Creating a general method for eMeasure development

Developing the process models for eMeasure development

Pim van de Laar

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Auteur	P.J.C. van de Laar
Studentnummer	1932519
Afstudeerscriptie in het kader van	Economie en bedrijfskunde Technology & operations management Rijksuniversiteit Groningen
Opdrachtgever	I. Lesman Nieuw EPD, UMCG
Begeleider onderwijsinstelling	Dr. H. Balsters Economie en bedrijfskunde Rijksuniversiteit Groningen
Begeleider UMCG	A. de Jong Nieuw EPD, UMCG

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Preface

This thesis is the final project and result of my master Technology and Operations Management at the University of Groningen.

It was both challenging and interesting which made it a a great project to work on. Due to the great support of the Large Teaching Hospital in the Netherlands (LTHN) and their staff, we felt that we were part of a bigger project. This gave the feeling that the project and its results were appreciated.
I would like to thank our supervisors from the LTHN for helping answering numerous questions and connecting us to the right persons. I also want to thank my fellow student Rick Beukeboom for his cooperation and the input during our lengthy discussions, which in the end were to great value to the process and results of my project.

Last but not least, i would like to thank my supervisor H. Balsters for providing me with this great opportunity to be involved with this project. I also would like to thank him for the advice and support he provided during the project and the time to meet almost weekly at the LTHN for discussing this project.

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ABSTRACT

As a result of the increasing availability of electronic health information and the increasing demand for quality reports on healthcare, HL7 developed a standard for the digital representation of quality measures: eMeasures. Unfortunately HL7 did not provide a standard method for developing these eMeasures. A LTHN is in the process of developing an eMeasure system. In this research a general method is developed for creating these eMeasures. This contains three stages. The initial stage is developing a process model in BPMN. Subsequently, the second stage transforms these models into data models. Finally, the third stage is the validation of the method with the end-users, developers and health care providers.

1 Introduction

Around the world, electronic health records (EHRs) are implemented to improve patient care, reduce health care expenses and fundamentally change the way in which medicine is practiced. In the last years this market has expanded and for the coming years a steady growth is expected as more countries or hospitals start initiatives to implement EHRs (Accenture, 2014). With the increasing number of EHRs there is also an increase in the quantity of electronic health information (EHI). To manage these amounts of data efficiently and to make it possible to exchange EHI the non-profit organization *Health Level Seven (HL7)* was founded in 1987. To illustrate, HL7 is an organization that develops frameworks and standards for exchange, integration, sharing and retrieval of EHI which supports clinical practice and delivery and evaluation of health services (HL7, 2014). Since 1987 HL7 has become one of the leading standards for exchange of EHI between EHRs (Hooda et al. 2004).

One of the standards developed by HL7 is the Health Quality Measure Format (HQMF). This is a standard format for electronically documenting the content and structure of a quality measure. Such formatted quality measure is called an eMeasure. Although HL7 gives a standard of how to format these quality measures, a standard on how to create these eMeasures is not provided.

Every year there are news reports that governments demand a higher quality health care system. As a result of this quality raise there is an increase in demand for quality reports from external and internal parties. All of these reports need health quality information generated from EHI by quality measures. Unfortunately the requested information within those reports is almost never the same; other information is needed; and threshold levels or measure periods change. This results in a situation of high demand for new or renewed quality measures.

The combination of these two situations, the high demand for quality measures and the lack of a standard method on how to create these quality measures in a digital form (eMeasures), gives an opportunity and a demand of developing such a method.

1.2 The Case

Nowadays, in a Large teaching hospital in the Netherlands (LTHN), these requests for quality reports are fulfilled by directly transforming the quality request into a query to the database. In other words, the care provider receives a request for information on quality performance, this request is answered by looking up all the necessary data in the care providers database and use this data to answer the request as correct as possible. This method is used for years and seems to provide adequate information. However this method has some serious downsides, one if which is that it is very time-consuming to gather the needed data and provide a correct answer. Also the information request cannot be compared between multiple data warehouses due to a missing functional layer. Furthermore, this method by directly extracting the data from the database makes it practically impossible to exchange information requests or re-trace the source of the data used for the answering the request. To overcome these problems a care provider can implement eMeasure to answer these information requests.

In this case the LTHN has signed a contract with an ICT company to develop an electronic health record system (EHR). Build on this EHR system and the data it will provide, the LTHN has made the decision to develop and implement an eMeasure system. The eMeasure system is responsible for generating documents that give information about the quality for all kinds of clinical processes within a hospital. Examples of these processes can be the quality of hip replacements or the level of post-surgical infections. The creation of such documents is at the intersection of hospital care and information processing. Consequently it is difficult to create a process that can generate those eMeasures which are understandable for software engineers and care providers.

1.2 Research objective and question

The research objective of the overarching project is:

Designing a validated general method for developing an eMeasure based on DCMs

The research objective for this thesis thereby only focuses on the development of business process models for the development of eMeasures and the corresponding questions for building these models. This results in the following main research objective:

Transforming the existing business process of developing quality measures to a validated business process model of designing an eMeasure at the LTHN.

In the context of the LTHN the business process that is going to be analyzed is the development of eMeasures

To answer the main research question, several sub-questions are formulated. The first three sub-questions will be used for creating the business process models. The fourth question will validate the correctness of the developed business process model and user interfaces. Finally the last question will help answering the overarching project objective.

- Who is currently involved in designing quality measures/eMeasures and how are they involved?
- Who is currently involved in using the developed quality measures/eMeasures and how are these used?

- What are the requirements or constraints of the designers or users of quality measures/eMeasures?
- Who needs to validate the design process model and the outputs of this design process?

1.3 Academic relevance

The academic relevance of the overarching project comes from the lack of a general method to develop an eMeasure using DCMs. When developing the process a proposed general method for extracting data models will be used. When the overarching project is completed there will be a validated method for developing eMeasures within the healthcare industry. Furthermore the proposed method for extracting data models from a business process will be validated within a complex environment or at least within the development of an eMeasure at a LTHN.

The academic relevance of this thesis can be derived from the development of a method for developing eMeasures and the validation of the first step of the extraction method: the step of transforming a business process to a business process model in a manner that is complete and suitable for the data modeler.

Whereas it is expected that developing an eMeasure is a complex process, this thesis will also provide an insight in the capability of Business Process Modeling Notation concerning modeling such complex processes. In addition this thesis will show if there is a demand for another notation to develop such complex systems.

1.4 Structure of thesis

The research process will start with theoretical background (chapter 2) in which the relevant literature for this thesis will be discussed. This chapter starts with the field of *design science* followed by requirement engineering*, the Business Process Modeling and Notation (BPMN) and systems thinking.* Thereafter the proposed methodology will be discussed (chapter 3) which includes the type of research, research framework, an overview of the overarching project and the methodology specific for this thesis.

2 Theoretical background

As stated in the introduction a general method for developing eMeasures needs to be designed. Furthermore a proposed method for data extraction will be used in order to generate the blueprints needed for developing the databases that support the eMeasure development process. The extraction method also supports the development of the eMeasure design process and is built upon the process of transforming user requirements to the (data) needs of each stakeholder. This method is a three stage method: the first stage is getting the requirements of the system or process. In this phase there will be build upon the theory of requirements engineering. The second stage refers to process modeling. During this stage a method called Business process model and Notation (BPMN) will be applied in which the requirements are modeled in a business process. The third stage concerns data modeling. The business model will be the base for a data model in this stage. The first two stages are performed in this thesis while the third stage is carried out by Martena (2015). All these steps are performed in the domain of design science.

2.1 Design Science

The field of design science aims at solving practical-knowledge problems with a utility goal (Balsters, 2013b). The aim of a practical-knowledge problem is resolving a difference between the way stakeholders experience the world and the way they would like to experience the world (Wieringa, 2007). Once a practical-knowledge problem has been identified, one can proceed by asking *how to do X?,* followed by actually trying to build X. In that case *How to do X* would be a statement of a design problem. The answer to this design problem would be evaluated with respect to a problem-dependent criterion: *does solving this problem bring us closer to attaining the problem specific goal?* However to answer a design problem the problem solver still needs to answer pure-knowledge questions when investigating the problem, asking diagnostic questions, propose possible solutions and validating these solutions. These design research problems followed by their goals can be described in a certain pattern. The first one describes the context, so what needs to be changed or improved. The context is always a given. The second one describes the artifact: the artifact is the object/system that helps attain the goal. An artifact is not a given but needs to be designed and influences or improves the problem context by contributing to the stakeholders goals. In the end the last goal is described: this goal is based on the requirements or success factors given by the stakeholders.

2.2 Requirement Engineering

Requirement engineering (RE) is one of the first steps when developing a software system. RE is the process of finding the requirements of the system. This is done by identifying the stakeholders and their needs. When identifying one can find be numerous stakeholders varying from developers to end-users of the system or its output. The number of stakeholders and their diversity can increase the difficulty of this process, because each stakeholder's requirements can vary or conflict with the requirements of another stakeholder.

Moreover these requirements can be broadly classified into Functional Requirements (FR) and Non Functional Requirements (NFR) (Li, Eberlein & Far, 2004). FR are requirements that affect the system's functionality and refers to the "what" question, whereas NFR are requirements that constrain the system and refer to the "how" question (Selvakumar & Rajaram, 2011).

Because RE is concerned with interpreting and understanding stakeholder terminology, concepts, viewpoints and goals. It must concern itself with the understanding of the beliefs of stakeholders (*epistimology*), the question of what in the world is observable (*phenomenology*), and the question what can be agreed upon as objectively true (*onthology*) (Nuseibeh & Easterbrook, 2000). Such issues become important when these requirements need validation especially when stakeholders have diverging goals. RE can help a developer with these diverging or even conflicting goals and is therefore critical for a successful project (Lamsweerde, 2000).

2.3 Business Process Modeling Notations (BPMN)

A business process model describes events and the ordering of those events: what is performed and when is it performed (Bridgeland & Zahavi, 2009). BPMN is an international accepted standard language for business processes and workflow modeling (Balsters 2013a). Furthermore BPMN provides a graphical representation based on workflow diagramming and provides a Business Process Diagram (BPD). Because of the graphical nature it is understandable by different types of business users, varying from business analysts - who sketch the preliminary drafts of the process - to the technical developers responsible for implementing them, and finally to the business staff when monitoring those processes (Chinosi & Trombetta, 2012).

A basic BPMN model can contain five types of elements when building a diagram (Object Management Group, 2011), these five elements will be described below.

Flow objects: the main graphical elements to define the behavior of a business process. There are three types of flow objects: Events, Activities and Gateways (Chinosi & Trombetta, 2012).

Data: expressed in four elements: Data objects, Data inputs, Data outputs and Data stores (Object Management Group, 2014).

Connection objects: Are used to connecting various objects to each other. There are four connecting objects: Sequence flows, Message flows, Associations and Data associations (Object Management Group, 2014).

Swim-lanes: provide the possibility of grouping the primary modeling elements. Two lanes can be distinguished: pools and lanes (Object Management Group, 2014).

Artifacts: do not affect the process flow but can be used to provide additional information about the process (Chinosi & Trombetta, 2012). The present set of artifacts includes group and text annotation (Object Management Group, 2014).

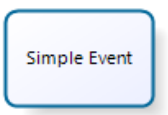
In this research only the basic elements of BPMN are used to keep the models simple and understandable. As a consequence there are only seven elements that will be used. Those are explained below.

Pool: helps to show a process. Within a pool several stakeholders can be used which can lead to subdivisions (see lane).

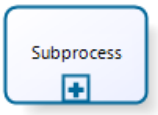
Lane: is a subdivision within a pool. Lanes are used to organize stakeholders within a process.

Start/End event: the start event indicates where the process starts while the end event points out where the process ends.

Activity: in this case an event, is used to show which work is done at that specific point in the process.



Sub-process: is a compound activity that is included in a process. Within this sub-process there can be two or more additional objects that are part of the process. In this case a sub-process can be a building block.



Gateway: is used to show the divergence of sequence flows. Furthermore gateways are often used the test for critical success factors. A parallel gateway is used to show that events can be performed at the same time.

Sequence flow: is used to show the order in which events will be performed in a process.

By using these elements a simple example of a BPMN digram can de developed (figure 2.1)

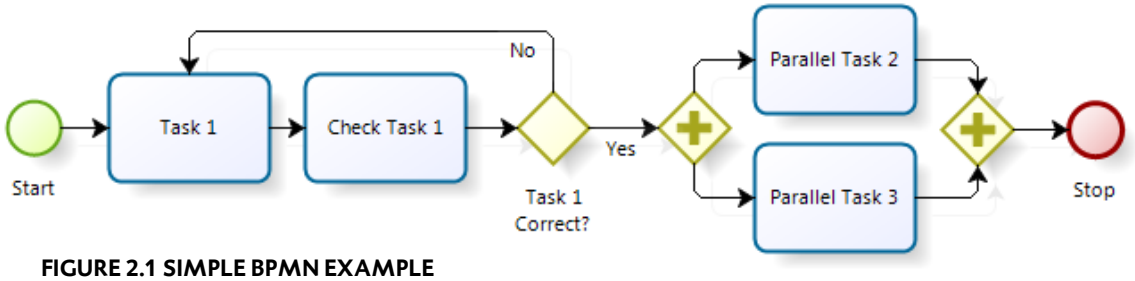


FIGURE 2.1 SIMPLE BPMN EXAMPLE

2.4 System Thinking

When applying system thinking one looks at a system as a complex whole the functioning of which depends on its parts and the interactions between these parts (Jackson, 2011). Therefore system thinking can be used to describe, analyze and structure processes during which problems can be solved (In 't Veld, 2006). The goal of the method is to map the processes using the steady state model. To illustrate, the steady state model is defined as: a model of a system state, which is created when the behavior of the system is repeatable in time, and if that behavior is in the one time period similar to that in the other time period (In 't Veld, 2006). According to In 't Veld (2006), the system approach works as follows: a system (black-box) is opened and the interactions and functions of the different sub-processes are studied. This can be repeated until the required elements are found. In other words, each time a black-box is opened a lower aggregation level is reached.

Within this system three phases that can be identified: coding, transforming and decoding (In 't Veld, 2006). Firstly, coding is the function that prepares the input for transformation and pertains to quality and quantity which is build upon the critical success factors given by the stakeholders. The coding phase is in most cases the largest phase in a process; as long as the coding is not done correctly the transformation phase cannot start. Secondly, the transformation phase is the actual change from input to output and can be as small as one event in a process. Thirdly, the decoding phase includes the events that are needed to present the output in such a way that it can be understood by the receiver of the output (In 't Veld, 2006)

The main themes of system thinking are abstraction and generalization which means that the system first needs to be designed before the various components of the system can be analyzed (In 't Veld, 2006).

2.5 Validity

In design science there are four test that must be addressed to ensure the validity and reliability of the results (Karlsson, 2009)

Validity:

- Internal validity: Is reached by matching the outcomes of multiple interviews to identify possible causal relationship between them.
- External validity: Is reached by checking if it is possible to generalize the findings.
- Construct validity: Is reached by interviewing multiple interviewees, using multiple interviewers and by letting interviewees review the draft and conclusion. This repeats until the interviewee states that they are correct and valid.

Reliability:

- Reliability: Is guaranteed by using a research protocol and storing interviews and the results.

3 Methodology

In this chapter the methodology is described. First of all the type of research is discussed followed by the research framework. In the third place there will be an overview of the overarching project and lastly the methodology for this part will be formulated.

3.1 Research Type

The goal of this research is to design a validated general process for developing eMeasures. This means that the research field refers to design science and that the artifact is the development process of an eMeasure. To fill the gap between theory and science for these types of practical problems van Strien (1997) developed the regulative cycle. The cycle consists out of five phases: design problem, diagnosis/analysis, design solution, implementation and validation (figure 3.1). The regulative cycle has often an iterative character of a negative feedback loop, because when the desired results are not attained in the validation stage, the process starts all over again. In the first stage, design problem, the problem which needs solving is being identified. The second stage, diagnosis/analysis, is often a mini-theory about the problem and possible solutions. The third stage, design solution, is the action of developing or further elaborating the solution for the problem. Moreover the fourth stage, implementation, is aimed at using the solution for the given problem. The fifth and last stage, validation, includes assessing the new situation and if the solutions meets the requirements.

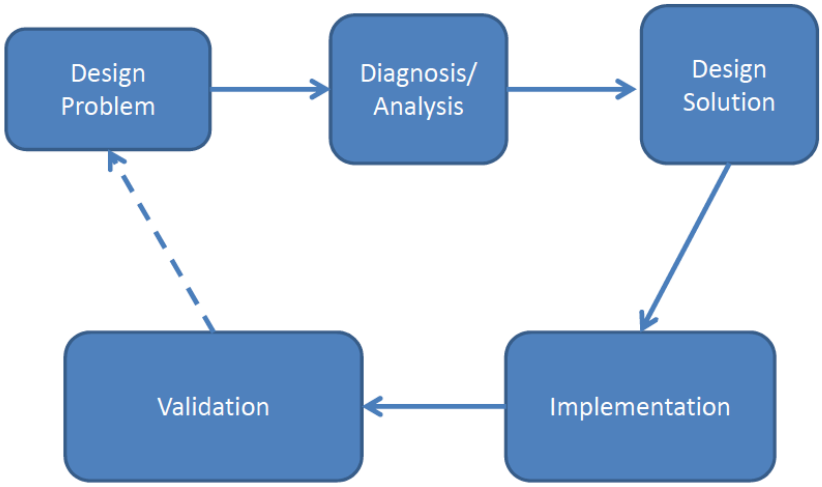


FIGURE 3.1 - THE REGULATIVE CYCLE

3.2 Research Framework

As described in the previous section, the regulative cycle of Van Strien (1997) consists out of five stages. To complete these phases Balsters (2013a) developed questions which should be answered in each stage. Part of these questions originates from the engineering cycle of Wieringa and Heerkens (2007). The questions per stage are described below.

Design problem phase:

- Who are the stakeholders?
- What are the goals of each stakeholder?
- What are the Critical Success Factors (CSF's) for each goal?

Diagnosis/Analysis phase:

- What are possible causes of the difficulty resolving a CSF?
- What are the quality attributes of CSF's and what are their restrictions?
- What are the CSF interdependencies?

Design solution phase:

- Which alternative solutions are available?
- Can we assemble old solutions to build a new solution?
- Can we invent a new solution completely from scratch?

Implementation phase

Validation phase:

- How to design test methods for each CSF?
- Are all CSF's met?
- Is there a trade-off between CSF's?
- How scalable is the solution/implementation?
- How well does the solution/implementation perform in comparison to previously established CSF quality attributes?
- Have we encountered new CSF's in the implementation result?

Balsters (2014b) states that often the correctness of a design solution can be validated without implementing the solution. For this research the solution will not be implemented, but the design phase will directly be followed by the validation phase. Therefore the regulative cycle will be adapted to fit this research. By going from design solution to validation.

3.3 Overarching project overview

As described earlier the goal of the overarching project is to create a validated method for developing eMeasures. The business process being analyzed is the development of quality measures/eMeasures at the LTHN. These eMeasures are used for quality measurements concerning internal and external parties. When the development process is transformed to a business process model and a data model, it can be used as a blueprint for developing eMeasures that can rely on the information within the EHR system at the LTHN. During this process different eMeasures will be developed and evaluated. The developed process will be validated by the end-users of the development process, the developers, but also by the end-users of their product, the requesting party of the quality report.

The three steps involved in creating the process and data models for developing eMeasures are divided over three individual researches. These steps and there corresponding research will be discussed below.

3.3.1 Developing the process models

The developing part is divided into two steps. Firstly the relevant steps for developing an eMeasure have to be found, and secondly these steps have to be validated. In the research framework the steps belong to the design problem phase, diagnosis/analysis phase and are part of the design solution phase and validation phase. By means of analyzing the eMeasures and interviews with end-users (developers and doctors), information about the eMeasures will be gathered. This information will be transformed to process models in BPMN and hence these models are validated again by the end-users. The exact approach of this part of the project is described in section 3.4 and will be done in close collaboration with Beukeboom (2015).

3.3.2 From process models to data models

During the second part of the overall project the output of the first part, mainly process models, are converted into data models using FBM. In the regulative cycle this step is part of the design solution stage. For this conversion from BPMN to data models the method of fact based business process modeling will be used. These data models can be used to make blueprints for a database that supports the development process of eMeasures. This part will also function as an interim validation of the process models, because in case of incorrectness a complete data model cannot be developed. This part, part 2, of the project will be performed by Martena (2015).

3.3.3 Validating the process

The last part of the project is the validation of the developed processes and data models in collaboration with the end-users. This will be done by applying the method for developing eMeasures that support existing and new requested quality reports. This third part will be performed within the research and in close collaboration with Beukeboom (2015) and Martena (2015). When during these validation sessions data seems to be missing the cycle is started again at the design problem stage, this is repeated until the results are fully validated by the end-users.

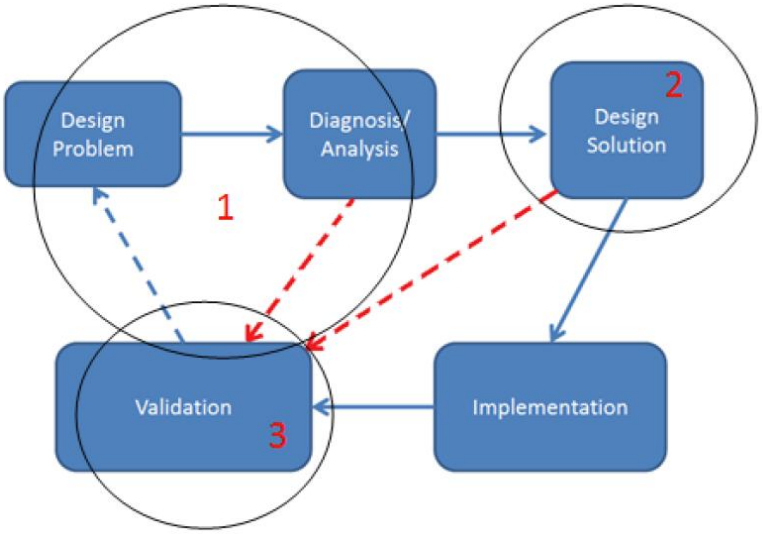


FIGURE 3.2 MULTI-STAGE PROJECT OVERVIEW

3.4 Research design

In this paragraph the research design formulated for the first and third part of the overarching project: developing the process models. Besides developing the process models the aim is also to validate these models during and after they are converted to database blueprints. This means that all steps in the process are all critically examined by analyzing the process for missing steps and non-contributing steps during the use of the process on an example. With these results the process can be improved.

3.4.1 Step 1. Develop a general overview of the process

In order to develop the processes, the first is the development of a general overview of the process. Consequently, it becomes clear which (sub)processes should be investigated and which boundaries can be set. To develop a general overview, existing quality and eMeasures are analyzed for common elements. This general overview will be a starting point for the use of the system approach. When the general overview is completed, the stakeholders and both end-users can be identified and the next step can be entered.

3.4.2 Step 2. Stakeholder analysis

In this step the stakeholders of the eMeasure process are analyzed. The questions are derived from the first two phases of the regulative cycle:

- Who are the stakeholders?
- What are the goals of each stakeholder?
- What are the Critical Success Factors (CSF's) for each goal?
- What are possible causes of the difficulty resolving a CSF?
- What are the quality attributes of CSF's and what are their restrictions?
- What are the CSF interdependencies?

At the end of this step, the questions above will be used to capture the functional and non-functional requirements. These requirements will be used during the development of the process.

3.4.3 Step 3. Develop the process models

By using information from the previous step as well as interviews with end-users of the process and end-users of its output, process models can be developed. In this stage the first model developed will include the so called "happy flow". This model will only focus on the most routine information request where no exceptions are included. Before starting to include the exceptions, the happy flow is set up to get a clear picture of the process. When the "happy flow" is validated the exceptions will be added and discussed in more detail. After these exceptions are added the process will be validated in step 4. In addition, the systems approach is used to come to the right level of detail (aggregation level).

The questions that are used for deriving the data for the data modeler come from the Process-driven Database Design method of Balsters (2013a):

1. At what instant does the event happen?
2. How can the event be identified?
3. Which entities are involved in the event as participants?

4. What is the input for the event?

5. What is the output for the event?

During the interview sessions all questions should be answered to get enough information to proceed to step 4. However, before proceeding to step 4, the process models are discussed with the data modeler to ensure that no important information is missing.

3.4.4 Step 4. Validating the method

The process is validated by interviewing the same end-users as earlier. During the validation of the process models, exceptions or questions are discussed and the process is changed, if needed. By getting a clear picture of possible exceptions the process can be adapted in such a way that it can handle these exceptions. Based on Balsters (2013a) and Karlsson (2009) the main questions for the validation are:

- Are all CSF's met?
- Is there a trade-off between CSF's?
- Is the method completely and correctly displayed in the process models? If not, should it be adapted?
- Is the data which is used at every event complete and correct? If not, how should it be adapted?

Next to the critical success factors given by the end-users, the developed process also needs to be validated on the HQMF requirements.

3.4.5 Step 5. Adapt results and method

When it appears that end-users are not satisfied with the process or the output of the process does not generate the expected results, something could have gone wrong in stage 1 of the overarching project. To locate these mistakes the results of the validation are used to find the errors. Hereafter the step that caused the error is examined. By improving the process and collecting the right information, the right data models can be generated. As a result, the validation can be re-done to see if the outcomes are correct and the process is valid.

4 Results

This chapter describes the results of the process described in section 3.4. First of all, a general process overview of the eMeasure process is given together with a description of what starts this process. Secondly, the results of the stakeholder analysis will be discussed followed by the process models that were designed based on the analysis.

4.1 Process overview

In the first place, an overview of the process is made to identify the starting and end event and to specify the boundaries of the project. Figure 4.1. shows a model of the eMeasure process on a high level of aggregation. The process is always started by a need for certain information and only ends when this need is fulfilled by receiving the information. As visible in figure 4.1, each product consists out of one or multiple other products. Data is the product on the lowest level and in this project it has been assumed that the data will always become available when needed. This thesis will focus on the development of eMeasures and the steps in the development of an Information Product (IP) that are required for the developing an eMeasure. The thesis of Beukeboom (2015) will focus on the development of Detailed Clinical Models (DCM).

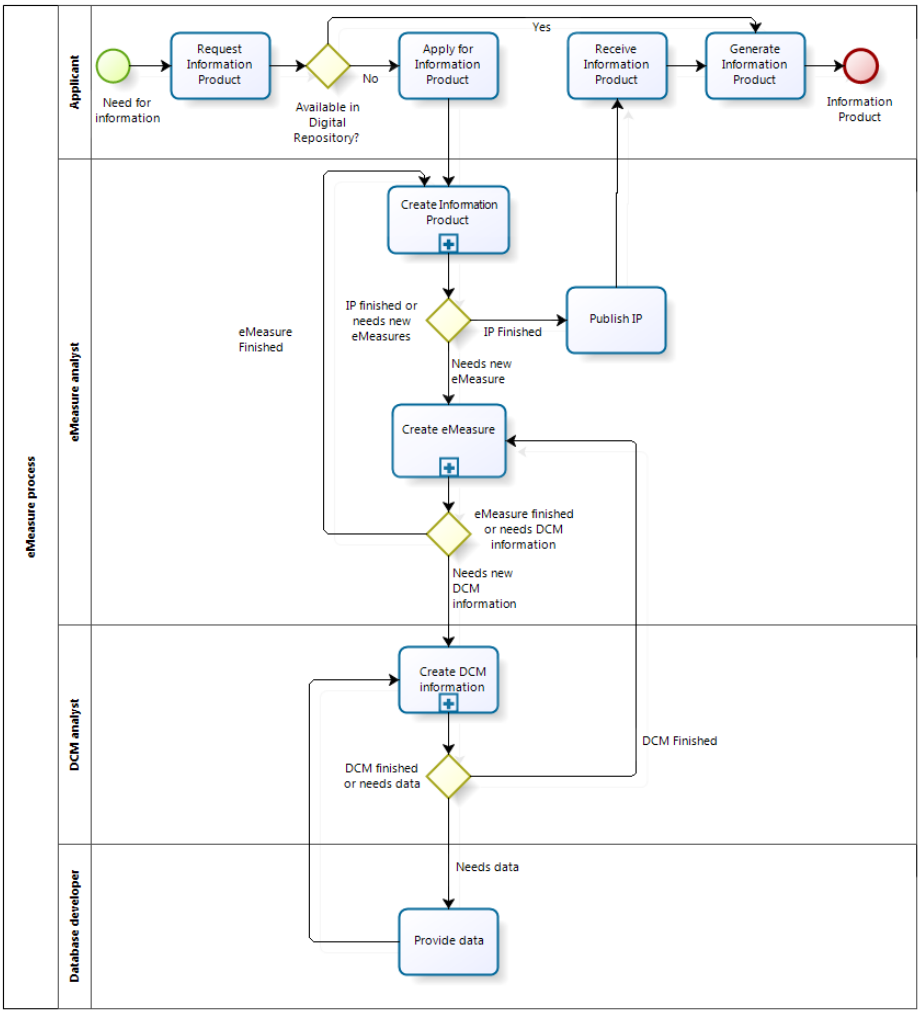


FIGURE 4.1 OVERVIEW PROCESS

4.2 Stakeholder analysis

Whereas an eMeasure is a formally defined quality measure, the stakeholders in the quality measure process are used for the initial interviews. Based on these interviews and the process overview more stakeholders for the new eMeasure process were identified. Because of the use of process driven design, multiple stakeholders are also end-users of the eMeasure process or the end-user of the product derived from the eMeasure process. These stakeholders were asked more questions due to their knowledge and expectations of the process.

4.2.1 Stakeholders

Based on the quality measure workflow and the interviews with members of the eMeasure project team at a LTHN a list of stakeholders was derived for a fully working eMeasure process.

eMeasure Stakeholders	
Internal	
	1. Applicant A. Researcher B. Medical staff C. Medical student D. Quality coördinator E. Other staff
	2. eMeasure Analyst
	3. DCM Analyst
	4. Database developer
	5. Domain Expert
	6. Second eMeasure Analyst
External	
	1. External Applicant
	2. HL7 / Nictiz
	3. Patient

All of the stakeholders above have their own goals. Knowing these goals reduces the chance of failure and increases the willingness of the stakeholders to cooperate with the development of the new eMeasure system (Boonstra & Goovers, 2009). Based on the list of stakeholders, an analysis of their goals and critical success factors is carried out, which is described in section 4.2.2.

4.2.2 Analysis

In this section each stakeholder is analyzed. The eMeasure analyst and DCM Analyst are actual end-users of the eMeasure process and therefore used during the development of the process models.

4.2.2.1 External stakeholders

This section describes the analysis of the external stakeholders of the eMeasure process.

External Applicant

External applicants include parties outside the hospital which apply for information. Most of these parties are government subsidiaries or parties tasked with healthcare quality assurance. The applications from these applicants are first processed by a quality coordinator from the hospital; the quality coordinator will then be the applicant in the eMeasure process. Accordingly, these external applications are indirect start events for the eMeasure process. The goals of these applicants are to receive the requested quality information so they can monitor the hospital's performance.

HL7 / Nictiz

HL7 and Nictiz are organizations responsible for standardizing electronic health information. They provide the hospital with the eMeasure and DCM standard. They are not directly involved in the eMeasure process, but are represented by a governance architect or the responsible analyst. Their goal is to improve the communication of electronic health information by standardization.

Patient

At the end the patient is the reason why all these information requests are done. The government to ensure and improve quality, the researcher/student/staff to improve clinical processes and the quality coordinator to ensure the quality provided for a specific department.

4.2.2.2 Internal stakeholders

This section describes the analysis of the internal stakeholders of the eMeasure process.

Applicant

The applicant is the stakeholder that triggers the starting event, hence he is responsible for the initial input. The initial input is always a request for certain information. The applicant is also the end-user of the product generated by the eMeasure process, so the requirements of the applicant need to be taken into account within the steps of the eMeasure process. The goal of the applicant is to receive the information applied for in such a way that it is directly usable in the particular process.

eMeasure analyst

The eMeasure analyst represents the biggest role in the eMeasure process and is responsible for receiving and analyzing the application from the applicant; developing the information product (IP); developing the eMeasure; collecting additional information for development; and delivering the IP to the applicant.

Accordingly, the eMeasure analyst needs to be able to translate the application with a clinical context to an eMeasure which has a more technical context. As the creator of the eMeasure, the eMeasure analyst is also responsible for requesting the DCM attributes needed for the eMeasure. This leads to the fact that the eMeasure analyst is the starting event for the DCM process and responsible for relaying all the information between the applicant and the DCM analyst.

The goal of the eMeasure analyst is delivering an IP that fulfills the information need from the applicant and delivering a reusable eMeasure.

DCM analyst

Since an eMeasure is built from DCMs, the DCM analyst is responsible for delivering the DCMs needed by the eMeasure analyst. This can result in three types of events that need to be performed by the DCM analyst. At first, a complete new DCM needs to be build. Secondly, a new attribute needs to be added to an already existing DCM. Or in the third place, a new value needs to be added to an already existing attribute in an existing DCM. How this process is developed can be found in "Design of the process of developing DCM's with regard to eMeasures" (Beukeboom, 2015).

The goal of the DCM analyst is providing the needed DCM, attributes and values needed for the development of an eMeasure as well as developing a technical and clinical validated DCM that can be reused.

Database developer

The data specialist is responsible for the availability of the data that is needed in the eMeasure. Data can be unavailable for two reasons: the data is not registered at all or the data is registered but not available for usage. The first reason is a long term problem and is outside the scope of this research. The second reason, however, is relatively easy to overcome and results in data that is available for usage in a DCM and eMeasure. Making data available is the only goal of the data analyst within the eMeasure process.

Domain expert

The domain expert is the stakeholder that possesses all the expert knowledge concerning the subject on which an IP or eMeasure is created. In many cases the applicant can be the domain expert, because he or she is the expert on the information needed. The domain expert is involved in the process to ensure the quality on the content related information. Due to the clinical and technical background of an eMeasure and the role the domain expert has in the process, one needs to remember that these experts are non-technical domain experts and can only validate the eMeasure on content. Therefore the only goal the domain expert has, is to ensure the quality of the clinical content of an IP or eMeasure.

Second eMeasure analyst

Due to the limited technical knowledge of the domain expert but the need for validation in the eMeasure process, a second eMeasure analyst is required to validate the eMeasure on all the technical related content. Hence, the goal of the second eMeasure analyst is to ensure the quality of the eMeasures.

Overall goals for healthcare staff

Although the main goal of the eMeasure process is to answer information requests, the reasons for these request can come from general goals of healthcare staff. Dijkstra (2012) has described these goals as follows:

- Reduction of mistakes in healthcare
- Easy transfer and retrieval of patient data
- Improved performance
- Easiness of the system

The eMeasure process should be designed in such a way that it takes all these general goals into account.

4.2.3 Critical Success Factors and business requirements

Based on the goals of the stakeholders, it is possible to define the CSF's. After being defined, the CSF's are translated to business requirements which can be used to develop the eMeasure process.

4.2.3.1 Critical Success Factors

This section describes the critical success factors per stakeholder.

Since the eMeasure process is a process there are two types of CSF's. The first group includes CSF's for the products of the process, the IP's, eMeasures and DCM's. The second group contains CSF's for the process itself. The CSF for the process can also be a derivative from a CSF for the products.

(External) Applicant

- The IP must be within the requirements of the applicant
- The information must be traceable
- The information must be correct
- The process must be transparent

HL7/Nictiz

- The eMeasures need to be in HQMF format
- The DCM's need to be in DCM format

eMeasure analyst

- The application should contain all the needed information

- The needed data must be available for usage
- The needed information has to be unambiguous
- The needed eMeasures must be available
- The needed DCMs/attributes/values should be available
- The eMeasure must be correct on content level
- The eMeasure must be correct on technical level
- The IP has to fulfill the applicants requirements as much as possible
- The eMeasure process must be transparent

DCM analyst

- All the eMeasure analysts requirements need to be known

Data analyst

- The needed data must be registered

Domain expert

- The eMeasure should be correct on content level

Second eMeasure analyst

- The eMeasure has to be correct on technical level
- The applicant requirements must be known

4.2.3.2 Business requirements

In this section all the CSF's are translated to business requirements. This means that the CSF's are rewritten to a manner in which they can be used in the eMeasure process.

As described in section 2.2, there are functional requirements (FR) and non-functional requirements (NFR). The FR's are expressed in "the process shall do [requirement]", while the NFR's are expressed in a "the process shall be [requirement] statement".

(External) Applicant

- The process shall do an IP requirement check
- The process shall be traceable
- The process shall do a content validation
- The process shall be transparent

HL7 / Nictiz

- The process shall do a format check

eMeasure analyst

- The process shall do an application completeness check
- The process shall do a data availability check
- The process shall do an all information understood check
- The process shall do an eMeasure availability check
- The process shall do a DCMs/attributes/value availability check
- The process shall do a content level review
- The process shall do a technical review

DCM analyst

- The process shall communicate all the needed information

Data analyst

- The process shall do a data registered check

Second eMeasure analyst

- The process shall do information forwarding

4.3 Developing the process models

Based on the quality measure workflow, the HQMF format, the workflow of the end-users (analysts) and the business requirements, an eMeasure process model is developed. This section will describe the development process and process model itself. The development process includes the validation process. To illustrate, these process models are one or more aggregations lower than the process model shown in figure 4.1. As a result, this will show the actual process of developing each of the eMeasure process products, IP and eMeasure. The actual process on the creation of DCMs can be found in the thesis of Beukeboom (2015).

In the first section the development of the preliminary process model will be discussed. The second part will focus on the validation of the preliminary process model which ultimately results in the final process model.

4.3.1 Developing the preliminary process models

The process model is developed by using the theory of systems thinking in combination with three out of the five questions from Process-driven Database Design (PDD). The three questions used are:

1. What is the input for the event?
2. What is the output from the event?
3. Which entities are involved in the event as participants?

Question 1 and 2 help the modeler in identifying the order of events. The answers on these questions will give the modeler insight on what the input should be for a certain event and therefore the output of the preceding event. Thus, when an event cannot receive the required input, the order of events needs to be changed or an event should be added. Question 3 helps identifying the participants at each event. As BPMN requires an event to be appointed to one and only one lane, it is important to know which entities participate and who or what is the main participant. Hence, the event can be assigned to the correct lane.

The research objective stated that the model will only contain the eMeasure process. When only one process is translated to a process model, just one pool is needed. Within this pool all internal stakeholders are given a swim lane. At this moment six important stakeholders are known in the eMeasure process: the applicant, eMeasure analyst, DCM analyst, Data analyst, Domain expert and second eMeasure analyst. This results in the following pool layout (figure 4.2).
Since the pool and the lanes are known, a first design of the eMeasure process can be made. This is done based on the quality measure workflow, the HQMF format, the workflow of the end-users (analysts) and the business requirements for an eMeasure process model. For the first model the focus is on the business flow of each individual product, IP, eMeasure and DCM as well as the requirements given by the stakeholders mainly responsible for these products.

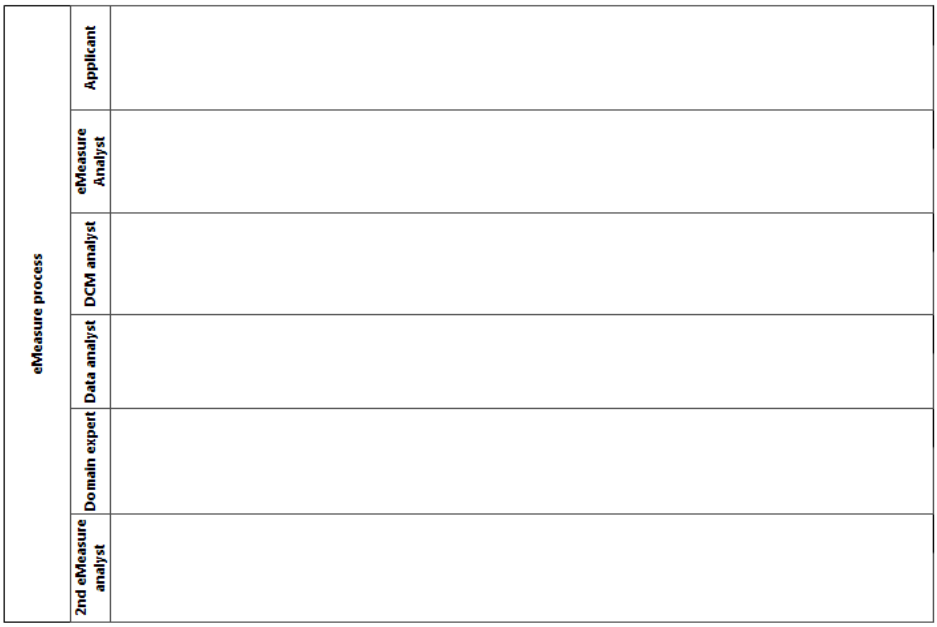


FIGURE 4.2 STAKEHOLDER POOL LAYOUT

The stakeholder's goals, CSF's and business requirements were implemented during the development of the process model. In addition, the process model needs to be developed conform the business requirements; the CSF's are translated to gateway events; and the goals of each stakeholder need to be met at the end of their swim lane and eMeasure process.

Since the focus of the preliminary process model is on the individual products and their stakeholders, these aspects are discussed first with the responsible stakeholders. In this case the stakeholders have a technical background and are capable of understanding the BPMN models.
The feedback received during these discussions were implemented in the process model.
This leads to multiple process models that are specifically made for each product and meet the requirements of the responsible stakeholders.

Because of the multiple product design, the processes need to be merged to deliver one single working IP. When merging the multiple process design, all the goals, CSFs and requirements need to be taken into account. This is done by limiting the need for changes in the models when merging.

Moreover, the merger results in a new overall process design which contains all individual products. This model is then discussed with the interacting stakeholders at the same time and focussing on the relations and information exchange between those stakeholders. During the discussion the three PDD questions were asked for each event that has an input/output from an event belonging to another stakeholder. The answer on question one and two tells which information needs to be transferred between the stakeholders and the third question reveals the initiating stakeholder for a multi-stakeholder event. An example of a multi-stakeholder event can be a discussion between an eMeasure analyst and a DCM analyst about the needed DCM/attribute/value which would be initiated by the DCM analyst when not all the needed information is given by the eMeasure analyst.

After the discussion with all the stakeholders, the preliminary process is redesigned taking all the feedback into account.

4.3.2 Validating the preliminary process models

After designing the preliminary process model, the model is validated. The validation is performed by asking the questions posed in section 3.4.4.

The first validation round is performed by means of an interview with the same stakeholders used in developing the preliminary process model. The particular reason for this is that at the time there were no other stakeholders in the same role available for validation.
Although the same stakeholders were used some valuable feedback was received due to the usage of the questions.
During the the validation it became clear that it is important to really separate the technical and clinical related validation within the process. This means that when a product is near completion, it needs to be send to two different stakeholders. In the first place a stakeholder with a the technical background to validate on the technical level, which is the second eMeasure analyst in this process. In the second place a stakeholder with the clinical/content related background, which is a domain expert in this process.

For efficiency reasons for the eMeasure process the decision has been made that this should be a parallel process.

When the first validation was done and the process was redesigned to implement the received feedback, a second eMeasure analyst became available for validation. As this person was new to the project and did not attend any other meetings nor gave input for the preliminary design, unbiased feedback was received.

The feedback in this validation session limited itself to changes of event names for more clarity.

The final version of the eMeasure process model can be found in appendix B. Additional information about the main process steps can be found in appendix C and a an example of the process going through each process step can be found in appendix D

5 Discussion

In the first part of this chapter the limitations of BPMN will be discussed based on difficulties or impossibilities of modeling certain events. The second part will discuss the research performed at the LTHN.

5.1 Limitations of BPMN

During the development of the eMeasure process two limitations of BPMN were encountered.

First the limitation to model a multi-stakeholder event; an event that has more than one stakeholder. Although this limitation is partially overcome by positioning the event at the initiating stakeholder. When doing so the information on who is participating at those multi-stakeholder event is lost. Making this possible to model in BPMN results in a more transparent and more information rich model.

The second limitation is found when trying to model multiple stakeholders in a sub-process.
As one of the goals of BPMN is communication, a goal for a modeler is to keep the models as easy as possible to read and when needed to go into more detail. This limitations prevent a modeler from creating correct BPMN models when using a sub-process as a black-box process when communicating to a certain audience, but wanting to keep the process in this black-box available for communicating to a more detailed oriented audience.

5.2 Performed research

The performed research in the LTHN will be discussed.

Since eMeasures and DCMs are relatively new and the process for eMeasure development was non- existing, it is hard to identify the correct stakeholders. The choice for using the quality measure workflow only helped identifying potential applicant or domain experts. This can be explained by the base change of the process. Where the quality measure process was build on manual data selection, the eMeasure process has a more query flow/programmable basis. This resulted in a more technical process where the difference between technical and non-technical domain experts increased.

The increase also explained the need for a two type validation. While eMeasures and DCMs are multi-expertise products, they require separate validation for each type of expertise. When this distinction of expertise is not made or underestimated, it can result in a lower quality end product or a not accepted reusable product, which is one of the goals of standardized documents.

The same difference between expertise fields also explained the need for the DCMs. These types of products can improve the communication between two stakeholders with different backgrounds; in this case a technical and a clinical domain expert.

6. Conclusion

The last chapter will present the conclusions of the research project including the limitations and the recommendations for further research.

6.1 Research conclusion

This research was part of a larger 3-part project with the aim of designing a general method for developing eMeasures. This part in particular was responsible for designing and validating the highest two products in the eMeasure process: the information product and the eMeasure itself.

For the development of the process model a process overview was made and a stakeholder analysis was performed. This resulted in specific goals and critical success factors for each stakeholder in the eMeasure process. With the use of three questions of the process-driven database design method and the "Systems Thinking" approach preliminary process design could be made. Since the individual process models had been developed on a detailed level, it became clear that combining these models led to a great need for using sub-processes. The main reasons are keeping the model readable and keeping the multi-product characteristics of the process visible.

It also became clear that in designing a development process, there are two end-users to take into account. Firstly the end-user of the product delivered by the system. Secondly the users or participants in the process itself. Finally, it is important that the needs from both end-users are satisfied.

The validation sessions showed that when working with products which require two types of experts, it is important for the quality of the end product that there are two domain experts for validation within the needed field.

During the last phase of the overall project it was found out that it is important to ask the right questions during the process model development phase, so a correct data model can be build. The results of this phase can be found in the thesis of Martena (2015).

6.2 Limitations of the research

This research is performed in a large teaching hospital in the Netherlands where they just started working on eMeasure and Detailed clinical models. At first this limited the available knowledge on the subject and posed a lot of discussion within the team responsible for using these products. This results in a process that is designed from a clean perspective on the matter, but also limits the design to the knowledge that was available at the time. Since the design is for a process that needs to be used, not implementing it poses a limitation. When the process could really be implemented, other results or feedback could have been found.

6.3 Recommendations for further research

This research delivered the first phase on the design and usage of the eMeasure process. Since this process is still new and more knowledge about eMeasures and DCMs is gained in the coming weeks there could be some minor changes to the process.

Such a need for changes can be found when implementing the designed eMeasure process. Furthermore, with the implementation it becomes more clear how an Information Product can be designed and what the possibilities are for compatibility.

A second recommendation for further research comes from the case when DCMs are more widely available. When these DCM are well designed on technical and clinical level it can give clinical staff the possibility to design their own eMeasure. For now this requires an expert knowledge on the format and technical background of eMeasures. DCM, however, can close the gap between technical and clinical experts.

The last recommendation stems from the fact that technically an eMeasure is a stored query flow. This means that an eMeasure can also be used for non-clinical information. In such a case the focus of the research could be the implementation of an eMeasure in a non-clinical environment.

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Appendix A: Theme poster

Designing E-Measures and Building Blocks for an EHR

Objective: **The goal of this project is to design a quality control system for patient treatments at a Large Teaching Hospital Netherlands**

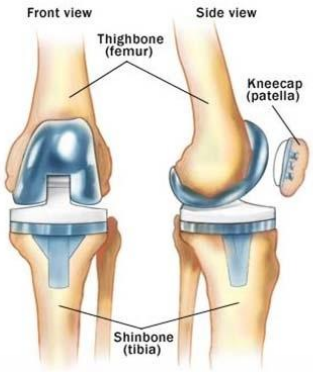
Introduction

- To reduce healthcare expenses, the government and Dutch national hospitals signed a covenant to bundle healthcare systems by building an Electronic Health Record System (EHR)
- Hospitals are building an EHR
- Controlling quality of patient treatments is one of the goals of the EHR
- So-called "Health Indicators" (HI) offer a protocol for quality control after a patient treatment has taken place
- HI-Reports are stored in a Datawarehouse
- Goals are to eventually create an Auditing System

As-is situation

- Word documents describing a HI-protocol
- Building Blocks (DCM= Detailed Clinical Models): reusable and often re-ocurring parts of patient treatments, along with their own (local) HI-protocols
- Examples of using a HI-protocol using existing building blocks

Example: Indicator "Knee Replacement"



Hospital Information

To-be situation

- Design of a validated process model (**query flow**) for HI-protocols
- Such a process model is called an E-Measure

Research Design

Major questions:

- Who are the major stakeholders in an E-Measure system?
- What are their goals and critical success factors?
- What is the state of the art concerning E-Measures and Building Blocks?
- What are the requirements of a reliable and technically feasible design?
- How could we validate the correctness of our design?

E-Measure (Quality control proces):

- Antibiotic profylaxe applied?
- Routine control applied?
- Registration of all relevant data applied?
- Etc.

Building Blocks (reusable parts of the system):

- Patient transfer
- Bloodpressure
- Etc.

Advisor

Dr. Herman Balsters
Associate Professor of Information Systems Design
h.balsters@rug.nl
+31-50-3633923

Student projects 2014-2015

Method: Systems approach

- E-Measurement as a System of Query flow, with input-, transformation-, and output functions
- Black-box approach in systematically building a more detailed system

BPMN

- The system to be designed can be modelled using BPMN
- BPMN is the international de facto standard for process modeling

From BPMN to Data Models

- By systematically extracting required data elements from activities inside the BPMN process models, we can gather tailor-made data for the E-Measure process
- After this extraction phase is completed, we have a complete set of data for the whole E-Measure process: the data model

From BPMN and Data Model to UI mock-ups: validating the end-user

- BPMN models and associated data models offer the ingredients for building UI mock-ups
- These UI mock-ups can be given to the end users to check (validate) that their requiremens have been fully met

From Practice to Science

- Abstract from examples of E-Measures to find the general principles of design of such systems
- Abstract from examples of validation of E-Measures to a general approach to validation of E-Measures

==========

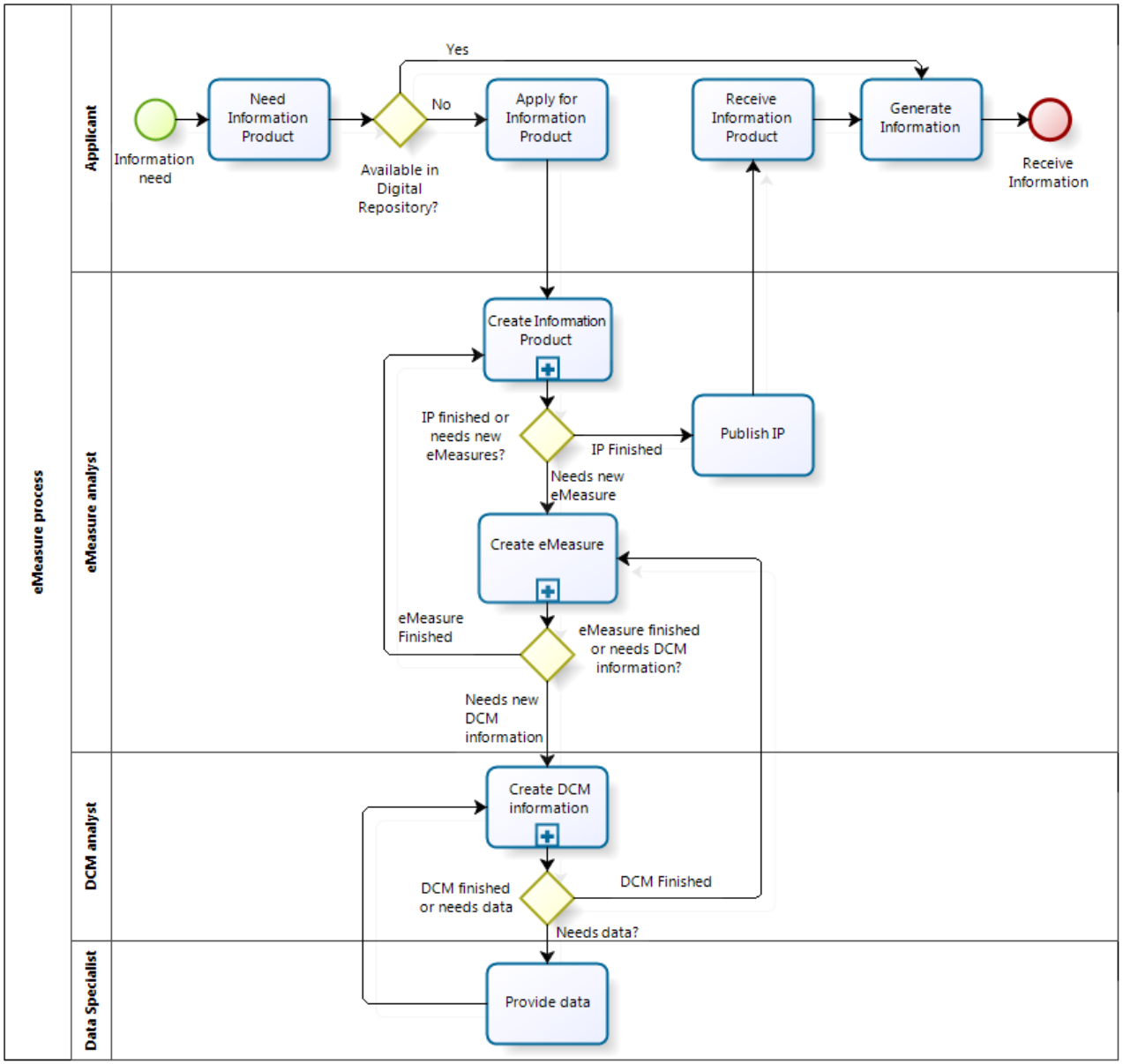
4 students:

- Gather data pertaining to specific E-Measures and Building Blocks, literature research
- Construct process- and data models (query flows) for specific E-Measures
- Validate E-Measures using UI mock-ups
- Translate the practical results into Science: general models and methods

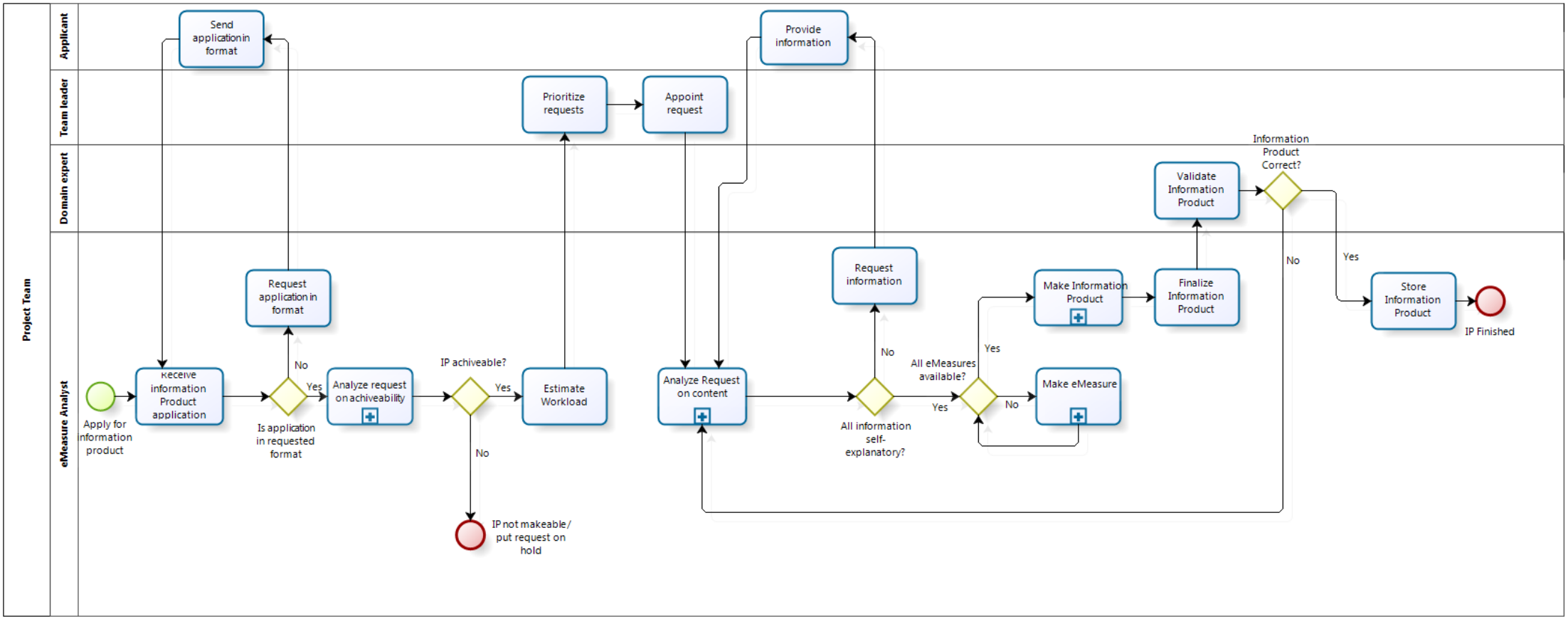
Appendix B: eMeasure process models

This appendix shows the designed process in BPMN models.

Process overview



Create Information Product



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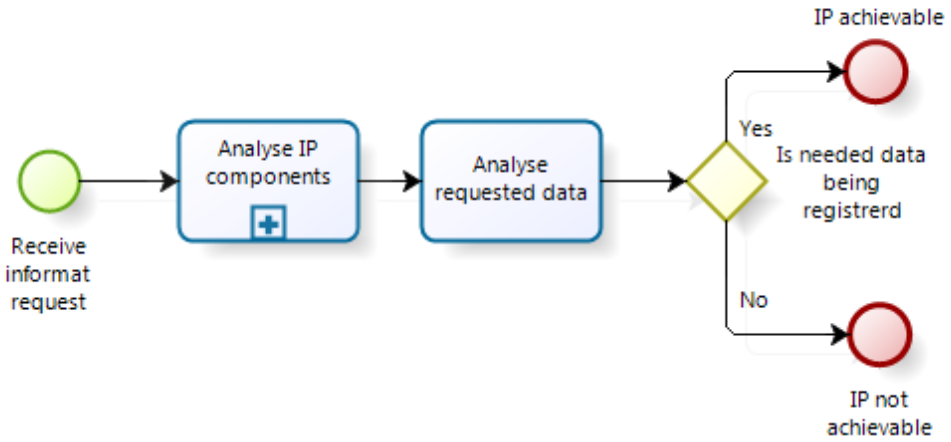
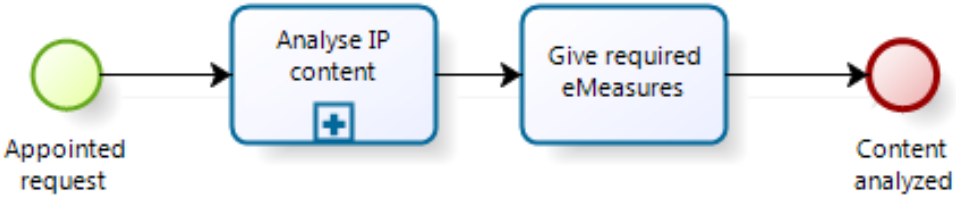
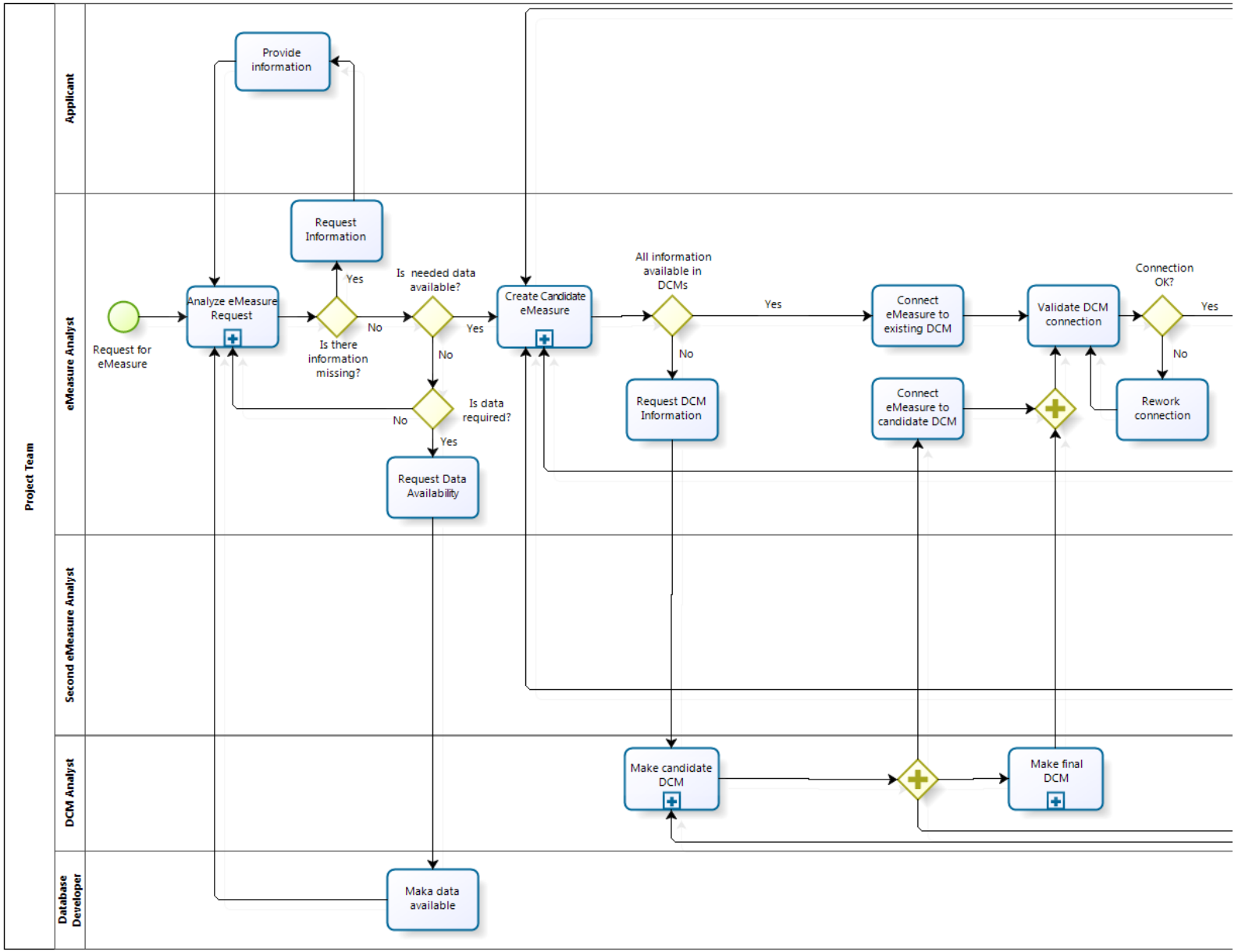
Analyse request on achiveability



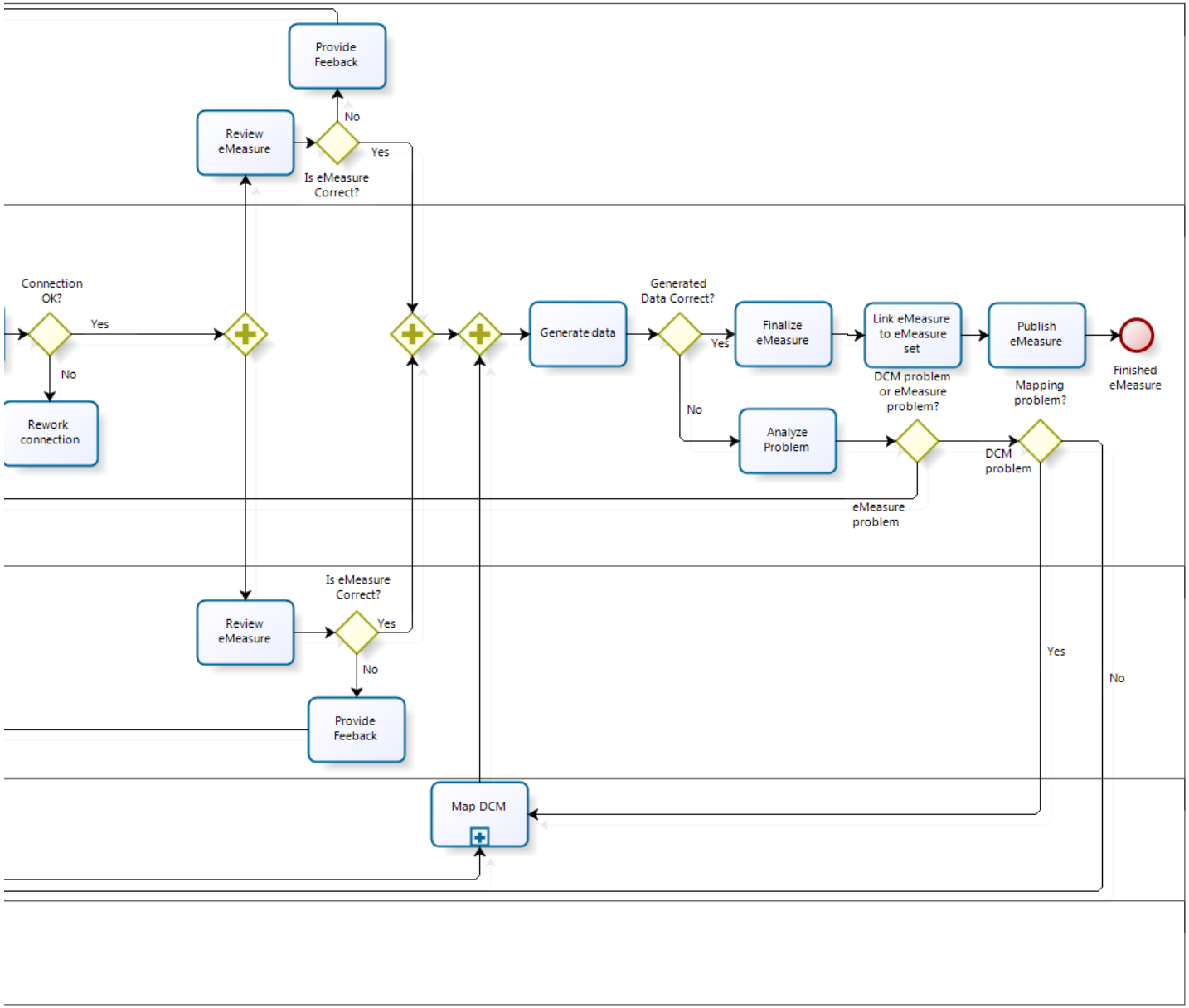
Analyse request on content



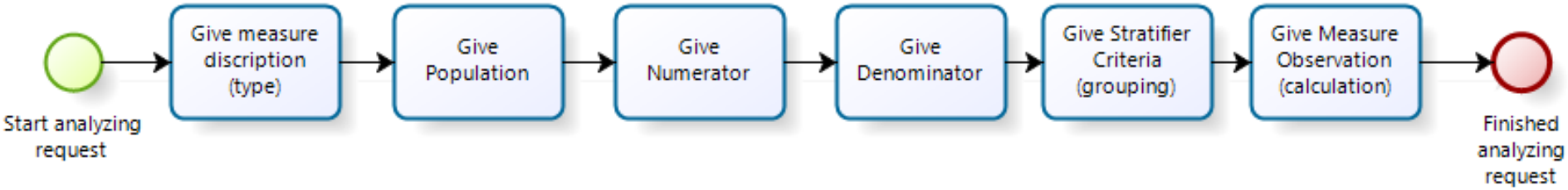
Make eMeasure - part 1



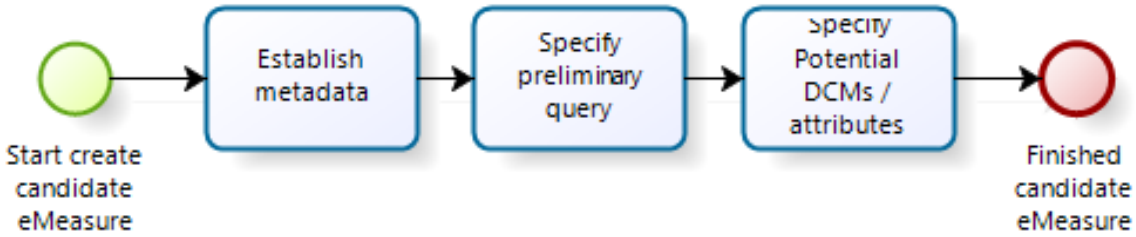
Make eMeasure - part 2



Analyse eMeasure request



Create candidate eMeasure



Appendix C: Event descriptions

In this appendix all activities and gateways from the main process models are briefly explained. Appendix D gives more detailed explanations in combination with an example.

Need Information Product

This activity is the starting event of the entire process and starts with an information need of the applicant.

Available in Digital Repository?

This gateway lets the applicant check in a digital repository if there is already an information product that fulfills their information need

Generate Information

When the IP is available it can be used to provide the needed information

Input: An information need

Output: The needed information

Apply for Information Product

When the IP is not available an application for an IP is sent

Input: An information need where an IP is not available for

Output: An IP application

Receive Information Product

When the IP is finished it is received by the applicant

Input: A published IP

Output: A received IP

Create Information Product

This nested activity creates the IP, the IP is the requested information in the requested format. Examples can be a percentage, a dataset in excel or a dashboard that gives a signal.

Input: An IP application

Output: A finished IP

Receive IP application

The application for an IP is received by the eMeasure analyst

Input: An IP application

Output: A received IP application

Is application in requested format?

This gateway checks if the application is in the requested format; this ensures that the needed basic information is always available on request and that there is a possibility for automatization.

Request application in format

When the application is not in format a request is sent to the applicant to ensure that the application is in format and contains all the preliminary needed information.

Input: an IP application not in format

Output: a request for an IP application in format

Send application in format

A new IP application is sent to the eMeasure analyst

Input: a request for an IP application in format

Output: An IP application

Analyze request on achievability

This nested process checks if an information product is possible to make and what needs to be made

Input: An in format IP application

Output: Information if an IP is makeable

IP achievable?

Is it possible to make the IP within the given criteria

Estimate Workload

Based on the analysis if an IP is makeable it is also known what is already available and what not. Based on this information an estimation of the workload can be made.

Input: Information if in IP is makeable and what needs to be made

Output: a workload estimation

Prioritize request

Based on the urgency for the needed IP and the workload all the requests are prioritized

Input: Information product application and workload estimation

Output: Prioritized IP request

Appoint request

Based on priorities and specialities all the tasks are appointed to the team members

Input: Prioritized IP request

Output: task appointments

Analyze request on content

When the task is appointed, a more detailed analysis on the content of the request is done. Questions like what information is requested, how do they want to receive this information etc.

Input: task appointment and IP application

Output: Request analysis

All information self explanatory?

Check if all the needed information is available and if the given information is understood correctly for further work.

Request Information

If not all the information is within reach or understood a request of the applicant is send for more information

Input: Request analysis

Output: Request for additional information

Provide Information

Give additional information needed for IP development

Input: Request for additional information

Output: Additional information

All eMeasures available?

Check if all the eMeasures needed for this information product are available for use

Make Information Product

When all the needed information is there and all the eMeasure are available the information product can be made.

Input: IP request, eMeasures

Output: Information Product

Finalize Information Product

The last information is added to the IP, this is non-functional information like meta-data, production data, creator etc.

Input: Information Product

Output: Finalized Information Product

Validate Information Product

The information product needs to be validated if it meets the requirements and if the information it provides falls within the expected range. Most of the time the domain expert and the applicant are the same person

Input: Finalized Information Product

Output: Validated Information Product

Information Product Correct?

Check if the IP met all the validation criteria

Store Information Product

When the IP is finished and validated it is stored in a repository

Input: Validated information product

Output: Stored Information Product

Publish Information Product

A message is send to the applicant and possible others that the IP is available for use

Input: Stored Information Product

Output: Published Information Product

Receive Information Product

The information product can be retrieved from the repository

Input: Notification of publication

Output: Received IP

Generate Information

Input: Received IP

Output: Requested Information

Analyze eMeasure request

Is a nested process where is checked if all the needed information for an eMeasure is available. The steps within this process are directly related to the content of the HQMF standard

Input: Request for eMeasure

Output: Analyzed eMeasure request, eMeasure definitions

Is needed data available?

Based on the definitions of the eMeasure, check if all the needed data is available

Is data required?

If data is not available, check if the data is required to provide the needed information

Request Data Availability

If data is not available, send a request to the data specialist to make the data available

Input: a need for data

Output: a request to make data available

Make data available

Make the data available for usage, mostly for DCM usage

Input: a request to make data available

Output: available data

Create Candidate eMeasure

A nested activity that contains all the preliminary steps for an eMeasure

Input: eMeasure definitions

Output: Candidate eMeasure

All information available in DCMs

Check if all the needed information is available in DCM attributes

Request DCM information

Make a request to the DCM analyst to make the needed data available in a DCM

Input: A need for data from a DCM

Output: A request for adding data to a DCM

Connect eMeasure to existing/candidate DCM

Connect the eMeasure definitions to the needed DCMs

Input: Candidate eMeasure

Output: Candidate eMeasure with connected DCMs

Validate DCM connections

Technical validation to check if all the connections are working and provide the needed data

Input: Candidate eMeasure with connected DCMs

Output: Candidate eMeasure validated on DCM connections

Connection OK?

Check if all the connections are OK

Rework connection

When not all the connections are OK the incorrect connections are reworked until they are working

Input: Candidate eMeasure with incorrect DCM connections

Output: Candidate eMeasure with connected DCMs

Review eMeasure

A review on technical or content level

Input: Candidate eMeasure with working DCM connections, request for eMeasure

Output: reviewed candidate eMeasure

Is eMeasure Correct?

Check if during the review no problems were found

Provide feedback

When during the review problems were found feedback is given to the creator of the eMeasure

Input: reviewed candidate eMeasure with problems

Output: Feedback on the problems

Generate data

Generation of data to check if the eMeasure is technically correct

Input: Reviewed candidate eMeasure

Output: Generated data

Generated data correct?

Check if all the needed output is there and if it is within the range of expectations

Analyze Problem

When the generated data is incomplete or not within the range of expectations an analysis is done on what the problem is.

Input: Reviewed candidate eMeasure, generated data

Output: Problem analysis

DCM problem or eMeasure problem?

Is the problem related to the DCM or the eMeasure

Mapping problem?

If it is a problem with the DCM: is it the mapping or something else

Finalize eMeasure

Last information is added to the eMeasure, this is non-functional information like meta-data, production data, creator etc.

Input: reviewed eMeasure

Output: Finalized eMeasure

Link eMeasure to eMeasure set

When an eMeasure is part of a bigger set it needs to be linked to these other eMeasures

Input: finalized eMeasure

Output: eMeasure set

Publish eMeasure

The eMeasure is made available for usage

Input: finalized eMeasure

Output: published eMeasure

Appendix D: Knee-replacement Process Example

In this appendix every step of the process will be explained.

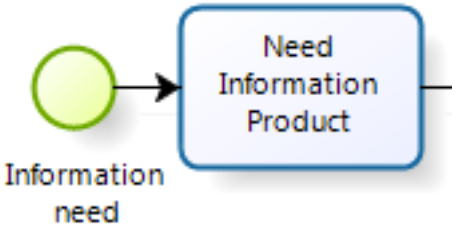
This is done by showing each step of the process in the left column, giving an explanation of the step in the middle column and giving a case example in the right column.

The case used is a request from an organization in the Netherlands that monitors the performance and quality of hospitals. In this case they a request for more information on knee-replacements was sent. For this example only indicator 1 of the entire document is used. The document is in Dutch, because the organization and the receiving LTHN are both situated in the Netherlands.

As this is a request from an external organization it is received by the board of the LTHN. The board sends it to a quality coordinator. This quality coordinator, if necessary, sends it to the quality coordinator of the responsible departments. In this case the surgery department. The quality coordinator of the surgery department will be the applicant because he or she makes the actual request to the process.

Indicator 1: Antibiotische profylaxe	
Relatie met kwaliteit van zorg	Antibiotische profylaxe is bewezen effectief in de preventie van diepe wondinfecties bij plaatsing van een totale knieprothese. Het optreden van diepe wondinfecties wordt mede beïnvloed door aanwezige co-morbiditeit (o.a. hypertensie, diabetes, obesitas). Deze antibiotische profylaxe moet wel op het juiste ogenblik wordt gestart: 60 tot 15 minuten vóór de incisie of vóór het opwekken van bloedleegte kan als het optimale tijdsinterval worden beschouwd. Het percentage wondinfecties dat na opereren optreedt weerspiegelt de kwaliteit van de geboden profylaxe. Overigens moet er rekening mee worden gehouden dat ook patiëntenkenmerken zoals de gezondheidsstatus het optreden van wondinfecties kunnen beïnvloeden.
Operationalisatie 1a	Is er een richtlijn of protocol beschikbaar voor antibiotische profylaxe in geval van een totale knieprothese? *Ja/Nee*
Operationalisatie 1b	Percentage operaties waarbij de patiënt peri-operatief antibiotica toegediend heeft gekregen, in geval van een totale knieprothese.
Teller 1b	Aantal operaties waarbij de patiënt peri-operatief antibiotica toegediend heeft gekregen, in geval van een totale knieprothese
Noemer 1b	Aantal operaties waarbij de patiënt een totale knieprothese heeft ondergaan
Operationalisatie 1c	Percentage operaties waarbij de patiënt 60 tot 15 minuten vóór de incisie of vóór het opwekken van bloedleegte antibiotica toegediend heeft gekregen, in geval van een totale knieprothese.
Teller 1c	Aantal operaties waarbij de patiënt 60 tot 15 minuten vóór de incisie of vóór het opwekken van bloedleegte antibiotica toegediend heeft gekregen, in geval van een totale knieprothese

Noemer 1c	Aantal operaties waarbij de patiënt peri-operatief antibiotica toegediend heeft gekregen, in geval van een totale knieprothese
Operationalisatie 1d	Percentage diepe wondinfecties in geval van een totale knieprothese
Teller 1d	Aantal diepe wondinfecties tot zes weken na de operatie bij patiënten in geval van een totale knieprothese
Noemer 1d	Aantal operaties waarbij de patiënt een totale knieprothese heeft ondergaan
Definities	Peri-operatief: Gedurende de klinische opname De volgende definitie (WIP) van een diepe wondinfectie is van toepassing. De infectie is ontstaan binnen 1 jaar na operatie en de infectie lijkt het gevolg te zijn van de operatie en betreft de diepliggende weefsels van de incisie (zoals fascie en spier) en voldoet bovendien aan één of meer van de volgende bevindingen: 1) Purulente afscheiding uit een diepe incisie maar niet van de organen en anatomische ruimten van het operatiegebied. 2) Spontane wonddehiscentie of wond geopend door de chirurg terwijl de patiënt koorts (>38°C) en/of lokale pijn of gevoeligheid heeft tenzij een wondkweek negatief blijkt. 3) Abces of ander teken van infectie van het gebied van de diepe incisie gezien bij directe observatie, tijdens heroperatie of histopathologisch of radiologisch onderzoek. 4) Diagnose 'diepe infectie van het operatiegebied' door de chirurg of behandelend arts. NB: Infecties die zowel oppervlakkig als diep zijn worden geclassificeerd als diepe postoperatieve infecties van het operatiegebied.
In-/exclusiecriteria	1d: Exclusie: Patiënten met ASA-klasse ³ 3
Bron	1a: Richtlijnen of protocollen 1b: Datamanagementsysteem anesthesiologie, anesthesielijst in patiëntendossier (teller), ZIS, DBC- en verrichtingenregistratie (noemer) 1c: Datamanagementsysteem anesthesiologie, anesthesielijst in



Stakeholder: Applicant

The eMeasure process always starts at the applicant who has a need for certain information.

This need can be a request from an external applicant who wants certain information and where the applicant is responsible for delivering.

It can also be from a researcher or student who needs information for a project.

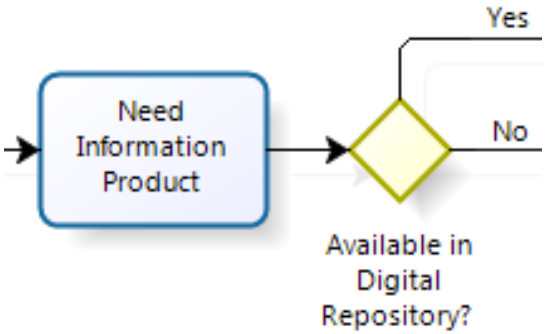
Because there are different types of applicants who need there information for a different reason there are also different types on how they would like to receive their information.

Therefore transforms this need for information to a need for an information product, which is information presented in a certain way.

The example starts when the external applicant „Zichtbare Zorg” makes a request for performance/quality numbers on knee replacements at a LTHN.

This request is received by the person who is responsible for processing these requests at the LTHN and who will be the applicant the eMeasure process.

As this is an external request who only wants performance percentages the information can be presented in a list which shows each percentage per indicator.

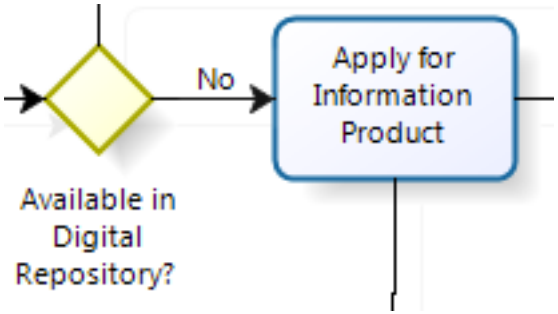
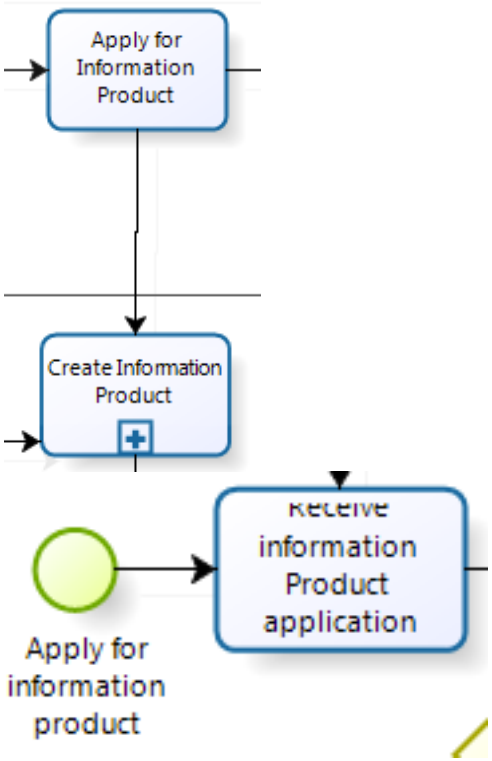


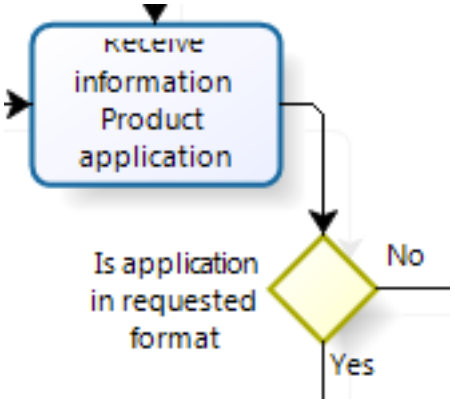
Stakeholder: Applicant

When the applicant knows what information product is needed to fulfill the information need he or she can look through the Digital Repository if there is already an information product that can be used.

This is done to reuse as much as information products as possible. But this also decreases the time it takes for the applicant to fulfill the information need.

All but one of the needed information products are available. Only the information product to answer „Indicator 1” is missing.

BPMN Model	Action Description	Example
 Stakeholder: Applicant	When the information product is not available in the repository the applicant needs to apply for an information product. In this application the applicant will give as much as information as possible that is needed for other steps in the process.	Only the information product for „indicator 1” is missing. The applicant will apply for this information product. This application will state; that only the indicators percentage is needed, the operationalization, the population, the dominator, the numerator and other information thats needed for the information product like background info, the name of the external applicant, evidence base etc etc. This also includes (part of) the original application from „zichtbare zorg”
 Stakeholder: eMeasure Analyst	When an applicant applies for an information product to process of creating this information product is started. The first step in this process is that the eMeasure analyst receives the information product.	All the information stated above is received by the eMeasure analyst.



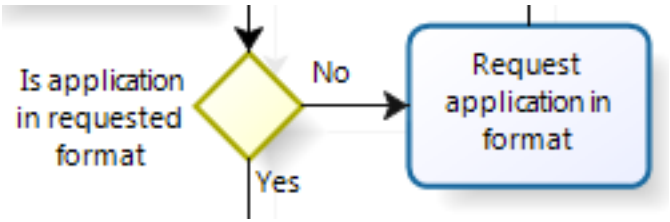
Stakeholder: eMeasure Analyst

Because there are types of information that are always required for creating an information product or an eMeasure the application is in a certain format. In this format all the needed information is mandatory and ensures that most of the required information is known from the start. This also triggers the applicant to think about the information applying for and the way they want to receive it.

The application can be in or not in format. An application is mainly not in format when it is missing one of the parts that is required for an information product or eMeasure.

This step is also important to make it possible to (partially) automate the process.

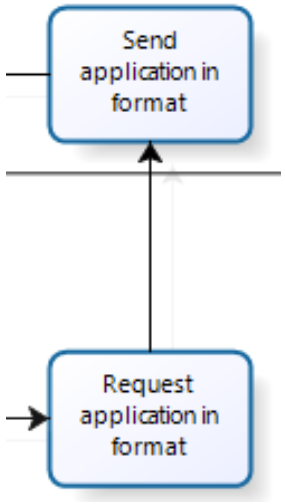
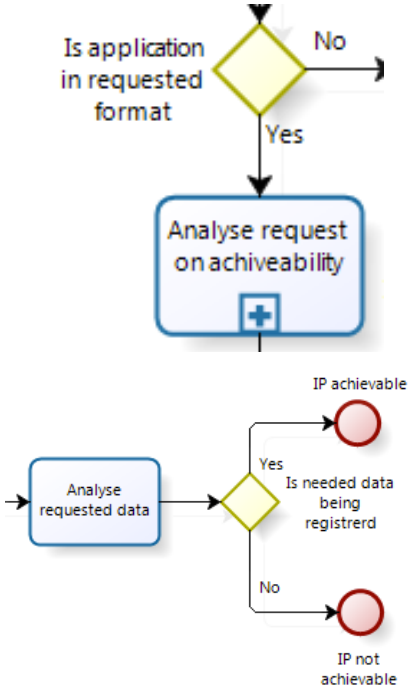
Because the document of „zichtbare zorg" already contains all the needed information for the eMeasure and the applicant stated that only the percentages where needed the application is in format.

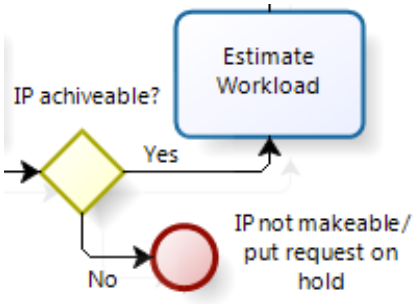
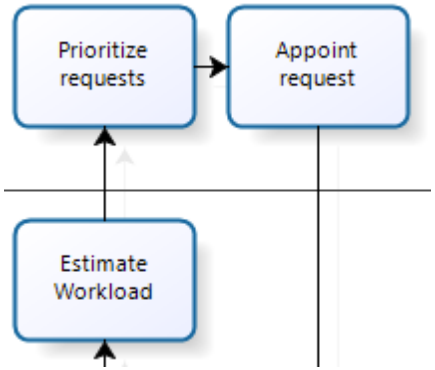


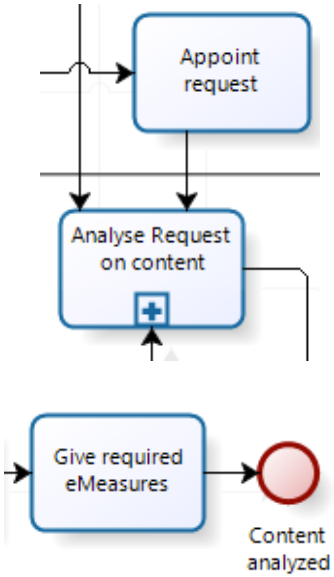
Stakeholder: eMeasure Analyst

When the application is not in format or there is important information missing. A request to send the application in format is send to the applicant that all the needed information is received.

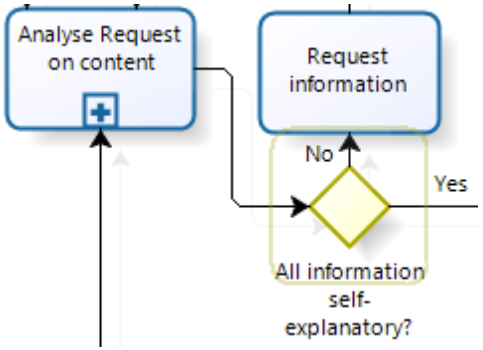
n/a - when for example information about he population was missing the application would have been send back with the request to give this information.

BPMN Model	Action Description	Example
 Stakeholder: Applicant	When a request for an in format application the applicant needs to add or change information on the application en sends it back to the eMeasure analyst. The eMeasure analyst receives the information product application again.	n/a - when the information like the population was missing it will be included and the information product application is send again to the eMeasure analyst.
	When the application is in format an achiveability analysis is done. The most important step of this analysis is to analyze the requested data and check if this data is being registered at the moment. When this is not the case other software and processes need to change and therefore the IP is marked as not achievable (yet). When the data is being registered the IP is marked as achievable. The analysis requires more steps but these are only related to the IP and not the eMeasure and out of scope.	The request is being analyzed and checked if the data for the population, numerator and denominator are all registered. In this case all the requested data is surgery related and saved in the surgery log so the data is being registered.

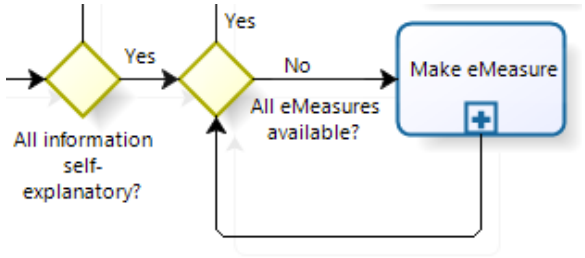
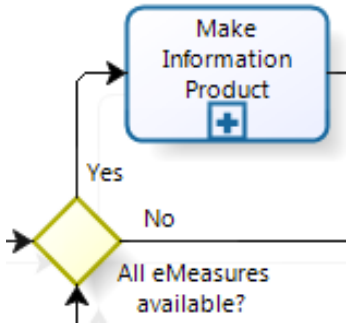
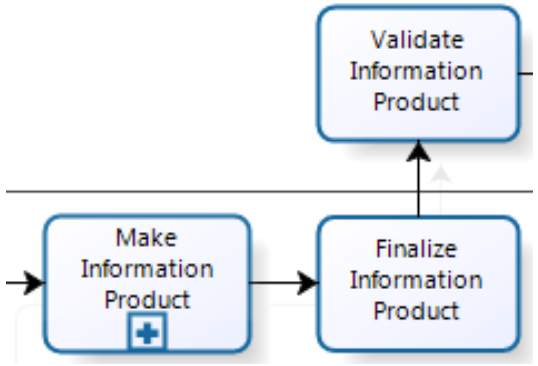
BPMN Model	Action Description	Example
 Stakeholder: eMeasure analyst	When the IP is not achievable the process is stopped. This has to due with the amount of time it takes to make it possible to register certain types of data. When an IP is achievable the workload for the complete process is estimated. The workload depends on if there are similar eMeasures already, or an eMeasure that needs a small adjustment, is there a need for a compleet new DCM or only a new value, etc etc.	The IP is achievable. The workload is estimated only the eMeasure for request 1d is missing and a DCM that includes deep wound infections.
 Stakeholder: Team leader	The estimation of the workload is communicated to the team leader. He prioritizes the requests based on the origin of the request and other additional information. When the request is prioritized it gets appointed to an eMeasure analyst.	Because this requests only needs 1 eMeasure and 1 DCM it has a low workload. Together with that it's a request from „zichtbare zorg" and has a time deadline it gets a high priority and is assigned to an eMeasure analyst.

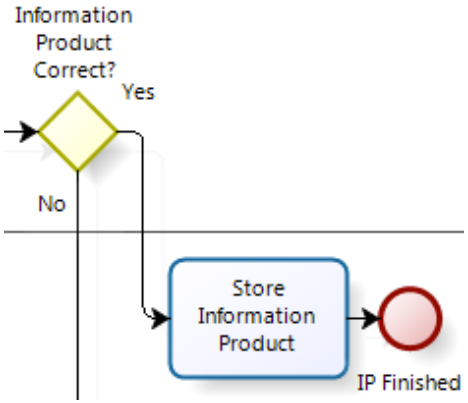
BPMN Model	Action Description	Example
	When the request is appointed it is being analyzed on content. Compered the previous analysis this is a more thorough analysis. During this analysis additional question can arise. During this analysis also the exact required eMeasure are given if they are available. This analysis includes also the only IP related content but is again out of scope.	As found in the workload estimation all but 1 eMeasure are there. eMeasures for a,b and c are available but d is missing. A question that arises is that if all the knee replacements need to be included or that a certain type is not included, otherwise a, b and c need minor adjustments.

Stakeholder: eMeasure Analyst

	When additional questions where found during the analysis a request for additional information is send to the applicant. This request for information and the applicant providing this information can also be an interview or conversation.	The questions about a, b and c are asked to the applicant and showed that all the knee replacements should be included.

Stakeholder: eMeasure analyst

BPMN Model	Action Description	Example
 Stakeholder: eMeasure Analyst	When all the needed information is known a check if all the needed eMeasure are available is done. If not the make eMeasure process is started. This process loops back to the check so that when there are multiple eMeasures missing they are all made.	As already known the eMeasure for d is missing. For this the eMeasure process is started. See page XXVII
 Stakeholder: eMeasure Analyst	When all the eMeasure are available the Information product is made. This can be the creation of a tool, web interface or document. The creation of this product has many options that is an entire other process and is outside the scope of this research.	As the eMeasure for d is now available the information product can be made. In this case a document that includes all the requested percentages generated by the eMeasures.
 Stakeholder: eMeasure Analyst and Domain Expert	When the information product is finished it needs to be finalized. This includes adding the last information like date of creation, creator, applicant etc etc. When the information product is finalized it is send to a domain expert. In most cases this will be the applicant. the domain expert will check if the information product is correct. Examples of things to check are; the correct eMeasures used, the correct measure period.	The information product is finished, the date of creation and the name of the eMeasure analyst are added also the name of „zichtbare zorg” is added as they are the external applicant. After this the information product is send to the quality assurer of the surgery department, the domain expert, for validation of this information product.



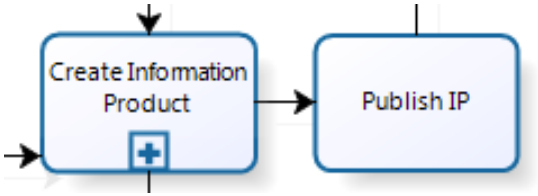
Stakeholder: Domain expert and eMeasure Analyst

The domain expert can say that the information is correct or incorrect.

When the information is incorrect it is send back to the step analyze request on content to ensure that all the steps of creation of the information product are retraced.

When the information product is found correct it is stored in a digital repository.

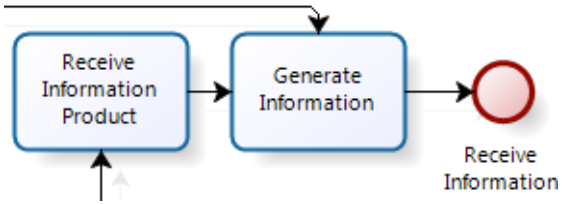
The head of surgery found the information product correct and the eMeasure analyst has stored it in the digital repository.



Stakeholder: eMeasure Analyst

When the information product is stored in the digital repository it is published. This means that a message to the applicant and possible others is send that the information product is ready for usage.

A message is send to the applicant that the IP is finished and ready to use.



Stakeholder: Applicant

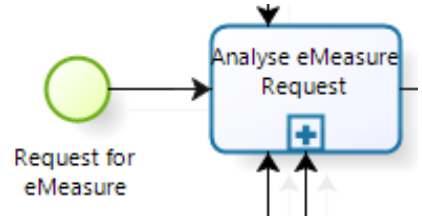
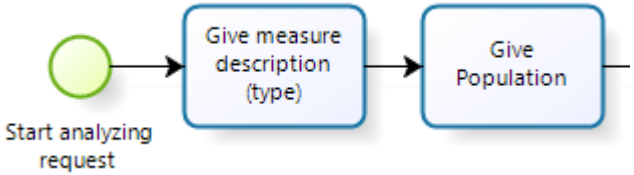
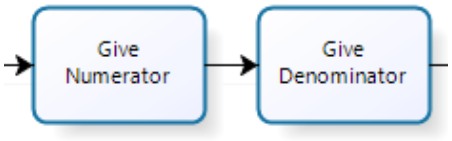
The message that the Information products is ready is received by the applicant.

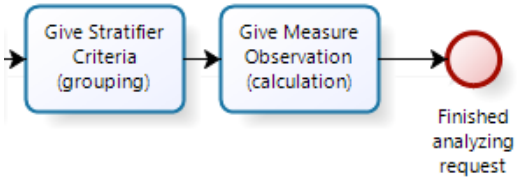
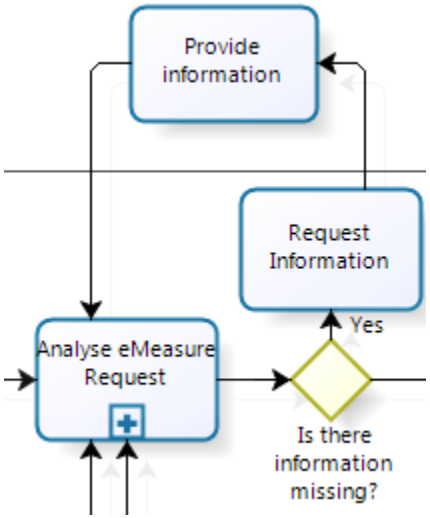
When the information product is a tool that needs to be started or a document that needs to be printed this is done by generating the information.

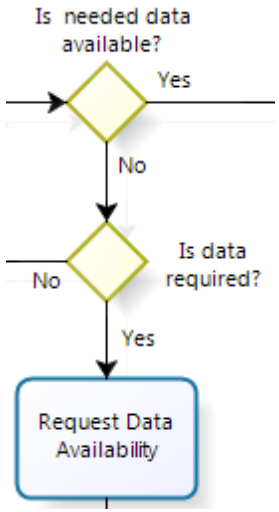
After this the requested information has been received by the applicant and the information need has been filled.

The email that the information product is ready is received. The applicant looks up the information product in the repository and prints the needed documents.

He uses the numbers on these documents to answer the requested data from „zichtbare zorg”

BPMN Model	Action Description	Example
 Stakeholder: eMeasure Analyst	The development of an eMeasure starts with a request for an eMeasure. This request comes from the information product process. See page XXV The request is Analyzed. This analysis only focuses on the attributes that are needed for an eMeasure.	As indicated the eMeasure for d is missing. The eMeasure for indicator d is requested and the request will be analyzed.
 Stakeholder: eMeasure Analyst	The analysis starts with an eMeasure description. This description contains a more detailed or more embellished description of the eMeasure. It also describes the type of eMeasure; indicator, dataset. Second the population is given. This is done by giving the criteria that identify the initial group of patients for the eMeasure.	Description: Percentage deep wound infections within 6 weeks after a total knee replacement. Type: Indicator (single number/ percentage) Population: Patients that had a total knee replacement surgery
 Stakeholder: eMeasure Analyst	The numerator and denominator are based on the population with, if needed, extra selection criteria. These are the actual groups that are used for the calculation.	Numerator: Population with extra criteria; patients that came back within 6 weeks and had a deep wound infection at their knee. Denominator: same as population

BPMN Model	Action Description	Example
 Stakeholder: eMeasure Analyst	The stratifier criteria are optional grouping criteria and can be used to group results in for example men/women or age. The measure observation are the optional calculations that need to be done with the results from the selection criteria from the population, numerator and denominator.	Stratifier criteria: none as there is no grouping. Observation: the fraction numerator / denominator = indicator
 Stakeholder: eMeasure Analyst and applicant	When not all the steps in the analysis can be answered or there is information missing a request is send to the applicant for more information. The applicant provides this information and is analyzed to see if all the steps can be answered.	All the information is provided in the document so there is no information missing.

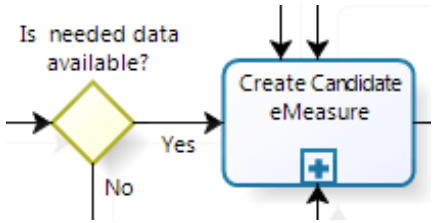


Stakeholder: eMeasure Analyst

When all the needed information is available a check is done if all the needed data is available. Compared to the previous check in the information product process is that this check is on availability which can be resolved in a shorter timeframe.

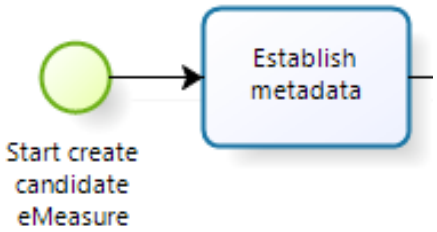
When the data is not available a check if the data is needed is done. When the data is not needed the process go's back to the analyze eMeasure request. When the data is needed the data is requested from the database developer. Who makes it available for usage.

In this thesis is assumed that when data is not available it will become available.



Stakeholder: eMeasure Analyst

When all the data is available the candidate eMeasure can be developed.

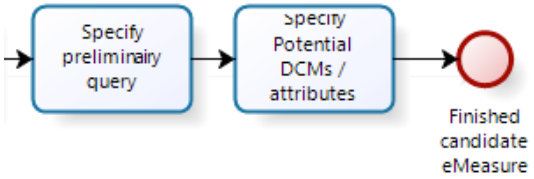
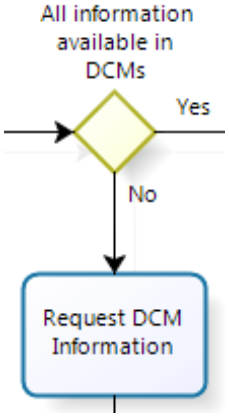
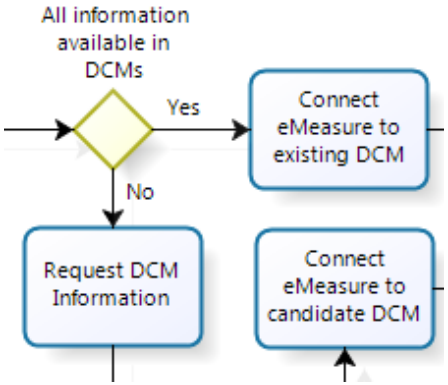


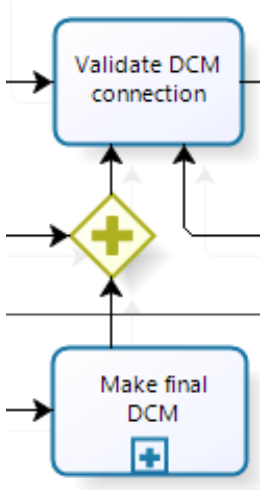
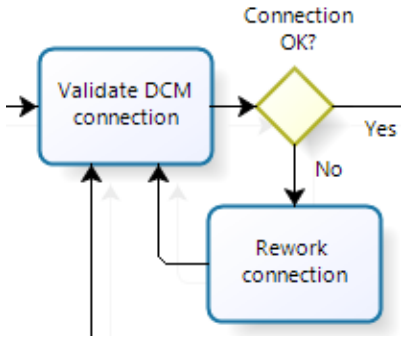
Stakeholder: eMeasure Analyst

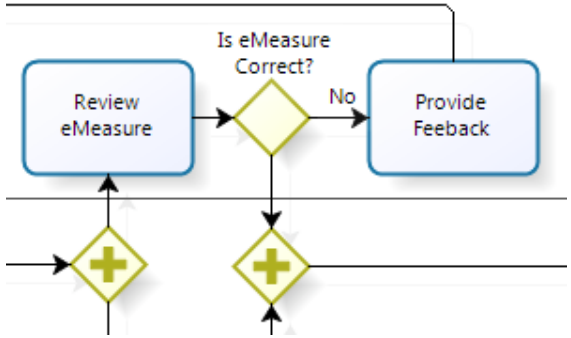
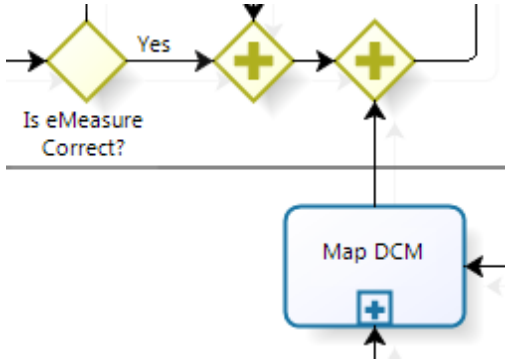
The create candidate eMeasure process starts with establishing the metadata. In this step non-functional information is given. Information like date of creation, name of creator, name of domain expert etc. etc. But also the additional information about the requested variables.

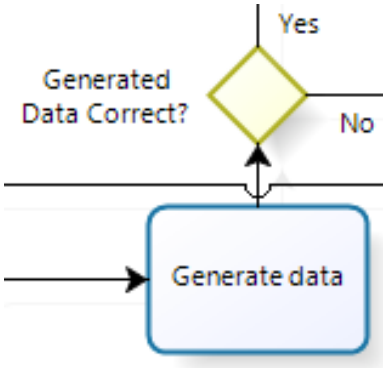
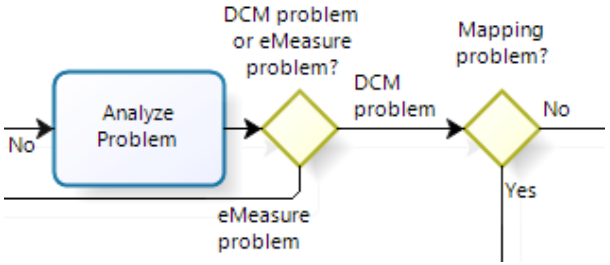
The meta data is established, date of creation 26-01-2015, name of creator; P. vd Laar, name of domain expert; Expert a.

Additional information; see „Definities" in the request document.

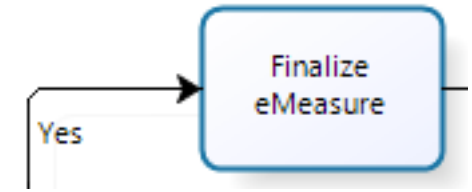
BPMN Model	Action Description	Example
 Stakeholder: eMeasure Analyst	The preliminary query is specified. With this query also the DCMs/attributes/ values that can be used are given.	Query numerator: select all patients that had a total knee replacement and select all patients that had a deep wound infection at their knee, join these two selections for patients that came back within 6 weeks after their total knee replacement. Query denominator: select all patients that had a total knee replacement
 Stakeholder: eMeasure Analyst	When potential DCM/attributes/values are defined it is checked if these are available. When this is not the case they will be requested. This request can results in a request for a complete new DCM, a request for a new attribute in a existing DCM or a new value in an existing attribute in an existing DCM. How these requests are handled and the DCM/attributes/values are created can be red in the thesis of R. Beukeboom (2015)	Potential DCMs/attributes: DCM Patient (attribute; patient number), DCM Operation (attribute; type operation (value; total knee replacement), date operation), DCM Infection (attribute; type infection (value; deep wound infection), date infection) Only the DCM for infections is missing. This DCM is requested from the DCM analyst. How this request is handled and the DCM/attributes/values are created can be red in the thesis of R.Beukeboom (2015)
 Stakeholder: eMeasure Analyst	The next step is connecting the eMeasure to the needed DCMs. This is the case when the DCM/attribute/value where available but also when they were not. Connecting the eMeasure to the DCMs is an important step because the DCMs deliver the ideal data needed by the eMeasure.	Connecting the eMeasure to the DCM/ attribute/value is done in the eMeasure. How and where this is done in the eMeasure is not yet known due to the newness of the combination of eMeasures and DCMs.

BPMN Model	Action Description	Example
 Stakeholder: eMeasure Analyst	When the eMeasure is connected to existing DCMs the connections can be validated. When one of the the DCMs is new or needed a new attribute or value the eMeasure analyst needs to wait for a final DCM before the validation of the connections can start. This is because between the candidate DCM and the final DCM the name of the DCM/attribute/value can change due to clinical domain expert input. The validation of the connections is a technical validation and can be done by the eMeasure analyst.	When the infection DCM is finished all the connections can be validated. During the validation the focus will be on the connections to the new infection DCM to ensure that all the names are still the same. Also the the connections to the exciting DCM are checked if they work properly.
 Stakeholder: eMeasure Analyst	When the connection are not OK they need to be reworked and validated again until they are found OK.	As the connections were correct no rework needed to be done.

BPMN Model	Action Description	Example
 Stakeholder: Applicant and second eMeasure analyst	When the connections are OK they are send for review. This review is done by two stakeholders at the same time. 1. The applicant as the expert on the information needed and to check if the created eMeasure can answers that question, this validation is in most cases on a clinical level. 2. A second eMeasure analyst, to check if the eMeasure is build correctly, this validation is a technical validation. When something is not correct they will provide feedback and the process returns to the create candidate eMeasure.	The eMeasure is send to the quality coordinator of the surgery department as he is the applicant/domain expert on the subject of the eMeasure. The quality coordinator will perform the clinical validation. The eMeasure is also send to a second eMeasure analyst for review. This analyst will check the eMeasure on the technical aspects. As if the query is written correctly, all the attributes of the eMeasure are filled out etc. Both these reviews showed that the eMeasure was correct.
 Stakeholder: eMeasure Analyst	When both reviews or correct, the process needs to wait until the mapping of the DCMs is done. The mapping is the connection from the DCM to the database, a more detailed explanation can be found in the thesis of R. Beukeboom (2015).	DCM Mapping is done.

BPMN Model	Action Description	Example
 Stakeholder: eMeasure Analyst	When the reviews and the mapping is done the eMeasure will be tested by using it to generate the requested data. This test will check if the entire process from the eMeasure query through the DCM to the data and back is working correctly and if the eMeasure generates output.	The data is generated. The eMeasure created output of 89% and falls within a plausible percentage range of 80 an 90% provided by the applicant. The generated data is assumed to be correct.
 Stakeholder: eMeasure Analyst	When during the generation of data something goes wrong the problems is analyzed. The problem can be with the eMeasure or DCM. When it is with the eMeasure the process goes back to create candidate eMeasure to ensure the entire process is followed again. When it is the DCM it can be with the mapping or something with the DCM itself. When it is the mapping it is send back to the Map DCM process and otherwise to the make candidate DCM process, in both cases back to the DCM analyst.	As the data was within the expected range no problem analysis is done.

BPMN Model



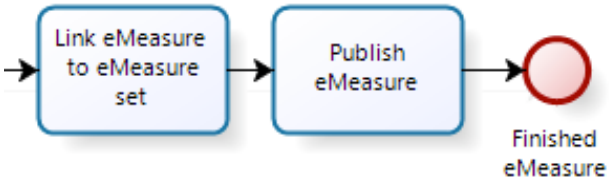
Stakeholder: eMeasure Analyst

Action Description

When the generated data seems correct the eMeasure is finalized. In this step the last details are added, like date of completion, the experts used for review.

Example

The date of completion is 26-01-2015, the experts used are, the applicant for clinical validation and a second eMeasure analyst for technical validation.



Stakeholder: eMeasure Analyst

When the eMeasure is comparable to other eMeasure or is used in a same category it can be linked to an eMeasure set.

The last step is publishing the eMeasure. This means that the eMeasure is fully validated and completed and can be used in information products or at other care providers.

After this the make eMeasure process is finished. The process continues in the Information product process at page XXV.

As this is an eMeasure to measure surgery quality it is added to the surgery set. Because the requests from „zichtbare zorg" are an annually request the eMeasure is also added to the „zichtbare zorg" set so the can be reused next year.

The eMeasure is published to a digital repository.