Validating a design methodology for the design of information systems

Improving the measurability of performance indicators in hospitals

Bianca Oosterloo

UMCG, Radiology
RUG, Economics & Business, Technology & Operations Management

Groningen, jjuni 2016

Studentenbureau UMCG

Universitair Medisch Centrum Groningen

Validating a design methodoly for the design of information systems

Improving the measurability of performance indications in hospitals

Groningen, juni 2016

Auteur Studentnummer	Bianca Oosterloo s2031523
Afstudeerscriptie in het kader van	Economics and Operations Management Technology and Operations Management University of Groningen
Opdrachtgever	prof.dr. R.A. Dierckx Radiology, UMCG
Begeleider onderwijsinstelling	dr. H. Balsters Economics and Operations Management University of Groningen
Begeleider UMCG	dr. P.M.A. van Ooijen Radiology, UMCG

Trefw

Validating a design methodology for the design of information systems

Improving the measurability of performance indicators in hospitals

ABSTRACT

Healthcare information systems play a critical role in the accessibility of healthcare information that is required for multiple purposes, such as providing treatments of high quality and obtaining insights on healthcare performances. Nevertheless, the success of information systems in healthcare is limited. This research focuses on a design methodology for the design and configuration of information systems in hospitals, to improve the measurability of performance indicators. The design methodology consists of the use of process models in BPMN and data models in ORM, whereby the correctness of the models is tested via User Interface Mockups (UIMs). Previous work of Alders (2015), Ten Holt (2015) and Oldenburger (2015) already investigated the pBractical applicability of the design methodology in one particular setting. The theoretical contribution of this research is two-folded. In the first place, this research tests the applicability of the design methodology in another setting. Secondly, this research focuses on the generalizability of the design methodology via interviews with other hospitals. Meanwhile, the aim of this research is to further develop standardized and model-driven procedures of the design methodology. The practical application and theoretical contribution is tested via design science. The findings include the second successful application of the design methodology in a hospital. Hereby, a new format for UIMs is tested and proven to be effective. Further, the design methodology can be applied by the other hospitals if hospitals are aware of the design methodology an if executors of the design methodology have proper modeling skills.

Keywords: Design methodology, BPMN,ORM, User Interface Mockup, information system design, information system configuration, design science

PREFACE

This thesis is the end result of a project at a Large Teaching Hospital in the Netherlands (LTHN) and the final step of the Master Technology and Operations Management at the University of Groningen. The project in the LTHN was strongly supported by a project team and supervisor from the University of Groningen, who made me enthusiastic every time I left a meeting. Therefore I am excited to present this thesis, which would not have been the same without the help of some important people.

First of all, I would like to thank the project team members and other employees of the LTHN who were involved in this research, for their feedback and support in the meetings and interviews. Special thanks go to Johan Groen, Michael van der Zel and Tjibbe Hoogstins, who made much time available to participate in the research. Secondly, I would to thank Herman Balsters as my supervisor from the University of Groningen, for his constructive feedback and inspiring insights. Next, I would like to thank Hans Wortmann as the second supervisor from the University of Groningen, for his feedback on the written documents. I would also like to thank my fellow researcher Marijn Vonk for the collaboration, in-depth discussions and support. Finally, I would like to thank my family and friends for their encouraging words and interest.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

BPMN	Business Process Modeling and Notation
CSF	Critical Success Factor
CUI Guidelines	Common User Interface Guidelines
DCM	Detailed Clinical Model
EHR	Electronic Health
Record HL7	Health Level 7
HNO	Head and Neck Oncology
HQMF	Health Quality Measurement Format
ISB	Information System Blueprint
ISDM	Information System Development Methodology
IT	Information Technology
LTHN	Large Teaching Hospital in the Netherlands
ORM	Object Role Modelling
PCP	Patient Care Pathway
SONCOS Oncologische	Foundation Oncology Collaboration (in Dutch: "Stichting Samenwerking")
SQL	Structured Query language
UIM	User Interface Mock-up

1. INTRODUCTION

The quality and cost of treatments in hospitals is under pressure (Van Rooijen, Goedvolk and Houwert, 2013). Healthcare cost of hospitals in the Netherlands have significantly increased in the last few years (Okma and Crivelli, 2013), because better treatments for a number of diseases become available (Rutten - van Mölken et al., 1999; Okma and Marmor, 2013) and the life expectancy has improved (Okma and Crivelli, 2013). Meanwhile healthcare providers have to deal with quality standards from foundations that commit to the improvement of care for patients (Vanberkel et al., 2010). Hospitals have to demonstrate that their quality is in line with the standards. These developments in the healthcare sector ask for more efficient ways of working (Vanberkel et al., 2010).

In order to accomplish this, more information about the treatments of hospitals needs to be available (McDonald, 1997; Van Rooijen, Goedvolk and Houwert 2013). Reliable healthcare information plays a crucial role in accurate assessments on what the best care is for a patient (Van Rooijen, Goedvolk and Houwert, 2013). Therefore, healthcare providers, government and insurance companies strive for a infrastructure in which data and records can be registered, managed and analyzed. This will result in a more transparent performance of healthcare providers and healthcare information can be used to obtain insights on areas for improvements.

Healthcare information systems play a critical role in the accessibility of healthcare information (Ash, Berg and Coiera, 2004; Brigl et al., 2005). However, the success of information systems and technology in healthcare is currently limited (Hillestad et al., 2005; Saleem et al., 2006; Jha et al., 2009; Thakur, Hsu and Fontenot, 2012). Performance indicators are difficult to measure, because data is entered manually in multiple systems in a unstructured way (Goossen and Dille, 2013). Also, information systems in healthcare often fail as a result of poor design and a misunderstanding of the system by its users (Berg, 2001; Ash, Berg and Coiera, 2004; Gagnon et al, 2012; Thyvalikakath et al., 2014; Park, Sharman and Rao, 2015). For that reason, it is of importance that processes and end users are considered whilst developing information systems for hospitals (Berg, 2001; White-Baker, 2011).

System developers need methodologies in the development of information systems (White- Baker, 2011). According to Iivari, Hirschheim and Klein (1998) an Information System Development Methodology (ISDM) can be described as "*a codified set of goal-oriented procedures which are intended to guide the work and cooperation of the various parties (stakeholders) involved in the building of an information systems applications*" (Iivari, Hirschheim and Klein,

2000). Several techniques, tools and guiding principles can be used for these procedures (Iivari, Hirschheim and Klein, 2000). The selection of an effective methodology is essential in the development of successful information systems (White-Baker, 2011).

This thesis discusses on a unique methodology that incorporates three important aspects of information system design and configuration, through the development of process models, data models and User Interface Mockups (UIMs). The design methodology consists of standardized and model-driven procedures on how the design and configuration of information systems in hospitals can be realized. The process models and UIMs define how the interaction between processes, stakeholders and the information system should be organized, while the data models visualize what data elements are involved in the processes.

This research fulfills two goals with regard to the design methodology. The first goal relates to the validation of an information system design whereby the design methodology is applied. The information system design will be developed for one specific department in one hospital. The second goal relates to the validation of the overall design methodology whereby the applicability of the design methodology in other departments and hospitals will be discussed.

With regard to the first goal, this research will be conducted at a Large Teaching Hospital in the Netherlands (LTHN). The Head and Neck Oncology (HNO) department of the LTHN has to deal with multiple quality standards. According to SONCOS, a Dutch abbreviation for Foundation Oncology Collaboration, 80% of the patients in the HNO Patient Care Pathway (PCP) should be helped within a time period of three weeks. Hospitals have to demonstrate that they are in line with this standard since the first of January 2016.

Currently, the HNO department of the LTHN is not able to measure patient cycle times in their information system which makes it difficult to control whether the standard is met. As a result, Alders (2015), Ten Holt (2015) and Oldenburger (2015) elaborated on the design of an information system for the HNO PCP (from start to end) that incorporates the measurability of patient cycle times. This research will take place at the radiology department of the same LTHN. The radiology department is highly involved in the HNO PCP to obtain images for the diagnosis of patients´ conditions. Until now, the radiology department was considered as a black box in the HNO PCP. The measurability of patient cycle times in the information system will have benefits for the radiology department. Knowledge of patient cycle times will lead to insights in radiology performances and areas for improvements (Hopp and Spearman, 2008). In addition, the combination of the information system designs for the HNO and radiology department will support stakeholders in the whole HNO PCP.

With regard to the second goal, the applicability of the design methodology in other departments and hospitals is discussed. Previous work of Alders (2015), Ten Holt (2015) and Oldenburger (2015) focused on the HNO department only. This research and the work of Vonk (2016) will discuss the application of the design methodology in another department of the same LTHN. In addition, other hospitals are approached to discuss whether the design methodology can be applied in other hospitals as well.

The following research question and sub questions are considered to achieve the two goals of this research. The main research question is as follows: "**To what extent can the design methodology for information system design and configuration be used in hospitals for the measurement of performance indicators in PCPs to improve healthcare performances?**" The sub questions are:

1. How can the design methodology be applied in information system design to ensure patient cycle times measurability at the radiology department of a LTHN in a HNO PCP?
2. How does the design methodology support the practical realization of validating the design of information systems?
3. How can the design methodology be applied in other LTHNs to ensure measurability of

performance indicators in PCPs?

In addition, some initiatives are started to enable a more structured manner to handle information in a healthcare context and to attain measurability of healthcare performances. Two concepts that are invented are eMeasures and Detailed Clinical Models (DCMs). The incorporation of eMeasures and DCMs in the design and configuration of information systems will lead to improvements in the use, reuse and exchange of healthcare information. Therefore, the next and fourth sub question is formulated to discuss on the applicability of the design methodology:

4. How can eMeasure and DCMs as part of healthcare information systems be used in the design methodology?

Moreover, a challenge in the design of information systems is related to adaptation. Hospitals, and other organizations, are subject to change. Consequently, information systems must have the adaptive ability to incorporate continuous change (White-Baker, 2011; Hess et al., 2012). The processes and information system is influenced if data needs are altered. The methods and

techniques used in the methodology must have the adaptive ability to support certain changes. For that reason, a fifth and last sub question is formulated, namely:

5. To what extent can the design methodology adaptively cope with changes in the context?

The theoretical contribution of this research about the design methodology is two-folded. In the first place, this research provides evidence for the practical applicability of the design methodology in another setting thereby encountering the limitations of the work of Alders (2015), Ten Holt (2015) and Oldenburg (2015). The aim is to further develop the standardized procedures of the design methodology. Second, this research discusses the generalizability of the design methodology with regard to the applicability of the design methodology in other hospitals.

This research is executed via design science. Design science can be described as a problem- solving approach for the development of new artifacts (Holmström, Ketokivi, and Hameri, 2009). Usually a practical and theoretical problem are addressed while applying design science (Wieringa, 2010). Also this research involves an practical and theoretical problem, concerning the two goals of this research. The first goal relates to the practical problem and the second goal relates to the knowledge problem. The combination of these two goals will be the outcome of this thesis. During this research the regulative cycle of Van Strien (1997) will be applied and a case study will be executed, which will be further discussed in the methodology section.

The remaining of this thesis is structured as follows. Section 2 elaborates on the theoretical background. In section 3 the methodology will be further explained. Thereafter, section 4 presents the results of the research. This thesis is ended with an discussion and conclusion is section 5 and 6 respectively.

2. THEORETICAL BACKGROUND

2.1 Design methodology

As stated during the introduction, the design methodology incorporates three aspects of information systems, consisting of process models, data models and UIMs. An overview of how the design methodology is executed is visualized in Figure 2.1. The design methodology starts with the creation of processes models, followed by the creation of data models and UIMs. Hereby, standardized procedures are defined to develop process models, data models and UIMs. Major part of the design methodology is the attendance of different stakeholders. The UIMs will be used to validate among stakeholders of the information system whether the design or

configuration takes requirements of different stakeholders into account. The validation is visualized in Figure 2.1 via the regulative cycle. Feedback of stakeholders on the UIMs will influence the process and data models, since the models and UIMs are closely linked. The feedback loops continue till all process models, data models and UIMs are correct. In that case, the design methodology is completed and the functionality of the (new) information system is validated.

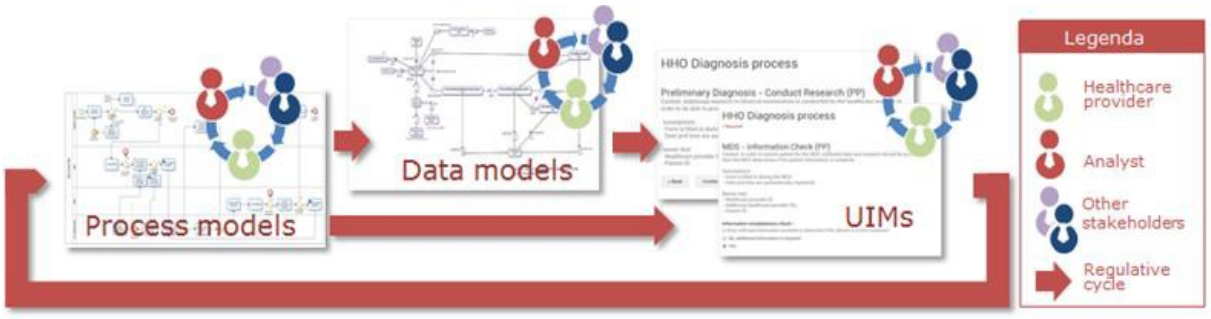


Figure 2.1 The design methodology

2.1.1 Process modeling

Modeling business processes is widely used in practice to define, analyze and improve processes (Ould, 1995; Mili et al., 2010). Business processes are often complex and difficult to understand as written text (Chinosi and Trombetta, 2012). Visualizing the process in graphical displays improves the understanding of processes and allows users to easily identify interruptions, inconsistencies (Chinosi and Trombetta, 2012) and areas for improvements (Hammer 1990; Hammer and Champy 1993; Ould, 1995). Soffer, Wand and Kaner (2015) highlight that business process models can be used to

analyze information systems, since the information systems should support business processes within an organization.

Nevertheless, process models that are developed for business purposes are often difficult to apply by software engineers (Mili et al., 2010). Mili et al. (2010) explain that "a *number of process modeling languages have emerged, but the languages are typically too abstract, and the models too coarse, to support the elicitation of precise functional specifications for information systems*". Identifying user requirements is a difficult but important task in software engineering (Phalp and Shepperd, 2000; Mili et al., 2010). Although the importance of business modeling in software engineering is recognized, it seems hard to find appropriate tecniques to model business processes and to use these techniques to define user requirements (Mili et al., 2010).

Several business process modeling languages are available to model business processes. Mili et al. (2010) provided an overview of business process modeling languages, divided into four broad categories (Mili et al., 2010):

1. Traditional process modeling languages. These languages are usually easy to understand by the users of the models and are applied for different types of analyses. The languages that are categorized in the traditional process modeling languages are Role Activity Diagrams, IDEF, Petri Nets, Resource-Event-Agent and Event Process Chains.
2. Object-Oriented languages. These languages provide a better understanding for software engineers. Often these languages focus on modeling the solution instead of the problem. The languages included in this category are Unified Modeling Language 1.x, Enterprise Distributed Object Computing and Unified Modeling Language 2.
3. Dynamic process modeling languages. These languages focus on the dynamics within business processes. This category involves Workflow Modeling Language, Business Process Modeling Language, Business Process Modeling and Notation (BPMN), Web Service – Business Process Executable Language and Business Process Definition Metamodel.

4. Process integration languages. These languages focus on the interactions between several stakeholders, especially if these stakeholders are not located at the same enterprise. Languages involving this category are RosettaNet, ebXML and Web Service – Choreographic Description Language.

One of the previously mentioned languages needs to be selected to be used in the design methodology discussed in this thesis. This research focuses on information systems to measure performance indicators in PCPs. Hereby, workflows and involvement of different stakeholders within one organization are important. A dynamic process modeling language will be selected, since the dynamics of the processes and the interaction between (internal) stakeholders are considered in these languages (Mili et al., 2010). The dynamic process modeling language that will be applied in this design methodology is BPMN. Compared to other dynamic process modeling languages, the BPMN models are easier to understand and interpret (Mili et al., 2010; Chinosi and Trombetta, 2012), which becomes a major aspect in the validation with end users. Also, previous research has proven that BPMN is a suitable method in modeling PCPs (Rojo et al., 2008; Rolón et al., 2008; Müller and Rogge-Solti, 2011; Barros and Quezada, 2014; Alders, 2015) and early stage system development (Dijkman et al. 2007).

During this research and the research of Vonk (2016) will be discussed how the use of BPMN influences the design and configuration of information systems. The process models in BPMN will become a valuable tool to recognize what kind of tasks the new information system should support and at what point certain registrations have to be performed. In this thesis will be explained how BPMN can be used – while applying the design methodology – to overcome the limitations of process models in software engineering, in the identification of user requirements and functional specifications. A description about how BPMN works is available in Appendix A.

2.1.2 Data modeling

Data modeling in the design of information systems is required to "*specify the structure and integrity of data sets*"(Spyns, Meersman and Jarrar, 2002). Data models help to define data elements and the meaning of data elements on a conceptual level. In their book, Halpin and Morgan (2008) discuss on three popular data modeling techniques: Entity-Relationship modeling, Object-Oriented modeling and Fact-Based modeling. Entity-Relationship modeling and Object-Oriented modeling are widely used in practice, but both approaches have modeling limitations and the models are often difficult to understand by technical and non-technical staff members. The third approach, Fact-Based modeling, overcomes these weaknesses and is easier to understand by others. The understandability of the data modeling technique is of importance in the design methodology due to the high involvement of different stakeholders, as described in section 2.1. Therefore is decided to apply the Fact-Based modeling approach as part of the design methodology. The most popular method of Fact-Based modeling is Object Role Modeling (ORM). The use of ORM over other methods has several advantages. First, with ORM it is less complicated to model constrains among attributes (Ten Holt, 2015). Second, the validation of the model is easier, because the model is also understandable by non-technical end users due to a verbalization tool that verbalizes what is modeled in the ORM model (Ten Holt, 2015). Third, data models in ORM can be mapped into relational databases via Structured Query Language (SQL) (Halpin and Morgan, 2008). An explanation about ORM is available in Appendix B.

Although, data models in itself contain valuable input for information system designs, some limitations arise when dynamic behavior is not modeled (Halpin and Morgan, 2008). For example, data models do not define how certain information fulfils business needs within an organization or how information will be used in a setting (Halpin and Morgan, 2008). Also, data models don't provide any knowledge on information dynamics, such as when information is created, modified or deleted (Halpin and Morgan, 2008). These aspects have to be considered while developing data models. This is where workflow dynamics and modeling business process becomes involved. Halpin and Morgan (2008) came up with the term "Universe of Discourse" (UoD). UoD refers to the business domain of interest whereby the business domain is described as part of the "universe" being considered in the data model (Halpin and Morgan, 2008). In the design methodology, the limitations of data models are covered with the development of BPMN

models to describe the UoD. For the design methodology, Vonk (2016) will further elaborate on how BPMN and ORM complement each other.

Recently, some researchers focused on the translation of process models in BPMN into data models in ORM. Work of Balsters (2014) describes the so called "BPMN-ORM methodology" whereby BPMN models can be directly mapped into ORM models. The BPMN-ORM methodology will be used in the design methodology discussed in this thesis. An explanation of the BPMN- ORM methodology is available in Appendix C.

2.1.3 User Interface Mock-ups

The validation phase defines what the information system should be able to do to support end users (Wieringa, 2009). In the end, the information system should support users in performing their tasks (Goodhue, 2006) and it should bring users closer to their goals (Wieringa, 2009). Literature suggests UIMs, also known as graphical user interfaces, in the validation and prototyping phases of information system development. Hereby an UIM can be described as a sketch that visualizes how the user interface should look like (Rivero et al., 2010).

Back in 1985, Kraushaar and Shirland (1985) already recognized the importance of prototyping for fast and effective development of information systems. Kraushaar and Shirland (1985) were the first researchers who provided predefined guidelines on how software engineers should execute and guide prototyping activities. Their work and the work of previous followers indicated that end users of information systems easily relate to a sequence of screen mockups whereby the correctness of the prototype is validated among end users. Kraushaar and Shirland (1985) suggest to use two prototyping rounds for information systems designs. The first round consists of defining the broad and general aspects of the information systems, and the second round precisely evaluates on the support of the information systems, comparable to how the final operating system should perform (Kraushaarand and Shirland, 1985).

In the past decades, the idea of Kraushaar and Shirland (1985) about prototyping via screen mockups is further applied. In the meantime, UIMs have proven to be a viable method for user requirements analysis (Scanniello et al., 2013). Currently, some researchers elaborate on more procedural and model-driven approaches, to enhance the

productivity of the development process (Rivero et al., 2010; Rivero et al., 2011; Scanellio et al., 2013; Rivero et al., 2014). For example, Rivero et al. (2014) experienced that UIMs are often considered in later stages of model-driven web engineering development. An outcome is the use of metamodels to avoid rework on the application (Rivero et al., 2014). Another example refers to five other researchers who tried to encounter some practical issues with regard to development of UIMs (Scannellio et a., 2013). They limit the effort, cost and time required to create mockups via a model-driven approach that links mockups and use cases.

Comparable, the design methodology discussed in this thesis elaborates on a model-driven approach to enhance the process of creating UIMs. The UIMs as part of the design methodology will be created based on BPMN and ORM models. This study discusses on model-driven and structured procedures to enable the mapping of BPMN and ORM models into UIMs. Hereby, broad and specific aspects of user interfaces are incorporated in the UIMs.

To enhance the validation of UIMs, close and direct collaboration with domain experts is required (Rivero et al., 2011). Domain experts can be described as stakeholders or end users of the information system with practical knowledge about the setting, but without advanced modeling skills (Hess et al., 2012). The validation with domain experts will result in an identification of user requirements (Rivero et al., 2011) and an agreement on broad aspects of the user interface (Rivero et al., 2010).

2.2 Information systems in hospitals

Information systems in healthcare play an important role in providing care of high quality to patients in an effective and efficient manner (Saleem et al., 2006). Within the development of healthcare information systems, DCM and eMeasure should be applied in a correct manner to enable information exchange between hospitals and the measurement of performance indicators in PCPs. In this section, PCP, performance indicators, DCM and eMeasure will be discussed.

2.2.1 Patient Care Pathways and performance indicators

Information systems in hospitals have to deal with PCPs. A PCP can be described as "*integrated management plans that display goals for patients, and provide the sequence*

and timing of actions necessary to achieve such goals with optimal efficiency" (Panella, Marchisio and Stanislao, 2003; Alders, 2015). PCPs are used in hospitals to cope with high variations and complexity and to continuously improve clinical processes. It involves the coordination of multiple interrelated activities and interdisciplinary teamwork for patient oriented healthcare processes (Vanhaecht et al., 2012). For a patient this means the best timing within a PCP to treat diagnoses and conditions (Panella, Marchisio and Stanislao, 2003). Healthcare staff members need insights on how care processes are executed for the evaluation of healthcare performances. In order to achieve this, performance indicators have to be measured during the treatment of patients in PCPs.

2.2.2 Detailed Clinical Models and eMeasure

For hospitals it is beneficial to develop a standardized and structured way of handling healthcare information and measuring performance indicators. One of the initiatives to enable the quality of information within healthcare is Health Level 7 (HL7). HL7 develops and controls international standards and models for electronic data transfer within a healthcare context. In order to do so, HL7 developed the Health Quality Measurement Format (HQMF). HQMF is "*a standard for representing a health quality measure as an electronic document*" (HL7, 2016). A quality measure is a quantitative tool that can be used in the measurement of an outcome or action. The results of the measurement will provide insights on the performance of an individual or the organization in a specific care process. The quality measures in HQMF are eMeasures. The use of the standard will result in a more consistent and unambiguous interpretation of concepts and will help healthcare providers to improve their care processes (HL7, 2016).

Another initiative to structure healthcare information is DCM. The DCMs that are used in the Dutch healthcare sector are developed in the Registration at the Source program (in Dutch: "Registratie aan de bron") by the Dutch Federation for University Medical Centers and Nictiz and are called "zorginformatiebouwstenen" (in English: "healthcare information building blocks"). The goal of the Registration at the Source program is to record healthcare information in a unambiguous way, so healthcare information can be reused for multiple purposes, such as in improving quality, business management, patient care and academic research. A DCM combines knowledge, data specification,

relationships between data elements and terminology in information models (Goossen, Goossen-Baremans and Van Der Zel, 2010). These information models can be applied in technical realizations of information systems in healthcare.

An example of a DCM in the Dutch healthcare sector about vaccination is shown in Figure 2.2. A root concept is defined, which is in this case “Vaccination” (in Dutch: “Vaccinatie”). Multiple data elements are defined for the root concept. An example of a data element is “Dose” (in Dutch: “Dosis”). For “Dose” the amount of vaccination in milliliters is recorded. Also multiple documents are involved. For “Vaccination” one of the documents is “ProductCodeGPKCodeList” (in Dutch: “ProductCodeGPKCodelijst”). The document entails all codes for Generic Product Codes (GPC).

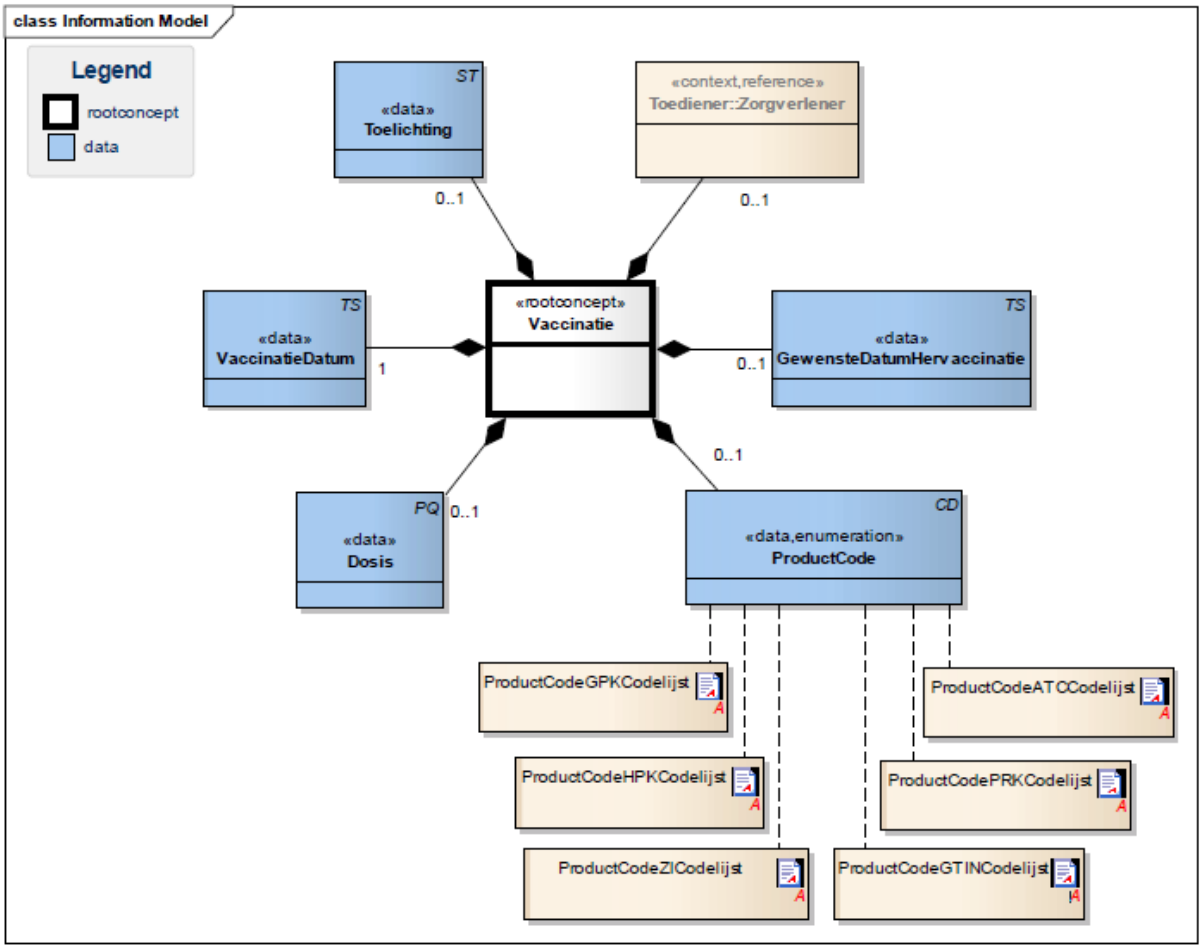


Figure 2.2 Detailed Clinical Model about vaccination

The concepts of DCM and eMeasure will be incorporated in the application of the design methodology. As a result, it becomes easier for hospitals to exchange patient information with other hospitals and to reuse healthcare information for multiple purposes.

3. METHODOLOGY

3.1 Research methods

The research methods define what techniques are applied to collect and analyze data for the research (Karlsson, 2009). During the introduction is shortly described that this research involves a design science problem. Design science is applied to cover both two goals of this research. Also, a case study will be performed and the regulative cycle of Van Strien (1997) will be applied, which will be further explained in this section.

3.1.1 Design science

Design science is the main method used in this research, because design science has proven to be useful in the development of information systems (Hevner et al., 2004; Balsters, 2015a). The

design science approach involves the development and evaluation of (new) artifacts to solve problems within an organization (Hevner et al., 2004; Holmström, Ketokivi and Hameri, 2009; Wieringa, 2009). Hereby, the main goal is the utility of the new artifact (Hevner et al., 2004). Design Science involves a combination of practical and knowledge problems (Wieringa, 2009; Balsters, 2015a), as shown in Figure 3.1. Practical problems are related to an organizational context and involve changes, such as the implementation of artifacts, that have to be performed to fully support stakeholders in achieving their goals. On the other hand, knowledge problems focus on using knowledge from the knowledge base and adding new knowledge to the knowledge base. The combination of the practical and knowledge problem focuses on current perspectives of stakeholders on the world and the desired perspectives of stakeholders on the world (Wieringa, 2007).

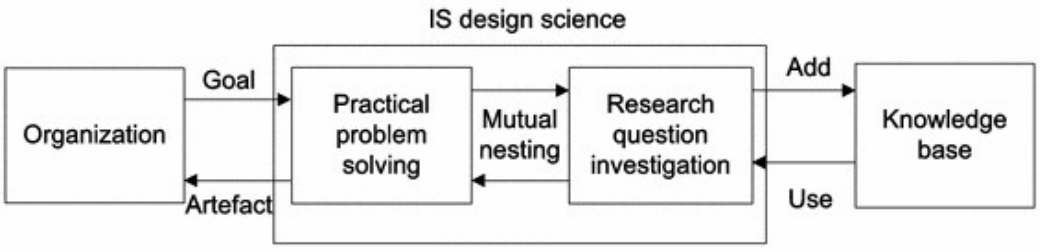


Figure 3.1 Practical knowledge problem (Wieringa, 2010)

This research concerns a practical knowledge problem. The practical problem (the first part of Figure 3.1) relates to the first goal of this research, where an information system for the radiology department of a LTHN is designed. The information system design will help to achieve the goal of measuring patient cycle times in the HNO PCP. The knowledge problem (the last part of Figure 3.1) relates to the second goal that focuses on the applicability of the design methodology in other departments and hospitals. Existing knowledge will be used from the knowledge base and the outcomes of this research will be added to the knowledge base.

3.1.2 Regulative cycle

Wieringa (2009) explains that the regulative cycle of Van Strien (1997) is suitable in solving practical problems (first part of Figure 3.1). Therefore the regulative cycle will be applied, as part of the design methodology, in the design of the information system.

The regulative cycle is a design cycle that starts with a practical problem and ends with a validated solution. Five stages are defined for the regulative cycle, including (1) design problem, (2) diagnosis and analysis, (3) design solution, (4) implementation and (5) validation. Figure 3.2 provides an overview of the five stages.

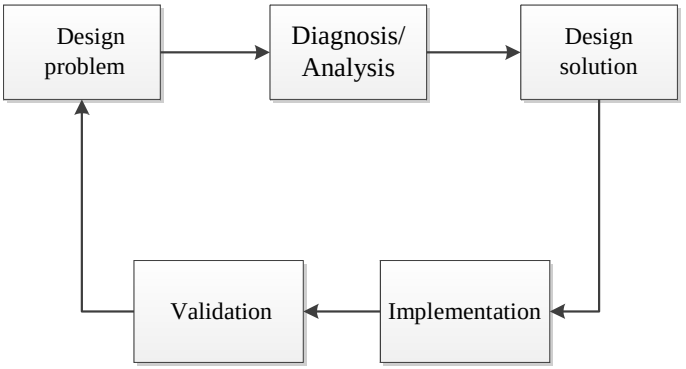


Figure 3.2 Regulative cycle of Van Strien (1997)

The five stages of the regulative cycle (Figure 3.2) can be described as follows (Van Strien, 1997; Balsters, 2015b):

1. Design problem. The context of the problem is analyzed and described in the design problem stage. This involves the identification of stakeholders, the goals of the stakeholders and the Critical Success Factors (CSF) for the goals.
2. Diagnosis and analysis. The diagnosis and analysis stage is applied to identify the causes of the problem. The causes of not achieving CSFs have to be checked with quality attributes. Quality attributes refer to attributes or components that have to be considered in the solution.
3. Design solution. The solution for the problem is identified in the design solution stage.

   The required solution components have to be considered in the design solution. The solution can consist of existing solutions or completely new solutions.
4. Implementation. The implementation stage consists of the development of the artifact.

   Multiple resources, such as man, materials and budget, are required to implement the solution.
5. Validation. The usefulness of the solution is tested in the validation stage. Several test methods need to be developed to test whether the CSFs are achieved with the implementation of the solution. The regulative cycle will start over again if not all CSFs are met with the solution and will continue till a satisfying solution is found.

In this research, the solution (i.e. stage 3 of the regulative cycle, Figure 3.2) for the radiology department of the LTHN consists of three elements, including (1) process models, (2) data models and (3) UIMs. Therefore are the first three stages of the regulative cycle performed three times. Once for the development of process models, once for the development of data models and once for the development of UIMs. Hereby, the development of the process models, data models and UIMs each takes place by their own sub regulative cycle. The development of the

process models, data models and UIMs will not require an implementation, as a result the implementation stage is missing in the three sub regulative cycles.

The three sub regulative cycles (for the process models, data models and UIMs) are iterative and closely linked to each other. The development of the data models depends on the process models and the development of the UIMs depends on the process models and data models. The feedback of domain experts on the UIMs will influence both the process and data models. The first three stages of the overall regulative cycle (Figure 3.2) are completed if the process models, data models and UIMs are fully validated. Then the implementation and validation phase of the regulative cycle (Figure 3.2) can start. An overview of the overall regulative cycle with the three sub regulative cycles is shown in Figure 3.3.

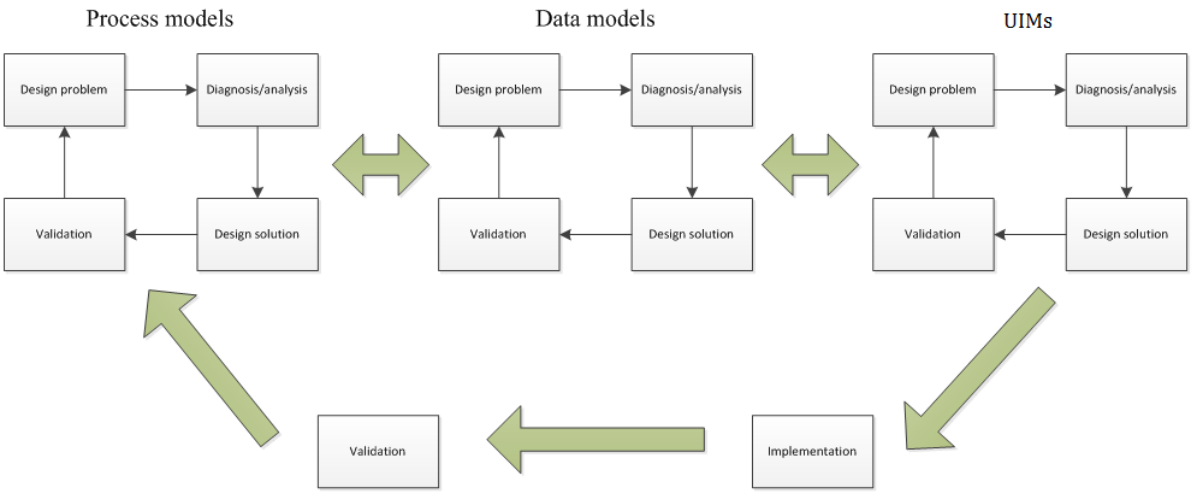


Figure 3.3 Regulative cycle(s) in this research

The development of the information system design for the radiology department of the LTHN takes place in a close collaboration with Vonk (2016). Vonk (2016) will develop the process and data models. Also, Vonk (2016) will be responsible for the implementation and validation stage of the overall regulative cycle via a proof-of-concept. The writer of this thesis will develop the UIMs and will validate whether the process and data models are in line with how the processes take place in reality.

3.1.3 User Interface Mock-ups for validation

The UIMs consist of a stream of forms to validate on the correctness of the models and the functionality of the information system. Hereby, each UIMs represents a screen of

an end user during a certain activity. Oldenburger (2015) developed an UIM format consisting of five general steps. This UIM format has proven to be effective and will therefore be applied by this study.

Hereby, the aim is to further develop the format proposed by Oldenburger (2015). The five general steps of Oldenburger (2015) are available in Appendix D.

Multiple software programs are available to create UIMs, such as Lumzy, ForUI, DesignerVista, Napkee, Mockingbird and Google Forms. In this research the program should support simple but accurate user interfaces. In combination with cost and accessibility of the program is chosen to use Google Forms. Google Forms is easy to understand and won't take much effort for user interface purposes.

3.1.4 Case study

A case research is a research where data is collected and analyzed via multiple cases. A single case can be described as a detailed explanation of phenomena, events or organizations (Karlsson, 2009). A case research can have multiple purposes, such as exploration, theory building, theory testing and theory extension or refinement (Karlsson, 2009). The purpose of this research relates to theory extension or refinement. Previous work of Alders (2015), Ten Holt (2015) and Oldenburger (2015) has shown the applicability of the design methodology in one particular situation (i.e. the HNO department of a LTHN). This research focuses on the applicability of the design methodology in other departments and hospitals and will answer whether the theory of the design methodology also holds for other cases (Karlsson, 2009).

This research is executed via data collection and analysis in six cases. The first case is the case in which the design methodology is applied at the radiology department of a LTHN. This case will be discussed extensively. The other cases, consisting of five other hospitals, are researched via interviews. The data collection in six cases will positively influence the external validity and will help to guard the bias of the researcher (Karlsson, 2009). The downsides relates to more resources and less depth per case (Karlsson, 2009).

3.2 Data collection and analysis

This section elaborates on data collection and analysis. The data for this research is mainly collected via interviews. The structure and the execution of the interviews are described in section 3.2.1. In addition, data is collected and analyzed in collaboration with Vonk (2016). A background on concurrent engineering is provided in section 3.2.2.

3.2.1 Interviews

Interviews are often the main source to obtain data in a case research (Karlsson, 2009). Also in this case study most of the data will be collected via interviews. This will result in a qualitative

data set that is required to answer the research question. Most of the interviews are conducted in personal meetings with the interviewees. It is a time consuming task to visit every interviewee personally, but it will positively influence the response rate, accuracy of information, completeness and overall reliability and validity (Karlsson, 2009). The interviews are conducted with two researchers or are recorded, to enhance the quality of this research (Karlsson, 2009). One interview is conducted via email contact, which results in a high ease of securing information, overall reliability and accuracy of information. Downsides of email contact refer to response rate, completeness and time to secure information (Karlsson, 2009). This interview is conducted via email, because the interviewee couldn't be reached via other communication types.

In this research, two different types of interviews will be conducted. The first type of interview refers to the single case, where the design methodology is applied at the radiology department of a LTHN. The second type of interview refers to the other cases, where five hospitals are approached to discuss on the applicability of the design methodology in other hospitals. The interviews in the single and the interviews in the other cases are described below.

Interviews in single case

The interviews in the single case are conducted to gain feedback on the UIMs. The feedback is required to iteratively apply the regulative cycle and to gain insights on the correctness of the process and data models. The interviews are executed with domain experts of the radiology department, since they are familiar with how the processes are performed, and they can imagine whether the UIMs support these processes correctly (Rivero et al., 2011).

The interviews in the single case are structured according to the system engineering approach. System engineering is a method to describe, analyze and structure processes (In 't Veld and Slatius, 2015). Hereby, processes transform input into desired output to achieve a function within its environment (In 't Veld and Slatius, 2015). The system engineering method has proven to be useful in interviews in which the process flow of a

certain system is discussed (In ‘t Veld and Slatius, 2015) and is therefore applied in the single case of this research .

The application of the system engineering approach can be established during the interviews by focusing on the material flow in a system (In ‘t Veld and Slatius, 2015). In this case, the UIMs as potential screens of the (new) information system are discussed. The flow of UIMs relates to the process flow visualized in the BPMN models. An interview protocol is compiled to structure the

interviews. The following interview protocol is established based on the recommendations of

In't Veld and Slatius (2015):

1. The interview starts with a short introduction. First the interviewee and interviewer are introduced to each other. Then the purpose of the interview is explained with regard to the design of an information system that ensures the measurability of the patient cycle times. The introduction is ended by explaining what will happen with the outcomes of the interview.
2. Then the UIMs are shown in a happy flow. The happy flow means that the discussion on the UIMs is based on when the input, output and transformation conditions are perfect. The UIMs are shown in sequence of how the processes are performed. Each time the context of an UIM is explained, to make sure that the interviewee knows exactly where we are in the process.
3. The stream of UIMs is repeated after the happy flow is finished. This time the discussion is based on imperfect conditions. Some examples of imperfect conditions are differences in input or output and exceptions for certain patients. Again, the UIMs are shown is sequence of how the processes are performed. Each time the context of an UIM is provided.
4. The interview is ended with a last conclusion on what should be changed in the UIMs. Also, the interviewee is asked for any final comments on the interview and discussions.

Interviews in other cases

The interviews in the other cases are conducted to gain insights on the applicability of the design methodology in other hospitals. The interviews are conducted with IT architects of other hospitals. They are familiar with how data is registered and used and how the development of information system designs and configurations is currently executed. Also, they know and understand the design methodology and can discuss on the application of the design methodology in their hospital. The following interview protocol, consisting of five points, is established:

› How are DCMs and eMeasures currently applied in the hospital and in the information system designs of the hospital?
› How is the design of an information system currently realized?
› How does the hospital deals with changes in information needs?
› How is data registered and used?
› What is the applicability of the design methodology in the hospital?

The answers on these points can vary a lot and it is unknown how each hospitals currently addresses these points. Therefore the interviews are only structured via the five points of the interview protocol. The funnel model will be applied in these interviews. This is a format in which the interview starts with broad and open questions, when the interview continues more specified questions will be asked and the interview is ended with very specific and detailed questions (Karlsson, 2009). The interview protocol is used as a checklist, to make sure that all points are covered during the interviews. Also, the interview protocol is known by the interviewees before the interview takes place. In that case, interviewees are properly prepared for the interview (Karlsson, 2009).

3.2.2 Concurrent engineering

A part of this research will be addressed with concurrent engineering. Concurrent engineering is the design and development of a product with overlapping processes (Savci and Kayis, 2006). Concurrent engineering is used in this research due to time limitations. With the help of Vonk (2016) more steps in the development of the information system design for the radiology department of the LTHN can be completed in a short period of time. The downside of concurrent engineering relates to multiple risks. According to Savci and Kayis (2006) the risks of the project should be identified and mitigated. Savci and Kayis (2006) identified eight potential risks in concurrent engineering. These risks are as follows:

- Technical risks. Technical risks refer to risk factors within the design, such as available knowledge, technological support and quality issues.
- Resource risks. Resource risks refer to resources, such as materials and manpower.
- Communication risks. Communication risks refer to the ability to share information inside and outside the organization.
- Schedule risks. Schedule risks refer to planning and sequence of actions that have to be performed, defined go or no-go decisions, task dependencies and required amount of time.
- Organizational risks. Organizational risks refer to the influence of the organization on the project. Some examples are management, support, stakeholders and ownership.

› External risks. External risks refer to external factors, such as customers and the government.
› Financial risks. Financial risks refer to budgetary constraints and costs.
› Location risks. Location risks refer to the distance between individuals involved in the project.

The risks for this research are limited due to multiple factors. The information system design is important for the radiology department of the LTHN and is therefore supported within the organization. A project team is available to guide and execute the project. The project team consists of four domain experts, the supervisor from the university, Vonk and a project manager. The domain experts have different backgrounds, all required in the project, and are familiar with how the end users should be supported by the information system. The project manager is guiding the project, organizing the resources and leading the meetings that are planned on Friday every week. Every member of the project team is located in Groningen and can easily be contacted. These factors reduce the location, technical, organization, resources, scheduling and external risks. The project doesn't have to deal with financial risks, since the development of the information system design is free of charge. An important factor in this research will be information sharing. Chen and Liang (2000) explain that management and sharing of information forms the basis in concurrent engineering. This research highly depends on Vonk (2016) within the BPMN, ORM and UIM modeling stage (as visualized in Figure 3.3) and will require much information exchange on the validation of the models.

3.3 Validity

It is important to ensure validity in a research. Three types of validity are identified for a research that applies design science. The validity in design science determines whether stakeholders are able to achieve their goals if the new artifact is implemented correctly (Wieringa, 2009). According to Wieringa (2009), internal validity, trade-offs and external validity should be ensured to validate the artifact. Internal validity, trade-offs and external validity are defined as follows (Wieringa, 2009):

- Internal validity. Internal validity refers to whether all requirements are met with the implementation of the new artifact and whether the artifact successfully supports stakeholders in achieving their goals.
- Trade-offs. Trade-offs refer to trade-offs in the design due to differences in requirements of stakeholders.
- External validity. External validity refers to whether the artifact can be implemented in another, quite similar context.

4. RESULTS

4.1 Results single case

4.1.1 Individual regulative cycle

The individual regulative cycle focuses on the development of the UIMs. The design problem, diagnosis and analysis, design solution and validation stages are addressed in the individual regulative cycle (Figure 3.3).

Design problem

The design problem refers to the UIMs for the radiology department to attain the measurability of patient cycle times. In the first place, the aim was to design an information system for the as-is situation. When the first process models, data models and UIMs were developed, multiple stakeholders explained that they would like to change some processes in the near future. Therefore is decided to develop an information system design for the to-be situation.

In the design problem stage of the regulative cycle, the stakeholders, the goals of the stakeholders and the CSF for the goals have to be identified. The direct stakeholders are healthcare providers in the radiology care process. They are visualized in the swimming lanes and pools of the process models in BPMN. The indirect stakeholders are others who have interests in the information system design. A stakeholder analysis is available in Appendix E. An overview of the stakeholders, their goals and the CSFs of the goals are shown in Table 4.1.

	Stakeholder	**Goal of stakeholder**	**CSF of goal**
Direct	Care administration, radiologist executors,	UIMs that result in the realization of an information system design and	The UIMs must be complete and should
	incorporate all required components in the	assistant radiologists that will support the and supervising	care processes correctly

Indirect	Process managers and quality managers	UIMs that enhance the realization of an information system design in which performance indicators define the measurement of performance indicators	The UIMs must
	Information managers	UIMs that incorporate eMeasure and DCM in the realization of an	The UIMs must incorporate the concepts of

Table 4.1 Overview of stakeholders, their goals and CSFs of individual regulative cycle

Diagnosis and analysis

The quality attributes have to be defined in the diagnosis and analysis stage. The quality attributes in the development of the UIMs can be identified based on Table 4.1. From the CSFs in Table 4.1 can be observed that the UIMs for the realization of the information system design should have the following four quality attributes. First, the UIMs should be complete, all required information should be accessible and all required registrations have to be performed. Second, the UIMs should be correct, the UIMs should be correct in terms of terminology and should properly support each of the processes involved. Third, the UIMs should support the accurate measurement of performance indicators. Last, the UIMs should be consistent in applying the concepts of eMeasure and DCM to enable use, reuse and exchange of healthcare information

Design solution

The design solution consists of the developed UIMs. The UIMs are discussed with each direct and indirect stakeholder. Each validation round resulted into insights on the correctness of the models and the functionality of the information system. As a result, multiple changes had to be made after each validation round. The feedback on the UIMs was incorporated into the new process and data models, and also the UIMs were adapted. The feedback of stakeholders related to new information needs and differences in the support of the system. Both, large and small changes had to be incorporated into the design. Usually, changes in the BPMN models, ORM models and UIMs could be executed in two days. In total, ten validation rounds were required to discuss on the correctness of the design. Some examples of the developed UIMs is available is Appendix F.

The UIM development starts with the BPMN models. The BPMN models consists of user and manual activities. An UIM is developed for every user activity in the BPMN model, because these are the processes in which an end user interacts with the system. The manual activities are modeled in the BPMN model to create a better understanding of the context. This is helpful in the validation with stakeholders.

The UIMs are developed based on the five steps of Oldenburger (2015). Step 1 and 2 refer to the identification of the banner text and titles of UIMs. Step 1 and 2 of the UIM

development have not been changed. In this study, a standardization is applied for step 3. Step 3 refers to a context description via pre-conditions, input, post-conditions and output. The pre-conditions and post- conditions define what has to be performed before and after a certain activity. The input and output define the flow and transformation related to a certain activity. The pre-conditions, input,

post-conditions and output can be directly mapped from BPMN models. An example of the standardization of step 3 is visualized in Figure 4.1.

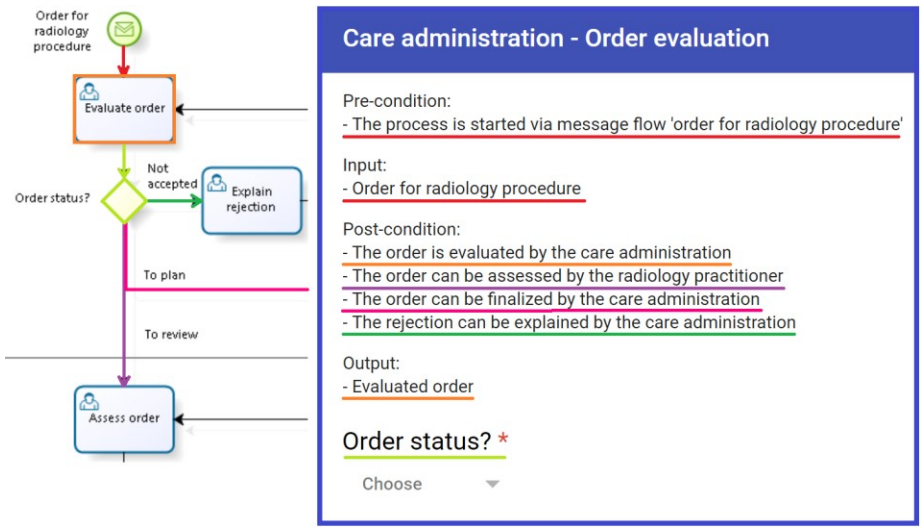


Figure 4.1 From BPMN to standardized UIM

From Figure 4.1 can be seen that the verb-noun description of the activities in the BPMN models can be used to define the pre-conditions, input, post-conditions and output descriptions of the UIM in a standardized manner. Figure 4.1 provides an overview of how the BPMN activity

'Evaluate order' (the orange square in Figure 4.1) can be mapped into an UIM. For the pre- condition, an start event is executed whereby a message flow goes to the radiology department. Therefore, the post-condition of 'Evaluate order' is "*The process is started via message flow 'Order for radiology procedure"* (the red line in Figure 4.1). For the input, the designation of the massage flow can be used, which is in this case "*Order for radiological examination*" (the red line in Figure

4.1). The post-condition and output of 'Evaluate order' can be identified based on the activity

that took place and the activities that are performed afterwards. The first post-condition relates to the activity that is performed, in Figure 4.1 this is the activity 'Evaluate order'. The verb-noun description is used to describe something that took place and by whom, namely "*The order is evaluated by the care administration*" (orange line in Figure 4.1). The other post-conditions relate to what is performed after the activity. In the BPMN model of Figure 4.2 the next activities are 'Assess order', 'Explain rejection' and 'Finalize order' (the latest is not visualized in Figure

4.1). For the post-condition, the verb-noun description of the activity is used to describe what can happen afterwards, such as "*The order can be assessed by the radiologist practitioner*" (purple line in Figure 4.1). The output consists of the verb-noun description changed into the adjective- noun description of the activity itself, in Figure 4.2 this is "*Evaluated order*" (orange line in Figure 4.1).

The next step, step 4, can also be executed in a more standardized manner. Step 4 refers to the visualization of question fields in the UIMs. Oldenburger (2015) already described how each gateway is transformed into a question field in the UIM. This study found out that each gateway in the BPMN model should be linked to the activity before that gateway. This becomes an important aspect when the sequence of the UIMs needs to be determined. Additionally, other question fields should be identified to support the care processes. UIMs can consist of one or multiple different question fields. The number of question fields in an UIM can be determined based on what the best support is for the end user. The modeling of sub processes in BPMN models is required in case a UIM consists of more than one question fields. Each activity in the sub process is mapped into a question fields in the UIM. As a result, the UIMs follow the same hierarchical structure as the different aggregation levels in BPMN models. An example of how multiple question fields can be addressed in the sub processes of BPMN models is visualized in Figure 4.2.

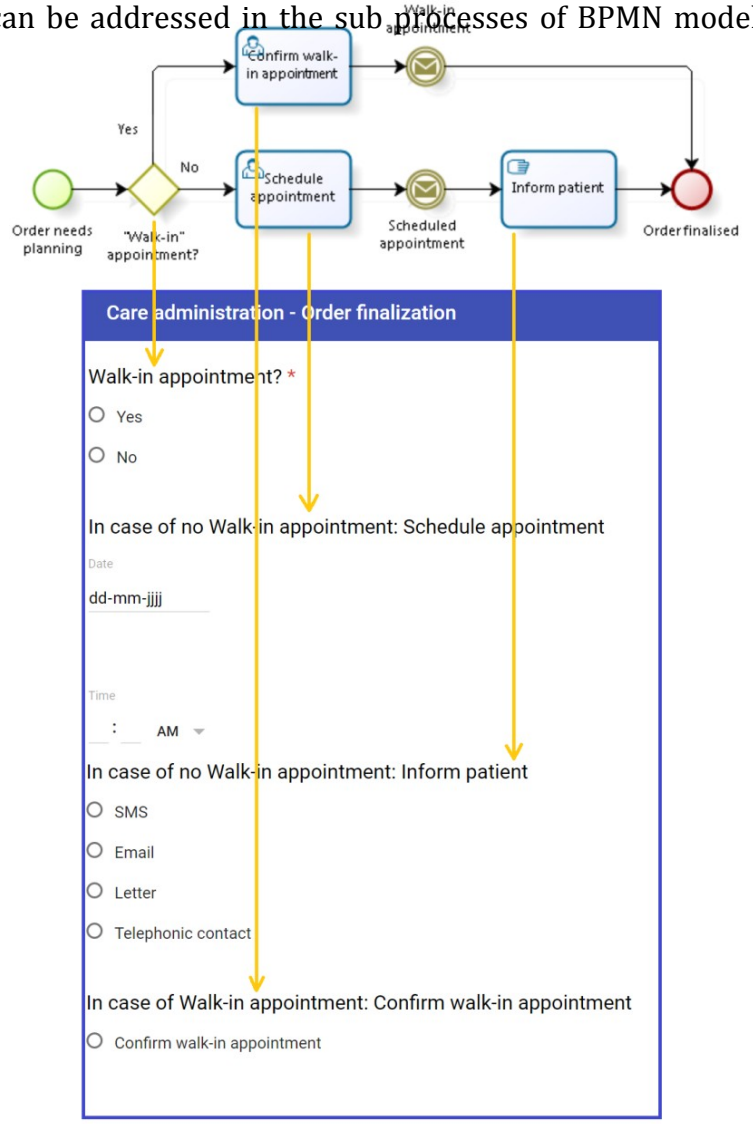


Figure 4.2 Multiple question fields in UIM

In addition, step 4 can executed in a more standardized manner due to the use of Common User Interface (CUI) Guidelines. The CUI Guidelines define clinical noting in forms and give guidance on how user interfaces in a healthcare context should look like (Health and Social Care Information Centre, 2015). For that reason, CUI Guidelines are applied in the UIMs. One of the CUI Guidelines that can easily be applied in the UIMs refers to hiding and revealing sections. The hiding and revealing CUI Guidelines can be applied when sub processes are modeled in the BPMN models. Then the UIMs consist of multiple question fields. The question fields linked to sub processes in BPMN models sometimes depend on patient or order specifications. Then the hiding and revealing section of the CUI Guidelines have to be applied. An example is also visualized in Figure 4.2. The questions field that are going to be addressed in Figure 4.2 depend on the answer of the gateway '"Walk-in" appointment?'. Gateways in sub process determine what question fields need to be addressed by the end user of the information system.

Another CUI guideline that is addressed in the UIMs is about required fields. A required field refers to a mandatory question field. The end user of the information system must address the required fields while executing the care processes. Often, these required fields ask for mandatory registrations on how care processes and treatments of patients are executed. The required fields are applied in the UIMs via the required option in Google Forms. The required fields are marked with a * in the color red, as can be seen in Figure 4.2 for the first question field.

Moreover, the CUI Guidelines define how certain type of registrations have to be visualized in user interfaces. The CUI Guidelines provide pre-defined rules on how multiple-choice, dropdowns, free text and dates have to be available for end users. These rules are also applied in the UIMs in Google Forms. For some type of question fields is already clear how it should be addressed by end users. An example refers to the time and date registrations when appointments can be scheduled. Other question fields should be manually addressed by the UIM developer. Figure 4.3 shows how question fields can be organized according to CUI Guidelines. In Figure 4.3, question fields are addressed via a dropdown and multiple-choice.

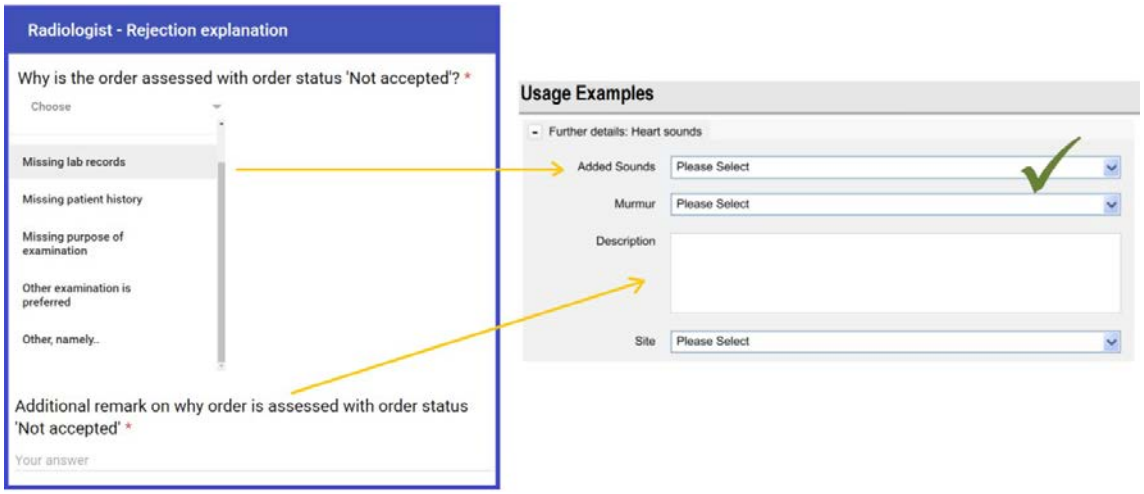


Figure 4.3 Question fields organized in Google Forms via CUI Guidelines

The last step, step 5, refers to the sequence of the UIMs and is not changed compared to Oldenburger (2015). The sequence of the UIMs depends on the flow in BPMN models. Therefore, gateways linked to activities before that gateway determine what sequence of UIMs will be followed. An example is available in Figure 4.1. In Figure 4.1 the UIM after 'Evaluate order' depends on the answer on the gateway 'Order status?'. For example, in case the order status is
'Not accepted', the next UIM will be linked to activity 'Explain rejection'.

Most of the result section elaborated on the use of BPMN models for the creation of UIMs. Also ORM models can be used in the UIMs. The BPMN models and ORM models are close linked through the use of the BPMN-ORM methodology. The ORM models follow the same process flow as is visualized in the BPMN models. The data elements of the ORM model are in line with the registrations specified in the UIMs.

Part of this project is to determine whether eMeasures and DCMs can be incorporated in information system designs. EMeaure is applied to determine at what point time stamps have to be registered to improve the measurability of the patient cycle times. The patient cycle times can be measured due to changes in order statuses. The start time is measured with order status
'Patient arrived' and the end time is measured with order status 'Patient leaves department'. The
DCMs are applied for two types of data elements, Healthcare Staff Member and Planned Order Activity. These DCMs are available in the banner text of the UIMs. Healthcare

Staff Member refers to the end user who is executing a certain activity and Planned Order Activity refers to the order that is executed, linked to the examination of a patient. Hereby, the applicability of Planned Order Activity was limited. The pre-defined order statuses for Planned Order Activity

were not enough to apply for the radiology department. Some additional order statuses were defined to enable the measurement of patient cycle times.

Validation

The internal validity discusses whether the goals of the stakeholder can be achieved with the UIMs. All stakeholders, goals and CSFs of the UIMs are available in Table 4.1. The UIMs are tested among all direct and indirect stakeholders. Each indirect stakeholders participated multiple times in the validation of the UIMs. Each direct stakeholders participated once in the validation rounds. Overall, the internal validity is ensured. The feedback was limited and the same in the final validation rounds with direct and indirect stakeholders. The UIMs fulfill all goals of stakeholders. The UIMs support the care process (goal of direct stakeholders), enable the measurability of patient cycle times (goal of process and quality managers) and incorporates eMeasure and DCM (goal of information managers). As a result, all four quality attributes are taken into account in the design solution.

Trade-offs refer to differences in the design due to conflicting goals and requirements of stakeholders. One trade-off refers to feedback on the order for requesters by the HNO department. The radiologists and process managers prefer the use of notifications in the system to aware requesters of mistakes in the order. The care administration prefers telephonic contact to discuss on mistakes in the order. The final design uses notifications to requesters. This is in line with the opinions of most of the stakeholders and corresponds with objectives used for Electronic Health Records (EHR).

External validity refers to the suitability of the design solution in a slightly different situation. Experts opinions and interviewees of other hospitals (which will be discussed in section 4.2) explain that processes in hospitals are quite similar. The main activities in these processes are the same. Some differences exist in work instructions of activities and whether activities take place centralized or decentralized. Besides, each hospital needs insights on healthcare performances to identify areas for improvements and deal with (external) standards. Therefore is expected that the UIMs are generic and can be broadly applied in other, slightly different situations. Some differences will exist in specifications of registrations due to differences in work instructions.

4.1.2 Overall regulative cycle

The overall regulative cycle focuses on the design (combination of the process models, data models and UIMs) of the information system, consisting of an Information System Blueprint

(ISB). The overall regulative cycle refers the combination of the three individual regulative cycles for the process models, data models and UIMs. Additionally an implementation and validation stage have to be performed (Figure 3.3). The overall regulative cycle will follow all five steps, including design problem, diagnosis and analysis, design solution, implementation and validation stage.

Design problem

The design problem refers to the ISB for the radiology department to attain the measurability of patient cycle times. An overview of the stakeholders, goals and CSFs is visualized in Table 4.2. The goals, stakeholders and CSFs in Table 4.2 are comparable with Table 4.1. Only this time, the design consists of an ISB instead of UIMs.

	Stakeholder	Goal of stakeholder	CSF of goal
Direct	Care administration, radiologist executors, assistant radiologists	An ISB which will support the processes correctly and should incorporate all required components in the information system	The ISB be complete and
Indirect	Process managers and quality managers	An ISB in which performance indicators can be measurement of certain	The ISB must define the
	Information managers	An ISB that incorporates the concepts of eMeasure and DCM	The ISB must incorporate the concepts of eMeasure and DCM

Table 4.2 Overview of stakeholders, their goals and CSFs of overall regulative cycle

Diagnosis and analysis

The quality attributes can be identified based on the CSFs of the stakeholders´ goals mentioned in Table 4.2. The quality attributes for the ISB are the same as for the UIMs in the individual regulative cycle. The ISB must be complete, correct, accurate and consistent, as previously described in section 4.1.1.

Design solution

The design solution consists of the ISB for the radiology department. Hereby, the solution consists of the validated process models, data models and UIMs. The process models are available in Appendix G and the data models are available in the thesis of Vonk (2016). Also, a description of the development and validation of process and data models is available at Vonk

(2016). The UIMs are already mentioned in section 4.1.1 and some examples are available in

Appendix F.

Implementation and validation

The implementation stage and validation stage of the overall regulative cycle are executed by Vonk (2016) via a proof-of-concept. The outcomes of the implementation and validation stage are therefore available in the thesis of Vonk (2016). Hereafter is the overall regulative cycle completed.

Hereby, a remark has to be made about the validation. The correctness of the process and data models is already tested via UIMs in the individual regulative cycles. In section 4.1.1 is discussed on whether the UIMs are generic. The processes in hospital are quite similar, just small differences exist due to work instructions and centralized and decentralized activities. Therefore is expected that the main activities in the BPMN models are comparable with other radiology departments. The differences will be visible in specific registrations visualized in data models and UIMs.

4.2 Results other cases

The results of five other cases are collected via interviews with other hospitals. The five points of the interview protocol are addressed during the interviews. These will be discussed in this section. A summary of each interview is available in Appendix H.

1. How are DCMs and eMeasures currently applied in the hospital and in the information system designs of the hospital?

The use of eMeasures and DCMs in technical realizations of information systems differs. Nor a single hospital is applying eMeasures in their information system designs and implementations. DCMs on the other hand, are applied by each hospital. Hereby, the application of DCMs depends on the Information Technology (IT) landscapes and the suitability of DCMs. Three hospitals are applying DCMs in their new EHR implementation (Case 1, 2 and 4). Two hospitals (Case 3 and 5) apply DCMs whenever possible, depending on the projects that are running. One hospital (Case

4) executes a project for the Registration at the Source program, to discuss on the suitability of DCMs. Each of the interviewed hospitals participates in the Registration at the Source program and is aware of the importance of DCMs in healthcare.

2. How is the design of an information system currently realized?

Most of the hospitals are not designing their own information systems. Often, hospitals buy standard IT products from suppliers. Two hospitals (Case 1 and 2) will design their own information systems when no suitable IT supplier can be found, which rarely occurs. Yet, hospitals do have some freedom in the configuration of information systems. The amount of freedom depends on the IT product of a supplier. For the configuration of information systems, some hospitals use methods similar to the design methodology. Case 4 explains the use of process models to align information systems with the care processes. During the alignment is checked how data should be organized to support processes with the information system. Case 3 takes this approach further. The interviewee if Case 3 uses a methodical approach, consisting of process models and an identification of data elements summarized in Excel. However, these methodical approaches are not used by others in the hospital (Case 3). Colleagues of the interviewee of Case 3 don't reflect on context and background of changes and come up with ad- hoc solutions.

3. How does the hospital deals with changes in information needs?

The hospitals respond similar on changes in information needs. All hospitals have one pre- defined department where changes in information needs can be notified. The department will determine what change is required and how the change can be executed. In some cases, changes are small and can be executed easily. In other cases, changes are larger and are executed via a project. Whenever needed, multiple departments will cooperate to successfully execute a change. The interviewee of Case 3 highlights that the execution of project in her hospital depends on the project leader. As mentioned in question 2, the interviewee of Case 3 prefers a method comparable to the design methodology, while her colleagues prefer less methodical approaches.

4. How is data registered and used?

In all hospitals, data is registered in repositories. The data is registered in the master file of the EHR system. Further, several specialized systems are available for certain processes or departments. All hospitals strive to register data in an information system.

However, sometimes data is registered in separated files when the registrations can't be performed in an information system.

Additionally, some questions are asked about the measurability of performance indicators in information systems. Case 3 highlights the importance of the measurement of performance indicators in the system. Often, these measurements are required for reporting about internal

and external standards. Case 1, 2 and 5 explain that performance indicators are not always measured in the information system. For Case 1 and 2, performance indicators are only measured if the measurement will not entail any registrations other than the ones required to provide care to the patient.

5. What is the applicability of the design methodology in the hospital?

The applicability of the design methodology differs per hospital. In the first place, the design methodology will not be applied for the design of information systems, since the hospitals buy standard IT products from suppliers. The applicability of the design methodology in the configuration of information systems depends on specifics within organizations. Some factors in hospitals limit the applicability. The interviewee of Case 3 describes the resistance of fellow colleagues for more methodical approaches for the configuration of information systems. Also Case 4 highlights the importance of readiness within a hospital to adopt the design methodology. Another aspect influencing the applicability of the design methodology refers to modeling skills of employees (Case 4). Not everyone has advanced BPMN and ORM modeling skills and knows how UIMs can be created. Knowledge about the techniques and tools is essential for the use of the design methodology (Case 4).

In addition, some questions are asked about the design of information systems by suppliers. How are suppliers designing information systems? How can suppliers come up with standard designs suitable for multiple different hospitals? How applicable is the design methodology for suppliers? The hospitals don't know what methods are used by suppliers for the design of information systems and how suppliers come up with standard products. The suppliers are only involved in the selection and implementation of information systems for hospitals. At that moment, the designs of the information systems are already completed.

Moreover, some questions are asked in Case 1, 2 and 3 about the similarities of processes in hospitals. Are the radiology processes of hospital A comparable to the radiology processes of hospital B? Case3 1, 2 and 3 agree that the main activities of the processes will be the same. Some differences exists in the specifics of the processes, such as at which point certain registrations have to be performed (Case 1 and 2). The

interviewee of Case 3 highlights that the processes can slightly differ due to centralized or decentralized activities.

5. DISCUSSION

5.1 Reflection single case

5.1.1 Individual regulative cycle

The information system design for the radiology department of a LTHN was validated among stakeholders via UIMs. The stakeholders involved in the development of the information system design were satisfied about the developed UIMs. The UIMs provided an easy and understandable overview of how the user interface should look like. One of the stakeholders explained that the UIMs help to identify what is really required by the information system. By executing the design methodology, stakeholders were assisted to critically evaluate on how the processes can be supported the best by the information system. The validation with the UIMs resulted into specific and extensive feedback from stakeholders on the functionalities and user requirements. This enhanced the design of the information system.

Additionally, this thesis elaborated on a more standardized method to map BPMN models into UIMs. The development of UIMs was standardized for the pre-conditions, input, post-conditions, output and some question fields. Some specific registrations had to be executed manually, since the BPMN and ORM models provided no information on how some registrations have to be performed. Meanwhile, the CUI Guidelines were applied to create an easy, understandable and usable user interface for the end users. The standardized procedures resulted into a more consistent and uniform format.

Despite the positive aspects of the validation with UIMs, some difficulties arose while mapping BPMN models into UIMs. Two problems arose with regard to gateways in BPMN models. First, it was not possible to clearly visualize two or more gateways that were modeled in sequence in the BPMN models. For the UIMs, this resulted in two or more question fields, and all question fields had to be answered to determine what next UIM was shown to the end user. This couldn't be mapped into the UIMs in Google Forms, because each UIM in Google Forms could only have one question field that determined what next UIM was shown to the end user. In that case the structure of the UIMs became unclear. In some cases the two or more gateways were replaced by one gateway. In other cases, the sequence of processes and gateways was changed. Second, every gateway was linked to the UIM of the process before that gateway. Sometimes the

activity before the gateway was performed manually, whereby the gateway couldn't be linked to an UIM. This was solved by changing activities and gateways in the BPMN model. In the end, the BPMN models were sufficient to develop the UIMs. Only a few times, correct BPMN models had to be redesigned before correct mapping to UIMs was possible.

Also other difficulties existed due to limitations of Google Forms. During the results section is discussed on revealing and hiding sections based on CUI Guidelines. The revealing and hiding section guidelines were applied while mapping sub processes of the BPMN models into UIMs. However, Google Forms was not supporting these features, what resulted into ambiguities in the UIMs.

5.1.2 Overall regulative cycle

The product of the overall regulative cycle, the ISB for the radiology department, was completed and fully validated with the UIMs. This improved the measurability of patient cycle times in the information system. All stakeholders agreed on the functionality of the information system and were satisfied with the ISB. Multiple validation rounds had to be executed before the final ISB was designed. One of the stakeholders explained that this was the strength of the design methodology. With the design methodology, the information system design was validated among different end users in early stage information system development. Multiple important aspects of the information system design were identified during the validation rounds. It was crucial that these aspects were identified before the actual implementation of the information system design starts.

Although the ISB for the radiology department was completed, some difficulties arose due to complexity of PCPs and care processes in hospitals. The sequence of activities in the care processes differs based on what the best care is for a patient. For the radiology department, the sequence and organization of activities differed based on characteristics of patients, what resulted in multiple exceptions. Modeling all these exceptions in the BPMN models would lead to difficult, complex and incomprehensible process models. Comparably, PCPs are rather complex and involve multiple different disciplines, patients and interrelated activities. As a result, information needs and user requirements of information systems differed. A trade-off had to be made in case of conflicting requirements.

5.2 Reflection other cases

The interviews that are conducted with other hospitals are valuable input to determine whether the theory about the design methodology can be generalized. Some hospitals were enthusiastic about the design methodology and have a desire for a more standardized method to deal with information system configurations and designs. Still,

the use of methodical approaches within and between hospitals highly differed. The interviews also revealed that hospitals are buying standard IT products from suppliers. Therefore, the design methodology for the configuration of information systems would be the most useful for hospitals.

One other party that is highly involved in the design of information systems in healthcare was identified during the interviews, the IT suppliers. The IT suppliers probably have their own method to design information systems, if else, how would they be able to come up with standard IT products. It would be valuable to know how they design information systems, how they define standard products suitable for different customers, and whether the design methodology can be adopted by IT suppliers. Therefore, an interview with an IT supplier would obtain more insights on the applicability of the design methodology by IT suppliers. Unfortunately, no IT supplier could be interviewed for this thesis due to time constraints and difficulty to contact IT suppliers.

6. CONCLUSION

This research focused on two goals that are closely related. The first goal referred to the design of an information system for the radiology department of a LTHN while applying the design methodology. The writer of this thesis focused on the UIM validation and the development of a more standardized method to create UIMs. The second goal referred to interviews with other hospitals to discuss on the applicability of the design methodology in other hospitals. The research question of this thesis is: "**To what extent can the design methodology for information system design and configuration be used in hospitals for the measurement of performance indicators in PCPs to improve healthcare performances?**"

With regard to the first goal can be concluded that the application of the design methodology at the radiology department of a LTHN in a HNO PCP has proven to the successful (referring to the first sub research question). The design for the information system for that particular department was validated among all stakeholders. In the result section was discussed that a trade-off between conflicting requirements of stakeholders had to be made. However, in the end each stakeholder was satisfied with the final design and understood why certain decisions in the design were made.

The use of the design methodology for the radiology department supported the practical realization of validating the design of an information system (referring to the

second sub research question). Currently two fully validated information system designs, for the radiology and HNO department, are developed via the design methodology. In the theoretical background is discussed on the importance of process modeling, data modeling and UIMs in software engineering. Yet, process modeling, data modeling and UIMs in itself have some limitations. These individual limitations are encountered through the combination of process modeling, data modeling and UIMs in the design methodology. In the design methodology, the process models

were useful to identify in what activities the (new) information system is involved. Subsequently, the data models identified what data elements are important for certain activities. The combination of process and data models tested via UIMs resulted in the identification of specific functionalities and user requirements. As a result, the design consisted of three important aspects of information systems, through describing (1) how the information system supports the business process, (2) what data elements are involved in the processes and (3) how the interaction between end user and information system should take place.

Thereto, structured and model-driven procedures are defined for the design methodology for the development of process models, data models and UIMs, to enable the productivity of the design process. This research contributed to the work of Oldenburger (2015) by defining a more standardized method to create UIMs. The new format of the UIMs was tested while validating the design of the information system for the radiology department. The UIMs were easy to understand for all stakeholders through a consistent and uniform format. Also, the standardized procedures led to time benefits due to one-on-one mapping between BPMN models and UIMs.

The validation rounds with the UIMs resulted in changes in the context (referring to the fifth sub research question). These changes related to feedback of stakeholders on the UIMs, thereby influencing the process and data models. During the design phase, as discussed in the result section, large and small changes were encountered. The exact time required to process changes depended on the size of the change, with a maximum processing time of two days. From this can be stated that changes in the context can easily be incorporated into the process models, data models and UIMs, enabling quick and agile software development.

The concepts of eMeasure and DCMs were applied in the design of the information system for the radiology department (referring to the fourth sub research question). The usage of eMeasure in the design methodology enabled the consistent and unambiguous interpretation of measurements. After all, a clear starting and ending point were defined for the measurement of patient cycle times. The applicability of the DCMs in the design methodology depended on the suitability of DCMs. Two concepts were applied in the design for the radiology department wherefrom one concept had limited applicability.

Feedback on the usage of the DCMs in the project will be communicated to the Registration at the Source program.

With regard to the second goal, this research discusses whether the design methodology is applicable in other hospitals as well (referring to the third sub research question). Interviewees explained that processes in hospital A are comparable to hospital B. Small differences exist

depending on work instructions and centralized and decentralized activities. Also, one hospital explained to use a configuration method similar to the design methodology. Based on the similarities of processes and the application of a similar configuration method in hospitals can be concluded that the design methodology is, in theory, applicable in other hospitals. In the last sentence, an emphasis is on "in theory". The interviews also revealed what is required to adopt the design methodology in other hospitals. Some interviewees explained that limited modeling skills of colleagues restrict the applicability of the design methodology. Other interviewees explained that individuals opinions towards methodical approaches as design methodology might cause problems in the adoption of the design methodology. From this, two statements can be made. First, executors of the design methodology need proper modeling skills or need training to improve modeling skills to an appropriate level before the design methodology can be applied. Second, awareness about the design methodology should be created among hospital staff before the methodology can be fully adopted by other hospitals.

Overall, the design methodology forms a basis to determine how performance indicators can be measured in PCPs to evaluate on healthcare performances. The process models define where certain performance indicators are measured in care process. The data models define how the performance indicators should be measured and registered. Lastly, the UIMs specify how the performance indicators are entered in the information system and what type of registrations have to be performed. Within the design methodology, the combination of the process models, data models and UIMs enables the measurement of performance indicators in PCPs. The measurement of performance indicators can be used in the evaluation of performances and areas for improvement.

6.1 Limitations and further research

One of the limitations mentioned in the discussion section refers to the use of Google Forms. Google Forms was useful for the development of quick and easy user interfaces. Nevertheless, some limitations arose with hiding and revealing sections, when registrations in UIMs became more specific. A suggestion for further research is to elaborate on adequacy and use of other user interface development programs in the design methodology.

Moreover, the culture in organizations influences the applicability of the design methodology. Iivari and Huisman (2007) researched the influence of organizational cultures on the successfulness of ISDMs. They identified a noticeable link between organizational cultures and ISDM deployment. This thesis discussed on the applicability of the design methodology in

hospitals. A suggestion for further research is to investigate whether the design methodology can be applied by other healthcare institutions or completely different industries as well.

7. REFERENCES

Alders, T., 2015. *Creating a blueprint for the implementation of an electronic patient database to measure cycle times in Head and Neck Oncology department.* Master thesis Technology and Operations Management, University of Groningen.

Ash, J.S., Berg, M. and Coiera, E., 2004. Some Unintended Consequences of Information Technology in Health care: The Nature of Patient Care Information System-related Errors. *Journal of the American Medical Informatics Association*, 11(2), pp. 104-112.

Balsters, H., 2014. Automatic Mapping of Business Process Models to an Associated Data Model.

Lecture notes, pp. 1-
9.

Balsters, H., 2015a. Design Methods: Building Utility-Driven Artifacts Part 1. *Lecture notes in*

Design Science, pp. 1-
44.

Balsters, H., 2015b. Design Methods: Building Utility-Driven Artifacts Part 2. *Lecture notes in*

Design Science, pp. 1-
16.

Barros, O. and Quezada, A., 2014. Integrated Modeling of Business Architecture and Process

Design with BPMN: Application to Hospitals. *Enterprise Architecture*, 1(7),
pp. 7-15.

Berg, M., 2001. Implementing information systems in health care organizations: myths and challenges. *International Journal of Medical Informatics,*. 64(2-3), pp. 143-156.

Brigl, B., Ammenwerth, E., Dujat, C., Gräber, S., Groβe, A., Häber, A., Jostes, C. and Winter. A., 2005. Preparing strategic information management plans for hospitals: a practical guideline SIM plans for hospitals: a guideline. *International Journal of Medical Informatics*, 74(1), pp. 51-65.

Chen, Y.M. and Liang, M.W., 2000. Design and implementation of a collaborative engineering information system for allied concurrent engineering. *Computer Integrated Manufacturing*, 13(1), pp. 11-30.

Chinosi, M. and Trombetta, A., 2012. BPMN: An introduction to the standard. *Computer Standards and Interfaces*, 34(1), pp. 124-134.

Dijkman, R.M., Dumas, M. and Ouyang, C., 2007. Formal Semantics and Analysis of BPMN Process
Models using Petri
Nets*.

Gagnon, M.P., Desmaris, M., Labrecque, M., Car, J., Pagliari, C., Pluye, P., Fremont, P., Gagnon, J., Trempley, N. and Légaré, F., 2012. Systematic Review of Factors Influencing the Adoption of Information and Communication Technologies by Healthcare Professionals. *Journal of Medical Systems*, 36(1), pp. 241-277.

Goodhue, D.L., 2006. A Critical (But Often Missing!) Construct in Models of Information Systems and Performance. In: Zhang, Y. and Galletta, D.F., *Human Computer Interaction and Management Information Systems: Foundation*, New York: Routledge, pp. 184-204.

Goossen, W. and Dille, J., 2013. Uitwisselen verpleegkundige gegevens oncologie met behulp van een Clinical Data Warehouse. *Raak-publiek rapportage 2013*, Windesheim.

Goossen, W., Goossen-Baremans, A. and Van Der Zel, M., 2010. Detailed Clinical Models: A Review. *Healthcare Informatics Research*, 16(4), pp. 201-214.

Halpin, T. and Morgan, T., 2008. Information Modelling and Relational Databases, 2nd edition, Burlington: Morgan Kaufmann Publishers.

Hammer, M., 1990. Reengineering work: Don't automate, obliterate. *Harvard Business Review*, Jul-Aug, pp. 104-112.

Hammer, M. and Champy, J., 1993. *Reengineering the cooperation*, New York: Harper Business.

Health and Social Care Information Centre, 2015. Clinical Noting in Forms: Admissions Clerking. User Interface Design Guidance. *Clinical Applications and Patient Safety Project*.

Hedge, A., 2007. Developing a Business Process Model: The first step to process efficiency is identifying where you are today. From: www.edocmagazine.com, March/April 2007.

Hess, J., Reuter, C., Pipek, V. and Wulf, V., 2012. Supporting end-user articulations in evolving business processes: A case study to explore intuitive notations and interaction designs. *International Journal of Cooperative Information Systems*, 21(4), pp. 263-296.

Hevner, A.R., March, S.T., Park, J. and Ram, S., 2004. Design Science in Information System

Research. *MIS Quarterly*, 28(1), pp. 75-
105.

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R. and Taylor, R., 2005. Can Electronic Medical Record Systems Transform Health care? Potential Health Benefits, Savings, And Costs. *Health Affairs*, 24(5), pp. 1103-1117.

HL7, 2016. HL7 Version 3 Standard: Representation of the Health Quality Measure Format (eMeasure) DSTU, Release 2. Available at http://www.hl7.org/implement/standards/product_brief.cfm?product_id=97 [Assessed 17 June

2015].

Holmström, J., Ketokivi, M. and Hameri, A.P., 2009. Bridging Practice and Theory: A Design

Science Approach. *Decision Sciences*, 40(1), pp.
65-82.

Hopp, W.J. and Spearman, M.L., 2008. *Factory Physics,* 3th edition, New York: McGraw-Hill.

Iivari, J., Hirschheim, R., and Klein, H., 1998. A Paradigmatic Analysis Contrasting Information

Systems Development Approaches and Methodologies. *Information Systems Research*, 9(2), pp.

1–30.

Iivari, J., Hirschheim, R. and Klein, H.K., 2000. A Dynamic Framework for Classifying Information Systems Development Methodologies and Approaches. *Journal of Management Information Systems*, 17(3), pp. 179-218.

Iivari, J. and Huisman, M., 2007. The relationship between organizational culture and the deployment of systems development methodologies. *MIS Quarterly*, 31(1), pp. 35-58.

In 't Veld, M. and Slatius, B., 2015. *Analyse van bedrijfsprocessen: Een toepassing van denken in systemen*, 11th edition, Groningen/Houten: Noordhoff Uitgevers.

Jha, A.K., DesRoches, C.M., Campbell, E.G., Donelan, K., Rao, S.H., Ferris, T.G., Shields, A., Rosenbaum, S. and Blumenthal, D., 2009. Use of Electronic Health Records in U.S. Hospitals. *New England Journal of Medicine,* 360(16), pp. 1628-1638.

Karlsson, C., 2009. *Researching operations Management*, New York: Routledge.

Kraushaar, J.M. and Shirland, L.E., 1985. A Prototyping Method for Applications Development by

End Users and Information System Specialists. *MIS Quarterly*, 9(3), pp. 189-197.

Martena, P., 2015. *Object-Role Modeling: Validation of a database design methodology in the context of an EHR system*. Master thesis Technology and Operations Management, University of Groningen.

McDonald, C.J., 1997. The Barriers to Electronic Medical Record Systems and How to Overcome

Them. *Journal of the American Medical Informatics Association*, 4(3), pp. 213-221.

Mili, H., Tremblay, G., Jaoude, G.B., Lefebvre, L., Elabed, L. and Boussaidi, G.L., 2010. Business

Process Modeling Languages: Sorting Through the Alphabet Soup. *ACM Computing Surveys*,

43(1), Art. 4.

Müller, R. and Rogge-Solti, A., 2011. BPMN for healthcare processes. In Proceedings of the 3rd Central-European Workshop on Services and their Composition, *ZEUS 2011*, Karlsruhe, Germany, CEUR-WS.org, 705, pp. 65-72

Object Management Group, 2013. *Business Process Modeling and Notation (BPMN)*, Version 2.0.2.

Okma, K.G.H. and Crivelli, L., 2013. Swiss and Dutch "customer driven healthcare": Ideal model

or reality? *Health Policy*, 109(2), pp. 105-112.

Okma, K.G.H. and Marmor, T.R., 2013. Comparative studies and healthcare policy: learning and misleading across borders. *Clinical Medicine*, 13(5), pp. 487-491.

Oldenburger, R.W.M., 2015. *Validating the design principles of an Information System Blueprint to attain cycle time measurability in Head and Neck Oncology pathways*. Master thesis Technology and Operations Management, University of Groningen.

Ould, M.A., 1995. *Business Processes: Modelling and Analysis for Reengineering and Improvement*, New York: Wiley.

Panella, M., Marchisio, S. and Di Stanislao, F., 2003. Reducing clinical variations with clinical pathways: Do pathways work? *International Journal for Quality in Health Care*, 15(16), pp. 509-
521.

Park, I, Sharman, R. and Rao, H.R., 2015. Disaster Experience and Hospital Information Systems: An Examination of Perceived Information Assurance, Risk, Resilience, and His Usefulness. *MIS Quarterly*, 39(2), pp. 317-344.

Phalp, K. and Shepperd, M., 2000. Quantitative analysis of static models of processes. *Journal of*
Systems and Software, 52(2-3), pp. 105-
112.

Rivero, J.M., Grigera, J., Rossi, G., Luna, E.R., Montero, F. and Gaedke, M., 2014. Mockup-Driven Development: providing agile support for Model-Driven Web Engineering. *Information and Software Technology*, 56(6), pp. 670-687.

Rivero, J.M., Rossi, G., Grigera, J., Burella, J., Luna, E.R. and Gordillo, S., 2010. From Mockups to User Interface Models: An Extensible Model Driven Approach. In: Daniel, F. and Facca, F.M., *Current Trends in Web Engineering, ICWE 2010 Workshops*. Berlin Heidelberg: Springer-Verlag, pp. 13–24.

Rivero, J.M., Rossi, G., Grigera, J., Luna, E.R. and Navarro, A., 2011. From Interface Mockups to Web Application Models. In: Bouguetta, A., Hauswirth, M. and Liu, L., *Web Information System Engineering – WISE 2011, 12th International Conference Sydney Proceedings*, Berlin Heidelberg: Springer-Verlag, pp. 257-264 .

Rojo, M.G., Rolón, E., Calahorra, L., Garcia, F.O., Sánchez, R.P., Ruiz, F. Ballester, N., Armenteros, M., Rodríguez, T. and Espartero, R.M., 2008. Implementation of the Business Process Modelling Natation (BPMN) in the modelling of anatomic pathology processes. *Diagnostic pathology*, 3(1), pp. 22.

Rolón, E., Garcia, F., Ruiz, F., Piattini, M., Calahorra, L., Garcia, M. and Martin, R., 2008. Process Modelling of the Health Sector Using BPMN: A Case Study. *International Conference on Health Informatics*, 2(1), pp. 173-178.

Rutten – van Mölken, M.P.M.H., Postma, M.J., Joore, M.A., Van Genugten, M.L.L., Leidl, R. and Jager, J.C., 1999. Current and future medical costs of asthma and chronic

obstructive pulmonary disease in the Netherlands. *Respiratory Medicine*, 93(11), pp. 779 – 787.

Saleem, N, Jones, D.R., Van Tran, H. and Moses, B., 2006. Forming Design Team to Develop Healthcare Information System. *Hospital Topics: Research and Perspectives on Healthcare*, 84(1), pp. 22-31.

Savci, S. and Kayis, B., 2006. Knowledge elicitation for risk mapping in concurrent engineering projects. *International Journal of Production Research,* 44(9), pp. 1739-1755.

Scaniello, G., Ricca, F., Torchiano, M., Gravino, C. and Reggio, G., 2013. Estimating the Effort to Develop Screen Mockups. *39th Euromicro Conference Series on Software Engineering and Advanced Applications*, pp. 341-348.

Schiever, N., 2015. *Building an information product for cycle time analysis: From process-to data models*. Master thesis Technology and Operations Management, University of Groningen.

Soffer, P., Wand, Y. and Kaner, M., 2015. Conceptualizing Routing Decisions in Business Processes: Theoretical Analysis and Emperical Testing. *Journal of the Association for Information Systems*, 16(5), pp. 345-393.

Spyns, P., Meersman, R. and Jarrar, M., 2002. Data modeling versus Ontology engineering. SIGMOD Record, 31(4), pp. 12-17.

Ten Holt, L., 2015. *Validating the BPMN-ORM methodology to develop an information system blueprint: the case of oncology cycle time*. Master thesis Technology and Operations Management, University of Groningen.

Thakur, R., Hsu, S. H. & Fontenot, G., 2012. Innovation in healthcare: Issues and future trends. *Journal of Business Research*, 65(1), pp. 562-569.

Thyvalikakath, T.P., Dziabiak, M.P. Johnson, R., Torres-Urguidy, M.H., Acharya, A., Yabes, J. and Schleyer, T.K., 2014. Advancing cognitive engineering methods to support user interface design for electric health records*. International Journal of Medical Informatics*, 83(4), pp. 292-302.

Vanberkel, P.T., Boucherie, R.J., Hans, E.W., Hurink, J.L. and Livak, N., 2010. Efficiency evaluation for pooling resources in healthcare. *OR Spectrum*, 34(2), pp. 371-390.

Vanhaecht, K., Ovretveit, J., Elliot, M.J., Sermeus, W., Ellershaw, J. and Panella, M., 2012. Have We Drawn the Wrong Conclusions About the Value of Care Pathways? Is a Cochrane Review Appropriate? *Evaluation & the Health Professions*, 35(1), pp. 28-42.

Van Rooijen, M., Goedvolk, R. and Houwert, T., 2013. A vision for the Dutch health care system in 2040 Toward a sustainable, high quality health care system. *A report from the World Economic Forum*, McKinsey & Company.

Van Strien, P.J., 1997. Toward a methodology of Psychological Practice: The Regulative Cycle. *Theory & Psychology*, 7(5), pp. 683-700.

Vonk, M., 2016. *Information System Development in Healthcare: Demonstration of a BPMN-, ORM- and DCM-Driven Information System Configuration Method to Attain Cycle Time Measurability in Oncology and Radiology Pathways*. Master thesis of Industrial Engineering and Management, University of Groningen.

White-Baker, A., 2011. Why situational method engineering is useful to information system development. *Information Systems Journal*, 21(2), pp. 155-174.

Wieringa, R., 2007. Writing a Report About Design Research. *Knowledge Creation Diffusion Utilization*, pp. 1-9.

Wieringa, R., 2009. Design Science as Nested problem Solving. *Conference on Design Science Research in Information Systems and Technology*, pp. 1-12.

Wieringa, R., 2010. Relevance and Problem Choice in Design Science. In: Winter, R., Zhao, J.L. and Aier, S. (Eds.) *DESRIST, LNCS, 6105*. Berlin Heidelberg: Springer-Verlag, pp. 61-76.

8. APPENDICES

Appendix A: BPMN

BPMN is a technique to visualize business processes in a flowchart-like diagram through a set of rules and symbols (Hedge, 2007; Halpin and Morgan, 2008). Business process models in BPMN visualize the activities, sequence of activities and communication flows of processes. The Object Management Group (OMG) develops and maintains the BPMN standard. The most up-to-date version, version 2.0.2, is launched in January 2014 (Object Management Group, 2013).

An example of a BPMN diagram about hiring candidates is visualized in Figure Appendix A.1. From Figure Appendix A.1 can be seen that each stakeholder is represented in a BPMN diagram. Each stakeholder is assigned to a swimming lane, in this case the lanes represent three employees within an organization. The overarching whole is visualized in the swimming pool, this case the swimming pool is an organization. Also, Figure Appendix A.1 shows that each process starts with a green start event and stops with a red stop event. In between the start and stop event are some activities, visualized as blue rectangular boxes, that have to take place and are connected through arrows. The activity is placed in the swimming lane of the stakeholder who is responsible for that activity. For example, the hiring manager is responsible to create a job requisition. The second activity in Figure Appendix A.1, at 'Search for candidates', is a sub process visualized. The sub process contains multiple other activities that have to be executed at 'Search for candidates'. Halfway through the process is a gateway, recognizable as a yellow rhombus. A gateway controls divergence and convergence. The next activity depends on the outcome of the gateway. In this case, the next activity depends on whether a candidate is found.

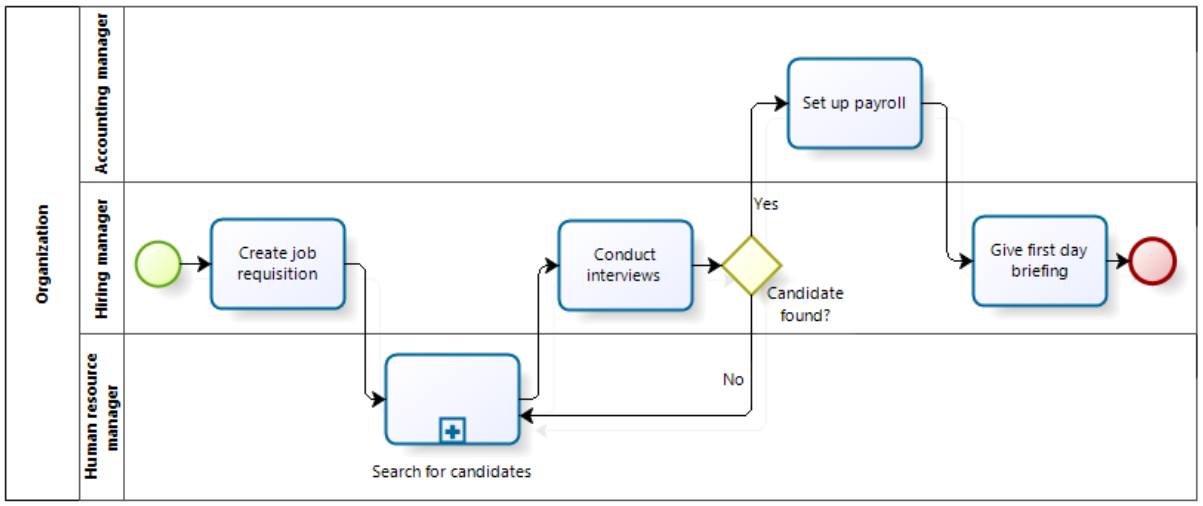


Figure Appendix A.1 Simple BPMN diagram about hiring candidates

OMG defined multiple different events, processes, gateways and connecting objects to define processes more precisely. An overview of other events, processes, gateways and connecting objects is available at Figure Appendix A.2.

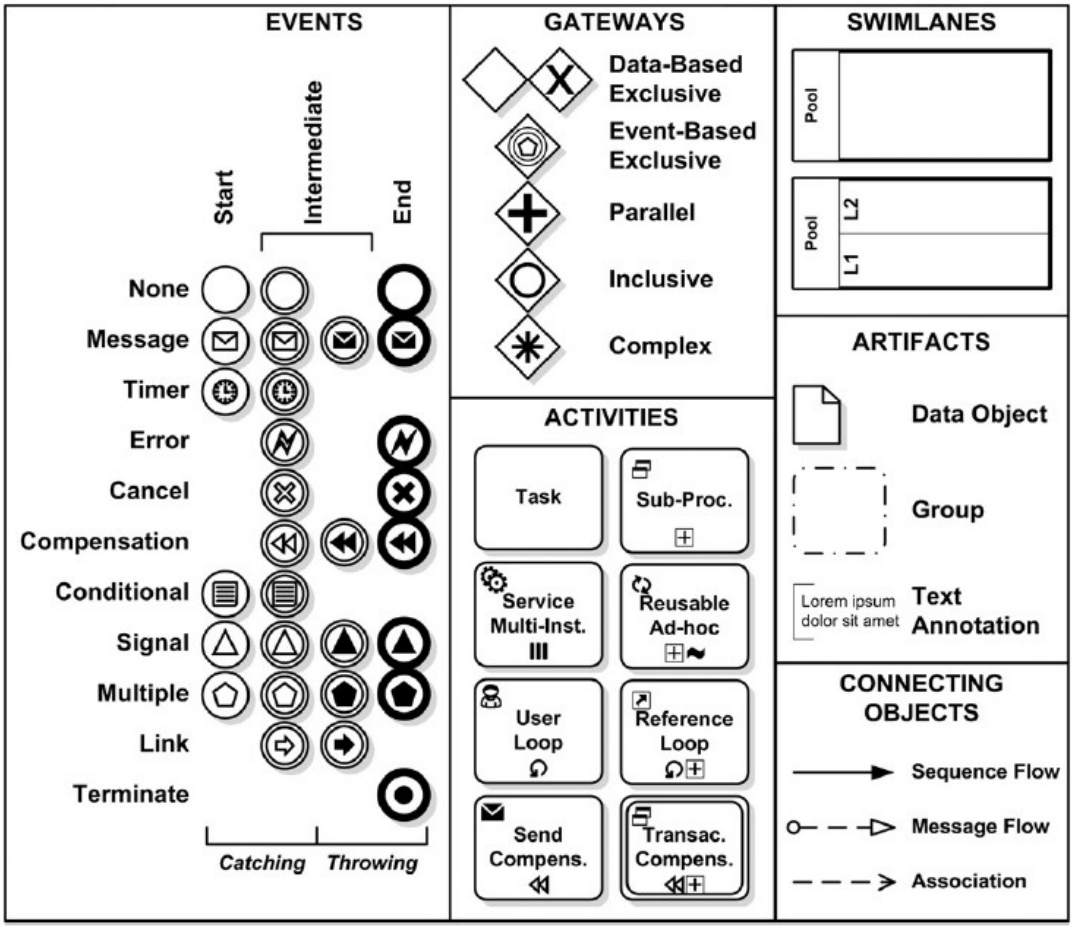


Figure Appendix A.2 Overview of BPMN symbols (Chinosi and Trombetta, 2012)

Appendix B: ORM

ORM started around 1970 and is still a popular method to use. ORM is a fact-based modelling approach that can be described as "*a semantic modeling approach that views the world simply in terms of objects (thing) playing roles (parts in relationships)*" (Halpin and Morgan, 2008). ORM is a method that visualizes objects and roles on a conceptual level. Seven steps have to be performed to create the models. These steps are (Halpin and Morgan, 2008):

1. Transform familiar examples into elementary elements
2. Draw the fact types, and apply a population check
3. Check for entity types to be combined, and note any arithmetic derivations
4. Add uniqueness constraints, and check the arity of fact types
5. Add mandatory role constrains, and check for logical derivations
6. Add value, set comparison, and sub typing constrains
7. Add other constrains and perform final checks

An example of an ORM diagram about movies is visualized in Figure Appendix B.1 (Halpin and Morgan, 2008). The main elements in an ORM diagram are the entity types and value types. The entity types are visualized as rectangular outlined boxes. Every entity type has a reference mode, which is the way in which a value is linked to the entity. Within Figure Appendix B.1 the reference mode of entity 'Movie' is '(.nr)'. A value type is a dotted rectangular box, as is shown as
'MovieTitle', which needs no reference mode. Relationships or associations between entity and value types are modeled via fact types, these consist of at least two small boxes that are adjacent. The lines above the fact types describes the unique relationship and are called uniqueness constraints. The dots, which are in Figure Appendix B.1 modeled at 'Movie' and 'Person', are mandatory constraints. Mandatory constrains highlight which information must be known, for example every 'Movie' must have a 'MovieTitle'. The circle with the X in the middle is an exclusion constraint. For Figure 1.1, this means that the person who directed the movie can't be the person who reviewed the movie. More constraints, besides the exclusion constraint, are defined for ORM.

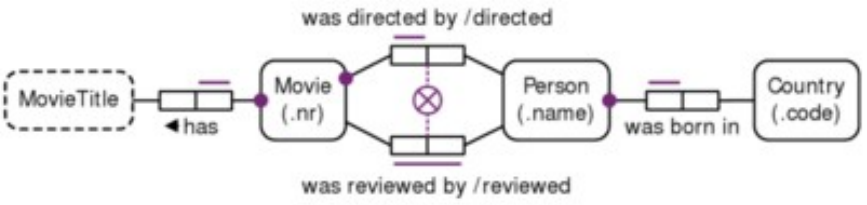


Figure Appendix B.1 Example of an ORM diagram about movies (Halpin and Morgan, 2008)

Appendix C: From BPMN to ORM

Balsters (2014) elaborated on the translation of process models in BPMN to data models in ORM. Also Ten Holt (2015), Schriever (2015) and Martena (2015) discussed on the translation of process models in BPMN to data models in ORM, which they refer to as the "BPMN-ORM methodology". Hereby, the modelled activities, start events, stop events and gateways in the process models in BPMN can be mapped into data models in ORM. An overview of the findings of Balsters (2014) is provided in this appendix.

Every process model in BPMN starts with a start event and will be followed by an activity. These two elements in the BPMN model, the start event and activity, will be mapped into two elements in the ORM model. An overview of how this is executed is visualized in Figure Appendix C.1. The start event in BPMN is transformed into data element 'StartEvent' in ORM with the reference mode '(.nr)'. The activity is transformed in data element 'NounPart Objectified-verbPart' with reference mode '(.nr)'. The element 'StartEvent' is linked to 'NounPart Objectified-verbPart' with the relationship 'is followed by'. Hereby the data element 'NounPart Objectified-verbPart' is mandatory, because the start event will always result in that next activity.

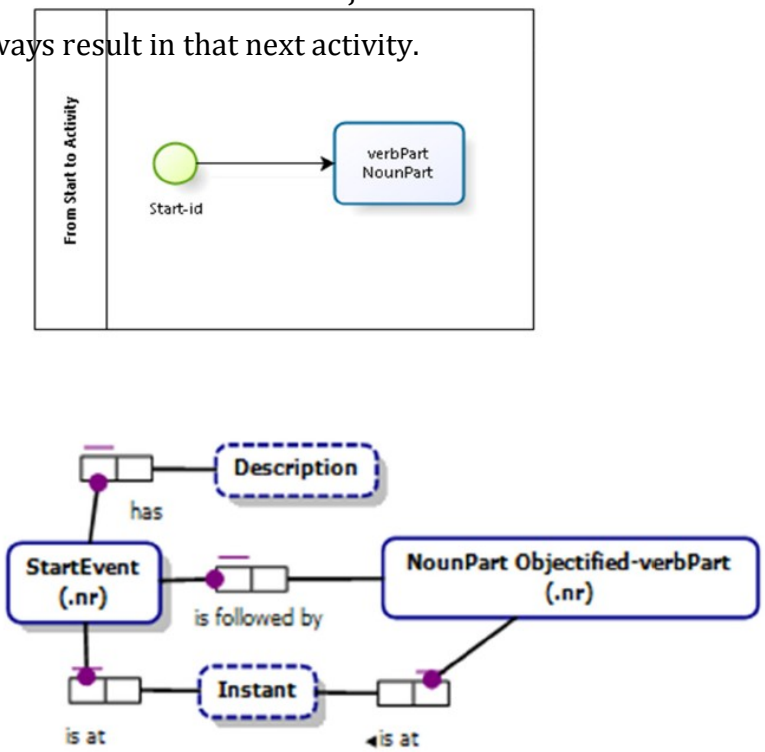


Figure Appendix C.1: From BPMN to ORM, start events (Balsters, 2014)

Within BPMN, every activity can be followed by another activity. An overview of how this is mapped from BPMN to ORM is visualized in Figure Appendix C.2. Each activity in BPMN is

transformed into a data element in ORM. The first activity is transformed into data element

´Noun1 Objectified-verb1´ and the second activity is transformed into data element ´Noun2

Objectified-verb2´. The relationship between the two data elements is described as ´is followed by´. Each activity is performed at a certain date and time. Therefore are both data elements linked to an instant.

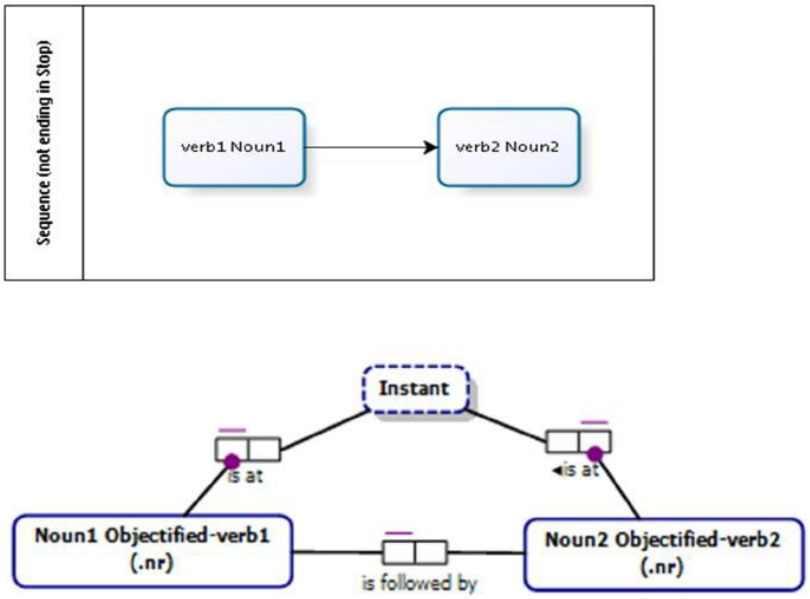


Figure Appendix C.2: From BPMN to ORM, activities (Balsters, 2014)

Also, every BPMN model uses gateways to deal with divergence and convergence. Figure Appendix C.3 provides an overview of the mapping of gateways from BPMN to ORM. First, each activity and event in the BPMN model is transformed into a data element in the ORM model. As a result, the data elements ´Noun Objectified-verb´, ´Noun´ Objectified-verb´´ and ´StopEvent´ are modeled in ORM. The modeling of gateways from BPMN to ORM is executed via constraints (i.e. the purple circles with a = or X) and a fact type with description ´isCorrect´. The fact type

´isCorrect´ is the answer on the gateway in the BPMN model. The exclusion constraint (the

purple circle with a X) means that only one of the two can be true. The equality constraint (the purple circle with a =) means that the two are equal to each other. So, the data element ´Noun´ Objectified-verb´´ will be triggered if the answer on the gateway is true. Else, the data element

´StopEvent´ will be triggered.

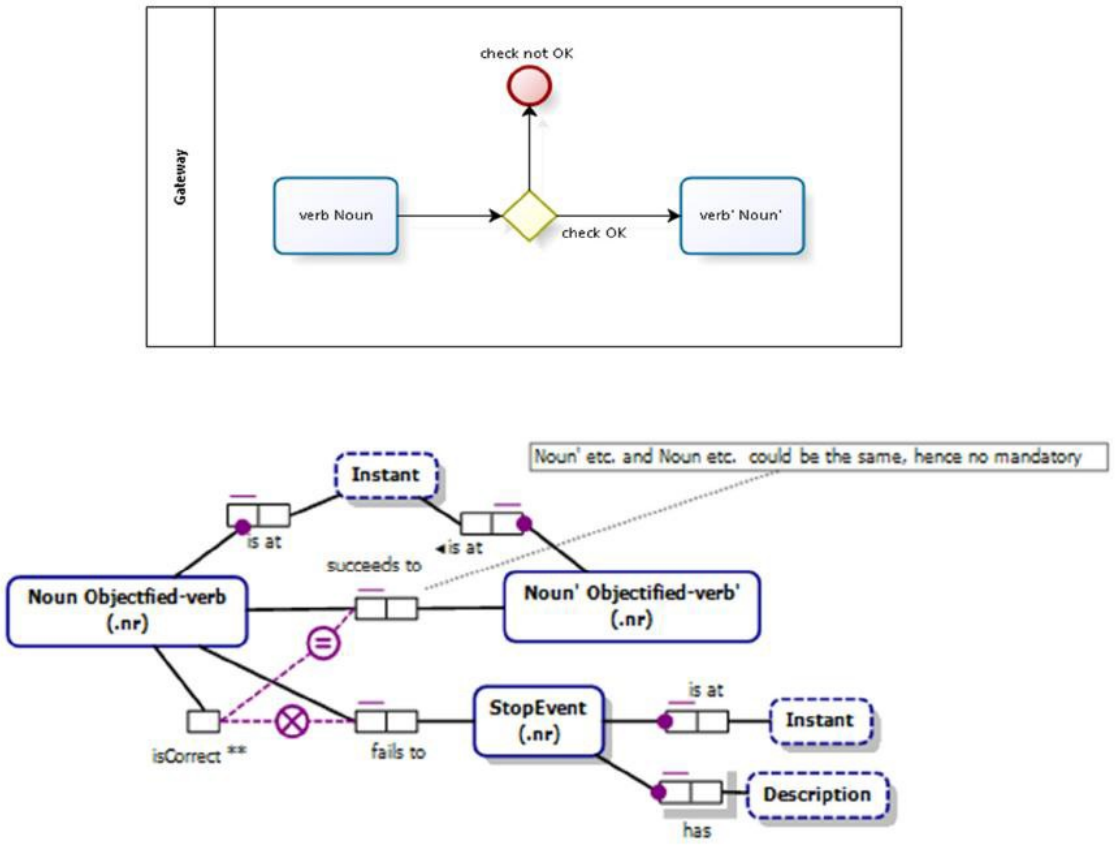


Figure Appendix C.3: From BPMN to ORM, gateways (Balsters, 2014)

BPMN uses different types of gateways to model divergence and convergence. The parallel gateway has a different characteristic compared to other gateways. The parallel gateway will model both divergence and convergence, while the other gateways will only model divergence or convergence. Therefore the mapping of parallel gateways from BPMN to ORM is executed differently. The mapping of parallel gateways from BPMN to ORM is visualized in Figure Appendix C.4. Again, each activity in the BPMN model is transformed into a data element in the ORM model. In the BPMN model, P will always result in both Q and R. In ORM this is modeled via mandatory constraints, each ´P-Event´ must have a ´Q-Event´ and ´R-Event´. Then activity S will be performed if both activity Q and R are performed. This is modeled in ORM via mandatory constraints and an equality constraint. The mandatory constraints mean that both Q and R have to be performed. The equality constraint means that both Q and R have to be performed before S can be performed.

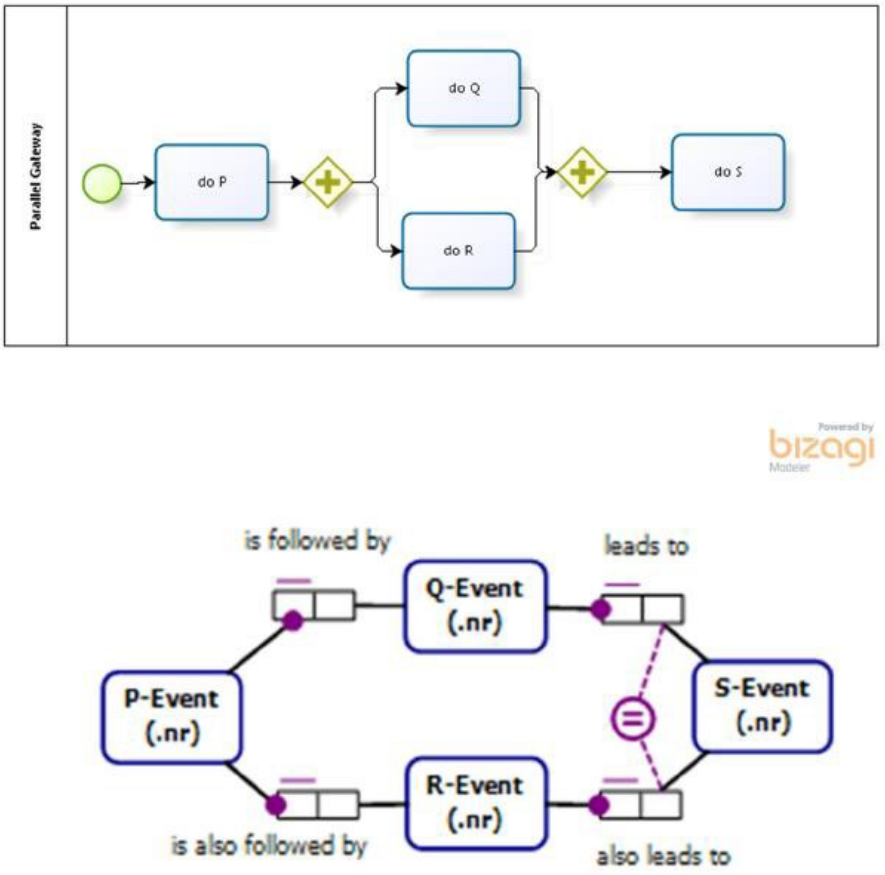


Figure Appendix C.4: From BPMN to ORM, parallel gateways (Balsters, 2014)

Appendix D: UIM format of Oldenburger (2015)

Oldenburger (2015) defined a general method to develop the UIMs, consisting of five steps.

Step 1: Create banner

A banner format has to be defined. The banner includes information that is always available in the user interface of an information system.

Step 2: Define title

The development of an UIM is continued with the identification of the stakeholder and activity. The stakeholder and activity can be identified from the process model in BPMN. The process model shows which activity is performed by which stakeholder. These two should be incorporated in the title of the UIM. Hereby the verb-noun description of the activity is transformed. The verb is transformed into a noun. For example, the activity 'Evaluate order' will result in UIM title 'Order evaluation'.

Step 3: Define context and pre-conditions, post-conditions input and output

The third step relates to the context in which an UIM is presented. The context consist of two elements. First, the activity is visualized in the process model. The activity is highlighted in the model, to show where in the process the UIM will be available. Secondly, the context is described in a textual description. Hereby, the pre-conditions, post-conditions input and output have to be identified.

Step 4: Define question fields

The fourth step refers to the question fields that have to be addressed by the end user while interacting with the information system. The nature of the question field can vary. Gateways in the BPMN model will always result in multiple-choice question fields. Other question fields can be answered in other ways.

Step 5: Define the flow

The last step consists of defining the flow of the forms. The sequence of the UIMs is in line with the sequence in which activities are modeled in the BPMN model.

Appendix E: Stakeholder analysis

Seven stakeholders of the radiology department are involved in the design of the information system. These can be divided into four direct stakeholders and three indirect stakeholders. The following stakeholders are identified.

Direct stakeholders

Care administration

The care administration is involved in the first process model in BPMN. The main responsibility of the care administration is scheduling the appointment. The tasks of the care administration, related to the interaction with the information system, is opening and evaluating the order and scheduling the order in case the order is approved. The care administration will benefit with the new information system design, because several manually tasks can be executed by the new information system.

Radiologist executors

The radiologist executor refers to the employee who is executing a procedure for an examination. The radiologist executor can be a technician, assistant radiologist or radiologist. Each of these employees is allowed to prepare, execute and document on the procedure used in the examination. The radiologist executor will benefit with the information system design, because it will complement how the processes will be performed in the near future.

(Assistant) radiologists

The (assistant) radiologist can execute a procedure of an examination, as described above. In addition, the (assistant) radiologist is allowed to report on the results of an examination. The information system design has the same benefits for the (assistant) radiologist as for the radiologist executor. The new information system design will complement how the processes will be performed in the near future.

Supervising radiologists

The supervising radiologist can also execute the procedure of an examination, as described above. Also the supervising radiologist can perform some other tasks, compared to other radiology staff members who are allowed to execute an examination. The supervising radiologist is allowed to report results and authorize the report. Again, the information system design has the same benefits for the supervising radiologist as for the radiologist executor. The new information system design will complement how the processes will be performed in the near future.

Indirect stakeholders

Process managers

The process manager is involved in how the processes take place at the radiology department. A process manager is responsible for projects and process improvements at the radiology department. With regard to the new information system, their benefit relates to the measurements of performance indicators. The measurement of performance indicators will be an indication on the performance of a process. Based on this information, improvement projects can be started and executed.

Quality managers

The quality manager is involved in the quality standards a hospital has to comply to. In this research the SONCOS standard is considered. The measurement of performance indicators by the information system will be a benefit for a quality manager with regard to time savings. Information on the performance and standard can be collected and used easily.

Information managers

The information managers are involved in projects of (new) information systems. Part of the research is the incorporation of the concepts eMeasure and DCM, to ensure a consistent and unambiguous interpretation healthcare information inside and outside the hospital. An information manager will benefit from the information system design if eMeasure and DCM are integrated in the design.

Appendix F: Examples of the developed UIMs

Radiology process: Planning

* Required

Banner text

Every UIM has the following banner text:
- A healthcare staff member is logged in with his/hers staff number
- An order (planned care activity) with a certain reference number is opened
- An order is linked to a patient with a patient number, name and date of birth

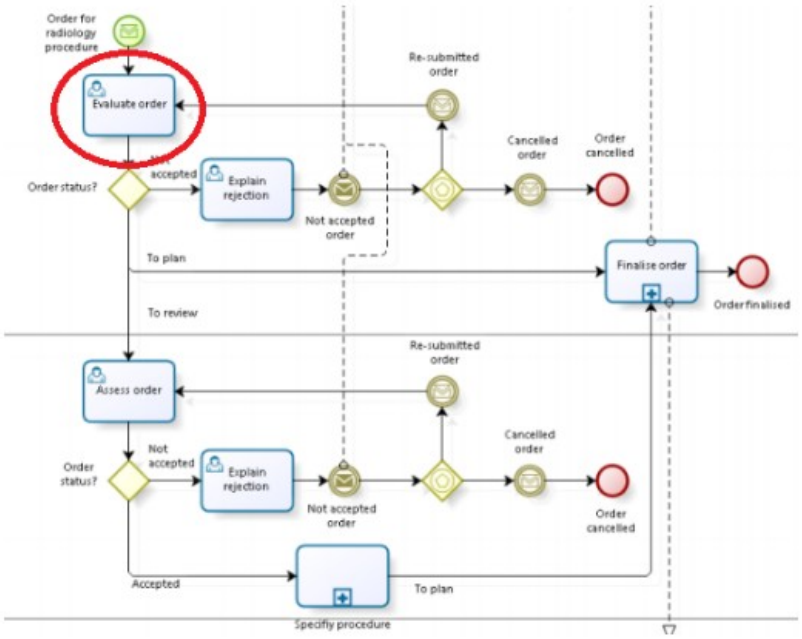
Care administration - Order evaluation

Pre-condition:
- The process is started via message flow 'order for radiology procedure'

Input:
- Order for radiology procedure

Post-condition:
- The order is evaluated by the care administration
- The order can be assessed by the radiology practitioner
- The order can be finalized by the care administration
- The rejection can be explained by the care administration

Output:
- Evaluated order



Order status? *

Choose

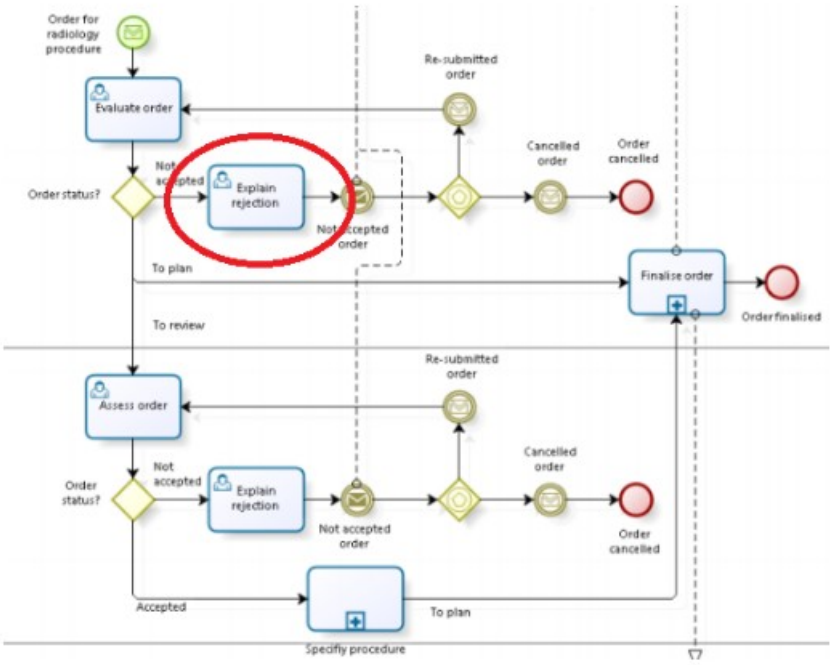
Care administration - Rejection explanation

Pre-condition:
- The order is evaluated by the care administration

Input:
- Evaluated order
- Order status: Not accepted

Post-condition:
- The rejection is explained by the care administration

Output:
- Explained rejection
- Message 'Not accepted order' is sent to the requester (analyst, assistant or pathologist)



Why is the order evaluated with order status 'Not accepted'? *

Choose

Additional remark on why the order is evaluated with order status 'Not accepted' *

Your answer

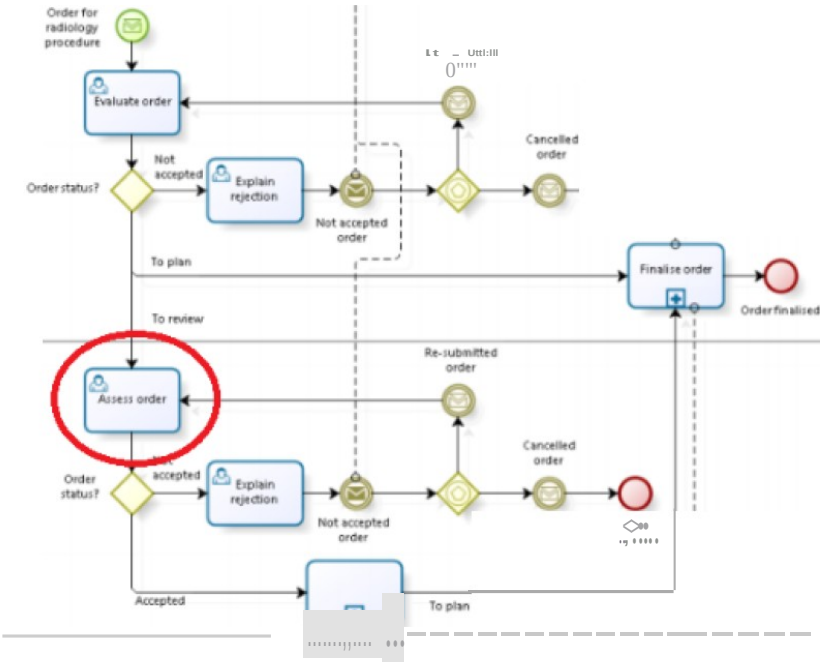
Radiologist - Order assessment

Pre-condition:
- The order is evaluated by the care administration

Input
- Evaluated order
- Order status: To review

Post-condition:
- The order is assessed by the radiologist
- The rejection can be explained by the radiologist
- The procedures can be specified by the radiologist

Output:
- Assessed order



Order status? *

Choose

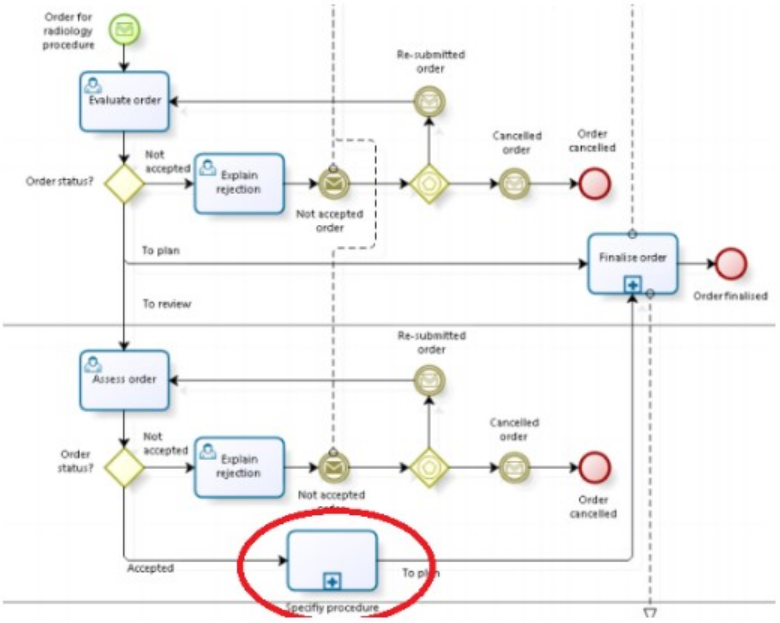
Radiologist - Procedure specification

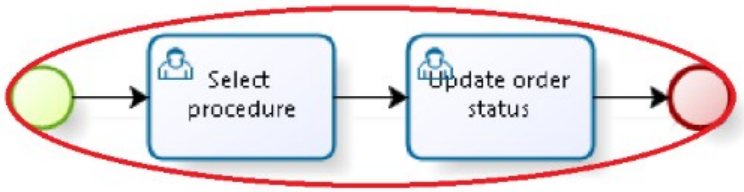
Pre-condition:
- The order is assessed by the radiologist

Input:
- Assessed order
- Order status: Accepted

Post-condition:
- The procedure is specified by the radiologist
- The order can be finalized by the care administration

Output:
- Specified procedures





Select procedure *

Choose

Additional remark on the selected procedure *

Your answer

Update order status

- [ ] Update order status to 'To plan'

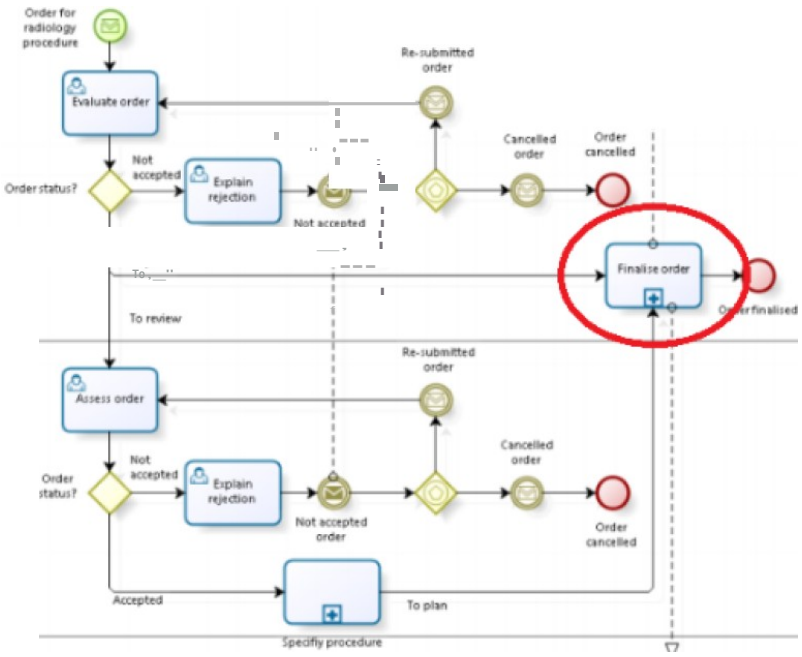
Care administration - Order f1nalizatior

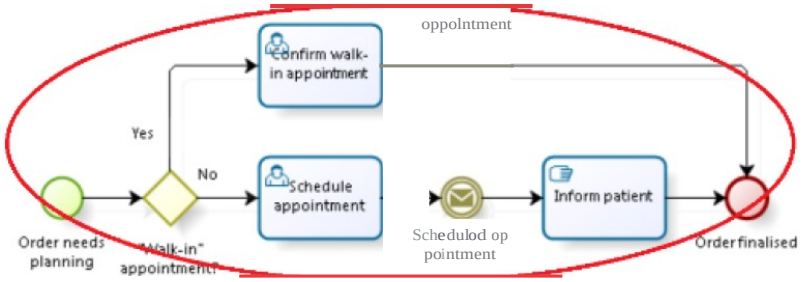
Pre-conditi on:
- The order i s eva luated by the care administrat on
- The procedures are selected by the radiol ogist

Input:
- Evaluated order
- Order status:To pl an
- Selected procedures

Post-condition:
- The order i s f1nalized by the care administration
- The process i s ended

Output:
- Finali zed order





Walk-in appointment? *

O Yes

O No

In case of no Walk-in appointment: Schedule appointment

Date

dd-mm-jjjj

Time

: AM

In case of no Walk-in appointment: Inform patient

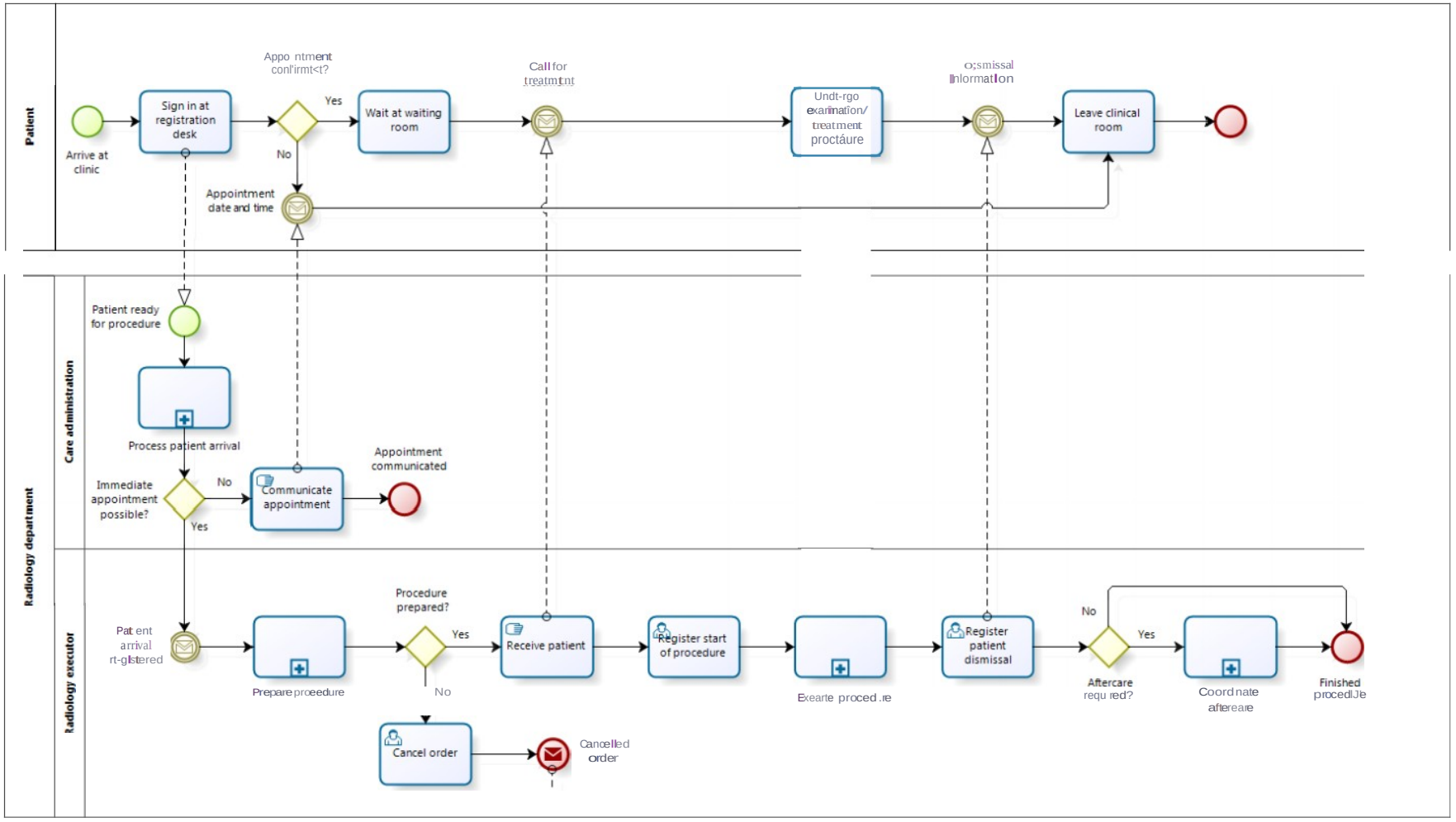
- ○ SMS
- ○ Email
- ○ Letter
- ○ Telephonic contact

In case of Walk-in appointment: Confirm walk-in appointment

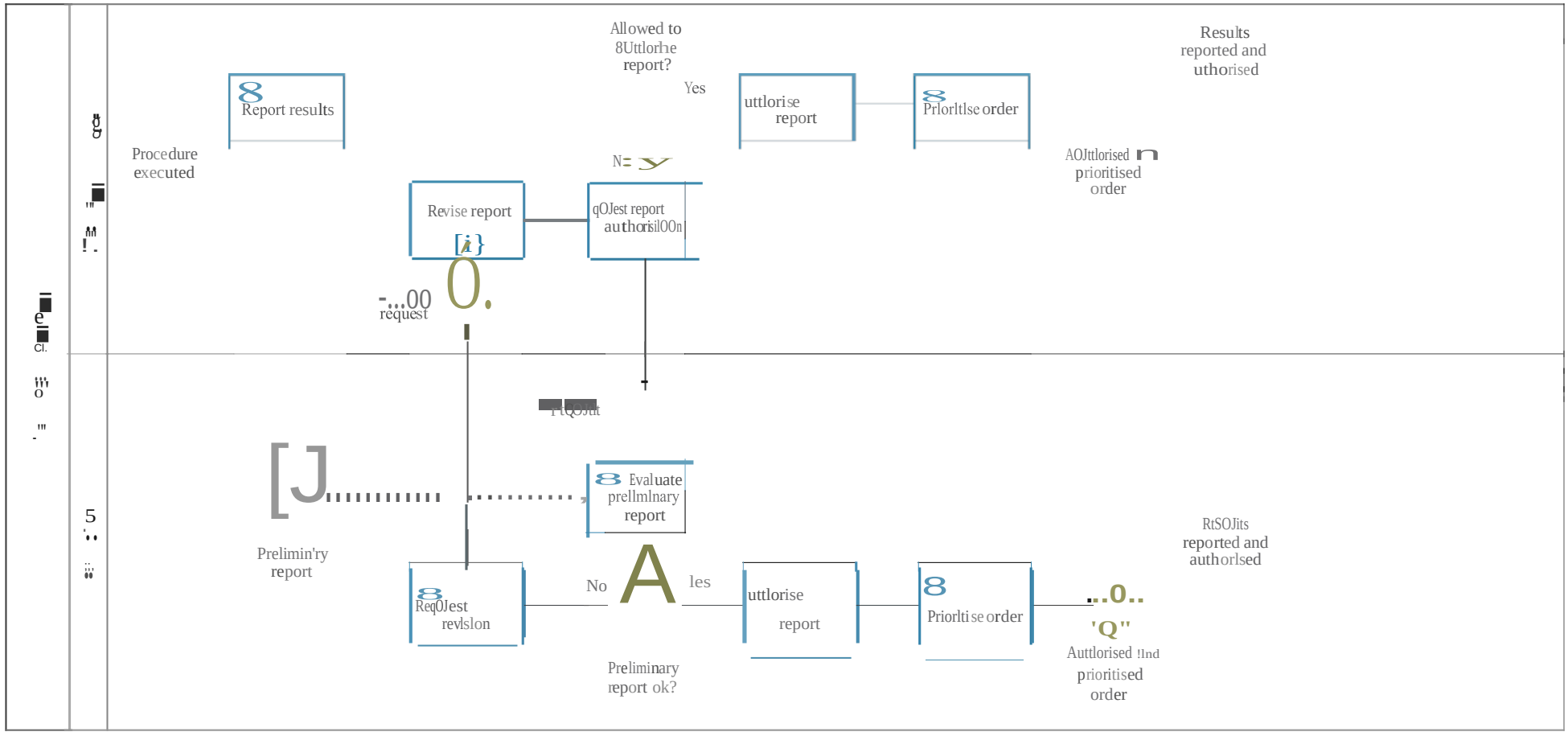
- ○ Confirm walk-in appointment

Process model: Plannin

Process model: Execute procedure



Process model: Reporting



Head and Neck Oncology department

Appendix H: Summaries interviews with other hospitals

Case 1 and 2

Communication type: Personal meeting

Interviewees: 2 IT architects

Duration: 1 hour and 30 minutes

Specifics: Interview took place for two hospitals at the same time, these hospitals share the same EHR system

1. How are DCMs and eMeasures currently applied in the hospital and in the information system designs of the hospital?

The hospitals are applying DCMs, but are not applying eMeasures. The hospitals have recently implemented a new EHR system and the IT architects are still running projects for the configuration of the EHR system. For the implementation of a new EHR system, the hospitals decided to use EPIC of an American supplier. The hospitals applied DCMs in the organization of the master file in the EHR system.

2. How is the design of an information system currently realized?

The decision to implement a new information system is based on whether new functionalities are required to fulfill information needs within the organization. The IT department is responsible to find feasible solutions for these functionalities. Hereby, the hospital uses a reuse- before-buy-before-build policy. It depends on the possibilities whether an information system will be reused, bought or build. In the first place, the IT department tries to fulfill new information needs with existing IT infrastructure. The search for a supplier is started if the function is not available in-house. If also the supplier is not capable of providing the function, then the decision is made to build an own system. However, the last option only happens in rare cases. The experience of the hospitals is that often standard products of suppliers are chosen, because these already cover the required functions.

As mentioned in the previous question, the hospitals have recently implemented a new EHR system. The decision for a certain IT supplier depended on how the suite is supporting processes within the organization. Currently the best suite is selected

which can cover and support as much processes as possible. The suite covers the care administration, order management, logistics and care planning, patient movement and a part of finance.

3. How does the hospital deals with changes in information needs?

For both hospitals, a notification has to be made when an information need changes. The notification is prioritized based on the urgency of the (new) information needs. Then one determines how much capacity should be available to find and implement solutions. Some changes can be executed quickly, while other changes require more time and efforts. The solution for a change depends on the situation. As describes in the previous question, both hospitals apply a reuse-before-buy-before-build policy.

4. How is data registered and used?

Both hospitals have just implemented a new EHR system. Further, the hospitals use multiple dedicated systems. Some small solutions are used when data can't be registered in an information system.

5. What is the applicability of the design methodology in the hospital?

The hospitals highlights that most of the time standard IT products are bought from suppliers. The hospitals use validation rounds in the selection of IT products and suppliers. The IT department tries to identify all requirements and functionalities required by the new information system. These requirements and functionalities are discovered in voting sessions and discussion meetings. The voting sessions and discussion meetings are held with healthcare providers who have knowledge about certain care processes in the hospitals. They are asked to vote or discuss on what the information system should be able to do. Multiple validation rounds are held to determine what IT product and supplier should be selected.

The design methodology is not applicable in the design of information systems, since the hospitals often buy standard products from suppliers. The hospitals admit the usefulness of process models in BPMN to describe the processes in a uniform and clear way is valuable. The data models in ORM are valuable for IT architects only, because healthcare providers will not understand the models. The data models will be obtained from the supplier.

The hospitals don't know what methods are used by IT suppliers to design information systems for hospitals. The design of information systems is already available on forehand. The IT supplier is mainly involved in the implementation phases of the information system.

Additionally, the hospitals explain that processes in hospitals are quite similar. Especially the main activities will be the same. Changes arise in specific registrations, and specifications on how main activities are shaped and organized.

Case 3

Communication type:	Personal meeting
Interviewee:	1 IT architect
Duration:	1 hour and 20 minutes

1. How are DCMs and eMeasures currently applied in the hospital and in the information system designs of the hospital?

The hospital is not applying eMeasures, but the hospital is applying DCMs. The hospital implemented the EHR system of ChipSoft, called HiX, five years ago. The hospital has some freedom with regard to the organization of the EHR system. It depends on the possibilities whether and to what extent DCMs will be applied.

2. How is the design of an information system currently realized?

The hospital is not developing its own information systems. Instead, the hospital buys standard IT products of external suppliers. The standard products of the supplier have some freedom in the configuration of information systems. The IT department is responsible for the organization and configuration of the systems. The answer on the next question, question 3, will explain how the configuration of information systems is realized by the hospital.

3. How does the hospital deals with changes in information needs?

In the beginning, the organization of the EHR system was mainly focused on how the information system should support the care processes. As a result, the organization of the EHR system is not based on purposes other than providing care to patients. Currently the hospital tries to change the organization of the EHR system, to not only facilitate the care of patients, but also perform additional registrations required for reporting and evaluation of performances. An example refers to external parties that need reporting on whether certain standards are met.

Hereby, the execution of a change depends on who is responsible for the project, the time pressure and the solutions or tools that the supplier has available. The interviewee explains that the execution of a changes differs per project leader. The interviewee prefers a method comparable to the design methodology. First, she analyzes the care processes and figures out what the influence of a change is on the processes. Then she identifies required data elements in the summarizes these in an Excel file. However, not all colleagues of the interviewee prefer this methodical approach. A few colleagues of the interviewee are more screen oriented. In that case

no focus is on the underlying meaning of a change. These colleagues immediately focus on the execution of the change via screens of end users, thereby providing more ad-hoc solutions.

4. How is data registered and used?

The hospital uses a EHR system, containing most of the information of patients and care processes. Multiple specialized systems are linked to the EHR system. However, the database has a poor accessibility. The supplier charges money to provide additional services, such as collecting data required in certain projects. The hospital needs the data for multiple purposes and tries to find the required data itself. However, this can be a risky and time consuming task.

Also, the hospital highlights the importance of measuring performance indicators in information systems. The hospital has to deal with multiple standards from external parties. The reporting to external parties can be executed quickly if performance indicators can be accurately measured in an information system. This data is also useful for internal usage, to determine how patients are helped within certain care pathways.

5. What is the applicability of the design methodology in the hospital?

As described previously, the hospital is buying standard products from suppliers. Therefore the applicability of the design methodology will be more useful for the configuration of information systems. The interviewee highlights that the design methodology can be useful for configuration purposes. She already uses a methods similar to the design methodology (as is described at question 3).

The interviewee doesn't know how IT suppliers are designing (standardized) IT products. The design is already completed when a standard IT product is bought. Hereby, the IT suppliers are mainly present in the selection and implementation phase.

The interviewee also explains that the processes between different hospitals are comparable. For example, the radiology department of hospital A is quite similar as the radiology processes in hospital B. Still, some differences arise depending of the centralization or decentralization of activities. For example, when taking blood samples

is a decentralized activity. Then taking blood samples will take place at the departments. Else, taking blood samples will take place at a special department.

Case 4

Communication type:	Personal meeting
Interviewees:	2 IT architects, 1 EPD specialist and 1 data manager
Duration:	1 hour and 30 minutes
Specifics:	Combination of a presentation, discussion and interview

1. How are DCMs and eMeasures currently applied in the hospital and in the information system designs of the hospital?

Currently the hospital started one project to determine how DCMs can be applied in the IT landscape. One of the interviewees is responsible for the project. She is defining what information is required by the healthcare providers and then identifies how DCMs can be used for the data elements. The applicability of the DCMs depends on what DCMs are required in their project. The feedback and experiences on the applicability of DCMs will be communicated with the Registration at the Source program. Additionally, DCMs are applied in the EHR implementation.

2. How is the design of an information system currently realized?

The hospital is buying its IT products from suppliers. At the moment, the hospital is focusing on a new EHR implementation. The hospital choose to buy a standard product from the supplier. Now, the hospital has to define how the care processes should be supported by the EHR system.

For the configuration of systems, the hospital is using a method similar to the design methodology. The hospital explains that process models are often used in the configuration of information systems, since the systems should support the care processes. Also, the hospital entails to identify how data should be organized to support the care processes. This is a bit similar to the design methodology, wherein process and data models are used to analyze care processes and to define data elements involved in these processes. Hereby, the hospital uses different techniques, for example a technique other than BPMN is used in process modeling. The hospital explains that models used for

information system configuration can be reused more often. Not all healthcare staff is aware of the models and are sometimes unnecessarily remaking models.

3. How does the hospital deals with changes in information needs?

The hospital has one specific department that is responsible for changes in the IT landscape. Healthcare providers and other hospital staff members notify the department when information

needs change. The department is guiding the change. Then the department comes up with one or multiple solutions. The type of solution differs depending on what change in the IT landscape is required. Sometimes small changes can be solved easily. In other cases, changes require more time and efforts. Whenever needed, the department cooperates with other departments to find and execute feasible solutions.

4. How is data registered and used?

The data of the hospital is registered in repositories. As describes previously, the hospital is busy with a new EHR implementation. The hospital is implementing the HiX system from ChipSoft. Besides the EHR system, the hospital has a separated database with additional data that cannot be registered in the EHR system. Also, the hospital uses some specified information systems for certain processes or departments.

5. What is the applicability of the design methodology in the hospital?

In theory the design methodology is applicable in the hospital. The four interviewees are interested in the design methodology and a discussion is started on how the design methodology can be executed in a hospital. The hospital is using similar methods in the configuration of information systems. Although, the hospital is not used to apply a design methodology that closely links processes descriptions and data needs, wherein process descriptions and data needs are modeled together as a comprehensive view.

In addition, some comments are made about the awareness of healthcare staff members in the applicability of the design methodology. The employees should be aware about how process and data models can be seen as a whole and how screen mockups can be applied in the validation of information system configurations. Also, healthcare staff members should be able to work with the techniques (i.e. BPMN, ORM and UIM) before the techniques can be effectively applied in the design methodology.

<u>Case 5</u>

Communication type: Email contact

Interviewee: 1 IT architect

1. How are DCMs and eMeasures currently applied in the hospital and in the information system designs of the hospital?

Currently the hospital tries to change the EHR system with regard to the DCMs. This takes place,

depending on the time and possibilities within the processes.

2. How is the design of an information system currently realized?

Sometimes a design for a new information system is established. Hereby, the new information system is not developed, because a standard product of a supplier will be bought and implemented. Therefore the hospital focuses on the coherence of the new information system with the processes and context in the hospital.

3. How does the hospital deals with changes in information needs?

A change in information needs is notified by the change advisory board. A standard change which not requires changes in the IT landscape will be executed depending on the time it takes and urgency. A change in the IT landscape requires more time and a budget has to be define. In that case a project is started. An analysis of the process and requirements takes place via multiple perspectives. The solution for the changes in information needs depends on the selected alternatives. The solution will be executed by a project team with a certain budget.

4. How is data registered and used?

Data is registered in repositories, such as databases, PACS systems and files.

5. What is the applicability of the design methodology in the hospital?

For process modeling is currently performed via Archimate in a TOGAF context and sometimes a tool as BPMN is used. ORM is not used at all.