

# Building an information product for cycle time analysis

*- From process- to data models -*

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Trefw BPMN, ORM, process, data, database, information product, blueprints, regulative cycle, , cycle time, cycle time analysis, SONCOS, large teaching hospital.

## **PREFACE**

This Master's Thesis is the final research project of the MSc Technology & Operations Management curriculum at the University of Groningen. Without the guidance of several people, this project could not be completed in such an innovative subject as design science, that is the main reason to point out my gratitude.

First of all I would like to thank the people at the LTHN for their enthusiasm, knowledge and insights that have been crucial for further understanding and meeting our eventual goal. Furthermore, the input and discussion held with my fellow students R. Lichtenberg and J. Meerman were very useful and made the project a memorable experience, thank you for that.

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## ABSTRACT

Regulations for medical organizations are becoming stricter. Inspection services and foundations like SONCOS will be checking hospitals regularly and ask for specific data cornering the cycle times of certain clinical pathways.

A Large Teaching Hospital in the Netherlands wants to change towards an information infrastructure which can provide these insights. After the stakeholders and goals are formulated, the second step towards such a data infrastructure is an information product blueprint of the system to-be. Generating this blueprint is the specific aim of this thesis research by means of translating Business Process Modelling Notation to ORM-diagrams to eventually generate information product blueprints to serve as a foundation for cycle time analysis.



## 1 INTRODUCTION

When first picking a hospital for a treatment or if one is referred to a certain hospital, this hospital will create a patient dossier. An issue with such a dossier is that there is one single copy in existence, available on one place only and has the risk of become missing. The most important objective of a patient dossier is to support the medical process (Michel-Verkerke, 2003). More important with such a single file is that inspection services will be checking hospitals regularly and ask for specific data cornering the cycle times of patients within clinical pathways (e.g. what is the cycle time for clinical path X?). Providing such information with the current single copy patient dossier is hard as data has to be collected from several different systems and it is not always clear what data is required. This leads to derivation and interpretation of data with room for errors. Also, the required data is often not available. A Large Teaching Hospital in the Netherlands (LTHN) suffers from this lack of data analysis functionality with their current information structure. Additionally, a foundation called SONCOS - Dutch abbreviation for Foundation Oncology Collaboration - sets the standards in current health care operations regarding the department of Oncology, which have developed new standards that need to be met mid 2015: SONCOS wants hospitals to be able to present data concerning cycle times of their Oncology patients for specific periods of time. When does a patient enter a hospital's oncology department? What actions does he or she take and how long do these steps take? At what time is the diagnosis established? What tasks are performed in the treatment? All these questions wants the SONCOS to be answered from the data within the patient dossiers, allocating the process times of the steps taken which are called time stamps. This timeline is also visualized by Meerman (2015).

These insights cannot be achieved with the current data structures. This illustrates that the current situation as-is, is undesired. The points mentioned above make clear the current situation needs to be improved to a certain state to-be. Moreover, if the diagnosis is not received within the stated

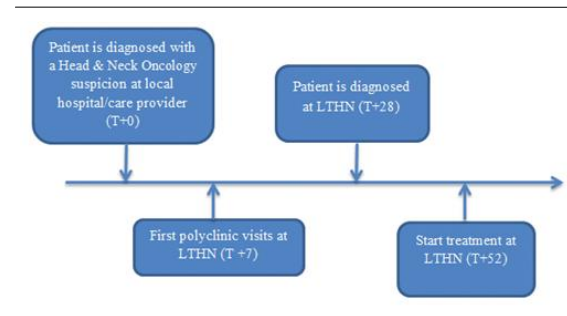


Figure 1 SONCOS regulation timeline (Meerman, 2015).

amount of time it could possibly lead to many unnecessary deaths on the long-term in the worst-case scenario.

This process for gaining more insights in the cycle times regarding clinical pathways and meeting the SONCOS standards can be achieved electronically by a new information product. The main advantage of such a new information product with respect to the current single copy patient dossiers, is the fact it can be used to perform cycle time analysis. Furthermore, it can be shared by multiple users and fulfil other functions as request examinations, decision-making support and show warnings (Michel-Verkerke, 2003). According to Martena (2015) an information product for such scenarios requires Detailed Clinical Models (DCMs) and the eMeasure (i.e. the building blocks and algorithm) to fulfil its main purpose as stated above. Martena (2015) also stated: *"However, there are a lot of applications over numerous disciplines within the healthcare sector. This increases the level of complexity for the creation and design of these DCM's and eMeasures.* To be able to deal with this relative high level of complexity, the LTHN wants to come up with a design of such an information product that contains the building blocks needed to design the database and such uncover DCMs and eMeasure for analysis purposes. The main objective of this overarching project is to design a sociotechnical system (relatively high end user

involvement with technology) that will make cycle time analysis possible. As the name sociotechnical already suggests, it has to be validated by the eventual users of the system, as they are the main reason such a project can be considered successful (Berntsson-Svensson, 2006). The system will be designed specifically for the Head and Neck Oncology department within the LTHN, due its general nature and the SONCOS standards that need to be met mid 2015 for this specific department.

Providing the DCMs, eMeasure and system blueprints is a large project. A possible strategy to tackle this main design problem is in a team of three, each person with its own area of interest. That is the main reason this overarching project consists of three parts, hence three individual theses. The first part of this overarching project consist of an information analysis regarding the people involved (stakeholders), work flows and creation and design of business process models in the Business Process Modelling Notation (BPMN), which is performed by Meerman (2015). The second part focuses on transforming these process-models in BPMN to database blueprints by data-models in Object-Role Modelling (ORM). The third part is about creating a library of building blocks and validating the methods used with the end-users of the system to-be, which is done by Lichtenberg (2015).

This thesis concerns the second part of the overarching project: translating the BPMN models to ORM-diagrams and creating information product blueprints for the processes. The blueprints will be validated by the end-users by Lichtenberg (2015) and adjusted if necessary as the whole project is to satisfy the stakeholders.

From the above stated context of this main problem - the lack of analysis possibilities in the current data infrastructure - the following overarching research objective can be derived:

*"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"*

With information product defined as a highly interdependent package of information that is capable of being distrib-

uted in digital form (Tiwana & Ramesh, 2001). Based on this main objective, the following individual research objective for this thesis is derived:

*"In the context of the clinical pathway Head and Neck Oncology at the LTHN, I translate BPMN-models towards ORM-diagrams which generate database blueprints to attain cycle time analysis of that clinical pathway"*

The three following sub-questions concerning this second individual part of the overarching project are formulated:

1. *"How can technical validated BPMN models be translated to a technical validated information product blueprint?"*
2. *"How can the current information product design method aid in the analysis of cycle times of patients?"*
3. *"How can the current information product design method be improved and generalized?"*

Now the overarching goal, this parts specific research objective and research questions are formulated, the eventual individual contribution of this thesis can be formulated as well. The very first contribution is that the model of Martena (2015) from prior research will be used in another context. This model of Martena (2015) has only been applied in a single context. Furthermore, his model is not (technically) validated yet, what will be another focus point to validate the generated ORM-diagrams with technical specialists to check the utility of the model of Martena (2015). As now the model will be used in another context then it initially was developed for, it is aimed to generalize the model and make it applicable in other fields of interest as well. The model will be adjusted and modified to do so if necessary. This research might initialize the development of a validated method to translate business process models to data models. Especially for the healthcare sector, that seems to be lacking behind in terms of data integration, this could be beneficial. A last, more societal contribution, could be made by conducting this research as it will develop a system that can attain cycle times, which allows further analysis to be performed. Critical path and bottleneck analyses could be performed to eventually reduce cycle

times and shorten the time patients have to wait to receive their diagnosis and treatment. Patients will benefit from having a shorter cycle time and receiving their diagnosis and treatment as soon as possible.

The next chapter, chapter 2, will cover the methodology to be able to answer the research questions. Chapter 3 will focus on the theoretical framework covering the background of the problem. In chapter 4 the results are summarized, while chapter 5 and 6 deal with the discussion and conclusion respectively.



## 2 METHODOLOGY

The points mentioned in the introduction make clear the current situation needs to be improved to a certain state to-be. This difference in as-is and to-be situations characterizes this problem as Design Science (Wieringa, 2013), which will follow the regulative cycle by van Strien (1997). Furthermore, this chapter deals with the overall project methodology as well as the individual thesis methodology.

### 2.1 DESIGN SCIENCE

The type of problems the LTHN sketches have a typical design science nature; the LTHN aims to create an artefact (an information product) to move from the current as-is situation to a new desired situation where the new information system is in use. According to Hevner, March, Park & Ram (2004) design science aims at the creation of an artefact to change the current situation to a new desired situation, which is exactly the case here. Within the design science framework, two more specific types of problems occur: type 1 or type 2 problems (Balsters, 2014). Type 1 problems aim to improve an existing context (e.g. Electronic Health Record system) which leads to a new theory or results. The type 2 problems focus on the experimentation of building systems and validate design principles with the end users or experts in the field (Balsters, 2014). Since this project will first experiment with constructing information product blueprints and validating it accordingly, this problem is characterized as a type 2 problem. Reviewing the first couple of questions within the BPMN-ORM methodology (also see chapter 3) confirms once more that we are dealing with a design science problem, as it covers the stakeholders and their Critical Success Factors (or CSF's); the factors required to make the system a success as perceived by the stakeholders (Balsters, 2014).

### 2.2 REGULATIVE CYCLE

Now that the problem has been characterized as a design science problem, the regulative cycle of van Strien (1997) can be used (see figure 2). This cycle strives to minimize the gap between science and practice as Wieringa (2007) states that design science deals with practical-knowledge

problems: moving from an undesired old or current situation to a new desired one.

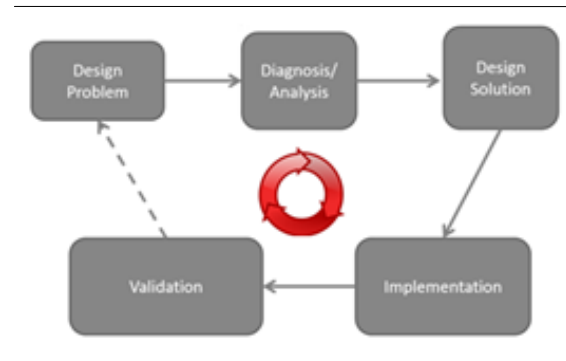


Figure 2 Regulative cycle by van Strien (1997).

Balsters (2014) has elaborated more on each of the phases presented in figure 2.1. His phase expansions contain multiple focus points and questions that should be answered in each phase to be able to continue to the next. These phases and their expansions are described as follows based on Balsters (2014) and Martena (2015), and form the backbone of this research:

1. **Design problem:** This first phase focuses on analysing the context of the problem. The main goal here is to identify the stakeholders, their goals and the critical success factors (CSF's). Critical success factors are those factors that define the success of a project for a certain stakeholder (Balsters, 2014).
2. **Diagnosis/Analysis:** The second phase of the cycle by van Strien (1997) focuses on identifying the causes for potential difficulties that occur when resolving the critical success factors. Also the quality attributes are checked, like price, speed and safety of the system. The final part in this phase is to identify a potential order dependency of the critical success factors.

3. **Design solution:** As the name of the phase already describes, the aim here is to come up with a solution. Can alternative solutions be used or reinvented? Are there alternatives?
4. **Implementation:** Realization of the artefact under design. For this individual thesis this will be done by generating the information product blueprints.
5. **Validation:** To validate the information product blueprints, it is presented to the end-users. When something is missing (stakeholders not satisfied), the cycle starts over, hence the iterating nature, to improve the artefact any further.

As this individual thesis is concerned with the construction of the information product, the main phases involved here with respect to the overarching project, will be the Diagnosis/Analysis (phase 2) and Design solution (phase 3). For this specific individual thesis, also a smaller local regulative cycle will be applied according to figure 3.

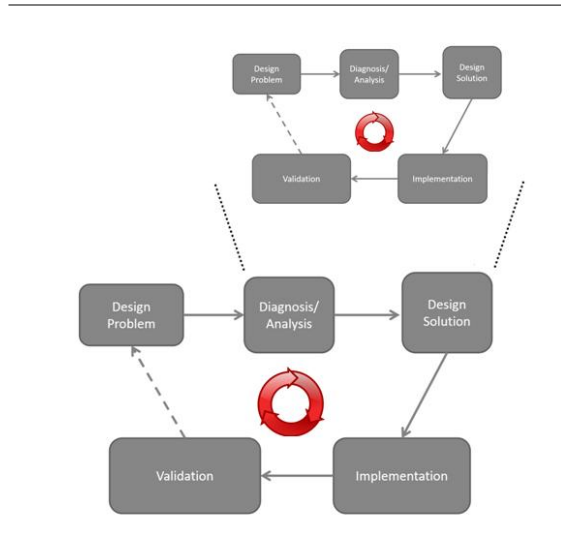
### 2.3 FROM BPMN TOWARDS INFORMATION PRODUCT BLUEPRINTS

This specific thesis focuses as said on the transition of BPMN-models to ORM-diagrams and thereby generating the database blueprints. It is performed according a local regulative cycle.

The following four steps for executing this creation of information product blueprints are formulated below, based on the theoretical framework (see chapter 3) and Martena (2015):

1. Understand the Universe of Discourse (UoD);
2. Design ORM-diagrams based on preliminary BPMN models;
3. Designing final ORM-diagrams based on end-user validated BPMN models;
4. Critically review the BPMN-ORM methodology.

Each step can be lined along a phase from the local regulative cycle.



**Figure 3** Smaller regulative cycle within.

#### 2.3.1 DESIGN PROBLEM

The main issue for this individual thesis is how can BPMN-models be translated to ORM-diagrams. To be able to derive the data models from the process models, as the first step of Martena (2015) points out, understanding the Universe of Discourse is essential as a understanding of the business processes is key to be able to work towards a successful design. In order to gain this understanding, the interviews held by Meerman (2015) and Lichtenberg (2015) with stakeholders and specialists to come up with the BPMN-models and validation are joined. Additionally interviews will be held with the technical specialists to derive their critical success factors concerning the transition of BPMN towards ORM.

#### 2.3.2 DIAGNOSIS/ANALYSIS

As Balsters (2014) and Martena (2015) stated the second step of the regulative cycle is to identify the causes of difficult and further analyse the determined CSF's from step 1. This is done in here, the CSF's of the technical specialist



with respect to the ORM-diagrams will be interpreted and taken into account for the further development of the ORM-diagrams themselves.

### 2.3.3 DESIGN SOLUTION

The second question from the framework of Martena (2015) is to design the Object-Role Modelling (ORM) diagrams, based on preliminary Business Process Modelling Notation (BPMN) models. The first BPMN model will be of the general process, representation on a high level. As time progresses and more BPMN models will be developed in detail, the nested processes are transformed into ORM diagrams to gradually incorporate them within the general process. The transformation is performed by the roadmap from Balsters (2013) discussed in chapter 3.5 and will be iterative of nature. This means that if the BPMN models are updated with new information, the ORM diagrams have to be updated as well. The ORM diagrams will be finalized based on validated BPMN models.

### 2.3.4 IMPLEMENTATION

The general process and the nested (sub)-processes in BPMN from Meerman (2015) will be translated to ORM-diagrams and eventually all these diagrams will generate their respective information product blueprint accordingly.

### 2.3.5 VALIDATION

The final step in this information product blueprint process, is to critically assess the Balsters (2014) BPMN-ORM methodology as proposed by Martena (2015). The inputs of the theses of Meerman (2015) and Lichtenberg (2015) will also be used to assess the methodology. Martena (2015) formulated the following review questions for the methodology:

- Are questions formulated clearly and correctly?
- Is the order of questions correct?
- Are there questions that can be combined?
- Are there questions that need to be included?
- Are there questions that can be excluded?

After the ORM diagrams are finalized and the information product blueprint is created, it will be validated with the

technical specialists. They are interviewed once again: are their CSF's met? Is it a useful representation to eventually be able to realise the database blueprints towards a real new information structure? Those are typical questions to address in this final phase. In case they are not satisfied, the local regulative cycle will start over to make sure they will become (more) satisfied in the new iteration.

This research will contribute to the scientific knowledge in the sense of a practical validation of the framework from Martena (2015) as presented in table 2.1. Furthermore, the Business Process Modelling Notation-Object Role Modelling (BPMN-ORM) methodology for the translation of BPMN towards information product blueprints design is reviewed due the usage in a practical setting. Moreover, due the generic character of the Head and Neck Oncology clinical pathway in the case of a successful project the method can be further applied on more similar clinical pathways and Oncology departments at other hospitals.

Concerning the overarching project cycle, the validation part is mainly treated in Lichtenberg (2015). When parts are missing or modelled wrong, the ORM model is incorrect and/or the corresponding BPMN model from Meerman (2015) is. Then the overarching regulative cycle starts over again into an subsequent iteration, until the models are correctly validated.



### 3 THEORETICAL BACKGROUND

This chapter will treat the theoretical framework of this thesis as already (partly) discussed within the methodology section. The following elements will be discussed in more depth to serve a better understanding of the methods presented in chapter 2:

- Business Process Modelling Notation (BPMN) as that is the main language to communicate the process of the Head and Neck Oncology department at the LTHN.
- Concurrent Engineering due the fact this project consists of several parts with each its own focus but serving the common goal within the same time window.
- Object-Role Modelling (ORM) as that is the main modelling language to map the relationship between the involved objects and what roles they play. These generated models will be used to derive the information product blueprint that is requested, based on the process models in BPMN from Meerman (2015).
- BPMN-ORM methodology as that is the main guideline of translating the specific BPMN-models from Meerman (2015) into ORM-diagrams. How patterns within BPMN will be modelled into ORM is discussed here.

Cycle times as those will also form an essential role within this overarching design project. What will be the used definition of cycle time here?

#### 3.1 BUSINESS PROCESS MODELLING NOTATION

A LTHN is like no other organization and for any organization as stated by White (2008):

*"All organizations are on a journey- a never ending voyage where the focus is on improving how things are done (however that is measured) for the benefit of shareholders,*

*stakeholders and or/profit. This notion is at the heart of Business Process Management (BPM); a way of thinking, a management philosophy centered on improving the operational processes of the organization. Wherever one looks, it is easy to find any number of articles or books that direct firms to engage in operational innovation (with the objective of overwhelming the competition). And yet, all of these examples have one thing in common- an underlying emphasis on understanding the business processes of the firm in order to improve them. One could argue that this is a fundamental principle of management discipline."*

The focus within this thesis is to construct blueprints for an information product for the benefit of the stakeholders, shareholders and profit. Also, the management philosophy is aimed on improving the operational processes of the LTHN by means of this information product. From this perspective, the notion of how the processes work is key. But why use the BPMN notation? Recker (2010) states that BPMN has basically become the standard for graphical process modelling. In the paper of Chinosi and Trombetta (2012), this statement is supported as BPMN is now an internationally accepted (ISO) standard for the representation of graphical business processes. It is a widely accepted notation and makes the processes both easier to understand for end-users and IT and is easier to communicate (Balsters, 2014).

BPMN uses various elements to represent processes (Balsters, 2014):

- Flow objects (tasks, gateways and events);
- Data objects (e.g. paper);
- Connections (arrows or dotted lines);
- Pools (rectangles representing e.g. an organization, company or division);
- Lanes (rectangles within pools: the departments or different stakeholder participating in the process);
- Artefacts (text annotations that provide additional information regarding objects).

The notation of BPMN will be more visualized by means of an example (see figure 4).



**Figure 4** Process description in BPMN (White, 2008).

The process starts on the left side (circle with the green border) after which the process is initialized. The first step will be to "Receive Credit Report" after this is received, the credit report will be checked for "Approval". It then enters an (Exclusive)-Gateway, either one of the two paths can be taken, as the payment cannot be yes and no. Only one path will be progressed with for a single case and after the required consecutive steps, the process is terminated at the circle with the bold red border. These constructed BPMN models will serve as an input for the creation of the ORM-diagrams and information product blueprints.

### 3.2 CONCURRENT ENGINEERING

It is also stated this thesis concerns the second part of a larger overarching project. Together with Meerman (2015) and Lichtenberg (2015), the DCMs, eMeasure and information product blueprints will be generated and validated by the end-users. This entire overarching project is not performed consequently but concurrently most of the time, entering the domain of concurrent engineering.

In the design of complex products (such as cars, aerospace systems, software, or industrial equipment), individual components are designed separately, but influence one another (Loch, 2003). From the paper of Koufteros (2001), uncertainty and equivocality will be reduced due the fact successful firms employ organizational designs that deal effectively with occurring changes in the competitive environment. They have reorganized the product development from a static sequential process to a concurrent process. Phases as marketing, product- and process engineering,

manufacturing, planning and sourcing activities overlap (Wheelwright and Clark, 1992; Clark and Fujimoto, 1991; Susman, 1992; Mansfield et al., 1971; Clark, 1989). The essence of such a concurrent approach is a cross-functional team where team members coordinate problem solving efforts to improve product innovation and enhance quality (Koufteros, 2001). The team who will be executing this overarching project is also cross-functional by nature, as IT-specialists will be working beside medical administrative personnel, medical specialists, (information) architects and consultants.

Concurrent engineering rests on several principles, some of them are the following (Yassine, 2003):

- **'Iteration' principle:** First, designers are only human and have bounded rationality. From humans it is simply impossible to simultaneously consider every relevant aspect of any given design. Secondly, design systems are limited: no known system is derived directly from a set of requirements that yields the optimum design in one go. The real world often responds differently than imagined, man has to anticipate.
- **'Parallelism' principle:** Complex system must be highly parallelizable if a short development is demanded. From another perspective, otherwise valuable development times and resources will be wasted. Multiple developmental stages have to be performed with (some) overlap by sharing preliminary upstream information with downstream stages.
- **'Decomposition' principle:** Complex system mostly require to be decomposed into several simpler subsystems which can be controlled independently, while maintaining the individual behaviours yield the performance of the original system. Decomposition is also intended to serve for parallel execution by breaking the whole into a number of these simpler subsystems. In complex product development, processes are generally split up into tasks and subtasks. Proper decomposition of design development tasks is concerned with assigning into the same team tasks that are anticipated to require high problem-solving inter-

action, while assigning to different teams tasks that require low problem-solving interaction.

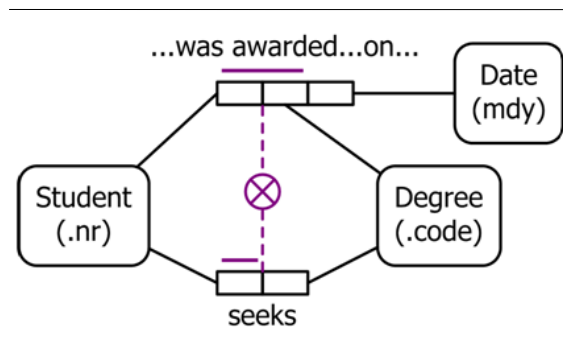
- **'Stability' principle:** The system is said to be stable if the state of the system converges to one of the equilibrium states for any initial conditions. A product development process is said to be stable if the total number of design problems being solved remains bounded as the project evolves over time, and eventually falls below an acceptable threshold within a specified time frame. As implied by the iteration principle, design iterations result in changes that must propagate through the design stages, requiring upstream rework. This additional rework might slow down the PD convergence or have a destabilizing effect on the system's behaviour.

These principles will be applied within this overarching project. As many steps that will be undertaken shall need some revision (iterations) to eventually derive towards the (near-) optimal solution as desired by the end-users. Within this team of diverse specialists everyone has its own task -hence the decomposition- where Meerman (2015), Lichtenberg (2015) and the modeller will be working in parallel with some parts overlapping to maintain interdependencies between the different subjects to aim for an end product as a whole. The stability is eventually achieved when the system will return the exact same answer on different moments in time for the exact same initial conditions.

### 3.3 OBJECT-ROLE MODELLING

Object-Role Modelling (ORM) is the proposed modelling language to use. ORM views the world in terms of *objects* playing *roles* (Halpin & Morgan, 2008). In contrast to the other modelling languages, this language allows facts and rules to be verbalized in an even for non-technical domain experts understandable language. In contrast to Entity-Relationship (ER) modelling and the Unified Modelling Language (UML), ORM treats all facts as relationships and its models are attribute-free (Balsters, 2013). As can be seen in figure 4, the model is unambiguous and requires only little knowledge of the domain expert to understand the model, hence it is intuitive to comprehend. The picture relates the objects "Student", "Degree" and "Date" by the

relationships *...was awarded...on...* and *seeks* represented as ternary and binary fact-types respectively. Also a single box relation can occur, this is called a unary fact-type. The figure is read as "a Student seeks a Degree" and "a Student was awarded a Degree on Date". The dashed line with the circle filled with a cross means that that combination of "Student seeks Degree" and "Student was awarded Degree..." are mutually exclusive, which makes sense as while one is studying they cannot be awarded with the degree they are currently working on. This is called an exclusion constraint. If the cross is replaced by an equality sign (=) it is an equality constraint. The purple bars above some of the boxes within the relationships mean for example, "1 Student seeks Degree" and " 1 Student was awarded 1 Degree on Date" which are the uniqueness constraints. Purple dots on the connections (not displayed here) are mandatory constraints, pointing out the cardinality is at least 1.



**Figure 5** Example of an ORM-diagram (<http://www.orm.net/overview.html>).

Next to this, ORM models are more stable under a changing business domain and often capture more business rules in diagram form (Halpin & Morgan, 2008). Typically, the design of an ORM model is done according to the Conceptual Schema Design Procedure, or CSDP. This procedure contains the following seven steps (Halpin, 2001):

1. Transform familiar information examples into elementary facts, and apply quick checks;
2. Draw a draft diagram of the fact types and apply a population check;
3. Check for entity types that should be combined, and note any arithmetic derivations;
4. Add uniqueness constraints, and check arity of fact types;
5. Add mandatory role constraints, and check for logical derivations;
6. Add any value, set comparison, and subtyping constraints;
7. Add other constraint and perform final checks.

As Martena (2015) validated the BPMN-ORM Methodology as discussed next, which is a recent developed methodology to translate BPMN to ORM models within the context of the same LTHN so this project focuses on the use of ORM. It will not focus on other modelling methods as Entity-Relationship (ER) modelling or the Unified Modelling Language (UML), due the fact it will be a more specific application of the methodology stated in Martena (2015) which mainly uses ORM as the information product modelling notation.

### 3.4 BPMN-ORM METHODOLOGY

The translation of process models to data models will be performed by means of the BPMN-ORM Methodology as constructed by Balsters (2013) and validated by Martena (2015). This approach consists of the following 12 steps (Martena, 2015):

1. What is the event we are addressing?;
2. Which stakeholders are involved?;
3. What are the stakeholders goals?;
4. What are the Critical Success Factors (CSF's) for each stakeholder in the context of this event?;
5. Which objects are involved in the event as participants?;
6. Which fact types are the event and participants engaged in?;
7. Which constraints pertain to these fact types?;
8. How do we identify the event and participants?;
9. What are the input events for the particular events?;

10. What do we have as output values of the event?;
11. What are the associated business rules for these outputs?;
12. How can we validate our model?

The questions in this list are called 'Fact-Type Identification' or FTI questions. Balsters (2013) also has a roadmap for modelling ORM diagrams. This roadmap consists of six steps and will be used as a guideline for this individual thesis:

1. Transform a BPMN task into a desired ORM-event;
2. Find a minimal model that realizes that event using our fact-type identifying questions;
3. Transform the next BPMN task into a subsequent ORM-event;
4. Find the minimal extension to the previous ORM model that defines that subsequent ORM event;
5. Repeat steps 1-4 until all events for all data stakeholders are finished;
6. In the end you will have created the complete corporate information product, associated to the original business process.

After completing the previously mentioned steps of the roadmap, the information product blueprints are created and, after the initial validation of the technical experts, has to be validated by the end-users at the LTHN as well. This validation is the main concept of Lichtenberg (2015).

### 3.5 DEFINITION OF CYCLE TIME

As the goal stated in the methodology section (chapter 2): *"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"*, a clear definition of cycle time is essential. Within Operations Management literature many definitions of cycle time are distinguished. As mentioned and applied by Meerman (2015) in his part, the definition of Hopp & Spearman (2011) on cycle time will be used in this overarching project (so for this individual part as well): The cycle time of a process in the Head and Neck Oncology clinical pathway is measured from the time when the process starts until the process is completed. The total cycle time of the entire

process is the sum of its individual processes. A more detailed explanation on the decision to apply this definition is discussed in Meerman (2015).

This last paragraph concludes the theoretical background. In the next section the results will be presented after which the discussion and conclusion(s) will follow respectively.





## 4 RESULTS

In this chapter the creation of the ORM-diagrams based on the BPMN-ORM Methodology will be discussed. The first two sub-questions derived from the common goal of designing an information product are the following:

1. *“How can technical validated BPMN models be translated to a technical validated information product blueprint?”*
2. *“How can the current information product design method aid in the analysis of cycle times of patients?”*

The following sections will discuss the way towards answering these two sub-questions in a point wise manner as stated in the methodology section (chapter 2).

In this figure 6 the several stakeholders involved are defined as well as their activities that play a role in this clinical pathway. Also several sub-processes are defined: Conduct Preliminary Diagnosis, Conduct MDS, Request Additional Information

Information and Conduct MDO. For more detailed information on these sub-processes, see Meerman (2015). This model is the starting point for the development of the ORM-diagrams where the stakeholders, activities and sub-processes are modelled into ORM and eventually will (partially) replace the figure of the Universe of Discourse.

### 4.1 UNDERSTANDING THE UNIVERSE OF DISCOURSE (UoD)

The main scope of the Universe of Discourse for this individual thesis at the clinical pathway Head and Neck Oncology is from the first polyclinic visit towards the final diagnosis - and thereby the development of a definite treatment plan - of a patient.

The Universe of Discourse is represented in figure 6 and is an overview of the general process at the clinical pathway Head and Neck Oncology. This overview is based on interviews with the stakeholders and gains more insights in the overall process at this clinical pathway. The exact definition of this Universe of Discourse is performed by Meerman (2015).

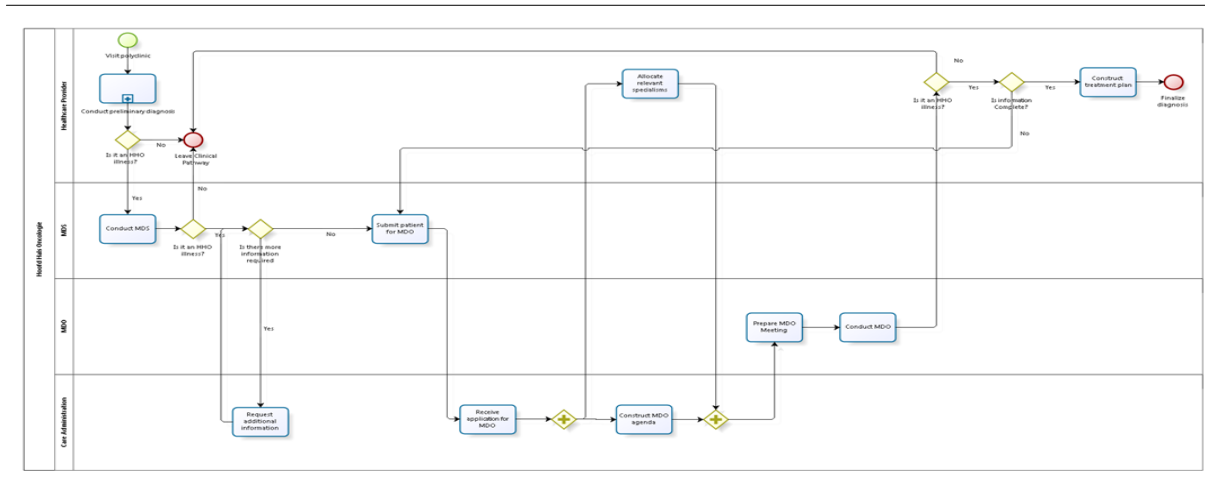


Figure 6 Universe of Discourse (Meerman, 2015).

## 4.2 DESIGN ORM-DIAGRAMS BASED ON PRELIMINARY BPMN MODELS

At first a black box approach is used to gain an initial insight of the clinical pathway and model this in the first BPMN-models. These very first BPMN-models are translated into initial ORM-diagrams. As time progressed, more and more insight is gained incrementally due more interviews and feedback which lead to more detailed BPMN-models which in turn lead to more detailed ORM-diagrams to be created. Due the iterative nature of this process, the intermediate ORM-diagrams are not included in this thesis. Only the final ORM-diagrams are shown in this thesis and can be found in appendix I.

The ORM-diagrams of the sub-processes are created as sufficient information on their internal structure is obtained, as their initial structure is not of great importance for the eventual derivation of cycle time. The start- and end times are the main indicators for the cycle time of each activity and therefore the total cycle time of the entire clinical pathway.

## 4.3 DESIGN ORM-DIAGRAMS BASED ON END-USER VALIDATED BPMN MODELS

The creation of these final ORM-diagrams is based on the 12 Fact-Type Identification questions from Martena (2015) and the roadmap of Balsters (2013). Four assumptions underly this creation process:

1. Only strictly one patient enters and flows through the Universe of Discourse (e.g. no couples, children and their parents etc.) accompanied with their corresponding patient file;
2. All activities and checks have mandatory instants (timestamps);
3. These instants (timestamps) are recorded automatically;
4. The patients enter the clinical pathway with a certain concern and the information gained

throughout the entire clinical pathway is updated and filled within the (electronic) patient file.

These timestamps are most crucial as those eventually define cycle time. As from section 3.5, the total cycle time of the entire clinical pathway is the sum of the individual processing times of all the activities. This points out their necessity and such this assumption has been formulated. Furthermore, to gain the best possible realistic view it is assumed the process steps are performed (partly) digitally by e.g. modifying or editing in the patient dossier which the computer tracks the instant at which this activity is performed. The first assumption regarding only one single patient mapped to the process is because if more than one patient is allocated to the same appointment (in case of e.g. child with parent which both want a diagnosis) this appointment may lead to different diagnoses. So the data is harder to allocate to the specific patient. All activities and data-elements concerning a patient track back to strictly one person only with only one patient file referring to that patient. In most practical cases this is already prevented by the healthcare provider due internal distinction between all involved patients, but for the consistency of this research this assumption is stated explicitly. The fourth assumption is that the patient file is used and filled with more information over time about the concern, the necessary data to fulfil the process steps and that input will eventually lead to the construction of a treatment plan.

### 4.3.1 ACTUAL DESIGN OF ORM-DIAGRAMS BASED ON BPMN

To provide more insight in the actual process of creating ORM-diagrams out of BPMN, based on the 12 Fact-Identifying questions, these questions are all discussed and elaborated on individually in this section. Recap of the 12 FTI-question (Martena, 2015):

1. What is the event we are addressing?;
2. Which stakeholders are involved?;
3. What are the stakeholders goals?;
4. What are the Critical Success Factors (CSF's) for each stakeholder in the context of this event?;
5. Which objects are involved in the event as participants?;

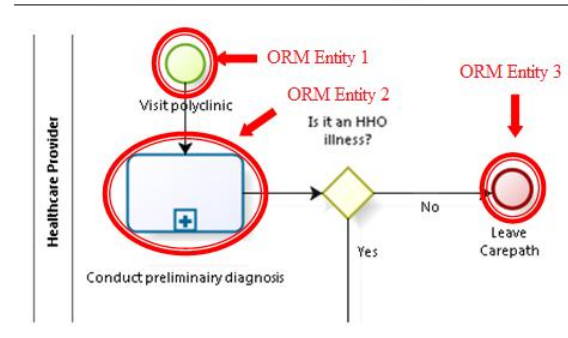
6. Which fact types are the event and participants engaged in?;
7. Which constraints pertain to these fact types?;
8. How do we identify the event and participants?;
9. What are the input events for the particular events?;
10. What do we have as output values of the events?;
11. What are the associated business rules for these outputs?;
12. How can we validate our model?

It all starts with the BPMN model. Then zoom in per activity and formulate transformation in terms of data to the next activity by using the BPMN-ORM patterns from Balsters (2014). Please note that there is a partial overlap regarding these 12 FTI-questions with Meerman (2015) and Lichtenberg (2015). The questions regarding the stakeholders, their respective goals, critical success factors (CSF's) and in- and outputs can also be found in their theses and BPMN-models. This thesis uses those answers and models as input for the creation of the corresponding ORM-diagrams. Meerman (2015) conducted semi-structured interviews to answer questions 1 to 5 and incorporate those results into the BPMN-models, while Lichtenberg (2015) used similar interviews to answer the questions 11 and 12 to verify and validate the generated ORM-diagrams and thereby also the BPMN-models accordingly.

Each of the 12 FTI-questions is now discussed individually focusing on explaining what is precisely done, together with further insights how specific parts within BPMN are modelled into ORM. The points of interest are marked with red circles.

*Question 1: "What is the event we are addressing?"*

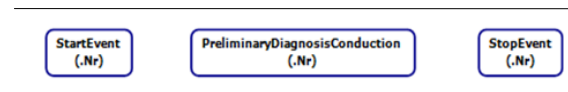
As with every process or activity, it needs a starting point. In BPMN a process start (start event) is modelled as a green circle. In this case the process starts with a visit at the polyclinic. This is defined as the first entity (or data-object) in ORM. Then the arrow continues to the blue box with rounded edges and a '+'-sign. This is an activity or process, which is the actual event we are addressing. The '+'-sign indicates it has a deeper internal structure (sub-process) which is also called a nested process. This is the second ORM entity to model.



**Figure 7** Identifying ORM entities in BPMN.

The third entity occurring in this figure is the red circle, the stop event 'Leave Carepath'. To get from ORM Entity 2 to ORM Entity 3 is not as straightforward as from ORM Entity 1 to ORM Entity 2. This is because it has this diamond-shaped question in between. This is called an Exclusive Gateway in BPMN, which will become another entity but more on that later on. Only one of the possible outcomes of the proposed question can be true and that corresponding path has to be followed. More on gateways will be discussed at a later question.

So in this picture there are already three ORM Entities: The start-event, the activity-event and the stop-event. They are given in ORM as follows:



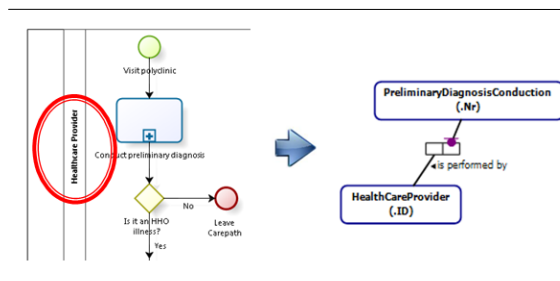
**Figure 8** Entities in ORM.

The 'Conduct Preliminary Diagnosis' activity is now written in the format of Noun and Objectified-verb according to Balsters (2014) as the information product uses data-objects. The unique identifiers in brackets underneath the name of the entities are numbers (.Nr) as it are process steps performed in a certain ascending order (see question 8).

The BPMN-ORM Methodology focuses on the flow from event to event to be modelled in ORM. How to get from event to event, or in ORM terms: How to get from one entity to the next (event-transitions)? Each such step is modelled as a separate ORM-diagram.

*Question 2: "Which stakeholders are involved?"*

Swimlanes in BPMN represent the stakeholder of the activity. The stakeholder in the swimlane is the person or department that is responsible for performing that activity. Looking at the same figure 4.2 again, the stakeholder in this case is the Healthcare Provider. As the stakeholder is the one responsible for a correct performance of the activity, the activity-entity in ORM has to be performed by the stakeholder. This is modelled in figure 9.



**Figure 9** Stakeholder and activity in ORM

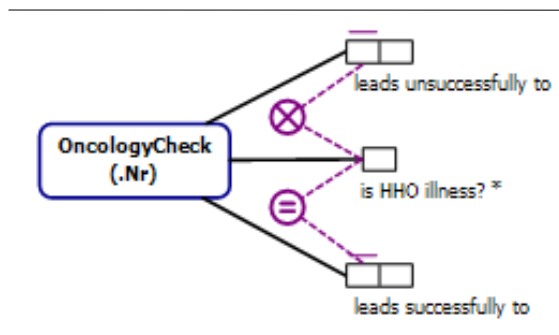
*Question 3: "What are the stakeholder goals?"*

The goal of the Healthcare provider within the scope of this clinical pathway is to diagnose a patient with an HHO illness and to eventually come up with a solid treatment plan in the least possible amount of time. This question is asked to all the stakeholders with respect of the objective of the system to derive cycle times. For a more detailed overview of all the stakeholders, their goals and CSF's please refer to the thesis of Meerman (2015).

*Question 4: "What are the CSF's for each stakeholder goal in the context of this event?"*

As already briefly mentioned in question one, the Exclusive Gateway forces some check to get from ORM Entity 2 to ORM Entity 3 or continue through another pathway. This Exclusive Gateway in BPMN is a CSF for the stakeholder.

Here in figure 6 with the Healthcare provider conducting a preliminary diagnosis, the CSF is to check whether the patient actually has an HHO illness. This is in ORM translated to a unary fact-type (section 3.4) where the outcome is either true or false, of which the data continues in one path or the other according to the exclusion or equality constraint.



**Figure 10** CSF Gateway in ORM.

So the CSF for the stakeholder is to check whether he or she has a suspicion of an HHO illness of the patient. This decision leads to either a stop-event entity (in case of unsuccessful) or the next activity entity (in case of successful). From the Universe of Discourse of Meerman (2015), the next event in the successful scenario is the conduction of a MDS or 'MDSConduction' in ORM terminology. This way the figure 10 can be extended to the following:

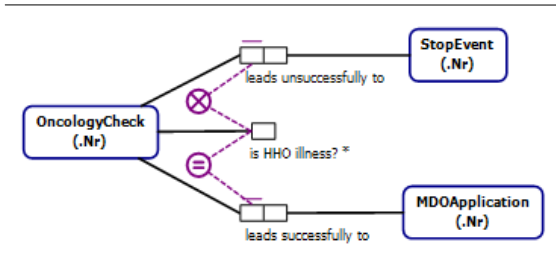


Figure 11 Gateway and its successors in ORM.

This is the ORM translation of a single gateway. Looking at the Universe of Discourse more closely, two gateways right after each other can occur as well. These double gateways require a bit more extensive translation. The first double gateway that occurs is between 'Conduct MDS' and 'Submit patient for MDO'. The decisions to be made between them read another 'OncologyCheck' and a request for additional information. The way these double gateways are modelled in ORM is shown in figure 12.

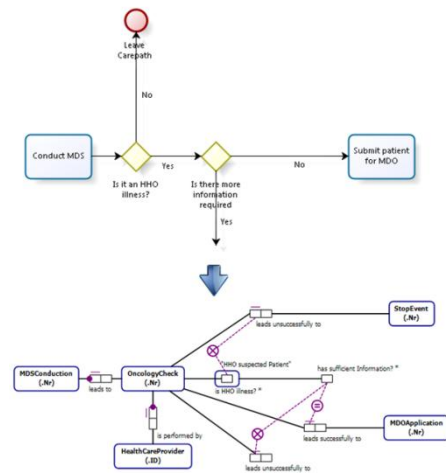


Figure 12 Double gateways in ORM.

At the 'MDSConduction' the first decision is to check whether it is still a suspected HHO illness, if that is indeed the case a certain population is generated at this first unary

predicate with all the patients of which it is still suspected their illness is within HHO. This population of suspected HHO Patients is objectified as an entity after which this population is asked the up following question if the HealthCareProvider has sufficient Information to continue the process to eventually apply the patient for the MDO. This is an example of a mapping from activity to activity from BPMN to ORM.

Question 5: "Which objects are involved in the event as participants?"

ORM is the abbreviation of Object-Role Modelling which means it is all about objects (entities) and their relationships (hence Role Modelling). Objects are the rectangles with the rounded edges as seen before. ORM is all about the relationship or transformation from one entity to the other and the data needed to fulfil this. The exact formulation of the required data to be able to perform this transformation is also discussed in Meerman (2015). What is the output of an activity and is transformed in what way to perform the next activity? Those are the objects needed. Take again the example of the step from 'Conduct MDS' to 'Submit patient for MDO'. The objects displayed in figure 12 are needed to perform this transformation. Some are already known from the previous question, others are new.

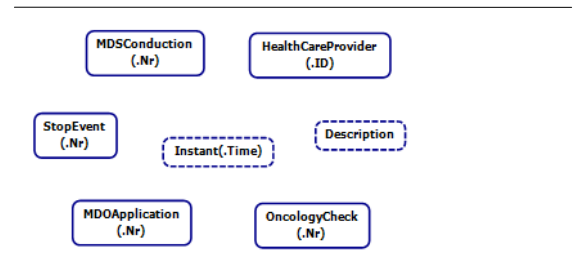


Figure 13 Building blocks.

The entities were already known, the new ones are the dashed rectangles. They represent value-types. As their name suggest they only hold values. Description is identified as a text-file with variable length. The Instant(.Time) is very crucial here as that value is the determinant of the cycle time of the particular interest. Instant(.Time) is given

the data-type of Temporal: Auto Timestamp as the actual time of performance is the point of interest which this data-type generates.

*Question 6: “Which fact types are these participants engaged in?”*

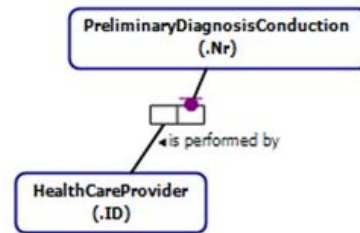
A fact-type is the connection between entities and/or values or as Halpin & Morgan (2008) state: “a fact type is a kind of fact that happens in a business domain”. Each stakeholder performs certain activities which generates the fact-type 'Activity is performed by Stakeholder'. From Balsters (2014) each Start- and StopEvent entity has a description value-type, so 'StartEvent has Description' and 'StopEvent has Description' can be formulated. As the focus point is to derive cycle times, the essence lays in the Instant(.Time) of each entity. So the most crucial facts types are the 'Entity begins at Instant(.Time)' and 'Entity ends at Instant(.Time)' on the assumption that the activity is logged on the moment of performance.

*Question 7: “Which constraints pertain to these fact types?”*

In all the figures displayed above, purple dots and thin purple bars are above all the fact-types. Those are called constraints. According to Halpin and Morgan (2008), there are various types of constraints in ORM. The most important constraints that are used in this research are mandatory-, uniqueness-, equality- and exclusion constraints.

The purple dot indicates the mandatory constraint (e.g. it *must* lead to the next event), while the thin purple bars are the uniqueness constraints. From assumption two that every activity must have a logged timestamp these fact-types are incorporated with mandatory constraints. The uniqueness constraints state the combinations possible in the database: A certain patient may have one appointment with a health care provider but a health care provider can have multiple appointments with multiple patients etc.

Lets view again the Health Care Provider which performs the Preliminary Diagnosis Conduction. A Health Care Provider *must* perform Preliminary Diagnosis Conduction.



**Figure 14** Mandatory and uniqueness constraints.

To check the mandatory and uniqueness constraints, the NORMA-tool has a Verbalization Browser to check the created model and the corresponding fact-types between the entities:

PreliminaryDiagnosisConduction is performed by HealthCareProvider.  
 Each PreliminaryDiagnosisConduction is performed by **exactly one** HealthCareProvider.  
**It is possible that more than one** PreliminaryDiagnosisConduction is performed by **the same** HealthCareProvider.

PreliminaryDiagnosisConduction is performed by HealthCareProvider.  
**It is impossible that some** PreliminaryDiagnosisConduction is performed by **more than one** HealthCareProvider.  
**It is impossible that some** PreliminaryDiagnosisConduction is performed by **no** HealthCareProvider.  
**It is possible that more than one** PreliminaryDiagnosisConduction is performed by **the same** HealthCareProvider.

**Figure 15** Verbal check within NORMA.

It translates the fact-type with its constraints as it is modelled to the verbal pronunciation, which the modeller can check if that is actually what is meant and it can be shown easily to the end-user as they immediately can validate if it is the correct representation of the fact-type. There are another two types of constraints which are regularly used in this research:

- Equality and
- Exclusion constraints.

These are mainly used to model the Exclusive Gateways. Taking a look at the modelling of a gateway again, these constraints show up. The OncologyCheck is performed and one arrives that conclusion that the answer is either a yes or a no. Only with a yes, so if it indeed is an HHO illness, the equality constraint shows that the process then successfully

leads to the MDSConduction. If the CSF test is unsuccessful the patient has to leave the clinical pathway by means of a StopEvent, which is modelled with the exclusion constraint.

*Question 8: "How do we identify the participants?"*

From question five, several different entities are distinguished. Between brackets the identification of the data objects are displayed, which is also known as their reference mode (Balsters, 2014). These references modes are identified during the semi-structured interviews held by Meerman (2015) and by the received corresponding data-objects (DCMs). As can be seen in figure 4.10 there are many various references modes for the variety of events, entities, checks and stakeholders. Take for example the 'HealthCareProvider'. He/she is identified by a unique identifier (.ID). At first a Healthcare provider is a person with a name, but has the risk of not being unique with first initial and surname. The same initial and surname can occur within the same hospital, while not referring to the same health care provider. That is the main reason of referring to 'HealthCareProvider' with his/her unique identifier. As the data-object building block (HealthCareProvider DCM) states: *The health care provider identification number is a number that uniquely identifies the health care provider.*

The processes from BPMN have their reference mode as a number (.Nr) in ORM. This because the fact every time the activity takes place it has a certain instantiation. If the process is initiated for the first time, the process is referred to as instant 1. For the up following patient the instant of that process becomes 2; it is the second time the process is initiated. So processes have instantiations which ascend in number order corresponding to that instantiation.

Checks are also referred to as numbers as these checks can also be seen as a process step like stated above. A gateway has an instant, input, output and a algorithm that determines the output. Again it is the instantiation used to uniquely determine what check is being referred to. The instants have a timestamp as reference mode, which is generated automatic (assumption 3) as a date (day, month and year) and time. Descriptions contain text fields of raw

variable text, so the essence of their description will be stated by a note next to the description in ORM:



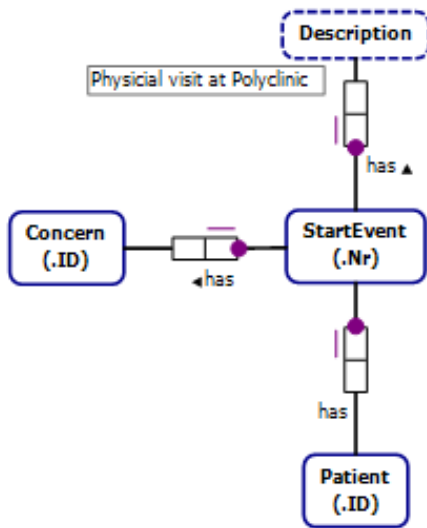
**Figure 16** Description and model note.

So when is concluded a patient is not suffering from a HHO illness he/she will leave the clinical pathway with the description that they do not suffer from a HHO illness (and probably are referred to another clinical pathway). In short, the stakeholders are identified by .ID, process steps and checks are identified by .Nr, instants are identified by time (date + time) and descriptions with raw variable text with a note in the ORM-diagram.

*Question 9: "What are the input events for the particular events?"*

Take the very beginning of the process, shown in figure 17 below.

The answer to this question can be derived from the Universe of Discourse by Meerman (2015). It can occur that a single event uses multiple events as input, or in the case of gateways that the successful path leads directly to the next event but the unsuccessful path leads to a follow up event which has to be performed to be able to lead to the particular event.



**Figure 17** ORM-diagram of the start event.

The StartEvent(.Nr) with a Patient(.ID), which has a certain Concern(.ID) and a description that the process kicks off with the physical visit at the polyclinic. So the inputs are a Patient with a certain Concern and a possibly also a description of this Concern from the referrer. This data will serve as the input for the PreliminaryDiagnosisConduction, which will further be treated throughout the rest of the process (aligned with assumption 4).

*Question 10: "What do we have as the output values of the event?"*

As from the previous question, the output values of an event can be a list of the relevant specialisms or a MDO agenda. The output of a previous event serves as the input of the next event and is discussed more extensively in Meerman (2015). Look at the activities 'Allocate relevant specialisms' and 'Construct MDO Agenda'. The outputs of these events in ORM are a MDO agenda and the relevant specialisms involved. Keep the following question in mind: "What does the event has to deliver?". This is the approach for all the events to transform BPMN into ORM regarding

this question. The inputs are also described more extensively in Meerman (2015).

*Question 11: "What are the associated business rules for these outputs?"*

In this overarching project an entirely new information product (artefact) is being build. That makes it hard to identify all the associated business rules. Within the semi-structured interviews and several meetings it became clear that the models and diagrams as being build must be according to Health Level 7 (HL-7), as that is the current set of standards used by the LTHN (Jaffe, Hammond, Quinn & Dolin, 2009). The second business rule is to ensure to conform to HL-7 standards, the ORM-diagrams must include the authorized personnel, or in the BPMN-ORM methodology, the stakeholders so they are indeed included in the final ORM-diagrams. In the meetings with the people involved in this overarching research from the LTHN, it is agreed to apply the terminology in the ORM- and BPMN-diagrams conform HL-7 to avoid confusion. This whole question list is repeated for all the activities and their transitions until the database was complete. The blueprints of the database, derived from the ORM-diagrams can be found in appendix II.

*Question 12: "How do we validate our model?"*

The verification of the model is done in several meetings with the people involved at the LTHN, the technical specialists and in correspondence with the supervisor. Also in the interviews that are joined with Meerman (2015) and Lichtenberg (2015) medical specialists provided guidelines towards a more and more realistic perspective of reality. The actual validation of the database blueprints with the end-users is the main topic in the thesis of Lichtenberg (2015). This is done by validation forms, or digital screens, to validate the correctness of the models and how they eventually indeed generate the accumulated cycle time as is desired.

#### 4.3.2 IMPLEMENTING THE DERIVATION OF CYCLE TIMES

The previous section dealt with all the details of the correct translation of BPMN-models to ORM-diagrams. The ORM-



diagrams are designed in such a way every activity its start and end times are logged by the mandatory fact-types begins at and ends at and their link to the Instant(.Time) value type. These are indirectly related to the derivation of cycle times, as the cycle time is the difference between the end instant (in date and time) minus the start instant (in date and time) (section 3.6). Take a look at the ORM-diagram of the transition from 'Submit patient for MDO' (MDOSubmission) to 'Receive application for MDO' (MDOApplicationReceiving) in figure 19.

Many of the constraints as discussed are in this model, together with the stakeholders performing each event. Both MDOSubmission and MDOApplicationReceiving start and end at a certain Instant(.Time), which now define the value-type CycleTime in the bottom middle of the figure. It is not a separate value-type, but a derived value-type which is indicated by the asterisks (\*) in the fact-type (has \*). The start and end times together define the CycleTime as stated earlier by subtraction, which the database then derives based on those values. It basically means the database keeps track of the cycle time of each event as defined by their start and end times. Important note is that the gateway checks in ORM not necessarily occur at the same time instant as their preceding activity. After the information is produced it can be stored and used in a later instant to eventually perform the check. This means the checks also have their own fact-type with 'Check is at Instant(.Time)' whereas the time between the end instant of the preceding activity and this instant of performing the check can also be a significant contribution to the total cycle time. The database is with this modelling capable of also tracking the time between finishing the preceding activity and the moment of finishing the checks after which the succeeding activity can take place. Besides the CycleTime, there is another value-type in this figure. That is AccumulatedCycleTime, again a derived value but with the slight adjustment that it not defines the cycle time of a single process, but as the name suggests, is the accumulated value of the cycle times up to that point. It is the sum of all the preceding events plus its own cycle time. As start and end times are formulated as date and time, the cycle time and accumulated cycle time derivation is performed in days, which makes decimal values still possible:

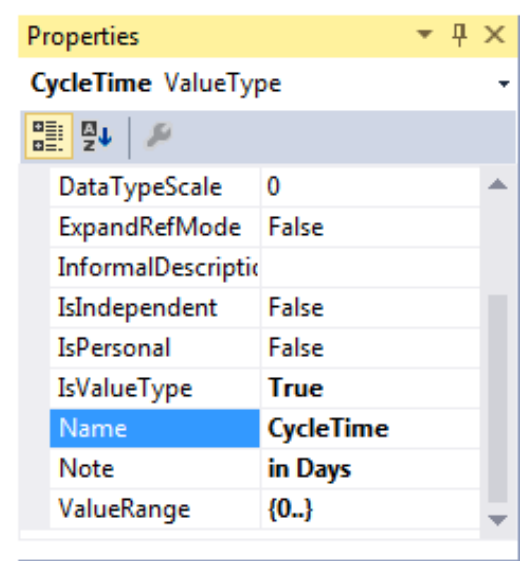


Figure 18 Properties of CycleTime.

The note points out that the unit of the numeric decimal value is in days, which can be zero and more. The same setup has been applied on the AccumulatedCycleTime value-type at every activity transition. For every transition except the last step to 'Finalize Diagnosis' this AccumulatedCycleTime is modelled with a derived fact-type (single asterisks \*), while at this very last 'Finalized Diagnosis' step the AccumulatedCycleTime is desired to be stored. Only at the very end it is the goal to give the total accumulated cycle time of the entire clinical pathway. This is represented with a derived and stored fact-type (double asterisks \*\*) as shown in figure 20.

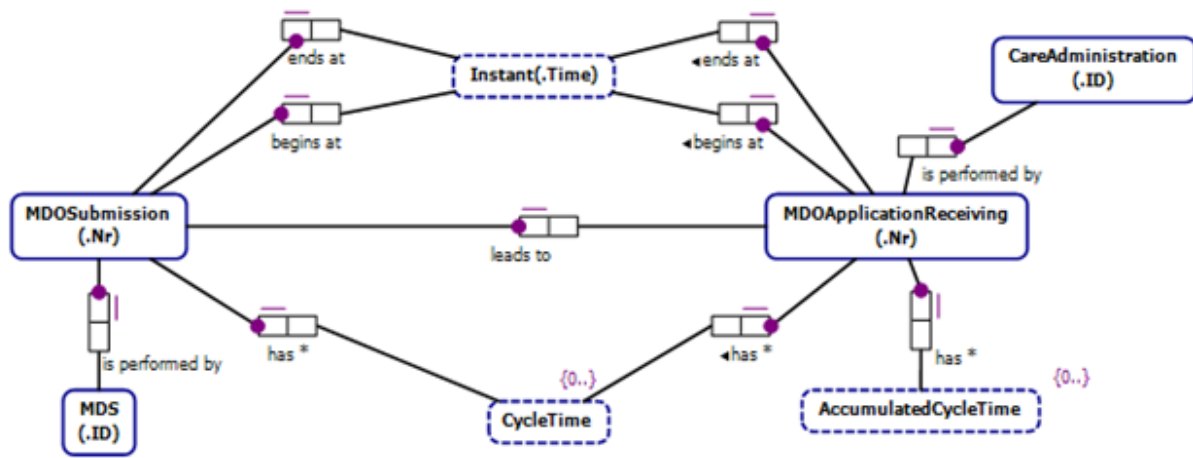


Figure 19 ORM-diagram of MDOSubmission to MDOApplicationReceiving.

26

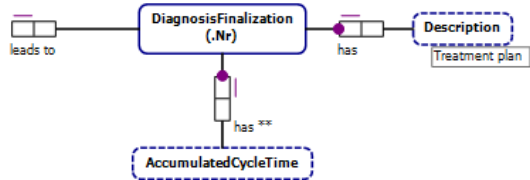


Figure 20 Derived and stored fact-type.

With the treatment plan ready the process within the scope of this research has ended.

#### 4.4 CRITICALLY REVIEW THE BPMN-ORM METHODOLOGY

The last step in the whole roadmap from BPMN towards an information product blueprint is to critically review the BPMN-ORM methodology (12 Fact-Type Identifying questions) of Balsters (2014) and Martena (2015). The review uses also the inputs and comments from Meerman (2015) and Lichtenberg (2015). It forms the answer to the third sub-question:

3. "How can the current information product design method be improved and generalized?"

The questions to review the BPMN-ORM methodology are (Martena, 2015):

- Are questions formulated clearly and correctly?
- Is the order of questions correct?
- Are there questions that can be combined?
- Are there questions that need to be included?
- Are there questions that can be excluded?

These will now be treated individually with their respective remarks. So, with respect to the first question ("Are questions formulated clearly and correctly?"), the modeller had no issues regarding the interpretation of the questions or how they should be tackled. The first question though ("What is the event we are addressing?") is sensitive to mis-interpretation as the BPMN-ORM methodology is concerning the *transition* of each activity to the subsequent one. That is the main reason this question is proposed to change towards concerning event-transitions instead of events themselves to point out once more the methodology is concerned with the flow from activity to activity. Overall the questions are easy to comprehend and intuitive to an-

swer for anyone with (minor) knowledge of BPMN and ORM. The meaning and the way to answer the questions are straightforward. However, after some external discussion the actual purpose of question three arose. Is it all about the stakeholder as in the swimlane or the external goal for whom the system is build?

Regarding the second question (*"Is the order of questions correct?"*), the modeller experienced an inconsistent flow from question to question. In meetings at the LTHN with the people involved it was pointed out that one of the first questions is to think of what goes in each process (inputs) and what they have to deliver as output, whereas these outputs form the inputs for the subsequent event. These input- output questions are opposed fairly late in the methodology (questions 9 & 10 respectively). As also stated by Meerman (2015), a black box approach was used initially and stays focussed on what comes in the event and what goes out. It is recommended to ask these questions 9 & 10 in the current situation earlier on the methodology. From this perspective of inputs- and outputs (and the BPMN) the transition of one activity to another can be mapped more easily. That is the main reason to oppose question 5 right after these input and outputs questions as those already define the transition together with the BPMN and such the objects involved can be defined. During the mapping of the stakeholders as performed by Meerman (2015) as his interviews were also joined, the reference to these data-objects were also raised in the interview so this question 8 about the identification of the event and participant can also move to an earlier stage in the methodology.

Another point was that the question 4 concerning the CSF's to be modelled in ORM already had to use constraints and fact-types which are not yet discussed according the current sequences of the questions in the methodology. So from this perspective move the questions concerning the stakeholders and their CSF's to a later position in the methodology.

For the third question (*"Are there questions that can be combined?"*) no questions were combined as for the interpretation it is most pleasant to work with single questions and no summation of several questions just for the sake of combining them. Take for example the current questions 9

& 10 about the inputs and outputs. It could be combined in *"What are the inputs and outputs regarding the event?"*. This is not recommended as one might miss the word *-and*, and such disregarding the outputs. It is far more pleasant and intuitive to use when these remain separate questions.

Looking at the fourth question (*"Are there questions that need to be included?"*) it has not ever been mentioned in the modelling process that there is any crucial question missing. The current questions cover the essence of the translation of BPMN to ORM so no extra question(s) are proposed to be included.

The last question in this review (*"Are there questions that can be excluded?"*) is the fact it can be answered with a yes: question 3 regarding the goal of the stakeholder in the process. It is a crucial part in the definition of the process and the entire goal of the design of the information product but it is further not taken into account in the exact translation of BPMN to ORM. The main answer for this question 3 of the methodology came down to view the thesis of Meerman (2015). So the contribution of this question is minimal. The goal has a direct relation with a CSF, as a gateway, which is indeed of importance in the modelling in ORM but the more upper layer on top of the CSF (the goal) is not.

As the main strategy of translating BPMN to ORM is to map the transition of activity to activity in a new ORM-diagram, with taking this and previous review into account, a new BPMN-ORM methodology is proposed. This is displayed below.

1. What is the event-transition we are addressing?;
2. What are the input events for the particular events?;
3. What do we have as output values of the events?;
4. Which stakeholders are involved?;
5. What are the Critical Success Factors (CSF's) for each stakeholder in the context of this event?;
6. Which (other) object types are involved in the event as participants?;
7. How do we identify the event, participants and stakeholders?;
8. Which fact-types are the event, participants and stakeholders engaged in?;

9. Which constraints pertain to these fact-types?;
10. What are the associated business rules for the particular events?;
11. How can we validate our model?

As can be seen, some questions undertook a slight modification as in this new sequence of questions it has to be clear what precisely has to be taken into account at that particular question. Question 10 regarding the business rules has also been aimed at the particular event now as at this research it was found that not only outputs can have business rules but there also exist more broad business rules to be taken into account within the project (e.g. the fact the terminology of the HL-7 had to be used). Also it was found that the authorized personnel had to be incorporated within the model, which is not only focussed on the output of an event but more on the event as a whole.

#### 4.5 CONTRIBUTION TO OVERARCHING PROJECT

The section above presented the results of the individual thesis and such the contribution to the overarching project by means of a local regulative cycle. With respect to the overarching project, the second and third phase of the regulative cycle are addressed: Diagnosis/Analysis and Design solution as figure 2.2 depicts. Now take a look at the bigger scope again, the specific focus of translating BPMN to ORM shifts to the contribution to the bigger whole: developing a system that can measure patient cycle time.

##### 4.5.1 DIAGNOSIS/ANALYSIS

The stakeholders and their CSF's are identified in the first step 'Design problem', which is the main focus of Meerman (2015). When analyzing these different stakeholders and their CFS's, the most important is again the CFS that the system shall be able to measure cycle times. Another particular CSF of interest is complying to the SONCOS regulations. 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 might be more stakeholders that have different interests. Possible difficulties with conflicting CFS's might occur.

##### 4.5.2 DESIGN SOLUTION

In this phase the strategy of choice was to come up with ORM-diagrams of which the database blueprints for the processes could be derived, because the technical specialists previously did such previous projects with UML which turned out not to be satisfactory. Furthermore, the frameworks of Martena (2015) was not validated. Those formed the main arguments to apply this methodology to this design project. The diagrams were non-existent in advance so all content creation is performed from scratch. The eventual database blueprints to shape the 'design solution' are all shown in appendix II.

## 5 DISCUSSION

This chapter will focus on the review of the used methods and the overarching design project as a whole while discussing their upsides and drawbacks. This chapter is divided in three parts: in the first part of the reflection will be on the results in ORM, the second section focuses on the methodology of Martena and the final subchapter will discuss the regulative cycle for such design projects.

### 5.1 REVIEW ON THE RESULTS IN ORM

The information product blueprints were created using ORM-diagrams of the process of Head and Neck Oncology in BPMN at the LTHN. ORM is a structured method to link all the data elements, but in this particular case, not many extra data elements occurred as was pointed out in the interviews of Meerman (2015) and Lichtenberg (2015) that were joined. The whole process under consideration here is aimed at gaining as much information as possible to eventually be able to come up with a solid treatment plan. An assumption was stated, as a patient with a concern entered the process, that this patient file and concern were taken through the entire process flow. So these data elements Patient(.ID) and Concern(.ID) were only mentioned at the start, after which these data files flow through the process where at every process step new information was updated in those files. Omitting these data elements in the other activity transitions benefitted the readability of the ORM-diagrams as some already became quite big due the double gateway constructions where every process step begins at, ends at and has a derived cycle time had to be included as well. It has to be pointed out that omitting them ensured a better readability but is not the best description of reality. So for further validation at Lichtenberg (2015) and eventual implementation this certainly has to be pointed out. ORM lacked the possibility to include a certain updatability option, because e.g. at the MDConduction step, the Patient(.ID) file that entered was more filled then at the beginning of the process. This cannot be shown systematically/schematically in ORM-diagrams.

Another crucial fact the modeller came across is that as the blueprints are aimed at the derivation of cycle times of pa

tients, cycle time in these ORM-diagrams require some interpretation. ORM also lacked the functionality to precisely point out what the actual cycle time at a certain moment in time has to be. These statements are currently included in the ORM-diagrams as model notes, e.g. the cycle time that has to be taken into account of the parallel paths of 'SpecialismsAllocation' and 'AgendaConduction' is the path that takes the longest cycle time only. This cannot be stated unambiguous in ORM, so the model note has to clarify this notion which is in turn sensitive to interpretation. Caution has to be taken to take the underlying calculation rules into account in this design.

### 5.2 REVIEW ON THE METHODOLOGY OF MARTENA

The methodology of Martena (2015) starts with the step to understand the Universe of Discourse (UoD). This is a rock solid step and was very important by joining the interviews held by Meerman (2015) to gain a better understanding as just an interpretation of the BPMN process model derived. It is useful in the sense the modeller gets his own view already making it significantly easier to interpret the BPMN-model and to model the translation into ORM-diagrams.

The subsequent steps concerning the actual design of the ORM-diagrams by use of the BPMN-ORM methodology formed a solid base to start the transition. Unfortunately many specific BPMN patterns were not already predefined towards their corresponding ORM counterparts (specifically the double gateways). The BPMN-ORM methodology itself is organized and easy to follow to come up with the corresponding ORM counterpart of the BPMN-model as seen in the results section. For the critically review as the final step: question three about the stakeholders goals however, was a bit unclear. Does it mean the goals of the stakeholder in the swimlane? Or the external stakeholder's goal on the higher conceptual level? As the CSF's of the stakeholders in the swimlane are derived from their respective goals, it is conceptually useful to know this goal but for the actual transition from BPMN to ORM it has to specific value or ORM construction. That is the main reason to propose that question obsolete in the review. As from

further discussion the proposition arose, what if there was no previous research from Meerman (2015)? Then having a certain question would most certainly contribute to the overarching project, but it would be of better use within the first step of understanding the Universe of Discourse. Therefore leave it out the BPMN-ORM methodology, but on the field of gaining a better understanding of the whole process it is still a most useful question and therefore is can also be allocated to the first step of understanding the Universe of Discourse. The further sequence of the BPMN-ORM methodology was slightly changed towards the more practical sequence as applied by the modeller. CSF's were mentioned fairly early and their respective modelling in ORM already required the identification of fact-types and constraints while these were mentioned later on in the methodology. The proposed BPMN-ORM methodology is changed into a more logic sequence.

### 5.3 REVIEW ON THE REGULATIVE CYCLE

The regulative cycle by van Strien (1997) forms the overall methodology of the overarching project as well as the individual thesis methodology. Design Science emphasizes the connection between knowledge and practice by showing that we can produce scientific knowledge by designing useful things (Wieringa, 2009). The main place of this specific individual part of the overarching project is of the diagnosis/analysis phase and the design solution phase. The first phase of the overarching design problem was the main concern of Meerman (2015, while Lichtenberg's (2015) primary concern was the validation step. This structure is considered to be highly valuable, as first a good definition of the desired situation has to be pointed out (the situation to-be) while also define the current as-is situation after which the transition from as-is to to-be can be designed. After the design solution has been created in this particular thesis, the validation with the end-users gains insights if the design solution really satisfies the stakeholders. It verifies and validates if the solution as designed is indeed a desired solution.

Beside the overarching regulative cycle, also a smaller local cycle has been conducted. To check the methodology, the second step from Martena (2015) was about creating preliminary ORM-diagrams after which these were verified in

their local validation step to eventually go back to a new analysis and so on towards a better design solution to be validated again. The regulative cycle as a whole, but also the smaller local cycle showed their use and value to this entire design project.

### 5.4 DESIGN SCIENCE REVIEW ON OVERARCHING PROJECT

From Balsters (2014), a report on design science should also address the following questions afterwards: 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?

All the phase expansions have been addressed regarding the local cycle, where only diagnosis/analysis and design solution are discussed with respect to the overarching project. The validation of the design is concerning this individual part performed on the technical level for eventual realization of the design, while the overarching end-user validation is performed by Lichtenberg (2015). Performance issues and trade-off situations are not yet encountered. Scalability could be an issue if processes become more and more complex as that will translate to even more complex ORM-diagrams but overall this remains applicable.

## 6 CONCLUSIONS

This overarching project focussed on the design of an information product to attain cycle time analysis of the clinical pathway Head and Neck Oncology at the LTHN. The first part of pursuing this goal was to map the current process (as-is) in BPMN to gain a better understanding of the context. This thesis focussed on the subsequent step: the translation of these BPMN-models to ORM-diagrams by the following research questions:

1. *“How can technical validated BPMN models be translated to a technical validated information product blueprint?”*
2. *“How can the current information product design method aid in the analysis of cycle times of patients?”*

These first two questions have been answered by means of the methodology of Martena (2015) which is considered to be a robust way of modelling data elements in ORM of which the information product blueprint can be derived. However, for the eventual implementation of the ORM-diagrams also some caution has to be taken which are discussed below in the limitations. With respect to the third and final sub-question,

3. *“How can the current information product design method be improved and generalized?”*

the BPMN-ORM methodology has been adjusted. As previously stated, the overall framework is a robust way for the derivation of an information product blueprint. The actual translation of BPMN to ORM by means of the BPMN-ORM methodology gained a slight improvement by moving question three about the stakeholders goals towards main step one about understanding the Universe of Discourse and change the sequence of questions to a more logical build up as proposed below.

1. What is the event-transition we are addressing?;

2. What are the input events for the particular events?;
3. What do we have as output values of the events?;
4. Which stakeholders are involved?;
5. What are the Critical Success Factors (CSF's) for each stakeholder in the context of this event?;
6. Which (other) object types are involved in the event as participants?;
7. How do we identify the event, participants and stakeholders?;
8. Which fact-types are the event, participants and stakeholders engaged in?;
9. Which constraints pertain to these fact-types?;
10. What are the associated business rules for the particular events?;
11. How can we validate our model?

### 6.1 RESEARCH LIMITATIONS

For this specific case, it has showed that ORM lacks the functionality to include status changes of the data elements. As here a patient and his/her concern enter the process, the whole process is aimed at finding root causes of the concern with respect to the condition of this patient. Little distinct data elements were identified because of this all going status changes of the patient information and the concern.

The blueprints as generated currently needs still some interpretation as this particular information product needs certain calculation rules that need to be followed to meet the actual cycle time of the patients within the clinical pathway. The information product is capable of cycle time derivation and thereby answering sub-question two, but for the eventual realization the main issue is the fact the ORM-diagrams as currently are ambiguous. In the model notes the calculation rules are stated for the derivation of cycle times that need to be generated. In the database blueprints these rules are also not visible so both the database blueprints and ORM-diagrams are needed for a correct implementation and thereby satisfying the need for such an information product.

## 6.2 SUGGESTIONS FOR FURTHER WORK

In this overarching project the BPMN's and ORM's of the Head and Neck Oncology clinical pathway were discussed, but it can also be applied on any other process as these will be modelled into BPMN of which the data structure in ORM can be mapped. The methodology of Martena (2015) is proven to be robust and cross-domain applicable making it capable for many different processes to be modelled in ORM. The first recommendation is to validate this framework outside the health care environment.

Another interesting part is now cycle times are able to be derived from this information product, it is also capable for more in-depth analysis of the clinical pathway. Which processes have long cycle times, where are the bottleneck in the processes? It provides more insights and room for further analysis as critical path and bottleneck analysis. These in turn could lead to a better process, patients can receive their diagnosis faster after which possibly treatment could start earlier, lowering possible risks and further propagation. Also more mathematical analysis could be performed to eventually all contribute to optimization of the clinical pathway/medical process.

The most important suggestion is to look for the possibility within ORM to include status changes within data-elements (as the patient and concern here) to be included in a more structured way instead of an assumption. Also, if the database has to derive certain calculations according certain specific rules these need to be included within the ORM tools to make the models unambiguous and less sensitive for interpretation. The most ideal would be that now the blueprint has been created it can be handed over to the implementation experts without any further questions. It lowers the level of complexity and possible errors. With the current blueprints caution has to be taken when actual implementation takes place.



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APPENDIX I

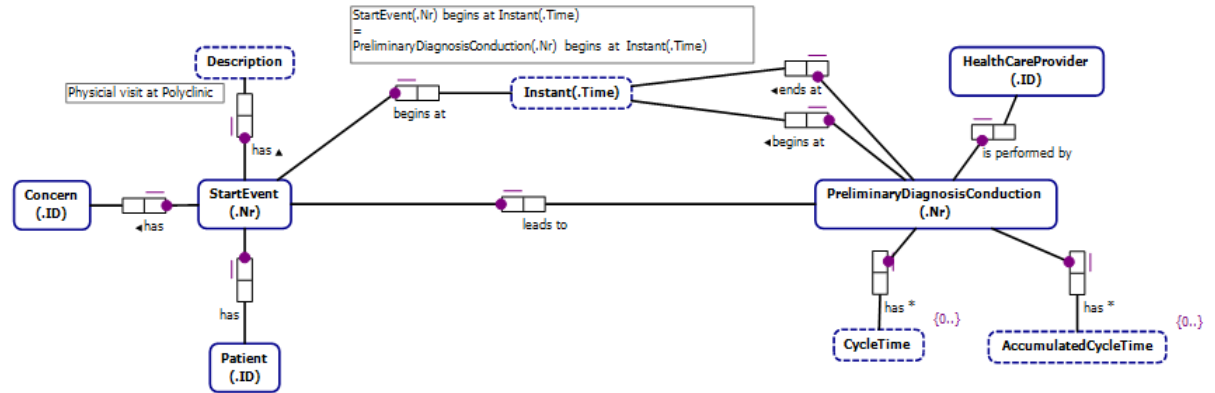


Figure 21 ORM of Conduct Preliminary Diagnosis.

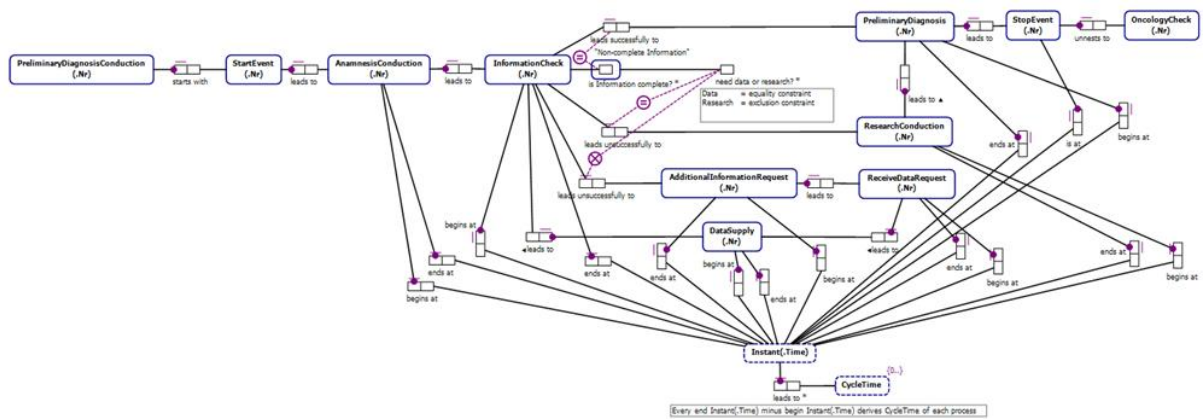


Figure 22 ORM of nested Conduct Preliminary Diagnosis.

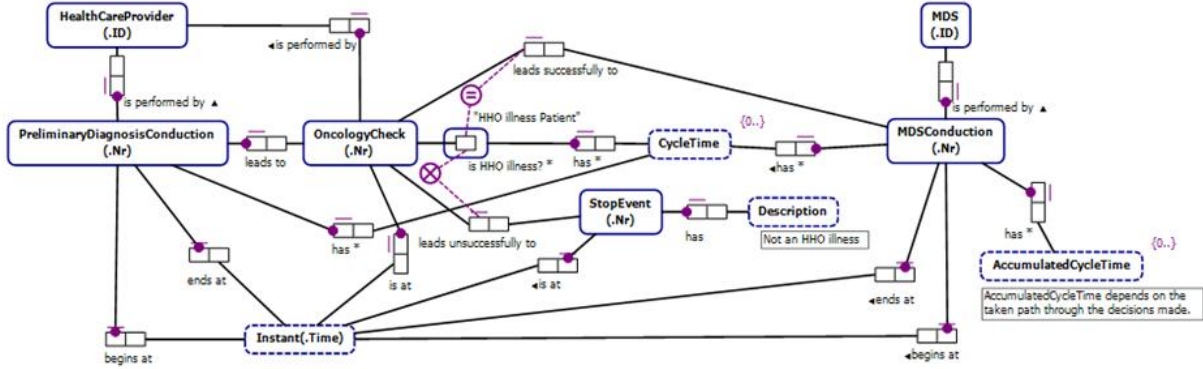


Figure 23 ORM of Conduct MDS.

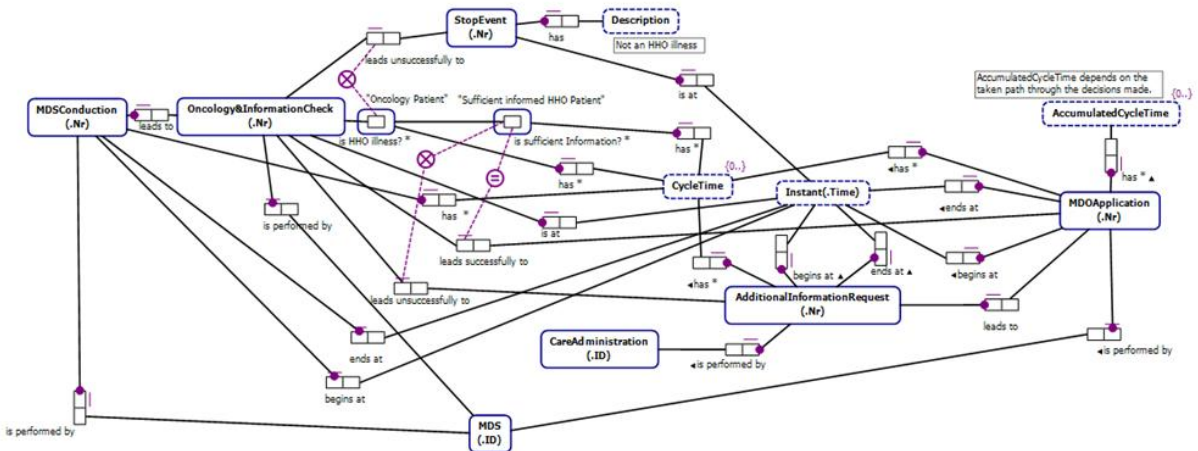


Figure 24 ORM of Submit to MDO.

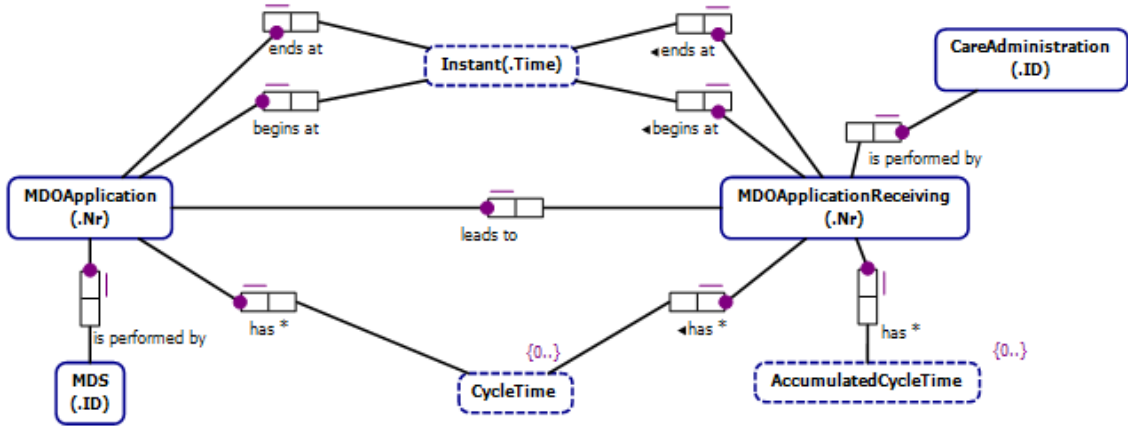


Figure 25 ORM of Receive MDO application.

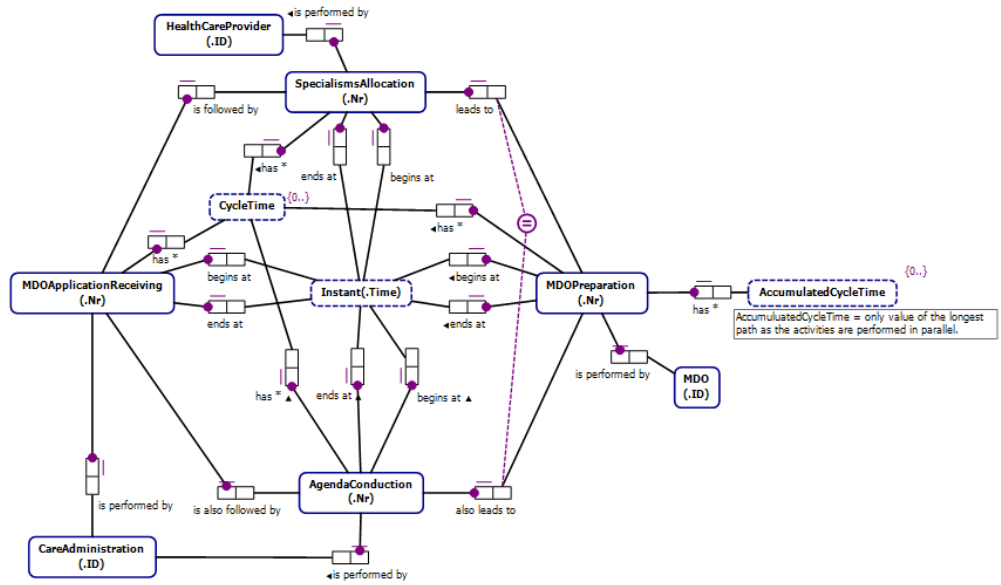


Figure 26 ORM of Prepare MDO meeting.

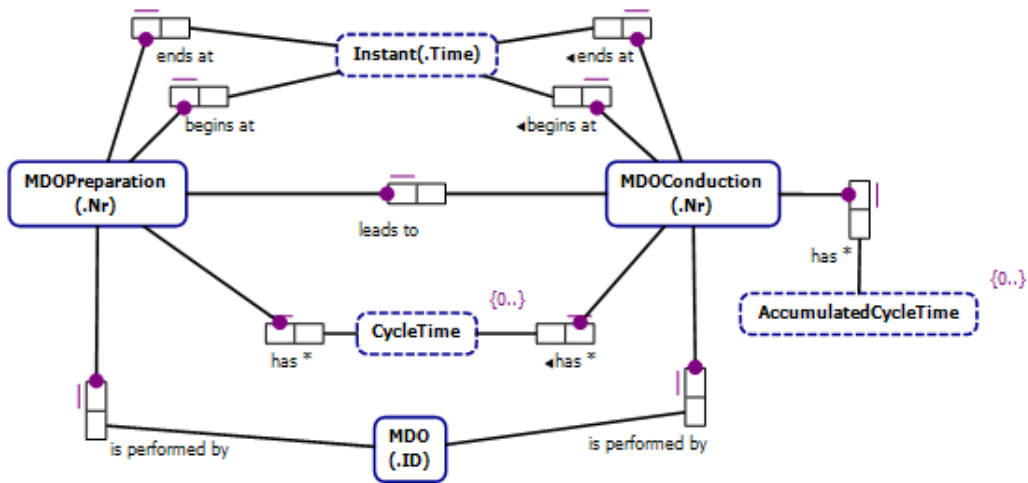


Figure 27 ORM of Conduct MDO.

38

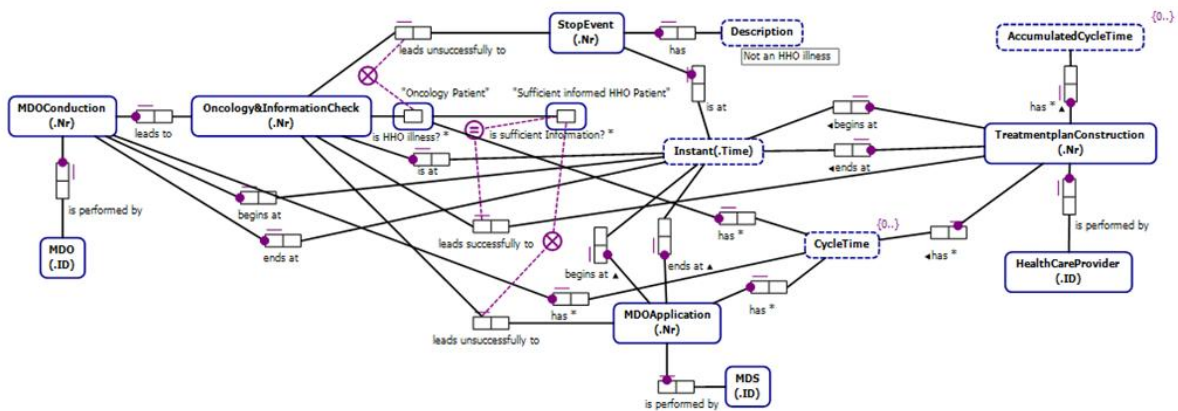


Figure 28 ORM of Construct treatmentplan.

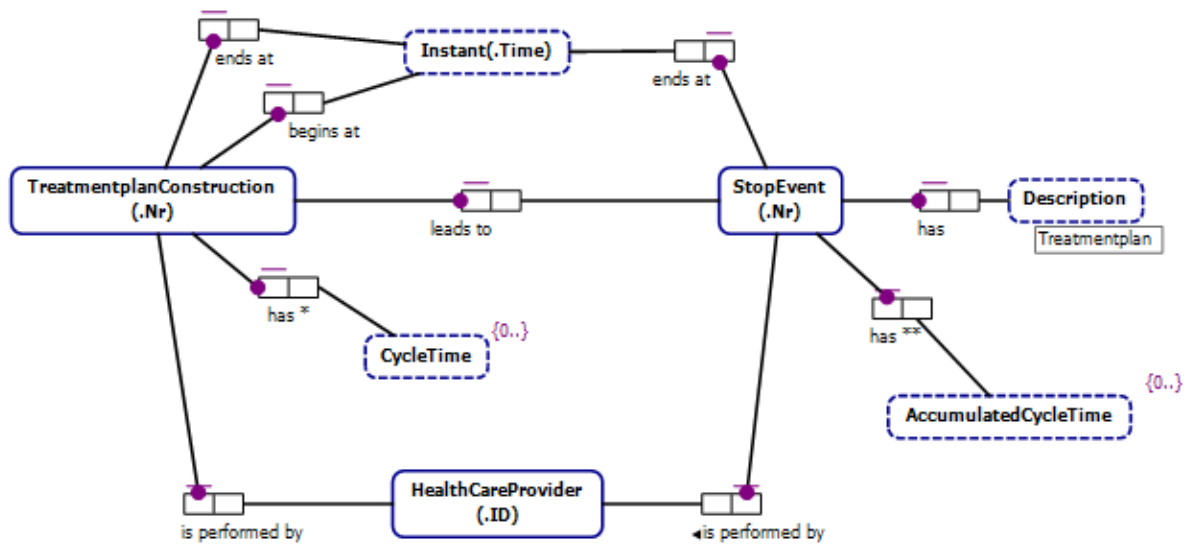


Figure 29 ORM of Finalize Diagnosis.

## APPENDIX II

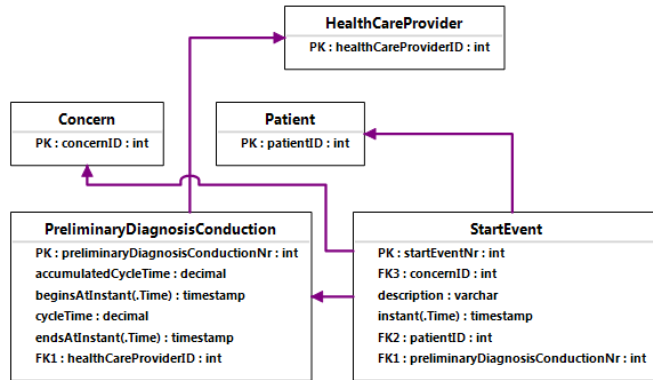


Figure 30 Database Blueprint from ORM of Conduct Preliminary Diagnosis.

40

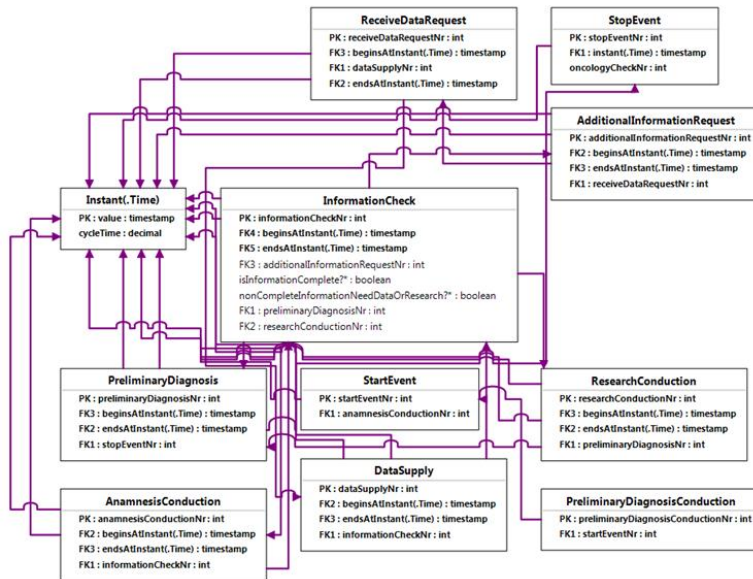


Figure 31 Database Blueprint from ORM of nested Conduct Preliminary Diagnosis.



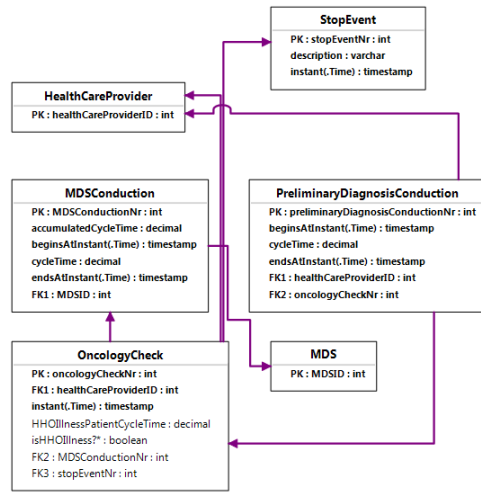


Figure 32 Database Blueprint from ORM of Conduct MDS.

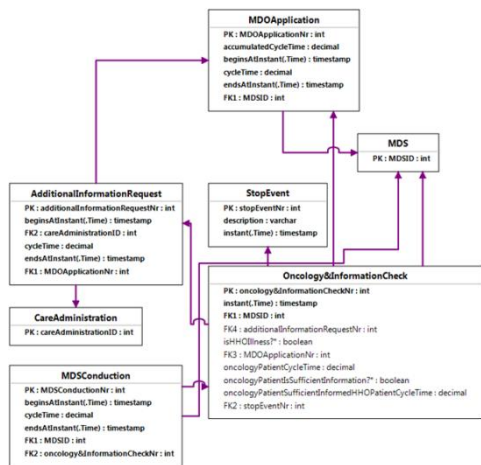


Figure 33 Database Blueprint from ORM of Submit for MDO.

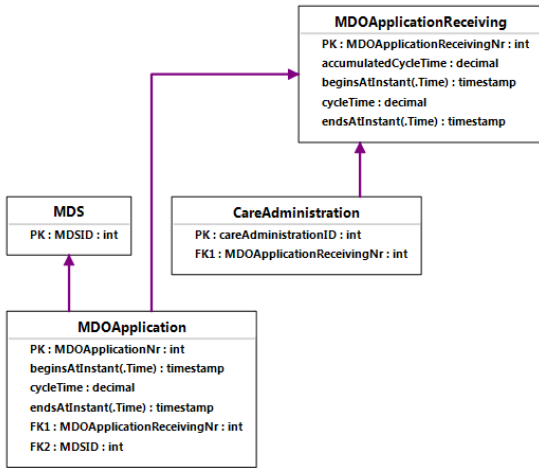


Figure 34 Database Blueprint from ORM of Receive MDO application.

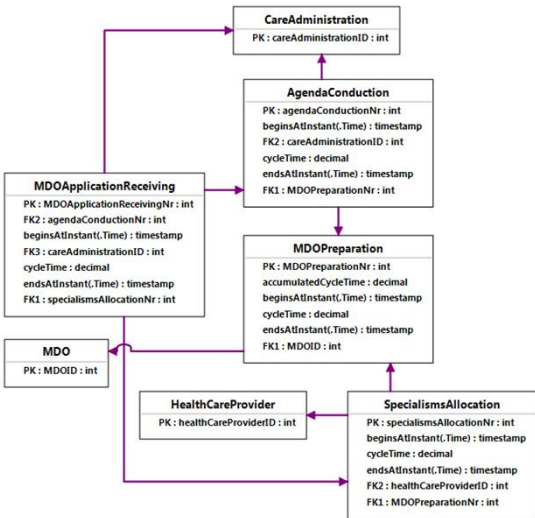


Figure 35 Database Blueprint from ORM of Prepare MDO meeting.

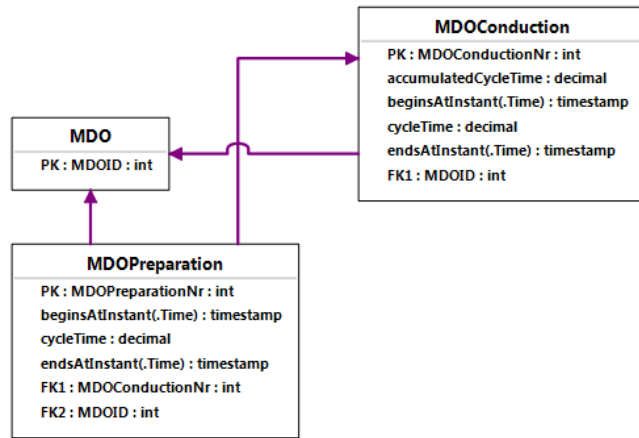


Figure 36 Database Blueprint from ORM of Conduct MDO.

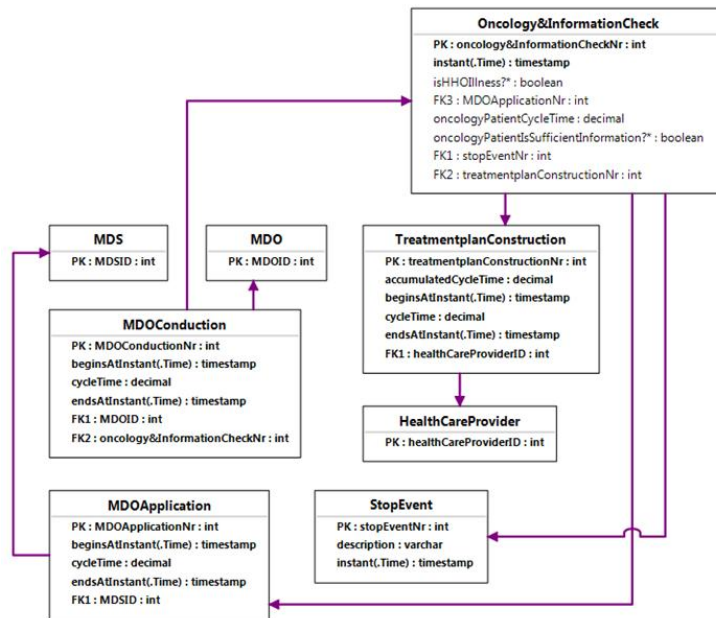
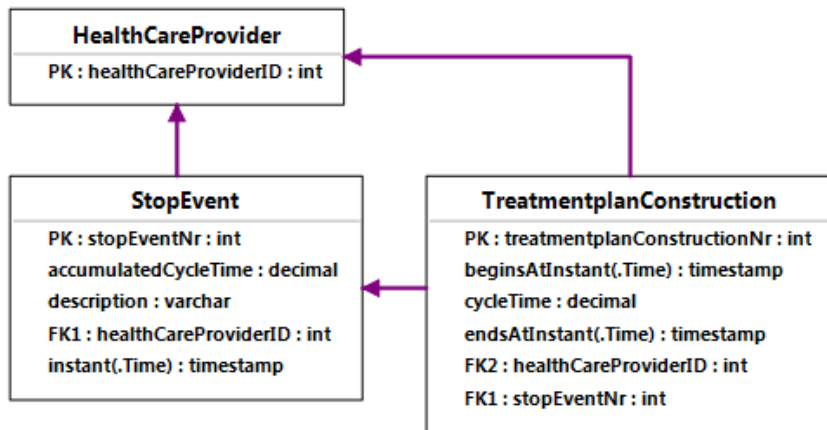


Figure 37 Database Blueprint from ORM of Construct treatmentplan.



**Figure 38** Database Blueprint from ORM of Finalize Diagnosis.