare expenditure as percentage of GDP in 2009, adapted from (OECD, 2012)

Hence, this research stems from the assumption that most **healthcare processes have become inefficient and unsustainable, which affects the management of the healthcare system.** Thus, we enunciate the following research question that we address in this thesis work:

Which is the contribution of Enterprise Ontology to improve the management of the National Health System?

Enterprise Ontology (EO) is the theory that underlies DEMO, which is a methodology for modeling, redesigning and reengineering organizations (Dietz, 2006). We have chosen EO since it can help to expand the expressiveness of the organization models, allows a good alignment between the enterprise design and the enterprise operation, and enables a different and unified approach for the enterprise reengineering. We want to use these benefits (explained in detail in Sections 2.4 and 3.2) with our proposal to improve the healthcare system.

Our main motivation derives from the rising problem described above and the need to improve healthcare business process models. However, modeling tools do not seem to have all the answers when it comes to analyze, reengineer and improve business process models and its design representation. It is estimated that over 70% of strategic initiatives such as TQM, BPR, and Six Sigma among others, tend to fail (Mintzberg, 1994; Dietz and Hoogervorst, 2008; Lifvergren et al., 2010).

Moreover, literature indicates that the lack of coherence and consistency among the various components of an enterprise is the core reason for strategic failures (Kotter, 1996; Dietz and Hoogervorst, 2008). Consequently, the research made in this thesis was also motivated by the need to produce unambiguous and coherent representation models of business processes. This need owes to the fact that flowchart and activity based modeling representations, in general, have some drawbacks, such as the absence of formal semantics, limited potential for verification and ambiguous notations.

As result, ontological modeling techniques have been identified as essential to leverage and clearly define a set of enterprise concepts, but it is still lacking in literature an analysis on how these concepts retrieved from the ontological models can support and improve healthcare management.

The success of this research field may have a big impact in the improvement of public health conditions, on the accessibility of its services, and the possibility of reallocating investment in other public services. Despite being a highly discussed topic, there is not a consensual method to solve these problems, as we will review in the related work (Chapter 2).

1.2 Contributions

This thesis work is expected to offer the following contributions:

- Provide a method based on EO to find non value-added transaction, and redesign them to improve the healthcare management;
- With the proposed method encourage management practices that advocates the development of self-awareness within healthcare organizations, and the integration among the various enterprise elements at the design level;
- Demonstrate the proposed method in different healthcare organizations as real case studies;
- Evaluate the method and its results using appropriate methodologies, namely to show its suitability and efficiency to solve the research problem, as well as to show that the design science research method extends the current state-of-the-art approaches;
- Communicate the research to relevant audiences through the publication of papers.

1.3 Research Methodology

This research was conducted using the **Design Science Research Methodology** (DSRM), which is a system of principles, practices and procedures required to carry out a study (Henver et al., 2004). It aims at overcoming research paradigms, such as the traditional descriptive research and interpretative research, in which the outputs are mostly explanatory and, one could argue, are often not applicable in practice (Peffers et al., 2008). Furthermore, it requires the creation of an innovative and purposeful artifact for a specified problem domain (Henver et al., 2004).

Information systems and BPR can draw advantage from DSRM since they are characterized by often using theories from diverse disciplines, such as social science, engineering, computer science, economics, and philosophy, among others, to address problems at the intersection of information technology and organizations (Henver et al., 2004). Several researchers have succeeded in integrating design as a major component of research in order to solve relevant organizational problems (Henver et al., 2004; Peffers et al., 2008; Österle et al., 2011).

To overcome these organizational problems, DSRM proposes the creation and evaluation of artifacts that may include *constructs* (vocabulary and symbols), *models* (abstractions and representations), *methods* (algorithms and practices) and *instantiations* (implemented and prototype systems) (Henver et al., 2004). In this research **the proposed artifact is a *method*** that provides guidance on how to find improvements through a set of steps. Though, this method produces models as part of the demonstration, but we are mainly interested in the evaluation of the method.

The application of strict practices is required in both the construction and evaluation of the designed artifacts, and it follows a sequential order composed by six steps, illustrated in Figure 3 with mappings for the thesis structure.

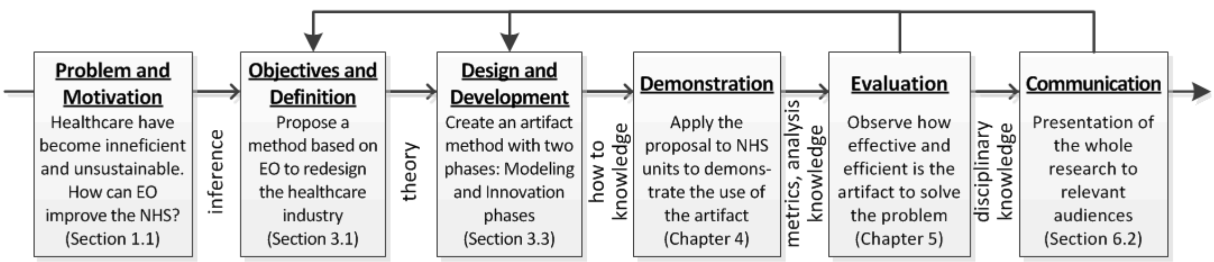

Figure 3: The DSRM process mapped with the thesis structure (adapted from Peffers et al., 2008)

The steps in the previous diagram are described as follows:

1. **Problem identification and motivation**: defines a specific research problem and justifies the value of a solution. In this research we considered an unsolved problem without an effective or efficient solution;

2. **Definition of the objectives of a solution**: from the problem definition, the related work, and the knowledge of what is possible and feasible, objectives are raised. They can be qualitative, such as the description of how a new artifact is expected to solve problems, or quantitative, such as terms in which a desirable solution would be better than the current ones;
3. **Design and development**: creates an artifact in which a research contribution is embedded in the design. It may extend the knowledge base or apply existing knowledge in new ways;
4. **Demonstration**: uses the artifact by solving one or more instances of the problem. This could involve its use in experimentation, simulation, case study, proof, or other appropriate activities;
5. **Evaluation**: the utility, quality and efficacy of the design artifact are demonstrated via well-executed evaluation methods. These methods may include interviews with practitioners, surveys, simulations, and the appraisal of the scientific community, among other strategies. At the end of the activity, researchers can decide whether to iterate back to improve the artifact;
6. **Communication**: is concerned with the presentation of the whole research (problems, objectives, artifact, demonstration and evaluation) to relevant audiences. This step can be accomplished with the submission and presentation of papers.

1.4 Thesis Structure

This thesis is divided in seven different chapters, described as follows.

1. **Introduction** (Chapter 1) gives a general context about the thesis, introduces the research problem and motivation, describes the research methodology, and introduces the structure;
2. **Related Work** (Chapter 2) provides a brief overview of the literature on the research area, and describes the needed concepts which underlie the proposal, namely the EO;
3. **Proposal** (Chapter 3) identifies the objectives of the solution, describes why we chose EO, and explains the artifact method;
4. **Demonstration** (Chapter 4) presents three case studies where the proposal was applied: an ED, a Pharmacy, and a PHC. Then it presents the redesigned healthcare as a summary of the conclusions obtained from the case studies;
5. **Evaluation** (Chapter 5) provides an explanation of the evaluation strategy used to assess the artifact method, then the evaluation results, and finally a final discussion about the results;
6. **Conclusion** (Chapter 6) presents a summary of the main conclusions and contributions of the thesis, the research communication, and some proposals for the future work;
7. **Appendixes** present: A) Legends from the DEMO diagrams; B) The Process Model from the ED; and C) The redesigned national health system.

Chapter 2

Related Work

This section covers the related work and the needed theoretical background for the thesis. This will serve as input for the *definition of the objectives for the solution*, to the *design and development*, and to the *demonstration* steps of DSRM. Therefore, to begin with, we introduce some practices about Healthcare Management (Section 2.1). Afterwards, we introduce the Quality Management to explain concepts of enterprise transformation, continuous improvement and improvement quantification (Section 2.2). Then, we introduce the Organization Design and Engineering as a subject to redesign and reengineer organizations processes (Section 2.3). Next, an overview of EO and its theoretical foundation is provided (Section 2.4). Finally, we present the summary (Section 2.5).

2.1 Healthcare Management

This section starts by giving a glance about healthcare management as a whole, then introduces three units: ED, Pharmacy, and PHC. We chose these units as they cover the first line of access to the healthcare system, and because we focused on them for the demonstration phase in Chapter 4. The concepts described in this section are considered essential standards to any healthcare improvement process (Walshe and Smith, 2010).

The provision of healthcare services within a regional or national health system can be usefully categorized and analyzed through the classification of three main subsystems or sectors: primary, secondary and tertiary care, as depicted in Figure 4. Each of these sectors can be modeled and analyzed as subsystem of the whole industry, though in many countries boundaries between these sectors are often ambiguous or blurred, and frequently shift as health services provision moves from one to another. A typical patient journey should start with contact with primary care for an initial diagnostic consultation, and might then involve the patient being referred to secondary care for more specialized diseases or treatment, or a tertiary service for even more specialized follow-up. However, these sectors overlap and it is frequently true that an individual patient may receive services within more than one sector at the same time (Walshe and Smith, 2010; Lapão and Dussault, 2012).

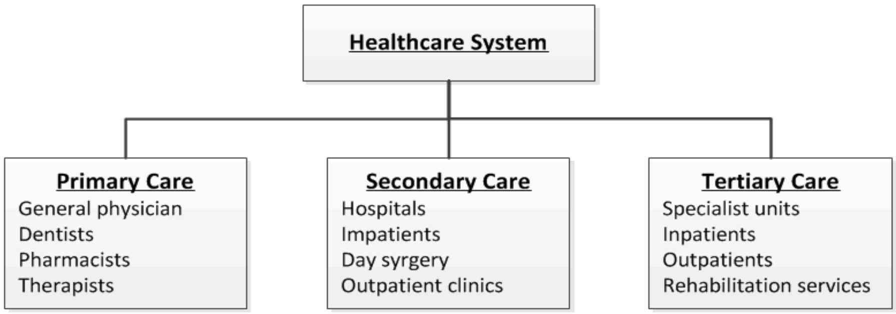

Figure 4: Sectors of within a healthcare system (Walshe and Smith, 2010)

Managing these systems can be complex and challenging since, on one hand, there is the concern about the overall expenditure that accounts from 8% to 17% of the economy on most developed countries. On the other hand, there are challenges in improving healthcare quality, providing services to the growing population, developing new means of treatment and diagnostic, among others. To face these pressures, in Table 1 we tried to group some improvement practices found in the literature, namely in (Jensen et al., 2007; Christensen, Grossman and Hwang, 2009; Walshe and Smith, 2010).

Category	Description of improvements practices
Patient relationship	Patients are concerned about medical errors, high quality services, affordable prices, effective services, safety, and reduced (or informed) waiting time.
Healthcare team	Healthcare team appreciate empowerment environments, effective formation, better support for nurses and caregivers, rewards and incentives, and a good leadership capable of unfreezing. This may improve the overall performance.
Internal structure and services	Create an efficient network of primary care as a first contact between patients and the healthcare system, which should include prevention, diagnosis, treatment, and follow-up. Hospitals should be an alternative solution for specific situations not solved in PHC.
Cost margin and financial success	It is possible to reduce average patient stay between 1.5 and 2.5 days, which leads to more patients admitted and expenditure reduction (for both the hospital and the patient). This can be achieved with a better patient flow, long-term relationships, improved operational management, and better use of resources.
Supply Chain	Long-term agreements with suppliers, reduce quantities of stored material, improve inventory management, implement push-based strategies, avoid the bullwhip effect, outsource services, and invest in vertical or horizontal integration.
Healthcare Information Systems (HIS)	Some covered points are: standardization in the HIS, decision support systems, monitoring and forecasting capabilities, efficient supply chain management, centralized patient records, information delivered on time, decrease the use of paper. These systems contribute to greater operational excellence, better response times and huge process improvements.
Other improvements	There are other practices concerning service and capital development, business planning, strategic management, costing models, commissioning and contracting, and improving discharge and routing processes.

Table 1: Summary of best practices in the management of the healthcare system

Most of the practices described above are not tied to any methodology, being created and implemented *ad-hoc* for specific problems or tasks. From some perspectives, these practices are important as they come from the accumulated experience, can be implemented during a redesign or reengineering project, and some of them report good results. For example, these practices help to avoid medical errors, increase customer satisfaction, reduce unnecessary work, and consequently, affect positively the quality of life, public health, and operational efficiency (Walshe and Smith, 2010).

From another point of view, the lack of a rigorous methodology makes these practices sometimes decontextualized, as they do not consider an integrated view among the enterprise elements at the design level (referred in the problem definition from Section 1.1), and there is a lack of vision to deal with the enterprise dynamics due to the inexistent enterprise construction models, which is referred also in problem definition (Mintzberg, 1994; Henriques, Tribolet and Hoogervorst, 2010).

Next, we present the three different healthcare units used as case studies in the demonstration from Chapter 4: the ED, the PHC, and the Pharmacy.

2.1.1 Emergency Departments

Emergency Departments (ED) are considered a highly complex system, with numerous managerial challenges, and accounting for the majority of the overall healthcare spending (Williams, 1996; Christensen, Grossman and Hwang, 2009; Walshe and Smith, 2010). Moreover, they have some concerns of their own, such as the fact that the cost of treating an episodic illness is higher than outside the ED, some patients cannot wait, several resources must be available for prevention, there is not much time to make decisions, and patients cannot stay in the service taking up space from other acute episodes.

Based on the available literature we can point out some suggestions to ***smooth patient flow***. For example, many authors argue that much of the demand is predictable and that flow and process analysis tools used widely in other industries can be brought to improve ED management. There are suggestions about the implementation of forecasting methods to predict future demand, to allocate the available human resources, to speed up patients' discharge thus freeing up resources, to create rapid response teams to act in very urgent situations avoiding mortality, among others (Jensen et al., 2007).

The ***Fast-Tracking System*** creates a separate staffed area for patients identified as low-acuity at triage, avoids huge waiting times, improves customer satisfaction, and reduces service occupation. It is particularly useful when a patient only needs a prescription or examination, and there are others needing an extensive and lengthy workup and treatment. This approach promises improvement results of almost 50% more patients handled (Jensen et al., 2007; Medeiros and et al., 2008).

A different approach called ***Provided Directed Queuing*** proposes an improvement placing a physician at triage as part of the team to provide a better assessment and faster service, especially when the ED is overloaded. For example, the provider may conduct a medical evaluation or diagnostic test during the triage, decreasing the stay's length for low-acuity situations. To achieve that, the PDQ provider listens to the triage nurse assessment, and will then take primary responsibility and definitively disposition for minor emergencies, which in some cases lead to an early or immediate discharge. This approach had improvement results up to 76% (Medeiros and et al., 2008).

In addition, the **triage strategy** has a great impact on the ED's mission, mortality and patients routing. It is used to manage risk, sort the most acute cases, and analyze statistics with performance indicators. There are different alternatives to avoid its bottleneck.

The previously presented strategies were some of the ones used in the demonstration from Chapter 4. Notwithstanding, there are many others, including: A) Strategies to reduce the length of stay in emergency medical services; B) Creation of intermediate care and rehabilitation services to require fewer acute care beds; C) Creation of stationary teams to standardize service levels, reduce the excessive rotation of teams avoiding medical errors; D) Automation of samples transportation through vacuum pipes; among others (Jensen et al., 2007; Walshe and Smith, 2010).

2.1.2 Primary Healthcare Center

Primary Healthcare Center (PHC) is a unit or subsystem that addresses the main health problems, providing preventive, curative, and rehabilitative services. It should act like an entry into the system for all new needs and problems, provide person-focused (not disease-oriented) care over time, provide for all but very uncommon or unusual conditions, and coordinate or integrate care provided elsewhere by others. Furthermore, it should consider four central features: 1) Represent a first point of contact for all needs; 2) Provide person-focused rather than disease-focused continuous care over time; 3) Provide comprehensive care for all needs that are common in the population; and 4) Coordinate care for both those needs and for needs that are sufficiently uncommon to require special services (Starfield, 1998; Lapão and Dussault, 2012).

Given the importance of having a strong primary healthcare orientation (WHO, 2008), it is striking that relatively little has been written about the management (as opposed to the delivery) of primary care, particularly in comparison with the amount of analysis accorded to the management of hospital services. Authors have asserted that a more integrated health sector is needed, with a much stronger emphasis on primary care. Secondary and tertiary cares, which are largely provided in hospital, should be clearly supportive to primary care, concentrating only on those diagnostic and therapeutic functions that cannot be performed well in primary care settings (Walshe and Smith, 2010).

To improve the PHC management, the literature points out some suggestions. For example, the **primary care gatekeeping** is considered as being crucial to the management of an effective health system, both in relation to cost and clinical effectiveness, as it entails the identification of fewer points of access to the health system. Within a system of PHC gatekeeping, patients cannot access hospital specialists or associated diagnostic services unless they have first consulted their family doctor. The strength of such a system is seen as being the ability of the family doctor to take a holistic view of a person's care, assuring only appropriate referrals to more specialist services, and thus avoiding unnecessary expensive tests and care in hospital settings (Walshe and Smith, 2010).

The **registration of patients** with a single practice or practitioner is viewed as being vital in relation to both individual and population health. It enables long-term relationships between patients and physicians, increasing the amount of information, which in turn improves the monitoring and the decision making process. The importance of a system of registration has been powerfully demonstrated, for example, in New Zealand (Hefford, Crampton and Macinko, 2005; Lapão and Dussault, 2012).

The provision of **comprehensive and multidisciplinary primary and community services** underlines the vision of primary care as being the center of a health system, and not the bottom of a pyramid of care. In many countries there is a common perception that healthcare is synonymous with hospitals. This should be avoided by offering community-based services to support people in maintaining and managing health levels (e.g. general practice, child surveillance, chronic disease management, physiotherapy, among others) (WHO, 2008).

There are many other means to improve primary healthcare management, including the use of contracts, financial incentives, and the development of primary care organizations. Also, some of the improvements identified in the previous sections would also be applicable here.

Overall, the main challenge for the management of primary care is to increase its influence in the healthcare system in relation to the power and resources of hospital services. If this shift in influence can be achieved, primary healthcare can become a route to improving health and developing stronger and more sustainable communities. This happens in some healthcare systems (e.g. UK), in which the general practitioner (also known as family physician) serves as the gatekeeper to other professionals within primary care or refers patients on to secondary or tertiary services. In many other healthcare systems (e.g. France, Germany, and USA), the patient has direct access to more specialist consultation (Walshe and Smith, 2010; Lapão and Dussault, 2012).

2.1.3 Pharmacy

The scope of pharmacy practice includes roles such as compounding and dispensing medicines, reviewing medications for safety and efficacy, and providing drug information or advice. They are responsible for guaranteeing a rational use of medications and healthcare products, thereby avoiding unsupervised self-medication. Recently, some pharmacies have begun to include clinical services such as medical consultations and some medical examinations and samplings.

Depending on the National Health System (NHS) rules, the distribution of the costs may vary. During a hospitalization, medicines may be free to the patient. Other prescriptions are financed according to the healthcare subsystem, insurance companies' rules, or patient's pension system. In most of these situations only a fraction of the price is charged, but there are some exceptions with medicines for severe or long-term diseases. In Portugal, the NHS spends above the average in the reimbursement of medicines, when compared to other countries in the European Union (Tribunal de Contas, 2011).

As private companies that need revenue, pharmacies have also their own challenges. In Portugal, pharmacies have been traditionally organizations with high profit margins and with almost no competition due to legislation. In recent times, with the rising interest in generics, the introduction of "para-pharmacies", and legislation that limits the margins of prescribed drugs, most pharmacies started to feel difficulties, and for practically the first time needed to look at their costs and increase their efficiency. *Antão and Grenha* go even further in their predictions, stating that the decrease in the profitability will continue, and it will be negative for most pharmacies in 2012. These assumptions may lead to the closure of a significant number of pharmacies, and consequently there will be an increase in the unemployment and a loss of tax revenue (Antão and Grenha, 2012).

In the previous scenarios, some authors defend that pharmacies and pharmacists will depend on pharmaceutical services provision, beyond medicines dispensing. Therefore, the future community pharmacists will also have to acquire or develop new competencies such as those related to management, leadership, marketing, information technologies, as well as behavioral and communication skills (Gregorio, Cavaco and Lapao, 2012).

As a primary care subsystem, pharmacies share some of the previously presented best practices. Pharmacies should act as a point of access to the whole health system, improving health and developing stronger and more sustainable communities (Walshe and Smith, 2010). For example, there are countries where a pharmacist may prescribe and deliver some kinds of drugs, reducing the number of accesses to the hospital (thus acting as a gatekeeping). These prescriptions are typically accompanied by some sort of diagnosis in the pharmacy, the signature of a term of responsibility, or it can be just a repeated treatment (Gregorio, Cavaco and Lapao, 2012)

In addition to the competencies identified for pharmacists, establishments also need to assume new management challenges, such as: A) Create larger pharmacies to take advantage from economies of scale and reduce overhead costs; B) Enter the e-commerce to increase sales; C) Automate the preparation of medicines, inventory control and other activities including mechanical robots; D) Increase pressure on government bodies and regulatory authorities, for example, to introduce information improvements in the barcodes to avoid having to manually check medicines for price or expiration date, and to avoid successive changes to the legislation and margins; E) Implement customer loyalty and customer relationship management programs; F) Introduce other services that may be provided on free time and space, such as primary care services, consultations, selling cosmetics, among others. Many other challenges could be listed from (Christensen, Grossman and Hwang, 2009; Walshe and Smith, 2010; Gregorio, Cavaco and Lapao, 2012).

2.2 Quality Management

Edwards Deming, one of the main and originator sources in Quality Management, defended that organizations can increase quality and reduce costs by adopting appropriate principles of management. He identified seven constructs as main drivers: visionary leadership, internal and external cooperation, learning, process management, continuous improvement, employee fulfillment, and customer satisfaction (Rungtusanatham et al., 1998). Hence, authors defend that these topics are considered crucial not only to compete and prosper, but also to merely survive against external forces (Kotter, 1996). The following sections review methodologies for quality management and to quantify improvements, particularly used in the healthcare management.

2.2.1 Six Sigma

Six Sigma was initially established as an internal quality initiative at Motorola in 1987 as a Quality Management methodology that identifies and controls the variation in the processes that most affect performance and profits. It follows a prescriptive methodology that takes four to six months and can have high returns. Furthermore, it also has taken part in the management of the healthcare system, sometimes accompanied by other methodologies such as Lean or TQM. It is typically grounded in the **DMAIC Problem Solving Methodology**, which stands for Define-Measure-Analyze-Improve-Control as depicted in Figure 5, and is used to guide the strategy and maximize returns (Zu, Fredendall and Douglas, 2008).

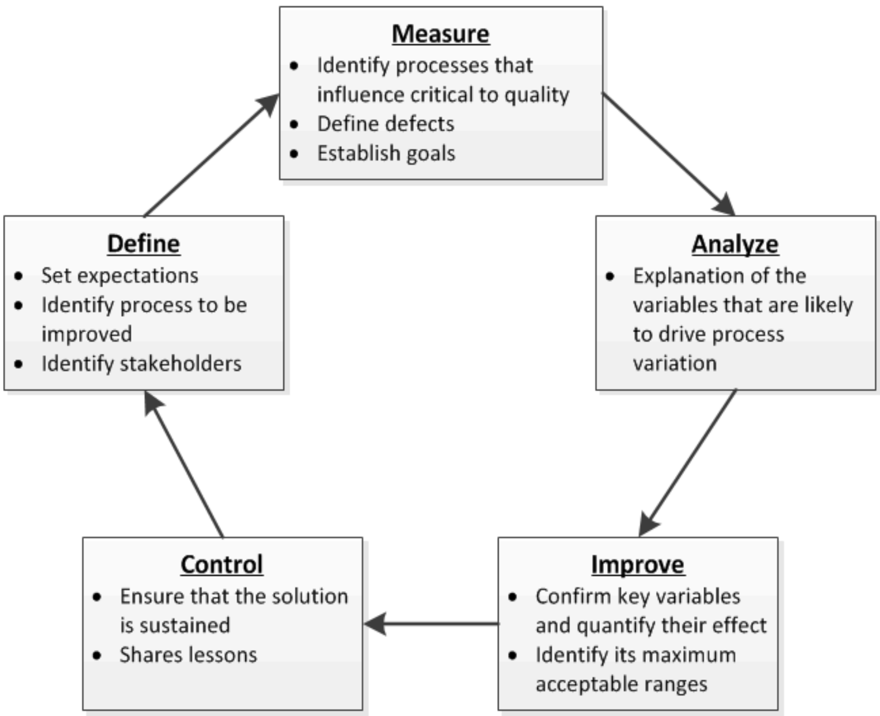

Figure 5: Six Sigma DMAIC Problem Solving Methodology (Lean Sigma Institute, 2012)

Three features differentiate Six Sigma from other quality management initiatives: 1) The **structured improvement procedure** previously presented (DMAIC Problem Solving Methodology); 2) **Focusing on metrics** adds a disciplined method by using extremely precise data-gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them; and 3) **The role structure** is often referred to as a *belt system* and can be seen as a way to standardize competence improvement in the organization. Following this, the black-belt role belongs to an improvement expert, who works full-time on that, and has practical experience. The white-belt only knows some basic quality improvement tools and they are under the guidance of black-belts (Zu, Fredendall and Douglas, 2008).

Some of the reported benefits from Six Sigma are the waste reduction, fast throughput, less inventory, lower fluctuation due to the performance measures for managers, and improved quality. Furthermore, some authors consider that its success rate is higher than the standards considered in Section 1.1 (Lifvergren et al., 2010). Other than that, it is claimed to be a very robust methodology, which enables organizations and individuals to "improve the way they improve" also in the healthcare system, where some of the reported benefits are: to standardize organizational procedures with its main focus on the patient, reduce complexity and time of processes, improved quality of healthcare, and cost reduction (Heuvel, Does and Verver, 2005; Zu, Fredendall and Douglas, 2008; Walshe and Smith, 2010).

However, the authors also showed there were still issues to solve, such as: projects that were not successful, results below the expectations, the difficulties in analyzing an organization, and the lack of experience in the management of the healthcare system when compared with Lean (Lifvergren et al., 2010). Moreover, Six Sigma is considered effective to "fix an existing process", but does not help to "come up with new products or disruptive technologies". In addition, Six Sigma needs to be adapted in order to be successfully applied, because it only proposes general guidelines (Harry and Schroeder, 2000; Zu, Fredendall and Douglas, 2008; Burgess and Radnor, 2010).

Next section presents Lean, which is another methodology to improve the Quality Management. Unlike Six Sigma that is focused on reducing variation to deliver a more uniform process output, Lean is focused on the waste removal to deliver an improved flow time. Furthermore, Lean is more common in the healthcare management improvement than Six Sigma (Medeiros and et al., 2008).

2.2.2 Lean Methodology

Lean is an improvement approach that consists in eliminating waste (steps that do not add value to the customer, such as interruptions, delays or mistakes), enabling the delivery of a more valuable service, having more flexible processes, and improving information or goods. Although its concepts were initially developed to improve car production, studies showed that the Lean principles could be applied to virtually any manufacturing system (Womack and Jones, 2003; Hines, Holweg and Rich, 2004; Souza, 2009). Its main principles can be summarized as (Womack and Jones, 2003):

- **Specify value** desired by the customer, identify him and his requirements;

- **Identify value stream** for each product or service and challenge wasted steps;
- **Introduce continuous flow** and standardize processes around best practices, allowing them to run smoothly, freeing up time for creativity and innovation;
- **Introduce pull** between all steps where continuous flow is impossible;
- **Pursue perfection** eliminating waste and non value-adding activities from the value chain (i.e. steps, time and information must be continually reduced).

Lean is typically grounded in the **PDCA Operating Framework** (or PDCA cycle), which stands for Plan-Do-Check-Act, or alternatively Plan-Do-Study-Act (PDSA). The PDCA cycle was first developed in the 1930s by *Walter Shewhart* (from Bell Telephone) and brought to Japan in the 1950s by *Edwards Deming* referred previously in this section as a father of Quality Management (Rungtusanatham et al., 1998; Womack and Jones, 2003). Afterwards we describe the steps.

1. **Plan:** Recognize an opportunity and plan a change. In other words, a plan is created with a clear identification of what is wanted to change, the needed steps, and a results' prediction;
2. **Do:** Test the change using small-scale studies. Therefore, the plan is carried out in a trial or test environment, under controlled conditions;
3. **Check or study:** The change is tested in a small-scale study to examine its results. In this step, one should verify that processes were improved and, if they were, should be considered the implementation on a broader scale. If it was not successful, return back and try again;
4. **Act:** Implement the changes that were verified in a broader scale, and then update the standard operating procedures. If the change did not work, repeat the cycle again with a different plan. If it was successful, incorporate the learning from the test into wider changes.

Since Lean focuses on eliminating waste in the value stream and performing activities according to established standards and practices, the PDCA cycle suggests that **all work should be measured and performed to standards**. Consequently, after implementing any improvement, one must standardize to perform consistently to this improvement state (Womack and Jones, 2003).

When standards are not present in the body of knowledge, the methodology suggests the SDCA variant, which stands for Standardize-Do-Check-Act. In this variation, the first step concerns with the establishment of initial standards and stability within a process. By standardization the authors are referring to all aspects of the process, such as: man, machine, methods, systems, materials, measurement, and environment. After reaching the first threshold of standardization, one should apply the PDCA cycle iteratively, as suggested by the continuous improvement (Womack and Jones, 2003).

There may be different implementations depending on the business and its purposes (usually maintaining the previous principles and steps). Some of these implementations are reported in the healthcare management. In fact, Lean is one of the most used methodologies in this industry, accounting for more than 50% of such initiatives in the UK (Burgess and Radnor, 2010). Some of the reported benefits in the healthcare system are the reduction of processing and waiting time, increase in quality through a reduction of errors, reduction in the service costs, lower resource expenditure, better warehouse management, and increased employee motivation and customer satisfaction (García-Porres, J; et al., 2008; Radnor, 2010). *Fillingham* quotes additional results as a reduction in paperwork by 42%, in length of stay by 30% and lower mortality rate by 38% (Fillingham, 2007).

However, some authors also point out some drawbacks such as the high rate of failed implementations referred to in Section 1.1, and the degradation or mischaracterization of services (Seddon and Brendan, 2009). Depending on how Lean is implemented, other nefarious consequences may include the loss of organization's essence, which may happen when quality drivers degenerate, the necessity to adapt the methodology so as to be successfully applied, the loss of creativity and power to react to external changes and, in some cases, risks in business continuity (Seddon, 2003; Boaden et al., 2008; Burgess and Radnor, 2010).

In Table 2, as example, we present the implementation steps from a Lean based methodology.

Phases	Proposed steps
1. Learning to sense	- View the organization from a customer (or patient) perspective - Evaluate value chain measurement horizontally and vertically - Understand front-line roles and responsibilities
2. Learning to respond	- Re-educate management - Introduce the *pull* theory of management - Replace *make and sell* mass production theories with *sense and respond* theories, which incorporate *systems thinking and lean production*
3. Leading change	- Utilize transformation leadership theories - Employ cognitive behavior methodology - Operate within a leadership and coaching framework - Award staff managers with accreditations
4. Mobilizing	- Provide detailed change programs to transform the corporate infrastructure - Design domestic and international plans for mobilization.

Table 2: Lean methodology based on "*Sense and Respond*" (Parry, 2004)

The previous approach was designed mainly to provide a better service and increase customer satisfaction. In addition, it also reports improved cycle times, reduced service costs, and increased customer and employee satisfaction. These goals were achieved because this implementation focuses on the customers' needs, and applies some practices on supply chain management, such as the *pull* theory, *sense and respond* production, and *just-in-time* strategy. We also refer the reader to other Lean examples in the healthcare system, such as (García-Porres, J; et al., 2008; Trilling et al., 2010). The previous example and bibliographic references denote the existence of different implementations, making it difficult to standardize improvement.

2.2.3 Improvement Quantification

When it comes to manage quality, there is also the need to quantify the improvements in terms of risk, feasibility and expected return. There are several approaches that can be used in these situations to quantify a business improvement. In Table 3 we briefly present some of them. We do not deepen in details since in this thesis our main focus is a modeling method to find improvements and redesign the organization. The following table groups some of the following contributions: (Hubert, 2007; Laudon and Laudon, 2010; Walshe and Smith, 2010; Kaplan and Porter, 2011).

Approaches	Approach Description
Empirical frameworks	They help to structure facts and concerns, and from them it is easier to quantify or discuss the improvements. As example, we have the Laudon Framework, in which a business challenge is considered to be divisible into three dimensions: organization, technology, and management. These dimensions must be analyzed separately to find problems and build the solution. Other empirical frameworks are the Value Chain Analysis that considers the internal strengths associated with to the supply chain and the internal structure that manages it; the PESTL and Porter's five forces, which analyze the external forces that may affect the business; and the SWOT, which joins external and internal strengths and can be extended to construct a solution.
Measuring investment and capital	Analytical methods are used calculate financial variables, such as the Net Present Value that recognizes the time value of money by discounting costs and benefits over a period of time, and focuses either on the impact on cash flow. Then, Return On Investment (ROI) helps to determine the financial benefits of an investment, and stands for the profit or loss from an investment transaction. The opportunity cost and the investment selection try to choose between different projects which one brings a higher ROI.
Costing models	Costing models, such as ABC (Activity Based Costing) identifies the cost from each activity in an organization, allowing for a greater knowledge about its indirect and variable costs. These models improve the knowledge about the services provided and allow realizing when a service is inefficient, thus giving good decision-making support to choose which service should be improved first.
Performance management	It is possible to assess the performance of each service, process, supplier or worker using methods such as: costing models, Balanced Scorecard framework, key performance indicators, benchmarking, and business administrating monitoring.
Portfolio management	It is a method to manage investments with the objective of achieving maximum value creation while, at the time, keeping a lid on risks and costs. Portfolio management describes services and projects as in terms of business value, articulating business needs and the service provider's response to those needs.

Table 3: Approaches to quantify or measure improvements

Having this information, it is easier for a manager to make informed and just-in-time decisions. Furthermore, it becomes possible to prioritize improvements and make decisions based on the present inefficiency level and on the expected improvement return (Hubert, 2007). To assess the feasibility and risk of the proposed improvements there are other subjects such as Project Management or Requirement Engineering, which we do not cover in our proposal. Afterward we describe the Time-Driven Activity-Based Costing, which we partially used in one of the demonstrations.

Time-Driven Activity-Based Costing

To understand the costing models, some main concepts should be expressed, based on (Kaplan and Anderson, 2007). The first concept is that costs are divided in two main categories: 1) Variable or Direct Costs, which are costs that usually vary linearly with the output volume of products or services, such as the quantity of medicines used during an intervention that depends on the number of patients admitted; 2) Fixed or Overhead Costs, which are costs that do not depend on the output, such as the occupancy costs that is independent of whether there are patients in the healthcare unit or not as space still needs to be paid.

The previous categories can also fall into two other categories: 1) Functional Costs, which are the ones directly related to the product that is presented to the final customer (e.g. sold medicine); 2) Support Costs, which are costs that although they do not produce anything outside the company's sphere, their output is necessary for functional departments (e.g. management or IT costs).

Finally, the concept of total cost or product cost, which is concerned with all the costs involved with achieving some objective for example making a particular product. Although a very large number of costing models exist, we will only focus on the Time-Driven Activity-Based Costing (TDABC) methodology, which appears as an improvement to the ABC with the purpose of solving or mitigating the major problems encountered in it.

TDABC proposes a set of activities that considers: 1) Identification of **resources**, which are the materials our human resources (e.g. medicine or physician); 2) Allocate resources to **activities**, which are specific deed or actions performed inside the company (e.g. registering a patient); 3) Use activities in **cost objects (products)**, which calculates a cost rate that reflects the cost of each department that executes an activity, calculated by dividing the cost of capacity supplied (cost of all resources used by department) by the real capacity, as shown in the next equation:

$$\text{Cost rate} = \frac{\text{Cost of capacity Supplied}}{\text{Practical Capacity}}$$

After having all the cost rates, one needs to model activities and allocate resources to them. TDABC introduces the concept of **time-equations**, which represents for each activity the time of the department used by that activity, as well as all the possible combinations of that activity. Finally, to calculate the costs of a specific period, one needs to use the already defined time-equations and, for each transaction, see which conditions apply in the time-equation to obtain the total amount of time. After obtaining the time, the calculation is obtained by **multiplying the time by the previously calculated** cost rate. For further reading we refer (Kaplan and Anderson, 2007; Kaplan and Porter, 2011).

2.3 Organizational Design and Engineering

Organizational Design and Engineering stresses the importance and need of continuously updated and updatable models of the organization. In this context, authors identify the Enterprise Architecture (EA) and Organizational Engineering (OE) as two main disciplines to describe organizations, understand relationships and dependencies between the enterprise elements, manage its transformation process, deal with their representation, and to identify best practices and business patterns (Tribolet, Winter and Caetano, 2005; Gama et al., 2007; Laudon and Laudon, 2010).

The EA is considered a consistent and coherent set of principles and standards that guides the system design. Thus, it plays a main role in guiding the system function and its development processes, in particular: the (1) enterprise design process, since it guides the construction of coherent and consistent constructional models; and the (2) engineering process, since it guides the transition to the construction models that can be implemented (Henriques, Tribolet and Hoogervorst, 2010).

The OE focuses on the management of organizational changes, providing methods and tools to align the business processes with the strategic goals of an organization and the requirements posed. In response to the need of OE, the enterprise redesign and BPR turn out to be two main concepts. They are considered a way to improve the business processes that govern a company, to build a more integrated view between the enterprise elements, and to rethink the business to overcome or respond to the competitive forces just mentioned (Tribolet, Winter and Caetano, 2005; Gama et al., 2007).

The enterprise design is based on the generation of representations and architectures, which describe the business perceived by some actor (Wegner and Goldin, 1999). These representations have various definitions, each of which giving emphasis on what it should represent and model, in order to provide a holistic view of the organization, facilitate human understanding and communication, and support BPR. Authors have showed that these representations can affect the ease of understanding a problem, which subsequently affects problem-solving performance. Furthermore, they demonstrated that problem solving on an insight problem became significantly easier when subjects chose an appropriate representation (Kaplan and Simon, 1990; Caetano, 2008).

Taken together, the above evidence suggests that how a process is represented can be crucial to the success of any task. What gets represented by the process designers, and the language through which they discuss and manipulate the process, determine the focus of the problem, thereby affecting the design process itself as well as the final product (Caetano, Assis and Tribolet, 2011). Therefore, in the next sections we provide some background on EA and we introduce some Business Process Modeling Languages.

2.3.1 Enterprise Architecture

The Enterprise Architecture (EA) has been used in literature with different connotations, and associated with different enterprise areas, such as BPR and Quality Management. It is considered a consistent and coherent set of principles and standards that guides the system design. Other than that, AE constitutes a discipline that contributes for the alignment between strategic and operational decisions that are necessary for implementing the strategy. It should be like a plan on how organizations should avoid threats, and how to take advantage of the business opportunities. Its overview should be used as a starting point to outline specific initiatives on the organization, whether in terms of processes, organizational structure or information structure (Pascoa, 2012).

There are examples in the management of the healthcare system in which the EA was used to manage a transformation process. In the ***Hospitais Universitários de Coimbra*** (Coimbra Hospital) a generic architecture for the healthcare delivery was proposed to face problems like the inconsistency of clinical information, the low interoperability between different healthcare units, the absence of a common rule to identify patients, and the existent barriers to the information sharing. To overcome these problems, a methodology was created to design the different types of architectures: technology, application, information, and business architectures (Vasconcelos et al., 2005).

As result, a new architecture was obtained where the business processes were defined and schematized, they categorized six services that could be better aligned to improve their collaboration, and they identified that only four information systems would be strictly necessary, instead of having many different applications in the whole healthcare units. Finally, this research identified suggestions on how to provide better healthcare services and improve resource usage (Vasconcelos et al., 2005).

Another major topic related with the EA is the **Information Quality (IQ)**. With the increasing business network, information exchange across organizations becomes a significant routine (also in the healthcare system). IQ Assessment and analysis of the exchanged information therefore is an important topic for academic and practical research work. Organizations have been increasingly investing in technology to collect and process information. Even so, they often find themselves stymied in their efforts to effectively use the information to improve business operation (Madnick et al., 2009).

Following this, academic and practitioner researchers have produced several generic IQ frameworks. That is, they are intended to be applied to a very broad class of information systems (Lee et al., 2002; Cappiello et al., 2006). As the trend of Information Systems have been migrating from hierarchical to a more cooperative based structure, the issue of IQ has become more complex and controversial as a consequence of this revolution. In the cooperative information systems, complex information exchanges processes within different operating sources are involved. As a consequence, the overall quality of the information flows across organizations can lower over time if there is no control over the quality of both information exchange processes and the information itself.

The literature provides a wide range of techniques to assess and improve the quality of information (Xie and Helfert, 2011). Overtime, these techniques have evolved to cope with the increasing complexity of IQ in the information systems. For the purpose of this paper, as part of the demonstration in the PHC (Section 4.3), we assessed the IQ in a healthcare service. The most commonly addressed steps of the assessment are *information analysis*, *IQ dimension identification*, and *measurement of quality*. For further information on IQ methodologies we refer some previous publications (Xie and Helfert, 2011; Dias et al., 2012).

According to (Ge and Helfert, 2008), IQ assessment is defined as the process of assigning numerical or categorical values to IQ dimensions in a given setting. They organize IQ assessment into three layers: the *IQ metric* layer, the *IQ dimension* layer, and *IQ assessment methodology* layer. The IQ metrics represent different IQ problems, and they determine how to evaluate data quality regarding those problems. The IQ dimensions are characteristics of the information such as accuracy, completeness, timeliness, and consistency, among others. These IQ dimensions are connected to corresponding IQ metrics. One dimension can be linked to multiple metrics and vice versa. The IQ assessment methodology layer contains IQ assessment models, frameworks, and methodologies. Components in this layer use a set of IQ dimensions to measure IQ. IQ assessment methodology employs a set of IQ dimensions, which are linked to different IQ metrics (Dias et al., 2012).

2.3.2 Business Process Modeling Languages

Business process modeling realizes a wide range of ends, such as facilitating human understanding and communication, supporting process redesign and reengineering through the process analysis, automating the execution of business processes, and facilitating coordinated business and system development by keeping the alignment between processes and their support systems. It entails capturing the essential concepts, their responsibilities, and meaningful relationships (Caetano, 2008).

Business process models can be represented using different standards, notations, languages and tools. Some standard process modeling methods are the UML Modeling Language (Rambaugh, Jacobson and Booch, 1999), ArchiMate (The Open Group, 2009), Petri Nets (Van Hee, 1994), BPMN (OMG, 2011), or even ad-hoc diagrams with some notion of activity. These workflow-oriented models show the sequence of activities to be performed and the actors doing so. Thus, a process model shows how a particular business case should be carried out (Caetano, Assis and Tribolet, 2011).

Next we present examples of business process modeling languages. Their descriptions are not meant to be exhaustive but representative of the different approaches that are usually used to study and reengineer organizations.

Business Process Modeling Notation

Business Process Modeling Notation (BPMN) is a graphical notation for drawing business processes flows, especially at the level of domain analysis and high-level design, which can be used for the modeling and redesign of organizations. Its diagrams can be used to represent various actions and models, and it gives a deep representation of the reality (OMG, 2011).

The primary goal of BPMN is to provide a notation that is understood by the stakeholders, the business analysts, the technical developers, and the business managers. Thus, it creates a standardized bridge for the gap between the business process design and implementation (Dijkman, Dumas and Ouyang, 2008). Another advantage is that it provides a small set of notation categories, so that the reader can easily recognize the basic types, which can be found in (White, 2004; OMG, 2011).

However, this traditional way to model processes draw events, activities and data in a sequence of symbols that may not represent completely all the actions in presence and, above all, does not detect and identify consistency between actors and actions (Pascoa, Tribolet and Sousa, 2009). Other than that, BPMN does not provide the means to assess the actual consistency and completeness of a business process, due to the lack of a formal theoretical foundation (Caetano, Assis and Tribolet, 2011). Another disadvantage is the weak hierarchical structure offered by the BPMN, the misunderstanding between several elements and types of definition, limited potential for verification, message-oriented approach, and modeling of multi-party collaborations (Nuffel, 2007).

ArchiMate

ArchiMate is a language for modeling EAs in accordance with a meta model and a conceptual framework of modeling concepts, called the Archimate Framwork. It is based on the descriptive notion of architecture, which means that EA in ArchiMate corresponds to a conceptual model of the business processes in the enterprise (Ettema and Dietz, 2009).

In Figure 6 is exhibited the ArchiMate Framework, which is composed by three layers: the business layer, the application layer, and the technology layer. The first one offers services to external customers, which are realized by business processes. The second one supports the business layer with application services, which are realized by application components. Finally, the third one offers infrastructural services to run the application components, which are realized by technological components, such as hardware and software (Ettema and Dietz, 2009; The Open Group, 2009).

On the horizontal axis from the same figure, three major aspects are distinguished: passive structure, behavior, and active structure. The first one is related to the discipline of information system engineering. The last two are referred to generic system aspects. This allows ArchiMate to distinguish between business processes and business functions. While the former is a collection of causally related units of internal behavior, the latter groups behavior according to, for instance, required skills, knowledge, and resources, among others (Ettema and Dietz, 2009).

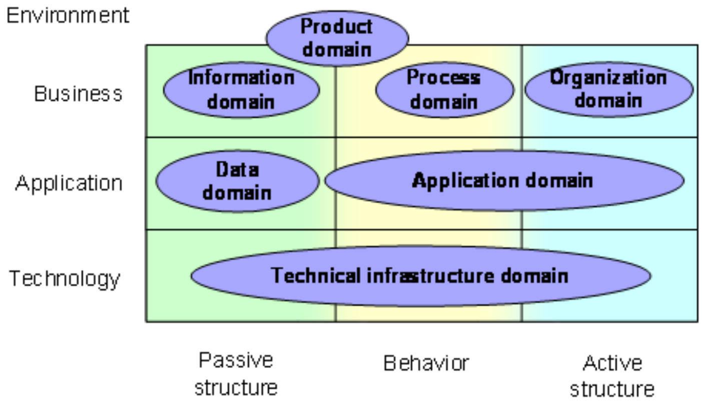

Figure 6: The ArchiMate Framework (The Open Group, 2009)

Hence, ArchiMate is considered to be comprehensive enough to provide a good structuring mechanism for architecture domains, layers, and aspects. It incorporates modern ideas of the "service orientations" paradigm that promotes a new organizing principle in terms of business, application, and infrastructure services for organizations. Moreover, it is considered to resemble the UML, but on the other hand it is considered much lighter, more intuitive, and more expressive, allowing the modeling of all layers and aspects of an organization in an integrated way (The Open Group, 2009).

Nevertheless, ArchiMate is considered to lack a rigorous theoretical foundation and its semantics are basically undefined, which unavoidably leads to miscommunication among ArchiMate users. Other than that, its diagrams are not concise and essential, because they represent too much information making it difficult to analyze the business as a whole (Ettema and Dietz, 2009).

2.4 Enterprise Ontology

The term "**Ontology**", dated from 1721, in its abstract philosophical notation can be defined as a branch of metaphysics concerned with the nature and relations of being (Merriam-Webster, 2012). Its notion has been used in several disciplines as a form of knowledge representation about the world or some part of it, or a specification of a shared conceptualization. In our thesis context, the purpose of ontology is the specification of a conceptualization for describing and understanding the construction and operation of the enterprise system, inline with previous researches (Henriques, 2010).

The **Enterprise Ontology** (EO), an ontology designed towards organizations, is a collection of terms and definitions relevant to business enterprises modeling and provides a formal way to define a particular domain. It has its roots in the Performance in Social Interaction Theory (PSI-Theory), which provides an explanation of the construction and operation of organizations at the level of human interactions, allowing a better understanding of the operation (Pascoa, 2012).

Dietz brings a complementary view on the EO, in which the ontology is viewed as the “highest level” conceptual model produced by the enterprise design process that is fully independent of the enterprise implementation, while at the “lowest level” there is the implementation model (Dietz and Hoogervorst, 2008). Furthermore, in his book he claims that the ontology is a conceptual model that satisfies five requirements: coherent, comprehensive, consistent, concise, and essential (Dietz, 2006), contrasting with some of the drawbacks identified in previous presented methodologies in this chapter.

Based on the EO theories, the **Design and Engineering Methodology for Organizations** (DEMO) is deemed able to provide a structured working approach for BPR by layering the organization into three parts, and focusing only on the one that refers directly to the complete knowledge and essence (or “highest level”) of the enterprise. This layer, known as the *Ontological* or *Essential Layer*, is completely independent on the way a system is implemented, being all the rest considered *realization* and *implementation*. Focusing only on the essence conducts to a reduction in the complexity of the obtained diagrams, considered in over 90% (Dietz and Hoogervorst, 2008).

For example, fifteen years ago a patient registration could differ strongly from the one performed today. Procedures were certainly changed, but the essence always stayed the same: contracts and responsibilities are entered into and complied with, between the patient and the secretary. Only the implementation of the registration service has really changed. That’s why using EO to identify and describe those contracts and responsibilities is crucial to give another perspective about the healthcare improvement and redesign.

As we can see in Figure 7, changes to the *Essential Layer* are the most drastic ones, since they also affect the organization’s *Informational* and *Documental* structures, which are the other two layers considered in DEMO. All the three systems belong to the category of social systems in the sense that the elements are subjects that “enter and comply with commitments towards each other”, changing only the production type (i.e. information or data) (Dietz, 2006).

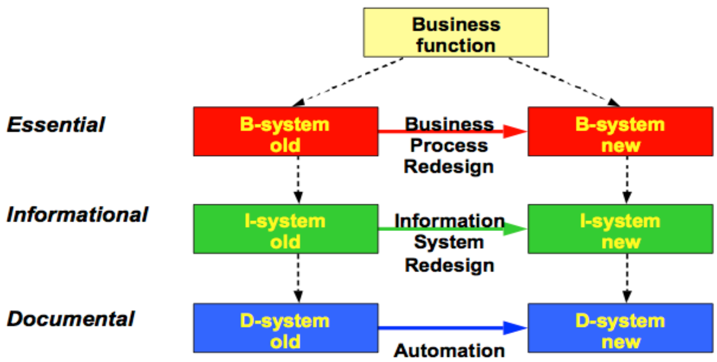

Figure 7: The layered transformation activities of enterprises (Reijswoud, Mulder and Dietz, 1999)

There are also some examples in the healthcare system in which EO was applied to study its internal transactions and simplify their analysis. These contributions validated that EO avoids the lack of integration among the various enterprise elements at the design level and produces strong enterprise construction models (Maij et al., 2000; Habing, Dietz and Zwetsloot-Schonk, 2001; Maij et al., 2002). In addition, we can find examples of using EO to improve operational processes (Reijswoud, Mulder and Dietz, 1999), among other successful validations (DEMO Publications, 2012).

The following sub-sections describe the PSI-Theory, the theory that supports EO, and the DEMO Methodology, which is used for modeling and redesigning organizations. All concepts described are based on (Dietz, 2006).

2.4.1 The PSI-Theory

The PSI-Theory is the theory that underlines the notion of EO (Dietz, 2006). It consists of four axioms and one theorem, which we describe in the following sections.

The Operation Axiom

The first axiom states that the operation of an enterprise is constituted by the activities of actor roles, which are elementary chunks of authority and responsibility, fulfilled by subjects. In doing so, these subjects perform two kinds of acts: *production acts* (P-acts) and *coordination acts* (C-acts). By performing P-acts, the actors contribute to bringing about the goods or services delivered to the environment of the enterprise. However, by performing C-acts, actors enter into, and comply with, commitments and agreements towards each other regarding the performance of P-acts. The result of successfully performing a P-act is a *production fact* (P-fact), and the same applies to a C-act, creating a *coordination fact* (C-fact). The Operation Axiom is illustrated in Figure 8.

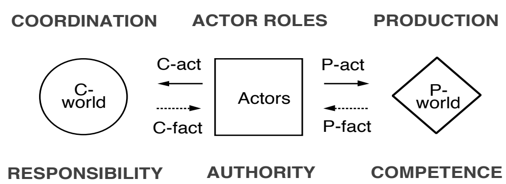

Figure 8: Graphical representation of the Operation Axiom (Dietz, 2006)

The realization of a P-act is inherently either material or immaterial. Examples of material acts are all manufacturing acts, as well as storage and transportation acts. The immaterial ones can be the judgment by a court to sentence someone, the decision to grant an insurance claim, and the appointment of someone as president (Dietz, 2006).

The Transaction Axiom

The Transaction Axiom states that C-acts are performed as steps in universal patterns. These patterns, also called transactions, always involve two actor roles (initiator and executor) and are aimed at achieving a particular result. The basic transaction pattern is shown in Figure 9.

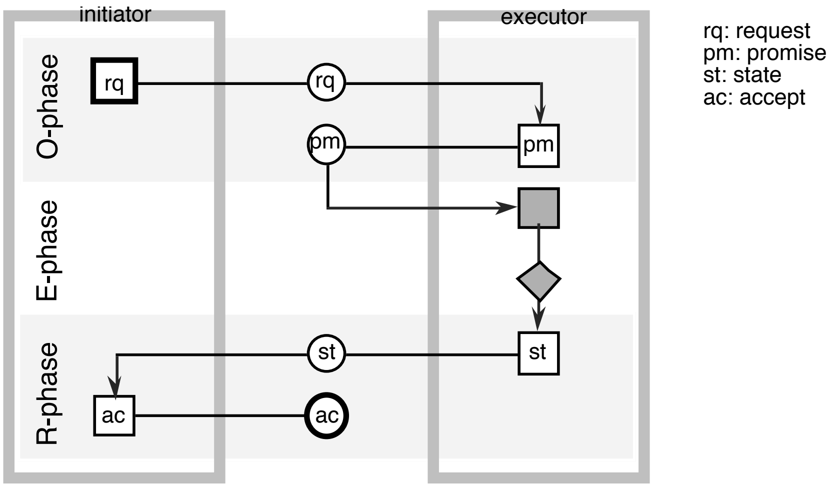

Figure 9: The basic pattern of a transaction with caption (Dietz, 2006)

A transaction is developed in three phases: the *order phase* (O-phase), the *execution phase* (E-phase), and the *result phase* (R-phase). In the O-phase the two actors agree on the expected result of the transaction; in the E-phase the executor executes the production act needed to create the anticipated result; and in the R-phase the two actors discuss if the transaction result is equal to the expected one. In other words, during the Transaction Axiom the initiator and the executor work to reach an agreement about the production fact. Only if this agreement is reached will the production fact come into existence.

The Composition Axiom

The Composition Axiom establishes the relationships between transactions, providing the basis for a well-founded definition of the notion of business process, which states that a business process is a collection of related transaction types. This axiom states that every transaction is either: A) Enclosed in another transaction; B) Is a customer transaction of another transaction; or C) Is a self-activation transaction. The latter case refers to transactions that give rise to further ones of the same types.

This axiom is illustrated in Figure 10, which shows that in order to execute transaction T1, the next one has to be done. For example, to handle a medical problem of a patient (T1), it may be necessary to perform examinations (T2).

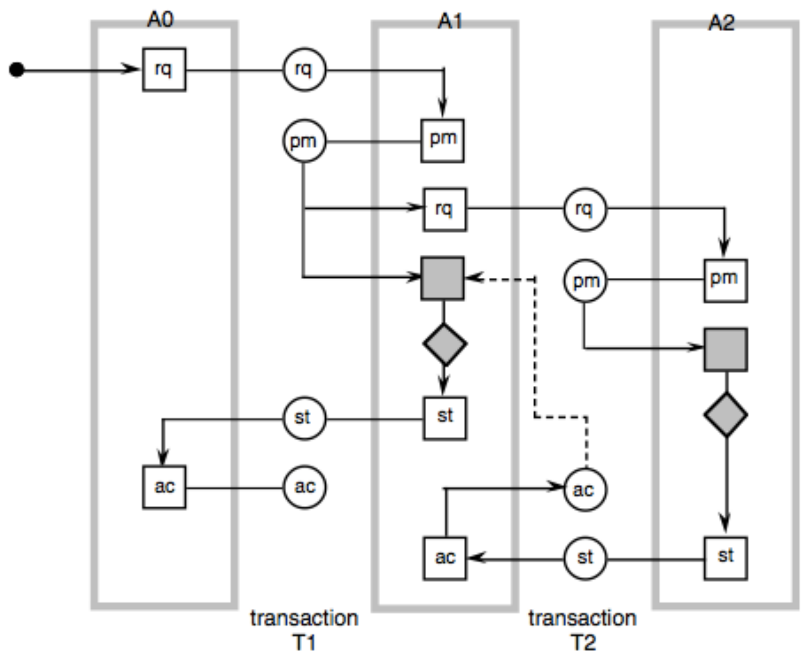

Figure 10: The structure of enclosing a transaction (Dietz, 2006)

The Distinction Axiom

The fourth axiom states that there are three distinct human abilities playing a role in the operation of actors. These are called *performa*, *informa* and *forma*, which are exerted both in C-acts and P-acts. The *forma* ability concerns the form aspects of communication and information (*datalogical layer*); the *informa* ability is related to the content aspects of communication and information, fully abstracting from the form aspects (*infological layer*); the *performa* ability concerns the creation of new, original things, directly or indirectly by communication (*ontological layer*). This last ability is regarded as the essential human ability for doing business. The Distinction Axiom is depicted in Figure 11.

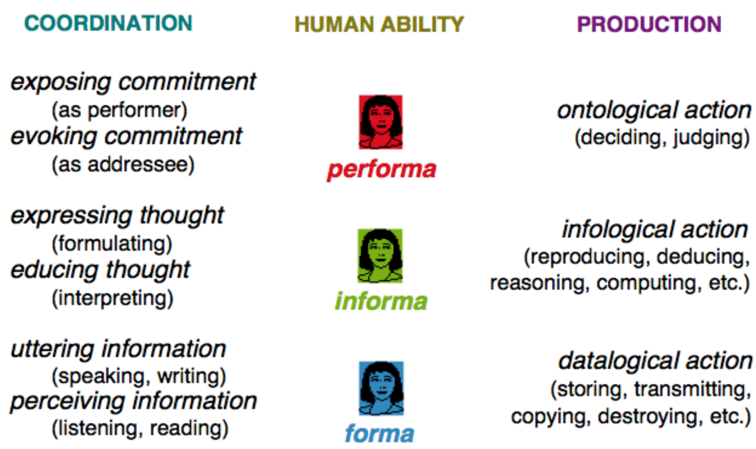

Figure 11: Summary of the Distinction Axiom (Dietz, 2006)

It should be noted that the transactions constituted by *ontological acts* are called *ontological* transactions (B-transactions), while transactions constituted by *infological* and *datalogical acts* are called *infological* transactions (I-transactions) e *datalogical* transactions (D-transactions), respectively.

The Organizational Theorem

The organization theorem is a combination of the axioms described above into one concise, comprehensive, coherent and consistent notion of the enterprise (Dietz, 2006). This theorem, represented below in Figure 12, states that an organization is a heterogeneous system constituted as the layered integration of three homogeneous (social) systems: the B-organization (from business), the I-organization (from intellect), and the D-organization (from document).

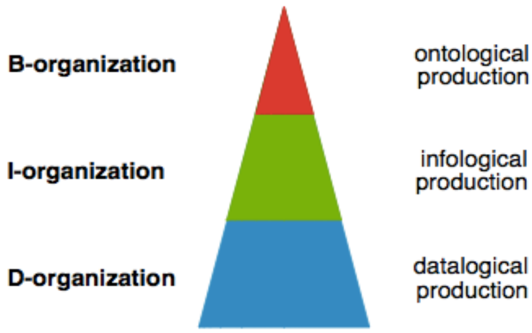

Figure 12: Representation of the Organizational Theorem (Dietz, 2006)

The coordination parts of these three systems are similar. They only differ in the kind of production: the B-organization has an *ontological* production, the I-organization has an *inforlogical* production, and the D-organization has a *datalogical* production. It is also possible to see that the D-organization supports the I-organization, and the second one supports the B-organization, which, in its turn, provides a complete knowledge of the essence of the enterprise.

One of the conclusions that we can take from the figure is that in the B-organization lies all the knowledge of the essence of the enterprise. The second conclusion is the narrowing of the layers from the D-organization to the B-organization that shows the proportion of such aspects as the number of C-acts, actor roles and P-acts.

Although EO is typically used to model the essence of the organization, it is possible, when intended, to deep into informational and documental details. In this case, we are considering the three layers, corresponding to the entire knowledge of the organization. This can be useful if one would like to deepen some implementation issue.

We just gave a short summary of the EO and discussed the relevant parts for the proposal. A complete overview of the theory is available in the book and papers (Dietz, 2006; DEMO Publications, 2012). This theory is widely accepted in the scientific community, with many published articles.

2.4.2 The DEMO Methodology

DEMO is a methodology for modeling, (re)designing, (re)engineering organizations and networks of organizations, which consists of four aspect models represented by particular diagrams, lists and tables, as illustrated in Figure 13.

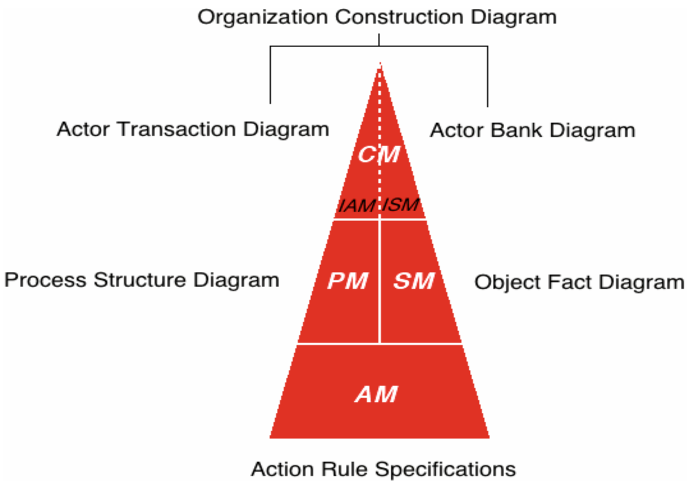

Figure 13: The ontological triangle, with aspects models and diagrams of DEMO (Dietz, 2006)

The Construction Model

The Construction Model (CM) specifies the identified transaction types and associated actor roles, as well as the information links between the actor roles and the information banks. In other words, it specifies the composition, environment, and structure of an organization, occupies the top of the triangle and it constitutes the complete ontological knowledge of an organization.

Within this model, there is the Interaction Model (IAM) that shows the active influences between the actor roles (i.e. the execution of transactions), which is expressed in an Actor Transaction Diagram (ATD) and a Transaction Result Table. In addition, there is the Interstiction Model (ISM) that shows the passive influences between actor roles (i.e. the taking into account by an actor role of existing facts when being active), which consists of an Actor Bank Diagram (ABD) and a Bank Contents Table. Usually the ABD is drawn as an extension of the ATD, and together they constitute the Organization Construction Diagram. In Appendix A we present legend of the ATD diagrams.

In the ATD, the composition and the environment are both a set of actor roles. By convention, we will always draw environmental actor roles as composite actor roles, even if we happen to know that an actor role is elementary. The reason for doing this is that generally we do not know whether an environmental actor role is elementary or composite. Moreover, we do not care: our interest is in the kernel of the organization. We start with modeling this kernel as one composite actor role. The resulting CM is usually referred to as the global CM of an organization. Likewise, the CM in which the kernel contains only elementary actor roles is called the detailed CM. The boundary divides the set of all (relevant) actor roles into the composition and the environment.

The Process Model

The Process Model (PM) of an organization is the specification of the state space and the transition space of the Coordination Worlds (C-world), thus, the set of lawful or possible or allowed sequences of states in the C-world. PM contains, for every transaction type in the CM, the specific transaction pattern of the transaction type. It also contains the causal and conditional relationships between transactions, which determine, in addition to the transaction patterns, the possible trajectories in the C-world. PM is expressed in a Process Structure Diagram (PSD) and an Information Use Table (IUT). In Appendix A we present legend of the PSD diagrams.

The PSD of a business process should be understood as the complete specification of the steps in a business process that an enterprise wants to monitor or control. As such, the PSD of a business process is the right starting point for the design of workflow support systems.

The State Model

The State Model (SM) specifies the state space of the Production World (*P-world*): the object classes, the fact types, and the result types, as well as the existential laws that hold (*ontological* coexistence rules). It also adds some details to the CM, namely the contents of the information banks. Furthermore, it is important to note that SM may allow one to visualize and measure IQ dimensions described in Section 2.3.1, since it is the source of ontological knowledge about the production world, which is considered a suitable starting point for developing and maintaining the information architecture. It is considered a *truly objective model* as only the information items that are relevant for the operation of the organization are included, contrasting with other methodologies that include information wished by users (Dietz, 2006).

SM is expressed in an Object Fact Diagram (OFD) and an Object Property List (OPL), which are considered the ideal starting point for developing and maintaining the data dictionary of an enterprise. The OPL is just a convenient way of specifying fact types that are proper mathematical functions, and of which the range is a set of values. One may as well specify them in an OFD, but that would make the OFD unnecessarily voluminous. The fact types in an OPL are called properties (of object classes). In Appendix A we present the legend of the OFD.

The contents of both the OFD and OPL of an organization are completely determined by its Action Model presented below. This makes the SM of an organization a truly objective model: only the information items that are relevant for the operation of the organization are included. This is in sharp contrast to the current practice in requirements engineering, in which the information wishes of users are collected. This way of working, which we like to infer to as the waiter strategy, leads on the one hand to incompleteness (absence of necessary information) and on the other hand to over completeness (presence of unnecessary information).

The Action Model

The Action Model (AM) specifies the action rules that serve as guidelines for the actors in dealing with every coordination step, which are grouped according to the distinguished actor roles. It is the most detailed and comprehensive aspect model, and is also atomic on the ontological level. Strictly speaking, the other three aspect models (PM, SM and CM) are derived from the AM, although it is practically convenient to follow the sequence that we adopt. AM is expressed in the Action Rule Specifications.

2.5 Summary

In this chapter we introduced the related work and the needed theoretical background for this thesis. To start with, the first section covers the healthcare management as a set of principles and practices considered essential to any healthcare improvement process. Most of the practices described in this section are not tied to any methodology, being created and implemented for specific problems or tasks. Consequently, they do not consider an integrated view among the enterprise elements, and there is a lack of vision to deal with the enterprise dynamics due to the inexistent enterprise construction models. However, these practices come from the accumulated experience, can be implemented along with other methodologies, and some of them report good results.

The Quality Management is then introduced to explain the concepts of enterprise transformation, continuous improvement, and improvement quantification. Following this, different methodologies are presented, particularly Lean, which is considered one of the most used methodologies in the management of the healthcare system, is typically grounded in the PDCA Operating Framework, and focus on the waste removal to deliver an improved flow time. Some of the benefits of these methodologies are the elimination of wasteful activities, reduction of errors and service costs, better warehouse management, increased employee motivation and customer satisfaction, among others. On the other hand, some authors point out some drawbacks, such as the high rate of failed implementations, the degradation or mischaracterization of services, and the loss of organization's essence. In addition, this section presents the Improvement Quantification describing some different approaches that help to make decisions and prioritize improvements based on the expected return.

The Organizational Design and Engineering is then presented as a main subject to describe organizations, understand relationships and dependencies between the enterprise elements, manage its transformation process, deal with their representation, and identify best practices and business patterns. In this context, three main disciplines are presented: EA, OE, and Business Process Modeling Notations. These disciplines are reported to mitigate some of the previous identified problems, such as the alignment between the business processes with the strategic goals of an organization, the engineering process through the transition to the construction models that can be implemented, and the loss of organization's essence. However, some methodologies for itself do not guarantee the integration among the various enterprise elements at the design level, the ability to deal with self-awareness or the enterprise dynamics, and there is a high failure rate in the BPR.

Finally, the EO is presented as a collection of terms and definitions relevant to business enterprise modeling, and to provide a formal way to define a particular domain. Furthermore, its design process is considered independent of the enterprise implementation, and to provide a structured working approach for BPR. Furthermore, EO is considered to provide a better understanding of the dynamics of an organization, is considered to have a strong and well-formed theory, and allows a good alignment between the enterprise design and the enterprise operation. For example, there are authors considering that EO provides means to assess the actual consistency, coherency, comprehensiveness, conciseness, and essentialness of its models.

Chapter 3

Proposal

This chapter belongs to the *definition of the objectives for the solution*, and to the *design and development* steps of DSRM, in which we infer the goals of the solution and present a DSRM artifact method, respectively. Therefore, we start describing our goals for the solution (Section 3.1). Then, we present a brief discussion about why we chose EO for the proposal (Section 3.2). Finally, we present the DSRM artifact method to address the identified problem (Section 3.3).

3.1 Objectives of the Solution

In order to overcome the problem statement about the inefficiency and unsustainability of the healthcare system, different approaches were presented, such as healthcare management solutions, methodologies used for the quality management and continuous improvement, enterprise engineering and design solutions, and the EO, among other theories and methodologies.

Although the identified healthcare problems could be addressed with some of these theories and methods, some authors still argue that there is not a reliable method to solve them (Dietz and Hoogervorst, 2008). It is estimated that over 70% of strategic initiatives such as TQM, BPR, and Six Sigma, among others, tend to fail (Mintzberg, 1994; Lifvergren et al., 2010).

In this context, three main reasons are addressed: 1) The lack of integration among the various enterprise elements at the design level; 2) The inability to deal with the enterprise dynamics at the operational level due to weak enterprise construction models; and 3) The need to encourage management practices that advocates the development of self-awareness within the organization (Aveiro, 2009; Henriques, Tribolet and Hoogervorst, 2010).

Dietz also adds that the current literature on enterprise engineering consists merely of best practices, without an integrating theory and a clear definition of the field (Dietz, 2006). Inline with that conclusion, *Caetano et al.* demonstrated that when comparing BPMN and DEMO models, there was a set of implicit and missing actions in BPMN, proving that it does not provide means to assess the actual consistency and completeness of a business process, due to the lack of formal semantics and unclear construct description (Caetano, Assis and Tribolet, 2011).

Following this, our research seeks to define an artifact method based on the theories of EO because of the strengths described previously, namely the properties of correctness and completeness it assures in its models, contrasting with BPMN, and the properties of essentialness and conciseness, which help to construct and analyze (more) models, making it possible to design the healthcare system and seek for inter-organizational cooperation improvements between its units. Furthermore, because the designs are also considered coherent, comprehensive and consistent, this gives strength to the obtained models, as described in (Dietz, 2006). Further reasons describing why we use EO are described in Section 3.2.

In addition, to take advantage from some already proven benefits from Lean for the Quality Management and Continuous Improvement, particularly in the healthcare system, we intend to combine the analysis from EO with the improvement identification from Lean. This way, the EO may be considered as input for the Plan step of the PDCA Operating Framework, to help with the identification of opportunities. In other words, from DEMO models one may identify improvements (as suggested in the Plan step), and in the end produce and Organization Redesign model that reflects the change plan. To identify improvements one should consider the existing standards on Healthcare Management, BPR, and Improvement Quantification (Chapter 2). Afterwards, one should continue with the next steps from the PDCA cycle (Do, Check and Act), but these ones are out of our scope for this thesis, as they need the creation of prototypes and implementation in a broader scale.

In short, our main objective is to **propose a method based on Enterprise Ontology to find non value-added transactions, and redesign them to improve the healthcare management.**

Other goals are to demonstrate, evaluate and communicate the artifact, to show its efficiency and efficacy. To do that are applying the proposal to different units of the National Health System, such as the ED, Pharmacy, and PHC, since they can be considered representative of the healthcare system in terms of actors, stakeholders, roles, processes, and they share a large part of the problems identified in Chapter 1 (Williams, 1996; Christensen, Grossman and Hwang, 2009). Besides the possible improvements in each healthcare unit, we are also interested in analyzing the interactions between them so that we can conclude how they can improve cooperation, as part of the demonstration.

3.2 Why Enterprise Ontology?

There is a wide set of formal languages and respective methodologies that can be used to redesign or reengineer organizations. Notwithstanding, our motivations to choose this methodology were that EO has a strong and well-formed theory, provides a better understanding of the dynamics of an organization, and allows a good alignment between the enterprise design and the enterprise operation, which leads to an improved self-awareness within the healthcare organizations. Furthermore, it focuses only on the essence, leads to differentiated and well-grounded improvements, and therefore enables a structured working approach for BPR. It is regarded as producing models considered coherent, comprehensive, consistent, concise and essential (as described in Section 2.4).

All these drivers mean that the produced models are considered to be correct (coherency and consistency), consequently practitioners may easily accept them, which in turn helps to frame discussions about the redesign of healthcare organizations. Furthermore, since its models are considered essential and concise, it is possible to analyze more healthcare units to improve their inter-organizational cooperation, finding gaps in the patient's handling and overlapping transactions. This conclusion is inline with previous researches described in the Related Work (Section 2.4), which describe that EO may help to simplify the analysis of healthcare services by producing strong enterprise construction models, and these models are considered suitable for BPR.

Other than that, EO clearly defines three notions that we considered relevant in governing the enterprise dynamics and to identify improvements in the healthcare system: competence, authority, and responsibility, as explained in the Operation Axiom (Dietz, 2006). Most of these notions are absent or not clear defined in other enterprise modeling techniques (Dietz, 2006; Henriques, 2010). This improved understanding is also possible since EO only focus on the essence of the organization, which leads to a reduction in the complexity of the obtained diagrams of over 90%, and conducts to the most drastic changes that affect the whole organization structures (as explained in Section 2.4).

3.3 Proposed Artifact Method

This section belongs to the *design and development* step of DSRM, in which we present a *different* artifact (Österle et al., 2011) to identify innovations to improve the healthcare management. It considers the contributions from EO (Dietz, 2006), some additional steps from a Lean proposal (García-Porres, J; et al., 2008), and also some concepts from healthcare management and BPR (from Chapter 2) as input for the improvement identification as Lean suggests (Womack and Jones, 2003).

The proposal starts with the **Modeling Phase,** which uses EO to study the organization and its processes. To construct its diagrams, it consists of a defined sequence of steps (illustrated in Figure 14) that begins with a textual or process representation of an organization, and ends with an aspect model. As result, this phase provides a structured working approach by layering the organization into three parts, and focusing only on the one that directly refers to the complete knowledge of the organization and independent of the implementation – the *Ontological Layer*. In this research we will focus on the *Construction*, *Process* and State Model*s*.

Then it continues with the **Innovation Phase**, which is based on four additional steps from Lean to assist in the Continuous Improvement and the Quality Management processes. These steps consist on the Plan step of the Lean Operating Framework (known as PDCA) that recognizes an opportunity and plans the change (Womack and Jones, 2003). Therefore, this phase identifies possible improvements from the previous models, prioritizes them in terms of impact and feasibility, and then proposes redesigned models for the organization. As result, this phase gives the appropriate tackle to handle the transformation process, and helps to choose the most profitable improvements first.

Figure 14 illustrates the proposal including its inputs and outputs. Then we explain each step in detail.

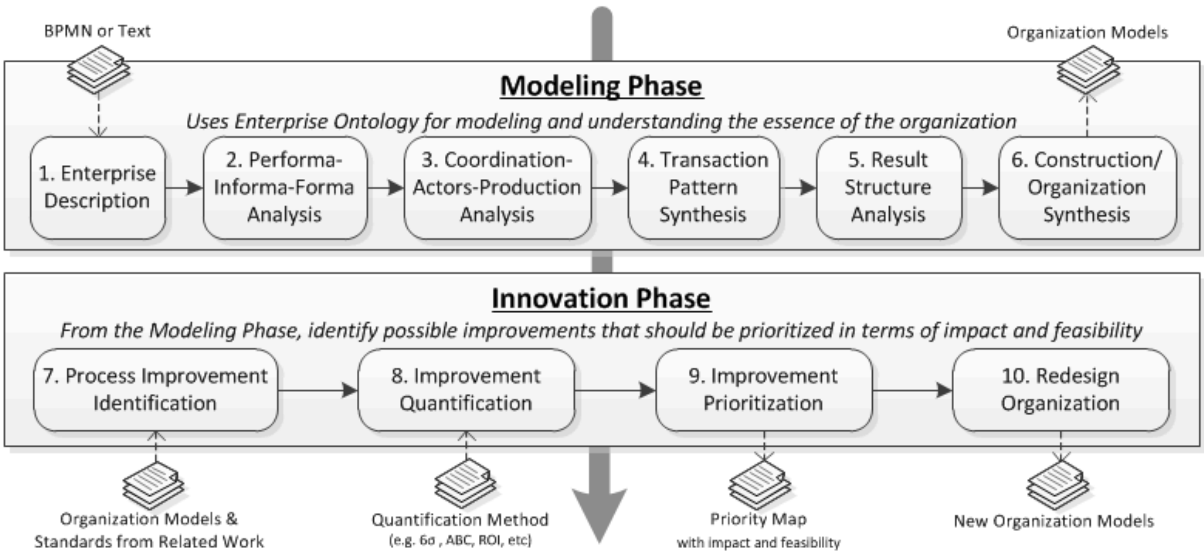

Figure 14: Graphical representation of the proposed method (DSRM artifact)

The Modeling Phase is composed by the following steps:

1. **Enterprise Description:** in this step a textual or process representation describes the actions performed in the organization. This description should be based in available documentation or written by someone who has enough knowledge about the activities performed. To ensure its validity, the description should be impartial, objective and focused on facts;
2. **Performa-Informa-Forma Analysis:** using the previous step, it identifies the three kinds of human abilities (*Performa*, *Informa* and *Forma*) performed, according to the Distinction Axiom, in the context of the organization;
3. **Coordination-Actors-Production Analysis:** the identified *Performa* items are divided into C-acts/facts, P-acts/facts and actor roles who perform those acts, according to the Operation Axiom. Here occurs the reduction of complexity relatively to other methodologies, because from now on, only the identified *Performa* abilities are considered;
4. **Transaction Pattern Synthesis:** the identified C-acts/facts and P-acts/facts are clustered into transactions types together with the corresponding result, according to the Transaction Axiom.

For each identified transaction type, the production fact created should be precisely formulated assigning variables to identify each entity;

5. **Result Structure Analysis:** check if there are any dependencies between the transaction types identified in the previous step. Generally, these dependencies occur when the executor of a transaction is the initiator of another (internal) one, as explained in the Composition Axiom. These dependencies can be identified by reading the enterprise description again;
6. **Construction Synthesis:** identification of the initiator and executor roles of each transaction type, and development of the corresponding graphical representation. Different models can be obtained such as the *Construction*, *Process* and State Model*s*. Their main diagrams are:
    - **Actor Transaction Diagram (ATD)**: identification of the initiator and executor actor roles of each transaction type and development of the corresponding representation. Afterwards, it is possible to identify the interaction structure of the organization;
    - **Process Structure Diagram (PSD)**: modeling of the processes inherent to each transaction type acknowledged in the ATD. Its notation is based on the Transaction Axiom, and it also includes the precedence relationships, both causally and conditionally between transaction types, which are used to highlight the communicative commitments;
    - **Object Fact Diagram (OFD):** includes the information items that are relevant for the operation of the organization, including categories, object classes, fact types, and result types.

Finishing the Modeling Phase, one can proceed with the Innovation Phase, or deepen some analysis. As explained in Section 2.4, it is possible to include more information on the Enterprise Description, examine non-*ontological* aspects (e.g. consider specific implementation details), or produce other aspect models. **The Innovation Phase** is composed by the following steps:

7. **Process improvement identification**: identifies improvements from the previous models, as well as from the existing standards, which come from the interviews and the Related Work in Section 2.1. Considering the Construction Synthesis, from the ATD one can identify transactions that do not seem essential and may be removed, changed, or automated. These transactions may be identified with the help of practitioners or literature. Then, using the PSD, one can change the network of communicative commitments to shorten processes, change precedencies, or move conditional relationships, which leads to shorten cycle (and waiting) times. Finally, using the OFD it is possible to make improvements to the information architect-ture. This step is based on (Reijswoud, Mulder and Dietz, 1999; Dietz and Hoogervorst, 2008), which propose four inter-transactional redesign principles subsequently presented:
    - **Deletion and replacement**: the principle of deletion focuses on the question whether all transaction types currently identified in the business system are necessary. The replacement of a transaction type implies a fundamental change to the preposition of the transaction type;
    - **Change of optimal relationships:** this principle assumes that all the identified transaction types are necessary, and focuses on finding the optimal structure of them, changing optional and causal relationships. The application of this principle may result in causal relationships becoming optional. This leads to shorten cycle (or waiting) times;
    - **Advancing initiating points:** inline with the previous technique, the advancement of the point of initiation is concerned with the assumption it can lead to a reduction of the total lead-time;

- **Parallelization of transaction types:** this principle examines the conditional relationships between the start of transaction types and explores the possibility to start others in parallel. This is possible removing conditional relationships that allow one transaction to start before the previous one is finished. The reduction of conditional restrictions improves the parallelization between transactions and prevents deadlocks.

8. **Improvement (or *kaizen*) quantification**: after identifying possible improvements, some metrics must be established to quantify them in terms of feasibility and impact. Some *kaizen* examples can be: time invested in each transaction compared to the total time spent on the whole service, people involved, management frameworks, associated defect, or other analytical methods (e.g. costing models, financial analysis, Six Sigma, etc.). The chosen theory or method is not part of this thesis' scope (one can choose the most suitable);
9. **Improvement prioritization**: in this step improvements are prioritized in terms of impact and feasibility, which helps to choose the most profitable improvements for the available resources. This is then represented in a map divided into four quadrants, being the X-axis the feasibility to accomplish it, and the Y-axis the quantified impact. Each improvement is placed in a particular quadrant, being the ones that fit into the superior diagonal also the ones that are more important to implement (the ones with higher impact and feasibility);
10. **Redesign organization**: after choosing the most profitable improvements the organization is redesigned to include the decisions. Alternatively, one can deepen some analysis by including more information in the Enterprise Description, or producing other aspect models from DEMO.

Having the redesigned organization models with the results from the Innovation Phase, it should be prepared a proposal with specific implementation strategies (i.e. the plan with the needed steps). Afterwards, one should continue with the next steps from the PDCA cycle (Do, Check and Act) to implement the planned changes. The implementation itself is beyond of the scope of this thesis.

Chapter 4

Demonstration

This section corresponds to the *demonstration* step of DSRM. To demonstrate the proposal we applied it to healthcare units including a hospital ED (Section 4.1), a Pharmacy (Section 4.2), and a PHC (Section 4.3). For each demonstration we tried to give more emphasis to different parts of the proposal, and in Section 4.4 the Healthcare Redesign and Summary is presented, with the main conclusions, overlapped transactions, and a proposal for the NHS redesign based on obtained results.

We chose these case applications since the correspondent organizations are considered representative from the healthcare system, and they share the responsibility for the growing problem identified in Chapter 1 (Walshe and Smith, 2010). Our expectations are that by redesigning them and eliminating wasteful transactions, it will be possible to improve the NHS and the healthcare delivery.

To conduct these demonstrations we interviewed different practitioners, namely to obtain input to apply the proposal (enterprise descriptions), feedback about the obtained outputs (models and improvements), and validation on the proposal and its results. This information was collected through field visits on location at each participating organization as well as through follow-up phone and e-mail. Different entities were represented in the interviews such as healthcare units and universities.

4.1 Emergency Department

For this demonstration we applied the method to the internal operation of an ED in a central hospital near Lisbon with more than 100,000 admissions per year. To conduct the demonstration, we interviewed 5 patients and 10 practitioners (the ED director, physicians, nurses, and health services researchers). The following sections describe the application of the proposal, giving more emphasis to the Modeling Phase, on how to apply EO to an organization, to the Construction and Process Models, and finally on how can a costing model help to quantify the improvements.

4.1.1 Modeling Phase

The starting point is called **Enterprise Description** and is characterized by the production of a text describing the actions performed by the service provider, based on documents and interviews. We present the text together with the application of the first two analyses in Table 4.

From this text, we try to distinguish between the *Ontological*, *Inforlogical* and *Datalogical* actions according to the **Performa-Informa-Forma Analysis** step, by using the Distinction Axiom. To do that, we should define a notation to differentiate those actions. In this example, we highlighted text using red, green and blue colors to identify the *Ontological*, *Infological* and *Datalogical* actions, respectively.

We continue with the **Coordination-Actors-Production Analysis**, in which we attempt to identify the *C-acts/facts*, *P-acts/facts* and actor roles, using the Performa (*Ontological*) items identified in the previous step, as stated in the Operation Axiom. We have also considered a notation to differentiate between them: square brackets to identify actor roles, brackets to identify C-acts/facts, and angled brackets to identify P-acts/facts.

Every [patient] arriving at the ED must be <registered> by a [secretary], being (requested) to give some personal information. The secretary writes the data in a registration form and provides an identifier to the patients. After that, they go to a triage room where a [nurse] <triages> them, assigns a priority level, and defines patients routing, giving them a printed wristband. Then, the patients must wait for their turn according their urgency level. Once called, the patients go to a treatment room where a [doctor] <handles their problem>. If necessary, this is followed by a <diagnostic> phase carried out by some internal [examiner], or an <intervention> phase carried out by some [specialist or caregiver]. The intervention depends on the patients' problems. It could be some therapeutic prescription, a chirurgery or other kinds of treatments. At any stage, patients may need to (grant) <permission> to continue the process. In complex situations, this permission must be written. To handle the patients' problems, the physician may also (ask for) <special examinations> such as radiology or lab tests. Some of these exams can be administrated indoor, such as electrocardiograms. Others have to be done outdoors, filling in forms that are sent electronically. Some <interventions> may require other internal specialists, such as minor surgery or orthopedics. These therapies (and also the examinations) may (require) <external stock supply> like medicines or other materials. Finally, the patients are <discharged> by a [nurse or a social assistant] with their problems solved, or they may need follow-up in another [specialty] outside the ED, with an <after-care or specialty consultation> that can be transmitted directly by the caregiver handling the patient. At that time (or during the registration) the patients may (need to) <pay> some taxes, depending on the healthcare system or the owned insurance.
Caption: Actions are colored in red for *Ontological*, green for *Inforlogical*, and blue for *Datalogical*. Square brackets "[ ]" stand for actor roles, brackets "( )" for *C-facts/acts*, and angled "< >" for *P-acts/facts*

Table 4: Enterprise Description with results from the first two analysis and respective captions

After these analyses we define the transactions in the text by clustering the identified *C-acts/facts* and *P-acts/facts* in what is denominated by **Transaction Pattern Synthesis**. The Transaction Axiom is used in this step, since it guarantees that each previously found *P-act/fact* or *C-act/fact* corresponds to a complete transaction. Then, for each previously found transaction type, the result type (i.e. the *P-fact* created) should be correctly and precisely formulated, which can be achieved by identifying an entity uniquely through the use of variables. This result is represented in Table 5.

#	Transaction Types	Initiator	Executor	Result Types
T1	Registering patient	Patient	Registrar	Patient P is registered
T2	Triaging patient	Patient	Triage handler	Patient P is triaged
T3	Handling patient problem	Patient	Patient handler	Patient P is handled
T4	Granting permission	Patient handler	Patient	Permission G is granted
T5	Performing examination	Patient handler	Examiner	Examination E is performed
T6	Delivering means	Examiner	Supplier	Stock S is delivered
T7	Performing intervention	Patient handler	Inter. performer	Intervention I is performed
T8	Delivering means	Inter. performer	Supplier	Stock S is delivered
T9	Performing suppl. exams	Patient handler	Ext. examiner	Examination SE is performed
T10	Consult other specialty	Patient handler	Ext. specialist	Consultation C is performed
T11	Discharging patient	Patient	Discharger	Patient P is discharged
T12	Paying taxes	Registrar	Patient	Taxes T are paid
T13	Managing department	Manager	Manager	Department D is managed

Table 5: Transaction Result Table

After having defined both the transaction types and the respective result types, one must check if there are any dependencies between the transaction types identified in the previous step, which may occur when the executor of a transaction is the initiator of another inner one, as explained in the Composition Axiom. This step is called **Result Structure Analysis** and can be executed by carefully reading the text one more time. Its results are illustrated in Table 6.

Transactions	Description
T1 and T2	To triage a patient the registrar must register the patient
T2 and T3	To handle patients' problems they need to be triaged
T3 and T4	To handle patients' problems physicians may need to ask for permission
T3 and T5, T7, T9, T10	To handle patients' problems physicians may need, respectively, to perform examinations, perform interventions, or re-route the patient to another specialist (outside the ED). T5, T7, T9 and T10 are all optional
T5 and T6	To make exams the examiner may need to order the necessary means
T7 and T8	To make interventions the performer may need to order means
T3 and T11	To discharge patients the caregiver needs to handle their problems
T3 and T12	To pay taxes the caregiver needs to handle patients' problems

Table 6: Result Structure Analysis with the found dependencies

After identifying the transaction types and having checked their dependencies, one has to determine the environment surrounding the ED, by mapping each transaction to the respective initiator and executor. This step is called **Organization Synthesis**, and it firstly produces the ATD illustrated in

Figure 15. In this diagram, a transaction is represented using a diamond in a disk. Each transaction connects two boxes, representing the initiator and the executor actor roles. The initiator is connected to the transaction symbol using a solid line, while the executor is connected to the transaction using a solid line ending in a black square. The grey boxes refer to composite actor roles, i.e. elements whose exact structure is not known. All the environmental elements, i.e. elements outside the organization that we are studying, are represented with grey boxes for that reason. This also means that we can represent the studied organization with a grey box when referring to the kernel of the organization, which can be further specified by using elementary actor roles represented by white boxes.

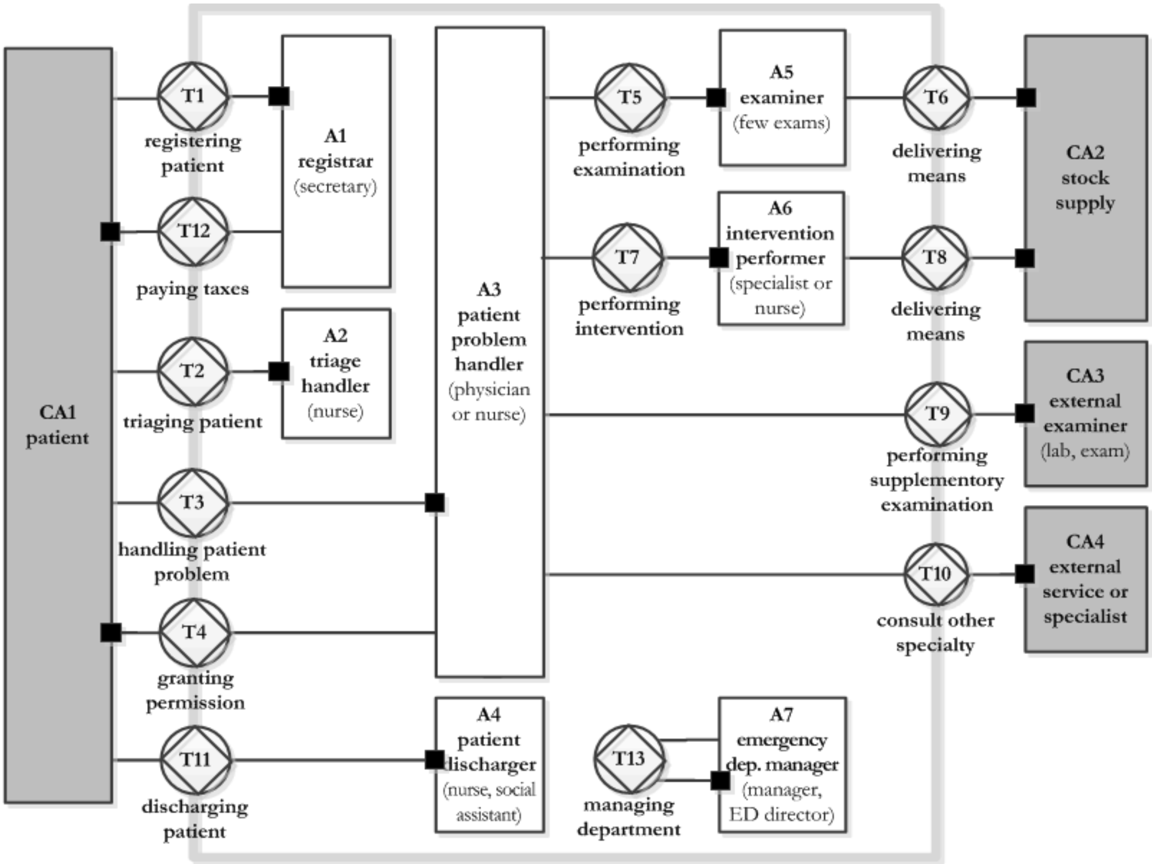

Figure 15: ATD of the ED

As depicted in the ATD, new patients are registered to the hospital (T1); then they go through a triage process (T2); after that, patients' problems are handled (T3); and finally, they are discharged (T11). These four transactions are initiated by an external actor, the *patient.* They are respectively requested to the *registrar*, *triage handler*, *patient problem handler*, and *patient discharger* that execute them.

The handling of the patients' problems may lead to the following actions: performing some urgent internal examinations (T5); performing medical interventions (T7); performing supplementary examinations (T9); and consulting another external specialty (T10). Since these tasks have different responsibilities, four different actors are discerned: *examiner, intervention performer, external examiner,* and *external service or specialist.* The first two are internal actors, used for urgent examinations and interventions (i.e. specific interventions may need specialists, such as a surgery or a psychiatry episode). The last two are used for non-urgent situations, such as some extended interventions or supplementary examinations. In addition, there are two transactions concerning the delivery of means (T6 and T8), a transaction concerning the patients' permission (T4), a transaction concerning the management of the ED, and finally the payment transaction (T12).

To finish the Modeling Phase, we may also create the PSD, which defines the inner processes from the ATD, and their dependencies that were stated in Table 6. As depicted in the PSD in Figure 16, the standard steps in a transaction are connected to each other by causal links. The first step the request transaction T1 (T1/rq), in which the patient requests for a service from the ED's secretary. The secretary acknowledges this request by promising to execute T1 (T1/pm), then the request T1 is executed (grey square), the service provider states the result of this execution (T1/st), and finally the patient accepts the result (T1/ac). In Appendix B we present the full ED PSD.

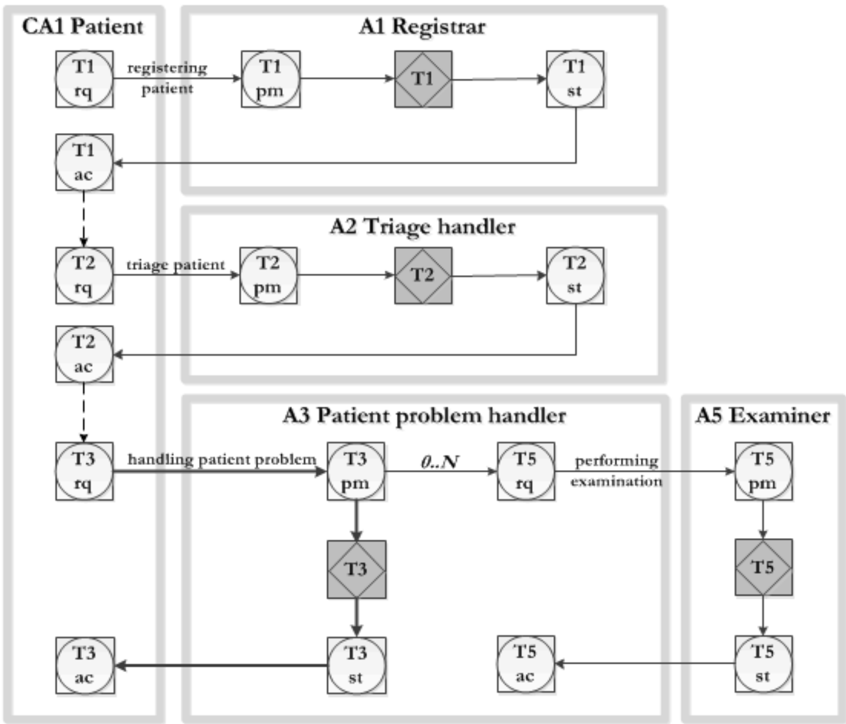

Figure 16: Small extract from the PSD

When there are dependencies between transactions (e.g. T3 and T5), after promising T3, the physician (A3) can request T5 (performing examination), when an exam is needed. To represent this we use a causal link from T3/pm to T5/rq, which means that when you get to promise T3, a request of T5 is automatically made. This causal link is optional since we do not always need such exams, and we represent that by using "0..N" which stands for a minimum of 0 times and maximum of N times. The dotted arrow is a conditional link, which means that T3 has to wait until T2 is accepted (finished), before T3 execution step is taken. Similar situations happen with the other transactions (Appendix B).

After completing the Modeling Phase we are now able to continue to the Innovation Phase, which will propose and prioritize improvements, and with them redesign the organization.

4.1.2 Innovation Phase

From the Modeling Phase, one must **identify process improvements** by analyzing the obtained diagrams. After some analysis from the ATD, it is possible to conclude that transaction T1 can be removed as the patient can register during the triage in transaction T2, or at least it is possible to automate T1 using a computer terminal with a standardized electronic form. This corresponds to the improvements A and B from Table 7, and they are inline with the carried interviews and some previous researches (Section 2.1). In other words, a common and shared registration is viewed as being vital to both individual and population health, and nowadays there is no need sign papers every time. This strategy is claimed to mainly improve waiting time and resource expenditure.

With the PSD, one can conclude that it is not efficient having to go through several iterations and actors to be forwarded to another external service, such as a specialist or examiner in transaction T10. For example, regarding a low-acute episode, instead of being forwarded immediately after triage, patients need to be admitted (T1), triaged (T2), and seen by a physician (T3) to be then forwarded to another specialty outside the ED (e.g. specialized consultation, pharmacy or PHC). This leads to unnecessary consumption of resources, higher waste of time, and the patient leaves without being treated in the ED. As presented in the related work (Section 2.1.2), *Provided Directed Queuing* (improvement C) and *Fast-Tracking System* (improvement D) can anticipate the resolution of some patients' problems. These strategies are claimed to improve waiting time, customer satisfactions, length of stay, and resource expenditure (Medeiros and et al., 2008).

Also from the PSD and following some suggestions from the practitioners and the related work on healthcare management (Section 2.1), one may conclude that a gatekeeping in the ED should be improved and complemented with a clearly defined separation of competencies and roles in the healthcare system. In other words, each healthcare unit should focus on a group of healthcare issues to handle, and particularly the ED should act only as a last resort. This gatekeeping could be created if patients can only access to an ED after being referred by a previous healthcare entity (e.g. emergency call, ambulance, or a PHC). Some researches even tell that a patient mostly choose for an ED because one always assesses his own urgency in a higher grade (Jensen et al., 2007). This situation leads to the duplication of resources in the ED and the PHC.

Other improvements could be concluded from the previous models or from the State Model that we use only in the PHC demonstration (Section 4.3). In a previous publication (Dias et al., 2012) we also concluded some improvements concerning the information quality using the State Model in an ED. In addition, we could also deepen in details about the execution of transactions in the PSD, or analyzing the infological or datalogical transactions.

In Table 7 we **quantify the improvements** in which we want to work at. To infer the level of impact, for a demonstration purpose, we consider that the elimination of a transaction has a higher impact than a precedence change. Avoiding a transaction conducts to the same classification as its elimination or automation. Avoiding an actor has even higher impact as it eliminates the transaction and reduces costs with human and physical resources. Finally, to assess the feasibility we considered that more changes leads to lower feasibility (i.e. hardware, software or people involved). The presented values were obtained with the help of the interviewed practitioners for this demonstration purpose. As we said in Chapter 3, we could choose a more formal and robust method to quantify the improvements.

#	Improvement	Impact	Feasibility	Impact description	Feasibility description
A	Patient registers in the triage	4	2	Avoid transaction T1 and transfer responsibility to A2	Triage should be fast
B	Automation in the register of patients	5	4	Avoid transaction T1 and actor A1	Terminal requires new hardware and software
C	*Provided Directed Queuing*	5	5	May eliminate transaction executions and reduce flow	Reallocate only one physician
D	*Fast-Tracking System*	4	3	May eliminate transaction executions and reduce flow	Reallocate physician and a new space
E	Gatekeeping to separate roles	5	3	Improve resource usage, reduce flow and expenses	Improve PHC and there should be a cultural shift
Caption: The range of impact and feasibility is classified from 1 to 5 for demonstration's purpose.					

Table 7: Improvements quantification from the ED

The **improvement prioritization**, illustrated in the priority map from Figure 17, addresses the impact and feasibility levels from the previous step: D shows large impact and feasibility, followed by B and C.

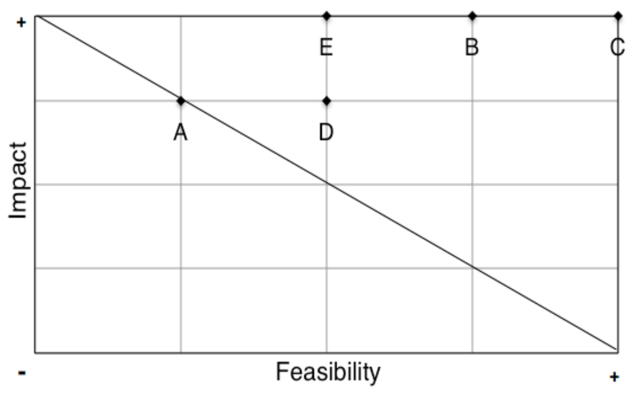

Figure 17: Priority map of the ED

Finally, the last step corresponds to the **redesign of organization**, in which we choose the most profitable improvements to produce improved aspect models. Due to space limitations, we present the resulting model in Section 4.4, together with the innovations identified in the following demonstrations.

4.1.3 Using Cost Analysis as Quantification Method

To demonstrate the improvement quantification step one may choose a more formal method without changing the proposal. In this research we do not deepen the quantification step because it is not a core feature of this thesis' scope. Nevertheless, to increase the relevance of this demonstration, we tried a different method to quantify improvements based on a TDABC (Section 2.2.3). To apply that, we used the expression and the information provided in a case study from (Kaplan and Porter, 2011), which presents the direct and indirect costs from a real ED and the necessary calculations.

Considering the studied ED as having a similar cost structure (i.e. similar salaries and expenses), we only have to measure the time from each transaction to calculate their costs. Therefore, using the times measured during our experimentations, depicted in Figure 18, we conclude that the registry itself (T1) accounts for 180,000€ (EUR) per year (considering the 100,000 admissions), and that a low-acute episode accounts for 27.6€ (EUR) for the whole visit. This could be even worse if we consider the overheads' costs, the wasted periods and the inventory consumption. The calculations are presented in Appendix B.

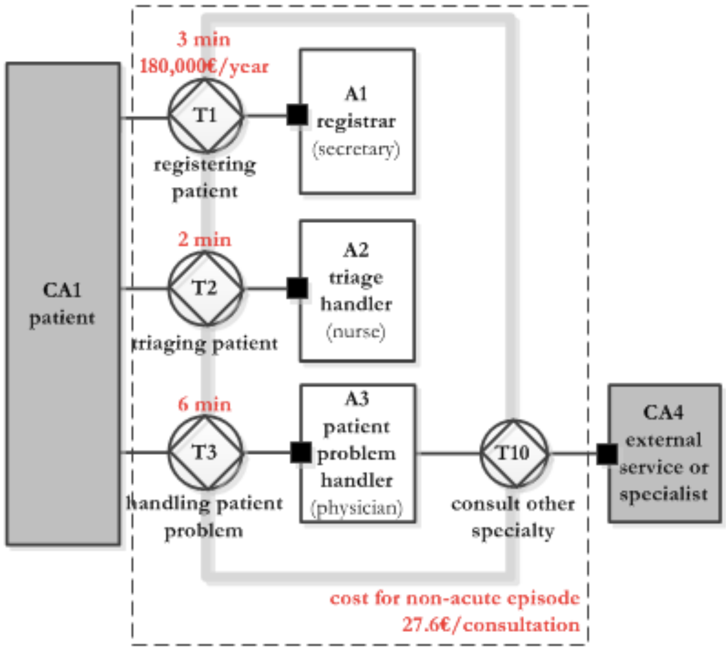

Figure 18: Segment of the ATD commented with time spent and cost

Although the quantification was not extensive, due to the lack of hospital data and for not being in our thesis scope, the obtained results allows one to get an idea about this step's purpose. Furthermore, these results may serve as a warning to consider that the identified problems (i.e. non value-added activities and their expenditure) are repeated several times in the whole National Health System.

4.2 Pharmacy

In this demonstration we applied the method to a Pharmacy in Lisbon. Therefore, we interviewed 6 practitioners (the pharmacy director, pharmacists, technicians, and some researchers) to obtain the enterprise description and validate the obtained results. These interviews included practitioners from the studied pharmacy and also some external and independent practitioners. The following sections describe the application of the proposal, skipping the intermediate steps as they were already demonstrated in the ED.

4.2.1 Modeling Phase

In order to give the needed context to this demonstration, we start with the **Enterprise Description** depicted in Table 8, obtained from the interviews with the pharmacy director and by direct observation. The **Performa-Informa-Forma Analysis** step and the **Coordination-Actors-Production Analysis** are also identified in the text, as demonstrated in the previous case study.

On arrival, a [patient] may (choose to) <create a new profile> to the [registrar], for establishing long-term relationships and get a client card. This is not a mandatory activity, and most people do not subscribe. After that, the patient (requests) <prescription refilling> by submitting it to the [pharmacy technician] or [pharmacist]. For a new patient the information system only registers the entry about the prescription and payment. For a registered one the prescription and payment are added to the database, and the system checks the current medicine for interactions with prescriptions the patient is already taking. The user is alerted if any interactions are found and the process stops. If there are no interactions, or if the patient has no profile, the computer (asks for) <a claim> to the patient's [insurance company], if one is provided. With the insurance company the computer contacts the [regulatory authority] that establishes a price for the drug, according to the insurance company. Sometimes the patient may need drugs without prescription and. In these case, the pharmacist (needs to) <examine> the patient. This <examination> consists in some questions, or in some cases it may consist on some technical examinations (e.g. blood or urine samples, cardiac measurements, etc.). In these cases, without a medical prescription, usually there is no refund for the medicine, so the computer presents the full price. After choosing medicines, if there is a robot then the [computer] generates a label and sends the information for automatic filing. The medicine is <dispensed> into a pre-selected bottle and counted using a laser and gear system, which places the medicine into the bottle. A conveyer belt sends the prescription out for a final check by the pharmacist. With no robot it has to be the [pharmacist] getting drugs and doing the <preparation> if they need so. Once everything is verified, the patient signs the prescription (if there is one) and <pays> the cashier. Every time a new prescription is issued, the [inventory] is also <updated>. If the level is low, it <orders> new restocking from a [supplier], and the supplier returns an invoice for <payment>. Finally, there are also some <primary care consultations> (e.g. nutrition, health checkups, osteopathy, etc.). There are also <management> activities regarding the human resources, finance, and so on. Finally, at any stage of the process, the patient may (ask for) <advising> (i.e. dosage and other pharmaceutical advices).
Caption: Actions are colored in red for *Ontological*, green for *Inforlogical*, and blue for *Datalogical*. Square brackets "[ ]" stand for actor roles, brackets "( )" for *C-facts/acts*, and angled "< >" for *P-acts/facts*

Table 8: Enterprise Description with results from the first two analyses and respective caption

After applying the steps from the proposal, we get the **Organization Synthesis**, which is illustrated in the ATD illustrated from Figure 19.

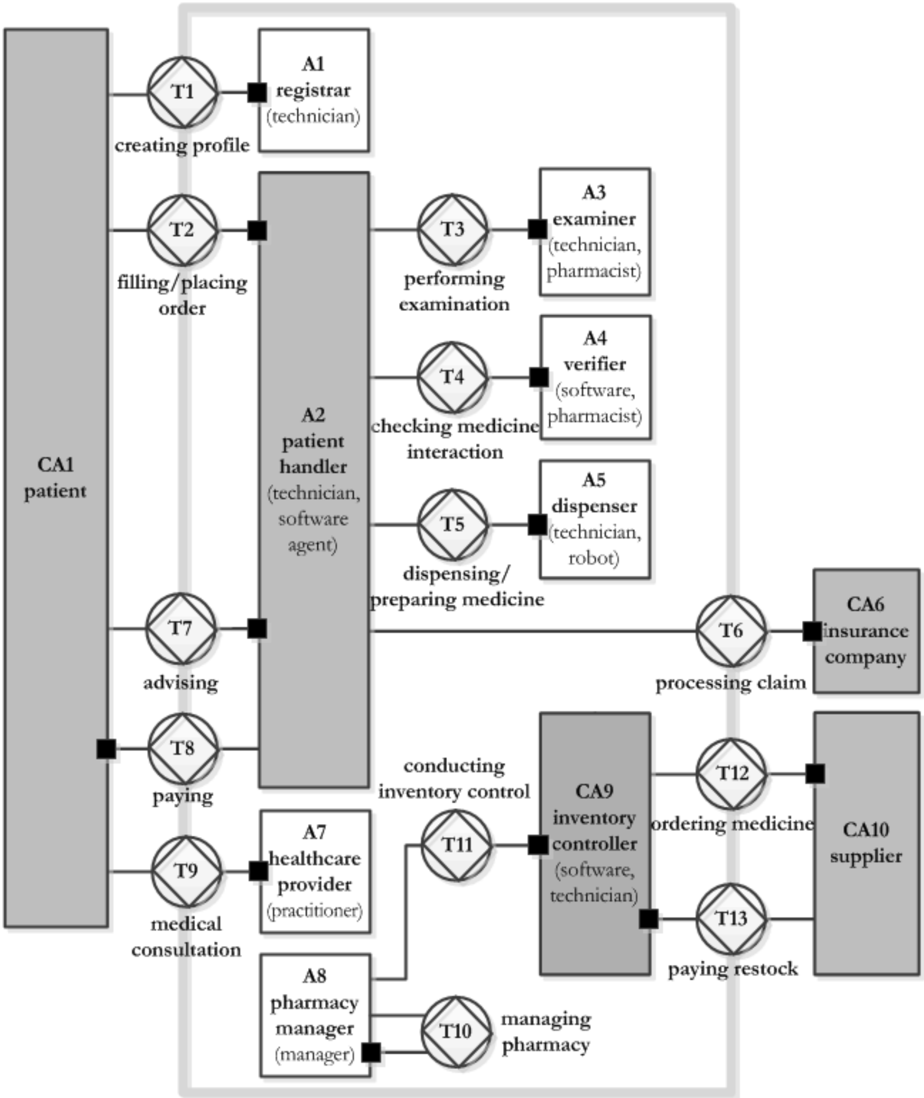

Figure 19: ATD of the Pharmacy

As depicted in this diagram, patients may choose to create a profile in the pharmacy (T1), fill a prescription for a medicine (T2), get advice about medication or health-related issues (T7), and attend to a consultation with a specialist (T8). These transactions are initiated by an external actor, the *patient*. They are respectively requested to the *registrar* and the *patient handler* (composite actor role) that execute them.

The handling of patients may in turn lead to the following transactions: performing examinations that can go from a simple diagnostic to laboratory analysis (T3), checking medicine interactions (T4), dispensing or preparing medicines (T5) and processing the claim to check for reimbursements (T6). Since these actions have different responsibilities, four different actors roles are discerned: *examiner*, *verifier*, *dispenser*, and *insurance company* (external actor role). After handling patients, they have to pay for the medicines or the provided services (T9).

In addition, there are transactions concerning the pharmacy management (T10), the inventory control (T11), the medicine supply (T12), and their payment (T13). Three action roles are discerned: *pharmacy manager*, *inventory controller*, and *supplier*. Finally, it is possible to schedule some kinds of medical appointments in the pharmacy with paramedics or other healthcare professionals. This corresponds to the transaction T8 executed by the *patient handler*.

With these results we have now stepped into the second phase of our demonstration, the Innovation Phase, in which we propose and prioritize improvements, and with them redesign the organization.

4.2.2 Innovation Phase

To start with, we **identify process improvements** from the Modeling Phase. After some analysis, it is possible to identify that <u>transaction T11 can be automated</u>, since the inventory control process requires much human intervention. In other words, the need to create some purchase orders manually and using paperwork, the lack of a decision support system to forecast the demand, the frequent need to manually verify inventories and prescriptions, and the amount of checks they have do when medicines arrive. For example, pharmaceutics need to manually verify the arrival of products for their quantities, expiration date and updated price. Other than that, they have to verify if prescriptions correspond to the purchase others, and so on. This corresponds to the improvements A from Table 9.

The second main improvement is the <u>automation of transaction T5</u> to use a robot instead of a human to dispense or prepare medicines (improvement B). Despite being a well-known and documented improvement, our analysis revealed that this was a bottleneck with great impact in the number of needed employees, and their service time. Without a robot, a pharmacy needs more employees available and there is a higher waiting-time to get medicines. In addition, robots also help in the storage of the ordered medicines, and on the identification of drugs that are almost expiring. This is considered to reduce human intervention and waste of products.

The third improvement is the <u>overlapping of responsibilities between hospitals and pharmacies in T2, T3 and T9</u> (improvement C). In spite of pharmacists' skills, patients need to seek a physician or a hospital to have a prescription, even for recurring or vulgar situations, such as an antibiotic for a sore throat. In addition, there are other legal restrictions hampering the existence of outpatient or primary care consultations in the pharmacies. This overlapping and the need to resort always to hospitals are considered to increase the expenditure of the National Health System, as described in Section 2.1. It is considered rational to improve the roles of PHC and Pharmacies, and to attempt a cultural shift.

The fourth and last improvement is the <u>elimination of the transaction T1</u>, since there should be a unified Patient Healthcare Record for all healthcare organizations to avoid duplication of information, improve access to information, and avoid wasting time creating profiles in different healthcare organizations (Dias et al., 2012). This corresponds to the improvement D from Table 9, and its impact is better explained in the Related Work about Information Quality (Section 2.3.1).

In Table 9 we **quantify the improvements** in which we want to work. To infer the level of impact we consider the same assumptions described in Section 4.1. Once again, we refer that a more formal method can be used to quantify improvements, without changing the proposal itself (Chapter 3).

#	Improvement	Impact	Feasibility	Impact description	Feasibility description
A	Automation in the inventory control	3	4	Reduce waste of time and errors in inventory control	Improve Supply Chain Management software
B	Automate medicine preparation	4	3	Avoid human intervention, reduce waste of time	New hardware (robot) and software
C	Avoid overlapping of responsibilities	5	4	Avoid duplication/overlap of transactions, reduce costs	Need to change rules, and a cultural shift
D	Unified registry and patient records	5	4	May eliminate transactions and reduce flow	Change legal restrictions and resistance
Caption: The range of impact and feasibility is classified from 1 to 5 for demonstration's purpose.					

Table 9: Improvements quantification from the Pharmacy

The **improvement prioritization**, illustrated in Figure 20, shows that improvements C and D have a larger impact and feasibility, followed by B and A.

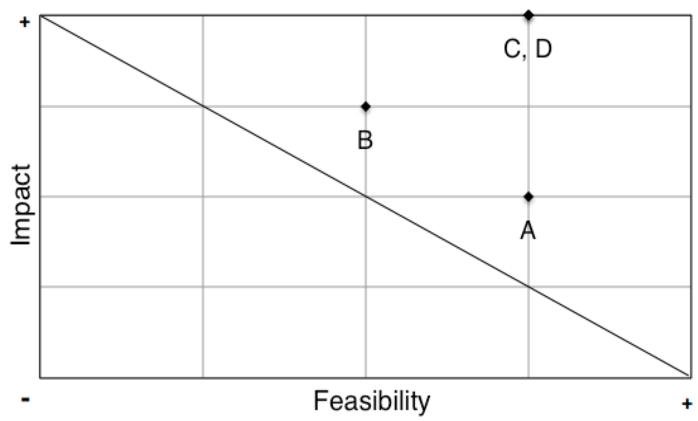

Figure 20: Priority map of the Pharmacy

With these results we may now step into the **redesign of organization** or we may deepen in details creating other models to analyze (such as the Process Model or the State Model), or apply a more formal and robust method to quantify improvements, or even consider some *infological* and *datalogical* transactions to get more improvements from them.

4.3 Primary Healthcare Center

This demonstration took place in a PHC (also called *Centro de Saúde*) near Lisbon, which covers a population with more than 170,000 residents. The mission of this PHC is strengthening family care services, provide universally accessible and adapted first contact services, and therefore improve the quality of life. For this we interviewed 2 patients and 5 practitioners, namely the executive director, the chairman of the clinical council, a physician, a nurse, and one researcher in the field. In this case study we also give more emphasis to the Construction and State Models. We use the State Model to find improvements related to the Information Quality, as described in a previous paper (Dias et al., 2012). We skip some steps from the Modeling Phase since they were demonstrated in Section 4.1.1.

4.3.1 Modeling Phase

Since the description from PHC is similar to the one given in the ED, and the steps from DEMO were already demonstrated, we skipped directly to the **Organization Synthesis**, which is illustrated in the *Construction Diagram* from Figure 21. As depicted in this diagram, new patients start by registering to the PHC (T1); then they may choose to book a domiciliary consultation (T3), or they may attend to a scheduled consultation (T4), or they may attend to an emergency consultation (T5). These four transactions are initiated by an external actor role, the *patient*. The first transaction is requested to the *registrar*, and the others are requested to the *patient problem handler*.

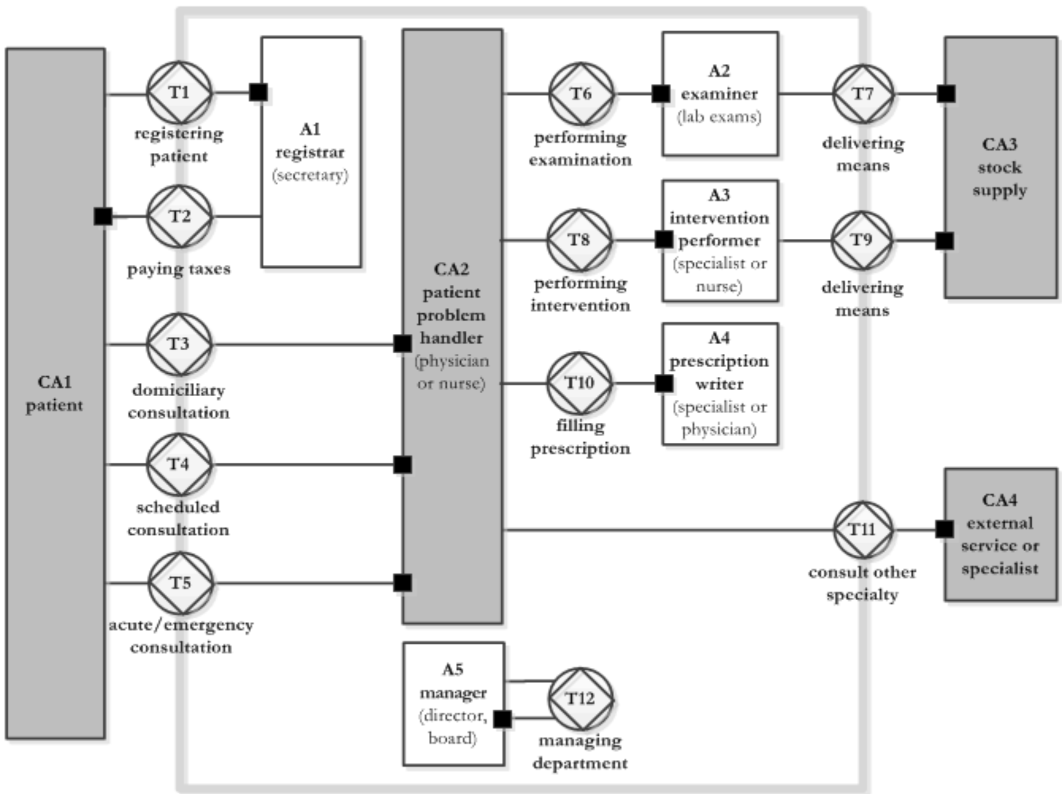

Figure 21: ATD of the PHC

The handling of patients' problems may lead to the following transactions: performing some internal examinations (T6); performing medical interventions (T8); filling in a prescription (T10); and consulting another external specialty (T11). Since these tasks have different responsibilities, four different actors are discerned: *examiner*, *intervention performer*, *prescription writer*, and *external service or specialist*. The first three are internal actor roles, and the last one is an external actor role, which can be another healthcare unit such as an ED, a pharmacy, or other specialty.

In addition, there are two transactions concerning the delivery of means (T7 and T9), one concerning the management of the PHC (T12), and another one for the payment (T12). The first two are executed by an external actor role (*stock supplier*), the third one is initiated and executed by the internal actor role *manager*, and the last one is initiated by the internal actor *registrar* and is executed by the *patient*.

The State Model is expressed in an Object Fact Diagram (OFD) and an Object Property List (OPL), as described in Section 2.4.2. The OPL specifies fact types that are proper functions and of which the range is a set of values. The OFD is fully based on the language WOSL and is constituted by categories, object classes, fact types and result types, as well as all pertaining existential laws. Only the information items that are relevant for the operation of the organization are included. The Figure 22 shows all categories of PHC. The object class Person is an external object class, and the others are internal. The result types from the Result Structure Analysis step could also be linked to the correspondent categories, but this would not add more information to use in the Innovation Phase.

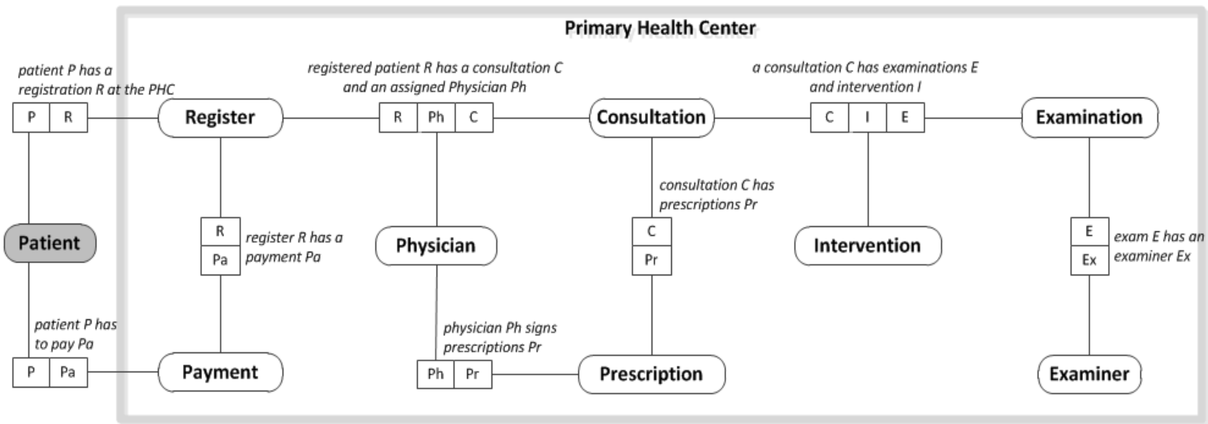

Figure 22: OFD from the PHC

The OFD shows, for example, that a Consultation is directly related (using a reference law) to: A) The Prescription since from a consult there are medical prescriptions (i.e. drugs and examinations); B) The Register and the Physician because each patient has a registry and a patient associated (i.e. a healthcare record file and a family doctor); and C) The Examination and the Intervention as one consultation is composed by exams and medical interventions.

After completing the Modeling Phase we are now able to continue to the Innovation Phase, which will propose and prioritize improvements, and with them redesign the organization.

4.3.2 Innovation Phase

From the Modeling Phase analysis we may **identify process improvements**. Considering the ATD, the first improvement is that transaction T1 can be automated for the same reasons presented in Section 4.1: the patient may register by using a computer terminal with a standardized form. This corresponds to the improvement A from Table 10.

The second improvement is the overlapping of responsibilities between ED and PHC in T5, T6 and T8 (improvement B). There should be a clear separation of competencies stating which kind of problems each unit should handle. This would avoid the duplication of resources (i.e. equipment and professionals) to perform the same activities. Furthermore, there should be a cultural shift to change the perception that healthcare is synonymous with hospitals, giving more emphasis to the primary healthcare (Walshe and Smith, 2010). This shift must be accompanied by changes in legislation, increased investment in primary healthcare, improved healthcare information systems, among others.

The third improvement is identified from the State Model, in which we may identify the lack of a common patient health records, and the repeated information between ED, Pharmacy and PHC (improvement C). The lack of a common health record could be verified during the interview, and the repeated information between units could be verified in a previous work where we identified that the lack of a unified patient record affects the information quality, namely the consistency rate of information and the timeliness rate of the critical patient information (Dias et al., 2012). Other that this, problems of information accuracy, completeness and understandability were also identified in the same paper. This may affect the healthcare delivery, increase medical errors, conduct to higher waiting-time to insert or correct information, and to lower patient satisfaction. Particularly in the PHC a unified record has even more impact to enable long-term relationships, and improve the monitoring and the decision making process. In other words, the PHC should act as the center of a healthcare system, where the family doctor needs information on time to regularly manage patients (Walshe and Smith, 2010).

#	Improvement	Impact	Feasibility	Impact description	Feasibility description
A	Automation in the register of patients	5	4	Avoid transaction T1, actor A1 and reduce flow	Terminal requires new hardware and software
B	Avoid overlapping responsibilities	4	4	Avoid duplication of transactions, costs and time	Change legislation and services, cultural shift
C	Common patient healthcare record	5	3	May eliminate transaction executions and reduce flow	New hardware, software, legislation and training
Caption: The range of impact and feasibility is classified from 1 to 5 for demonstration's purpose.					

Table 10: Improvement Quantification from the PHC

The **improvement prioritization**, illustrated in Figure 23, shows that improvement A has larger impact and feasibility, followed by B and C.

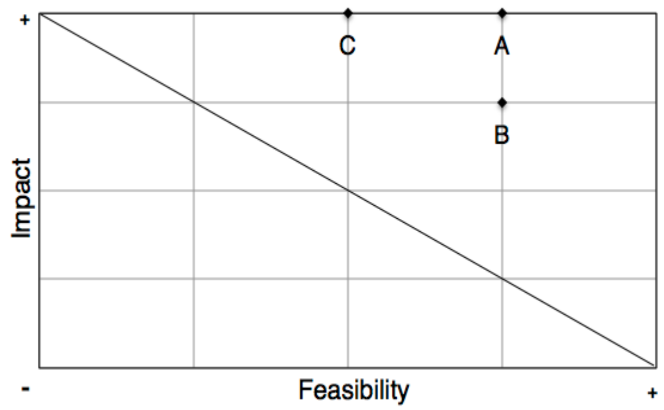

Figure 23: Priority map of the PHC

The last step corresponds to the **redesign of organization**, in which we choose the most profitable improvements to produce improved aspect models. We are presenting the resulting model in Section 5.5, together with the innovations identified in the previous demonstrations.

4.4 Healthcare Redesign and Summary

In this chapter we applied the proposal presented in Chapter 3 to some NHS units. With those case studies we wanted to demonstrate the suitability of the proposal to find out non value-added transactions and redesign the organization in order to improve healthcare efficiency. Other than that, we wanted to demonstrate that the proposed method could be applied effectively and efficiently to solve the research problem regardless of whom applies it, as DSRM suggests (Henver et al., 2004).

By analyzing the previously identified improvements altogether, we may find that it is possible to improve also the cooperation between the different healthcare organizations. Some overlapped transactions can be found in the previous models, thus suggesting that: A) The relationship between these entities need to be redesigned; B) There is a lack of definition regarding the responsibilities, authorities and competencies; and C) There are inefficiencies in the patient referral between different units. To exemplify, in Table 11 we identify some overlapped transactions.

ED Transaction	Pharmacy Transaction	PHC Transactions
T1 – Registering Patient	T1 – Creating Profile	T1 – Register Patient
T3 – Handling Patient	T9 – Medical Consultation T2 – Filing Prescription	T5 – Emergency Consultation T10 – Filing Prescription
T5 – Performing Examination	T3 – Performing Examination	T6 – Performing Examination
T7 – Performing Intervention		T8 – Performing Intervention
T10 – Consult Other Specialty		T11 – Consult Other Specialty
T6, T8, T12 – Management and stock supply transactions	T10, T11, T12 – Management and stock supply transactions	T7, T9, T12 – Management and stock supply transactions

Table 11: Overlapped transactions between ED, Pharmacy and PHC

From the previous table, one may identify that a patient has to register and create healthcare records in every healthcare organizations, consuming much time, replicating resources, and repeating information. This affects some information quality requirements, such as the *consistency* and *completeness* (Dias et al., 2012). Other than that, as exemplified in Section 4.1.3, this transaction in the ED accounts for 180,000€ (EUR) per year, without considering overhead costs and the problems associated with the information quality. This makes us consider the registry outsourcing.

The second improvement is the overlap of responsibilities between units, when it comes to handle a patient. There should be a clear separation of competencies on which kind of problems each unit should handle. For example, although a pharmacist has skills to handle a simple sore throat by prescribing an antibiotic, the patient needs to seek for an emergency healthcare service to get that prescription, contrasting with other countries with less restrictive laws (Walshe and Smith, 2010). This example fits in the previous described case of a non-acute episode that accounts for 27.6€ (EUR) (Section 4.1.3). This leads to an increase in expenditure and waiting time, which could be avoided by going directly to the pharmacy.

The third improvement is the implementation of gatekeeping rules as described in Section 2.1.2, in which fewer points of access to the health system are considered. Within a system of primary care gatekeeping, patients cannot access hospital specialists or associated diagnostic services unless they have first consulted their family doctor, or they are referred by an emergency call or transportation. For this measure, it is necessary to improve the efficiency of the PHC, namely to receive the low-acuity episodes within the established standards and level of services (i.e. time, specialties and resources).

In addition, there are problems such as the legal restrictions hampering the existence of medical consultations or specialties in the pharmacies, the inexistence of a unified Patient Healthcare Record, there is not a well-defined referring policy between ED and PHC making it difficult to select the right organization to handle a patient, there are duplicated resources (i.e. human resources, specialty consultations, available medical examinations), among others.

Considering the previous innovations we propose a redesigned Construction Model in Appendix C for the NHS. The main purpose is to demonstrate that it is possible to redesign the healthcare system using the proposal. To do that we tried to merge: 1) The results from the previous demonstrations; 2) The overall conclusions from this section; and 3) The feedback obtained during the interviews with different practitioners. It is important to note that the diagram itself may be considered subjective and it is not part of our DSRM artifact, but instead it is only for demonstration of the proposal last step.

Chapter 5

Evaluation

This chapter explains how we proceeded in the *evaluation* step of DSRM. With this assessment we intend to demonstrate that the proposal addresses the research problem. In Section 5.1, we present the evaluation strategy. Then, in Section 5.2, we apply this strategy to the previous demonstrations to evaluate the artifact. Finally, Section 5.3 provides a discussion in which we address how effective and efficient is the artifact to answer the research question.

5.1 Evaluation Strategy

In order to evaluate the proposal, we used the framework proposed in (Pries-Heje, Baskerville and Venable, 2004), which aims to help science researchers to build strategies for evaluating the outcome of a DSRM. This framework identifies **what is actually evaluated**, **when the evaluation takes place**, and **how it is evaluated**. To answer the third question, we based on different authors to propose a strategy with steps outlined to evaluate a design science research artifact method. The evaluation strategy entails the following steps, also depicted in Figure 24 and described in the following sections.

1. Constructing scenarios to **demonstrate the artifact**, and how to use it to solve the research problem. This is considered a way to validate an artifact of type *method* (Henver et al., 2004).
2. Gathering **feedback through interviews with practitioners**, regarding the artifact, ability to follow its steps, and potential to obtain relevant results;
3. The **Moody and Shanks Quality Management Framework** (Moody and Shanks, 2003) to assess the quality of the DEMO models produced in the demonstration phase, and their ability to handle the proposed problem and research question;
4. Evaluating the DSRM artifact using the **four principles proposed in** (Österle et al., 2011);
5. **Appraisal of the scientific community** through the submission and presentation of papers.

With this strategy our motivation was to evaluate the utility, quality and efficacy of the design artifact (as recommended in DSRM), as well as to **improve the proposal** according to the results obtained in the evaluation, and iterate back in the DSRM to improve the artifact when needed. In Figure 24 we illustrate the evaluation strategy.

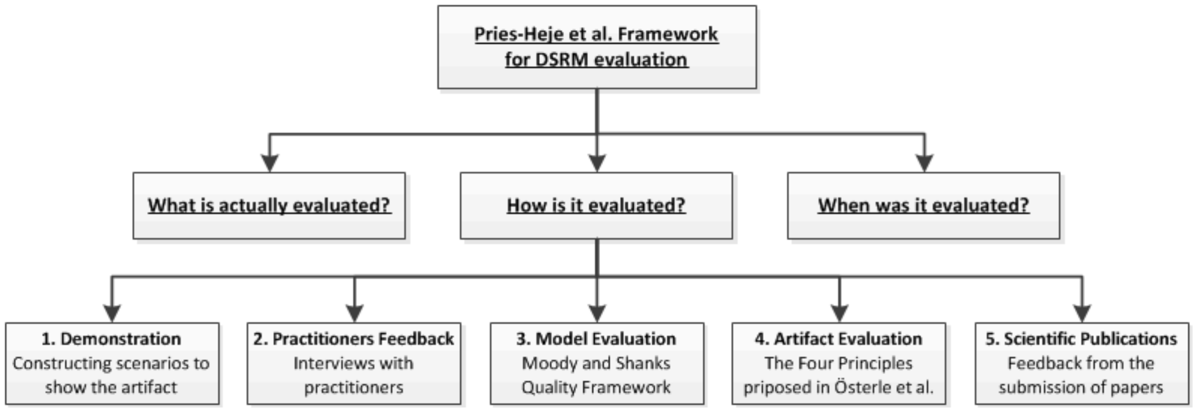

Figure 24: Illustration of the evaluation strategy

This evaluation method follows the **design evaluation guideline within DSRM**. In other words, *Henver et al.* describe five design evaluation methods in the context of DSRM (Henver et al., 2004): *observational*, *analytical*, *experimental*, *testing* and *descriptive*. In this research we have mainly used the ***descriptive* evaluation** method to assess the artifact, which uses relevant research to build a convincing argument for the artifact's utility, and constructs detailed scenarios around the artifact to demonstrate the utility. Other than that, we partially used the ***observational* evaluation**, in which the artifact is studied in depth in a business environment (i.e. a case study in a given environment). Nevertheless, the observational and analytical methods could be further detailed, but this would involve introducing observable metrics, conducting socio-technical experiments, and selecting modeling tasks that would allow such measurement (Henver et al., 2004) (Caetano, 2008). Such evaluation is beyond the scope of this thesis.

In the following sub-sections we briefly describe the methods that need for explanation.

5.1.1 Framework for DSRM Evaluation

In (Pries-Heje, Baskerville and Venable, 2004), a framework for DSRM evaluation was proposed to help science researchers to build strategies for evaluating their outcomes in order to increase the accuracy of the research. This framework, depicted in Figure 25, distinguishes the strategies in three aspects, to identify: 1) What is actually evaluated; 2) When the evaluation takes place; and 3) How it is evaluated.

As illustrated in Figure 25, the framework distinguishes the strategies in three aspects: *ex ante* and *ex post*, *naturalistic* and *artificial*, *design process* and *design product*. First, the distinction between *ex* *ante* and *ex post* evaluation is used to identify when that evaluation is performed, being the first before the artifact construction, and the second occurs after.

Second, the distinction between *artificial* and *naturalistic* is used to define how the evaluation is performed. The first evaluation is performed in an artificial scenario like laboratory experiments, simulations and case studies, while the second evaluation involves real users using real systems to solve real problems. The *artificial* evaluation has the advantage of being more controllable and with lower costs, while the *naturalistic* is more realistic. On the other hand, the *artificial* could not be applied in a real life, contrasting with the *naturalistic* that may become complicated due to the use of many variables from real life.

Finally, the third aspect distinguishes the artifact between *design process* and *design product*. A *design product* is the result of a particular process, which can be considered tangible. On the other hand, a *design process* can be defined as the set of activities, tools, methods, and practices that can be used to guide the flow of production.

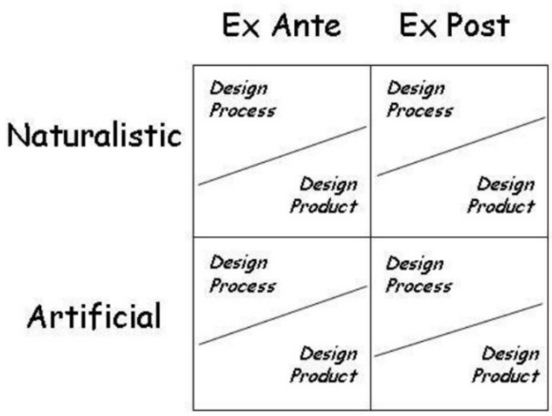

Figure 25: Framework for DSRM Evaluation (Pries-Heje, Baskerville and Venable, 2004)

Answering the first question (what), one specifies whether it is an *artifact design process* or a *design product*. On the second question (when), one may choose the *ex ante*, *ex post* or both. Finally, the answer to the third question (how) conducts the remainder evaluation, and one must specify whether it is a real setting with real users (*naturalistic*), or it is based on laboratory experiments (*artificial*). The remainder evaluation is depicted in the method from Figure 24, and described in the next sections.

5.1.2 Interviews With Practitioners

The objectives of the interviews are mainly to validate the research, its proposal, and results from demonstrations. Other than that, we wanted to obtain feedback on the related work and the proposal, and input to conduct the demonstrations (i.e. obtain the enterprise description, validate the obtained models, and get improvements from them). The main criteria that guided the interviewees' selection were: 1) The experience with the research field; 2) The position or activity in organizations where demonstrations were conducted; 3) The knowledge about the operations, processes and management of the healthcare units analyzed.

Interviews with practitioners follow a procedure with five main steps: 1) Validation of the research problem, its relevance, and the proposed method; 2) Evaluate the demonstration of the Modeling Phase, namely the resulting models, which are used to understand and analyze the organization; 3) From the obtained models, practitioners are encouraged to suggest improvements without conditioning their opinion with the next steps or results; 4) The practitioners compare and review the anticipated improvements with the ones obtained in the Innovation Phase; 5) Finally, they evaluate the whole method in terms of effectiveness and efficiency, and provide input for the model evaluation through the Moody and Shanks Framework described in the next section.

Prior to each interview, a summary of the research and relevant information is given to the respondents. Validation here means that respondents check the transcripts of the interviews for inconsistencies, and judge whether or not the transcripts are a truthful account of the interview.

5.1.3 The Moody and Shanks Quality Framework

Moody and Shanks Quality Framework proposes the following quality factors (Moody and Shanks, 2003):

1. **Completeness:** refers to whether the model contains all user and information requirements;
2. **Integrity:** definition of business rules or constraints from the user requirements to guarantee model integrity;
3. **Flexibility:** is defined as the ease with which the model can reflect changes in requirements without changing the model itself;
4. **Understandability: t**he ease with which the concepts and structures in the model can be understood;
5. **Correctness:** is defined as whether the model is valid (i.e. conforms to the rules of the modeling technique). This includes diagramming conventions, naming rules, definition rules, and rules of composition and normalization;
6. **Simplicity:** means that the model contains the minimum possible constructs;
7. **Integration:** is related to the consistency of the models within the rest of the organization;
8. **Implementability:** is defined as the ease with which the model can be implemented within the project time, budget and technology constraints.

We used this framework because it helps to validate the models produced by EO, which are one of the main outputs from the proposed method as they influence the Improvement Identification and the Organization Redesign steps from the Innovation Phase. Other than that, our research question is to prove that EO may contribute to improve the healthcare management, so it is important to assess the quality of the produced models to validate the research.

5.1.4 The Four Principles to Evaluate a DSRM Artifact

In *Memorandum on design-oriented information systems research*, (Österle et al., 2011) propose four principles to evaluate a DSRM artifact. This memorandum is supported by 111 full professors, with the objectives of providing: A) Providing rules for scientific rigor and improved guidance for researches; B) Providing criteria for journal and conference reviewers work; C) Providing criteria for selection of young researchers and tenure procedures; D) Providing criteria for evaluation of researchers and research organizations; and E) Positioning design-oriented information systems research in the international research community (Österle et al., 2011). The proposed principles are:

1. **Abstraction**: the artifact must be applicable to a class of problems. In this case, the proposed method should be applicable to improve different healthcare systems;
2. **Originality**: the artifact must substantially contribute to the advancement of the body of knowledge;
3. **Justification**: the artifact must be justified in a comprehensible manner and must allow for its validation;
4. **Benefit**: each artifact must yield benefit – either immediately or in the future – for the respective stakeholder groups.

We used these principles since its objectives are considered essential to evaluate a research, and because of the great support that these principles have.

5.2 Evaluation Results

To evaluate the research we start by using the **framework proposed in** (Pries-Heje, Baskerville and Venable, 2004), which is formulated as follows:

- **What was actually evaluated?** The evaluated artifact was the method described in Chapter 3, which is considered a design science research artifact method. This evaluation represents an *artifact design process*, since it is defined as a set of activities, methods and practices that can be used to guide a procedure workflow to improve the healthcare management;
- **When was it evaluated?** It was evaluated after the artifact construction, and after the demonstration. Therefore, the evaluation strategy is *ex post*, since it was performed after the design artifact development;
- **How is it evaluated?** To evaluate the artifact and its results (or suitability for solving the problem) we used the evaluation strategy described in Figure 24, which is applied below. This represents a *naturalistic* evaluation since it is conducted using a real artifact in a real organization facing real problems as a case of study.

In the following sub-sections, we apply the evaluation strategy from Figure 24.

5.2.1 Demonstration of the Artifact

The demonstration revealed that: A) The proposal is generic enough to be applied in different healthcare organizations; B) It is a formal method, with a list of specific steps to follow; C) From a given enterprise description anyone can achieve similar enterprise models, as Dietz suggests (Dietz, 2006), thus verifying the drivers presented in Sections 2.4 and 3.2; D) From the obtained models it is possible to find non value-added transactions and from them suggest and prioritize improvements; and F) It is possible to obtain a redesigned organization.

In other words, **it was possible to demonstrate the artifact's utility**, and how to use it to solve the research problem. Furthermore, it showed that EO provides a better understanding of the dynamics of an organization, enables a different and unified approach for the enterprise design and engineering, and improves the self-awareness within the organization when analyzing its models. These concerns are inline with the three aspects identified in Section 3.1 to overcome redesign reliability.

Furthermore, **some of the obtained improvements were inline with the Related Work in the field** (Section 2.1), namely the overlapping competencies between the primary and secondary healthcare systems, the existence of repeated transactions due to the lack of a unified Patient Healthcare Record, and the benefit of having the *Provided Directed Queuing* or *Fast-Tracking System* in the ED.

5.2.2 Practitioners Feedback

The interviews with practitioners followed the structure and objectives described in Section 5.1.2. We used field visits on location at each participating organization, face-to-face interviews, as well as follow-up phone and e-mail conversations. Each interview lasted about 1.5 to 2 hours. The main interviewees and their companies were the ones described during the demonstrations in Chapter 4: the ED director, four physicians, three nurses, the pharmacy director, two pharmacists, two pharmacy technicians, the executive director and the chairman of the clinical council from a PHC, ten patients, and five researchers.

The obtained feedback from these interviews was rather positive because, following the five proposed steps for the interviews (Section 5.1.2), we concluded that: 1) They validated the importance of the research problem and the motivations behind the proposal; 2) They understood and agreed with the obtained models (after explaining them), which were considered to properly depict the studied organizations; 3) Practitioners occasionally identified some possible improvements without seeing our own results; 4) Improvements were discussed and the interviewees agreed that the ones we identified were sometimes similar to those suggested by them; 5) Practitioners concluded that our proposal could be applied effectively and efficiently to solve the research problem, regardless of whom applies it, and provided feedback for the Model Evaluation.

From the interviews we also received some suggestions that were included, such as corrections in the enterprise description (with impact on the resulting models), new results from the Innovation Phase, and the need to deepen some issues in the related work. Their feedback also allowed us to gain more structured knowledge about the subject, and appropriate foundations for writing scientific papers.

Furthermore, during some interviews there were interesting discussions around the results, which demonstrated that this research is interesting from the practitioners' point of view. For example, the PDQ in the ED triggered a discussion between the ED director and a physician, with one agreeing with the improvement and the other presenting some reservations. In the end they concluded that it would be a breakthrough improvement, but it would need a better quantification to be widely accepted. Other example that also triggered some discussions between in the ED, Pharmacy and PHC was the overlap of responsibilities, roles and tasks between different healthcare units. In fact, these discussions helped us to present the redesigned healthcare system in Appendix C, and from it practitioners concluded that EO might help to easily outline the healthcare system.

Overall, practitioners showed a **good acceptance and enthusiasm for this innovative approach**. For example, one positive comment was that **the obtained models helped to frame the discussions, restricting the undesirable freedom, while ensuring the consistence and coherence of the improvements found**. On the other hand, one suggestion for a future work improvement was to better quantify the improvements, namely to include costing models to the obtained DEMO diagrams. After all, they concluded that our method could be applied effectively and efficiently to solve the research problem, validating the research.

5.2.3 Model Evaluation

The following results were obtained from applying the Moody and Shanks Quality Framework to the demonstrations' resulting diagrams. We tried to consider the feedback from the interviews.

1. **Completeness**: was evaluated in terms of the missing information (i.e. actors or transactions) in the models produced. The practitioners verified that the obtained models were consistent with the initial description, containing all the important details;
2. **Integrity**: this quality aspect was fulfilled in the dependencies between transactions from the PSD. This aspect is only influenced by the information present in the enterprise description. For example, during the evaluation interview one physician discovered a missing dependency because the correspondent business rule was also missing in the enterprise description;
3. **Flexibility**: the obtained models are stable with *Datalogical* and *Infological* changes, and sufficiently flexible to, for instance, deal with *Ontological* changes, inline with previous researches (Reijswoud, Mulder and Dietz, 1999). Adding new responsibilities to the *Ontological* Layer is possible, and is eased since there are fewer roles, transactions and dependencies;

4. **Understandability**: was evaluated in terms of the ease with which one can draw conclusions or understand the operation of the ED from the models. At first, stakeholders found it difficult to interpret the models, because of the specific constructs used by DEMO (e.g. transaction symbols and the axioms). After explaining the methodology there was an adaptation period, due to the lack of *Infological* and *Datalogical* actions in the models, but then there was great acceptance and enthusiasm for this innovative approach, inline with other previous research results (Mendes, Ferreira and Mira da Silva, 2011);
5. **Correctness**: was assessed in terms of errors in the models produced. Since DEMO models are considered coherent and consistent, this driver was also verified. Furthermore, we did not face obstacles to correctly apply the proposal following its theoretical foundation;
6. **Simplicity**: was assessed in terms of the number of constructs. Since EO only considers the *Ontological Layer*, there is a significant reduction on the number of elements when we consider the original source with several *Datalogical* and *Infological* aspects. This is inline with the drivers of essence and conciseness referred in the theoretical foundation;
7. **Integration**: is concerned with the extent to which two different models can be integrated or compared to each other. Demonstration showed that different healthcare units may be integrated. Furthermore, models were developed by taking into account their modularity and consistency with the rest of the organization;
8. **Implementability**: the produced models considered only the *Ontological Layer*, which describe only the essence of the organizations, so they are implementation independent. In DEMO, we can only consider the Action and Interstiction Models as partially implementable.

To sum up, **almost all the quality factors were accomplished**. Only the *Understandability* was partially accomplished, and the *Implementability* was not. The first factor since practitioners found models difficult to understand at the beginning, needing an adaptation period. The second one, since models are implementation independent they only describe the essence of an organization.

5.2.4 Artifact Evaluation

The Four Principles proposed in (Österle et al., 2011) to evaluate the artifact are then answered:

1. **Abstraction**: the artifact can be applied to any healthcare system from a given enterprise description, which is easily obtained from interviews, documents or workflow representations;
2. **Originality**: the proposed artifact is not present in the body of knowledge of the domain since it was designed by relating different subjects, such as healthcare operational management, BPR, EO, and some additional steps from Lean;
3. **Justification**: the artifact is supported by the related work and by the strong theoretical foundation from EO. Then, the artifact itself was described and justified in a comprehensible manner using textual and graphical representations with clear steps and instructions. In addition, the demonstration also helped to further explain and justify it;

4. **Benefit**: the artifact provides a structured working approach for reengineering, leads to differentiated and well-grounded improvements, and provides a better understanding of the dynamics of an organization, among other benefits when comparing with existing methods. Furthermore, we may consider as benefits the feedback obtained in Sections 5.2.2 and 5.2.3.

To sum up, **the four principles to evaluate a DSRM artifact were verified**, thus showing the validity of the artifact.

5.2.5 Appraisal of the Scientific Community

At the moment three full papers were already accepted in international conferences, and others are about to be completed or waiting approval, as presented in the Research Communication (Section 6.1). Wherever possible, the feedback from the reviewers was included in the research, with successive amendments in the related work, proposal and evaluation strategy.

Regarding the scientific publication, the first paper was validated for a conference in the medical informatics field, with practitioners in the healthcare sector, for a track in information and knowledge representation, in the theme of process and information models.

The second paper was validated for a top ranked conference in the information systems field, for a track on systems analysis and design. This one had also the collaboration (and therefore the appraisal) of two international researchers from Dublin City University.

The third paper was validated for the special session on EO with *Dietz* as part of the chair conference committee, which is the author of our main reference in the field (Dietz, 2006). Therefore, this one had the validation and feedback from experts in EO.

Finally, some presentations were also performed, where we also obtained some feedback from the scientific community. These communications are also present in Section 6.1.

5.3 Discussion

Considering the main objective of “proposing a method based on EO to find non value-added transactions, and redesign them to improve the healthcare management”, and based on the previous evaluations, we may conclude that we largely achieved our expectations because it was possible to: 1) Formulate such a method; 2) Demonstrate its use in three real case studies; 3) Find non value-added transactions when applying the method; 4) Suggest redesign improvements; and 5) Get validation and positive feedback from the method and its results.

With the evaluation we may conclude that the proposal supports the solution of the problem statement, and the feedback was rather positive: A) The importance of the research problem was validated; B) It was possible to demonstrate the artifact's utility; C) The obtained models were considered suitable to innovate the healthcare system, and almost all quality factors were accomplished with the Moody and Shanks Quality Framework; D) Practitioners concluded that the proposal could be applied effectively and efficiently to address the research problem; E) The proposal verifies the Four Principles proposed by (Österle et al., 2011); F) Feedback from the scientific community was rather positive, with papers accepted and presentations performed. Table 12 summarizes the results from this evaluation, mapping the evaluation method with the main proposal outputs.

Proposal main outputs \ Evaluation method		Demonstration of the artifact	Interviews with practitioners	Moody and Shanks Framework: Completeness	Integrity	Flexibility	Understandability	Correctness	Simplicity	Integration	Implementability	Four Principles from *Österle*	Scientific publications
Modeling Phase	Construction Model	✓	✓	✓	✗	✓	◔	✓	✓	✓	✗	✓	✓
	Process Model	✓	✓	✓	✓	✓	◔	✓	✓	✓	✗	✓	✓
	State Model	✓	✓	✓	✓	✓	◔	✓	✓	✓	✗	✓	✓
Innovation Phase	Process Improvement Identification	✓	✓									✓	✓
	Improvement Quantification	✓	◔									✓	✓
	Improvement Prioritization	✓	✓									✓	✓
	Redesign Organization	✓	✓	✓	✓	✓	◔	✓	✓	✓	✗	✓	✓

Caption: ✓ for accomplishment; ◔ for partial accomplishment; ✗ for not accomplished; ? for results in progress; <empty space> stands for not applicable.

Table 12: Evaluation summary - map between evaluation method and proposal steps

To complete the DSRM evaluation, an artifact method has not only to be demonstrated in terms of effectiveness and efficiency, but it also has to address the research problem. Subsequently we answer the previously raised research question – **Which is the contribution of EO to improve the management of the National Health System?**

- **EO allows for a better understanding of the authorities, responsibilities, competencies and delegations**, as explained in the Operation Axiom (Dietz, 2006), which helps to identify improvements. This improved understanding is also possible since EO only focus on the essence of the organization, which leads to a reduction in the complexity of the obtained diagrams, of over 90% (Dietz and Hoogervorst, 2008). Furthermore, the changes to the *essential layer* are considered the most drastic ones, since they also affect the organization's *Information* and *Documental* structures (Dietz, 2006). This conclusion is supported in Demonstration (Chapter 4), Model Evaluation (Section 5.2.3), Practitioners Feedback (Section 5.2.2), and by previous researches (Henriques, 2010);

- Therefore, by **using EO to analyze different healthcare systems, it is possible to identify gaps in the patient's handling, and overlapping transactions**. This conclusion is supported by the demonstration in Section 4.4, and practitioners' feedback in Section 5.2.2. As was previously concluded, practitioners agreed that the obtained models help to frame discussion, restricting the undesirable freedom, while ensuring the consistence and coherence of the improvements found and which they agree with;
- Finally, **EO enables a different and unified approach for the enterprise design and engineering** (Dietz and Hoogervorst, 2008). Concordantly, it is also possible to suggest differentiated and well-grounded improvement for the National Health System. This was also proven by the demonstration phase and the feedback from interviews. Furthermore, several authors support it, since the changes to the *Essential Layer* are considered the most drastic ones, affecting the organization's *Informational* and *Documental* structures (Dietz, 2006; Dietz and Hoogervorst, 2008; Henriques, 2010) (Section 2.4).

Regarding the **research limitations** we may state that:

- Despite the strong points of EO, the evaluation identifies two limitations: *Understandability* and *Implementability* of its models. The first factor since practitioners found models difficult to understand at the beginning, needing an adaptation period. The second one, as modes are implementation independent, they only describe the essence of organizations;
- The proposal does not fully apply the PDCA Operating Framework from Lean since the last three steps require the creation of prototypes for the improvements and the implementation in a broader scale. Although it was beyond the scope of this thesis, it would be the only way to finish the research and assess the failure rate pointed out in Section 1.1;
- The improvement quantification could be improved in demonstrations, namely including costing models and other methodologies to assess the impact and feasibility of the identified improvements. This is a major topic from Lean, but for demonstration purposes we could not obtain sufficient information on time (for example the service costs). However, the choice of a quantification method does not change the proposal itself;
- This is a descriptive study of changes within healthcare units, so the demonstration and evaluation cannot be generalized to the whole healthcare system. However, our goal with the proposal was only to plan improvements, and the purpose of the demonstration of a DSRM artifact method was to show that the method can be applied step-by-step;

Nevertheless, it is expected that healthcare organizations may use some of the described advantages of the proposed method to address problems of inefficiency and unsustainability in the healthcare management, and perhaps reduce the failure rate that some authors identify in the existing initiatives and methodologies to redesign and reengineer organizations (as described in Section 1.1). Furthermore, this work can also be a contribution towards helping healthcare professionals to validate processes and improve their way of working, even if it is used together with other existent methods.

Chapter 6

Conclusion

This thesis addresses healthcare management problems, in which its processes have become inefficient and unsustainable. Following this, some concerns are raised in the literature, such as the high failure rate of the traditional organizational sciences to implement management strategies effectively, the growing business dynamics that force organizations to evolve, the inability to deal with these dynamics at the operational level due to weak enterprise construction models, and the consequent lack of organizational self-awareness.

To overcome these problems, this research proposes a method based on EO to find non value-added transactions, and redesign them to improve the healthcare management. Therefore, the artifact method relies on a structured set of steps that include the development of enterprise models, their analysis in order to understand the essence of the organization and to find inefficiencies in transactions, the elicitation of possible improvements, their prioritization in terms of feasibility and impact, and finally the redesign of the organization.

We chose the EO as foundation for our proposal as it is deemed able to provide a better understanding of the dynamics of an organization, allows a good alignment between the enterprise design and operation, and enables a structured reengineering strategy. Furthermore, since its models are regarded coherent, comprehensive, consistent, concise and essential, it gives strength to the obtained models. On the other that, with the addition of Lean, we intended to take advantage from the proven benefits of Lean particularly in the healthcare industry, for the Quality Management and the Continuous Improvement, therefore considering the combination of EO with the PDCA Operating Framework to identify, plan and quantify improvements.

To assess the utility of the proposed artifact and its results we have used: 1) The framework proposed in (Pries-Heje, Baskerville and Venable, 2004); 2) Demonstrations of the utility of the method using three different healthcare organizations as case studies (ED, Pharmacy and PHC); 3) Interviews with practitioners; 3) The Four Principles of (Österle et al., 2011) to evaluate the artifact; 4) The Moody and Shanks Quality Framework to assess the quality of the produced models (Moody and Shanks, 2003); and 5) The appraisal from the scientific community through the submission and presentation of papers. These evaluations showed that the proposal is generic enough to be applied in different healthcare units, and that it is possible to identify improvements and redesign organizations. Furthermore, the other evaluations methodologies were positive, as well as practitioners showed a good acceptance and enthusiasm for this approach, since the obtained models helped to frame discussions while ensuring the consistence and coherence of the improvements found.

Some of the main contributions of this research are: A) The proposal to improve the healthcare management, which differs from the current state-of-the-art approaches; B) Its attempt to solve the problem statement by relating different topics, such as Healthcare Management, BPR, EO, and some additional steps from Lean; C) Its practical demonstrations using three different organizations as case studies; D) The improved inter-organizational cooperation and self-awareness obtained from the redesigned models; E) The evaluation using different methodologies and interviews with experienced practitioners; and F) The communication to relevant audiences with three scientific papers accepted in international conferences, which shows an active interest in this research.

Despite the strong points presented before, the evaluation also identified some limitations. The first one, beyond the scope of this thesis, is the implementation in practice of the obtained improvements in the national health system. Moreover, it was not possible to completely (and quantitatively) demonstrate the improvement quantification, as this information was unavailable in the analyzed organizations. Finally, two limitations were identified in EO: the understandability and implementability of its models, as practitioners find the models difficult to interpret needing an adaptation period, and since models are implementation independent (describing only the essence of organizations).

Nevertheless, it is expected that healthcare organizations may use some of the described advantages of the proposal to address problems of inefficiency and unsustainability in the healthcare system. Furthermore, this research can also be a contribution towards helping healthcare professionals to validate processes and improve their way of working, even if it is used together with other existent methods. Finally, we believe that the proposal may be successfully applied in other fields different than the healthcare, since EO is applicable to any organization from a given enterprise description, and the second phase with Lean is only dependent from the produced models.

6.1 Research Communication

This section corresponds to the *communication* step of DSRM. During the execution of this thesis, three scientific papers were published in international conferences, and other two papers are about to be submitted. Starting with the accepted ones we have:

- **MIE 2012**: Dias, D.G., Lapão, L.V. and Mira da Silva, M. (2012) 'Using Enterprise Ontology for Improving Emergency Management in Hospitals', 24th European Medical Informatics Conference (MIE 2012), Pisa.
- **AMCIS 2012**: Dias, D.G., Xie, S., Mira da Silva, M. and Helfert, M. (2012) 'Using Enterprise Ontology Methodology to Assess the Quality of Information Exchange', 18th Americas Conference on Information Systems (AMCIS), Seattle.
- **KEOD 2012**: Dias, D.G., Mendes, C. and Mira da Silva, M. (2012) 'Using Enterprise Ontology for Improving the National Health System', 4th International Conference on Knowledge Engineering and Ontology Development, Barcelona.

The first two papers will be presented in August 2012, and the last one in October 2012. The first one is a main conference in the medical informatics field, the second one is in information systems ranked as top level in its field (ERA Ranking, 2010), and the third one is in a special session on Enterprise Ontology. Next we present the papers in progress, to be submitted in July:

- **IJMI (Journal):** Dias, D., Mendes, C., Lapão, L. and Mira da Silva, M. (2012) 'A Method for Improving Healthcare Management Using Enterprise Ontology', *International Journal of Medical Informatics*.
- **BISE (Journal):** Xie, S., Dias, D., Mira da Silva, M. and Helfert, M. (2012) 'Enterprise Ontology Methodology to Structure the Exchanged Information for Quality Assessment', *Business and Information Systems Engineering*.

The first one will cover the complete thesis work and will be submitted to the IJMI or EIS (Enterprise Information Systems), which are raked as top-level journals (ERA Ranking, 2010). The second one is an extension from the AMCIS paper, in collaboration with two international researchers from Dublin City University.

Finally, some presentations were already performed during classes or thesis' milestones. In addition, a presentation was performed in May 2012 for the itSMF/IST Workshop where the main topic was the good practices of IT Management.

6.2 Future Work

Further research is being performed to better quantify the impact and feasibility of the proposed improvements during the demonstration, namely by including costing models to the obtained DEMO diagrams. This can be a step towards the implementation of innovations in the healthcare system, the understanding of its costs, and also an asset to the EO by adding support for costing models. Furthermore, the Proposal should be expanded to consider the remaining application of Lean PDCA Operating Framework, which consider small-scale trials and the implementation of improvements.

The Modeling Phase can also be improved by adding the Action and Intersticion Models, which can be useful in the redesign of information systems, inline with previous researches (Reijswoud, Mulder and Dietz, 1999). Additionally, it may be useful to add some implementation details to DEMO, including *Infological* and *Datalogical* transactions in the produced models, which may help to obtain new innovations for the healthcare system and solve the implementability limitation. The quality and exchange of information can also be further analyzed using the State Model to improve the Informational Architectures, thus continuing the work started in (Dias et al., 2012).

Finally, we still can apply the proposal to other healthcare services and units, namely the six different process missions identified in (Vasconcelos et al., 2005), thus continuing the research approach initiated in *Hospitais Universitários de Coimbra*, in order to cover all the secondary healthcare system.

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Appendixes

Appendix A: The Enterprise Ontology Methodology

This appendix (from Section 2.4) shows the legends of the DEMO aspect models.

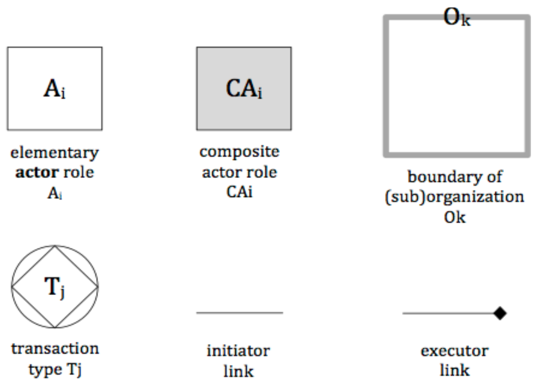

Figure 26: Caption of the ATD (Dietz, 2006)

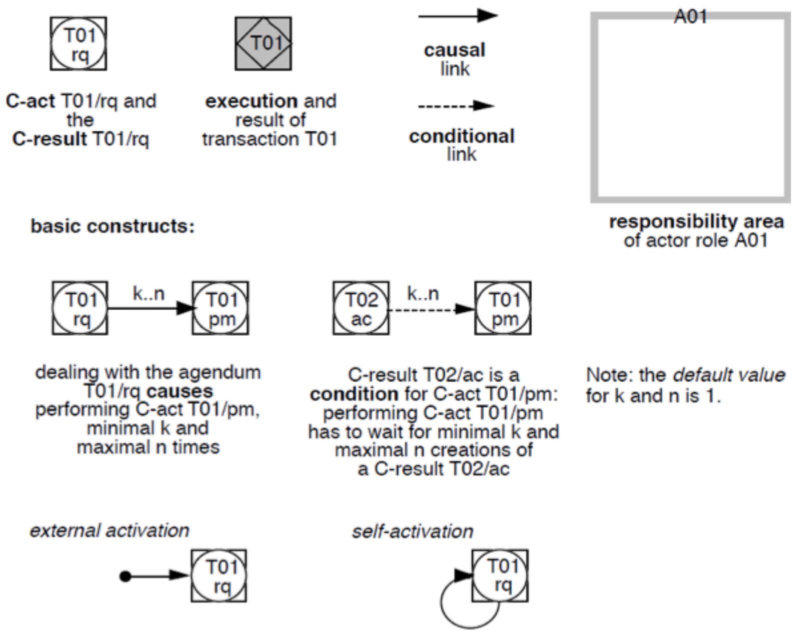

Figure 27: Caption of the PSD (Dietz, 2006)

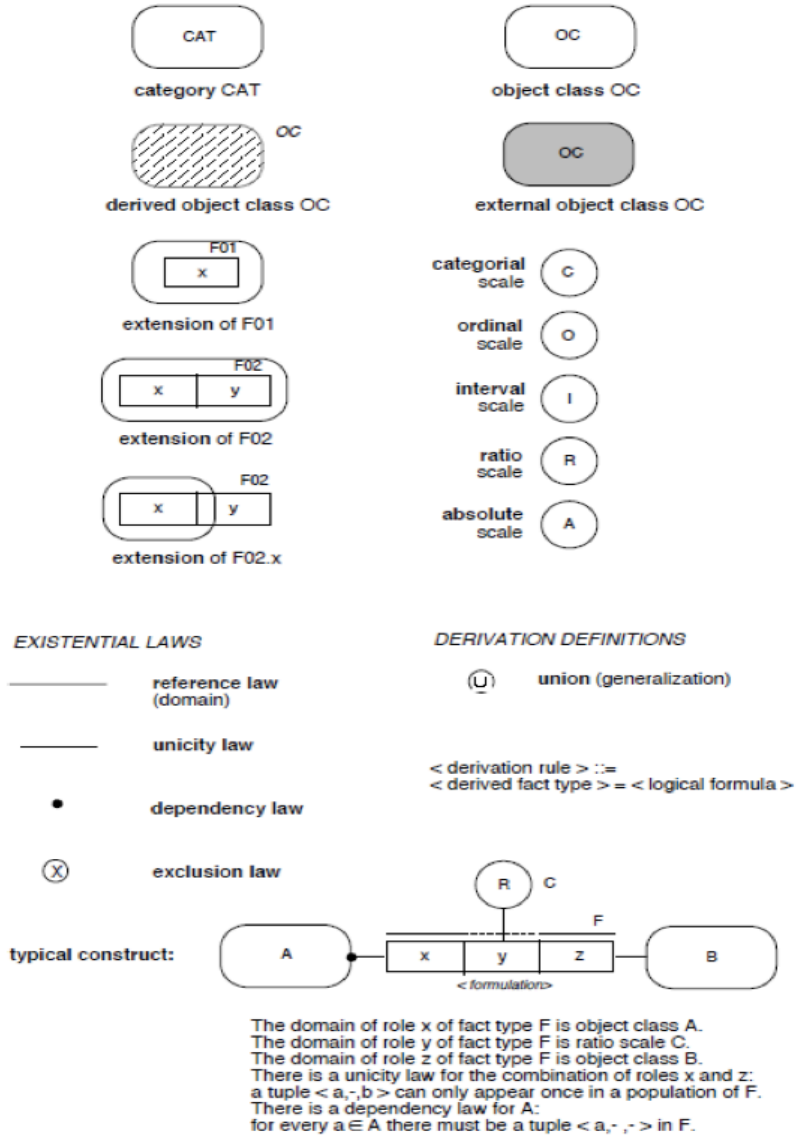

Figure 28: Caption of the OFD - second part (Dietz, 2006)

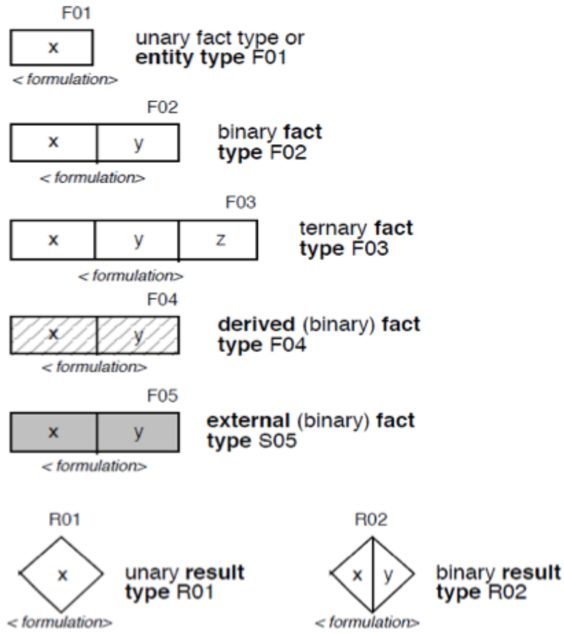

Figure 29: Caption of the OFD - first part (Dietz, 2006)

Appendix B: Emergency Department Demonstration

This appendix shows the PSD and the Cost Analysis from the Demonstration in the ED (Section 4.1).

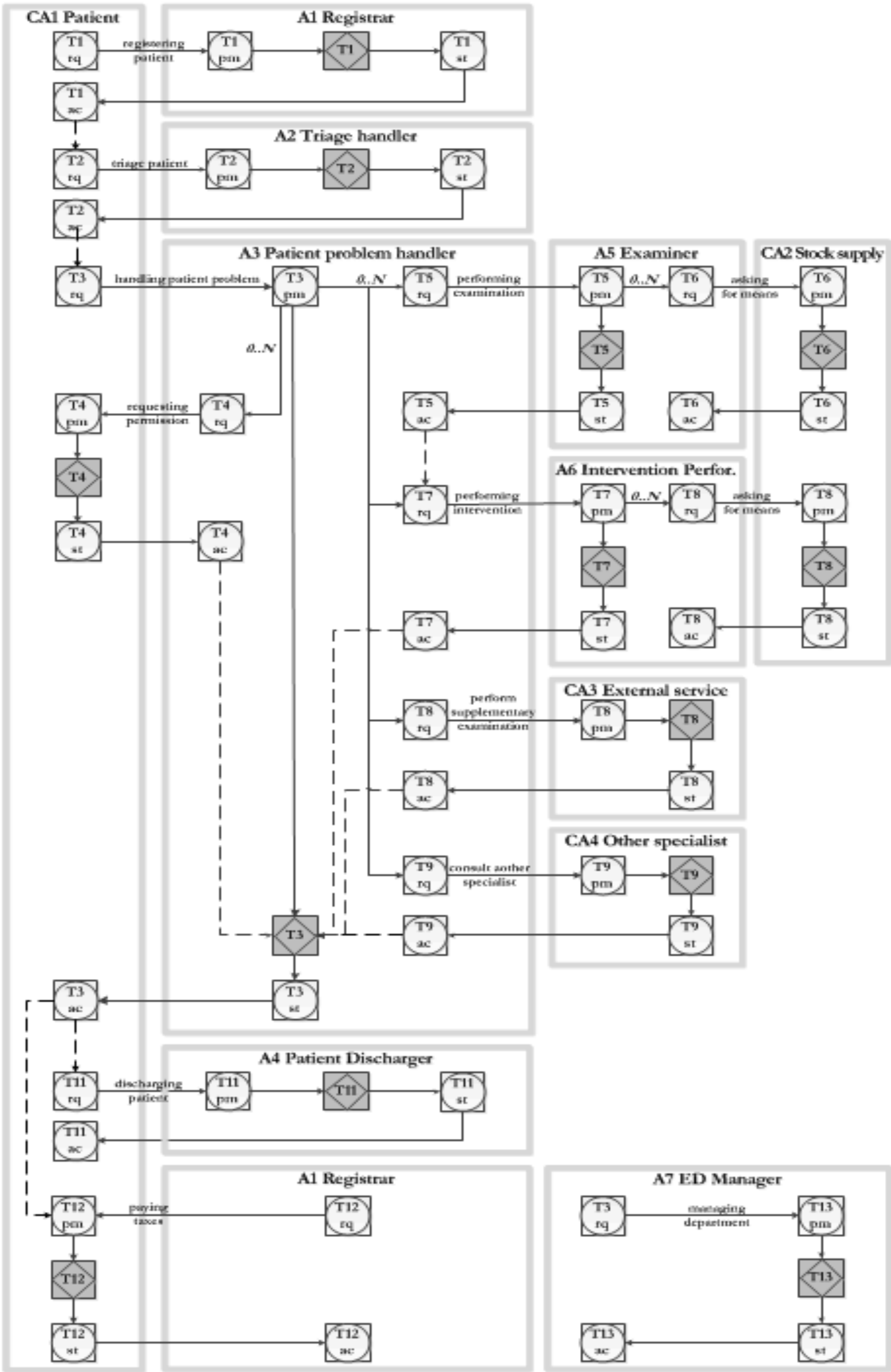

Figure 30: PSD from ED

To **demonstrate the improvement quantification step using TDABC**, we used the expressions and the information provided in a case study from (Kaplan and Porter, 2011), which presents the direct and indirect costs from a real ED and the necessary calculations. This information was unavailable in the hospital where we applied the method. Nevertheless, we consider that the studied ED has a similar cost structure (i.e. similar salaries and expenses), so we only had to measure the time from each transaction to calculate their costs.

To calculate the cost rate for each resource, we used the following equation from Section 2.2.3:

$$\text{Cost rate} = \frac{\text{Cost of capacity Supplied}}{\text{Practical Capacity}}$$

Assuming the following information for a nurse (Kaplan and Porter, 2011):

- Annual compensation (including benefits): $65,000
- Supervision cost: $9,000
- Occupancy (9 square meters at $1,200/sq. meter/year): $10,800
- Technology and support: $2,560
- Annual total cost of the nurse: $87,360

Using that information, the monthly total cost of the nurse is: $7,280.

Calculating her availability for patient care:

$$\text{Days per month} = \frac{\text{full year} - \text{weekends} - \text{vacations} - \text{holidays} - \text{sick days}}{12\ \text{months}}$$

$$\text{Days per month} = \frac{365 - 104 - 20 - 12 - 5}{12} = 18.7$$

$$\text{Available clinical hours} = 7.5\ \text{hours per day} - 0.5\ \text{scheduled breaks} - 1.0\ \text{meetings} = 6\ \text{hours/day}$$

Therefore, the nurse is available 6 hours a day for 18.7 days per month. Dividing the monthly cost of the resource ($7,280) by monthly capacity (112 hours), gives us the nurse's cost rate of $65 per hour. To convert that from US Dollars to Euro, we consider the exchange rate of $1.00 = 0.80€. Hence, the employees' cost rates are:

- Secretary: 36€ per hour;
- Nurse: 52€ per hour;
- Physician: 240€ per hour.

Considering the visit described in Section 4.1.3: registering patient period is 3 minutes, the triage is 2 minutes, and the patient handling is 6 minutes, **the registry accounts for 180,000€ per year** (considering the 100,000 admissions), and a **low-acute episode accounts for 27.5€ for each visit**.

Appendix C: Redesigned National Health System

This appendix presents a redesigned ATD of the NHS (Section 4.4).

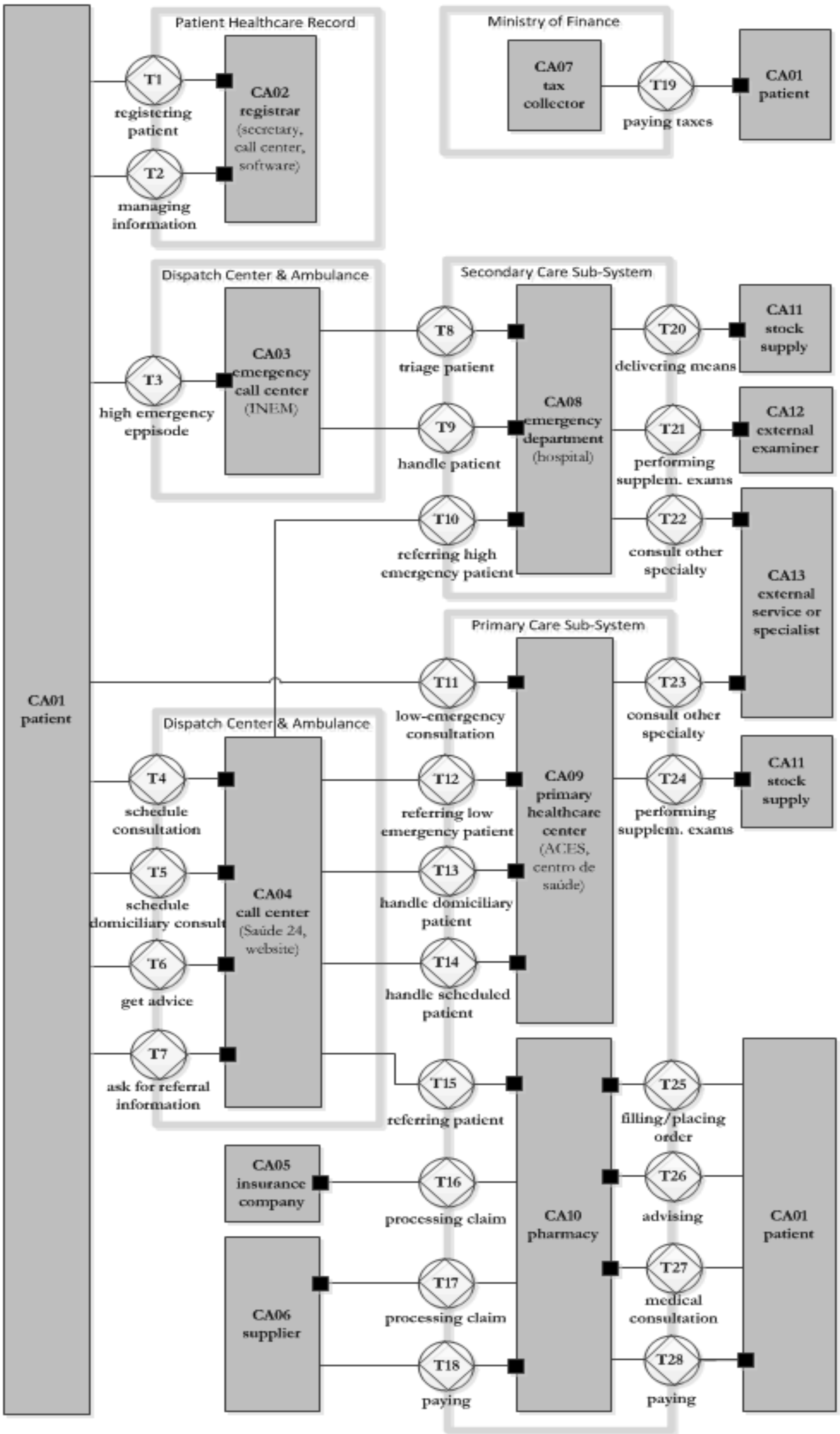

Figure 31: Healthcare System Redesign – General ATD