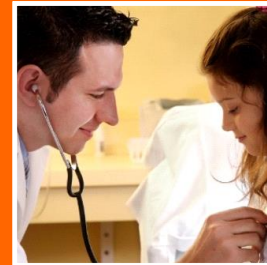# Building an information product for cycle time analysis

Developing process models for the head & neck oncology clinical pathway

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Groningen, Juni 2015

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Trefw: BPMN, Process Modelling, Stakeholder Analysis, Design Science, Regulative Cycle, Van de Laar.

Voorwoord

While conducting this Master Thesis we received help from various persons, in this section I would like to thank these persons.

During our stay at the Large Teaching Hospital in The Netherlands (LTHN) we received some great support from the staff. Not just in terms of actual support in answering our questions, but also in facilitating the project. This allowed us to actually conduct our research, and work on it fulltime.

Also the supervisors from the LTHN that guided us during the project deserve a special note. By always being willing to answer our questions and help out when needed, they supported us in a great way. I would like to thank Dr. H. Balsters for the overall guidance during this research. He provided us with all the necessary knowledge to actually model the processes and data structures. Without his guidance this research would not have been possible .

Lastly, my fellow two students N. Schriever and R. Lichtenberg helped out a lot when conducting this research. The daily discussions and talks about the subject helped me to get a better understanding of the problem.

INHOUDSOPGAVE

SAMENVATTING

Governmental regulations require from hospitals to comply with certain cycle times for patients. Measuring this cycle time and complying with this information request proves to be hard for certain hospitals. An inconsistent way of storing data and ad hoc ways of process modelling adds to this problem. This overarching research project takes place at a Large Teaching Hospital in The Netherlands (LTHN). By analyzing the oncology clinical pathway, and designing the data model blueprints, this research tries to provide a consistent way of answering the data requests from the government. This is done in three different research projects. The first research project analyzes the current oncology clinical pathway and designs the process in BPMN. The second research project translates this BPMN process to an ORM model to encapsulate the data requirements to generate patient cycle times. The last research project validates the research and designs forms for the actual end-user to serve as an input for the data request. The focus of this thesis is on analyzing the current oncology clinical pathway and designing the process in BPMN.

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1. INTRODUCTION

A globally growing population is pressing healthcare to its limits. Not just the population is growing; also the average age is increasing. According to the Central Bureau of Statistics in the Netherlands, it is expected that there will be an increase of elderly people (65 years and older) of 27% in 2012 to 51% in 2040. Putting a huge strain on the national healthcare system. Healthcare is one of the biggest cost drivers of the national budget in The Netherlands. For 2014 it is already mounting up to 30% of the total expenditures. It does not take an expert to see that this amount will further increase over the following years.

To reduce healthcare expenses, the government and different hospitals agreed to participate in a project to bundle healthcare information systems (HIS). Bundling these HIS is not an easy objective. Multiple stakeholders require different features of such an HIS. One of the main objectives is to transfer information about the specific patient, to different hospitals once he gets referred. Not only is this integration hard, the system also has to deal with very privacy sensitive medical patient data.

Not only from a cost perspective, but also from a quality of care perspective, this growing strain on the healthcare system is becoming a problem. Often national inspection services will request specific data concerning clinical pathways. Currently, giving a consistent answer to these kinds of questions proves to be hard. The lack of an integrated HIS makes it hard to gather all the required information about the specific clinical pathway, or even the specific patients. This leads to misinterpretation of data, tasks being performed multiple times, and in general inefficient ways of operating.

One of the organizations that set the standards in health care operations for clinical pathways is "Stichting Oncologische Samenwerking" (SONCOS). SONCOS recently developed new health care operations standards that have to be met by the Large Teaching Hospital in The Netherlands (LTHN) were this research takes place in. From what have been mentioned above, meeting these require

ments proves to be hard. From these examples, it can be understood that the as-in situation is undesired. The discrepancy between the current as-in and the desired to-be situation is an example of a Design Science Problem (Wieringa, 2013). Design science follows the logic of the regulative cycle that was developed by van Strien in 1997.

A means to meet these new SONCOS regulations is an Electronic Health Record (EHR). The main benefit of using an EHR over, what is currently being done is the integration of data. Alongside this centralized data storage, multiple users can use the EHR; it helps with request examinations, decision-making support and shows warnings (Michel-Verkerke, 2003). The EHR database needs a Detailed Clinical Model (DCM) and eMeasures. (Martena, 2015)

In order to design an integrated EHR, the exchange of information must first be understood as a process. This is one of the critical steps before the design of an EHR can take place. The process model allows for an understanding of the patients that are receiving care, data flows and the involved participants. This process model, or conceptual blueprint,

offers the backbone of the EHR. Based on this process model, the construction of an EHR system should become obtainable. This brings us to the aim of this research project.

This research project takes place within a LTHN. The scope of this research is limited to the head and neck oncology clinical pathway. Within this research project an analysis of the head and neck oncology clinical pathway will be made. A brief overview of the process is mapped in figure 1.1. T represents the time in terms of days. These days are the maximum amount of days a patient can spent in a certain part of the process according to the SONCOS regulations. The focus of this research is between the first polyclinic visit (T+7) and the patient is diagnosed at LTHN (T+28) (SONCOS, 2015) As can be seen, the maximum amount of time the patient can spent in this part of the process is three weeks.
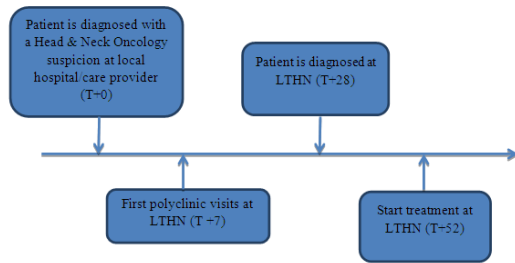
This research tries to provide the DCM's, eMeasures and blueprints for the EHR. It does so by using the regulative cycle of van Strien (1997). One can imagine this is a daunting task to perform individually. Therefor this thesis is part of a bigger research project, in total consisting of three parts. The main goal of the overarching research project can be formulated as: "In the context of the clinical pathway Head and Neck Oncology at the LTHN, we design an information product to attain cycle time analysis of that clinical pathway". The second part of this research project, performed by Schriever (2015), aims at translating BPMN models to ORM models and creating a database blueprint for the EHR. The final part aims to generate forms based on the ORM models and validate the entire research project. This is done by Lichtenberg (2015).

This thesis, the first part in the research project, focuses on understanding the process. The Head & Neck Oncology clinical pathway will be modelled in BPMN to understand the patient and data flows to form the backbone of the EHR. The main means of doing this research will be by conducting interviews and process modelling. Both of which will be more thoroughly elaborated upon in the methodology and theoretical background section.

Based on the above, the following research question for this thesis has been formulated:

"What does the process of the head & neck oncology clinical pathway look like, and how can this be modeled to form the backbone for the EHR?"

Also two sub questions have been formulated:

"Who are the main stakeholders in the clinical pathway?"

"What are the Goals and Critical Success Factors of each stakeholder?"

Now that the scope and context have been stated, the academic relevance of this research project will be elaborated upon. As will

be explained more extensively in the methodology and theoretical background section, this thesis uses the regulative cycle and prior conducted research as a basis for this research. The first addition to the body of knowledge is in the form of using the research methods that have been developed in a prior research project. Van de Laar (2015) developed a method to model business processes by using BPMN. This model currently has not been validated yet and has only been applied in a single context. By using his method and testing the robustness (Krätschmer et al. 2014) of it, in another context then it initially was developed for, we hope to generalize the model and make it applicable for other fields of interest as well. Also some additions or modifications to the model that might occur during the conduction of this research will be presented to further improve the method. The second addition is made by using the regulative cycle of Van Strien (1997). The regulative cycle by Van Strien (1997) is used to solve design science problems. Design science is still a young field of research and has recently been receiving more interest (Denyer et al. 2008). By using the regulative cycle in this context, an assessment can be made whether the regulative cycle fits this type of research. Another contribution to the existing body of knowledge comes from the emerging awareness that Healthcare Information Technology (HIT) will take an important place in the near future (Cresswell, 2015). This overarching research project might allow for the development of a validated method to translate business processes to data processes. Especially for the healthcare sector, that seems to be lacking behind in terms of data integration, this could be beneficial. A final argument could be made for a societal benefit by conducting this thesis. Eventually patients benefit from having a shorter cycle time and receiving their diagnosis and treatment as soon as possible. By developing a system that can track cycle times, an analysis can be made. Process improvements based on critical path and bottleneck analyses could reduce cycle times and shorten the time patients have to wait to receive their diagnosis and treatment.

The remainder of this thesis is structured as followed. Section 2 will elaborate on the methodology. Section 3 will explain the theoretical background. Section 4 will highlight the key findings in the results sections. The discussion can be found in section 5. Lastly the conclusion is presented in section 6. A last remark with regard to the Appendices has to be made. Quite a bit of models have been developed during the conduction of the research. These models and their corresponding explanations have been added in the appendices. The reader is kindly advised to visit the ac-

companying appendices to fully understand
the line of reasoning of this thesis.

2. METHODOLOGY

Now that the context and the scope of this thesis have been presented, the details on how this research will be conducted will be elaborated upon. First an explanation of what design science is will be made. This is followed by how to solve a type II problem and lastly the regulative cycle, on which this entire research project relies heavily, will be addressed.

2.1 DESIGN SCIENCE

Before starting to conduct this research, it is important to note what kind of research we are dealing with. Within this thesis Design Science has a prominent place. The following section will elaborate on the fundamentals of Design Science. Also the framework on how to conduct a Design Science research project will be presented.

First of all it is important to make a distinction between pure knowledge problems and practical knowledge problems. Wieringa (2007) defines a pure-knowledge problem as: "A

knowledge problem is a difference between what stakeholders know about the world, and what they would like to know". An example of a pure-knowledge problem that a stakeholder might have is: what new innovations are coming into the market soon? And what makes these products or services innovative. The stakeholder has no knowledge about the specifics and would like to know it. This is also referred to as a "pure-knowledge-Δ (Delta)". A practical knowledge problem however is defined by Wieringa (2007) as: "A practical problem is a difference between the way stakeholders experience the world and the way they would like to experience it." It is crucial to note that stakeholders with practical problems want to change the world. This is also referred to as a "practical-knowledge Δ". An example of this would be to build an EHR system satisfying the needs of doctors and patients in the current world (Balsters, 2014a). The main difference between pure-knowledge problems and practical knowledge problems lies within the way they are answered. Pure knowledge problems are judged by only one criterion. Either: is it true, or is it false. The answer to a practical

knowledge problem is answered by: Is it useful or is it useless? Practical-knowledge problems can be considered as an instrument in reaching a goal (Balsters, 2015). However the explicit distinction between these two types of problems, they are not considered in a vacuum of each other. To answer a practical knowledge problem, often first a pure knowledge problem has to be answered.

To solve a design problem the solver needs to follow a four step approach. This approach is relevant to describe because it shows how pure-knowledge problems and practical-knowledge problems are related with each other via sub-problems

The first step is to investigate the problem. This is by means of investigating who the stakeholders are, what their goals are and finally which success criteria apply to these goals. These steps are all pure knowledge problems. Secondly a diagnostic question has to be made. The main purposes of these questions are to highlight what enables the current failure of the desired success. After this second step a possible solution can be proposed. Lastly the solutions have to be validated. Does

this proposed solution meet the success-criteria? (Balsters, 2014a)

An important remark to make with regard to design science is the distinction between Functional Critical Success Factors (CSF) and Non-Functional CSF. Functional CSF explains what the system shall do. Whereas Non-Functional CSF explains what the system shall be. (Balsters, 2015) Again an example relating to the EHR would be; The EHR shall exchange data between different departments of the hospital. The EHR shall be fast, easy to use and useful. This distinction between the different CFS's will be used to map the main differences for the various stakeholders within the EHR. One can imagine that these CSF for the different stakeholder might vary quite a bit. So this seems like a logical way to map these differences.

Lastly there are two kinds of problems within design science: type I and type II problems (Balsters, 2015). Type I problems aim to improve an existing context which leads to new theory. Whereas type II problems mainly focuses on the experimentation of building systems, and validate design principles with the end users or experts in the field (Balsters,

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2015). When relating these two types of problems back to the research questions, we can now understand that we have to deal with a type II problem. Experiments in building a particular information system (IS) lead to validated design principles for building an IS.

The structure of the paper follows the structure of a report on design science. This structure is guided by answering the following nine questions (Balsters, 2015):

- Is this research about a design problem, or a pure-knowledge problem?

- Is it design research of type I, or type II?

- Which phases of the design cycle are we involved in?

- Have we covered each of these phases in sufficient detail?

- Have all of the phase-expansions been addressed?

- Have we validated our design solution properly?

- Have we looked at performance issues?

- Have we looked at trade-off situations?

- Have we looked at scalability issues?

Now that the reason why design science is being used has been explained, the regulative cycle will next be elaborated upon.

2.2 REGULATIVE CYCLE

Within this section, the Regulative Cycle on which this entire research project relies heavily will be explained. First an explanation of the Regulative Cycle will be presented. This is followed by an explanation on how it will be used within this thesis and the overarching research project.

Design science emphasizes the connection between knowledge and practice by showing that we can produce scientific knowledge by designing useful things (Wieringa, 2009). This is a useful standpoint to start from. When confronted with practical problems, science often offers useful solutions. However, the reverse

also appears to be true. Practical problems can add to scientific knowledge as long as they are embedded within a sound methodological framework (Wieringa, 2010). A framework that supports these kinds of research types was first developed by van Strien (1997). The yawning gap between theory and practice sparked the desire to develop an approach towards practice which is both scientific and realistic (Van Strien, 1997). In the regulative cycle of van Strien (1997), five phases are characterized. The first step is the identification of a problem, followed by a diagnosis of the problem situation. The next phase is a plan of action. Lastly there is an intervention phase and the cycle is completed with the evaluation phase. This model has been used quite extensively throughout. Different mappings of this cycle exist. For this research paper the original model of van Strien (1997) will be used which is displayed in figure 2.1.
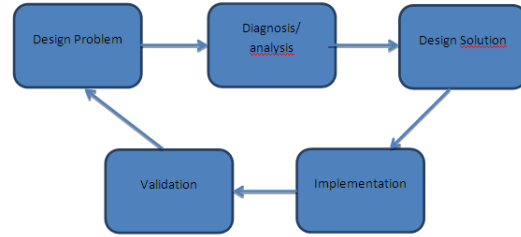
Figuur 2.1 Regulative Cycle

Now that the original model and the consecutive phases have been mentioned, a detailed description of the different phases will be given.

The first phase is Design Problem, within this phase the context will be mapped. This is done by three different steps. The first step is to indicate the different stakeholders. The second step is to identify what the goals are for each stakeholder. A goal can be interpreted as a desired change in the current state of the world. Lastly the CSF's for each goal are identified. Once these steps are taken, the diagnosis/analysis phase can be entered. Within the diagnosis phase again three steps have to be

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taken. First off, the possible causes of the difficulty of resolving a CSF have to be identified. This is followed by testing causes of a CSF by checking quality attributes. Quality attributes can be described as for example: how easy to implement, secure, expensive must the solution be. The final step in this phase is to check if there is an order-dependency in which the CSF's should be treated in order to achieve a properly working solution (Balsters, 2015). The third phase within the regulative cycle is the Design Solution phase. Here the designing as an artifact will take place. Again a few steps are taken. First alternative solutions that are available are identified. Secondly an assessment is made, whether old solutions can be assembled to make a new solution. If this isn't the case it is checked whether a new solution must be made from scratch. Within the implementation it is important to realize that there are some constraints impacting this phase. Implementing is limited to the assembly of available components to build new solutions from the prior stage. Also, there are constraints with regard to resources and existing body of knowledge that allow for this implementation. Lastly, there is the validation phase. Within this phase, test methods are designed. It is important to realize that the test methods align with the earlier set formulated CSF's from the different stakeholders. Any new CSF's might also be encountered

within this process. This is obviously important since it will allow for a deeper understanding of the problem and possible solution (Balsters, 2014b).

It is important to note that this thesis will focus on the first two steps of the regulative cycle as shown in figure 2.1. The work of Schriever (2015) and Lichtenberg (2015) will elaborate upon the other three phases. However, even though the focus of this thesis within the overarching research project is on the first two steps of the regulative cycle, the entire cycle will also be applied to each small step within this thesis. This Also is shown in figure 2.2. As presented earlier, the research questions of this thesis is: "What does the process of the head & neck oncology clinical pathway look like, and how can this be modeled to form the backbone for the EHR?" Each individual step of the Regulative Cycle should allow for a consistent way of answering this question.
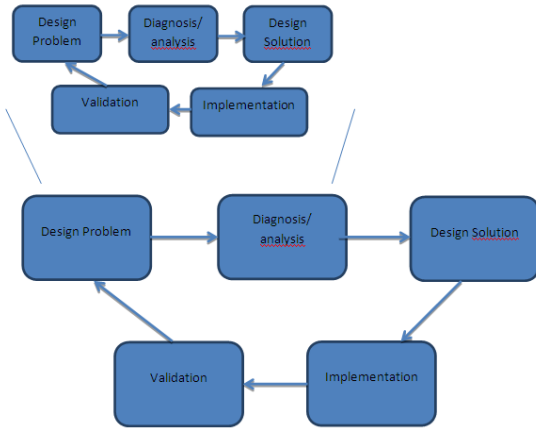
Figuur 2.2 Local Regulative Cycle

In order to conduct this research, there is a deeper understanding required of a few topics. Mainly with regard to: Process modelling, BPMN, interviewing and cycle times. This section will elaborate on these topics.

3.1 PROCESS MODELLING

This part will highlight how the process modelling will take place. An important remark to make is that the work of Van de Laar (2015) will be used as guidance for the process modelling. Van de Laar conducted research in the same LTHN. He created a general method to develop the process models for eMeasures development. His five step process will be explained later on. First a general description of processes will be given to further guide the reader.

Before heading into the details of what process modelling is, and what it does, it is important to define what a process is. Davenport (1993) defines it as: "structured, measured sets of activities designed to produce a specified output for a particular customer or market". Within Operations literature there are dozens of definitions of the term process. It is

however beyond the scope of this thesis to map these.

Van de Laar (2015) developed a five step procedure to developed process models. These five steps are:

- Develop a general overview of the process

- Stakeholder analysis

- Develop the process models

- Validating the model

- Adapt results and method

These five steps will now briefly be highlighted. The first step is to develop a general overview of the process. From this overview it becomes clear which (sub) processes should be investigated and which boundaries to set. When this general overview is completed, the stakeholders and both end-users can be identified. This brings us to the second step. The main questions to identify the stakeholders are directly related to the regulative cycle that has been presented earlier in the methodolo-

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gy section. These questions are: Who are the stakeholders? What are the goals of each stakeholder? What are the critical success factors (CSF's) for each goal? What are the 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? The answers to these questions will be used to gather the functional and non-functional requirements of the stakeholders. The next step is to develop the process models. The information of step two will be combined with: interviews with end-users of the process and end-users of the output. This will be used to model the process. It is important to note that at first only the process where no exceptions are included will be modeled. This is the so called ''happy flow''. The name "Happy Flow" is based on the conscious simplification of the model, where only the desired behavior and ideal movements are modelled (Beckers et al. 2007). The main reason for modelling it as a happy flow is so that the general outline of the process is well understood. Once this basic process model has been validated, exceptions to the process will be added.

The fourth step is validating the model. This is done by interviewing the same end-users as earlier. The processes that have been modelled will be shown, discussed and if needed altered. This allows for a continuous improved until the model meets the criteria of the end-users. The main questions for validating are: Are all the CSF's met? Are there any tradeoffs between CFS's? Is the method completely and correctly displayed in the process model? Is there any data not correct? Once the model has been validated the final step can be entered, adapt the results and method. If it turns out that the end-users are not completely confident with the process, some errors have been made. Validating the model helps to find these mistakes. By improving these mistakes the model should be re-examined and generated. (Van de Laar, 2015)

3.2 BUSINESS PROCESS MODELLING NOTATION (BPMN)

To model the processes and relationships within the Head & Neck Oncology clinical pathway, BPMN will be used. Therefor a brief summary of the most common BPMN features will be addressed. Readers who are already familiar with BPMN can skip this part, as it will cover the basic notation forms of BPMN.

Before heading into the details of what BPMN is, and what it does, the same definition of a process will be used as has been presented

earlier. Davenport (1993) defines it as: "structured, measured sets of activities designed to produce a specified output for a particular customer or market". This definition will be used as a starting point to further explain BPMN. Just as well as there are numerous of definitions of the term process, there are also numerous ways of process modelling. It is important to realize that BPMN is also just one of them. However, BPMN is one of the most widely accepted ways of notation. Alongside this wide acceptance, it also helps to bridge the gap between business and IT (Balsters, 2015). Therefor BPMN has been selected to be applied within this thesis. The following section will provide an overview of the most commonly used BPMN building blocks. A graphical example and an explanation will be presented. Lastly it is important to note that the explanations of these BPMN building blocks are derived from Balsters (2015).

One of the basic building blocks of BPMN is the pool. Pools are represented by rectangles and set the boundaries of a business process. Pools can contain flow and connection objects, these will be presented later on. Also, pools cannot contain other pools; these have to be modelled separately. The entire business process is build up as a collection of communi-

cating pools. Pools can however be further broken down into different swim lanes. This is shown in figure 3.1. These swim lanes are used to organize participants within the process. It is important to note that a single swim lane belongs to exactly one stakeholder.

Figuur 3.1 BPMN Pool and Swin Lanes

The next symbols are the start and stop event. To indicate the start and the end of an event, separate symbols are used. These are shown in figure 3.2. A process has one start event. But it can have one or more stop events.
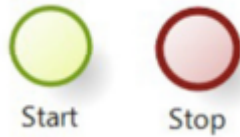
Figuur 3.2 BPMN start and Stop Event

The main building block of the process consists of tasks. These tasks tell us something about what is being done, by whom and in what stage of the process. The symbol used to indicate the tasks is shown in figure 3.3
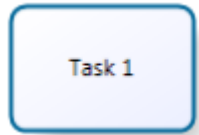
Figuur 3.3 BPMN Task

Some of the processes might contain more steps then they initially represent. In terms of

modelling this often happens in the Happy Flow. These process steps are modelled as a sub –process and is shown in figure 3.4. Within sub-processes there can be two or more additional objects that are part of the process (Van de Laar, 2015)

Figuur 3.4 BPMN Sub-Process

To indicate the relationship between tasks, an arrow can be drawn between two tasks. Figure 3.5 illustrates the sequenced relationship between the tasks.

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Figuur 3.5 BPMN Task Relatioship

Within a process, it often occurs that a decision has to be made; this is represented by so called gateways. Mainly, there are two kinds of gateways. The XOR Gateway and the Parallel Gateway. These are shown in figure 3.6

Figuur 3.6 BPMN Gateways

The XOR Gateway tells us that there can only be one decision being made. Either one of the

paths has to be followed. The parallel gateway means that all following decisions can be taken simultaneously, or all incoming branches have to be completed first before continuing the process.

Lastly it is important to indicate how pools can communicate with each other. This can be done through messages. These messages are indicated by the Data object symbol. Communication between swim lanes or pools is represented by a message flow. These symbols are shown in figure 3.7

Figuur 3.7 BPMN Communication

A complete overview of the building blocks that have been briefly explained in this thesis are displayed in figure 3.8
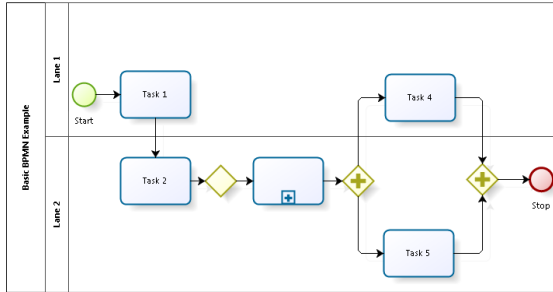
Figuur 3.8 BPMN Dummy process

These are but a few of the building blocks used on BPMN. However, with these building blocks, the developed model should be under-standable.

3.3 INTERVIEWING

One of the main means by which the information will be gathered is via interviews. Interviews are a powerful way of gathering information directly from the interviewee. The main advantages of using interviews are: flexibility in sequencing the questions, details and explanations; possibility of administering highly complex questions (Karlsson, 2009). However there are some downsides to using interviews. It will require significantly more time compared to other methods, which might make the interviewee reluctant to cooperate. Yet, in order to grasp such a complex process, and gather all the right information, interviews are crucial in the conduction of this research project (Karlsson, 2009). Within this thesis two types of interviews will mostly be used; unstructured interviews and semi-structured interviews. Unstructured interviews allow for an open ended debate about the subject. The subject has a central place but the interviewee can maximize its own contribution to the interview (Verhoeven, 2011). Semi-structured interviews do use a pre-defined list of questions. The questions are used as a base for the interview. However, the interviewee is free to deviate from the questions as he seems fit. Flexibility in the interview allows for a broad understanding of the subject (Verhoeven, 2011). It might also occur

multiple persons are interviewed at the same time, a so called group-interview. In this case the researcher will present himself as the moderator of the interview. Meaning he will provide both structure and information to the debate. Especially when combining knowledge from different fields of interest this

might be beneficial. One can imagine that this allows for a broad understanding of the subject (Verhoeven, 2011).

When conducting semi-structured interviews, a checklist of 4 steps will be used to guide the interviewer and interviewee. These will be highlighted within this section. Before conducting the interview, it is important to first set the boundaries of the research project. This is mainly done by highlighting the scope of the research and explaining it to the interviewee. One of the first steps in conducting the interview is to determine the function of the process. This is done by asking general process related questions. Once a clear understanding of the main process is achieved, a preliminary drawing of the process will be made. Also the main inputs and outputs of the process will be mapped during this stage (In 't Veld, 2010). By taking this step wise proce-

dure, it enables for a ''Black Box'' approach to understanding the process. Once this general ''Black Box'' process has been mapped, it is important to zoom in on the specific elements on the process. Once the specifics have been explained, it is important to map these within the black box model. This is where we reach the first checkpoint. On this point in the interview, it is beneficial to show the model to the interviewee for the first time. He might have suggestions to further improve it. Once this has been done, the interview is continued. More details of the process are added to the model to really understand the as-is situation. As soon these have been incorporated it is important to check again with the interviewee. This is the second checkpoint in the interview (In 't Veld, 2010).

To control a process, quality and quantity inspections have to take place. Certain employees within the process should fulfill tasks such as: measuring, comparing, supervise, to make sure the process is stable. These are key elements that have to be asked to the interviewee. Once the quality and quantity employees and the different regulations have been mapped, it is important to show these relations again to the interviewee, the third checkpoint. Next some final elements and re-marks will be added to the model to encapsulate the entire process. Once this has been done the interviewee is asked one last time to see whether the model matches exactly what is going on in the real world, the fourth checkpoint. This concludes the main interview. When finalizing the interview there is room for discussion about the model. Any information that has not been mentioned yet, might surface and could be incorporated (In 't Veld, 2010).

3.4 CYCLE TIMES

As a final paragraph of this theoretical background section, an explanation of the term cycle time will be given. The goal of the overarching research as stated in the introduction is: *"In the context of the clinical pathway Head and Neck Oncology at the LTHN, we design an information product to attain cycle time analysis of that clinical pathway".* To fully meet this goal, the term cycle time has to be defined. Within Operations Management literature numerous definitions of cycle time are used. For this research project we decided to choose the definition as presented by Hopp & Spearman in Factory Physics (2011). Hopp & Spearman (2011) define cycle time as: *"The cycle time of a given routing is the average time from release of a job at the beginning of*

the routing until it reaches an inventory point at the end of the routing". However, as this does provide a clear definition of the term cycle time, it is still not entirely clear what this means for our process. Therefor it seems beneficial to graphically map it on the head & neck oncology clinical pathway. This is shown in figure 3.9.

cycle time of the entire process is the sum of the individual processes.

This last paragraph concludes the theoretical background. In the next section the results will be presented.
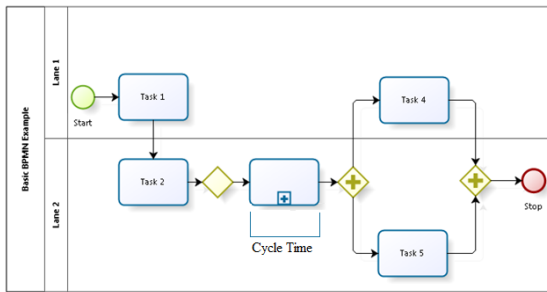
Figuur 3.9 BPMN Dummy process Cycle Time

When looking at the dummy process model as presented earlier, we now also incorporated how the cycle time is measured. As can be seen, the cycle time of a process in the head & neck oncology clinical pathway is measured from the time when the process step starts until the process step is completed. The total

4. RESULTS

This section follows the line of reasoning as presented in chapter 2 & 3. The regulative cycle will be used to guide the reader through the results. Each new step of the regulative cycle as presented in figure 2.1 will be highlighted. Alongside the regulative cycle the five step sequence by Van de Laar (2015) as presented in chapter 3, will be used to structure the results. First the entire regulative cycle for this Thesis will be presented. This is shown in section 4.1 till 4.4.1. Once this has been completed, the first two phases of the regulative cycle for the overarching research will be elaborated upon. This is shown in section 4.5 till 4.5.2. First the general process overview will be presented. Followed by the stakeholder analysis and lastly the process models will be developed.

4.1 DESIGN PROBLEM

The first step of the Regulative cycle is Design Problem. In this phase the stakeholders are identified, the stakeholder's goals are described, and lastly the CSF's are presented.

4.1.1 General process overview

As has been described in the model of Van de Laar (2015), first a general process overview has to be made. This general model will be referred to as the "Happy Flow". This Happy Flow presents a high level of aggregation to understand the basics of the process. Later on, the details will be elaborated further upon. A black box view of the process is presented in figure 4.1.
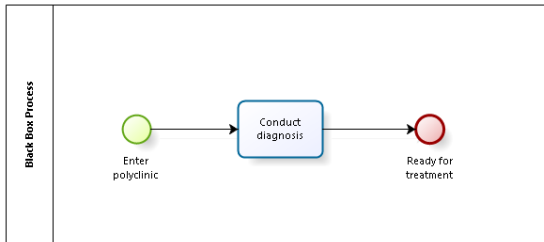
Figuur 4.1 BPMN Black Box

While this black box model offers little information, it does help to conceptually understand what is happening in the process (Zorzetto et al. 2000). Also the scope of this overarching research project becomes clear from this black box approach. The patient entering the polyclinic serves as the input for the process. This is followed by the conduction of the diagnosis by the healthcare provider. The patient that is ready for treatment represents the output of the process. After a clear understanding of the basics of the process itself had been established, interviews with relevant employees have been planned. These interviews with employees from different fields of expertise helped us to get a good understanding of the process. The general process overview that resulted from these interviews is presented in figure 4.2. Again, the same start and end points as in the black box model are used. However, the steps in between are way more detailed for this happy flow. Based on this general process overview, the next phase can be entered: the stakeholder analysis.
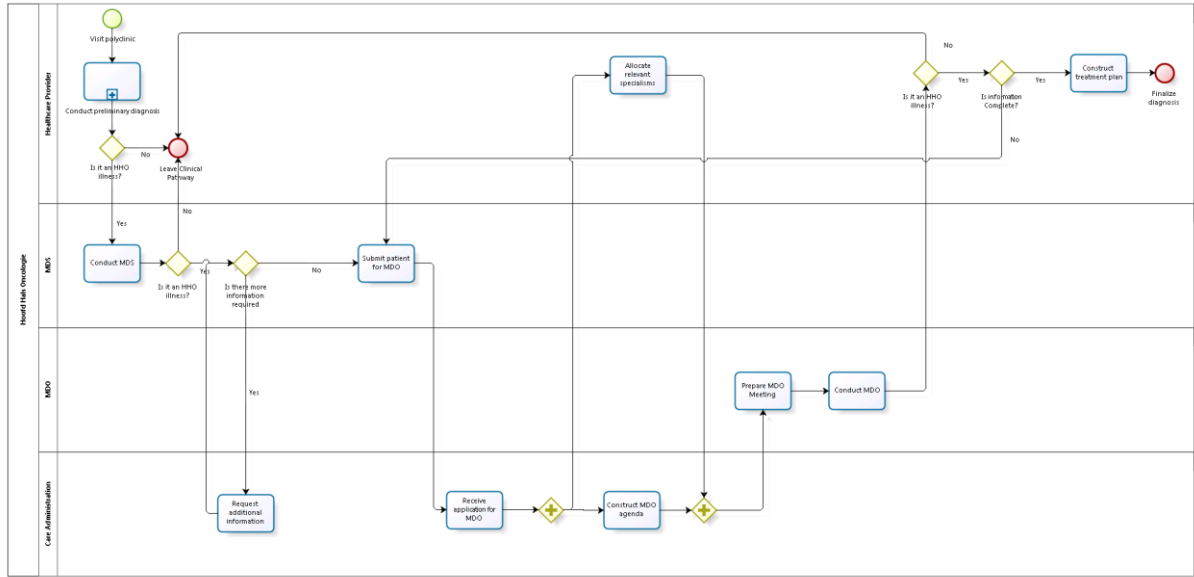
Figuur 4.2 BPMN Happy Flow

time. External stakeholders will therefor also be included in this analysis.

4.1.2.1 STAKEHOLDER IDENTIFICATION

The general process overview as shown in figure 4.2 has been derived from various sources. The main sources are interviews and informal conversations. However, also documents on the specific process steps have been received. Based on this combined information the stakeholders have been identified. Table 1 shows an overview of the various stakeholders. The Dutch abbreviations are used in the thesis. An English explanation of the abbreviations will be presented.

4.1.2 STAKEHOLDER ANALYSIS & STAKEHOLDER GOALS

In this section the stakeholders that are shown in figure 4.2 will be discussed. As aforementioned in the theoretical background, the swim lanes in the BPMN model represent the different stakeholders. These will be considered as the internal stakeholders of the process. However, one can imagine that there also might be external stakeholders that are not represented in the BPMN model. An example would be SONCOS, which requires from hospitals to maintain a certain cycle

NFU

HL7/Nictiz

IT Specialist

Client

Patient

Tabel 1Stakeholders

Head & Neck Oncology/Hoofd-Hals Oncologie (HHO) Stakeholders	
Internal Stakeholders	Healthcare provider
	MDS
	MDO
	Care Administration
External Stakeholders	External Healthcare Provider
	Soncos

Based on these stakeholders, an analysis is made. Firstly, a quick introduction of each individual stakeholder is made. The role of the stakeholder in the process and its relevance is explained.

4.1.2.2 INTERNAL STAKEHOLDERS

Healthcare Provider

The process is triggered when a patient visits the healthcare provider at the polyclinic. The healthcare provider is responsible for the patient throughout the process. Therefor he can be seen as the problem owner (McKay et al. 2001). The problem owner usually brings knowledge and context in problem solving. The goal of the healthcare provider is to diag-

nose the patient with an illness. If this proves to be another illness than the patient initially was diagnosed with, the patient is referred to a different clinical pathway. Also the data might not be complete. If this is the case, additional information is requested from the external healthcare provider or more research might be needed. The healthcare provider has to trigger these events.

Multi-Disciplinary Consultation/Spreekuur (MDS)

The MDS has an important role in the diagnosis of the patient. The MDS consists of multiple different medical specialists. Depending on the patient illness suspicion, the required disciplines are represented. Alongside the medical specialists, also the patient and his/her family are present. The goal of the MDS is to conduct further diagnostics which will serve as the input for the MDO later on in the process.

Multi-Disciplinary Meeting/Overleg (MDO)

The MDO is an important stakeholder; it has to come up with the final diagnosis of the patient. Similar to the MDS, at the MDO also multiple disciplines meet to have a consultation about the diagnosis for the patient. The

data that has been gathered from the MDS is analyzed at the MDO. Based on this data, a diagnosis of the illness will be made. The main difference with the MDS is that the patient and his/her family are not present during this meeting, and therefor is a lot more formal. The goal of the MDO is again to diagnose the patient based on the present data. This diagnosis will serve as the input for the healthcare provider in the final stage of the process.

Care administration

The care administration mainly has a supporting role in the entire process. Documents that have to be requested from external stakeholder, planning and scheduling of appointments and general information transfer are the main tasks of the care administration. The goal of the care administration is to support the healthcare provider in its administrative tasks.

4.1.2.3 EXTERNAL STAKEHOLDERS

External healthcare provider

The external healthcare provider has a few different roles within the process. It initiates the process prior the visit to the polyclinic. The pa-

tient is equipped with a referral from the external healthcare provider before it can visit the polyclinic. Secondly, the external healthcare provider also provides the healthcare provider with additional information about the patient when requested upon. The goal of the external healthcare provider is to support the healthcare provider in its information need to diagnose the patient.

Stichting Oncologische Samenwerking (SONCOS)

SONCOS is a Dutch platform that has been founded in 2009. It facilitates interdisciplinary consultation between different professional associations. SONCOS publishes guidelines for large teaching hospitals in the Netherlands with regard to oncological illnesses. Large teaching hospitals have to comply with these guidelines, therefor making it an important external stakeholder. The goal of SONCOS is to provide guidelines to regulate and safeguard oncological illness treatment. SONCOS is also the stakeholder that required that the cycle times from: the first visit polyclinic till finalize diagnosis, may not exceed 21 days. The overview of the maximum number of days a patient can be in a certain part of the clinical

pathway is shown in figure 1.1 in the Introduction.

Netherlands Federation of University Medical Centers (NFU)

The NFU represents the eight cooperating University Medical Centers (UMCs) in the Netherlands, as an advocate for and employer of 65.000 people. The goal of the NFU is to ensure that agencies that decide healthcare issues in the Netherlands take into account the special role of the LTHN. Again, this external stakeholder provides rules and guidelines which the LTHN has to comply with. A big initiative the NFU launched is called "Regsitratie aan de bron". Registratie aan de bron has as goal to have a clear and concise way to register their patient and care data between the eight different UMC's.

HL7/NICTIZ

HL7 and NICTIZ are organizations that help parties in the medical field to develop, implement and maintain their information standards. Using information standards allows for a concise way of transferring medical data. Their

goal is to obtain better care by having better information transfer.

IT Specialist

The IT specialist is also considered as an external stakeholder. Even though he might not be considered a stakeholder of process at all at first glance, it is an important stakeholder. The overarching research requires to first develop the process design in BPMN, then translating the BPMN to an ORM model and lastly validating it. Namely when it comes down to translating BPMN to ORM and validating the models, the IT specialists plays an important role. The IT specialist has the in-house knowledge to judge if the DCM´s and eMeasures that are mapped in the ORM model are appropriate. Therefor the IT Specialist is mapped as an external stakeholder. For more details on the IT Specialists role in the research, the reader is advised to visit the work of Schriever (2015).

Client

The client also has a big role in this research project. The client is the person who initiated the project and indicated the notion to measure the cycle times of the patients to comply

with the SONCOS regulations. In the end, the design that is modelled will be presented to him and either will be approved or disapproved. Therefor he is also mapped as an external stakeholder for this process.

Patient

Last but not least, the patient is an important stakeholder. The patient is not incorporated as an internal stakeholder for a number of reasons. The patient does not have a direct impact on the process itself. When the final diagnosis and treatment plan are presented, the patient has the opportunity to accept or decline the treatment plan. However, in most of the other steps it does not have an ability to change the sequence of the process. Yet it is important to keep in mind that the patient is the reason why the process is initiated. The goal of the patient is to get a diagnosis and tailored treatment plan if needed. Therefor it is included as an external stakeholder.

4.1.2.4 FINAL STAKEHOLDER REMARKS

A final remark about the internal stakeholders can be made. Most of the activities are aimed at fulfilling two types of questions: ''Is it a Head & Neck Oncology/HHO (Hoofd-hals Oncologie) illness?'' and "Is all the required in-

formation available?''. The questions are answered by various loops in the process as can be seen from figure 4.2. Because the different stakeholders have similar goals, the goal of the internal stakeholders could be formulated as: diagnose the patient with a specific illness and come up with a treatment plan. While making sure that the 21 days as required by SONCOS is not exceeded.

Lastly the goal of this research project deserves a remark. SONCOS guidelines provide regulations in terms of throughput times which the UMCs have to comply with. By analyzing this specific part of the clinical pathway, we try to design an information system that can measure the cycle times of the patients that flow through the system.

4.1.3.1 CRITICAL SUCCESS FACTORS AND BUSINESS REQUIREMENTS

Now that the stakeholders and their corresponding goals have been presented, the next question can be addressed. Following the model van Van de Laar (2015), the next questions is: *''What are the critical success factors (CSF's) for each goal?''* As has been mentioned in the methodology section, different success-criteria apply to different goals. Two kinds of requirements with respect to a CSF are either functional or non-functional. Functional CSF's describe what the system shall do. Non-functional CSF's describe what the system shall be. For a more detailed explanation the reader is kindly advised to visit the methodology section. Based on the goals of each individual stakeholder, the CSF's will be broken down. Following the same structure as in the last section, first the internal stakeholders will be addressed followed by the external stakeholders.

4.1.3.2 CRITICAL SUCCESS FACTORS INTERNAL STAKEHOLDERS

Healthcare Provider

- The information shall be complete

- The information must be correct

- The information has to be available

- The system shall safeguard the cycle times

MDS

- File output location has to be known

- All disciplines shall be available

- The information shall be complete

- The information shall be complete

- The information shall be correct

- The information must be correct

- The information has to be available

- The information has to be available

- The system shall be fast

- The patient shall be available

- The system shall exchange data

- The system shall safeguard the cycle times

- The system shall safeguard cycle times

MDO

4.1.3.3 CRITICAL SUCCESS FACTORS EXTERNAL STAKEHOLDERS

External healthcare provider

- All disciplines have to be available

- The information shall be complete

- The information request shall be clear

- The information must be correct

- The information request is known

- The information has to be available

- The required cycle times shall not be exceeded

- The system shall safeguard the cycle times

Care Administration

SONCOS

- Entry and Exit forms have to be available

- The process shall be executed within the stated cycle times

- The process shall be executed within the stated boundaries

- The information about the process shall be in a certain format

- The information shall be complete

- The LTHN shall comply with the regulations

NFU

- The process shall follow the standards of the NFU

- The process shall be in line with "Registratie aan de bron"

- The process shall be executed within the stated boundaries

- The information shall be complete

HL7/NICTIZ

- The data shall be stored in a concise manner

- The data is traceable

- The data is transferable

- The data about eMeasures shall be in HQMF format

- The data about DCM shall be in DCM format

IT Specialist

- The system shall be easy to understand

- The system shall applicable

- The system allows to trace the data

- The system shall use DCM's

- The system shall use eMeasures

- The system shall be able to calculate cycle times

Client

- The system shall measure cycle times

- The system shall comply with the SONCOS regulations

Patient

- The process shall receive a diagnosis

- The storage of data shall be secure

- The process shall be fast

- The process shall be in time

- The process shall not exceed the maximum stated cycle time

4.2 DIAGNOSIS/ANALYSIS

Now that all the stakeholders, goals and CFS's have been mapped, the relations between the CFS's are analyzed. As can be seen from what has been presented in section 4.1.2.1 till 4.1.3.3, the most common CSF is that the process shall safeguard cycle times. This turned out to be the most important CSF of the process. This also aligns with why the overarching research project initially was initiated. Measuring patient cycle times proves to be hard, and by modelling it in BPMN, the first step towards measuring can be made.

4.3 DESIGN SOLUTION & IMPLEMENTATION

In this phase of the regulative cycle, the designing of an artifact will take place. The way this artifact will be designed is by means of BPMN. Even though alternatives are available, BPMN allows for a consistent and concise way of modelling. To generate the BPMN models, old data was recovered. This allowed for a good starting point. It did need however some serious re-modelling, as different ad-hoc ways of modelling had been used. The majority of the model was made from scratch. While designing the model, the limitations of the earlier mentioned constraints have been considered. The main limitations consist of the existing body of knowledge and in-house expertise.

4.3.1 DEVELOP THE PROCESS MODELS

Now that the stakeholders, their goals and their corresponding CFS's have been identified, it is able to move to the next step: developing the process models. Again, the model presented by Van de Laar (2015) has some guiding steps towards developing the process models. As a starting point the earlier pre-

sented ''Happy Flow'' will be used. This forms the basis of the as is process. By conducting additional interviews, we are able to derive more detailed steps within the process. This will be validated in the next step. The questions that will be used to derive the additional information from the interviewee come from the process-driven Database Design method of Balsters (2014a). The questions are:

- At what instance does the event happen?

- How can the event be identified?

- Which entities are involved in the event as participants?

- What is the input for the event?

- What is the output for the event?

The relevance of the questions and how they help to construct the model will now be elaborated upon.

4.3.1.1 AT WHAT INSTANCE DOES THE EVENT HAPPEN?

After having a basic understanding of the as is process, the happy flow was constructed. This happy flow was presented to the interviewee throughout. The question *"At what instance does the event happen?"* was crucial in understanding the process. Initial mistakes that had been made with regard to the process lay-out could be eliminated. Re-allocating them to their corresponding place was the result of this question. Also some process steps that initially were included into the happy flow have been eliminated. The main reason for this was they either took place before the first polyclinic visit, or after the finalization of the diagnosis. The black box view shown in figure 4.1, helped to clarify the general outline of the process to the interviewee.

4.3.1.2 HOW CAN THE EVENT BE IDENTIFIED?

An understanding of the events is crucial in modelling the process. Different activities take place at a different moment in time. As can be seen in the theoretical background section, BPMN uses different classifications for different process steps. To get a better understanding of these different steps, the reader is invited to visit the theoretical background section.

It is crucial to note however, that most of the interviewee's did not have a clear understanding of BPMN. This made it difficult to get a grasp of the as is process. However, this was

overcome by conducting multiple interviews with the same interviewee's. Explaining the BPMN process each time, and checking it with the documents and knowledge they had at hand. Using this approach helped us a great deal to identify certain events. Also, some events in the Happy Flow are nested. As described in the theoretical paragraph, these nested processes contain sub processes. Some of these nested processes have been modelled more detailed. An example of a detailed nested process is: "Conduct Preliminary Diagnosis". Also shown in figure 4.3. The detailed overview of this process step is shown in Appendix II. The reason we decided to detail this specific nested
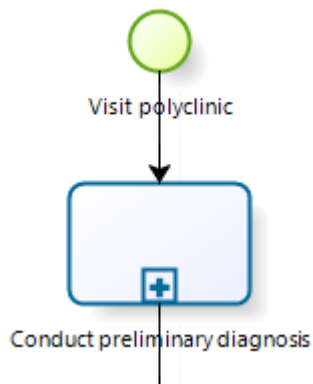
Figuur 4.3 Nested Process Example

process was because it was of influence on the cycle time of a patient. Also a few clear steps had to be taken within this process. This allowed us to model it in a clear and concise way that represented reality as best as possible. The detailed breakdown of this process step can be found in Appendix II. An example of a nested process that has not been detailed more extensively is the: "Conduct MDO" step shown in figure 4.4.
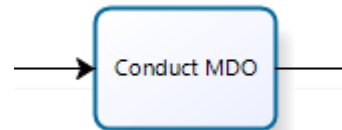
Figuur 4.4 Conduct MDO

.

The reason this has not been more detailed was mainly because of the complexity of this process. As will also be elaborated extensively upon later, this process was highly detailed. Not taking a clear route every time the process step was performed. Resulting in different activities per patient. In terms of actual cycle time this event is modelled with a clear start event and stop event. This allowed us to still calculate the cycle times, for this specific process step.

4.3.1.3 WHICH ENTITIES ARE INVOLVED IN THE EVENT AS PARTICIPANTS?

This question might appear quite clear cut; however it did bring some difficulties. In terms of BPMN modelling it is required to place an activity in the swim lane of the stakeholder that is responsible for it. The problem that this rule brings is for example: one could argue that the patient is ultimately responsible for the entire process, as he is the one with the suspicion of an illness. To overcome this problem some serious conversation with the involved stakeholders were needed. This led to the four internal stakeholders as shown in 4.2. Initially the patient was also considered to be a stakeholder but was removed for earlier mentioned reasons.

The MDO and MDS proved to be a special case, needing a bit more explanation. As mentioned in section 4.1.2.2 Internal Stakeholders, the MDS and MDO consist of multiple disciplines. One can imagine that it is quite hard to identify the single stakeholder that is responsible for the event, as they all contribute. Ultimately the healthcare provider, with whom the patient had the initial contact with, was responsible for the process. Yet due to the sheer size of the activities and their importance, we decided to model them as an individual stakeholder. This was beneficial for a number of reasons. It allowed for a clear understanding of the separation of activities. Also the time the MDS and MDO consume are quite extensive. So of purposes of tracking the cycle time it was more beneficial to model them as separate stakeholders. The entire overview of what entity performs which task is shown in Appendix V & VI

4.3.1.4 WHAT IS THE INPUT AND OUTPUT FOR AN EVENT?

These lasts two questions proved to be very beneficial to understand patient and data flows within the process. The majority of the data that we used to derive the input and output relations came from interviews. However, a part of the data also came from excel files that had been presented to us. These excel files had been developed earlier by the LTHN, with the purpose to serve as a process lay-out for a to-be developed electronic patient file. These excel files clearly stated the input and output relation of each single step in the process. After these relations had been modelled, they were again presented back to the persons that provided the information. The input and output per process step are shown in Appendix III and IV. Now that the process model has been developed, the next step is to validate it. This will be explained in the next section.

4.4 VALIDATION

The last phase of the regulative cycle is now entered. Validation of the proposed solution is presented to the earlier interviewed stakeholders. The guidelines of Van de Laar (2015) were used to validate this part of the design solution.

4.4.1 Validating the process model

To validate the process, the same interviewee's are interviewed again. During these conversations the model keeps getting updated and changed to make sure it represents the as-is situation as best as possible. Balsters (2013) and Karlsson (2009) provide four questions that guided us through the process of validating. These questions are:

- Are all CSF's met?

- Is there a trade-off between the 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?

As can be seen from section 4.1 till 4.3.4, various validation loops have been incorporated. Each time checking if the model represents the as-is situation. It is however crucial to note that Lichtenberg (2015) will do an entire validation of the research project. Giving a more in depth insight on how this validation took place. It also encompasses if this way of doing

research, was a correct way of doing research for this specific topic. Therefore, for a complete insight of how the validation took place, the reader is kindly invited to visit the work of Lichtenberg (2015).

4.5 Regulative Cycle on Overarching Research Project

Now that the Regulative cycle has been completed for this thesis, the regulative cycle can be applied to the first two steps of the overarching research project. As has been mentioned in the Methodology section, this thesis focusses at the first two steps of the Regulative cycle for the overarching research project. It is important to realize that the focus now shifts from designing the business process in BPMN to developing a system that can measure the patient cycle time.

4.5.1 Design Problem

The first step is to again see who the stakeholders are. The three main stakeholders in meeting the goal of designing a system that can measure the patient cycle time are:

- SONCOS

- Healthcare Provider

- IT Specialist

A description of each stakeholder has been presented in section 4.1.2. The goal of these different stakeholders is the same: The system should be able to measure the cycle times of patients within the Head and Neck Oncology clinical pathway. They do have different CFS's however. These will now be presented

4.5.1.1 Critical Success Factors

SONCOS

- The process shall be executed within the stated cycle times

- The process shall be executed within the stated boundaries

- The information about the process shall be in a certain format

- The information shall be complete

- The LTHN shall comply with the regulations

IT Specialist

- The system shall be easy to under-
stand

- The system shall applicable

- The system allows to trace the data

- The system shall use DCM's

- The system shall use eMeasures

- The system shall be able to calculate
cycle times

4

Healthcare Provider

- The information shall be complete

- The information must be correct

- The information has to be available

- The system shall safeguard patient in-
formation

- The system shall safeguard the cycle
times

- The cycle times shall not exceed the
SONCOS regulations

4.5.2 DIAGNOSIS/ANALYSIS

When analyzing the different CFS's the most important one is again the CFS that the system shall be able to measure cycle times. Also complying with the SONCOS regulations proved to be important. The main difficulties lie within the technical implication of the system. These are but a few of the stakeholders that have been analyzed, but from what have been presented earlier, there are more stakeholders that have different interest. Possible difficulties with conflicting CFS's might occur.

5. DISCUSSION

This section will discuss the research project. This allows for a reflection on the chosen research method, the results gathering and the interpretation of the results. This discussion section will contain three parts. The first part will discuss the results section, the second part will discuss the model of Van de Laar (2015) and lastly the regulative cycle will be addressed.

5.1 REFLECTION ON THE RESULTS

As the results section shows, a number of different stakeholders can be identified. The method for identifying these stakeholders was mainly conducting interviews. The interview methods of In 't Veld (2010) and Verhoeven (2011) proved to be a useful way of deriving information from the interviewee's. Both using formal and more informal interview's allowed us to gather rich information. It has to be noted however, that these interviews have not been transcribed or coded. Transcribing and coding the interviews could have been beneficial to increase the value of the overall research project. Also the selection of persons to interview could have been more extensive. General domain experts and IT experts have

been interviewed to gather information. Interviewing medical experts could have led to more detailed information about the medical steps that are presented in the happy flow. For the purpose of this research project it is however still able to develop a model that can come up with the cycle times of patients without the details of these steps. Simply by having a start and finish

time of the event enables for the calculation of the cycle time. One can imagine however, that a more detailed breakdown of these process steps, will lead to a more detailed calculation of the cycle times.

Secondly some remarks about the usage of BPMN to model the findings have to be made. BPMN offers a detailed way to notate the various steps that are taken within the process. It does however, has its own limitations. When conducting the interviews, a lot of rich information was presented to us. Not only in terms of verbal expressions, but also in the data we received. Mainly excel files with detailed information about each process step, contained

a lot of useful information. To capture all this rich information into a BPMN model, proved to be hard for a number of reasons. BPMN requires that the process step has to be modelled in the swim lane of the stakeholder that is responsible for it. This is also more detailed explain in the Theoretical Background. When confronted with detailed information however, it proved to be hard to model it in this particular way. Some of the richness of the information might be lost when modelling it in such a way. To overcome the loss of information, each step has been explained extensively within the appendix. While this does prevent that essential data will be lost, it does make the model more complex. When someone with no prior knowledge of this specific clinical pathway tries to understand the BPMN model, he/she might struggle to understand the details without the detailed information in the appendix.

5.2 REFLECTION ON METHOD OF VAN DE LAAR

This thesis relied heavily on the research design of Van de Laar (2015). Therefor a reflection on this method is in place. First of all it is important to note to context of this research project before heading into the details.

The overarching research is performed by a team of three students, all of whom are responsible for a different area of the research. This overarching research project however, can also be fitted into a bigger research project. The prior research group developed a way to formulate process models in BPMN and translate these into ORM models. The same methods that have been applied in their research project have been applied here. This has been done for two reasons. By using the same way of modelling, a consistency is obtained. Making it easier to interpret the results. Especially because the research took place within the same LTHN. The second reasons to use this way of modelling, was to validate the method. The remainder of this section will elaborate on the validation of this model.

Van de Laar (2015) offered a five step approach to develop the process models. These five steps have been explained in the theoretical background section and have been used in the results section. While it was a useful way to develop the process models, some remarks about it have to be made. The steps in the model are presented in a way that they seem to have a clear cut sequence. It is however important to note that in this research project the sequence was sometimes more "messy", and not as clear as presented in this model.

When combining this with the interview literature as presented by In 't Veld (2010) and Verhoeven (2011) it also becomes clear that in order to obtain rich data, sometimes an unstructured way of interviewing is required. While the model of Van de Laar (2015) definitely provides a clear guideline, it would seem beneficial to the research, to tailor the questions to the required state.

Validation of the process models also has an important place in the model of Van de Laar (2015). While this phase was absolutely essential to understand the details of the process, some smaller validation loops have also been added to streamline the process of modelling. Again when combining the literature of In 't Veld (2010) with the method of Van de Laar (2015), there is some room for improvement of the method. By already modelling the process with the relevant stakeholders during the interview, a quick feedback loop is incorporated. Not only does this shorten the process of gathering and modelling the information, it also increases the value by making sure the process is modelled correctly in the first place. Once the entire process has been modelled correctly a final validation check with the same interviewee's has to be made to ensure the correctness of the model.

5.3 REFLECTION ON THE REGULATIVE CYCLE

As presented in the Methodology section, the Regulative Cycle as first developed by van Strien (1997) has a prominent place in this research project. Design Science emphasizes the connection between knowledge and practice by showing that we can produce scientific knowledge by designing useful things (Wieringa, 2009). The focus of this thesis for the overarching research was placed within the first two sections of the Regulative cycle. Namely the design problem and the diagnosis/analysis phase. The regulative cycle was a great guidance through this research project. It did however also bring its difficulties. At first, the Regulative Cycle was viewed as an overview for the entire research project. As this is still true, an addition to this can be made. Also for incremental steps in the process of conducting this research, some "smaller" regulative cycles have been made. When for example designing the process models, it was very beneficial to do a quick: design problem, diagnosis/analyze, design solution, implementation and validation sequence with the stakeholders. Making sure that the data that was being modelled was in fact correct. Combined with the model van Van de Laar (2015) and In 't Veld (2010), this allowed for an efficient way of modelling. Even though these incremental loops are not incorporated

in the Regulative Cycle, it proved to add value to the entire research project.

5.4 FINAL REMARKS ON THE RESEARCH

For the purpose of answering the research question, the process has been modelled. From entry at the polyclinic until the diagnosis is finalized. When validating this model with the various stakeholders and interviewee's it proved to be a good representation of the reality. Yet some additional remarks about this model have to be made.

4

Conceptually this model might represent reality. One can imagine however, that when actual patients with different illness suspicions flow through the system, the system might behave differently. Patients that require a more urgent diagnosis and treatment plan might take alternative routes. Also the clear cut sequence of process steps might not apply to these kinds of patients. For the purpose of calculating cycle times, this might or might not matter. However, it is crucial to keep in mind that patients with different characteristics are entering this part of the clinical pathway. Making it a dynamic environment where this conceptual process model might not always apply.

This final section will encompass the conclusion of this thesis. Also the limitations of this work and recommendations for future work will be stated.

6.1 RESEARCH CONCLUSION

The goal of this overarching research project was to come up with a model design that can measure patient cycle times. In order to come up with this design, the overarching research was divided into three different subjects. The first being: from in-house knowledge and information to BPMN process models. The second focused on translating these BPMN process models to ORM Models (Schriever, 2015). Lastly the third project focused on generating forms based on the ORM models and validating the entire research project (Lichtenberg, 2015).

Based on the BPMN model, an ORM model was created. This ORM model is capable of tracking every start time, end time and accumulated time of each event. By doing so, meeting the aim of the research project. The BPMN model that was developed in this thesis functioned as a backbone for this ORM model.

Knowledge of the Head & Neck Oncology clinical pathway was essential to create the ORM model.

To generate the BPMN models, prior work of Van de Laar (2015) and Design Science knowledge was used. This proved to be a challenging task. BPMN has its own rules

when it comes down to modelling. To make this model represent the reality as best as possible, feedback sessions

with the stakeholders and other interviewee's were required. This allowed for validation and continuous improvement of the models.

Combining the presented model of Van de Laar (2015) with additional process modelling interview techniques from In 't Veld (2010) proved to be especially useful. The techniques of In 't Veld (2011) proved to be a comprehensive way of process modelling while the stakeholders were present. The model of Van de Laar (2015) helped to give structure to the overall way of deriving the information.

As aforementioned; Design Science emphasizes the connection between knowledge and practice by showing that we can produce scientific knowledge by designing useful things (Wieringa, 2009). This research project fits this description. By generating an ORM model based on a BPMN model, via the guidelines of a previously proven to be successful way, an addition to scientific knowledge can be made. Also a validation of the model of Van de Laar (2015) has been made by conducting the research in this way. This model, with a few side notes, was a beneficial way of conducting this research.

6.2 LIMITATIONS

As has been mentioned earlier, BPMN proved to have its own limitations when it comes down to modelling. The process models follow the rules of BPMN, meaning that the process is placed in swim lane of the stakeholder that is responsible for it. By modeling it is this manner, some of the data richness is lost. This is partly overcome by adding the input and output relations in the appendix III and IV. Also the detailed process description has been added in appendix V and VI.

Also the data that was derived has some limitations. It mainly came from general domain experts and IT-specialists. While they did know a lot of essential information, the model could have been richer when also medical specialists had been included.

Lastly there are some limitations to the data that was presented to us. Some of the process description data that we received used ad-hoc ways of notating. While the true meaning of these processes was derived from interviews with the stakeholders, some of it was still party unclear and open for debate. This leaves some room for error, but only to a small degree since the model has been validated with the stakeholders.

6.3 RECOMMENDATIONS FOR FUTURE RESEARCH

While this research project does allow to conceptually calculate the cycle times of patients, still some additions can be made. First of all the scope of this research focused on the entry at the polyclinic till the finalization of the diagnosis. This allows to partly measure the cycle times of the entire clinical pathway. Each specific part of the clinical pathway has to comply with the SONCOS regulations. For this

part of the clinical pathway this is now measureable, however, the other parts still have to be modelled. This is a great opportunity for future research. Not only does it provide insight into the entire cycle time of the clinical pathway, it is also an opportunity to further validate the research model as presented in this thesis.

A second research project might entail a more mathematical approach of analyzing the clinical pathway. Now that it is possible to generate the cycle times of this part of the clinical pathway, calculations can be made to analyze the specific process steps. Bottlenecks or critical paths can be identified by analyzing this data, allowing for process improvement.

Healthcare Information Technology is a young and developing field of research. Adding to this body of knowledge has great potential by conducting case studies at various locations. Using a design science approach of conducting research has proven to be beneficial for this research subject, and might also be the case for other future research.

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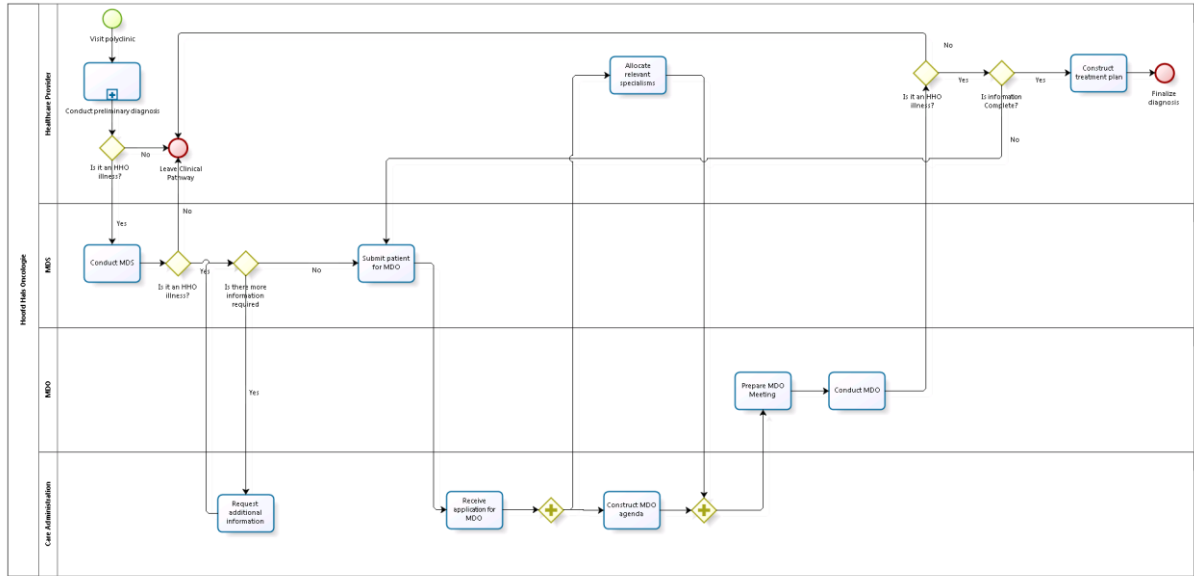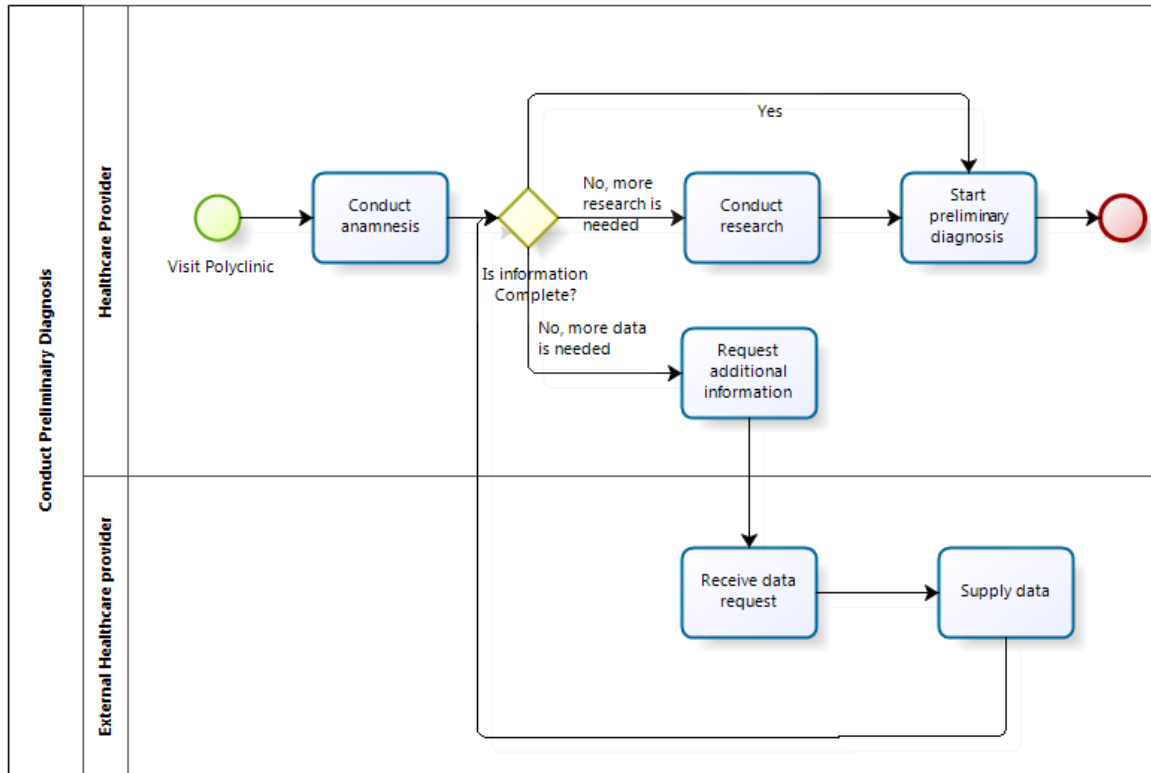
1   APPENDIX II

2   APPENDIX III: DESCRIPTION – HAPPY FLOW

This appendix gives an overview of each process step, input and output. The logic behind the sequence is as followed:

patient flows are initially measured in a logical sense. Meaning that the normal flow of events, without any loops, is discussed first. Appendix I shows the process as described.

Process step	Input	Activity	Output
Visit polyclinic	Patient with referral from external healthcare provider	Patient visits the polyclinic to receive preliminary diagnosis	Patient is ready to receive preliminary diagnosis
Conduct preliminary diagnosis	Patient that is ready to receive diagnosis	Series of questions and examination of the patient	Preliminary diagnosed patient
Check if it is an HHO illness	Preliminary diagnosed patient	Determine if it is an HHO illness based on the prior conducted diagnosis	If: yes then patient is ready for MDS conduction If: No then patient leaves the clinical pathway
Conduct MDS	Patient with an HHO illness	Diagnose patient with multiple disciplines. Patient is involved during the diagnosis	Patient that has received the MDS diagnosis
Leave clinical	Patient without	Patient leaves the	-

pathway	oncology illness	clinical pathway.	
Check if it is an HHO illness	Patient that has received the MDS diagnosis	Determine if it is an HHO illness based on the prior conducted MDS	If yes: then the patient has a suspicion of an HHO illness If no: then patient leaves clinical pathway
Is there more information required?	Patient that received MDS and has an oncology suspicion.	Determine if based on the available information the patient is ready for MDO	Patient is ready for an MDO application
Leave Clinical pathway	Patient without oncology illness	Patient leaves the clinical pathway	-
Submit patient for MDO	Patient that has received MDS and has and oncology suspicion with all the right data	MDS submits patient for the MDO	Submitted patient to MDO

Request additional information	Patient that received MDS and has an oncology illness but needs more information	Information from the external healthcare provider is requested about the patient	Once the data is provided, the completeness of data is re-evaluated
Receive application MDO	Submitted patient for MDO	Receive message flow from MDS	Patient ready to be scheduled.
Conduct MDO Agenda (parallel with Allocate relevant specialisms)	Patient ready to be scheduled	Care administration creates the agenda for the MDO meeting.	If both steps completed. Patient is scheduled for MDO meeting.
Allocate relevant specialisms (parallel with construct MDO agenda)	Patient ready to be scheduled	Healthcare provider determines which specialisms are needed to perform the MDO	If both steps completed. Patient is scheduled for MDO meeting.
Prepare MDO Meeting	Scheduled patient for MDO	All relevant specialists prepare	All relevant specialists are ready for MDO

		the MDO meeting	
Conduct MDO	Prepared specialists	During the MDO the patient's illness suspicion is discussed extensively. Possible causes of the illness are discussed.	Patients illness suspicion is further detailed
Is it an HHO illness	Completed MDO	Healthcare provider determines based on the MDO findings if it actually is an HHO illness	If yes: healthcare provider checks if all the information is complete If no: patient leaves clinical pathway
Is information complete?	Patient with an HHO illness after receiving MDO	Healthcare provider checks if he needs more information about the patient	If yes: then the treatment plan in constructed. If no: the patient is submitted to an MDO again
Leave Clinical	Patient without HHO illness af-	Patient leaves the	-

pathway	ter MDO	clinical pathway	
Construct treatment plan	Patient that has an oncology illness with all the required information available	Healthcare provider constructs the treatment plan based on the MDO findings.	Patient is diagnosed
Finalize diagnosis	Diagnosed patient	Communicate treatment plan to patient	Start treatment

As can be seen from the happy flow diagram, some processes are nested and included more detailed processes steps. This table shows the breakdown of the process step: "conduct preliminary diagnosis". Appendix II shows the process overview. Appendix VI shows the visual representation of this breakdown.

Process step	Input	Activity	Output
Visit Poly-clinic	Patient with referral from external healthcare provider	Patient visits the polyclinic to receive preliminary diagnosis	Patient is ready to receive preliminary diagnosis
Conduct Anamnesis	Patient is ready to receive preliminary diagnosis	Patient explains his illness suspicions to the healthcare provider.	Patient with completed anamnesis
Is the information complete?	Patient that has received an anamnesis	The healthcare provider checks if the information is complete	If yes: the preliminary diagnosis is started If no, more research is needed the healthcare provider will conduct more research if no, more data is needed then the healthcare provider with request additional information.
Start preliminary research	Patient that has received anamnesis and has complete information	The healthcare provider conducts a preliminary diagnosis based on the patient file and an-	Patient with a preliminary diagnosis

		amnesis	
Conduct research	Patient that has received an anamnesis but still needs some additional research	The healthcare provider conducts specific research that go beyond the physical examination. Additional diagnostic equipment is required. diagnosis that does not need a specific request for additional research	A patient that has received his anamnesis and additional research and is ready for its preliminary research.
Request additional information	Patient that received an anamnesis but needs more detailed information	The healthcare provider requests additional information about that patient from the external healthcare provider	Information request
Receive da-	Request addi-	Process the infor-	Knowledge of the information request

ta request	tional infor-mation from the healthcare pro-vider	mation request	
Supply data	Receive data re-quest	The external healthcare provider supplies the data to the healthcare pro-vider	Healthcare provider checks if the data is up to date and determines again if the information is complete

This appendix will combine the happy flow of Appendix I and the input/output relations shown in appendix III. Allowing for a clear understanding of the entire process. For purposes of this explanation, an example will be used. A pa tient with an oncology suspicion visits the polyclinic. In this explanation the logical flow will be followed, meaning that any processes that remove the patient from the clinical pathway or cycle the patient back into the process are not explained.

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BPMN Model	Process Description	Example description
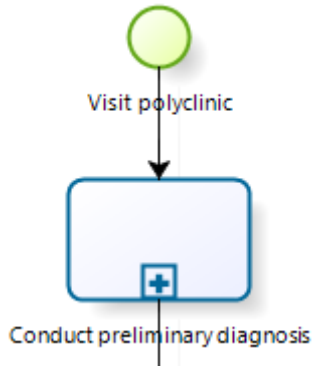
Stakeholder: Healthcare provider

The process always starts with a patient that visits the polyclinic. Once the patient visits the polyclinic the healthcare provider will conduct the preliminary diagnosis. In Appendix VI the detailed step by step explanation of the preliminary diagnosis is presented once the diagnosis is completed the healthcare provider moves to the next step.

A patient who has an oncology suspicion has received a referral from the external healthcare provider.

This referral allows him to visit the polyclinic. Once the patient enters the polyclinic, the healthcare provider will conduct the preliminary diagnosis.

Conduct preliminary diagnosis

No

Is it an HHO illness?

Yes
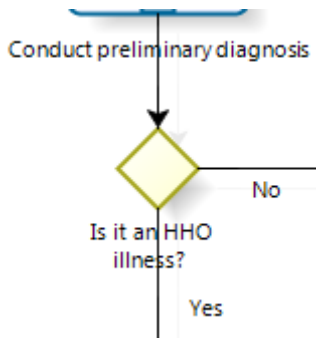
Stakeholder: Healthcare provider

The preliminary diagnosis results leads to a gateway. Based on this diagnosis the healthcare provider has to judge if it is an oncology suspicion or not.

The healthcare provider successfully completed his preliminary diagnosis. Based on his analysis he believes the patient has a oncology suspicion and the patient is applied for the MDS

Is it an HHO illness?

Yes

Conduct MDS
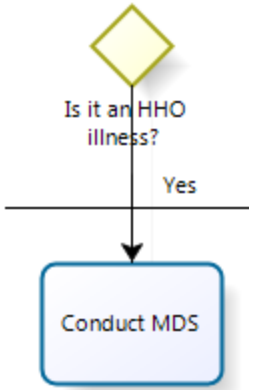
Stakeholder: MDS

The patient enters the MDS. A range of different medical specialists diagnoses the patient. Based on the oncology suspicion a different range of specialists can be present.

Once the patient enters the MDS, he has an active role in the diagnosis phase. The patient is allowed to bring family and can view the various diagnosis steps on a screen. This MDS takes approximately one day before it is finished.

Once the diagnosis within the MDS is

After the patient has visited the MDS, the MDS
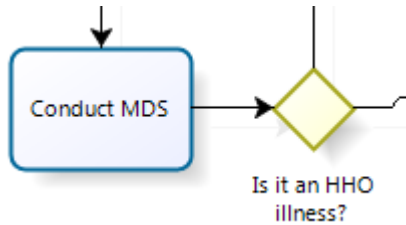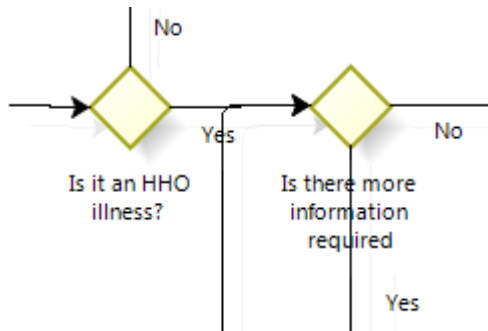
Stakeholder: MDS

completed, a gateway is reached. Within this gateway a decision has to be made whether the patient has an HHO suspicion or not.

diagnoses the patient with an oncology illness.

Stakeholder: MDS

Once the patient is diagnosed with an HHO illness, the MDS has to determine if the information about the patient is complete. If the information is complete the next step is initiated. If the information is not complete more data is requested from the external healthcare provider. Once the data is re-

The MDS decides that the information about the patient is complete and no additional information is needed. Therefor the MDS moves to the next step of the clinical pathway

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ceived, the completeness of the data is re-evaluated.
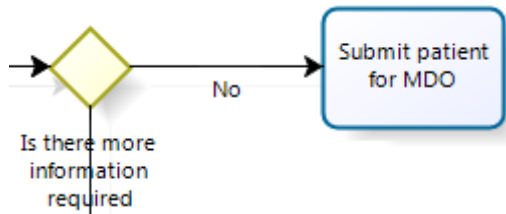
Stakeholder: MDS

This is the last step in the MDS. All the diagnosis steps have been completed. And the MDS applies the patient for the MDO

The patient can go home. Based on the appointment with the MDO that still has to be scheduled, the patient will receive a letter when his MDO meeting is. The MDS will submit the data to the healthcare provider. This data will later on be used on the MDO
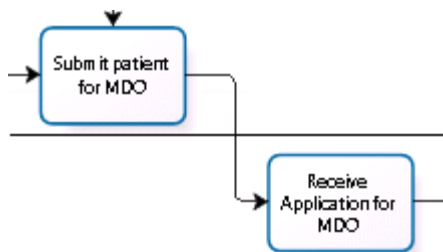
Stakeholder: Care administration

The care administration receives the patient application for the MDO from the MDS. The care administration has to process this

The care administration receives a letter stating that the patient is submitted for the MDO. Before the meeting can be planned the care administration needs infor-

information in order to continue towards the next step.

mation from the healthcare provider.
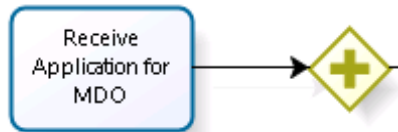
Two activities have to be performed in parallel before the next phase can be entered

Stakeholder: Care Administration

Both the healthcare provider and the care administration have to perform a task before the next phase of the process can be entered.
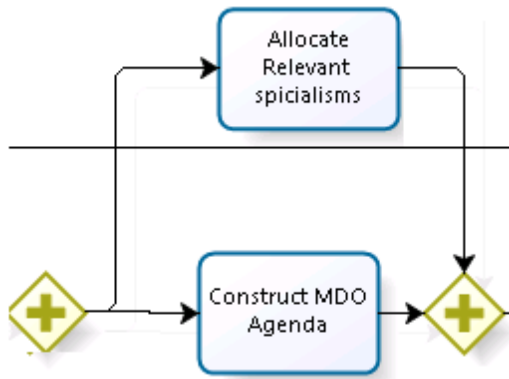
Stakeholder: Healthcare provider/care administration

The healthcare provider has to allocate all the relevant specialisms for the

MDO.

The healthcare provider will schedule a the MDO meeting based on the schedules of the different specialisms

Stakeholder: MDO
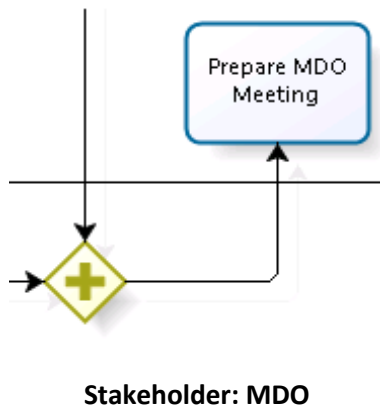
Now that the MDO agenda has been constructed and the relevant specialisms have been allocated, the MDO meeting can be prepared

The different MDO specialisms have received documents from the healthcare provider. These documents entail information about the patient, preliminary diagnosis and the MDS. These documents will be studied before the MDO will be conducted.

Now that the MDO meeting has been prepared, the MDO

Different specialisms meet in the MDO. Based on the oncology suspi-

Stakeholder: MDO

Stakeholder: Healthcare Provider
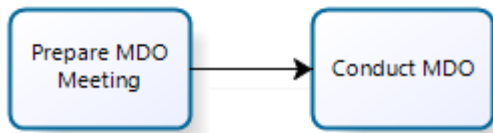
meeting will be held in a meeting, the required medical specialists are present. Here the different specialists will try to come to a diagnosis based the available data of the patient
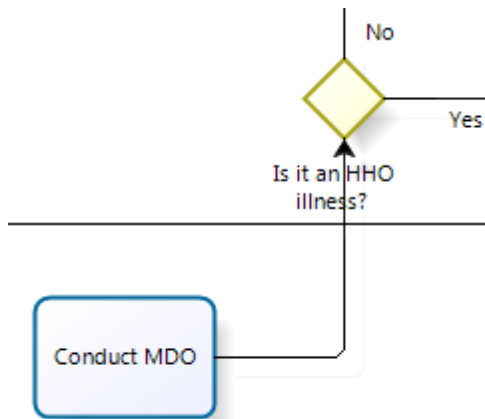
Based on the findings from the MDO, a gateway is reached. Here a decision has to be made whether the healthcare provider thinks it is an HHO illness. Or another illness, if it is another illness the patient leaves the clinical pathway.

The healthcare provider studies the documents and suggestions of the MDO, based on this he will make a final decision if the patient has an oncology illness or not.
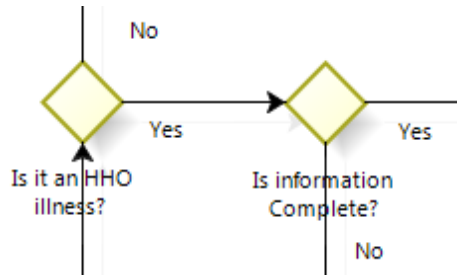
Stakeholder: Healthcare provider

If it is an HHO illness, the healthcare provider has to do a final check if the data is complete. If the healthcare provider still needs some more information, the patient cycles back to phase: Submit patient for MDO

If the healthcare provider still is unsure about the HHO illness, he can decide to submit the patient to the MDO again. If he is sure however, he can move to the final stage of the process.
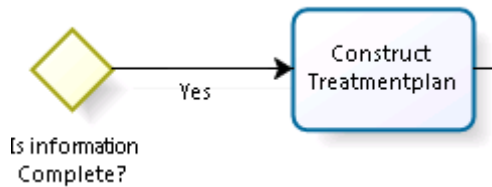
Stakeholder: Healthcare Provider

The patient is diagnosed with an HHO illness, and all the information is complete. The treatment plan based on the MDO findings will be formulated

All prior received information will be used for the treatment plan specific to the patient. Mainly the findings of the MDO are important for the treatment plan.
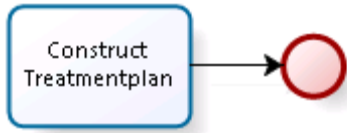
Stakeholder: Healthcare Provider

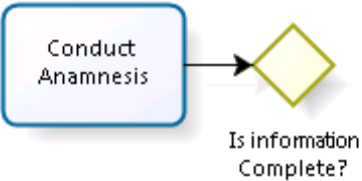The treatment plan has been constructed. This will be communicated to the patient.

This is the final step of the process.

The patient is requested to come to the polyclinic again. The healthcare provider will communicate his treatment plan to the patient.

In this appendix the process step: "conduct preliminary diagnosis" as shown in Appendix II will be explained in detail. The input/output relations as described in appendix IV will also be included. Again, like appendix V, an example will be used where a patients flows through the clinical pathway.

| BPMN Model	Process description	Example description
Visit Polyclinic → Conduct Anamnesis **Stakeholder: Healthcare provider**	The process starts when a patient visits the polyclinic. The healthcare provider will conduct the anamnesis	The patient arrives at the polyclinic. Here he verbally describes to the healthcare provider what his symptoms are.
Conduct Anamnesis → Is information Complete?	Once the Anamnesis is completed, a gateway is reached, here the healthcare provider has to	After the patient has verbally expressed his symptoms, the healthcare provider will now make a

Stakeholder: Healthcare provider

check if the information is complete enough to complete his preliminary diagnosis

decision.

Stakeholder: Healthcare provider

The healthcare provider has three options in this gateway. Either the information is complete. More research is needed. Or more data about the patient in general is needed before he can conduct his preliminary diagnosis.

The healthcare provider has to assess the situation at hand with the patient and make a decision.
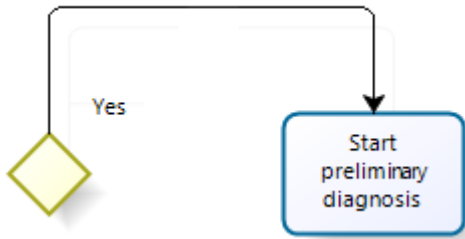
Stakeholder: Healthcare provider
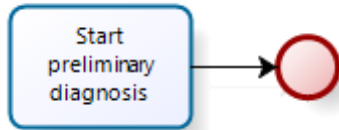
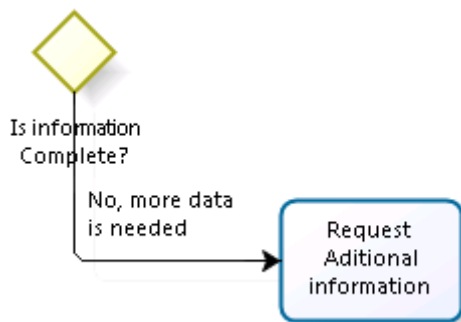

Stakeholder: Healthcare provider
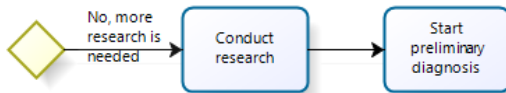
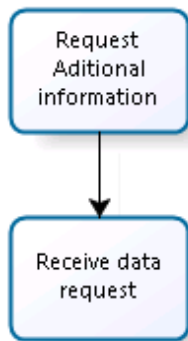**Stakeholder: Healthcare Provider**

If the information about the patient is complete, the healthcare provider can continue to star this preliminary diagnosis.

Based on the anamnesis and the referral documents the healthcare provider is able to start his preliminary diagnosis

Once the healthcare provider has started his preliminary diagnosis this process will end.

After the preliminary diagnosis the healthcare provider will determine if it is an HHO illness suspicion or not. This can be found in the happy flow

If the information is not sufficient enough, the healthcare provider can opt to conduct additional research. Once this research has been done, the preliminary diagno-

The healthcare provider will examine the patient more thoroughly. Based on the anamnesis, the healthcare provider will also do a physical examination and apply more diagnostic tools.

Stakeholder: Healthcare provider

If the data from the anamnesis in not complete and more data is needed, the healthcare provider will request additional information from the external healthcare provider

Based on the patient file, a letter will be sent to the external healthcare provider. Asking to provide more detailed information about the patient.

Stakeholder: External healthcare provider

The external healthcare provider receives the data request from the healthcare provider

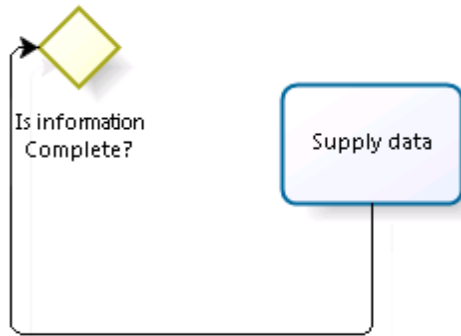A letter stating the requested data is delivered at the external healthcare provider

Once the request has been received, the external healthcare provider

Once the data is received by the healthcare provider, he has to again make the decision if the information

Stakeholder: External healthcare provider

will supply the re-quested data to the healthcare provider

is complete.

Is information Complete?

Supply data

The healthcare provider now has to check of the information is complete

Based on the new information the healthcare provider will determine the next step to take.

Stakeholder: Healthcare Provider