MASTER

The suitability of process modelling languages for supporting medical processes with workflow technology
what extent of process flexibility is required?

de Groot, H.W.M.

Award date:
2009

Eindhoven, January 2009

The suitability of process modelling languages for supporting medical processes with workflow technology: What extent of process flexibility is required?

by
H.W.M. de Groot

ing. H.W.M. de Groot (Mechanical Engineering) – 2006
Student identity number 0511404

in partial fulfilment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

Supervisors:
Dr.ir. H.A. Reijers, TU/e, IS
Prof.dr.ir. P.W.P.J. Grefen, TU/e, IS
Dr. N.C. Russell, TU/e, IS

TUE. Department Industrial Engineering & Innovation Sciences
Series Master Theses Operations Management and Logistics

ARW 2009 OML

Subject headings: workflow management systems, process modelling, process flexibility, workflow patterns, flexibility patterns, hospital information systems, healthcare, clinical decision support systems.

Preface

This report is a Master Thesis for the study of Industrial Engineering and Management Science in the Faculty of Industrial Engineering & Innovation Sciences at the Eindhoven University of Technology (TU/e). The Master Thesis has been conducted in cooperation with the TU/e and the Dermatology outpatient clinic of the Catharina Hospital Eindhoven.

My personal objective for this project was to gain experience in conducting academic research. The open cultures of both university and hospital allowed me to fulfil this objective. I enjoyed the newness and learning experience of working in healthcare to tackle organisation's requests, while also acting in a specific research area.

I would like to thank Dr. Gertruud Krekels and the Dermatology outpatient clinic for their information, support throughout the project and the warm culture. I also would like to thank my supervisors, Dr. ir. H.A. Reijers, Prof. dr. ir. P.W.P.J. Grefen and Dr. N.C. Russell, who showed ongoing motivation and commitment to my project, as well as always tolerating my unplanned office visits and answering my questions. Last but not least, I would like to thank my wife, Jolanda, for motivating and supporting me in every thinkable way. Without her, this report would have never existed!

Finally, I would like to thank everybody who contributed to this research. These people include family, friends, my office mates, the secretaries and their superb coffee, my dart competitors and all people I have forgotten to mention.

Robert de Groot,
January 2009

Executive Summary

What does this study explore?

Due to an increase in patient numbers, the Dermatology outpatient clinic of the Catharina Hospital Eindhoven is looking for new and innovative ways of increasing treatment capacity. Since the number of patients increases at a much higher rate than qualified personnel, it is not just a matter of increasing resources. One of the innovative ways of optimising the patient's process is by applying workflow technology. Workflow technology is used for supporting the administration and orchestration of work during the patient's care process as much as possible. Workflow technology is widely used in business practice and shows significant performance improvements, but how appropriate is this technology for supporting healthcare processes?

Academic literature shows that medical processes can become very complex and, where as Workflow Management Systems (WFMS) offer good support for cyclic and predictable business process. This study's aim is to investigate the requirements for supporting the medical treatment processes at the Dermatology outpatient clinic at the Catharina Hospital Eindhoven. This resulted in the following research question:

To what extent is workflow technology suitable and able to support medical treatment processes?

How is this explored?

To find answers for the proposed research questions, first the As-Is processes were identified by observing consultation meetings of physicians with patients, three Mohs surgery days and two Photodynamic Therapy days at the Catharina Hospital Eindhoven. By observing only, a large part of the process could be formalised. By interviewing the responsible resources the remaining process fragments were identified. To validate these findings, several resources where interviewed independently and validation of the processes was conducting by reflecting the process models with three physicians independently. This phase took about three weeks and resulted in a set of As-Is processes that were captured using the YAWL-language.

The captured processes showed opportunities for improvements. It is likely that the organisation desires to improve the processes, not only to gain direct process benefits but also to prevent inefficient process to be automated. Analysis of the identified processes led to a number of process redesign propositions. These propositions were developed by using 'Redesign Best Practices' and by capturing improvement requests from the organisation. These requests are captured during interviews with resources of different organisational roles. By capturing the requests of nurses, secretaries or physicians different perspectives on process opportunities were gained. As it appeared some recommendations looked beneficial from the recommender's perspective but did not lead to real process improvements. The proposed redesign scenarios are reflected and validated by all oncology Dermatologists and several oncology nurses during a two hours workshop and resulted to the proposition of 'improved process models'.

The As-Is and improved processes support the workflow trajectory for 'normal' patients. These are patients who require only one treatment intervention per treatment cycle. Physicians prefer this trajectory as they can clearly deduct the diagnostic and therapeutic effects of single treatment intervention. However, more complex patients require another trajectory. To identify the requirements for supporting those complex patients, two of the three Dermatology oncology physicians were interviewed. The interviews showed that physicians always make a treatment plan beforehand and do not deviate from this plan once commenced. This means that the flexibility required for supporting the complex patients is anticipated and can probable be modelled at design-time. The requirements revealed that it should be possible to select combinations from the available treatment interventions and allow the possibility to perform any selected treatment several times. Via an interview with the Chief of Dermatology, the requirements were validated and the presence of unanticipated process behaviour was excluded. The transformation of these requirements to process solutions fulfilling these requirements has been guided by the Flexibility Patterns and led to the 'To-Be' processes. The Flexibility Patterns provide a solution for handling certain flexible process behaviour given a specific type of flexibility, which is independent of the used process language or workflow system.

Up to this point three different set of medical treatment processes have been described: The As-Is, the improved and the 'To-Be' processes. For specifying the requirements a workflow process-modelling tool should provide for delivering proper support, Workflow Patterns are used. The role of the Workflow Patterns in this study is to capture process behaviours independent of the used process modelling language or used technology. The Workflow Pattern analysis resulted an overview of typical workflow constructs that have to be supported by any system to ensure the intended process enactment.

Main conclusions

From the study's process analysis can be concluded that the Dermatology oncology treatment processes are highly structured. Explanation for this conclusion can be drawn from the fact that compliance to the process seems to be very important, the nature of the process is fairly linear, the level of knowledge on skin cancer is very high, therefore uncertainties tend to decrease, and at least the Dermatology oncology outpatient clinic does not have to anticipate for acute care deliveries.

The process redesign phase showed that the examined processes showed several opportunities for improvements. From a set of seven redesign propositions, two propositions were accepted for short-term application, three propositions showed opportunities for long-term application and two propositions were not accepted.

This high level of structure showed that the flexibility requirements for supporting these processes are mostly design-time flexibility requirements. Dependent on the type of flexibility that has been used for defining the 'To-Be' process, all requirements can be solved using design-time flexibility. Typical required constructs are: (Exclusive) choices, foreseen bypasses for skipping activities, creating process cycles, or interleaved routing. In case it is decided to use typical run-time flexibility types (such as flexibility by deviation or change), more advanced technological requirements are required that support run-time flexibility functionalities. Typically, workflow products that act from a design-time flexibility perspective outnumber the amount of run-time systems (such as ADEPTflex, Declare).

It should be noted that the examined Dermatology oncology processes do not represent all medical processes. Future research should point out what other medical processes show some degree of equivalence with the Dermatology oncology processes at the Catharina Hospital Eindhoven.

Contents

Table of Tables

Table of Figures

1 Introduction

In recent years the numbers of patients undergoing medical treatments at hospitals have increased dramatically. There are a lot of reasons for this increase, such as the fact that the number of inhabitants increases, as well as the average age people become. One way of coping with the increase of patients is to expand the hospital capacity by hiring/educating new medical personnel and increasing other resources such as real estate and equipment. Healthcare professionals are facing the fact that the number of medics is not increasing fast enough, to cope with the increase in patients. Therefore new ways have to be found to cope with the increase in patients. One of these new ways can be found in the field of Workflow Management Systems (WFMSs), which support the definition, execution, registration and control of business processes (Van der Aalst, 1998). Workflow technology has proven to be quite successful and is widely used in industry (Reijers and Van der Aalst, 2005a). Lawrence (1997) states that the advantages of WFMSs are clear: "By having a dedicated automated system in place for the logistic management of a business process, such process could theoretically be executed faster and more efficiently." Empirical evidence indeed shows significant improvements in the examined process' service, lead and waiting times (Reijers and Van der Aalst, 2005a).

Several authors in the academic literature have recognized the need for workflow technology in hospitals. Sutherland and Van den Heuvel (2006) state that modern healthcare has outrun the capabilities of manual and paper based operations and others (Ammenwerth et al., 2002, Haux et al., 2003) indicate that process support of information systems is the best solution for improving critical performance criteria.

Business processes that are ideal for being supported by workflow technology are clearly structured, predefined, highly predictable and consistent. Examples of such processes are the manufacturing of a car, the handling of an insurance claim, or a mortgage application process. On the other hand, healthcare processes may tend to be highly unpredictable. Reichert and Lenz (2007) state that clinical decisions are made by "interpreting patient specific data according to medical knowledge", which results in a "very complex decision process, as medical knowledge includes medical guidelines of various kinds and evidence levels as well as individual experience of physicians". Based on those considerations it may be concluded that medical treatment processes may become highly unpredictable. Workflow systems orchestrate and coordinate the workflow given predefined process models. These models describe *what* and/or *how* things should be done. Given the possible complexity of medical treatment processes, it may become practically impossible to predict all treatment scenarios beforehand. In order to make WFMSs more suitable to support medical treatment processes, the WFMSs perhaps should offer medical personnel the possibility to deviate or change the process structure that was created before commencement. These types of 'run-time' flexibility are very advanced and may bring along other complications. In order to investigate exactly what a medical process looks like and to what extent flexibility a requirement is, treatment processes from the Dermatology oncology outpatient clinic at the Catharina Hospital Eindhoven are subjected for analysis.

This study aims at exploring the degree and types of flexibility that are required to support the subjected medical treatment processes. The main question of the research is: *'to what extent is workflow technology suitable and able to support medical treatment processes?'*

To investigate this question, the report describes the exploratory study in a couple of phases, following the regulative cycle (Van Strien, 1997), which is illustrated in Figure 1. Chapter 2 elaborates on the project details, stating the context of the study, the research questions and the study's design. Chapter

3 will present findings from the literature review that might increase the understanding of the examined topic. In chapter 4, the identification process and results of the examined medical processes is defined, after which chapter 5 is devoted to process and results of redesigning the identified processes. In chapter 6, Flexibility Patterns theory was used in order to investigate whether the application of these Patterns would result in better processes.

As last chapter, chapter 7 specifies the requirements a process modelling/enactment tool should provide for supporting the examined Dermatology oncology treatment processes. At last, chapter 8 will provide an overall conclusion, reflection and proposal for further research.

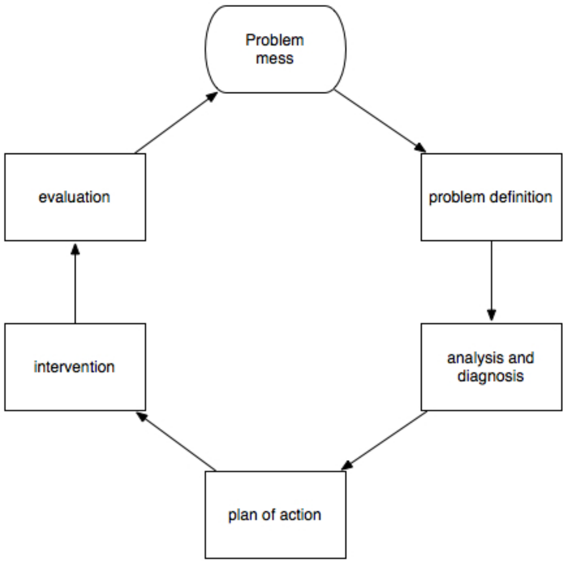


Figure 1 Regulative cycle

2 Project details

This chapter elaborates on the context of this study's project, the design of this study and its deliverables. This content will serve as the basis for this master thesis project.

2.1 Context of the study

The context of this study is settled around the fit between WFMSs and medical processes. Investigating the problem using this scope would require the incorporation of different perspectives on WFMSs as well reflecting them onto medical processes of different kinds and of different settings. Therefore the scope of this study is limited to the following subsets of WFMSs properties and medical processes:

The examination of the appropriateness of WFMSs for supporting medical processes is taken from a process modelling perspective. The area of main interest within process modelling languages is their ability to handle uncertainties in workflows. Since physicians are not supposed to follow a step-by-step treatment plan (Lenz and Reichert, 2007), the whole idea of following a predefined process structure in any WFMS might become a bottleneck for offering the intended process support. Be aware that taking a process modelling perspective only covers a subset of the issue relating WFMS appropriateness. From a higher-level perspective there is much more to say about the appropriateness of WFMSs, such as the ability to integrate in the existing architecture, but which are not considered in this study.

From a medical processes perspective, it can be stated that conclusions based on processes from one setting cannot be generalised to all medical processes. For example, emergency rescue processes might require a lot of support for handling unpredicted scenarios, where else gynaecology processes might be more predictable. For this study the medical processes of the Dermatology oncology outpatient clinic of the Catharina Hospital Eindhoven are used to reflect on the appropriateness of process modelling languages for supporting those processes. It should be taken into account that there are differences between medical processes. For example, Mans et al. (2008) provide a classification of healthcare processes, illustrating the different types of medical processes require different types of flexibility. Generalising this study's conclusions to other medical processes might not be appropriate and has to be considered carefully.

Figure 2 illustrates the examined subjects and the relations to it higher level entities.

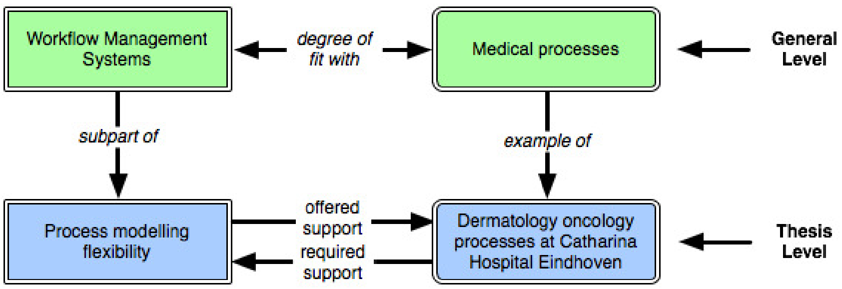


Figure 2 Context study illustrating differences between general and thesis level

The next subsection provides information regarding the Dermatology outpatient clinic at the Catharina Hospital Eindhoven and explains why workflow technology would deliver the means for improving operational efficiency.

2.1.1 The clinical setting: Dermatology oncology outpatient clinic at the Catharina Hospital Eindhoven

After examining the orchestration of work at the dermatology outpatient clinic of the Catharina Hospital Eindhoven and interviewing several physicians, it could be concluded that the orchestration and coordination of patient-centric information has to be improved. The reason for this conclusion is that professional medical personnel spend too much time on scheduling and informing patients, as well as gathering the right information to perform daily activities. One critical comment by Sutherland (2006) truly holds for this study: “The complexity of modern healthcare has outrun the capabilities of manual and paper based operations.” This paper based way of working also results in a high degree of data duplication and (in some cases) lost information. For example, a dermatologist has to fill in the patients name, address, disease, and proposed treatment method several times along the treatment process. Patient records are (temporarily) lost on a regularly basis and precious time is wasted by retrieved them.

Figure 4 An overload of documents

Figure 3 Message on locker states that no patient records should be saved in any locker

Figure 4 shows a rack of documents located at a physician’s office. A workflow system could automatically generate the required documents and send them to the required process actors. A problem arising with paper-based patient records is that there is only one copy, which sometimes gets lost. In order to prevent this, staff are requested not to leave patient records in their personal lockers. The message in Figure 3 states, “If a patient record is found in your locker you should treat a big pie!” Although this request is quite humorous, the subject is pretty serious.

Based on directions offered in the academic literature and observations of the current way of working at the Catharina Hospital Eindhoven, it can be stated that introducing workflow technology is an innovative way of supporting hospital personnel in their daily routine and releasing them from secondary (administrative) tasks by automating the orchestration of information.

2.2 Study design

Theoretical background in process flexibility and observations at the Catharina Hospital Eindhoven provided the context in which this study is developed. This chapter will elaborate on the structure of the study. This chapter addresses three main topics: The aim of the study, its research questions and the model that is used for guiding this project.

2.2.1 The aim of the study

One of this study's areas of interest is related to retrieving the present level of flexibility in the examined Dermatology oncology processes. To determine this, these processes have to be identified, formalised, and validated. Based on these data the first aim deals with investigating whether the efficiency of the current medical processes can be improved. The aim of improving these processes is to prevent inefficient processes from being used for further analysis. Also, it can be assumed that the hospital's organisation will intend improving the processes whenever efforts are being made for deploying workflow technology.

The second aim relates directly to process flexibility. For realising this aim, the improved process definitions are subjected to process scenarios that might occur in real life but which are not supported by these process models. The aim of this phase is to identify what flexibility is required for supporting possible behaviour that cannot be supported by current process models. The identification of required flexibility, and providing solutions to meet these requirements is guided by theory of Flexibility Patterns (Mulyar et al., 2008). This identification leads to new process solutions that are referred to as 'To-Be' processes and are able to support the required flexible behaviours.

The third part aims at identifying what technological capabilities a WFMS should include, in order to support the examined processes. By realising this aim, a technical process tool specification is created. Workflow Patterns (Russell et al., 2004a, 2004b, 2006) are used for making an independent relation between the processes and the technical capabilities that are required for supporting these processes.

2.2.2 Research questions

This study's research questions are presented in a layered style in Figure 5. Level 1 presents the highest-level view on the research questions. Moving to lower level research questions, the questions become more operational. Moving to a higher-level question, generalisations have to be made.

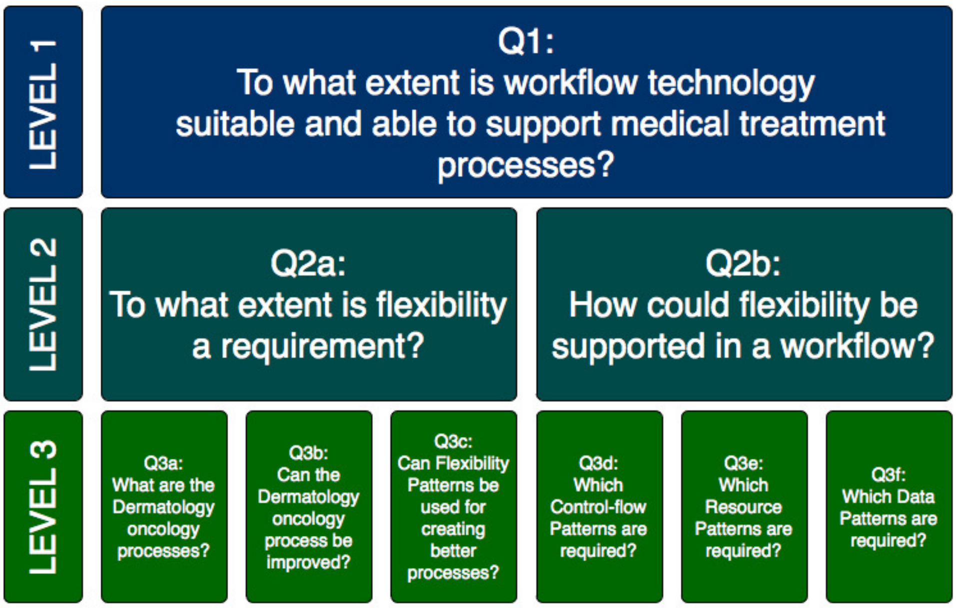


Figure 5 Research questions

In Figure 6 the relations between the Level 3 research questions, the used theories, and the deliverables are visualised. The study's deliverables (middle column, Figure 6) are presented in detail in the remainder of this chapter. During the investigation towards a specification of process modelling capabilities for supporting the Dermatology oncology processes, three different sets of process models will be created. The original (As-Is) processes, the improved processes and the To-Be processes. For each set of process a different requirements specification might roll out.

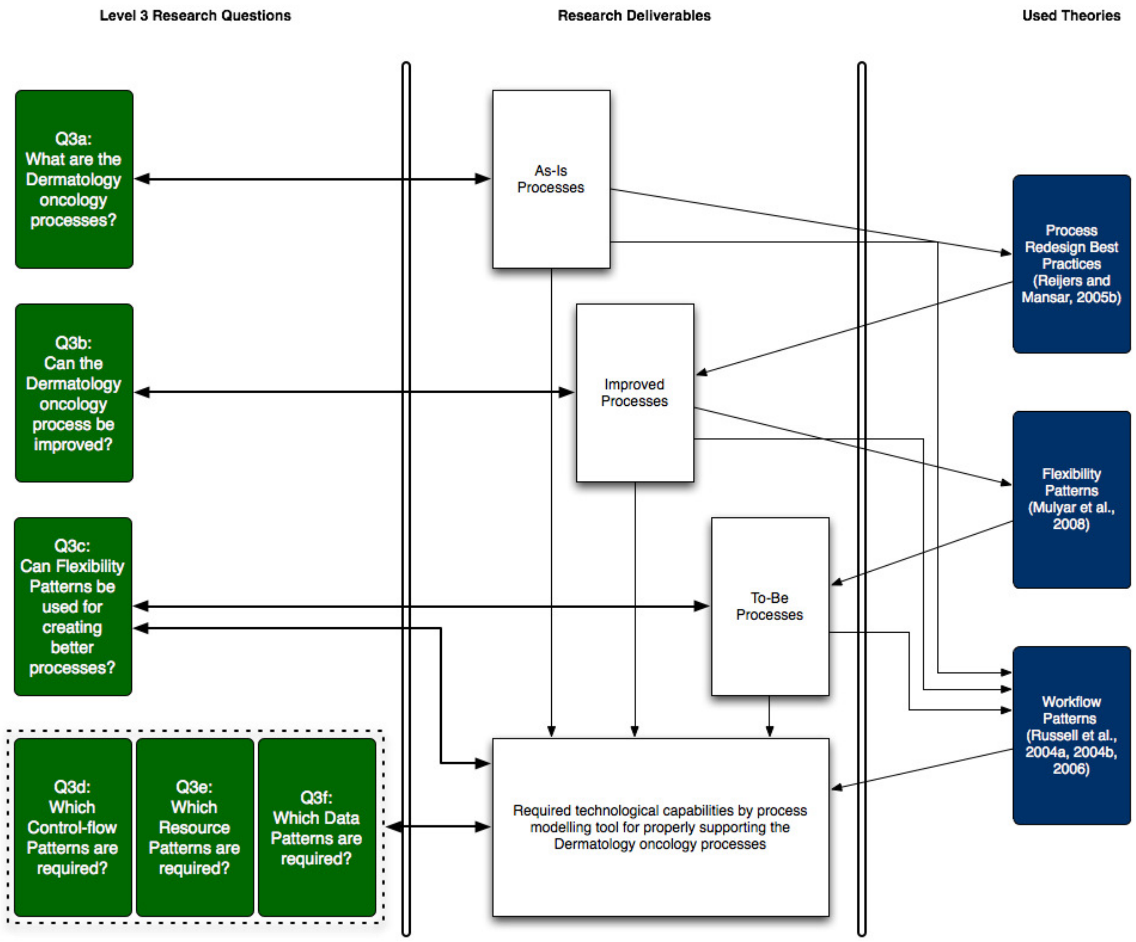


Figure 6 Research process

2.2.3 Research model

To research the questions presented in section 2.2.2, a research model will be. The research model presented in Figure 7 is based on Verschuren (2000). The research begins with a critical literature review, with which the identification of the critical aspects regarding the development and usage of workflow technology in a medical environment can be clarified. Through on-site surveys and case studies, insights are gained in the structure of medical treatment and the to what process modelling support is required.

This master thesis aims at the exploration of medical processes in order to investigate for existing process redesign opportunities and the ability of process modelling languages for supporting those medical processes. The identification of process flexibility can be labelled as **explorative research**, since it helps clarifying and defining the degree of required flexibility. Secondly, an **empirical research** strategy is chosen, due to the fact that real-life processes are analyzed in terms of their process flexibility requirements.

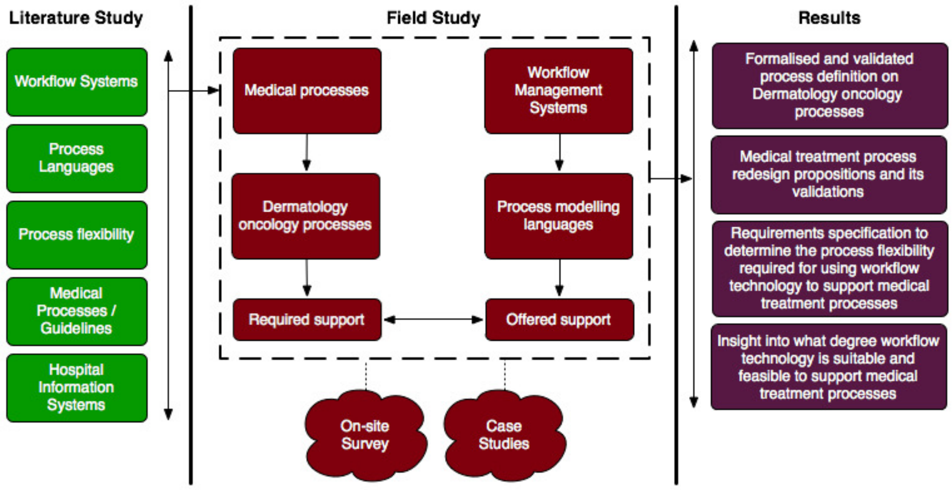


Figure 7 Research Model

Another viewpoint on the type of research is whether it is quantitative or qualitative. During this master thesis most of the data gathering will be **qualitative**. The decision to perform a qualitative study is in line with the explorative research study approach. In order to understand what flexibility requirements are needed to properly support medical treatment processes based on workflow technology, data from multiple sources has to be gathered from the original context. In order to realize this, several patients have been followed throughout their treatment process and several physicians and other experts from the field have been interviewed and observed in their courses of action.

2.2.4 Project goals

Several goals (Table 1, page 7) are identified that must be reached by the end of the master thesis project. The goals are divided into goals 'in the project' and goals 'of the project'. Goals in the project should provide insights into the design, development and execution of the project itself; where as goals of the project should lead to improvement of the subject's setting.

Table 1 Project goals

Goals in the project	Goals of the project
Specification of the required information that was collected at the Hospital by observing the Dermatology oncology processes and interviewing process actors.	Specification presenting the identification, formalisation, and validation of the Dermatology oncology processes.
Analysis specification of the Dermatology oncology processes, in order to optimize process by offering process redesign propositions.	Specification providing process redesign scenarios that improve the process' performance
Identification document of process flexibility requirements.	Identification and evaluation specification of the required flexibility solutions in order for supporting the Dermatology oncology processes with the aim of workflow technology.
	Identification of technological capabilities specification to provide the required support for process definition and enactment.
	Draw conclusions based on study's outcomes

2.3 Project deliverables

This master thesis will lead to a number of deliverables to ensure the defined goals to be met. In this paragraph the deliverables are explicitly defined along with its process phases:

- Phase 1: Identification of Dermatology oncology processes.
    - Deliverables:
        - Validated process models, describing the Dermatology oncology processes at the Catharina Hospital Eindhoven.
        - Description of the methods used for identification and validation of those processes
- Phase 2: Process analysis and development of process redesign propositions
    - Deliverables:
        - Process redesign propositions intending to improve the processes before actual implementation
        - Description of the methods used for identification and validation of the process redesigns propositions.
        - Evaluation of the process redesigns propositions.
- Phase 3: Development of higher flexible process models
    - Deliverables:
        - Identification of currently not support – but yet required – process behaviour and its translation to formal process requirements
        - Process solutions given different perspectives on process flexibility
        - Description of methods used for identification and validation of the proposed solutions.
        - Evaluation of the proposed solutions
- Phase 4: A specification of technological capabilities process modelling tools should incorporate for properly supporting the examined Dermatology oncology processes.
    - Deliverables
        - Specification of required process behaviours from the control-flow, resource, and data perspectives.
        - Methods used for identifying the required process behaviours
        - An overview presenting the capabilities to meet these requirements of evaluated WFMSs or process standards.

2.4 Concluding

The success of workflow technology in healthcare is largely dependent on the capabilities of those systems to cope with the required level of process flexibility. Based on this argument it can be concluded that the degree of which process modelling tools are able to cope with the dynamic properties of medical properties is an important sub-question in assessing the appropriateness of workflow technology for supporting medical processes in general.

As can be concluded from the examined literature, part of the dynamic properties of medical processes stems from variations and uncertainties occurring during the clinical decision. Besides the uncertainties in the patient-related information, medical knowledge evolves. No medical process is equal to another and from a higher-level view differences exist for supporting the workflow of one medical process versus another. The medical processes examined in this study are the Dermatology oncology processes at the Catharina Hospital Eindhoven. Initial investigations of the setting and environment showed that there is room for improvement and that workflow technology has not yet been introduced to the organisation.

By conducting this study, knowledge will become available regarding the structure of the examined medical processes, its process improvement possibilities, its required level of flexibility and its WFMSs requirements.

3 Literature review analysis

In August 2008, before the start of this master thesis project, a separate literate review has been conducted. From this literature review the most relevant topics are presented in this chapter. These topics might increase the understanding of this study.

Topics of interest which are presented in this chapter are:

- The notion of making a clinical decision;
- Factors that result in evolvement of a medical process;
- Definition and realisation of flexibility within process modelling;
- Measuring the performance of medical processes.

3.1 Clinical Decision Process

The majority of medical processes include a clinical decision. Based on the patient's health, the level of medical knowledge and the environment a decision is made that defines what should happen with this patient in the remaining part of his/her treatment process. Knowledge about the properties of clinical decisions, its foundations, and about automating this decision process contributes for understanding the nature of the medical process.

3.1.1 The Diagnostic-therapeutic cycle

The Diagnostic-therapeutic cycle is a medical representation of the clinical decision process. In this perspective the physician makes a decision using the patient-related information as well as medical knowledge. The patient-related information is not entirely certain. Therefore the physician might not be certain what treatment(s) to selected. It should be noted that this uncertainty in the clinical decision might require a level of process flexibility to anticipate these uncertainties.

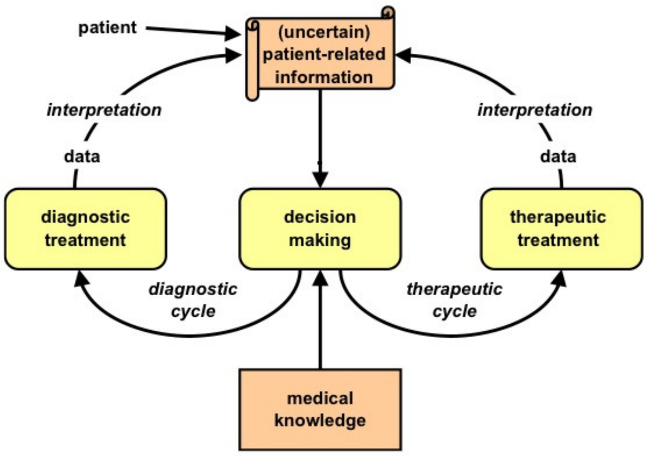


Figure 8 Diagnostic-therapeutic cycle (taken from Lenz and Reichert, 2007)

Several authors acknowledge that a higher degree of process flexibility is required to enhance the fit between the dynamic behaviour experienced in reality and the modelled behaviour in process definitions (Reichert and Dadam, 1998; Berlin et al., Sutherland and Van den Heuvel, 2006; Lenz and Reichert; Mulyar et al., 2007).

3.1.2 Guidelines

The actual execution manner of medical processes varies from one hospital to another. To guarantee completeness and quality of care, the medical domain started to standardise treatment processes, which they refer to as 'clinical guidelines' (Mulyar et al. 2006). Guideline information is public and can be viewed at, for example, http://www.guideline.gov/. Researchers who worked on the 'computerisation' of medical guidelines encountered several difficulties. In the first place, the definition of a *medical* process is not clear according to Lenz and Reichert (2007). They state that a clear distinction has to be made between treatment processes and organisational processes. Although this distinction sounds logical, it is not clear whether they can be kept separate easily.

Ambiguity in guidelines forms an obstacle for successfully implementing a guideline. Shiffman et al. (2004) proposed a document-centered approach to implement guidelines and acknowledge the lack of explicit definitions. Maviglia et al. (2003) add that guidelines have received little use, due to "inconsistencies in literature supporting one practice versus another" and "biases and perspectives of guideline authors, who may be specialists or generalists, payers or providers, marketers or public health officials." Therefore it can be concluded that guidelines are (1) too vague to be easily made operationalizable and (2) are high level guides of a treatment plan, but needs to be highly adapted to local, hospital specific needs and habits. Lenz and Reichert (2006) seem to be among the first researchers who propose a model that describes the convergence of a clinical guideline to a (patient-specific) pathway.

From the literature review can be concluded that the usage of guidelines as basis for the automation medical workflows might not be as appropriate as thought beforehand.

3.1.3 Clinical decision support systems

A large amount of research has focused on better ways for supporting physicians in their clinical decision-making (Fox et al., Zielstorff, 1997; Dadam et al., 2000; Kaplan, 2001; Bates, et al., Feischi et al., Mavligia et al., 2003; Shiffman, et al., 2004; Berlin et al., 2006). "Clinical decision support systems (CDSS) are aimed at clinical decision-making in which the characteristics of an individual patient are matched with a computerized clinical knowledge base, and patient-specific assessments or recommendations are then presented to the clinician and/or the patient for a decision" (Berlin et al. 2006). Although the idea of a CDSS is to improve quality of care, academics have doubts regarding the technical feasibility and practical usefulness of such a system. Zielstorff (1998) states that the foundations of a clinical decision are ambiguous, where as Lenz and Reichert (2006) acknowledge that clinical decision-making is a very complex process "as medical knowledge includes medical guidelines of various kinds and evidence levels as well as individual experience of physicians".

The idea of a CDSS can best be explained by visualising it in Figure 9. Information from guideline content, the patient's health and the physician's medical knowledge are entered into the CDSS. With this information the CDSS provides both physician and patient with clinical decision suggestions.

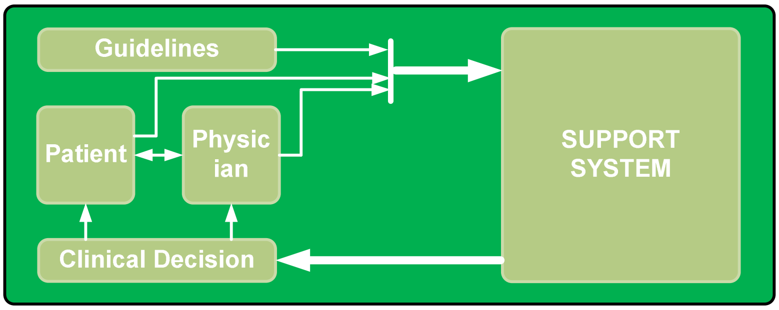


Figure 9 Clinical Decision Support System

The notion of CDSSs is important since it provides information regarding the automation of the decision process (as part of the entire patient's workflow) and the difficulties encountered doing so. Based on these outcomes it has been decide to not further elaborate on the CDSS, since results show that there are still a number of difficulties regarding the usage and implementation of CDSSs and it shows no direct benefits for to incorporating this in the patient's workflow.

3.2 External factors causing process evolutions

Shelleke et al. (2006) identified six situations after which *clinical guidelines* have to be adapted. Of course, the actual treatment process differs in most cases from its higher-level guideline (Lenz and Reichert, 2007), but one could state that changes in a guideline can eventually lead to changes in the medical treatment processes and therefore the same external factors contribute to the need for process adaptation. It should be noted the influence of external factors might require the need for a type of flexibility that supports process adaptations.

3.3 Flexibility of process models

This section elaborates on the classification of process flexibility types for process-modelling tools/languages. Flexibility is a vague construct and can be interpreted in different ways. In the next subsections the notion of flexibility is explained based on a taxonomy of flexibility types. Besides, a set of 34 Flexibility Patterns (Mulyar et al., 2008) for realising flexible process behaviour given different types of flexibility is presented.

3.3.1 Process flexibility types

Mulyar et al. (2008) present a fivefold classification of process flexibility (Figure 10). "Each of the five flexibility types aim at improving the ability of business processes to respond to changes in their operating environment without necessitating a complete redesign of the underlying process definition, however they differ in the timing and manner in which they are applied." (Mulyar et al., 2008)

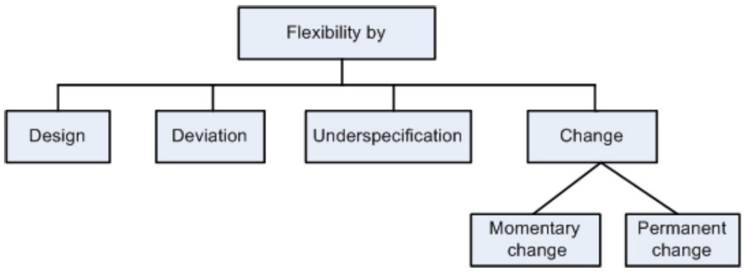


Figure 10 Process flexibility types (taken from Mulyar et al., 2008)

When deviating from the standard process model, it is important to know at what moment this need was recognised and whether this need applies to just one instance in the process (instance level), or affects all existing and future instances (type level). Figure 11 shows the moment of recognition for different types of flexibility. A distinction is made between design-time and run-time. Anticipated changes at design-time are implemented during the design of the process model and therefore *before* initiation of the model. On the other had, run-time changes are recognised *during* the execution of the process.

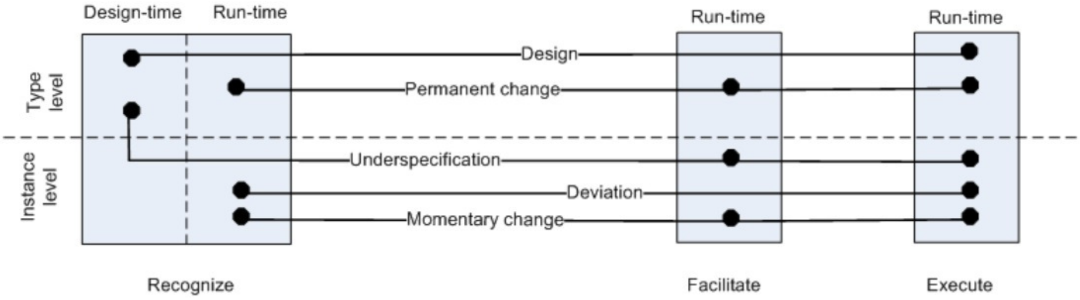


Figure 11 Moment of scope of flexibility types (taken from Mulyar et al., 2008)

Some types of flexibility require facilitation at run-time. This means that the process model is changed while running the process, while other forms do not need facilitation because this flexibility functionality is already built-in the process model.

3.3.1.1 Flexibility by design

Schonenberg et al. (2007) define flexibility by design as "the ability to incorporate alternative execution paths within a process definition at design time such that selection of the most appropriate execution path can be made at runtime for each process instance". This means that this flexibility has to be built into the process when the process model is created. Predefined flexibility is in different extents supported by today's WFMSs. The advantage of flexibility by design is that it allows flexibility to process without asking end-users to make special efforts to accommodate this type of flexibility. The biggest disadvantage is that no other execution options are supported, other than those that are modelled into the system.

3.3.1.2 Flexibility by deviation

Schonenberg et al. (2007) define flexibility by deviation as "the ability for a process instance to deviate at runtime from the execution path described by the original process without altering its definition". In practice this means that the process model remains unchanged, but instead the end-user gets the freedom to decide which tasks can be skipped, redone, or undone. This method does not change the process model itself, but allows for deviating from that model by temporarily ignoring it. An existing system supporting this type of flexibility is the FLOWer system that is based on 'case-handling' (Van der Aalst et al., 2005).

3.3.1.3 Flexibility by underspecification

Schonenberg et al. (2007) define flexibility by underspecification as "the ability to execute an incomplete process specification at run-time, i.e. one which does not contain sufficient information to allow it to be executed to completion". In general, this flexibility type is realized in two ways: (1) *ad-hoc modelling* and (2) *late-binding*. In the former case the model is not known beforehand and is modelled during execution. It is hard to label this as flexibility, since there is no baseline model. One could state that without concrete model, flexibility is not one of the process characteristics. However, ad-hoc modelling proves that incompleteness within a process model is recognized. Heinl et al. (1999) argues that ad-hoc modelling is not a proper solution because (1) the modelling of workflow processes is too time consuming to perform during execution and (2) typical end-users are not qualified to create process models. Functionality to ad-hoc model is merely available in commercial systems. The academic WFMS ADEPTflex (Reichert and Dadam, 1998) supports ad-hoc modelling.

Late binding means that the end-user can select a proper process fragment during execution, which is automatically integrated into the process model. The academic WFMS YAWL (Van der Aalst and Ter Hofstede, 2005) supports late binding via the notion of *Worklets* (Adams et al., 2006).

3.3.1.4 Flexibility by change

Schonenberg et al. (2007) describe flexibility by change as the "ability to modify a process definition at run-time such that one or all of the currently executing process instances are migrated to a new process definition". As this definition describes, the process can be changed during execution such that the instances of that process are migrated to the newly changed process definition. Changing a process model while also executing this process brings along some difficulties. As described by Schonenberg et al. (2007) the *dynamic change bug* (Van der Aalst, 2000) is a common issue, but also Rinderle et al. (2004) describe essential criteria that ensure completeness and consistency whenever changing process definitions. To clarify the notion of change, Weber et al. (2007) describe and evaluate 17 defined Change Patterns and 6 Change Support Features. Examples of changes are adding, deleting activities, or changing the sequence of activities. These changes can affect only one instance (instance level) or all existing and future instances (type level). Flexibility by change is in some way supported by for example the WFMS ADEPTflex (Reichert and Dadam, 1998) and MILANO (Agostini and De Michelis, 2000).

3.3.2 Flexibility Patterns

In the previous paragraphs, the different types of flexibility were highlighted. There are many different realisation strategies for each flexibility type. Therefore, Mulyar et al. (2008) developed 34 Flexibility Patterns. These Patterns endeavour to "describe a specific aspect of process flexibility such as *flexible initiation*, *flexible termination*, *flexible reordering*, *flexible selection*, *flexible elimination*, *flexible extension*, *flexible concurrency* and *flexible repetition*" (Mulyar et al., 2008). These Flexibility Patterns will be used to create solutions for the flexibility requirements of the medical treatment processes at the Catharina Hospital Eindhoven.

Flexibility requirements can be met in multiple ways, using different types of flexibility. For example, imagine there is the need to start at a different point in the process than the defined start of the process. A process model can be designed with multiple entry points, which provide a solution based on flexibility by design. However, when there is only one starting point, the user could skip the first (couple of) tasks to actually start at the desired process task. This is a solution based on flexibility by deviation, since the user only deviates from the standard sequence of tasks, but does not change the model. Using flexibility of underspecification, the solution would result in an undefined entry point of the process. When using flexibility of change the process model is changed in such a way that a new entry point is defined. This can be a momentary or permanent change.

Mulyar et al. (2008) identified a pattern matrix describing the required pattern for realising a type of flexible behaviour given a type of flexibility. This matrix is presented in Table 2. It should be noted that the Flexibility Patterns are based on the control-flow perspective of process modelling.

Table 2 Process flexibility matrix [taken from Mulyar et al., 2008)

	Flexibility by:				
	Design	Deviation	Underspecification	Momentary Change	Permanent Change
Flexible initiation	*Alternative entry points*	*Entrance skip*	*Undefined entry*	*Momentary entry change*	*Permanent entry change*
Flexible termination	*Alternative exit points*	*Termination skip*	*Undefined exit*	*Momentary exit change*	*Permanent exit change*
Flexible selection	*Choice*	*Task substitution*	*Late selection*	*Momentary choice insertion*	*Permanent choice insertion*
Flexible reordering	*Interleaving*	*Swap*	*n/a*	*Momentary reordering*	*Permanent reordering*
Flexible elimination	*Foreseen bypass*	*Task skip*	*n/a*	*Momentary task elimination*	*Permanent task elimination*
Flexible extension	*n/a*	*Task invocation*	*Late creation*	*Momentary task insertion*	*Permanent task insertion*
Flexible concurrency	*Parallelism*	*n/a*	*n/a*	*Momentary task parallelization*	*Permanent task parallelization*
Flexible repetition	*Iteration*	*Redo*	*n/a*	*Momentary loop insertion*	*Permanent loop insertion*

3.4 Measuring performance of medical processes

One of the frameworks that can be used to describe the impact and trade-offs made when proposing process redesigns is called the 'Devil's Quadrangle' (Brand and Van der Kolk, 1995), which is illustrated in Figure 12. The aim of this model is to illustrate that a trade-off exists intending to optimise performance dimensions. The 'Devil's Quadrangle' will be used for evaluating the impact of the proposed redesign scenarios.

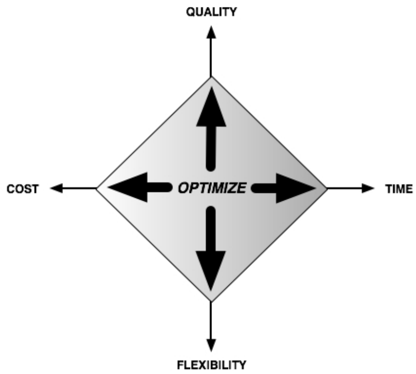


Figure 12 Devil's Quadrangle

For those interested in factors determining quality and costs in healthcare, 'Appendix 9: Factors influencing quality and costs in healthcare' provides more information on those topics.

3.5 Concluding from the literature review

The literature review showed that the whole notion of making clinical decisions strictly based on medical guidelines might not be the appropriate paradigm for usage as input to support the workflow of the medical decision process. Not only do other researchers encounter a number of difficulties using guidelines as operational algorithms in CDSSs, field studies also show that physicians are not committed enough to guidelines. Work from Shelleke et al. (2001) shows that medical processes are influenced by several external factors that cause changes in medical processes. Awareness of these factors ensures that workflow technology should be able to anticipate to these external influences.

Theory on the flexibility of process modelling tools provided by Schonenberg et al. (2007) and Mulyar et al. (2008) showed that the notion of flexibility is divided into four major types. To need for one type of flexibility versus another depends on whether the flexibility functionality is required at design-time of run-time and whether it affects a process instance or type. By using the Flexibility Patterns to assess what level of flexibility is required, it is likely that all possible interpretations of the notion of flexibility are covered. Be aware that at the current moment Flexibility Pattern theory only covers the control-flow perspective of process modelling.

4 Discovering the medical processes

This chapter describes the identification, formalisation and validation methods that have been applied for retrieving the Dermatology oncology processes at the Catharina Hospital Eindhoven. The retrieved processes describe the As-Is situation at the Dermatology oncology outpatient clinic. As-Is is an abbreviation of the situation ‘as it is’ at the moment this survey was conducted.

The next sections describe the methodology used for identifying the Dermatology oncology processes, some information on the Dermatology oncology treatment interventions, and ending with the formalised processes covering the control-flow, resource and data perspectives. The control-flow perspective describes *what* and *how* the process should be executed. The resource perspective describes which resources should undertake what activities. This is described by allocating a group and a role to every activity that requires a human resource. For example, resources with the role ‘secretary’ and group ‘secretariat’ make appointments with patients. And last, the data perspective shows which data elements are required in order to perform a given set of tasks and what data is generated from these tasks. Student Thiemo Keijzers will cover the data perspective and will use this activity for fulfilling his Bachelor Thesis.

4.1 Process identification methodology and treatment interventions

This section describes the methods used for identifying and validating the Dermatology oncology processes at the Catharina Hospital Eindhoven. First, domain knowledge about the different treatment interventions at the Dermatology oncology outpatient clinic is presented, in order to get an idea of the differences and content of the treatments. Second, the methods for identifying these processes are described where after the validation methodology is described.

4.1.1 The available treatment interventions

In this study the scope is limited to oncology processes at the Dermatology oncology outpatient department only. Within this scope several treatments are conducted, dependent on the type of cancer, its size, its location on the human body, etc. Domain knowledge about these treatments is presented, in order to convey an insight into what is happening with the patient.

The treatments can be divided into the following categories:

- **Photodynamic Therapy (PDT):** This treatment is performed when suffering a beginning, superficial, cancer area (in Dutch: ‘superficieel basaal celcarcinoom’) or at so-called ‘sun-damaged spots’ (in Dutch: actinische keratose). The aim is to reduce or remove the cancer spot. This is realised by using a special ointment that is lubricated onto the cancer spot and is illuminated with a special infrared light.
- **Laser PDT:** This treatment is equal to the PDT with the difference that no infrared light, but a laser light is used for activating the ointment.
- **Excision:** When the cancer spot has to be removed from the human body, this spot can be excised. Mostly, this standard excision is performed at locations other than the head/neck and for relatively small cancer spots.
- **Mohs:** This is a special form of excision that is aimed at removing the cancer spot causing as little as skin damage possible. Main difference with the default excision is that the patient is staying for one complete day in the hospital. The surgery continues until it can be guaranteed that the spot is cancer-free. This treatment is mainly conducted at cancer spots around the head/neck. If necessary (for larger cancer areas) the patient is anaesthetised, which requires some additional resources and activities.
- **Self-treatment:** In these cases the patient is provided with a special ointment that can be used for the self-treatment of cancer spots, mostly ‘actinische keratose’.

4.1.2 Methodology for identifying and validating the process models

In the current situation, no process-aware information systems are used. Therefore no quantitative process/system data could be extracted from the environment as input for identifying the processes.

The methodology presented by Law and Kelton (2000) is used for identifying the processes, which will be explained from here on:

- Regular conversation with subject-matter experts;
- Observe the system;
- Interact with the manager on a regular basis;
- Perform a structured walk-through of the conceptual model.

The observations and interviews at the Dermatology oncology outpatient clinic took about two weeks. In this timeframe about five patients undergoing Mohs surgery, twelve patients undergoing the Photodynamic therapy and half a day of consultation meetings have been observed. During those observations I was able to ask questions about the processes. These questions mostly intended identifying the arguments for certain decisions in the process, whether the observed things were part of a defined medical procedure, what information was required in order to start an activity or treatment intervention, etc. At the end of each treatment intervention one of the present nurses informed the patient about post-treatment activities and scheduled these. This information provided with me with insights in post-treatment activities.

Observations of consultation meetings between patients and the physician showed which steps are required in order to get the right information for making a clinical decision. By observing about 15 patients during their consultation meetings it became clear what the generic process behaviour of a patient looks like before the actual treatment intervention is started. During the consultation observations I was free to ask questions for gathering data on the consultation's follow-up activities and reasons why physicians decide to skip (or not) certain process activities.

Details about the other treatment interventions were recovered by interviewing oncology nurses and physicians who perform those treatments. These resources have performed these treatments over multiple years and were able to identify the possible scenarios a patient can be confronted with. The Mohs surgery, which was captured during the observations, was used as a basis for capturing the Excision surgery and the Mohs-with anaesthetisation processes. As it appeared the Excision surgery is a simplified version of the Mohs surgery and the Mohs anaesthetisation is an extended version of the Mohs surgery processes. To find the differences between those treatments, three Dermatology oncology physicians and two nurses were interviewed. The last two or three interviews already showed consistencies in the reported process behaviour. It was therefore assumed the model's fit with reality was quite high.

Following the identification of the Dermatology oncology processes, validation of the identified processes. Validation of the captured process models is an important aspect in the medical process identification phase. By validating the process models, it is ensured that the models offer a trustworthy representation of the process in reality. Another advantage is that a validated process model acts as a strong argument towards people who question the correctness of the process models.

For validating the process models it was decided to perform a structured walk-through by using the input of the highest ranked physicians at the Dermatology oncology outpatient clinic. The three leading physicians (Chief of Dermatology included) at the outpatient clinic have years of experience in treating oncology patients and are the resources whom are responsible for making decisions about the activities that should be performed in the patient's workflow. This is in contrast to the activities performed by nurses. These activities are based on the physician's decisions. Nurses will probably be able to tell whether the modelled behaviour is representing reality, but might not be able to properly indicate what could be missing in the process models. Since physicians are the decision-makers, they should be able to indicate missing parts in the process model.

The first step of the validation process existed out of making the interviewed physician familiar with the used process-modelling notation. It was not expected that the physician would master all facets of the used notation, but it should be required that physician was able to follow the logic of the modelled processes. Letting the resource explain the modelled process behaviour tested this capability. Once the interviewee showed to understand the process models well enough, a complete structured walk-through was modelled. The aim of this walk-through was to validate whether the modelled behaviour reflected the real behaviour and whether process parts were missed during the identification of the processes.

During the validation meeting with the first physician a number of changes have been made to the model and some decision constructs were added to the model. The second and third interviewed physicians agreed upon the updated process models. Based on their expertise it can be concluded that these models reflected the actual patient process adequately.

4.2 The formalised medical processes

The process models are described using the YAWL-notation complemented with the resource perspective as described by Van der Aalst and Van Hee (2002). These models describe the process' control-flow dimension as well as the resource dimension. The decision to use the YAWL language (Van der Aalst and Ter Hofstede, 2005), instead of Petri-Net, EPC, BPMN, etc. had several reasons. First, this research uses Workflow Patterns (Russell, 2004a, 2004b, 2006) in order to describe the suitability of WFMSs in healthcare. The YAWL-notation is based on those Patterns and therefore might simplify the process of making the relations between the process models and its required Workflow Patterns for supporting these models. Explanation of the syntactic elements of this language is given in 'Appendix 1: Legend process definitions'. The data perspective will be presented in a UML Static Structure, which is created by Bachelor student Thiemo Keijzers as mentioned in the opening of this chapter.

In the next subsections the models of the different perspectives will be presented and explained.

4.2.1 Resource perspective

When supporting an operating environment by workflow technology, the process definition used as input for a WFMS should incorporate knowledge about the structure of the organisation. In the end, it should be defined which resource (or group of resources) should commence on any given activity. This is realised by classifying the roles of the resources (for example, nurse, secretary, dermatologist) according the their place in the organisation (for example, Dermatology outpatient clinic, Pathology, etc.) – also referred to as the group in the organisation. For any process activity that is performed by a human resource, the right group and role attached.

The organisational model is presented in Figure 13. Note that this model only covers the groups and roles that are of interest for enacting the Dermatology oncology processes. The organisational model for the entire Catharina Hospital Eindhoven would be much more complex.

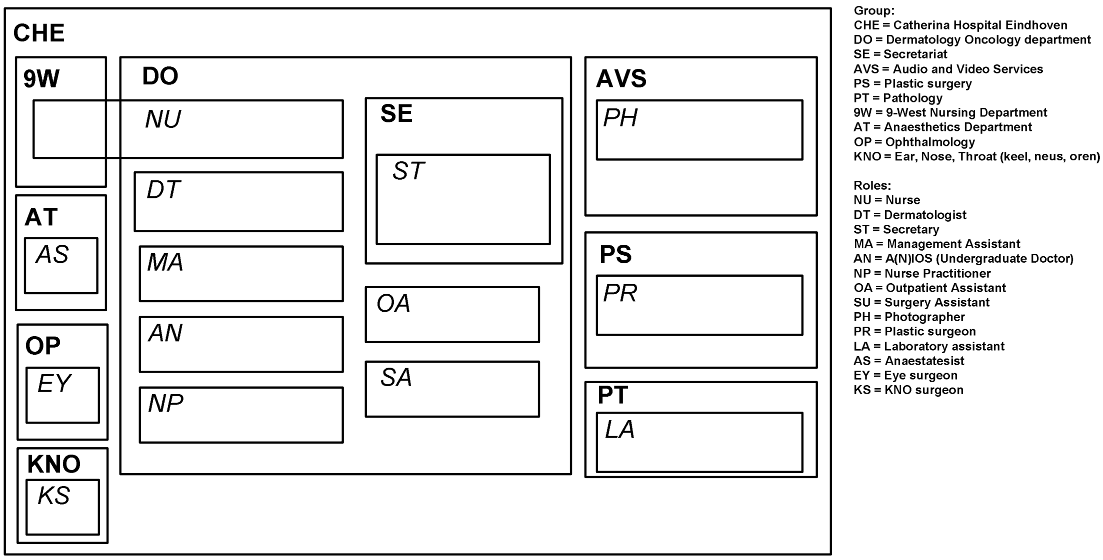


Figure 13 Organisational model

A role-based classification relies on the skills resources posses and a group-based classification relies on the resource's place in the organisation (Van der Aalst and Van Hee, 2000). Examples of groups are the Dermatology department (DO) or the Anaesthetics department (AT). Examples of roles are Nurse (NU) and Dermatologist (DT). As shown in Figure 13 resource classes may overlap, or be a subset of another – larger – resource class. For example, nurses (NU) are part of the Dermatology department (DO) or the 9-West Nursing Department (9W) and also the Secretariat (SE) is part of the larger group Dermatology (DO).

4.2.2 Control-flow perspective

The control-flow perspective of a process model covers the process' behaviour, showing *what* should be done and *how* it should be done. A high-level presentation of the patient-centric treatment process is represented in Figure 14. This model will be used for describing the general sequence of activities in the patient's workflow of the Dermatology oncology outpatient clinic at the Catharina Hospital Eindhoven.

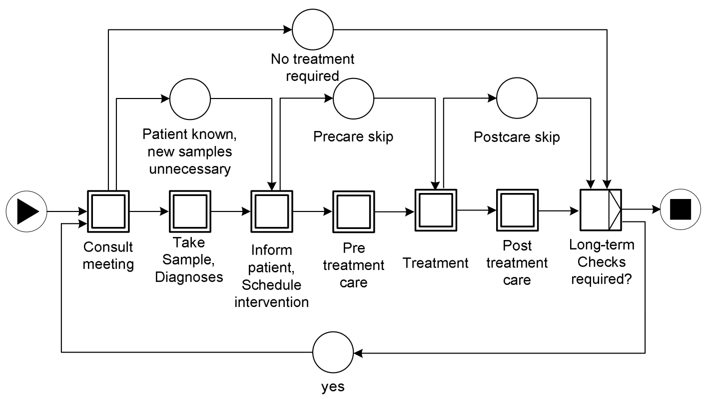


Figure 14 High level patient-centric treatment process

New patients or returning patients arrive at the 'consult meeting' subprocess. After this consult the doctor can decide (1) that the patient does not need medical treatment, (2) the patient needs to be analysed, or (3) the patient has already been diagnosed before, requires no additional analysis and can therefore directly commence on the next treatment.

Based on the patient's health analysis, the diagnosis is made and the physician determines the treatment that offers the best probability of recovery. Pre-treatment care is required whenever the surgery requires a patient to be anaesthetised. In these cases Pre-Operative screening is required if this has not already been done in the last three months. Pre-Operative screening is not conducted at the Dermatology outpatient clinic, but takes place at the Pre-Operative screening department. The description of the Pre-operative screening is not incorporated in the As-Is models – since it is not part of the scope of this study – but is described in detail by Vonk et al. (2008).

After the Pre-treatment care subprocess, the execution of a Dermatology's treatment intervention is commenced on. Under normal circumstances, a patient undergoes one treatment intervention. The selection of one of these treatment interventions is defined in the clinical decision. Process definitions of these treatment intervention subprocesses are presented in 'Appendix 2: As-Is process models'.

According to the project stakeholders at the Catharina Hospital Eindhoven, at least eighty percent of the patients fit the normal circumstances and require one of the treatment interventions at the Dermatology oncology outpatient clinic. Therefore the selection of a process is realised in the As-Is treatment process by means of a choice pattern, realised with an exclusive 'OR'-construct (XOR).

Treatments that include surgery require Post-treatment care, which mainly consist of a wound check and/or the removal of stitches. In case the results of the Excisions show that the patient is not cancer-free, the patient will undergo Mohs-surgery to excise the remaining cancer cells. Most patients who have suffered skin cancer for the first time have to return to the clinic for frequent health checks.

The entire patient process is illustrated in Figure 15 (page 21). The treatment subprocesses are presented in Appendix 2: As-Is process models'.

4.2.3 Data perspective

The amount of data that is generated while executing the process is tremendous. Since every piece of information – except for the scheduling of patients – is handled on paper, high efforts are made for filling in all required documents and also delivering them to the required destinations during the process. This complicates the process. Not only are medical personnel spending a significant amount of time with handling all this information; it also decreases the quality of care. This last premise can be found in observations, which showed that patient records are missing very frequently and required parts of information are sometimes missing in a patient record when care is delivered. For example, medical photographs of patients are missing while delivering care, because the photographer was not able to catch up with the pace of the treatment process. Another disadvantage of a paper-based working environment is that the same information is duplicated several times, scattered onto different documents across the treatment process.

In order to get a comprehensive overview of the data elements in the process, Bachelor student Thiemo Keijzers joined this research in order to evaluate the data perspective of the medical treatment process. By complementing to this research, Thiemo intends to acquire his Bachelor of Science degree, at the Eindhoven University of Technology. The data model is defined in an UML Static Structure and is shown in Figure 39 (page 63). The data model is based on a collection of medical forms that are used during the treatment process. Via these forms a set of data classes were identified. Classes that represent information regarding the patient (and its history) as well as information required for treatments, or diagnosis. The relation between the data attributes with the separate forms is illustrated the numbers that are added along with each data attribute. These numbers refer to the individual forms.

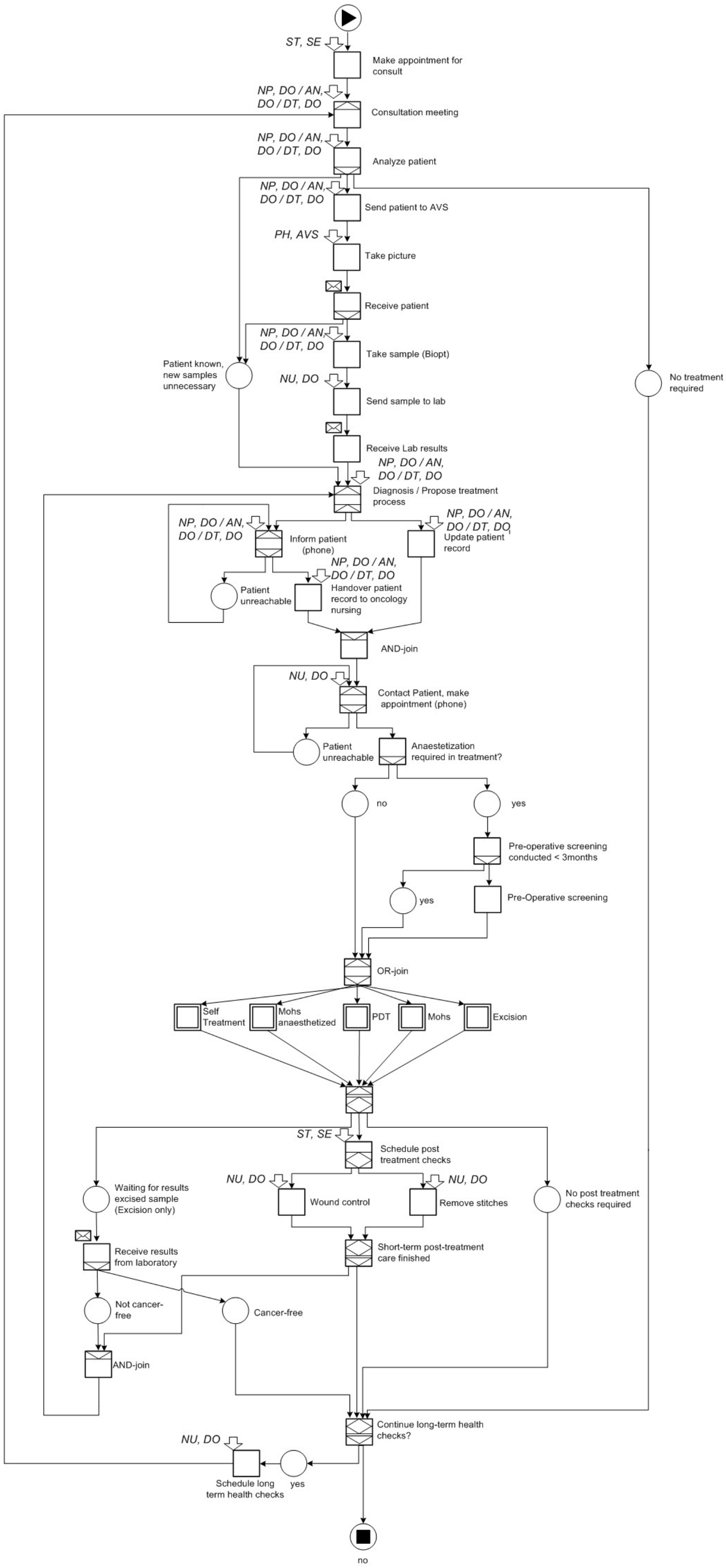


Figure 15 Overall patient process model

4.3 Concluding from the process identification and formalisation

Observing the patient-related activities across the entire process and interviewing human resources on different levels in the organisational hierarchy captured the patient's treatment processes. This answered research question Q3a (*What are the Dermatology oncology processes?*) Two main findings will be discussed in this section:

- The medical personnel has a high level of process understanding;
- Medical scenarios are well anticipated.

Based on the examined literature it was expected that the capturing of a default process structure could become a very though part of the project. As Lenz and Reichert (2006) state, physicians are not supposed to follow a step-by-step treatment plan or rely heavily on clinical guidelines (Maviglia et al., 2003) that are supposed to standardise the process (Mulyar et al., 2006). This suggests that one could wonder whether it is possible to define a default process structure that supports the treatment workflow of the majority of the patient population at the Dermatology oncology outpatient clinic. However, during the identification of the processes it became evident that the physicians at this outpatient clinic do have high level of process understanding. Given the complexity of medical processes (Anyanwu et al., 2003) one would expect that each resource would have a limited overview of his/her responsibilities only.

During the process identification interviews it also became clear that physicians were able to provide process scenarios a patient could undergo, without having any direct patient-related information. The diagnostic therapeutic cycle (Figure 8, page 10) suggests that uncertainties of the patient's health and the level of medical knowledge available at the moment would lead to a clinical decision and that the outcome of this decision may not be anticipated beforehand. Current identified process models just prove the opposite. The possible scenarios a patient can undergo at the Dermatology oncology outpatient clinic are explicitly defined in the process models, which exclude process behaviours other than incorporated in the models.

The current process models support the average – normal – patients, whom require only one treatment based on their diagnosis. According to the Chief of Dermatology, these patients cover about eighty percent of their entire patient population. Supporting these normal patients requires a degree of design-time flexibility such as (exclusive) choices for delivering the required process support. One of the challenges that remain unanswered is the whether it is possible to create more flexible solutions that are also able to support the complex patients.

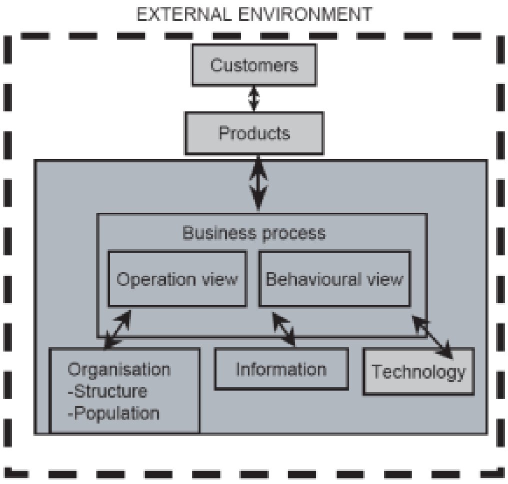
5 Redesigning the medical processes

At this point of the study the As-Is processes of the Dermatology oncology outpatient clinic at the Catharina Hospital Eindhoven are identified. As described in the study's design section (section 2.2) one of the goals of this project is to specify what technological capabilities a WFMS should offer for supporting the examined processes properly. To get more benefits from the power of workflow technology, it is desirable to investigate whether the As-Is processes can be improved. In the end, it may be assumed that any company would prefer the implementation of improved processes above the implementation of the As-Is processes. Redesigning these examined As-Is processes seems relevant, since the chances are high that this would be done in real-life too.

By doing so, it might be suggested that by redesigning the processes a more complex (or simplified) process is created. These changes might bias the specification of the technological capabilities from a methodological perspective. Therefore, the effect of the accepted redesign propositions will be taken into account when specifying the requirements for process support.

In the remainder of this chapter the used redesign framework, the methodology, the redesign propositions themselves, and its evaluation will be described.

5.1 Business Process Redesign framework



To guide the process of redesigning the examined process, the Best Practices presented by Reijers and Mansar (2005b) are used. "An ideal best practice prescribes the best way to treat a particular problem than can be replicated in any situation or setting" (Reijers and Mansar, 2005b). In order to cover all redesign aspects of a business process, Reijers and Mansar (2005b) extended Steven Alter's WCA framework (Alter, 1999) with the MOBILE workflow model (Jablonski and Bussler, 1996), the CIMOSA enterprise modelling views (Berio and Vernadat, 2001) and the process description classes of Seidmann and Sundarajan (1997). This framework is illustrated in Figure 16.

Figure 16 BPR framework (taken from Reijers and Mansar, 2005)

According to this Business Process Redesign (BPR) framework several distinct viewpoints can be taken in order to improve a business process: (1) Customer viewpoint, (2) operational viewpoint, (3) behavioural viewpoint, (4) organisational viewpoint, (5) informational viewpoint, (6) a technological viewpoint, and an (7) external environment viewpoint.

5.2 Methodology used for capturing and evaluating redesign opportunities

The aim of BPR is to increase the operational process performance. However, while thinking of better ways for executing the examined processes, trade-off exists between the optimisation of one performance dimension versus another. Brand and Van der Kolk (1995) identified the 'Devil's Quadrangle' that illustrates the difficult trade-off that exists between cost, quality, time and flexibility. This quadrangle is illustrated in Figure 12 (page 15).

Within the Catharina Hospital Eindhoven emphasis is put on the dimensions of time, costs, and flexibility. The quality level has at least to be maintained, but requires less attention in this study since it already complies with strict healthcare regulations. Regarding improvements on the time-axis, the hospital wishes to reduce the number of direct contacts between the patient and the hospital. Also, the hospital length of stay (HLOS) of patients at the hospital needs to be reduced. This would probably result in an increase of patient capacity and reduces the medical personnel's administrative task load. Optimisation of these criteria will automatically affect the cost dimension to some extent. Less contact with patients, or less time spend on patients, reduces costs, naturally. A more efficient way of working will also reduce time and costs indirectly spent on patients

The methodology used for redesigning the Dermatology oncology processes at the Catharina Hospital Eindhoven is illustrated in Figure 17. The Redesign Best Practices (Reijers and Mansar, 2005b) were reflected on the As-Is processes. For each Best Practice it was investigated whether realisation was possible and effective. Besides using the theoretical perspective, some suggestions for redesigns were presented by the Dermatology's resources. This was not achieved by conducting a dedicated interview, but these requests were captured during along with other interviews, observations, lunches, or at the coffee machine. During a workshop the stakeholders themselves could introduce new redesign proposals. Both theoretical and organisational perspectives led to the development of seven redesign scenarios.

A workshop of one and a half hours was organised for evaluating the redesign propositions. During this workshop the three main dermatologists (including Chief of Dermatology), two oncology nurses (including head of oncology nursing) and other resources (all present resources are presented in Table 14, page 69) were gathered for conducting the qualitative evaluation of the redesign propositions. The mentioned dermatologists and oncology nurses all have at least ten years experience in the field of Dermatology-oncology. During this workshop each redesign scenario was presented individually. All participants had the opportunity to provide feedback on the presented scenario. By doing so the feasibility and impact of each scenario were discussed. Another intention of the workshop was the possibility for participants to think of new redesigns themselves.

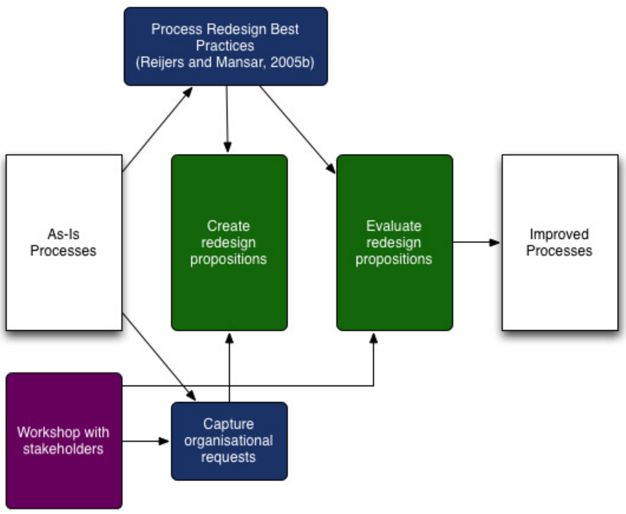


Figure 17 Process redesign methodology

During the next sections the developed redesign propositions, as well as the evaluation of the redesign scenarios are discussed.

5.3 *Redesign scenarios*

5.3.1 Medical photograph

During the consult meeting between the patient and the physician, the latter can decide to send the patient to the Audio & Video Services department (AVS) in order to make a medical photograph. This activity is frequently executed and is needed when a patient shows up with a new skin cancer area. In practice, the physician hands over a special document and sends the patient to the AVS department. The photographer prepares his equipment whenever a patient arrives, shoots the photo and archives it. A copy of this photo returns in the patient record, which is needed at the moment of surgery. The surgeon can take a look at the original state of the patient's cancer, for example to check whether surgery takes place in the correct area. However, due to the complex logistics of this process, the photographer sometimes is not capable of delivering the photo, before care is delivered to the patient. The photographer is responsible for the printing and archiving of the photo, which sometimes requires more time than available.

This process fragment is illustrated in Figure 18.

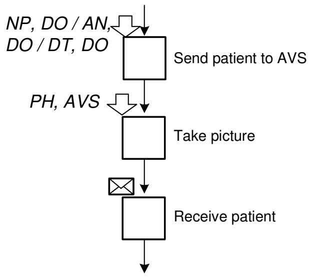


Figure 18 Medical photograph process steps

5.3.1.1 Redesign objectives

- Reduce service time regarding the photo-creation process;
- Reduce HLOS performance parameter;

5.3.1.2 Realization alternatives

<u>Scenario 1: Use own camera</u>

Physician shoots photograph with own camera, uploads it into the system and e-mails it to AVS department, illustrated in Figure 19.

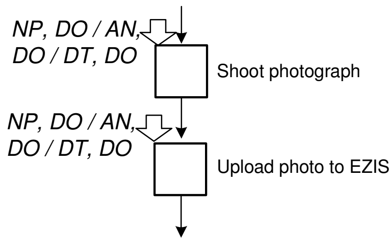


Figure 19 Photograph scenario

This redesign proposition is based on the following heuristics:

- **Order assignment:** The physician performs as many steps as possible whenever he/she is meeting a patient face-to-face;
- **Integral technology:** The photograph is directly integrated in the patient's electronic file in of the used Document Management System

<u>Scenario 2: Relocate photographer</u>

According to the Dermatology personnel, they claim the photographer services most of all outpatient clinics at the Catharina Hospital Eindhoven. By assuming this, it could be proposed to relocate the AVS and photographer to the Dermatology department. The physician sends the patient to the photographer (as it is done today), but the patient does not have to travel across different stories and wings of the hospital building. Again in this case the photograph is directly uploaded to the system to guarantee direct availability. When relocation of the photographer is not an option, the patient still has to move to the AVS department. However, for both cases the process illustrated in Figure 20 stays the same.

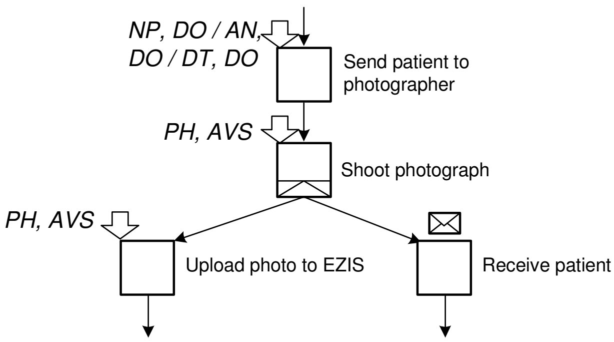


Figure 20 Photograph scenario 2

This redesign proposition is based on the following heuristics:

- **Parallelism:** The photographer is able to upload the photo, while the patient is returning to the dermatologist.
- **Integral technology:** The photograph is directly integrated in the patient's electronic file in the existing system.

5.3.1.3 (Dis)Advantages scenarios 1, 2

	Advantages	*Disadvantages*
Scenario 1	Fast access to digital photograph	Additional work load medical personnel
	No need to send the patient across the hospital	
	Decrease service time during consult meeting and analysis	
	Decrease HLOS	
Scenario 2	Fast access to digital photograph	Relocation of AVS might cause organisational resistance, since other outpatient clinics also require the photographer which becomes part of Dermatology, instead of clinic independent.
	No need to send the patient across the hospital	Non-dermatology patients have to come to the dermatology department to get a photograph.
	Decrease service time during consult meeting and analysis	Process behaviour becomes more complex
	Separation in concerns with regard to the employee's tasks.	

5.3.2 Minimize synchronous communications with patient

Human skin samples are prepared and analyzed by the pathologist at the Pathology department. This laboratory is located in another part of the hospital, but hospital management has already planned to create a Pathology room at the Dermatology department. This reallocation of resources prevents nurses and pathologists transporting human tissue across the hospital, which is a good thing. In this paragraph it is therefore assumed that Pathology services are located at the Dermatology department.

Currently, there are three distinct process fragments in which communications between Dermatology and Pathology are required:

- Whenever a sample (biopsy) is taken from a patient in order to examine whether this patient is suffering cancer;
- During the regular Excision process, when the excised tissue is analyzed by the pathologist;
- During the Mohs process, in which the excised tissue is prepared by the pathologist and directly returned to the Dermatology department for analysis.

The largest advantage of this last option is the fact that the results of the surgery are revealed while the patient is waiting. This scenario can also be applied to the first two process fragments in order to reduce synchronous communication with the patient. In this case that applies to the biopsy that has been taken at the consult meeting, as well as the removed human tissue during the Excision treatment, which will immediately be prepared and analysed by the Pathologist and returned to the physician, as intended. In this scenario the physician can make a diagnosis and inform the patient while the patient is still in the hospital. If necessary a new treatment appointment can be made too. The patient is requested to wait about 30-60 minutes until examinations of the biopsy are finished. Meanwhile the physician can receive other patient during the consulting hours. The patient is most probably willing to wait, since clear future prospects are ensured before leaving the hospital. Today, patients are informed by telephone sometimes up to seven days after their previous visit leaving them in doubt of their future.

5.3.2.1 Redesign objectives

- Reduce time between analysis results and informing patient;
- Reduce HLOS performance parameter;
- Reduce number of contacts with patient.

5.3.2.2 Realization alternatives

Scenario 3: Biopsy results while patient waits

The As-Is process fragment is taken from the general process structure, presented in Figure 15 (page 21). This process fragment includes the biopsy taking, laboratory analysis, diagnoses, informing patient, and scheduling of the treatment steps.

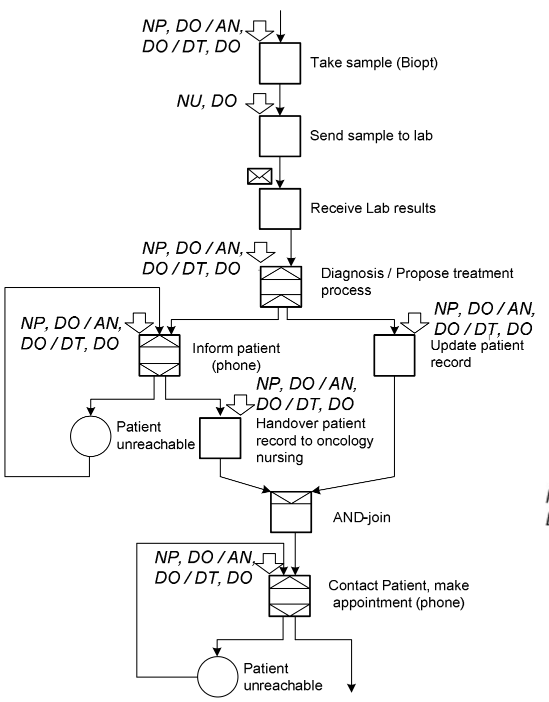


Figure 22 As-Is Biopsy process fragment

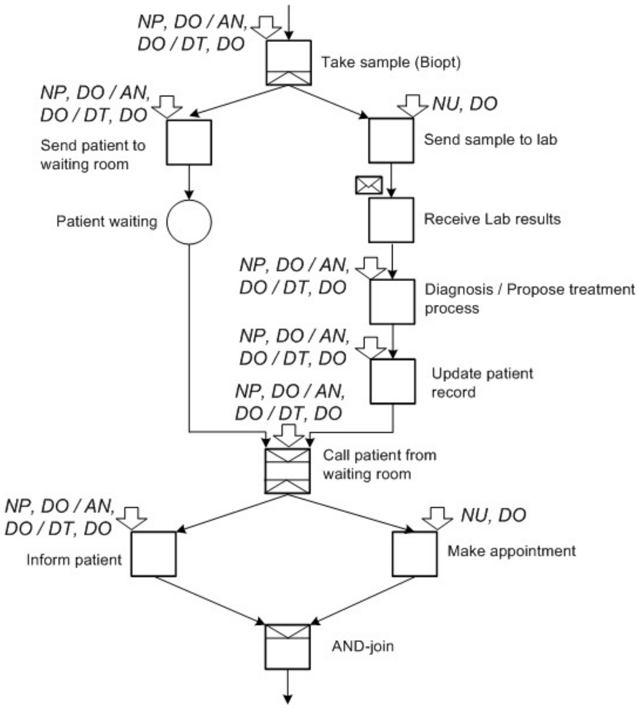


Figure 21 Biopt scenario 3

The To-Be process situation is illustrated in Figure 21. This process redesign proposition ensures that all patient-dependent tasks are executed while the patient is visiting the hospital. For example, a biopsy is taken from a patient, where after the patient waits and the biopsy is immediately analysed. After the results are returned to the Dermatologist, the patient is called from the waiting room, the patient gets informed about the state of the disease, the proposed treatment intervention and is scheduled right away.

This redesign proposition is based on the following heuristics:

- **Parallelism:** Activities regarding informing and scheduling the patient are performed in parallel, as well as the analysis of the biopsy while the patient is waiting in the hospital.
- **Contact reduction**: The patient is only contacted once to handle all pre-treatment process steps, instead of three times.

- **Task elimination:** The task “handover patient record to oncology nursing” has been deleted, since it has become superfluous.

Scenario 4: Pass control towards patient

To improve contact with the hospital, a solution is offered shifting scheduling controls to the patient. In this case the patient triggers the scheduling of an appointment, instead of the nurse. The advantage of this approach is less time is spent in order to achieve synchronous (alias one-to-one/direct) contact with the patient. Since the patient rings the hospital, synchronous contact is established immediately. In the current situation the nurse attempts to contact the patient by phone, which might require several tries before the patient is finally contacted. Scenario 4 is illustrated in Figure 23.

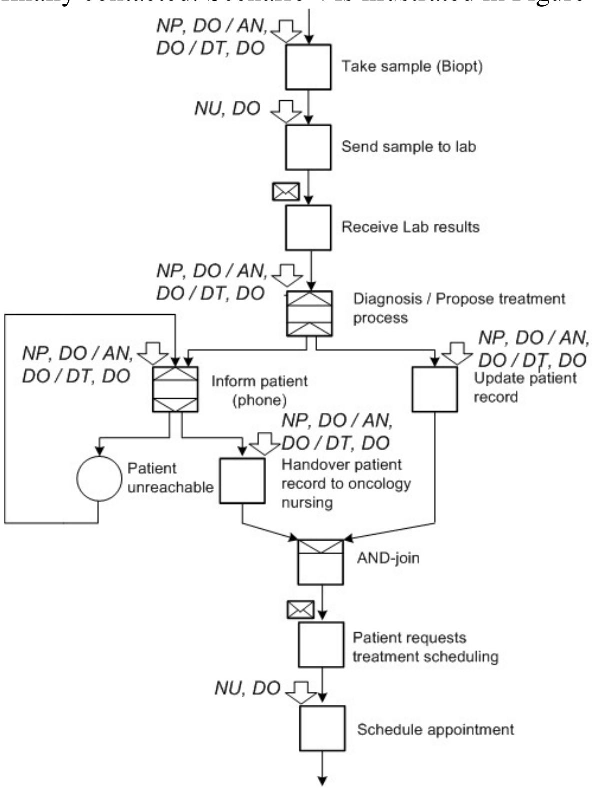


Figure 23 Scenario 4 Pass control towards patient

This redesign proposition is based on the following heuristics:

- **Control relocation:** Control of scheduling appointments is relocated to the patient.

Scenario 5: Combine scheduling and informing the patient

In the As-Is process, the physician rings the patient to inform him or her about the laboratory results. Thereafter, the patient record is passed to the oncology nurse who again rings the patient to make an appointment and explain the treatment in more detail. This way of work seems very patient-friendly, but it creates large bottlenecks in the performance of the process. Each of these interactions generally requires more than one phone call, which creates a delay in the process’ progress of days and is very bureaucratic. It is therefore desirable to reduce the number of contacts with the patient. One way of realising this is by either giving the physician scheduling responsibilities or by giving the nurse responsibility to inform the patient about the laboratory outcomes. Both considerations are illustrated in Figure 24.

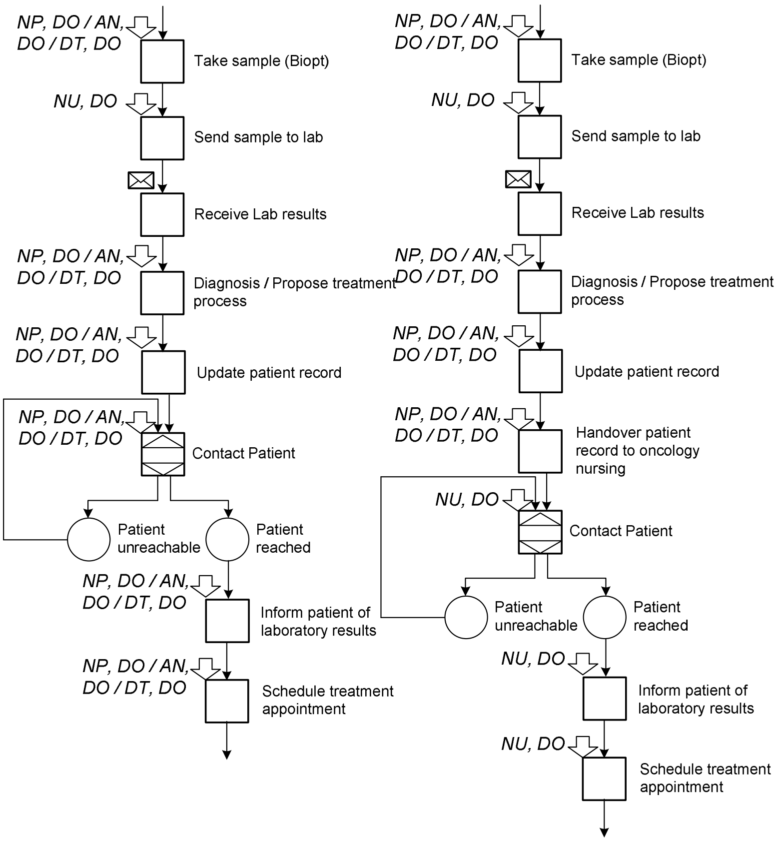


Figure 24 Scenario 5a and 5b: Combine scheduling and informing patient

This redesign proposition is based on the following heuristics:

- **Contact reduction:** The number of contacts with the patient is reduced from three to two contacts.
- **Order assignment:** The goal is to let workers perform as many steps as possible whenever contact with the patient has been established.

5.3.2.3 (Dis)Advantages scenarios 3, 4, 5

	Advantages	*Disadvantages*
Scenario 3	Number of contacts reduced from three to one.	The work of the pathologist becomes more ad-hoc alias 'on demand'.
	Informing patient about samples results and appointment scheduling can be combined during same visit.	A nurse has to be available to create the appointments while patient is present in hospital.
	Nurses spend less time in scheduling patients	Patient has to wait in hospital for laboratory results
	Time between laboratory results and treatment decreases. Care is delivered faster	
	Patients receive laboratory results same day/visit.	
Scenario 4	Scheduling patient succeeds in one try	No real contact reduction, but time used for contacting patient reduced.
	Nurse's utilization regarding administrative scheduling tasks decreases	No performance improvement for physician in this scenario.
Scenario 5a	Number of contacts with patient reduced to	Resource utilisation of nurse increases

	two.	
	Resource utilization of physician decreases	
	Less task redundancy	
Scenario 5b	Number of contacts with patient reduced to two.	Resource utilisation of physician increases
	Resource utilization of nurse decreases	
	Less task redundancy	

5.3.3 Reallocate PDT scheduling

In the As-Is situation nurses schedule all patients who require photodynamic therapy (PDT). The main advantage of this decision is that nurses have the highest level of domain knowledge, since they perform these treatments mostly themselves. The secretariat group schedules non-oncology patients, instead of the nurses. When asking a random secretary why she does not schedule patients for the PDT, she answered that she could not foresee how many patients would fit in the schedule, since there is variation in treatment variables and she does not know how to interpret them. Indeed, there is a wide variation in the level of thermal energy (Joules) and the corresponding duration of the treatment and the secretary's arguments are therefore valid. However, after examining the PDT patient schedule in the patient scheduling history the surprising conclusion could be drawn that every day around six patients visit the hospital for PDT treatments, regardless of the mentioned treatment variables. To examine the dependency between the type of treatment with the number of treatments a day, the PDT scheduling data from 18. August 2008 until 7. November 2008 was analysed using the SPSS statistical software package. The descriptive statistics show that on average 5,68 PDT treatments are performed each day (days without PDT treatments were excluded). To examine the influence of the chosen energy level and its corresponding duration, a linear regression model was created using the number of PDT treatments per day as dependent variable and the different energy level options as independent variables. The regression coefficients of this model are displayed in Figure 25. All other SPSS output is represented from at 65.

Coefficients[a]

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95% Confidence Interval for B Lower Bound	95% Confidence Interval for B Upper Bound
1 (Constant)	,077	,120		,639	,526	-,166	,319
70J	,972	,022	1,464	44,920	,000	,929	1,016
20J+80J	1,029	,028	1,072	36,274	,000	,971	1,086
37J	1,003	,027	1,115	37,339	,000	,949	1,058
60J	,980	,079	,320	12,329	,000	,819	1,140
80J	,996	,112	,195	8,888	,000	,770	1,222
LASER	,995	,054	,449	18,422	,000	,886	1,104
2x70J	,927	,073	,324	12,780	,000	,780	1,073
100J	1,051	,163	,147	6,458	,000	,723	1,380
37J+70J	1,082	,163	,151	6,636	,000	,753	1,412
2x20J	,999	,089	,238	11,177	,000	,819	1,180
3X70J	1,080	,162	,151	6,686	,000	,754	1,406
2x(20L+80J)	1,006	,145	,141	6,953	,000	,714	1,298
3x(20L+80J)	,876	,110	,172	7,974	,000	,654	1,098

a. Dependent Variable: [#PDT]

Figure 25 Regression coefficients

The regression coefficients (second column, Figure 25: B-coefficients) show that every chosen energy level leads to about one additional PDT appointment. Therefore, the relation between the required energy level and the number of treatments a day is linear. This means that nurses are not necessarily required to perform scheduling activities, since their know-how adds no value to the scheduling of PDT patients. Releasing this administrative scheduling duty from the nurse's workload should free more time that can be spent on primary treatment tasks. Figure 40 (page 64) represents the working schedule of the oncology-nursing group. In this schedule it is clear that from 4pm the nurses are busy with secondary obligations. From personal observations it became clear that nurses spend these last hours calling patients for informing them about their treatment and scheduling the required appointments. When replacing these duties with additional PDT treatments, more patients can be treated with PDT each day.

5.3.3.1 Redesign objectives

- Increase patient capacity
- Decrease administrative task-load nurses

5.3.3.2 Redesign scenario

Scenario 6: Reallocation of PDT scheduling to secretariat

In this scenario, all patients for new PDT treatments are scheduled by the secretariat. It is possible that patients are returning to finish their previous PDT treatment session. For example, this occurs when the skin area is too large to treat in one session. In these cases, the nurse is the most appropriate person to schedule the new appointment, since he/she can schedule a new appointment directly with the patient during the last PDT session. This means that the process model of the PDT treatment itself stays equal to the representation in Figure 34 (page 59). The scheduling of patients becomes the secretary's duty, as illustrated in the process fragment in Figure 26 (page 31).

Reallocating activities to the secretariat could result in an overload of activities in this group. It is therefore wise to investigate whether the secretariat's capacity can handle the proposed changes.

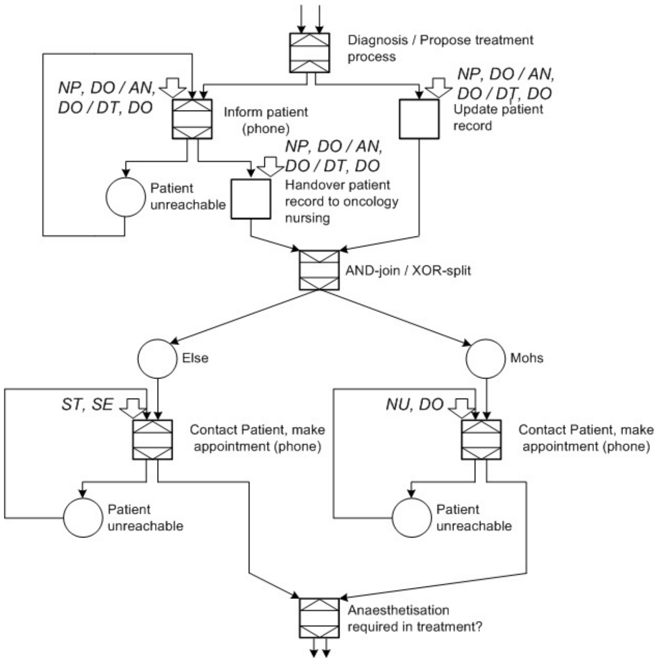


Figure 26 Scenario 6: PDT scheduling reallocated to secretariat

This redesign proposition is based on the following heuristics:

- **Split responsibilities:** Scheduling is one of the main tasks of the secretariat group.
- **Specialist-generalist:** By allocating the treatment tasks primarily to nurses and scheduling tasks to the secretariat, a more specialized dispersion of activities is realized.

5.3.3.3 (Dis)Advantages scenario 6

	Advantages	*Disadvantages*
Scenario 6	Nurses are able to spend more time on treatment activities	Workload of secretaries increases, capacity problems might occur
	Nurses relinquish control over scheduling of PDT patients	Equal amount of time spend on contacting patients as in the As-Is situation
	Capacity PDT treatments increases	

5.3.4 Minimize duplication of information

Except for the scheduling of patients, all information at the Oncology Dermatology department is handled on paper. This paper-based way of working increases the amount of information that is duplicated enormously. For example, information elements like the patient's name, the diagnosed type of disease or the requester's name have to be noted on multiple forms during the process. This paragraph intends to provide a redesign scenario that describes the advantages of an information system that assists with filling in forms with predefined information elements. To illustrate the duplication of data on paper a hypothetical scenario (Figure 45, page 68) will be used to illustrate the need for digital data handling. The process scenario presented in Figure 45 (page 68) is hypothetical and describes a new patient that is diagnosed with skin cancer and undergoes the Mohs surgery treatment. The process chain is based on a best-case scenario, which results in the situation that – for example – the patient is reached in just one phone call, or the cancer is completely removed after just one Mohs surgery cycle. These assumptions are made to decrease the complexity of the process model, since the objective is to only illustrate the amount of data duplication. Along with the process model, the added numbers represent the used forms. These numbers refer to the forms as described in the UML Static Structure (Figure 39, page 63) and are connected to the tasks by dashed lines. The addition of the letters 'N' or 'A' state whether new forms are used (N) or information is added (A) to existing forms. Regarding information that was added to existing forms, it has been taken into account what data attributes were added to existing forms and what were not. Based on the forms used it can be deduced how many times data attributes have been duplicated (which is equal to the number of times it is written down, minus one). In Table 3 the duplicated data attributes are presented in decreasing order. From this table can be concluded that – even for a relatively simple process scenario – the level of duplication is quite large.

Table 3 Number of replications in illustrative process scenario

Data attribute	Duplications
Name physician	11
Consult date	8
Description disease	6
Location spot	4
Location (at hospital)	3
Size of spot	3
Nature of material	2
Date of application	2

5.3.4.1 Redesign objectives

- Decrease administrative task-load personnel

5.3.4.2 Redesign scenario

<u>Scenario 7: Implementation of a Document Management System (DMS)</u>

The implementation of a WFMS and/or DMS will open up the accessibility of information between the resources in the Catharina Hospital Eindhoven. However, the most important aspect is the reduction, or even deletion, of data duplication. As one of the physicians stated during an interview: *"Day in day out, I need to write down the same information on up to five or six different forms."* Information systems can retrieve data elements that have been entered earlier on and simplify the administrative aspect of the treatment process dramatically.

This redesign proposition is based on the following heuristics:

- **Integral technology:** A future WFMS or Document Management System (DMS) will reduce the duplication of data and open up information to all process actors. With the use of a WFMS the logistical handling of information will be automated.

5.3.4.3 (Dis)Advantages scenario 7

	Advantages	*Disadvantages*
Scenario 7	During the process data will be added to a document management system, which leads to a reduction of data duplication.	High initial investments
	Data will be accessible by multiple resources.	End-user commitment required.
	Data does not have to be physically relocated as done right now.	Implementing changes to the data structure becomes less flexible since the DMS has to be adapted which are the physicians not in control of.
	Decrease of operational cost and administrative time.	
	Minimize risk of loosing documents, which increase quality.	
	Ensure compliance with medical quality standards.	

5.4 Evaluation of redesign scenarios

In this paragraph the developed redesign scenarios will be qualitatively evaluated during a workshop. The goal of this workshop was to get feedback on the feasibility and (dis)advantages of the proposed redesign scenarios as well as offering an opportunity for stakeholders to propose new scenarios, or change the proposed ones. To ensure that trustworthy 'expert's opinions' were retrieved from the workshop, stakeholders with more than decade of experience in Dermatology participated the workshop. These resources are the Chief of Dermatology and the two Dermatologists, complemented by the Head of Oncology nursing and another oncology nurse. In total 16 participants took part of the workshop, who are are listed in Table 14 (page 69).

The workshop took about one and a half hours of time and started with a presentation of the medical process as a whole, after which the redesign scenarios were presented individually. After each presented redesign, the participants provided feedback on this scenario. The detailed evaluation descriptions of the redesign scenarios can be found in 'Appendix 4: Redesign evaluation outcomes' and the evaluation's results are presented in Table 4.

Table 4 Process redesign evaluation results

Scenario	Declined	Short Term Interest	Long Term Interest
(1) Use own camera	x		
(2) Relocate photographer		x	
(3) Biopsy results while patient waits		x	
(4) Pass control towards patient	x		
(5) Combine scheduling and informing the patient			x
(6) Reallocation of PDT scheduling to secretariat			x
(7) Implementation of a Document Management System			x

5.5 Conclusion and improved processes

Based upon organisational requests and the redesign heuristics (Reijers and Mansar, 2005b) a number of redesign scenarios were developed. These redesign alternatives aimed at improving patient-centric performance criteria – like the number of hospital visits/contacts, or hospital length of stay – and were evaluated in a qualitative manner with the physician and nursing staffs of the Dermatology outpatient clinic at the Catharina Hospital Eindhoven. This evaluation resulted in the categorisation of two propositions for short-term interest. These scenarios are implemented in the As-Is processes and are referred to as the 'improved' processes. The improved process model is presented in Figure 27, page

35. The new organisational model is presented in Figure 50, page 73.The changed parts are labelled red. The delivered processes should provide an answer for research question Q3b (*Can the Dermatology oncology process be improved?*).

Besides process-based conclusions, there is also something to be said about the organisation's culture and structure. The meeting clearly exposed political and personal difference in viewpoints of how care should be delivered to the patient. On one hand there are the doctors who are pursuing faster and more efficient delivery of care, but hardly want to be bothered with the management or administration of the patient's process. On the other hand there are the nurses who are made responsible for this management and administrative work-load, but who have a preference for delivering the highest quality of care to patients. According to the doctors, the nurses might be putting just too much emphasis on the patient's well being, which does not result in the desired increase in patient capacity. As long as the doctors refuse to incorporate their effort in the management and administration workload, this situation might end up in an endless cycle of arguments and responsibilities.

It was positive to observe that stakeholders instantly mentioned possibilities to implement several redesign scenarios to processes outside this study's scope (Non-Oncology Dermatology processes). Altogether, it can be expected that the chosen set of redesign propositions offer an improvement of the current situation given the current state of technology.

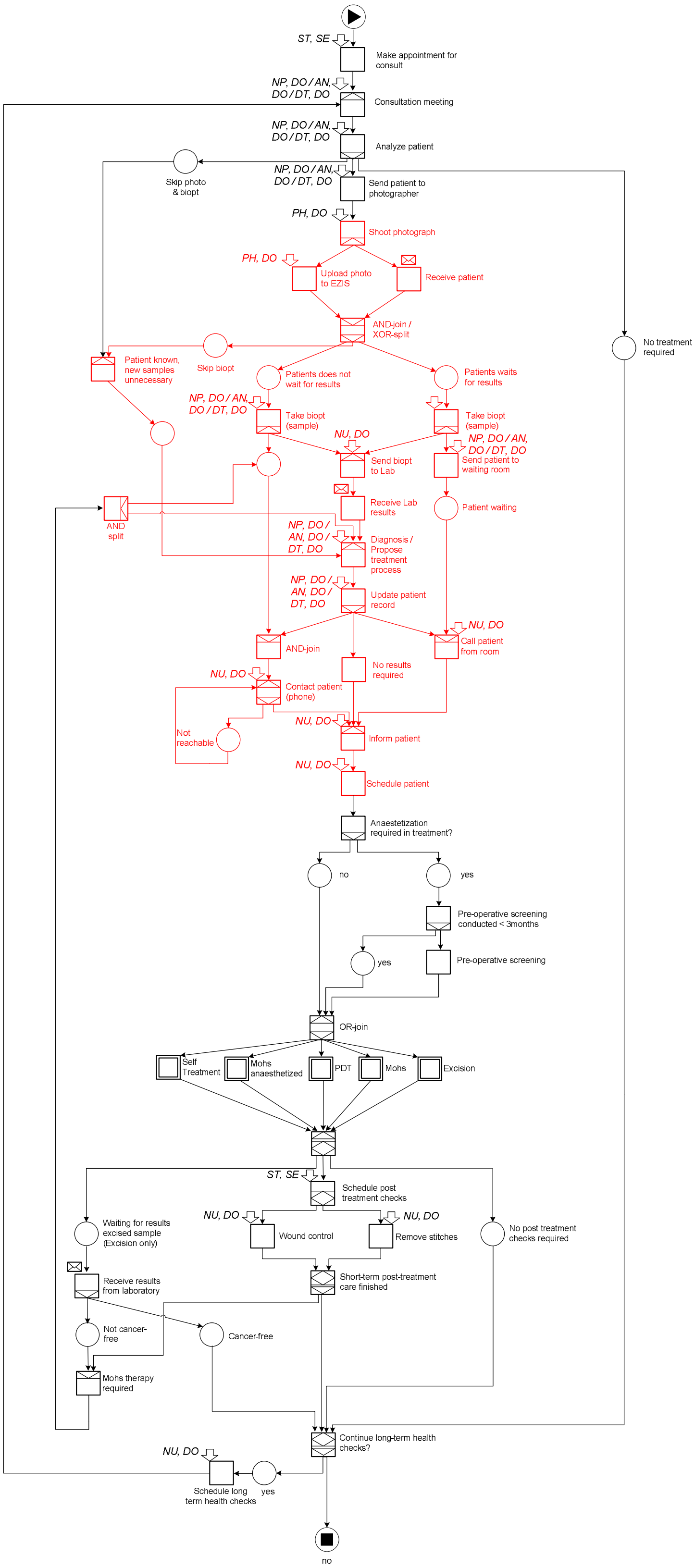


Figure 27 Improved overall patient treatment process

6 Capturing enhanced flexibility for medical processes

Up to this chapter the Dermatology oncology processes first have been presented as As-Is processes (the original situation), after which analysis of the process' performance led to the 'improved processes'. These models already show that a certain level of design-time flexibility is required for proper process enactment, since for examples choices are incorporated and activities can run in parallel.

Before starting the specification of technical requirements for process modelling tools to support the examined processes, a last process analysis will be presented that particularly investigates whether a higher level of process flexibility is able to provide better support. As concluded in chapter 4 ('Discovering the medical processes'), the modelled processes are built for supporting the normal patient population. This population undergoes one of the available treatments following its clinical decision, as can be seen in the overall treatment process (As-Is: Figure 14, page 19; Improved: Figure 27, page 35).

The Chief of Dermatology states that not all patients fit in this normal/desired way of delivering care. As she states, about eighty percent of the patients can be supported by the As-Is or 'improved' processes. The remaining twenty percent of the entire patient population requires another type of process support. In this chapter it is investigated whether a higher level of flexibility is required and (if so) whether it can provide the required process support for handling the complex patient population.

6.1 Methods used for capturing enhanced flexibility requirements

Methods used for capturing the required enhanced flexibility exist out of two parts. On the one hand information about the complex patient's process behaviour, or other unanticipated behaviours, have to been retrieved from the stakeholders. On the other hand, these requirements have to be translated to process modelling solutions. The developed solutions will be used for specifying the requirements of process modelling tools for delivering proper process support.

For retrieving information about the process flow of complex patients and retrieving other unanticipated process behaviour two separate meetings with the main Dermatologists were scheduled. Both stakeholders have over a decade of working experience as Dermatologists and have seen many patients meanwhile. Beforehand, the stakeholders stated that the differences between normal and complex patients mainly exist in the type of treatment interventions that was required for recovering these patients. During the scheduled meetings it was discussed what the process of a complex patient looks like and whether some level of predictability might be present. Second topic of discussion was to investigate whether a workflow might occur in real-life, which cannot be supported by the presented (As-Is, Improved) process models. The same interview was conducted with each Dermatologist separately. The findings were consistent between all interviews; therefore it may be assumed that the findings are valid.

After retrieving all required information, process-modelling solutions have been developed that should offer the desired process support for all (normal and complex) patients. The Flexibility Patterns (Mulyar et al., 2008) were used for the translation of the stakeholders' input to the developed solutions. The Flexibility Patterns provide an instrument describing most common flexible artefacts independent of the used process modelling notation or used workflow technology and fitting solutions within the taxonomy of process flexibility (Schonenberg, et al., 2007).

The developed solutions are referred to as the 'To-Be' processes and can be seen as the most appropriate processes for supporting the examined Dermatology oncology processes.

6.2 Requirements for enhanced flexibility

During two separate interviews with two distinct physicians information was gathered to capture scenarios that show that actual process behaviours differs from expected process behaviour. One of those differences exists between the applied treatments of normal and exceptional patients. From the interviews it can be concluded that the treatment interventions of exceptional patients differs as follows from the normal behaviour:

- During each medical intervention, combinations of different treatments are executed in a sequential manner (e.g. Mohs and Excision);
- Any treatment intervention can be executed multiple times (e.g. 2xMohs)
- Combinations of (1) and (2) are possible (e.g. 1xMohs AND 2xExcision)

When performing multiple treatments during the same intervention, the physicians state that they prefer a standardised order of treatment execution. According to the interviewed Dermatologists, the following order of activities is maintained:

- Mohs anaesthetised
- Mohs
- Excision
- PDT
- Self-treatment

The normal behaviour is specified as the exclusive choice of **one of the** available treatment interventions. The process fragment in Figure 28 illustrates the treatment selection of the normal patient population. This fragment is taken from the overall patient process (Figure 14, page 19)

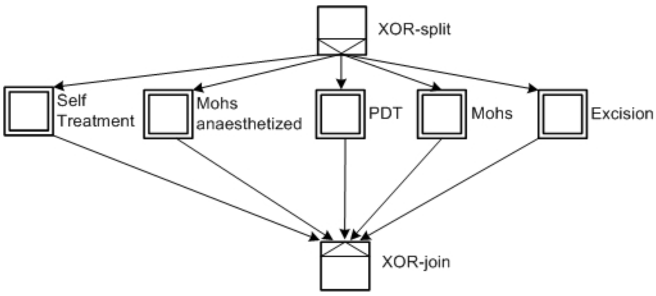


Figure 28 Treatment selection normal patient population

Since the interviewed stakeholders are able to provide the required specifications beforehand and exclude other scenarios, it can be concluded that the flexibility regarding the selection of a treatment for complex patient is fully anticipated. Anticipated flexibility generally can be solved by solutions based on design-time flexibility, where else flexibility that has not been anticipated generally has to be solved at run-time.

Another goal of the interviews was to review the entire patient process model and investigate whether the Dermatologists could think of patients they encountered that did not conform to the formalised process model. During both interviews the Dermatologists were unable think of a patient that followed another process path than supported by the formalised process models. This means that for the Dermatology oncology processes no unanticipated behaviour has to be taken into account. Based on these findings it may be stated that the chance is high that the required level of process flexibility can be supported with design-time flexibility.

6.3 Flexibility solutions

In this section, solutions will be presented that meet the flexibility requirements defined in the previous sections. The notion of process flexibility is rather ambiguous and can be covered from many different perspectives. However, for these solutions a taxonomy process flexibility presented by Schonenberg et al. (2007) will be used. As illustrated in Figure 10 (page 12), flexibility in processes can be divided into four categories. Dependent on the moment at which the need for flexibility is required (design-time, or run-time) and whether the flexibility is required for a process instance or type, one of the process types will be the most appropriate one.

Based on the four types of process flexibility (Schonenberg et al., 2007), four different solutions can be presented that meet the requirements. In the next four subsections each type of flexibility is investigated to find whether it can provide a solution for the proposed requirements and how such a solution would look like. For deriving the proper solutions, the Flexibility Patterns (Mulyar et al., 2008) are used as tool to find an independent solution given the required flexible behaviour and the desired type of flexibility. The Flexibility Patterns are presented in Table 2 (page 14).

6.3.1 Flexibility by design

Flexibility by design represents the most common form of process flexibility. For this type of flexibility, the required flexible behaviour should be known beforehand such that the flexible requirements can be incorporated in the process model. This type of flexibility is also referred to as design-time flexibility. Based on the Flexibility Pattern evaluation it can be stated that a combination of the 'interleaving'- and 'iteration'-pattern, leads to supporting requirements (1) and (2). This automatically leads to the support of requirement (3), which is a combination of the first two requirements. The combination of interleaved treatment interventions and treatment iterations is presented in Figure 29. The entire Patterns evaluation for flexibility by design is documented in Table 15 (page 75).

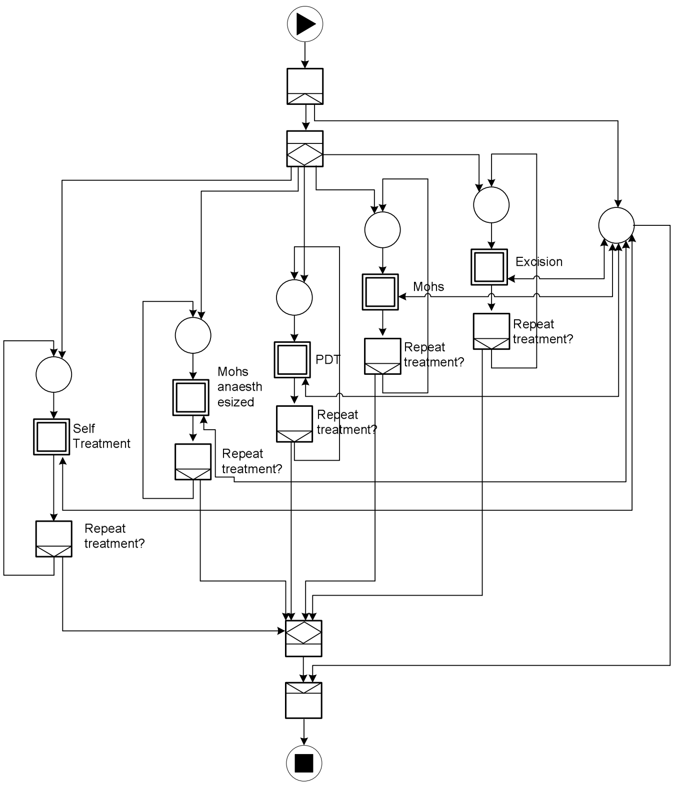


Figure 29 Solution using flexibility by design

The interleaving pattern used in this model ensures that none of the treatment interventions occur simultaneously, but any combination of treatments can be commenced to. The iteration pattern ensures that each treatment can be performed multiple times.

6.3.2 Flexibility by deviation

The notion of flexibility by deviation allows the process actor to ignore the process model by allowing the actor to deviate from the modelled process structure. When applying this type of flexibility it should be questioned to what extent compliance to the process models is important. In the medical domain, compliance to the medical procedures could be of great importance in some settings. This might be an argument for not using this type of flexibility.

Given the derived flexibility requirements, the Flexibility Pattern evaluation for this type of flexibility (Table 16, page 76) revealed that the 'task invocation'-pattern provides the desired process support. An example of using this pattern is presented in Figure 59 (page 84). In this example the patient has to undergo Mohs surgery after which two Excision have to be executed. This makes three treatments for one intervention in total. Bear in mind that in case of process deviation the process is not changed and stays the same as the model presented in Figure 28 (page 37). What happens actually but is not directly visible to the end-user, is that the workflow engine will ignore the running process model and allows the end-user to commence to another task in the model. The system's designer may include constraints for not allowing the end-user to just pick any other task. Regarding to the example drawn in Figure 59 (page 84), first Mohs surgery is commenced to. When surgery is finished the case would move on in the process to the XOR-join construct, but the end-user decides to ignore the model and uses the 'task invocation'-pattern for invoking the Excision surgery activity. After this surgery is ended the pattern is used again for invoking the second Excision surgery. After the second Excision surgery, control to the workflow engine is returned and the process moves from where it had stopped.

6.3.3 Flexibility by underspecification

The first types of flexibility focussed on either design-time or run-time flexibility. What in case the need for flexibility is recognized at design-time but the facilitation is required at run-time? For such situations, flexibility by underspecification is the required type of flexibility. The Flexibility Pattern evaluation (Table 17, page 78) revealed that the 'late selection'-pattern meets the revealed flexibility requirements. What the 'late selection'-pattern assumes is that the treatment task is included in the model, but at design-time it is not specified what this task stands for. At run-time the end-user knows the required treatment for recovering the patient. Via the 'late selection'-pattern, the end-user can select the required treatment (or combination of treatments) and this selected process fragment replaces the unspecified treatment task.

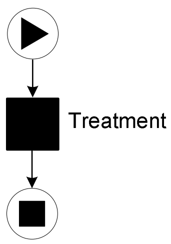


Figure 30 Underspecified process solution

As example, the academic WFMS YAWL (Van der Aalst and Ter Hofstede, 2005) can support the 'late selection'-pattern via the 'Worklets' service. A Worklet is defined as a "small, self-contained, complete workflow process which handles one specific action in a larger, composite process (activity)" (Adams et al., 2006). Applying this idea to the Dermatology oncology treatment process, than the treatment process fragment, using flexibility by underspecification, would like Figure 30. The <Treatment> task is yet unspecified and is called a *placeholder* in YAWL terminology.

In order to select the required treatment (combination) at run-time, YAWL provides decision tree as they refer to as 'Ripple Down Rules' (RDR) (Adams et al., 2006). The selectable objects are the different compositions of processes/process combinations and are referred to as a Worklets. An example of a RDR for the Dermatology oncology process is presented in Figure 60 (page 85) and the corresponding Worklets start at Figure 61 (page 86).

6.3.4 Flexibility by change

The last of four types of flexibility is the flexibility of change type. In this type of flexibility it is possible to change the process model at run-time. Once the new process design is finished the system automatically migrates the running case(s) to this new process definition and ensures correctness and consistency (Weber et al., 2007). In theory it looks like flexibility by change provides the highest degree of flexibility, but there are some critics to this approach. Heinl, et al. (1999) states that process modelling is a precise and time-consuming activity, which should be done by qualified people.

Be aware that flexibility by change can affect the running process instance only (momentary change) or the process type itself (permanent change). The derived flexibility requirements are focussed on flexibility at the instance level, since it intends to adapt the process to the patient's individual treatment plan. The Flexibility Patterns evaluation (Table 18, page 78) revealed that different patterns offer the required support for the flexibility requirements. For providing the required support at an instance level, the 'task insertion'- and 'loop insertion'-patterns are required.

It will be understandable that medical processes will change over time, due to several circumstances. For example, medical processes need to be adapted to changes in the environment, as the BPM-lifecycle (Van der Aalst et al., 2003) prescribes, or due to changes in the medical domain (Shelleke, 2001). These are process changes that affect all cases, which are changes at a type level (permanent change). The Flexibility Patterns evaluation (Table 18, page 78) revealed that different patterns offer support for the anticipating process evolutions. The required patterns are the 'choice insertion'-, 'task insertion'-, and 'loop insertion'-patterns.

6.4 Flexibility solutions evaluation

The previous section presented four different solutions for meeting the flexibility requirements to support the entire patient population of the Dermatology oncology outpatient clinic at the Catharina Hospital Eindhoven. As stated by Van der Aalst, et al. (2008) it is not realistic to assume a single process modelling language that suits multiple flexibility types, since the flexibility paradigms are fundamentally different. Based on this argument it can be concluded that normally a process modelling language is implemented that excels in one of the four types of flexibility. Table 5 provides an overview of several criteria that were encountered during the development of the flexible process solutions.

Table 5 Evaluation of process flexibility types

Criteria	Design	Deviation	Underspecification	Change
Skills and knowledge on process modelling techniques and process migration are required.	Not an issue	Not an issue	Not an issue	Changing models requires special skills and is very time-consuming.
Compliance with the process definition needs to be guaranteed.	Not an issue	No compliance guaranteed	For this application of flexibility by underspecification, compliance is not an issue.	Compliance with the process may not be guaranteed in case no limitations are provided to changing the existing models
New treatments should easily be added to the existing model.	The process model needs to be changed and running instances have to be migrated to the new process, manually.	The process model needs to be changed and running instances have to be migrated to the new process, manually.	The new treatment can be added to the Worklets service without changing the patient's process model.	The process model needs to be changed and running instances are migrated to the new process automatically, guaranteeing consistency and correctness.

The process should be readable to the end-users, so they can keep improving their own processes.	Treatment solution is more complex than for the other flexibility types. This may decrease readability	Not an issue	Not an issue	Not an issue
Changing the process for adapting to the patient's treatment requirements should not be a time-consuming activity.	All possible treatment selections are incorporated into the process model. No adaptation time is required	The required activities have to be invoked, but this is probably not too time-consuming	The proper treatment Worklet has to be selected. Using the RPR would lead directly to the required Worklet, therefore any time is consumed	Changing the process to fit to the patient's treatment requirement is a time-consuming activity (Heinl et al., 1999).

It is up to the hospital's managers for determining what criteria are most important, which may be differ from one environment to another. For the examined Dermatology oncology processes it can be stated that compliance to the defined process may be of great importance. For making a proper decision regarding the required type of flexibility for supporting the entire patient population, each criterion should be discussed after which the most preferred type of flexibility will be identified.

Examples of solutions based on flexibility by design and flexibility by underspecification are presented in Figure 85 (page 98) and Figure 86 (page 99). Solutions based on flexibility by deviation or flexibility by change would result in processes that are the same as illustrated in Figure 15 (page 21).

For answering Q3c (*Can Flexibility Patterns be used for creating better processes?*) the To-Be processes showed that the Flexibility Patterns have proven to be an effective tool for creating better processes, taking different perspectives on the paradigm of process flexibility.

An overview of the required Flexibility Patterns given the type of flexibility is provided in Table 6. In this table, the required Flexibility Patterns are coloured green.

Table 6 Required Flexibility Patterns for supporting the To-Be processes

	Flexibility by:				
	Design	Deviation	Underspecification	Momentary Change	Permanent Change
Flexible initiation	*Alternative entry points*	*Entrance skip*	*Undefined entry*	*Momentary entry change*	*Permanent entry change*
Flexible termination	*Alternative exit points*	*Termination skip*	*Undefined exit*	*Momentary exit change*	*Permanent exit change*
Flexible selection	*Choice*	*Task substitution*	*Late selection*	*Momentary choice insertion*	*Permanent choice insertion*
Flexible reordering	*Interleaving*	*Swap*	*n/a*	*Momentary reordering*	*Permanent reordering*
Flexible elimination	*Foreseen bypass*	*Task skip*	*n/a*	*Momentary task elimination*	*Permanent task elimination*
Flexible extension	*n/a*	*Task invocation*	*Late creation*	*Momentary task insertion*	*Permanent task insertion*
Flexible concurrency	*Parallelism*	*n/a*	*n/a*	*Momentary task parallelization*	*Permanent task parallelization*
Flexible repetition	*Iteration*	*Redo*	*n/a*	*Momentary loop insertion*	*Permanent loop insertion*

7 Requirements specification for medical processes

Recall Figure 6 (page 6). This figure shows that three different sets of process models are developed in this project. The original processes were captured in the As-Is processes. The second stage provided the 'improved processes' after which flexibility analysis resulted in the To-Be processes. The latter provide support for the entire patient population and would therefore be the most suitable set of processes for implementation when using workflow technology. In this chapter a requirements specification will be presented for each of the three sets of processes. By specifying each set of process, the impact of the process changes for delivering the required process support is clarified.

7.1 The role of the Workflow Patterns

The Workflow Patterns (Russell et al., 2004a, 2004b, 2006) are part of the results from the Workflow Patterns Initiative. This Initiative is defined as "a joint effort of Eindhoven University of Technology and Queensland University of Technology. The aim of this initiative is to provide a conceptual basis for process technology" (source: http://www.workflowpatterns.com).

The role of the Workflow Patterns in this study is to capture process behaviours independent of the used process modelling language or used technology. Via the Workflow Patterns it is possible to create a requirements specification for the Dermatology oncology processes that can be applied to all process languages or WFMSs in the field.

The Workflow Patterns are divided into three categories:

1. Control-flow perspective: Describing the control-flow behaviour of a process (Russell et al., 2006);
2. Resource perspective: Describing the interaction of the WFMS and its resources (Russell et al., 2004b);
3. Data perspective: Describing the data representation and utilisation in workflows (Russell et al., 2004a).

In the next sections, each of the three perspectives will be covered individually.

7.2 Control-flow Patterns analysis

The Control-flow Patterns are defined in Russell, et al. (2006) and identify 43 different Control-flow Patterns. The Control-flow Patterns analysis of the As-Is, improved, and To-Be processes, resulted in the following requirements:

Table 7 Required Control-flow Patterns

Nr.	CF Pattern	Required for?
1	Sequence	As-Is / improved
2	Parallel Split	As-Is / improved
3	Synchronization	As-Is / improved
4	Exclusive Choice	As-Is / improved
5	Simple Merge	As-Is / improved
6	Multi-Choice	As-Is / improved
7	Structured Synchronizing Merge	As-Is / improved
10	Arbitrary Cycles	As-Is / improved
20	Cancel Case	As-Is / improved
21	Structured Loop	To-Be (flex. by design + flex. by underspecification)
37	Local Synchronizing Merge	As-Is / improved
40	Interleaved Routing	To-Be (flex. by design + flex. by underspecification)
43	Explicit Termination	As-Is / improved

The complete analysis is presented in Table 19 (page 100). The analysis shows that there is no difference in requirements for supporting either the As-Is processes or the 'improved' process. For supporting the To-Be processes based on flexibility by design or flexibility by underspecification, two more Control-flow Patterns (21 and 40) are required.

By specifying the required Control-flow Patterns, research question Q3d (*Which Control-flow Patterns are required?*) has been answered.

7.3 Resource Patterns analysis

The Resource Patterns are defined by Russell et al. (2004b) and provide a comprehensive treatment of the resource perspective, independent of any workflow technology or modelling language. The existing roles and groups are defined in the Organisational Model (Figure 13, page 19), which has been adapted (Figure 50, page 73) due to process redesigns. To identify how activities should be dispersed through the Dermatology oncology outpatient clinic, it is important to know "in which manner items are advertised and ultimately bound to specific resources for execution" (Russell et al., 2004b). In the Work item lifecycle presented (Figure 31) by Russell et al. (2004b) a series of potential process states are presented. Each node presents a possible state of a work item. The characters 'S' or 'R' indicates whether the transition from one state to another is initiated by the system (S) or resource (R). In this model it is made explicit that work items are either allocated or offered to one or more resources. The difference between offering and allocating is that the latter includes the resource's commitment to execute the allocated work-item.

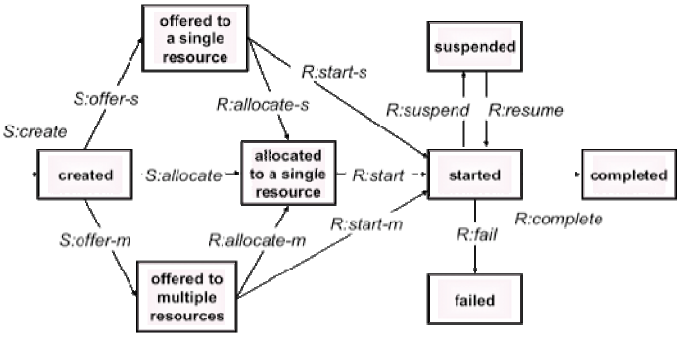


Figure 31 State Transition Diagram for Work Distribution (taken from Russell et al., 2004b)

Analyses of the Resource Patterns (Table 20, page 106) for the examined medical processes revealed requirements for the following Patterns:

Table 8 Required Resource Patterns

Nr.	Res Pattern	Required for?	Applied for what activities?
1	Direct Allocation	As-Is, improved, To-Be	Medical
2	Role-Based Allocation	As-Is, improved, To-Be	Administrative
7	Retain Familiar	As-Is, improved, To-Be	Medical, administrative
11	Automatic Execution	As-Is, improved, To-Be	-
13	Distribution by Offer - Multiple Resources	As-Is, improved, To-Be	Administrative
14	Distribution by Allocation - Single Resource	As-Is, improved, To-Be	Medical
19	Distribution on Enablement	As-Is, improved, To-Be	Administrative
21	Resource-Initiated Allocation	As-Is, improved, To-Be	Administrative
22	Resource-Initiated Execution - Allocated Work Item	As-Is, improved, To-Be	Medical
23	Resource-Initiated Execution - Offered Work Item	As-Is, improved, To-Be	Administrative
26	Selection Autonomy	As-Is, improved, To-Be	Administrative

27	Delegation	As-Is, improved, To-Be	Administrative
32	Suspension/Resumption	As-Is, improved, To-Be	Administrative
43	Additional Resources	As-Is, improved, To-Be	Medical

The third column in Table 8 classifies each Resource Patterns for supporting medical and/or administrative activities. It appeared that a clear separation exists between the distribution and allocation of activities to resources for either medical treatment activities, or administrative activities. The medical tasks can be seen as tasks that require physical presence of the patient and are mostly performed by physicians. Administrative tasks do not require physically presence of the patient.

When resources perform medical tasks they work according to a predefined week schedule that defines who is doing what medical treatments given the day in the week. This means that for these tasks it is already known beforehand what resources are requires for what patients, performing which tasks. If this information is known beforehand, activities can be directly allocated to the required resource(s). This distribution strategy is also referred to as 'push' strategy.

The administrative tasks are not explicitly scheduled and can (for example) be performed by resources in the same role. This means that direct allocation to a single resource might not be necessary, instead the activity is offered to a group of resources. Each of those resources can commence to the offered activity. This distribution strategy is referred to as 'pull' strategy.

The Resource Patterns are equal for all presented process (As-Is, improved, To-Be). By specifying the required Resource Patterns, research question Q3e (*Which Resource Patterns are required?*) has been answered.

7.4 Data Patterns analysis

The Data Patterns are presented in Russell et al. (2004a). The Data Patterns intent to tackle several issues regarding data handling in WFMSs independent of the used process language or WFMS. The Data Patterns cover areas like:

- Which tasks require data?
- How does data arrive at tasks? Is data passed from one task to another, or is it stored centrally?
- Should data be visible to multiple resources, or only the tasks' executors?
- What data is needed to make decisions?

The entire analysis of the fourty Data Patterns is presented in Table 21 (page 108). The analysis revealed that support for three Data Patterns is required and is the same for all presented processes (As-Is, improved, To-Be). These Data Patterns are presented in Table 9.

Table 9 Required Data Patterns

Nr.	Res Pattern	Required for ?	Applied for what activities?
1	Task Data	As-Is, improved, To-Be	Medical, administrative
5	Case Data	As-Is, improved, To-Be	Medical
9	Task to Task	As-Is, improved, To-Be	Administrative

As for the Resource Patterns, the Data Patterns allowed for a classification to medical and/or administrative tasks. For medical tasks, the presence of the patient is required. Beforehand, the patient was directly scheduled to a resource at the Dermatology oncology outpatient clinic. Therefore this resource only requires the patient schedule for gathering the required patient information. For example, on Monday-morning Mohs surgery is scheduled which Dermatologist X will perform on patient Y, starting at 9:00am. The gathered patient related information is used throughout the entire process. This can be represented by the 'Case Data'-pattern.

Administrative tasks do not require the presence of the patient. Therefore the resource commencing to administrative activities cannot rely on this patient schedule for gathering the required patient information. Another way to provide the administrative activity's resource with the required patient information is by pushing the information on a task level from one task to the next. For example: Suppose a patient is analysed and a biopsy is taken, after which the patient returns home. The diagnosis states that the patient requires the Photodynamic Therapy. This resource passes the patient identity at a task level to the next task (inform patient), which is performed by a nurse. By passing the patient-related information, the nurse knows who to inform and what to inform about.

By specifying the required Data Patterns, research question Q3f (*Which Data Patterns are required?*) has been answered.

7.5 Workflow Patterns support for evaluated systems and process languages

Since it has been examined what Workflow Patterns are required to support the examined medical treatment processes, a direct link can be established to the suitability and appropriateness of several WFMSs for supporting these processes. This coupling shows to what extent a selection of widely used commercial, open source, or process-modelling standards provide support for the observed processes. Bear in mind that is an evaluation for a set of widely used system/language and does (by far) not cover the entire spectrum of available tools. Russell et al. (2004a, 2004b, 2006) provided the Workflow Patterns evaluation for those different tools. Table 10 shows the results of the evaluation of the As-Is and 'improved' processes and Table 11 for the To-Be process based on flexibility by design and underspecification. The complete evaluation tables are presented in Table 22 (page 110) up to Table 24 (page 111).

Table 10 Workflow Patterns evaluation for As-Is and 'improved' processes

		Commercial Products							Open-source Products			Process Modelling Standards							
		Staffware	*WebSphere MQ Workflow*	*FLOWer*	*COSA*	*iPlanet*	*SAP Workflow*	*FileNet*	*jBPM*	*OpenWFE*	*Enhydra Shark*	*BPEL*	*WebSphere Integration*	*BPEL4WS*	*Oracle BPEL*	*BPMN*	*XPDL*	*UML*	*EPC*
Control-Flow for (12)	FS	6	8	8	9	8	7	9	6	6	8	9	9		9	11	11	10	9
	PS	0	0	1	0	0	0	0	1	3	0	1	1	-	1	0	0	1	0
	NS	6	4	3	3	4	5	3	5	3	4	2	2		2	1	1	1	3
Resource (15)	FS	11	10	11	12	10			8	6	7				13	5		5	
	PS	1	1	0	2	0	-	-	0	0	0	-	-	-	0	0	-	0	-
	NS	3	4	4	1	5			7	9	8				2	10		10	
Data (3)	FS	2	2	2	3				2	2	2	2		2		3	2	1	
	PS	1	1	1	0	-	-	-	1	0	1	1	-	1	-	0	0	1	-
	NS	0	0	0	0				0	1	0	0		0		0	1	1	

Table 11 Workflow Patterns evaluation for To-Be process based on flexibility by design and underspecification

		Commercial Products							Open-source Products			Process Modelling Standards							
		Staffware	*WebSphere MQ Workflow*	*FLOWer*	*COSA*	*iPlanet*	*SAP Workflow*	*FileNet*	*jBPM*	*OpenWFE*	*Enhydra Shark*	*BPEL*	*WebSphere Integration*	*BPEL4WS*	*Oracle BPEL*	*BPMN*	*XPDL*	*UML*	*EPC*
Control-Flow (14)	FS PS NS	6 0 8	9 0 5	9 2 3	10 0 4	9 0 5	8 0 6	10 0 4	6 1 7	8 3 3	8 0 6	11 1 2	11 1 2	-	10 1 3	12 1 1	12 1 1	11 1 2	9 0 5
Resource (15)	FS PS NS	11 1 3	10 1 4	11 0 4	12 2 1	10 0 5	-	-	8 0 7	6 0 9	7 0 8	-	-	-	13 0 2	5 0 10	-	5 0 10	-
Data (3)	FS PS NS	2 1 0	2 1 0	2 1 0	3 0 0	-	-	-	2 1 0	2 0 1	2 1 0	2 1 0	-	2 1 0	-	3 0 0	2 0 1	1 1 1	-

7.6 *Answering research question Q1, Q2a, and Q2b*

Answers for all level-3 research questions (presented in Figure 5, page 5) have been provided during this point in the report. By answering these level-2 research questions the means are present for answering the level-2 research questions.

7.6.1 Q2a: To what extent is flexibility a requirement?

During the identification and formalisation of the As-Is processes, it became clear that the Dermatology oncology processes are highly structured. Besides, the medical personnel posseses a lot of knowledge about the entire patient process. This might indicate that the processes are predictable up to a level that provides a decent level of common knowledge about the process.

The process analysis showed that flexibility requirements for handling unanticipated process behaviour (run-time flexibility) is not necessarily required. Handling the anticipated is normally covered by design-time flexibility. The conclusion that may be drawn from the analysis of the Dermatology oncology processes is that design-time flexibility is required to an extent that it allows the process actors to:

- Make (exclusive) choices;
- Bypass tasks that are not required for every patient;
- Perform tasks in parallel;
- Be able to perform different cycles within the processes;
- Select desired combination of treatments for the planned intervention and allowing performing each of these treatments multiple times, but prohibiting treatments from being executed simultaneously (this bullet is required for supporting the ‘complex’ patients only).

These flexible design-time requirements are specified independently of process languages or WFMSs in terms of Control-flow Patterns at Table 7 (page 42).

Run-time flexibility is not necessarily required for supporting the Dermatology oncology processes. Analysis of the Flexibility Patterns revealed that for all types of flexibility a supportive solution could be accomplished. However, it should be taken into account that not all types of flexibility may be appropriate for supporting the examined processes. For example, using flexibility by change may provide “extreme flexibility” (Mans et al., 2008), but also provides some concerns that should be concerned carefully. One of those concerns might be the question: "who will be able and responsible for changing processes at run-time?" and whether there is enough time for applying these process changes. Table 6 (page 41) provides an overview of the required Flexibility Patterns per type of flexibility.

7.6.2 Q2b: How could flexibility be supported in a workflow?

The answer to the question '*how could flexibility be supported in a workflow?*' is dependent on the used type of flexibility. As Muyar et al. (2008) state: the types of flexibility represent "orthogonal dimensions and are intended to operate independent of each other". Therefore, different types of flexibilities result in different process solutions.

In Table 12 an overview is presented that provides the process solutions and required Patterns for supporting the different sets of Dermatology oncology process models.

Table 12 Workflow solutions overview

Process set*	Process models	Required Workflow Patterns	Required Flexibility Patterns
As-Is	Figure 15 (page 21)	Table 7 (page 42) Table 8 (page 43) Table 9 (page 44)	n/a
Improved	Figure 27 (page 35)		n/a
To-Be - Design - Underspecification - Deviation - Change	Figure 85 (page 98) Figure 86 (page 99) Figure 27 (page 35) Figure 27 (page 35)		Table 6 (page 41)
* The treatment sub processes are the same for all process sets and are presented in 'Appendix 2: As-Is process models'.			

For the examined Dermatology oncology processes, it has been revealed that all requirements for flexibility were anticipated. This means that the degree of flexibility is known at design-time. Given the classification provided by Mulyar, et al. (2008) – Figure 11 (page 12) – flexibility by design might be the most appropriate type for supporting anticipated flexibility and provides the required means for delivering the required process support.

The evaluation of the different types of flexibility (Table 5, page 40) showed that incentives might exist for using (or not using) another type of flexibility than flexibility by design. For example, when using flexibility by underspecification, the actual treatment is not specified in the model, but selected at run-time. The YAWL-example provided in this study shows that this type of flexibility offers a relatively easy way of maintaining the treatments and possible combinations of treatments (via the so-called Worklets). Each type of flexibility might also bring along intolerable disadvantages. For example, compliance to the medical processes seems of great importance for the Dermatology oncology outpatient clinic. In case flexibility by deviation is used, it is assumed that compliance to the process structure is less important which might be an argument for not using flexibility by deviation.

For answering research question Q2b it not only relevant what types of flexibility the required functionality offer, but also whether properties of any type of flexibility do not contradict with relevant process criteria. These relevant criteria may vary across the medical domain. Table 5 (page 40) provides an evaluation of the examined processes' criteria for the different types of flexibility.

Besides these criteria, the type of medical process may be used for predicting how flexibility should be delivered in a workflow. Mans et al. (2008) provide a classification of medical processes (Figure 32, page 48) and related each class to the most suitable type(s) of flexibility. Based on this classification it may be assumed that the Dermatology oncology processes can be classified as "Elective care/Low complication probability/Diagnosis/Low complexity of care". According the classification, the required types of flexibility for supporting this type of healthcare process are supposed to be either flexibility by design or deviation.

Given the evaluation of the different types of flexibility (Table 5, page 40), flexibility by deviation might not be the most appropriate type of flexibility for supporting flexibility in a workflow. Instead, flexibility by underspecification looks like a more promising way for delivering flexibility in the created workflows. Mans, et al. (2008) state that flexibility by underspecification is required for handling elective, complicated processes (with or without diagnosis). Given the description of 'high complexity of care', the Dermatology oncology processes are not likely to be 'complex'. These findings may indicate that some classes are missing in the classification, or relations are missing between the classes and the types of flexibility.

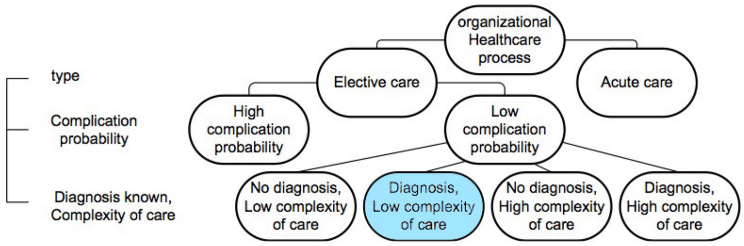


Figure 32 Classification of healthcare processes (taken from Mans et al., 2008)

7.6.3 Q1: To what extent is workflow technology suitable and able to support medical processes?

The level-1 research question covers the general level of this study's problem. As illustrated in Figure 2 (page 3), the study examines a smaller scope in order to fit in the timeframe of a master thesis project. To provide an (partial) answer to the level-1 research questions, generalisation from the lower-level research questions have to be made.

The examined medical processes are taken from the Dermatology oncology outpatient clinic. The process analyses show that the need for flexibility is well anticipated and there might be a couple of reasons for this:

- The level of knowledge in the area of skin cancer is very high. Therefore, the processes clearly showed that the uncertainty in selecting the appropriate treatment for patient recovery is very low.
- Compliance to the medical process seems to be very important.
- Acute care – which deals with critically ill patients in which patient conditions change rapidly (Mans et al., 2008) – is not delivered at the Dermatology oncology outpatient clinic.
- The nature of the process is fairly linear, which means that once a process path has been chosen, deviations are not very common.

Given these process properties it can be stated that generalising the required process support to other medical processes that have the same properties might be possible. Still, generalising findings from one medical process to another should be considered carefully.

Taking the system's perspective, the appropriateness of workflow technology is taken from a process modelling perspective. By covering this perspective by using Workflow and Flexibility Patterns a specification has been created that is independent of the used process language (in this study: YAWL) or any specific WFMS. This means that the requirements specification can be used to investigate any process modelling language or system whether it delivers the required process support. Generalising this study's outcome for investigating the suitability of workflow technology in healthcare should therefore only apply to the 'process definitions tools' (interface 1) - part of a WFMS, as indicated in the Workflow Reference Model in Figure 33.

Determining the appropriateness of WFMSs in healthcare is a much more complicated topic, than investigating the process definition/enactment part only. Other relevant topics in this area are, for example: application integration, or data integration.

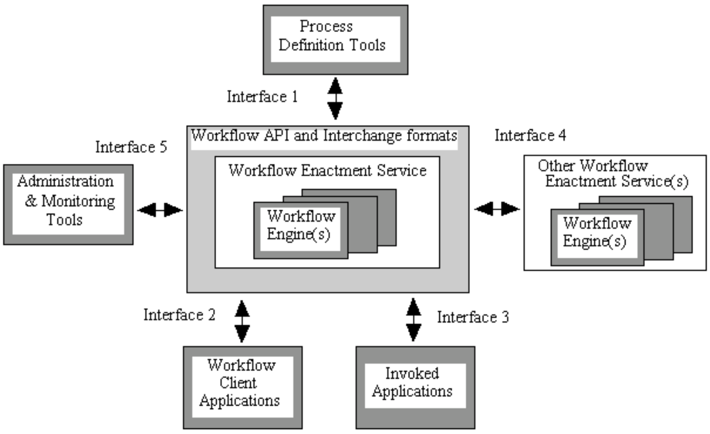


Figure 33 Workflow Reference Model

Table 10 (page 45) and Table 11 (page 46) provide an overview of the supported Workflow Patterns by some widely used WFMSs or process modelling standards. It can be stated that none of the evaluated systems/tools provide total support, but be aware that hundreds of different workflow solutions exist in the market that not have been evaluated.

8 Conclusion and future research directions

8.1 Introduction

In this study's introduction it became clear that new and innovative ways for increasing hospital capacity deserved more attention. This study explored the suitability and ability of workflow technology for supporting medical treatment processes. In order to realise this exploration, a number of project phases have been conducted including:

- A literature study;
- Identification of the medical treatment processes;
- Redesign of the identified medical treatment processes;
- Improvement of the processes by means of Flexibility Patterns (Mulyar et al., 2008);
- Specification of process requirements using Workflow Patterns (Russell et al., 2004a, 2004b, 2006).

The concluding chapter will focus on this study's contributions and limitations, reflections on this master thesis process, and proposals for future research

8.2 Contributions

This project's contributions are presented in this section. The two following subsections will present contributions that are meaningful for practice, as well as for science in the field of Workflow Management and Information Systems in general.

8.2.1 Practical relevance

The practical relevance is defined as the direct benefits the Catharina Hospital Eindhoven gained by conducting this master thesis project. During the project several deliverables are presented. The identification of the process provided the Dermatology oncology outpatient clinic's personnel with knowledge about there entire patient process. This can be used for understanding or improving the processes. The process redesign scenarios provided the hospital with some direct (short-term) improvements and a couple of long-term improvements. The short-terms improvements were received with a lot of enthusiasm and resulted in two direct changes:

- The Photodynamic Therapy (PDT) treatment schedule is redefined after investigation of the scheduling data pointed out that the type of PDT treatment has no influence on PDT patient capacity.
- A redesign proposal for excising, examining, and diagnosing the patient's biopsy within one day was received with much enthusiasm. A colleague student from the OPAC-department at Industrial Engineering and Management Sciences is investigating this idea from a planning/logistics perspective.

The workflow requirements specification was created by using Workflow Patterns (Russell et al., 2004a, 2004b, 2006) and Flexibility Patterns (Mulyar et al., 2008). This specification is independent of any process language or WFMS. This means the Dermatology oncology outpatient clinic has been provided with the means for implementing a WFMS given the As-Is, improved, or To-Be processes, and can be used for implementing any WFMS.

8.2.2 Theoretical rigour

The original goal of this project was investigate the match between the offered support of WFMSs and required support from medical processes. This goal was scoped down to the investigation of the Dermatology oncology processes at the Catharina Hospital Eindhoven for retrieving the requirements

of any process-modelling tool for supporting these processes. This project's outcome provide new knowledge that can be used for investigating to what extent workflow technology is capable of supporting these particular Dermatology oncology processes, what extent of flexibility is required and how different solutions based on different types of flexibility look like. It also shows that 'extreme' flexibility (such as ADEPTflex {Reichert and Dadam, 1998}; or Declare {Pesic et al., 2007}) is not necessarily required for all medical processes, which was also concluded by Mans et al. (2008)
The project's redesign phase showed that the redesign Best Practices (Reijers and Mansar, 2005b) were also useful when applied in healthcare and resulted in short-term and long-term improvements.

The captured requirements specification can be used for research in the area of workflow management – such as development of the YAWL system (Van der Aalst and Ter Hofstede, 2003).

8.3 Limitations

The entire scope of workflow management is too broad to examine during a single master thesis project. Therefore the scope of this project has been limited to the requirements that process-modelling tools should provide for supporting the examined Dermatology oncology treatment processes. The appropriateness of a WFMS for supporting these processes is much more complex, but other aspects have not been examined in this study. Examples of other WFMS-related topics are: data integration, application integration, establishing communication between multiple processes across hospitals, etc.

During the process identification and improvement stages, unfortunately hardly any quantitative process data was available. Therefore, validation of the processes and process redesign scenarios has been established in a qualitative manner (observations, interviews, workshop, etc.).

Within the area of process modelling, flexibility properties were emphasized during the project. Theories regarding process flexibility until now are developed from a process control-flow perspective. This means that the requirements that tackle the resource and data perspectives of the processes are specified, but no further flexibility analysis have been conducted for these perspectives.

From a medical perspective, this study is limited to the Dermatology oncology treatment process only. Generalising this study's outcomes to other medical process should be considered very carefully.

8.4 Reflection

In the following subsections a reflection on the used methodology as well as my personal reflection are presented.

8.4.1 Reflecting methodology

Capturing operational processes directly from the organisation's resources raises the question whether all relevant data is being gathered. In order to validate the soundness of the models, two different physicians crosschecked them. It would be ideal if the processes were logged in some kind process-aware information system, from which the *actual* processes could be mined. Unfortunately, this information was not at hand.

When redesigning the As-Is processes, a theoretical perspective was used to come up with redesign scenarios based on Reijers and Mansar's (2005b) work as well as an organisational perspective for retrieving redesign scenarios based on the stakeholders' requests. All redesign scenarios were evaluated qualitatively during a stakeholder meeting. Besides a qualitative evaluation, it would have been nice if a simulation study could have provided the figures for a quantitative evaluation. Unfortunately, no data was available for building the simulation model.

For increasing the flexibility of the process in order to handle all patients, the Flexibility Patterns by Mulyar, et al. (2008) were used. The Flexibility Patterns are limited to the control-flow perspective and research regarding the resource and data perspective is ongoing but may have been beneficial during this research. Capturing the flexibility requirements for supporting all patients was realised by interviewing two physicians, which resulted in a set of flexibility requirements, which were evaluated by another physician. Ideally, log-files from a process-aware information system would provide a more waterproof validation that all present flexible behaviours were captured during this project phase.

8.4.2 Personal reflection

Performing a master thesis is not only an exiting moment – since there is a lot at stake (from a student perspective) – but it also forces you to independently build a research proposal, find the right literature and explore the environment for answering the research questions within a predefined timeframe.

This study was conducted in a healthcare environment, which was a new experience. It appeared that working in healthcare is working in a highly dynamic setting were situations tend to change every hour. Conducting research in healthcare was very interesting and made me realise that an improvement of a process characteristic, is not only an improvement by itself, but also serves the public who directly benefit from more efficient delivery of care.

Conducting a master thesis project in a real-life setting made me also aware that performing a real-life project requires handling much more difficulties, then just applying knowledge gained from college. For example, to let a project become successful the stakeholder's commitment is required. Easy communications in a new setting and being accepted as a 'newbie' is very important. This project also made me realise that there is more to the eye than just combining figures and observations. Thankfully my supervisors are used to first understand the big picture, before jumping into tiny details and made me aware of that.

All together this project was a success. The desired project goals were achieved by also keeping in line with the predefined research schedule.

8.5 Proposal for further research

This exploratory investigated the suitability and ability of workflow technology in healthcare from a process modelling perspective. Medical treatment processes of the Dermatology oncology outpatient clinic at the Catharina Hospital Eindhoven were used in order to investigate the extent of required process flexibility for supporting these processes by workflow. Based on this study's outcome, several propositions for further research can be presented.

8.5.1 Researching external validity

Based on this study's outcomes, it can be questioned to what extent the observed medical treatment process' structure can be generalised to 'medical processes'. By conducting this research to other Dermatology oncology outpatient clinics, it might be possible to propose a standardised specification for handling these processes. Generalising this study's outcomes to all medical processes might not be possible. Healthcare processes differ a lot, as Mans et al. (2008) show and different classes of healthcare processes might require different types of flexibility. However, it might be possible to extract constructs from this study – for example, the flexible selection of treatments – and investigate whether these constructs hold for other classes of healthcare processes

In the field of Business Process Management (BPM) and healthcare a lot of processes have already been defined and used for different purposes (e.g. Mans et al., Vonk et al., 2008). However, the formal definition of the control-flow, resource and data perspectives of those processes can be used to investigate what Workflow and/or Flexibility Patterns are required for supporting these processes.

8.5.2 Resource and data flexibility

Current study has dealt with the issue of flexibility from a control-flow perspective. The main reason for this limitation is the fact that research on process flexibility does not yet cover the resource and data perspectives. However, based on this study's outcomes it may be stated that the control-flow perspective requires less flexibility than the resource or data perspectives. The reason for this is that the control-flow flexibility is fully anticipated, but observations of the process showed that the allocation of resource to work items is very complex. For example, when scheduling surgery that requires an Operating Room and assistance of the Plastic Surgeon, the scheduler faces a very complex, cross-hospital situation. In this case, the easiest way of scheduling the surgery is by browsing the schedule until a timeframe is found in which all required (human) resources are available. However, this might be weeks – or even months – ahead given the current need for capacity increase in Dutch hospitals. A flexible, priority-rules based resource allocation requires smart (data) based algorithms and Flexibility Patterns for allowing deviation from the standard way of resource offering and/or allocation.

8.5.3 Operational management and process ownership

The application of workflow management implicitly states that some resources are responsible for managing the flow of work in the organisation. To make the use of workflow management (and systems) systems successful over time, continuous improvement and management of the workflows is required. Guarantee for continuous improvement might be realised by designating (several) process owners (Hammer, 2007), or by working according a process management cycle (Hardjono and Bakker, 2006. These are just two examples from the paradigm of Business Process Management Maturity (BPMM).

During this master thesis project, it did not become clear whether there are persons made responsible for the patient process and for monitoring this process. Therefore it might be interesting to examine how knowledge from the field of BPMM or process ownership can be used in healthcare

References

Van der Aalst, W.M.P. The Application of Petri Nets to Workflow Management. *Journal of Circuits, Systems and Computers*, 8(1): 21-66, 1998.

Van der Aalst, W.M.P. Exterminating the Dynamic Change Bug: A Concrete Approach to Support Change. *BETA Working Paper Series*, WP 51, Eindhoven University of Technology, Eindhoven, 2000.

Van der Aalst, W.M.P., Van Hee, K. *Workflow management: Models, methods, and systems*. Cambridge: 2002.

Van der Aalst, W.M.P., Ter Hofstede, A.H.M., Weske, M. Business Process Management: A Survey. In W. Aalst, A. Hofstede, & M. Weske (Eds.), *International Conference on Business Process Management (BPM 2003)*, 2003.

Van der Aalst, W.M.P., Ter Hofstede, A.H.M. YAWL: Yet Another Workflow Language. *Information Systems*, 30(4): 245-275, 2005.

Van der Aalst, W.M.P., Wekse, M., Grünbauer, D. Case Handling: A New Paradigm for Business Process Support. *Data and Knowledge Engineering*, 53(2): 129-162, 2005.

Van der Aalst, W.M.P., Adams, M., Ter Hofstede, A.H.M., Pesiç, M., Schonenberg, H. Flexibility as Service. Technical Report, *Center report BPM*, BPMcenter.org, 2008.

Adams, M., Ter Hofstede, A.H.M., Edmond, D., Van der Aalst, W.M.P. Implementing Dynamic Flexibility in Workflows using Worklets. *Center report BPM*, BPMcenter.org, 2006.

Agostini, A., De Michelis, G. Improving Flexibility of Workflow Management Systems. *Lecture Notes on Computer Science,* 1806:218–234, 2000.

Alter, S. Information Systems: a management perspective. Amsterdam: Addison Wesley; 1999.

Ammenwerth, E., Buchauer, A., Haux, R. A Requirements Index for Information Processing in Hospitals. *Methods Inf Med*, 41: 282-288, 2002.

Anyanwu, K., Seth, A., Cardoso, J., Miller, J., Kochut, K. Healthcare Enterprise Process Development and Integration, *Journal of Research and Practice in Information Technology*, 35(2): 83-98, 2003.

Asselman F.F.. *Kostprijzen in ziekenhuizen*. Houten: 2008.

Bates, D.W., Kuperman, G.J., Wang, S., Gandhi, T., Kittler, A., Volk, L., Spurr, C., Khorasani, R., Tanasijevic, M., Middleton, B.. "Ten Commandments for Effective Clinical Decision Support: Making the Practice of Evidence-based Medicine a Reality", *Journal of the American Medical Informatics Association*, 10(6): 523-530, 2003.

Berlin, A., Sorani, M., Sim, I.A taxonomic description of computer-based clinical decision support systems. *Journal of Biomedical Informatics*, 39: 656-667, 2006.

Bernio, G., Vernadat, F. Enterprise modelling with CIMOSA: functional and organisational aspects. *Production Planning & Control*, 12(2): 128-136, 2001.

Brand, N., Van der Kolk, H. Workflow analysis and design. Deventer: Bedrijfswetenschappen; 1995 [in Dutch].

Dadam, P., Reichert, M., Kuhn, K. Clinical Workflows - the killer application for process oriented information systems?, *Abramowicz, W.; Orlowska, M.E. (Eds.): BIS 2000 - Proc. of the 4th Int'l Conference on Business Information Systems,* Poznan, Poland, Springer-Verlag,, pp. 36-59, 2000

Feischi, M., Dufour, J.C., Gouvernet, J., Bouhaddou, O. Medical Decision Support Systems: Old Dilemmas and new Paradigms?, *IEEE Transactions on Information Technology in Biomedicine*, 8(3): 279-286, 2003.

Fox, J., Johns, N., Rahmanzadeh, A., Thomson, R. PRO*forma*: a general technology for clinical decision support systems. *Computer Methods and Programs in Biomedicine*, 54: 59-67, 1997.

Hammer, M. The Process Audit. *Harvard Business Review*, 85(4): 111-119, 2007.

Hardjono, T.W., Bakker, R.J.M. *Management van processen*. Deventer: Kluwer, 2007.

Haux R., Seggewies, C., Baldauf-Sabez, W., Kullmann, P., Reichert, H., Leudecke, L., Seibold, H. Soarian™ - Workflow Mangement Applied for Health Care. *Methods Inf Med*, 42: 25-36, 2003.

Heinl, P., Horn, S., Jablonski, S., Neeb, J., Stein, K., Teschke, M. A comprehensive approach to flexibility in workflow management systems. *In WACC '99: Proceedings of the international joint conference on Work activities coordination and collaboration*: 79–88, 1999.

Jablonski, S., Bussler, C. Workflow management: modelling concepts, architecture ad implementation. London: International Thomson Computer Press; 1996.

Kaplan B. Evaluating informatics applications – clinical decision support systems literature review. *International Journal of Medical Informatics*, 64: 15-17, 2001.

Law, A.M., Kelton, D.W. *Simulating modelling and analysis (3rd ed.)*. New York: MacGraw-Hill: 2000.

Lawrence, P. (Ed.). (1997). Workflow handbook 1997. New York: Wiley.

Lenz, R., Reichert, M. IT support for healthcare processes – premises, challenges, perspectives. *Data & Knowledge Engineering*, 61: 39-58, 2007.

Mans, R.S., Aalst, W.M.P. van der, Russell, N.C., Bakker, P.J.M. (2008). Flexibility schemes for workflow management systems: regular paper. In R. Lenz, M. Peleg, M. Reichert (Eds.), *2nd international workshop on process-oriented information systems in healthcare : ProHealth'08 : in conjunction with 6th International Conference on Business Process Management (BPM 2008), Milan, Italy.*

Maviglia, S.M., Zielstroff, R.D., Paterno, M., Teich, J.M., Bates, D.W., Kuperman, G.J. Automating Complex Guidelines for Chronic Disease: Lessons Learned. *Journal of the American Medical Informatics Association*, 10: 154-165, 2003.

Mulyar N., Aalst van der, W.M.P., Peleg, M. A Pattern-based Analysis of Clinical Computer-Interpretable Guideline Modelling Languages, *Center Report BPM*, BPMcenter.org, 2006.

Mulyar, N., Pesiç, M, Aalst van der, W., Peleg, M. Towards the Flexibility in Clinical Guideline ModellingLanguages. Technical Report, *Center Report BPM*, BPMcenter.org, 2007.

Mulyar, N., Van der Aalst, W.M.P., Russell, N. Process Flexibility Patterns, Process Flexibility Patterns. *Beta Working Series*, WP 251. Eindhoven University of Technology, 2008.

Nationale Raad voor de Volksgezondheid (NRV). *Discussienota begrippenkader kwaliteit van instellingen*. Zoetermeer: 1990

M. Pesic, M.H. Schonenberg, N. Sidorova, and W.M.P. van der Aalst. Constraint-based workflow models: Change made easy. In Robert Meersman and Zahir Tari, editors, OTM Conferences, volume 4803 of Lecture Notes in Computer Science, pages 77–94. Springer, 2007.

Reichert, M., Dadam, P. ADEPTflex – supporting dynamic changes of workflows without losing control. *Journal of Intelligent Information Systems*, 10(2): 93-129, 1998

Reijers, H.A., Van der Aalst, W.M.P. The effectiveness of workflow management systems: Predictions and lessons learned, *International Journal of Information Management*, 25: 458-472, 2005a.

Reijers, H.A., Mansar, S.L. Best practices in process redesign: an overview and qualitative evaluation of successful redesign heuristics. *Omega: The international journal of management science*, 33: 283-306, 2005b

Rinderle, S., Reichert. M., Dadam, P. Correctness criteria for dynamic changes in workflow systems – a survey, *Data & Knowledge Engineering*, 50(1): 9–34, 2004.

Russell, N., Ter Hofstede, A.H.M, Edmond, D., Van der Aalst, W.M.P. Workflow Data Patterns. *BPM Center Report BPM-04-01*, BPMcenter.org, 2004a.

Russell, N., Ter Hofstede, A.H.M, Edmond, D., Van der Aalst, W.M.P. Workflow Resource Patterns. *BPM Center Report BPM-04-07*, BPMcenter.org, 2004b.

Russell, N., Ter Hofstede, A.H.M., Van der Aalst, W.M.P., Mulyar,N. Workflow Control-Flow Patterns : A Revised View, *BPM Center Report* BPM-06-22, 2006.

Schaaf, J.H. *Kwaliteitsmanagement in ontwikkeling*. Hzh, 1, 1992.

Schonenberg, M.H., Mans, R.S., Russell, N.C., Mulyar, N.A., Aalst van der, W. Towards a Taxonomy of Process Flexibility(Extented Version), Technical Report. *Center report BPM*, BPMcenter.org, 2007.

Seidmann, A., Sundararajan, A. The effects of task and information asymmetry on business process redesign. *International Journal of Production Economics*, 50(2/3): 117-128, 1997.

Shelleke, P., Eccles, M.P., Grimshaw, J.M., Woolf, S.H. When should clinical guidelines be updated?,*BMJ*, 323: 155-157, 2001.

Shiffman, R.N., Michel, G., Abdelwaheb, E., Thornquist, E. Bridging the Guideline Implementation Gap: A Systematic, Document-Centric Approach to Guideline Implementation. *Journal of the American Medical Informatics Association*, 11: 418-426, 2004.

Sutherland, J., Van den Heuvel, W. Towards an Intelligent Hospital Environment: Adaptive Workflow in the OR of the Future. *Proceedings of the 39th Hawaii International Conference on System Sciences*, 2006.

Van Strien, P.J. Towards a methodology of psychological practice, *Theory and Psychology*, 7(5): 683-700, 1997

Verschuren, K., Doorewaard, H. *Het ontwerp van eenonderzoek*. Utrecht; 2000

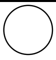
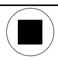
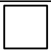
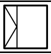
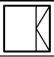
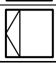
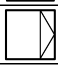
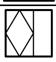
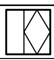
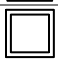
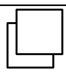
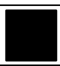
Vonk, J., Wang, T., Grefen, P.W.P.J. An analysis of contractual and transactional aspects of a cardiothoraric surgery process. *BETA Working Paper Series*, WP 244, Eindhoven University of Technology, Eindhoven, 2008.

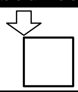
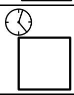
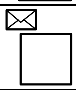
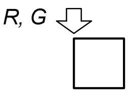
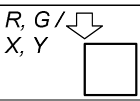
Weber, B., Rinderle, S., Reichert, M. Change Patterns and change support features in process-aware information systems. In J. Krogstie, A.L. Opdahl, and G. Sindre, editors, Advanced Information Systems Engineering, 19th International Conference, CAiSE 2007, Trondheim, Norway, June 11-15, 2007, Proceedings, volume 4495 of Lecture Notes in Computer Science, pages 574–588. Springer, 2007.

Zielstorff, R.D. Online Practice Guidelines: Issues, Obstacles, and Future Prospects. *Journal of the American Medical Informatics Association*, 5(3): 227-236, 1998.

Appendix 1: Legend process definitions

YAWL: Yet Another Workflow Language (Van der Aalst and Ter Hofstede, 2005) is a very powerful, yet fundamentally simple language. In this appendix the semantics of the YAWL language will be briefly explained. The YAWL notation was extented with the resource perspective, presented by Van der Aalst and Van Hee (2002).

Control-flow semantics	
	The **condition** represents a state for the process.
	The **input** condition is where a process starts.
	The **ouptut condition** is where a process ends.
	The **atomic task** represents a single task to be performed by a human or external application.
	The **AND-join** activates this task when all incoming links have been activated.
	The **AND-split** activates all outgoing links from this task upon completion.
	The **XOR-join** activates this task each time an incoming link has been activated.
	The **XOR-split** activates one outgoing links from this task upon completion.
	The **OR-join** activates this task each time when one or more incoming links are activated and there is no possibility for other links to be activated if the task continues to wait.
	The **OR-split** activates a number of outgoing links from this task upon completion.
	The **Composite task** is a container for another YAWL process, and as such provides a decomposition mechanism.
	The **Multiple Instance task** allows multiple instances of a task to run concurrently. The minimum and maximum number of instances, the threshold for completion and whether new instances can be created on the fly or not can be specified for this task.
	The **Placeholder** task represents an unspecified process activity.

Resource semantics	
	The arrow represents that a **human resource** is responsible for the activation of its task.
	The clock represents that a **time trigger** is responsible for the activation of its task
	The envelope represents that a **external event** is responsible for the activation of its task
	Whenever a **human resource** is responsible for the activation of its task, this human resource needs to be specified. To do so, a **role** (R) and a **group** (G) are allocated, based on the **organisational model**.
	Whenever the activity can be allocated to multiple resources roles and groups a **slash** (/) sign is used as separator.

Appendix 2: As-Is process models

Photodynamic Therapy

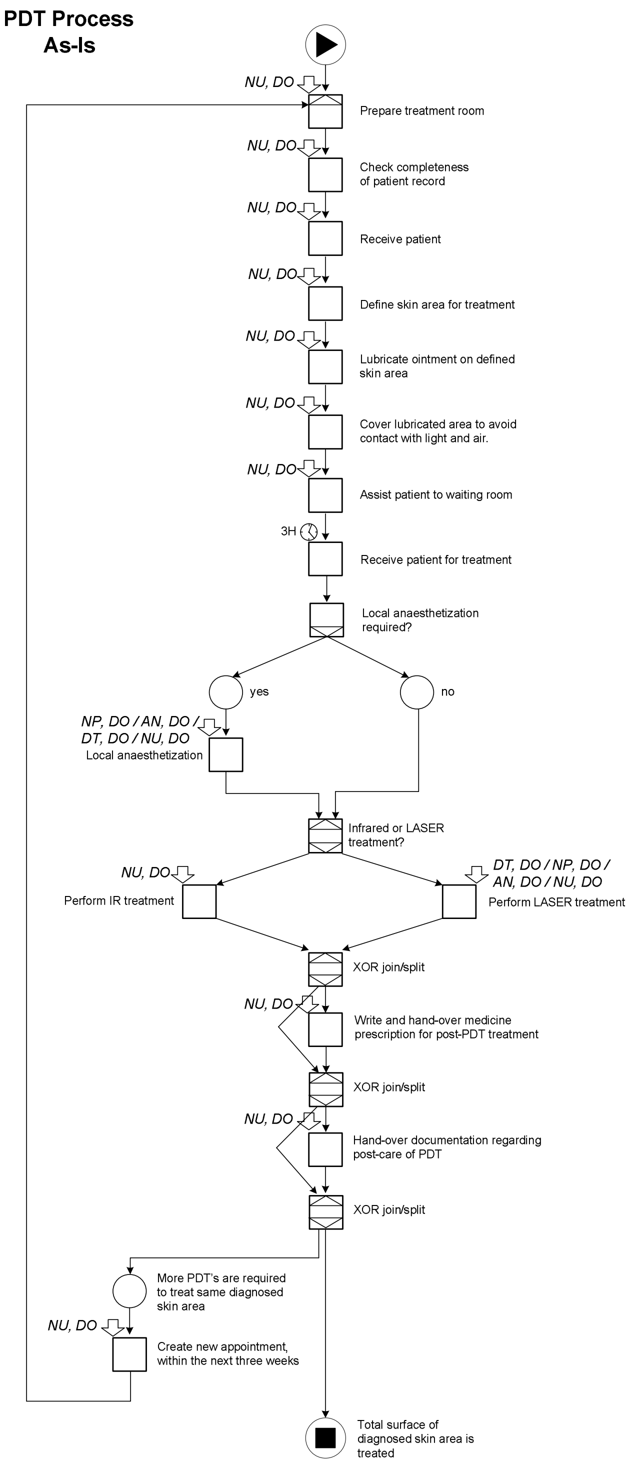


Figure 34 PDT process

Mohs treatment process

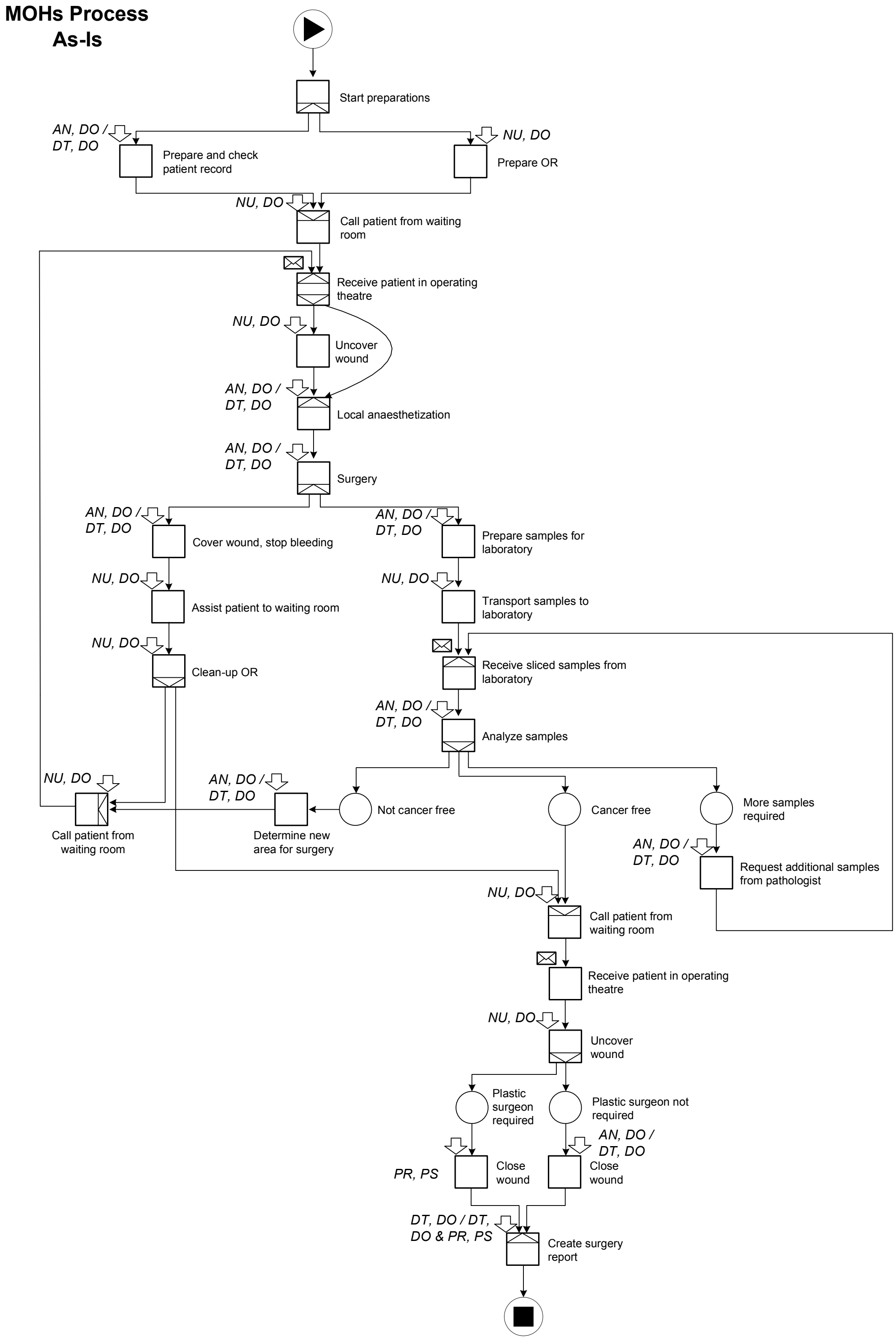


Figure 35 Mohs treatment process

Mohs treatment process with anaesthetization

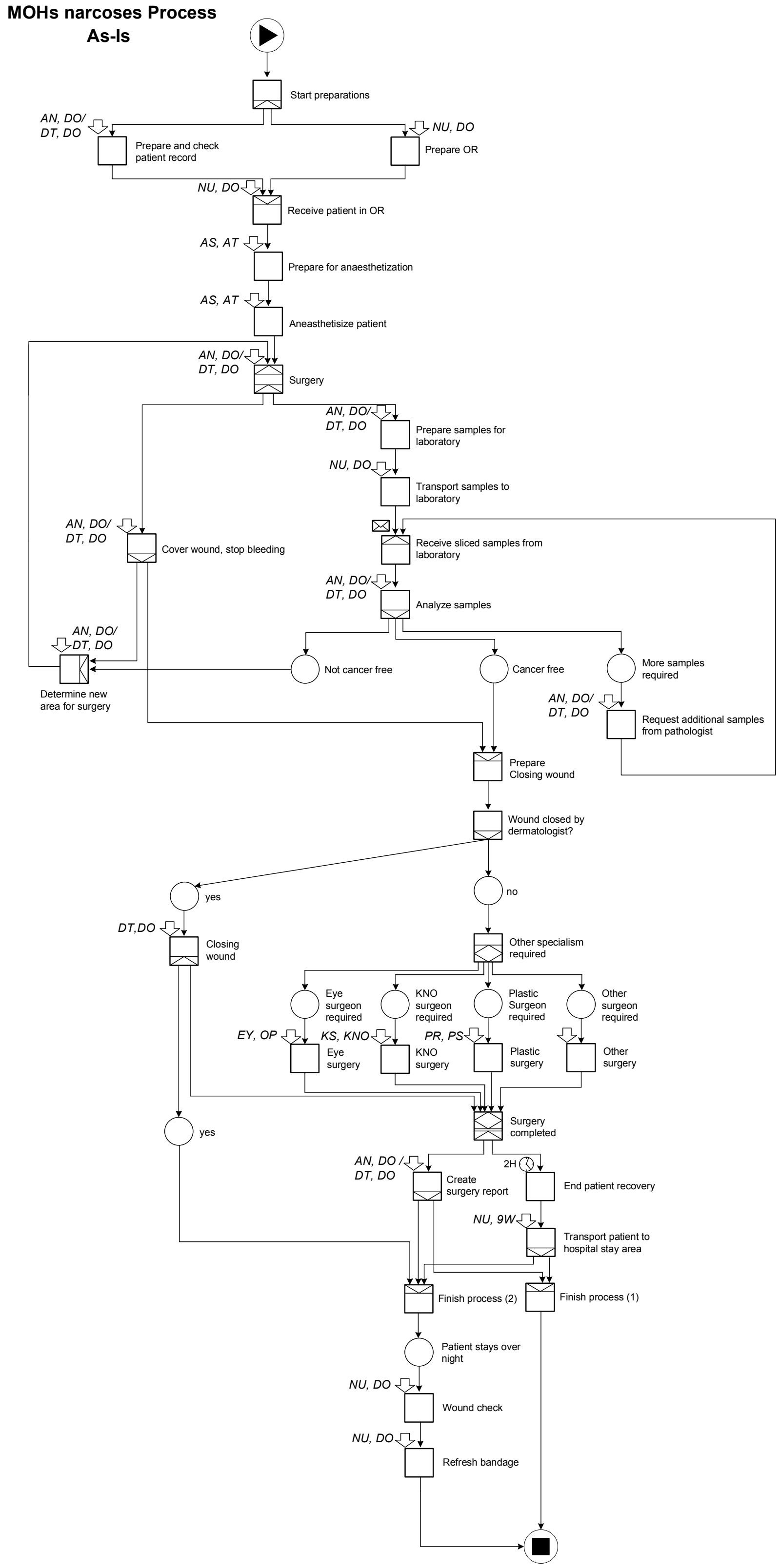


Figure 36 Mohs treatment process with anaesthetization

Excision treatment process

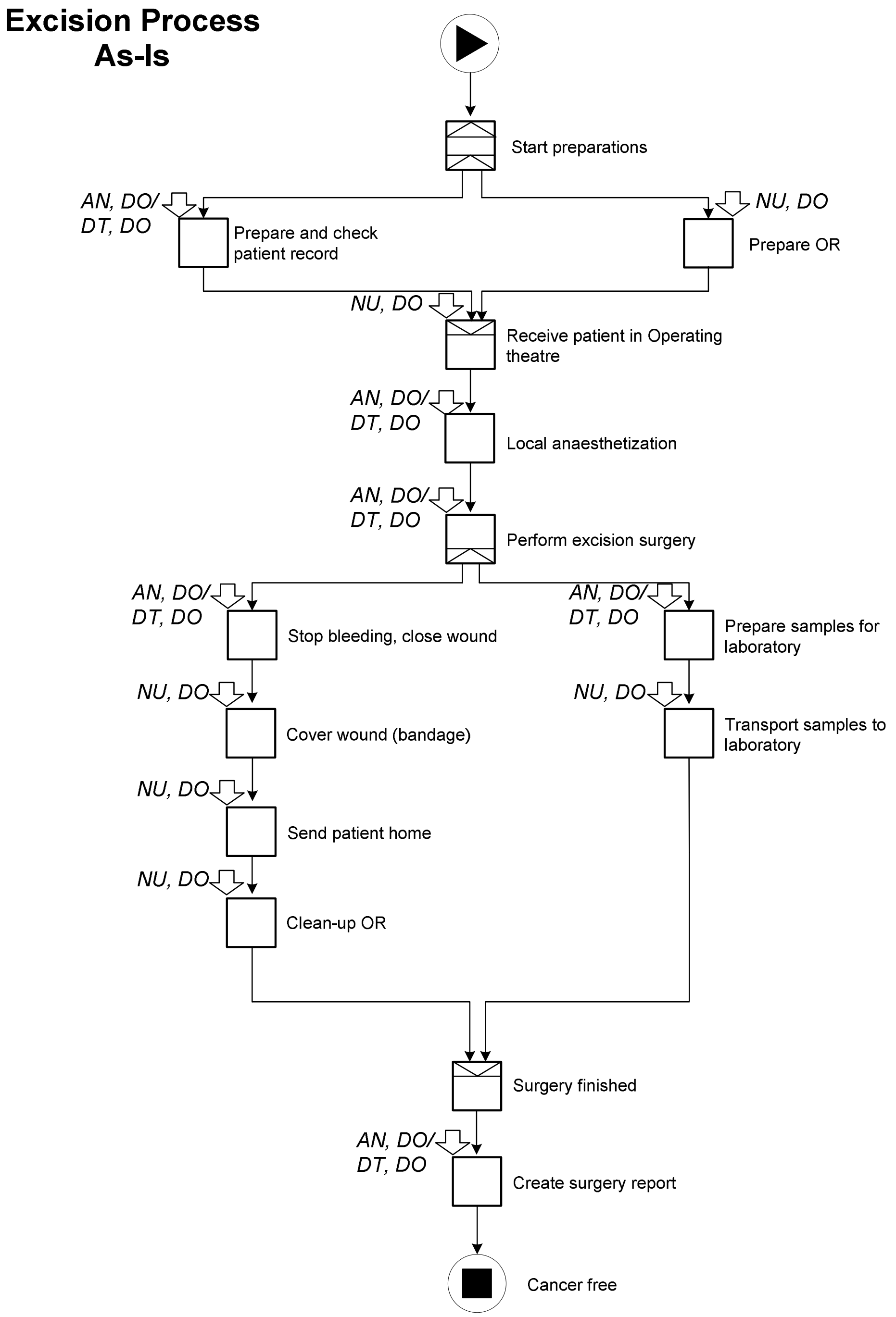


Figure 37 Excision treatment process

Self treatment process

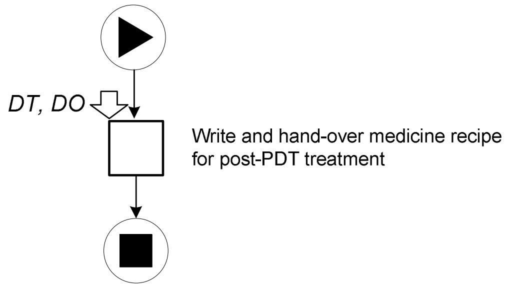


Figure 38 Self treatment process

Data model

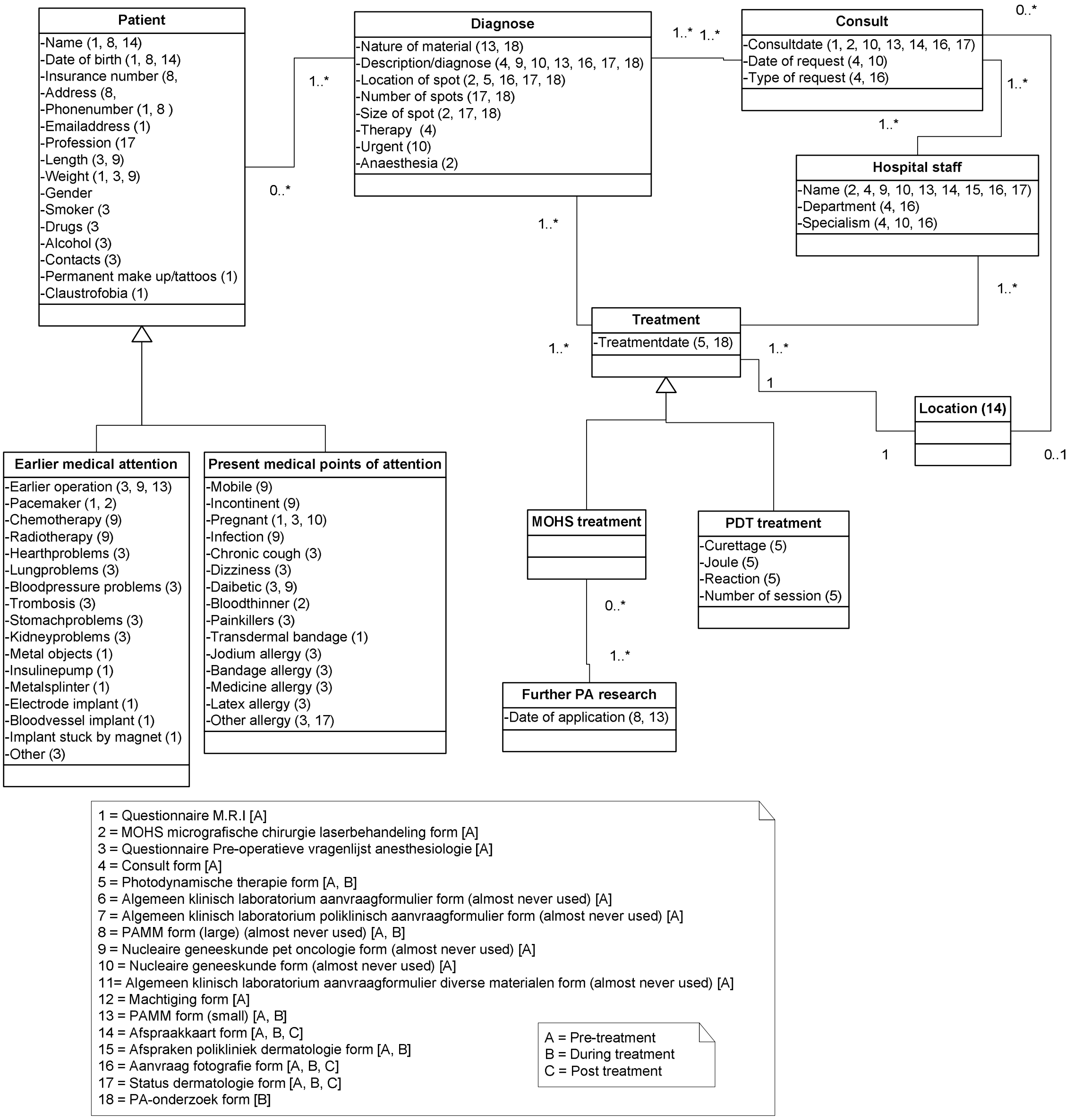


Figure 39 UML Static Structure of Information in Treatment Process (made by T. Keijzers)

Appendix 3: Process redesign data

Weekly working schedule nursing group

dag→	maandag				dinsdag				woensdag			donderdag					Vrijdag				
uren ↓	onco	onco	alg	alg	onco	onco	alg	alg	onco	alg	alg	onc	onco	alg	alg	alg	onco	onco	onco	alg	alg
08.30		p	a			p	b		p	a	d	pdt	e	a	d	b	p	e	a	b	d
09.00		d	l			d	e		d	l	i		x	l	u	e	d	x	d	e	i
09.30	m	t	l		m	t	n		t	l	v		c	l	p	n	t	c	m	n	v
10.00	o	w	e		o	w	e		a	e		w	i	e	l	e	w	i		e	
10.30	h	o		h	h	o	n		d			o	s	d	e	a	o	s		n	
11.00	s	c		v	s	c			m			c		i	x	d	c	i			
11.30		o				o						o		v		m	o	e			
12.00		p	v	d		p			p			p					p				
12.30		d	p	i		d			d			d					d				
13.00		t	k	v		t		v	t		d	t					t			s	d
13.30			z					p			i		h	a	d					o	i
14.00			a					k			v		v	l	u					a	v
14.30			k					z						l	p					s	
15.00			e					a						e	l					o	
15.30			n					ken						r	e					a	
16.00	d	d			d	d		d	vpk	vpk		vpk			x					vpk	
16.30	i	i			i	i		i	za	za		za								za	
17.00	v	v			v	v		v	ken	ken		ken								ken	
	mei	reona	willy	Loes	ellen	elis	pau	2x DA	Helma	Willy	Loes	Hel	Annet	Anja		Pauli	Ellen	Helm	Reona	pauline	
	janny				janny		anja													anja	
	elis				reona		DA													DA	
	3	1	2		3	1	3	2	1	2		1	1	1		1	2		1	3	1

Mohs'
PDT
Vlekjes
Excisies
HV
adm
Benen
Allergie
Duplex
Omloop
Wondco
Diversen
vpk zaken

Figure 40 Oncology nursing schedule

PDT schedule data analyses

	[DAY]	[#PDT]	70J	20J+80J	37J	60J	80J	LASER	2x70J	100J	37J+70J	2x20J	3X70J	x(20L+80.	x(20L+80J
19-08-12	Monday	7	5	1	1	0	0	0	0	0	0	0	0	0	0
20-08-12	Tuesday	7	5	2	0	0	0	0	0	0	0	0	0	0	0
21-08-12	Wednesday	7	4	3	0	0	0	0	0	0	0	0	0	0	0
22-08-12	Thursday	6	4	2	0	0	0	0	0	0	0	0	0	0	0
23-08-12	Friday	5	2	3	0	0	0	0	0	0	0	0	0	0	0
26-08-12	Monday	6	5	0	0	1	0	0	0	0	0	0	0	0	0
27-08-12	Tuesday	5	2	0	1	0	1	1	0	0	0	0	0	0	0
28-08-12	Wednesday	5	3	2	0	0	0	0	0	0	0	0	0	0	0
29-08-12	Thursday	6	5	0	1	0	0	0	0	0	0	0	0	0	0
30-08-12	Friday	5	2	2	0	1	0	0	0	0	0	0	0	0	0
02-09-12	Monday	5	1	2	0	0	0	1	1	0	0	0	0	0	0
03-09-12	Tuesday	7	4	0	1	1	0	0	0	1	0	0	0	0	0
04-09-12	Wednesday	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-09-12	Thursday	3	2	1	0	0	0	0	0	0	0	0	0	0	0
06-09-12	Friday	7	5	0	0	1	0	0	0	0	1	0	0	0	0
09-09-12	Monday	6	4	1	0	1	0	0	0	0	0	0	0	0	0
10-09-12	Tuesday	6	3	2	1	0	0	0	0	0	0	0	0	0	0
11-09-12	Wednesday	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-09-12	Thursday	5	3	1	0	0	0	0	0	0	0	1	0	0	0
13-09-12	Friday	6	5	1	0	0	0	0	0	0	0	0	0	0	0
16-09-12	Monday	5	3	1	1	0	0	0	0	0	0	0	0	0	0
17-09-12	Tuesday	5	3	1	0	0	0	0	1	0	0	0	0	0	0
18-09-12	Wednesday	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-09-12	Thursday	5	3	0	0	0	0	0	1	0	0	0	1	0	0
20-09-12	Friday	6	3	2	0	0	0	0	1	0	0	0	0	0	0
23-09-12	Monday	5	4	0	0	0	0	1	0	0	0	0	0	0	0
24-09-12	Tuesday	6	1	4	0	0	0	0	1	0	0	0	0	0	0
25-09-12	Wednesday	6	4	1	0	0	0	0	0	0	0	0	0	1	0
26-09-12	Thursday	6	3	0	2	0	0	1	0	0	0	0	0	0	0
27-09-12	Friday	5	2	0	2	0	0	0	0	0	0	1	0	0	0
30-09-12	Monday	7	4	1	0	0	1	1	0	0	0	0	0	0	0
01-10-12	Tuesday	6	4	1	1	0	0	0	0	0	0	0	0	0	0
02-10-12	Wednesday	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-10-12	Thursday	6	3	1	2	0	0	0	0	0	0	0	0	0	0
04-10-12	Friday	7	3	1	1	0	0	0	1	0	0	1	0	0	0
07-10-12	Monday	6	4	2	0	0	0	0	0	0	0	0	0	0	0
08-10-12	Tuesday	5	2	2	0	0	0	0	0	0	0	0	0	0	1
09-10-12	Wednesday	7	4	2	1	0	0	0	0	0	0	0	0	0	0
10-10-12	Thursday	4	1	1	2	0	0	0	0	0	0	0	0	0	0
11-10-12	Friday	6	6	0	0	0	0	0	0	0	0	0	0	0	0
14-10-12	Monday	5	4	1	0	0	0	0	0	0	0	0	0	0	0
15-10-12	Tuesday	6	5	0	1	0	0	0	0	0	0	0	0	0	0
16-10-12	Wednesday	6	0	3	2	0	0	0	0	0	0	0	0	0	0
17-10-12	Thursday	6	3	0	2	0	0	1	0	0	0	0	0	0	0
18-10-12	Friday	4	3	1	0	0	0	0	0	0	0	0	0	0	0
21-10-12	Monday	6	5	0	0	0	0	1	0	0	0	0	0	0	0
22-10-12	Tuesday	3	1	1	0	0	0	0	1	0	0	0	0	0	0
23-10-12	Wednesday	5	0	1	4	0	0	0	0	0	0	0	0	0	0
24-10-12	Thursday	5	3	0	2	0	0	0	0	0	0	0	0	0	0
25-10-12	Friday	4	2	2	0	0	0	0	0	0	0	0	0	0	0
28-10-12	Monday	6	4	1	0	0	0	1	0	0	0	0	0	0	0
29-10-12	Tuesday	6	3	2	1	0	0	0	0	0	0	0	0	0	0
30-10-12	Wednesday	6	0	3	2	0	0	0	0	0	0	0	0	0	1
31-10-12	Thursday	6	3	2	1	0	0	0	0	0	0	0	0	0	0
01-11-12	Friday	7	4	3	0	0	0	0	0	0	0	0	0	0	0
04-11-12	Monday	6	1	1	1	1	0	2	0	0	0	0	0	0	0
05-11-12	Tuesday	6	3	2	1	0	0	0	0	0	0	0	0	0	0
06-11-12	Wednesday	6	1	1	4	0	0	0	0	0	0	0	0	0	0
07-11-12	Thursday	7	2	1	4	0	0	0	0	0	0	0	0	0	0
08-11-12	Friday	5	2	2	1	0	0	0	0	0	0	0	0	0	0

Figure 41 Raw dataset

Table 13 Descriptive statistics on the number of PDT treatments/day

Statistics

[#PDT]

N	Valid	56
	Missing	4
	Mean	5,68
	Median	6,00
	Mode	6
	Std. Deviation	,956
	Variance	,913
	Minimum	3
	Maximum	7
	Sum	318

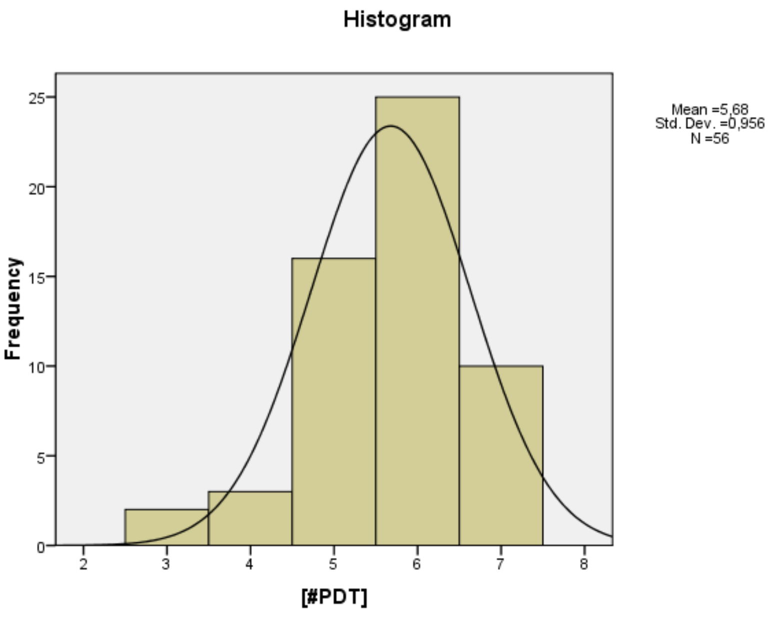


Figure 42 Histogram number of PDT treatments

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,992[a]	,983	,978	,141	1,863

a. Predictors: (Constant), 3x(20L+80J), 2x(20L+80J), 3X70J, 37J+70J, 100J, 80J, 2x20J, 37J, LASER, 2x70J, 20J+80J, 60J, 70J

b. Dependent Variable: [#PDT]

Figure 43 R-square linear regression model

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	49,384	13	3,799	192,113	,000[a]
	Residual	,830	42	,020		
	Total	50,214	55			

a. Predictors: (Constant), 3x(20L+80J), 2x(20L+80J), 3X70J, 37J+70J, 100J, 80J, 2x20J, 37J, LASER, 2x70J, 20J+80J, 60J, 70J

b. Dependent Variable: [#PDT]

Figure 44 ANOVA results table

Process scenario with Mohs

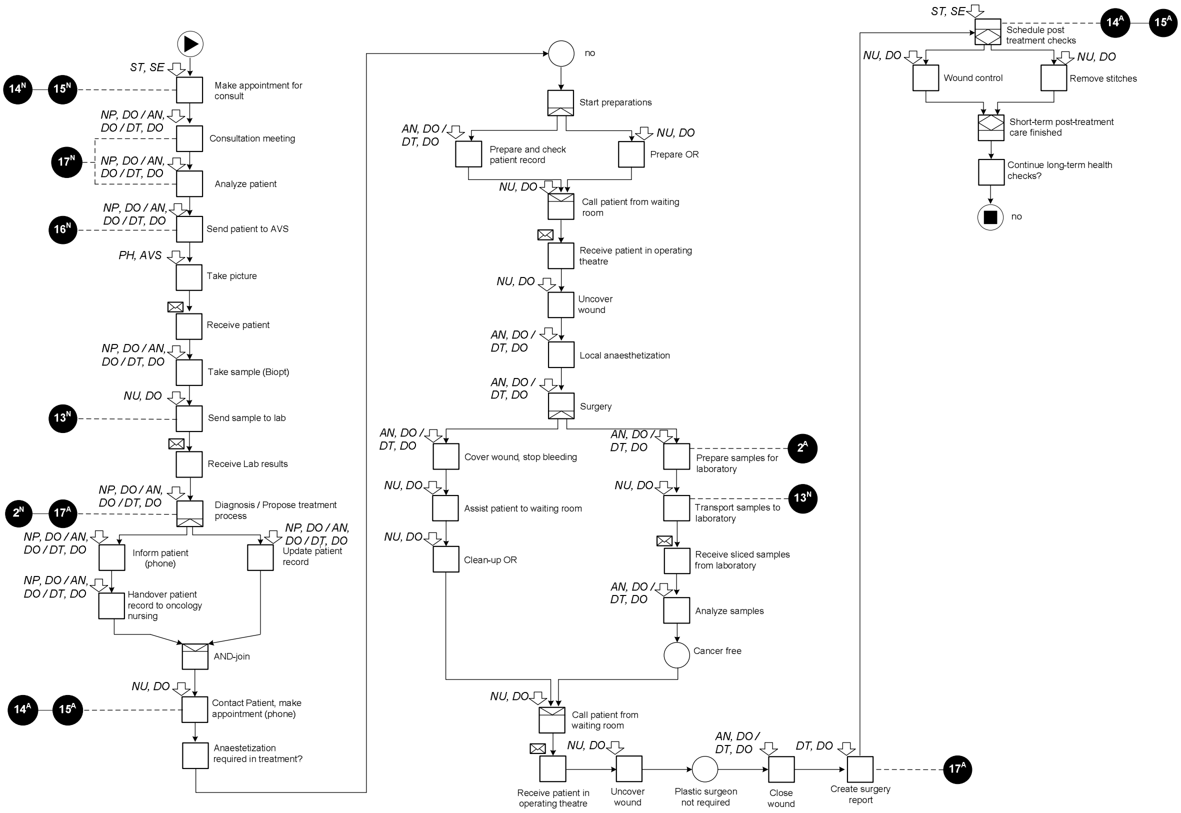


Figure 45 Process scenario including used forms

Appendix 4: Redesign evaluation outcomes

Evaluation meeting representatives

Function	*Number of stakeholders*
Project leader (me)	1
Dermatologist	3
A(N)IOS	6
Nurse practitioner	1
Nurse	1
Chief of Dermatology	1
Head of nursing	1
Co-assistant	1
Semi-doctor	1
Total	***16***

Table 14 Stakeholders evaluation meeting

Evaluation outcomes

Scenario 1: Use own camera

The stakeholders acknowledged that the usage of separate cameras will speed up the process. One assistant doctor (A(N)IOS) even mentioned having observed this idea in the Erasmus Hospital Rotterdam. He stated that flexibility was the largest advantage. For example, doctors where able to add a ruler to the picture so that the dimensions of the skin cancer can be recognized/measured on the photo later on.

Other stakeholders – mainly doctors – stated that the quality of the picture can only be guaranteed by a specialized photographer. The photographer makes sure that the right exposure is used, the correct distance, etc. *"Making our own photographs results in technically unacceptable quality of those photographs"* one doctor mentioned. The doctor adds that photographs have to be shot in rooms with a minimal length of six meters and no windows.
Another indirect complaint that was made dealt with the fact that in this scenario doctors have to shoot the photo their selves, which they have no time for.

The idea of uploading the photographs directly to the patients file in the Chipsoft EZIS was also recommended by the stakeholders.

Altogether can be stated that this scenario lacks commitment and therefore should not be implemented

Scenario 2: Relocate photographer

The second scenario aims at shifting the responsibility to improve the process from the Dermatology staff to the Audio and Video Services department (AVS). In this case the photographer is relocated to the Dermatology department. This relocation ensures that patients do not have to travel across the hospital and also ensures that the quality of the picture is guaranteed.

Doctors state that they feel this is the ideal situation. Their reasoning is quite logical since their patient's process improves, without making trade-offs their selves. Since the photographer's duty is one of the hospital's internal services, this reasoning is easy to follow. Again in this scenario, the photograph is directly uploaded in the Chipsoft EZIS, ensuring direct and easy accessibility.

Evaluation scenarios 1 and 2 by Devil's Quadrangle

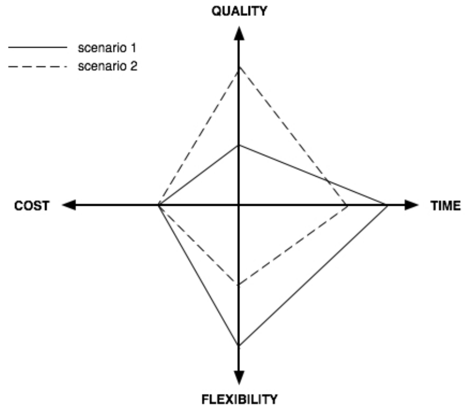


Figure 46 Devil's Quadrangle scenarios 1 and 2

Scenario 3: Biopsy results while patient waits

In this scenario a biopsy (sample) is taken from the patient and analyzed immediately by the pathologist. Normally, a biopsy is taken from the patient after whom the patient is send home. The biopsy is analyzed by the pathologists, who are also responsible for the diagnosing and reporting duties. This report is returned to the dermatologist who informs the patient. All together this process takes about one week. In the proposed scenario, the patient will receive the status of his condition after one or two hours.

The chief of Dermatology responses surprisingly positive to this idea, stating this scenario fits in the future vision of the Dermatology department. In this vision they aim at diagnosing and treating a patient in just one day. This proposition in combination with the Mohs surgery technique could realize this vision for a certain category of patients. Another positive consequence of this scenario is the elimination of both synchronous contact moments with the patient by phone in order to inform and schedule this patient. So the quality, flexibility and time performance dimensions are enhanced.

One assistant doctor mentioned that patients are perhaps not eager to wait in for the results and prefer to leave the hospital. Other stakeholders did not acknowledge this issue, but stated that in case a patient does not want to wait it must be possible to leave and get the results afterwards.

Scenario 4: Pass control towards patient

In this scenario the patient is in first place by phone informed by the doctor about the state of the disease. Normally a nurse rings the patient again to schedule the treatment. However, in this case the control over the latter action is passed towards the patients. This situation results in the situation that the patients needs to call the hospital to make an appointment.

The stakeholders agreed unanimous that this option should not be implemented. The reasons for that are mostly based on ethical dilemmas. First, most patients are older persons from above 70 years. The stakeholders argued that those people tend to not make the appointment due to several reasons, such as fear, anxiety, etc. Another reason to no implement this scenario is that the stakeholders argue that they loose control over the patient's status, which is not desired when dealing with oncology patients. Given the current – paper-based – way of working, facilities to monitor patients are indeed very poor. Also the patient record is not available whenever a patient decides to call the hospital.

It can be concluded that this scenario potentially could improve time and flexibility but decreases quality significantly.

Scenario 5: Combine scheduling and informing patients

To decrease the number of synchronous contacts with the patient (by phone), this scenario suggests combining both tasks that require patient involvement. First, both separated tasks add just little value to the process and slow up the process dramatically. Since the doctor and nurse conduct both separate activities, it is a logical decision that either the former or the latter will be responsible for the combined task execution.

When the stakeholders were confronted with the scenarios they immediately stated that this change would lead to more efficiency. Besides that, most stakeholders agreed that the nurses would be responsible for the combined task execution. Arguments to pursue this allocation are that nurses are familiar with the type of disease; schedule patients and can therefore can see 'the big picture' of the patient's process. On the other hand, doctors complain that they have to call those patients, which is a time consuming task.

Evaluation scenarios 3, 4 and 5 by Devil's Quadrangle

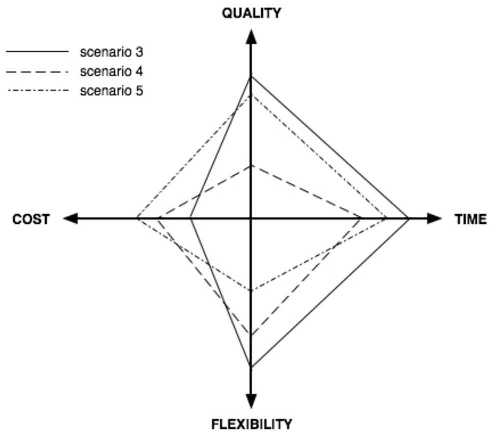


Figure 47 Devil's Quadrangle scenarios 3, 4 and 5

Scenario 6: Reallocation of PDT scheduling to secretariat

The nursing department conducts the scheduling of oncology patients. Outsiders typically qualify these tasks as part of the secretariat group and therefore it is illogical that secretary personnel do not perform the scheduling tasks of oncology patients. Based on historical scheduling data of Photodynamic Treatment (PDT) a linear regression model proved that there is no dependency of the type of PDT and its treatment duration on the patient scheduling. Therefore, no domain specific knowledge is required to schedule PDT treatments and therefore the secretaries could handle these activities.

When evaluating this scenario it became clear that there are different cultural viewpoints on how the way patients need are treated and informed before any treatment is scheduled. Again the doctors advise to shift the scheduling tasks to the secretariat, so that nurses have more time to treat more patients a day. The nursing stakeholders state that this is in fact something they pursue too, but they stress that nurses can provide the best information and can combine the informing, scheduling and executing of the PDT. Relocating those responsibilities to the secretariat could decrease the quality of the communication with the patient.

As a result from these differences no real decision has been made and it is up to the stakeholders to discuss these cultural/political viewpoints with each other to find a compromise.

Evaluation scenarios 6 by Devil's Quadrangle

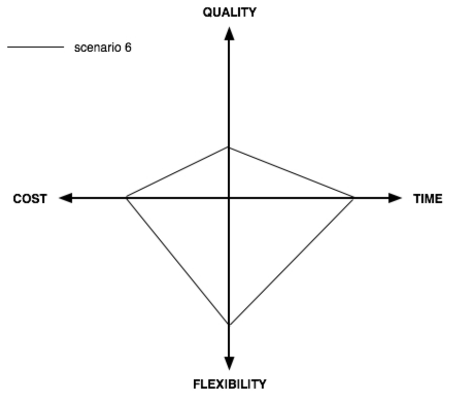


Figure 48 Devil's Quadrangle scenario 6

Scenario 7: Implementation of a WFMS/DMS

In this scenario, the handling of information is done via an information system, instead of working in the paper-based environment as it is done now. Implementing an Electronic Patient Record system (EPR) would ensure that data is added to the patient file along with the process. At the moment, a lot of gathered information has to be duplicated across the forms. Using the current – paper-based – way of working, this situation cannot properly be enhanced without shifting the administrative workload from one resource to another. Using an EPR would prevent data from being duplicated unnecessarily, which enhances efficiency. Another aspect of an EPR is that data is not easily to be lost. In the current situations, one of the biggest complaints is that Patient Files get (temporarily) lost frequently. The EPR will indefinitely increase the quality of the data completeness that is of great relevance to the medical treatment process. Downsides of an EPR are that changes to the data structure require changes of the system. These changes have to be conducted by trained software engineers, which decrease the flexibility of the medical personnel to process changes to the data structure. Also, the implementation of an EPR requires significant investments.

Evaluation scenarios 7 by Devil's Quadrangle

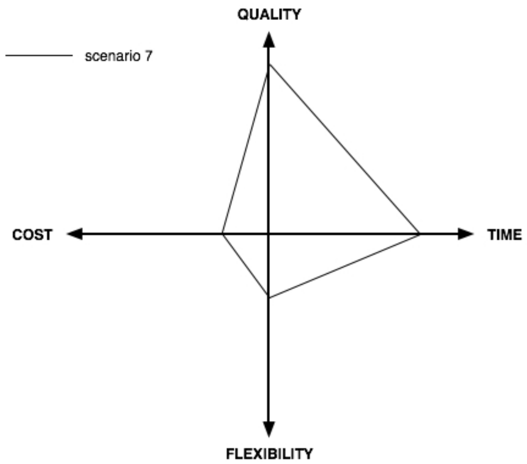


Figure 49 Devil's Quadrangle scenario 7

Appendix 5: Improved process models

The implemented redesign changes are highlighted in red, in order to improve the recognition of changed elements. Processes that remained unaffected are not duplicated into this Appendix, but can still be found at ‘Appendix 2: As-Is process models’.

Improved Organisation Model

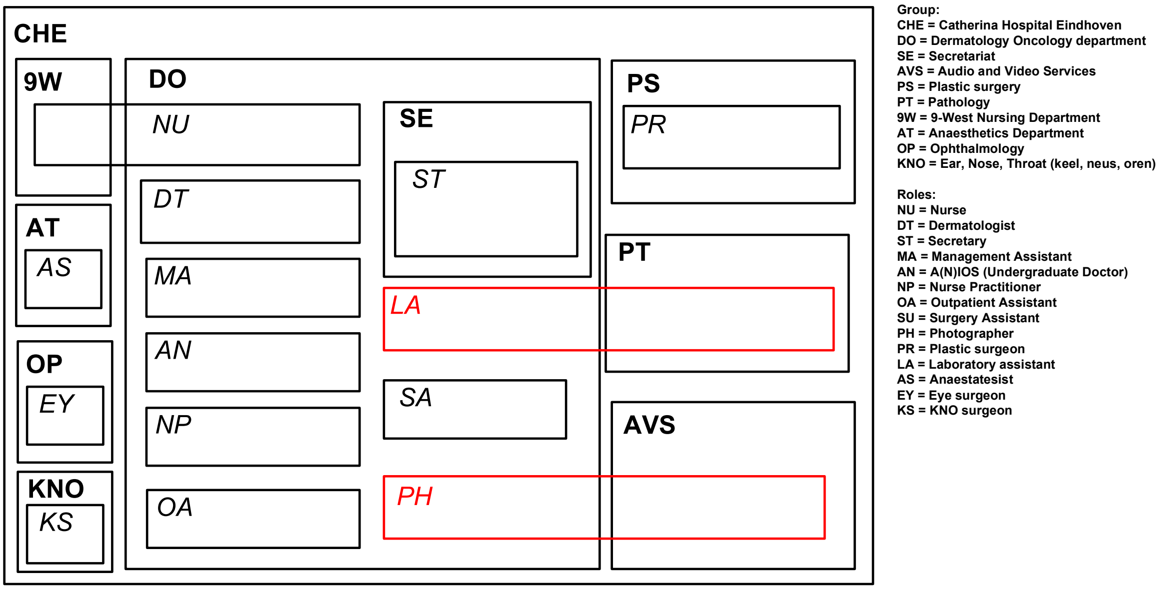


Figure 50 Improved organisational model

Distinction between pre-, post-, and treatment process fragments

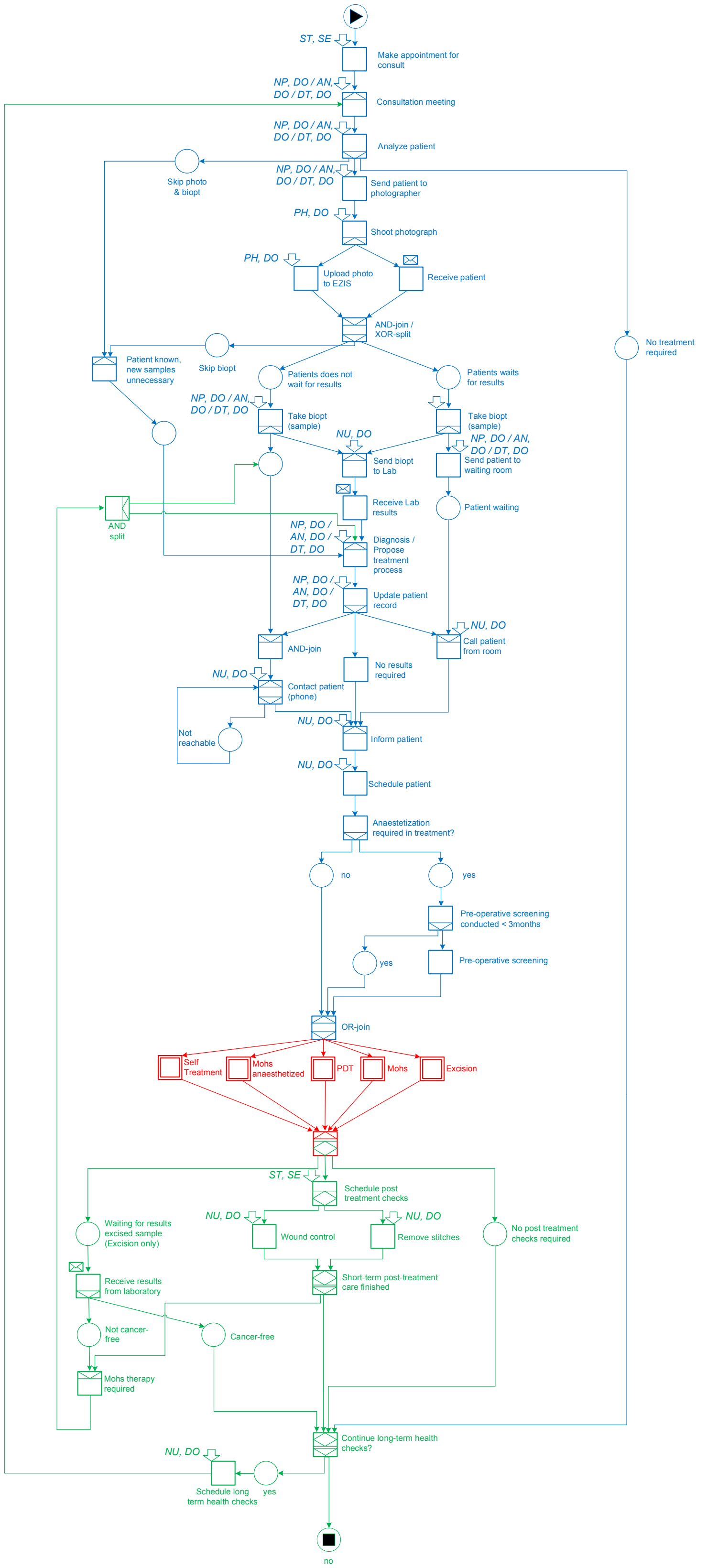


Figure 51 Process model with colours indicating different process parts

Appendix 6: Flexibility requirements

Flexibility pattern evaluations

Flexibility by design pattern evaluation

Table 15 Flexibility by design pattern evaluation

Flexible behaviour	Flexibility pattern	Example	Advantage	Disadvantage	Score
Initiation	Alternative entry points	Figure 52, (page 80)	It allows skipping unnecessary preceding activities.	In the To-Be process an exclusive choice will be made between one of the treatment interventions, where after the treatment stage is finished. Altogether this pattern is not applicable to the current situation, since starting from another starting point does not change any actual behaviour and increase flexibility.	-
Termination	Alternative exit points	Figure 53 (page 80)	It allows skipping unnecessary following activities.	In the To-Be process an exclusive choice will be made between one of the treatment interventions, where after the treatment stage is finished. Altogether this pattern is not applicable to the current situation, since exiting from another termination point does not change any actual behaviour.	-
Selection	Choice	Figure 54 (page 81)	The choice pattern illustrates that a decision is made. This pattern supports all 'normal' patients, but does not fulfil any of the flexibility requirements since no combinations and/or iterations of treatments can be supported	The (exclusive) choice pattern is does not change to To-Be process as compared to the As-Is model and therefore does not provide the required flexibility.	-
Reordering	Interleaving	Figure 55 (page 81)	It offers the possibility to execute a given set of treatment interventions in any order and assures that treatment interventions are not executed at the same moment of time. Flexibility requirement (1) is supported by this pattern.	By creating an interleaved process structure using an OR-split (instead of an AND-split) it is possible to select on or more treatment subprocesses, but prevent them from being executed simultaneously. Flexibility requirements (2) and (3) are not supported, since interleaving does not incorporate iterations of activities.	+/-
Elimination	Foreseen bypass	Figure 56 (page 82)	This pattern provides the possibility to eliminate the execution of certain activities by bypassing them.	The main disadvantage of this pattern is the fact that it cannot be foreseen what treatment interventions need to be bypassed and which not, which is required for this pattern to be useful. Although it is possible to create a bypass for every treatment intervention and use an AND-split instead of a XOR-split (see Figure 56) , several treatment interventions might be	-

				performed simultaneously which is prohibited.	
Extension	n/a	n/a	n/a	n/a	n/a
Concurrency	Parallelism	Figure 57 (page 82)	This pattern provides the possibility to execute several activities in parallel.	In this pattern all available treatment interventions would be activated and performed simultaneously, which is not possible.	-
Repetition	Iteration	Figure 58 (page 83)	The iteration pattern ensures the possibility to repeat a task (or subset of tasks) whenever necessary. This means that flexibility requirement (2) is supported by this pattern.	In the To-Be processes, this pattern would only realize functionality to repeat tasks. However, flexibility requirement (1) requires the selection of multiple treatment intervention, while prohibiting simultaneous execution.	+/-

Flexibility by deviation pattern evaluation

Table 16 Flexibility by deviation pattern evaluation

Flexible behaviour	Flexibility pattern	Advantage	Disadvantage	Score
Initiation	Entrance skip	It allows skipping unnecessary preceding activities.	In the To-Be process an exclusive choice will be made between one (or more) of the treatment interventions, where after the treatment stage is finished. Al together this pattern is not applicable to the current situation, since shifting the threat of control to another starting point does not lead to any increase in flexibility or the support of one of the flexibility requirements.	-
Termination	Termination skip	It allows skipping unnecessary following activities.	In the To-Be process an exclusive choice will be made between one (or more) of the treatment interventions, where after the treatment stage is finished. Al together this pattern is not applicable to the current situation, since shifting the threat of control to another termination point does not lead to any increase in flexibility or the support of one of the flexibility requirements.	-
Selection	Task substitution	It allows resource to substitute a given task by another task that is also part of the process. In situations where a certain task becomes irrelevant and upcoming tasks can already be executed enhanced flexibility is offered by this pattern.	In the To-Be process an exclusive choice will be made between one of the treatment interventions. Substituting this treatment intervention by one of the other's does not contribute to the required flexibility, since one could also choose for the required treatment intervention in the first place.	-
Reordering	Swap	It allows changing the order of activities, if business constraints allow.	In the To-Be process an exclusive choice will be made between one of the treatment interventions. Swapping this treatment intervention by one of the other's does not contribute to the flexibility, since one could also choose for the required treatment intervention in the first place.	-
Elimination	Task skip	It allows skipping tasks, if the business constraints allow.	In the To-Be process an exclusive choice is made between one of the treatment interventions. It would be highly illogical to skip an activity that just has been chosen, which also does not meet the flexibility requirements.	-
Extension	Task	As flexibility requirement (1)	The pattern is used during execution of the	+

	invocation	states, it is required to perform multiple treatment interventions during the same moment of surgery. In this case, the physician could choose for one of the options and invoke the other required treatment interventions. Flexibility requirement (2) states that certain treatment interventions need to be performed multiple times. By invoking the same activities multiple times this requirement can be fulfilled.	treatment process. This suggests that the flexible behaviour is recognized just after finishing the first chosen treatment interventions. In reality the chosen treatments are already recognized just after the diagnosis has been made (so on a earlier moment of time).	
Concurrency	n/a	n/a	n/a	n/a
Repetition	Redo	This pattern allows certain activities that have already been executed – but not successfully – to be redone.	Redoing a treatment intervention, after just finishing this intervention is very uncommon. For example, during surgery a wound is created and stitched at the end of the surgery. It is not accepted to reopen the wound again to redo surgery. Another aspect could be that the Redo-pattern is used whenever an intervention needs to be performed multiple times. However, from a data perspective this would indicate that a certain intervention was not performed correctly and was therefore executed again. In practice the same intervention is applied at another area of the human body that also needs medical attention.	-

Flexibility by underspecification pattern evaluation

Table 17 Flexibility by underspecification pattern evaluation

Flexible behaviour	Flexibility pattern	Advantage	Disadvantage	Score
Initiation	Undefined entry	It allows the end-user to define the starting activities at run-time.	Since the treatments are mutually exclusive and a decision for either one of the treatment interventions leads to the direct execution of this treatment no flexibility enhancements are offered by this pattern.	-
Termination	Undefined exit	It allows the end-user to define the termination activities at run-time.	Since the subprocess automatically finishes after any of the chosen treatment finishes, the application of this pattern does not offer additional flexibility.	-
Selection	Late selection	At the moment that is recognized how the treatment of the patient will be executed and what interventions will be performed, the required process combination can be selected and bond into the existing process structure. Since the flexibility requirements are known beforehand, the required intervention subprocess can be selected tailored to the patient's needs.	-	+
Reordering	n/a	n/a	n/a	n/a
Elimination	n/a	n/a	n/a	n/a
Extension	Late creation	This pattern provides the option to invoke a task at an anticipated moment, if this is required.	The part of the process that requires flexibility (the treatment execution) is either performed or skipped. This means that the offered flexibility by this pattern does not provide the desired flexibility requirements, since the desired flexibility should provide possibilities to combine and repeat different treatment interventions that are not offered by this pattern.	–
Concurrency	n/a	n/a	n/a	n/a
Repetition	n/a	n/a	n/a	n/a

Flexibility by change pattern evaluation

Table 18 Flexibility by change pattern evaluation

Flexible behaviour	Flexibility pattern	Advantage	Disadvantage	Score
Initiation	Entry change (momentary)	The entry point of the process is changed by changing the process, allowing freedom in deciding where to start a process.	Since the treatments are mutually exclusive and a decision for either one of the treatment interventions leads to the direct execution of this treatment no flexibility enhancements are offered by this pattern.	–
	Entry change (permanent)	See momentary.	See momentary.	–
Termination	Exit change (momentary)	The termination point in the process is changed by changing the process, allowing freedom in deciding where to end a process	Since the subprocess automatically finishes after any of the chosen treatment finishes, the application of this pattern does not offer additional flexibility.	–
	Exit change (permanent)	See momentary.	See momentary.	–

Selection	Choice insertion (momentary)	It may be the case that a choice is required but not incorporated in the process. The process can be changed on the run and a choice construct can be added to the process model	The actual selection of one of the processes is already realised with an exclusive choice construct. Adding another choice would not lead to an increase in flexibility.	–
	Choice insertion (permanent)	In the future it may be required to add new choices to the process model. For example, if in case the non-oncology treatment interventions are added, it may be necessary two separate these patients in the process from the oncology patients.	-	+
Reordering	Reordering (momentary)	In case the order of tasks does not comply with the needs of the end-uses, these tasks could be reordered.	In the As-Is process, a choice is made between mutually exclusive treatment interventions. Either one or the other treatment intervention is executed during that moment of time, which makes reordering impossible. Another aspect of medical processes is that they are performed in a well-grounded manner and that changing the sequence of activities might not be a powerful tool to increase process flexibility	–
	Reordering (permanent)	See momentary.	See momentary.	–
Elimination	Task elimination (momentary)	Tasks that become unnecessary can be eliminated from the process	In the As-Is process, either one or another treatment intervention is chosen. Eliminating a treatment intervention that has been chosen to be executed is illogical.	–
	Task elimination (permanent)	In the future it may become possible that certain treatment interventions become superfluous. In that case those activities may be eliminated by changing the process model	-	+
Extension	Task insertion (momentary)	In case the execution of one treatment is not sufficient, other treatment interventions can be added before the treatment subprocess will finish.	Extending the chosen treatment interventions with other treatment interventions to fulfil flexibility requirement (1) might be too time consuming. Since twenty percent of the patients require multiple treatment interventions, the process efficiency might even drop if these patients require manually editing of process models.	+
	Task insertion (permanent)	In the future new treatment interventions will be introduced. Adding the option to select these new interventions might be realized by dynamically adding the new intervention.	-	+
Concurrency	Task parallelization (momentary)	-	In this pattern available treatment interventions would be activated and performed simultaneously, which is not possible.	–
	Task parallelization (permanent)	See momentary.	See momentary.	–
Repetition	Loop insertion (momentary)	The loop insertion pattern ensures the possibility to repeat a task (or subset of tasks) whenever	This pattern does not offer functionality to choose between one or more treatment interventions and making sure that they	+

		necessary. This means that flexibility requirement (2) is supported by this pattern.	are not performed simultaneously.	
	Loop insertion (permanent)	See momentary.	See momentary.	+

Example solutions based on flexibility by design

Flexible initiation

In the design example in Figure 52 it is possible to start at any given treatment subprocess

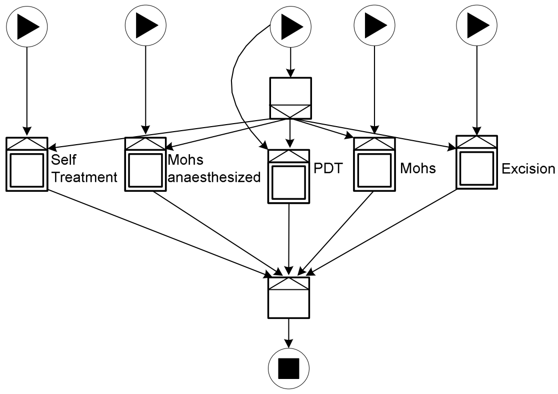


Figure 52 Design: Alternative entry points

Flexible termination

In the design example in Figure 53 it is possible to end the process after any given treatment subprocess

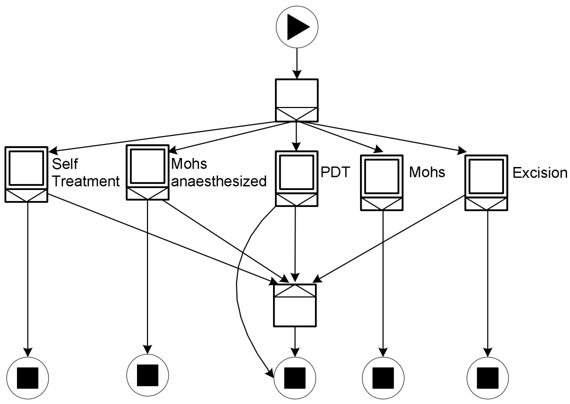


Figure 53 Design: Alternative exit points

Flexible selection

In the design example in Figure 54 it is possible choose one of the available treatment processes.

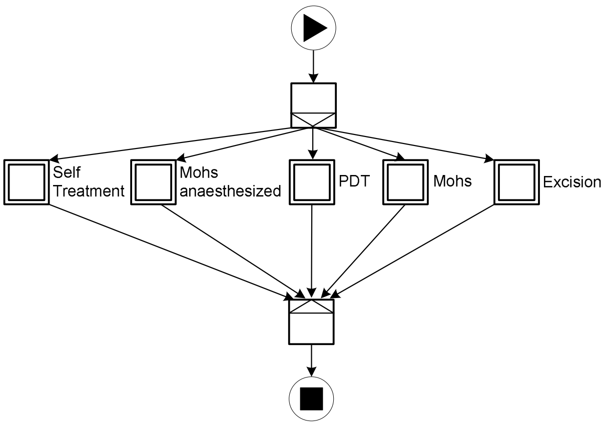


Figure 54 Design: Choice

Flexible reordering

In this process, the user can select one or more treatment interventions, which cannot be performed simultaneously.

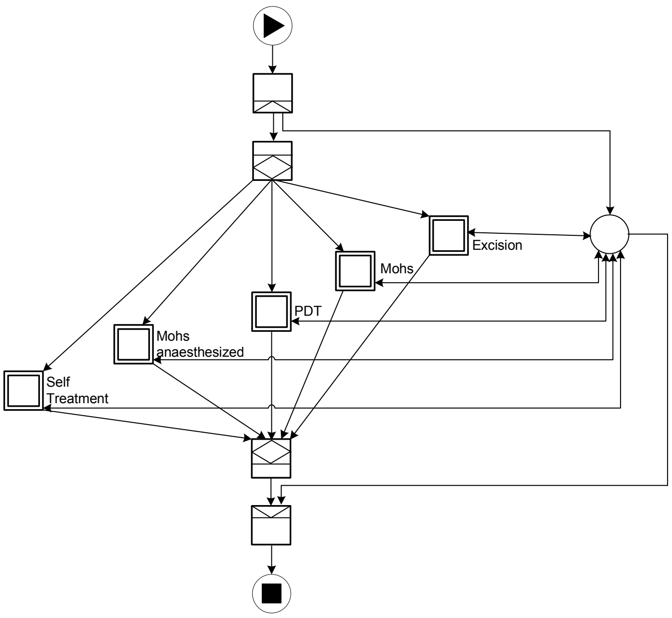


Figure 55 Design: Interleaving

Flexible elimination

In this example, all treatment interventions are activated and the user can decide to bypass treatment interventions that will not be performed.

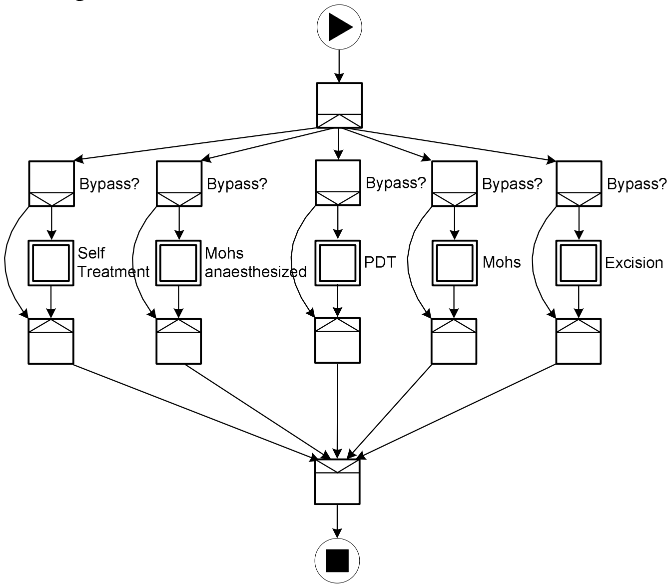


Figure 56 Design: Foreseen bypass

Flexible concurrency

In this example, all treatment interventions are activated and can be performed simultaneously.

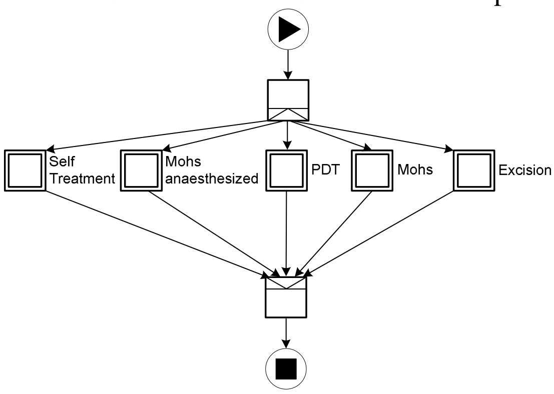


Figure 57 Design: Parallelism

Flexible repetition

In this example one treatment intervention is chosen and the user can decide to execute this intervention one or more times.

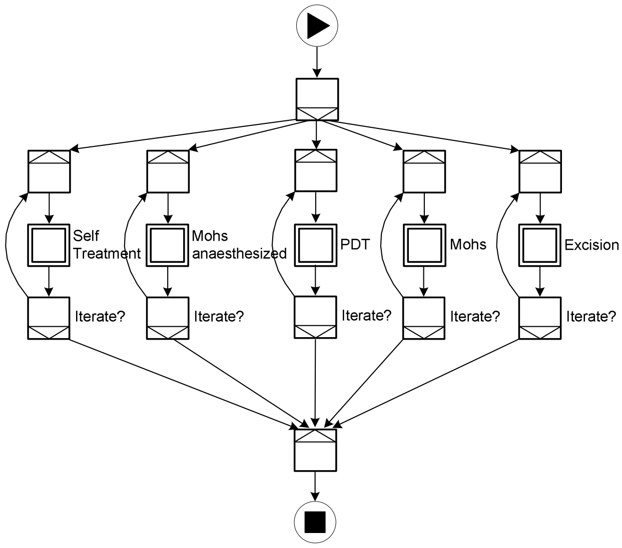


Figure 58 Design: Iteration

Example solution based on flexibility by deviation

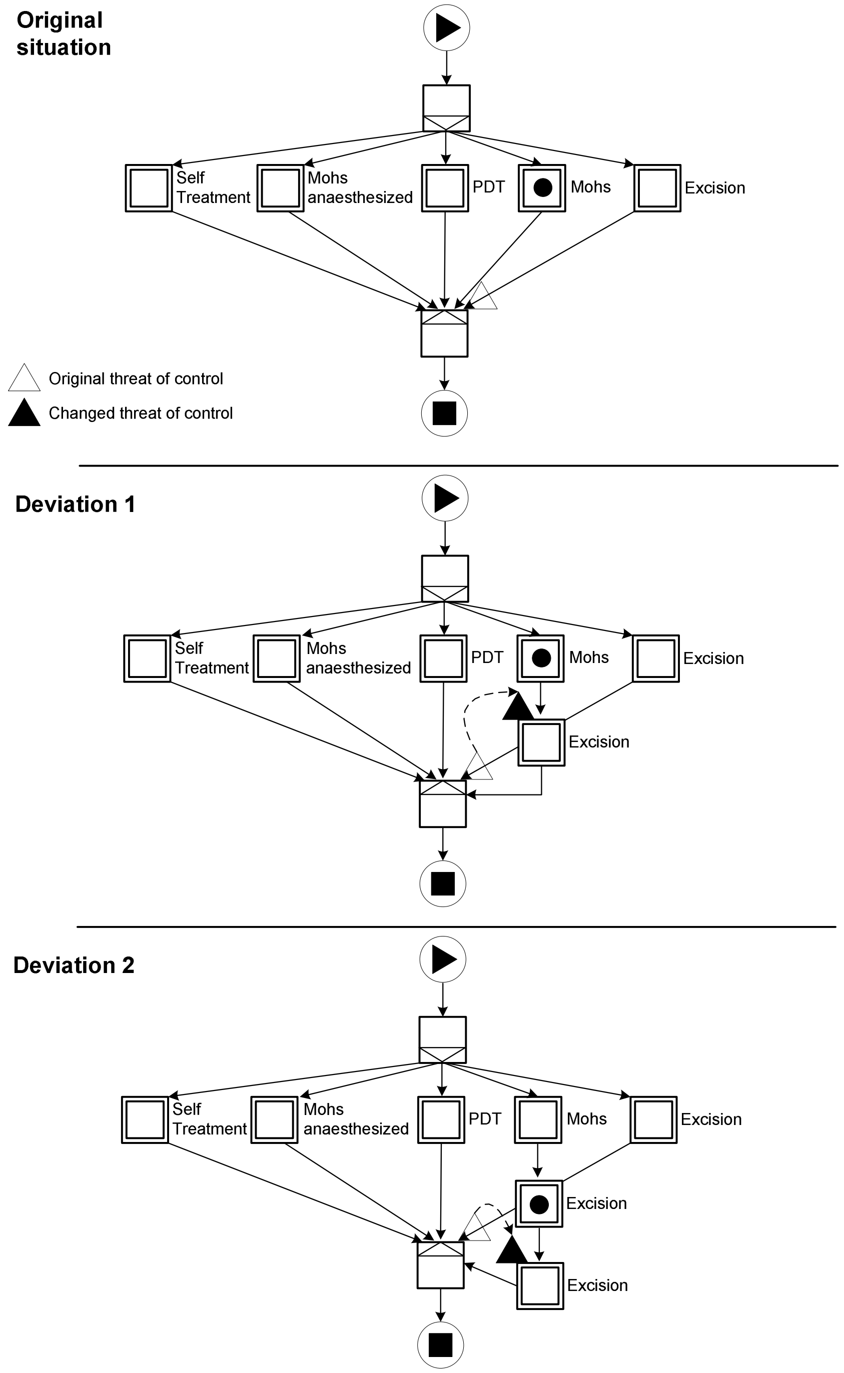


Figure 59 Example flexibility by deviation

Example solution based on flexibility by underspecification

Ripple Down Rules for Treatment selection

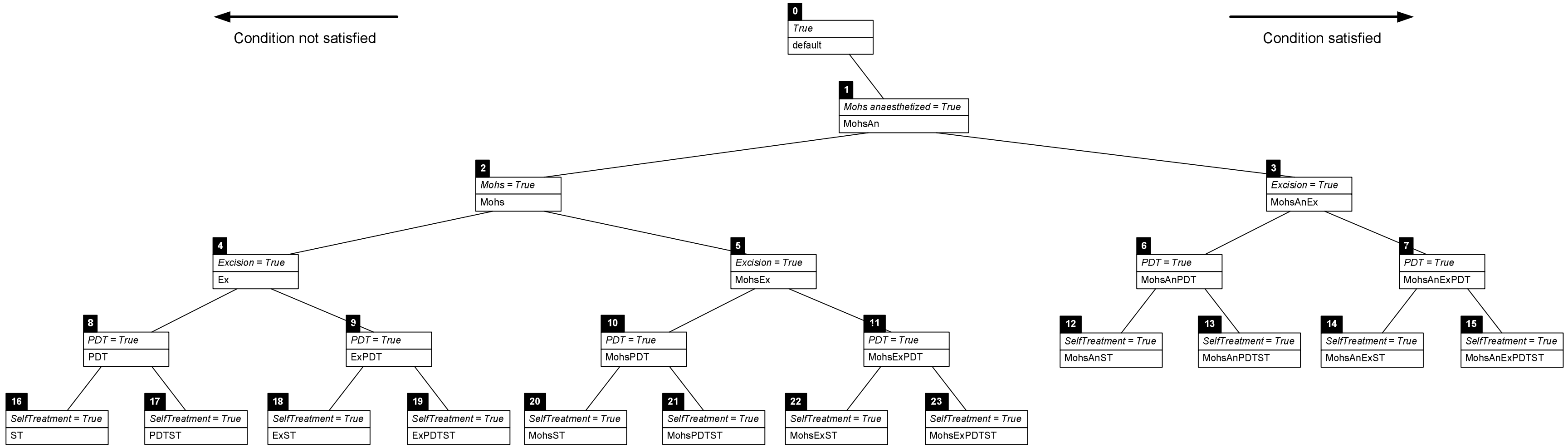


Figure 60 Ripple Down Rules

Worklets

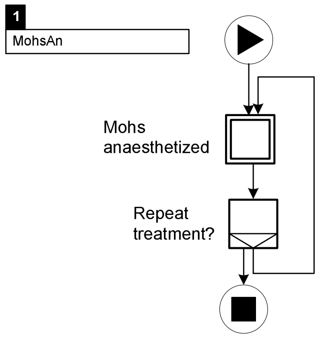


Figure 61 Worklet 1: MohsAn

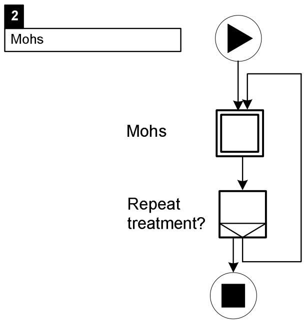


Figure 62 Worklet 2: Mohs

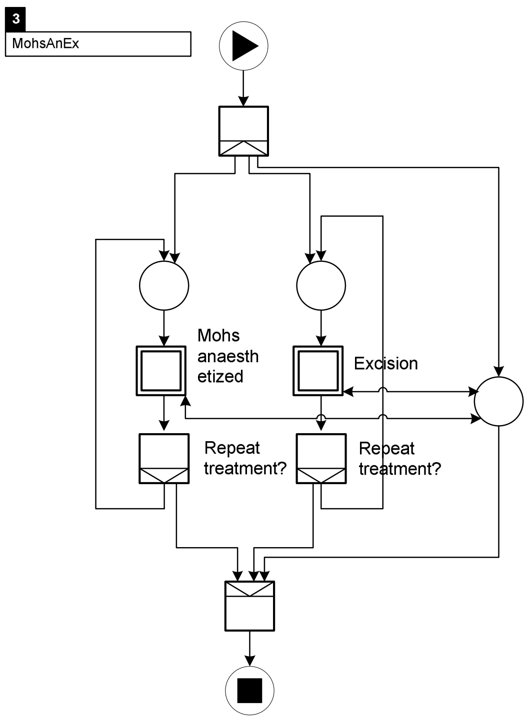


Figure 63 Worklet 3: MohsAnEx

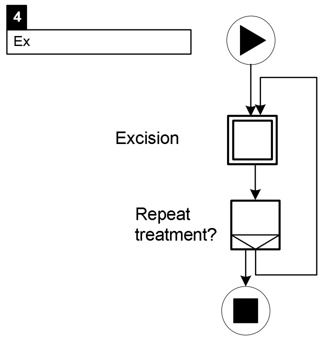


Figure 64 Worklet 4: Ex

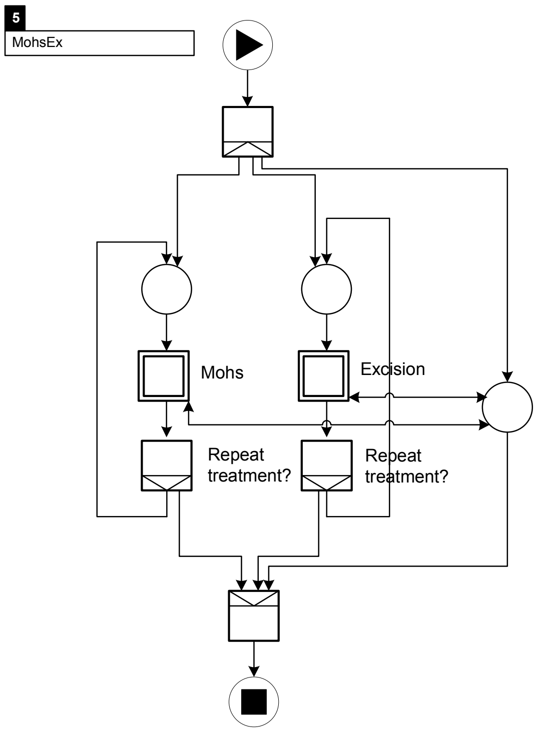


Figure 65 Worklet 5: MohsEx

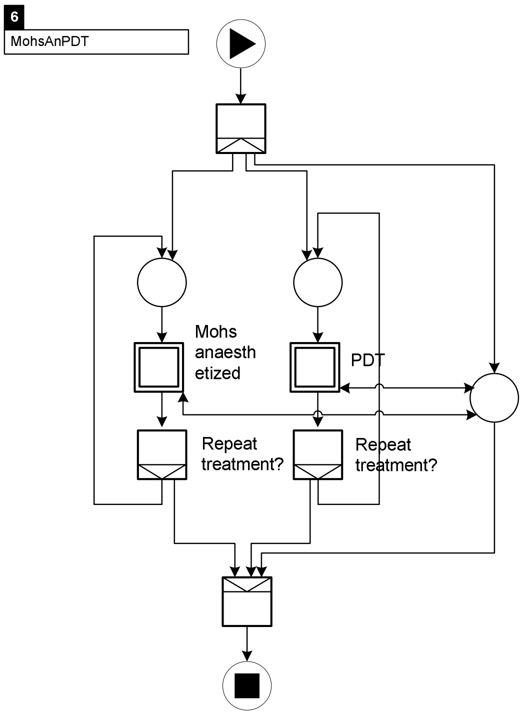


Figure 66 Worklet 6: MohsAnPDT

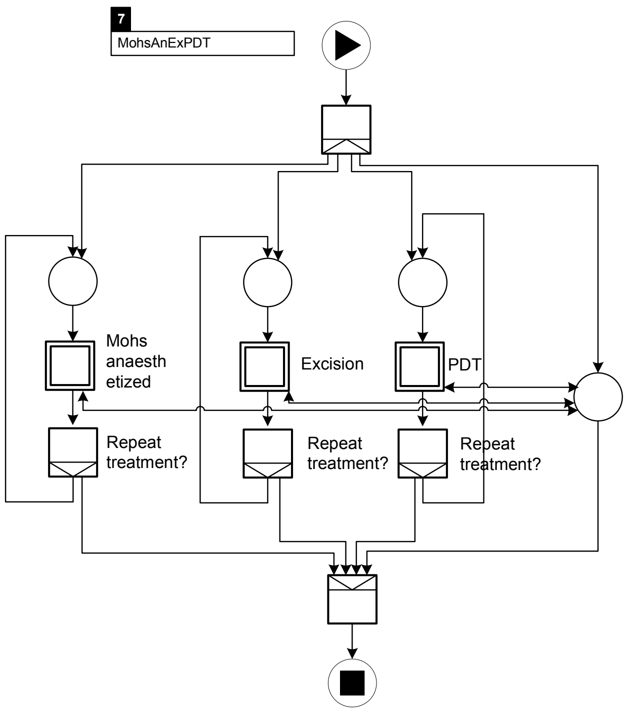


Figure 67 Worklet 7: MohsAnExPDT

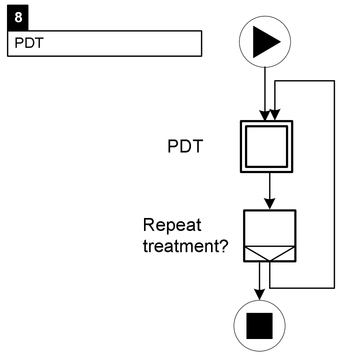


Figure 68 Worklet 8: PDT

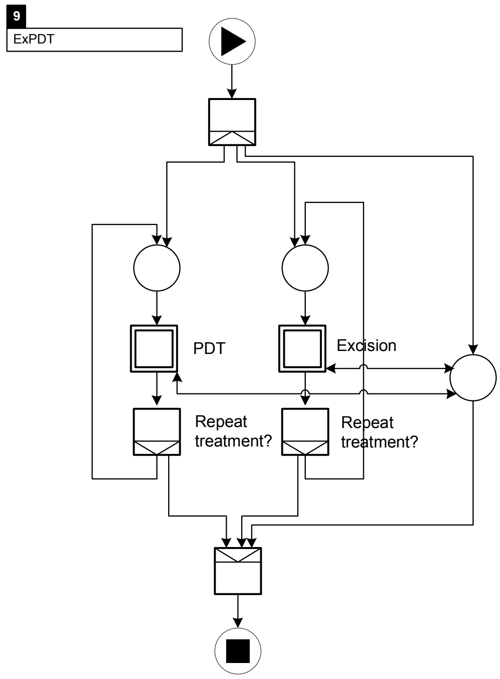


Figure 69 Worklet 9: ExPDT

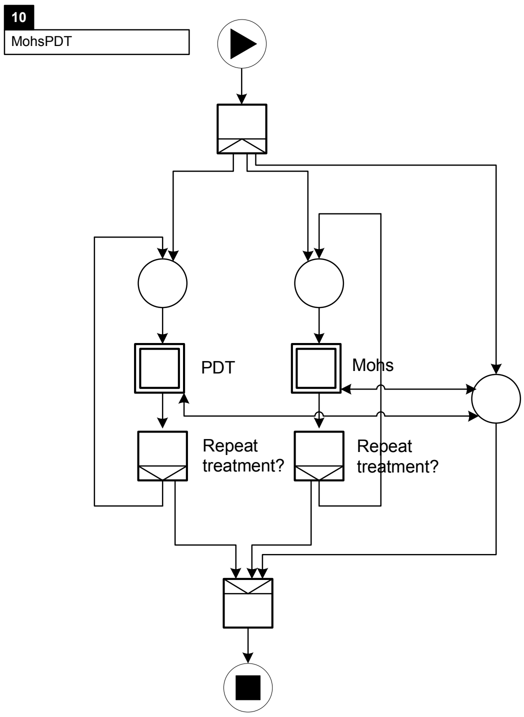


Figure 70 Worklet 10: MohsPDT

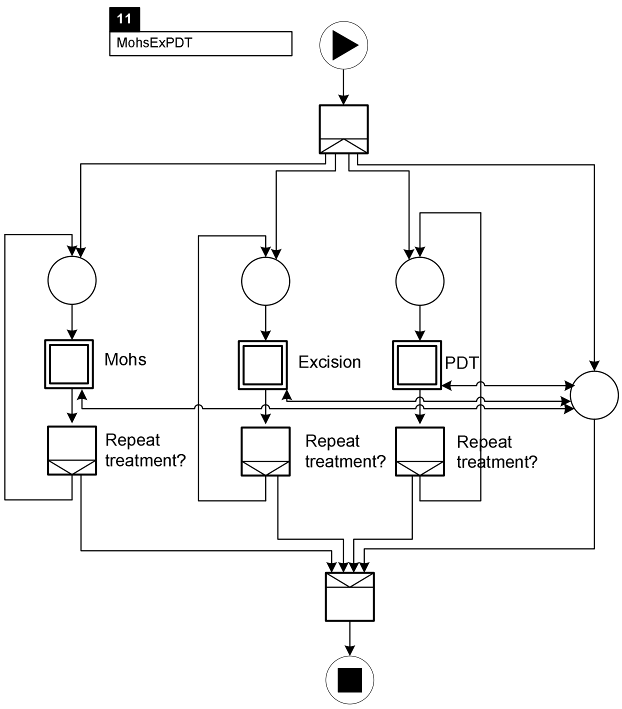


Figure 71 Worklet 11: MohsExPDT

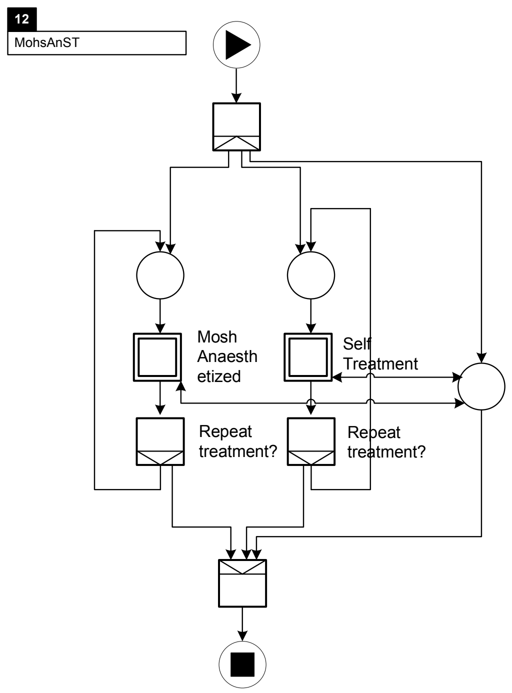


Figure 72 Worklet 12: MohsAnST

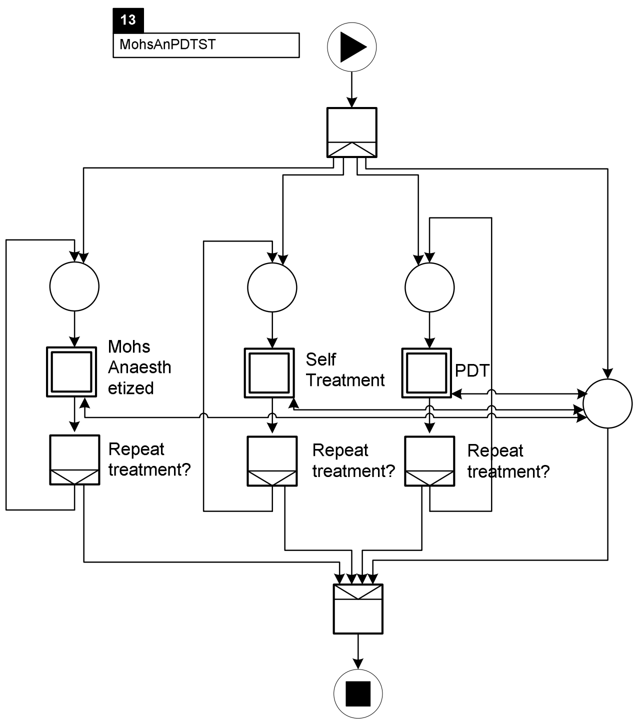


Figure 73 Worklet 13: MohsAnPDTST

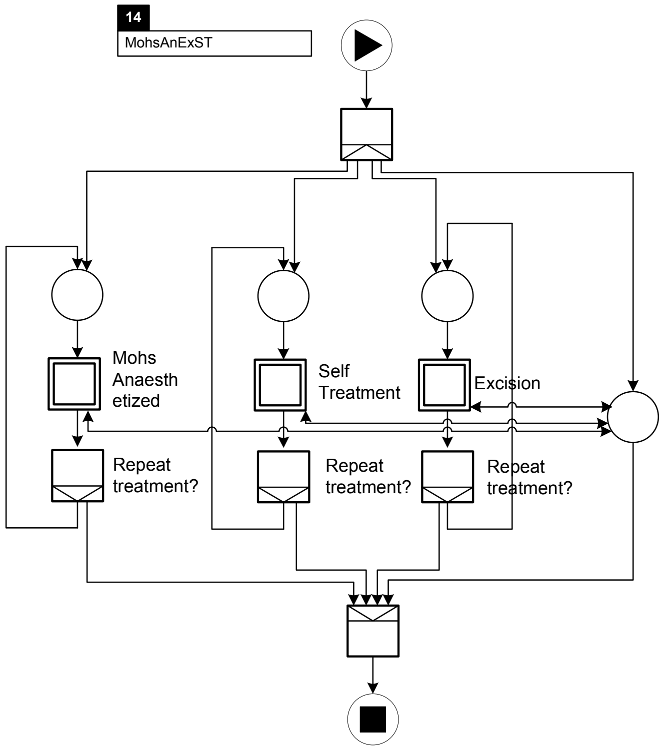


Figure 74 Worklet 14: MohsAnExST

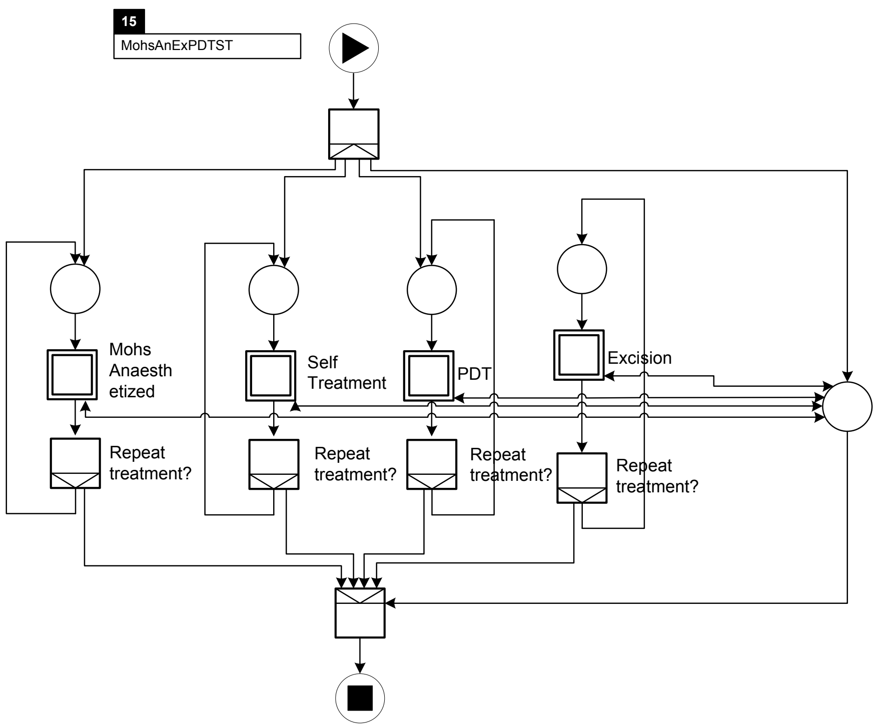


Figure 75 Worklet 15: MohsAnExPDTST

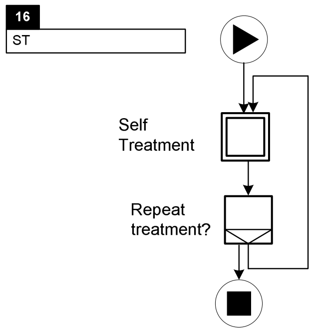


Figure 76 Worklet 16: ST

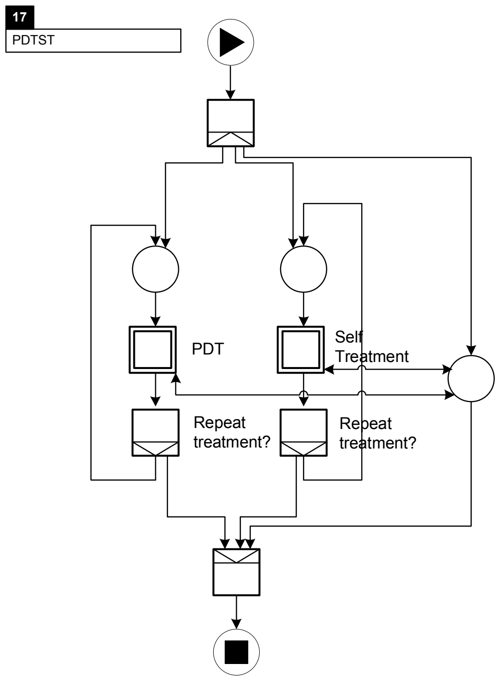


Figure 77 Worklet 17: PDTST

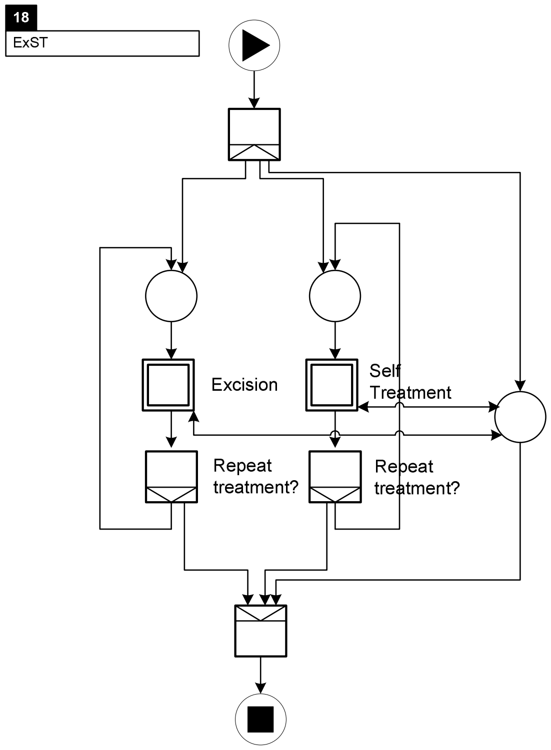


Figure 78 Worklet 18: ExST

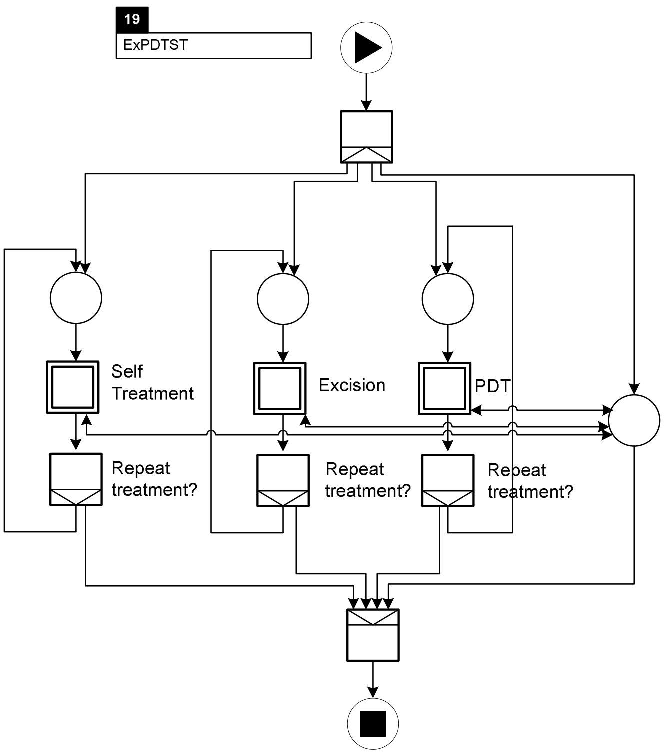


Figure 79 Worklet 19: ExPDTST

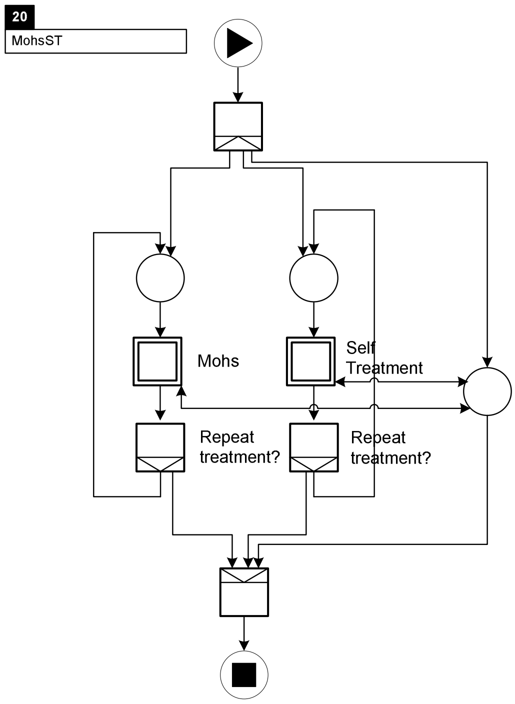


Figure 80 Worklet 20: MohsST

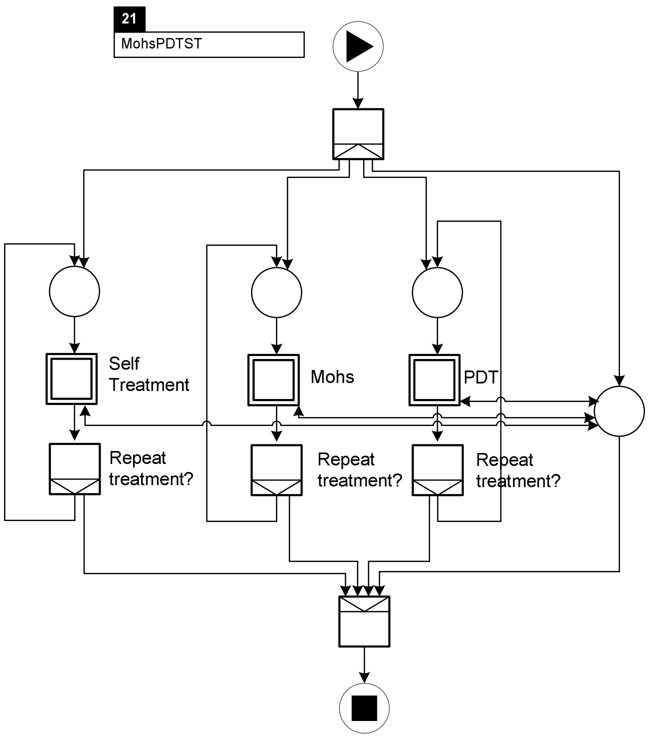


Figure 81 Worklet 21: MohsPDTST

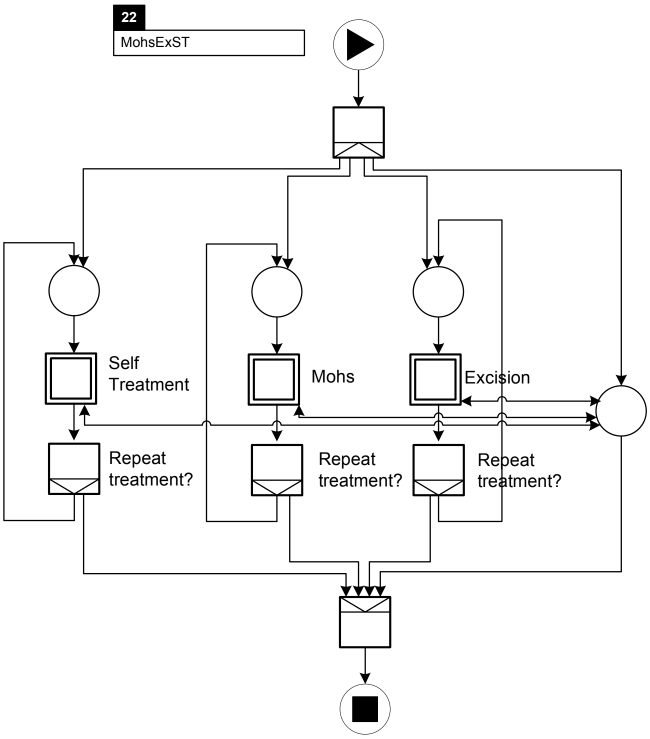


Figure 82 Worklet 22: MohsExST

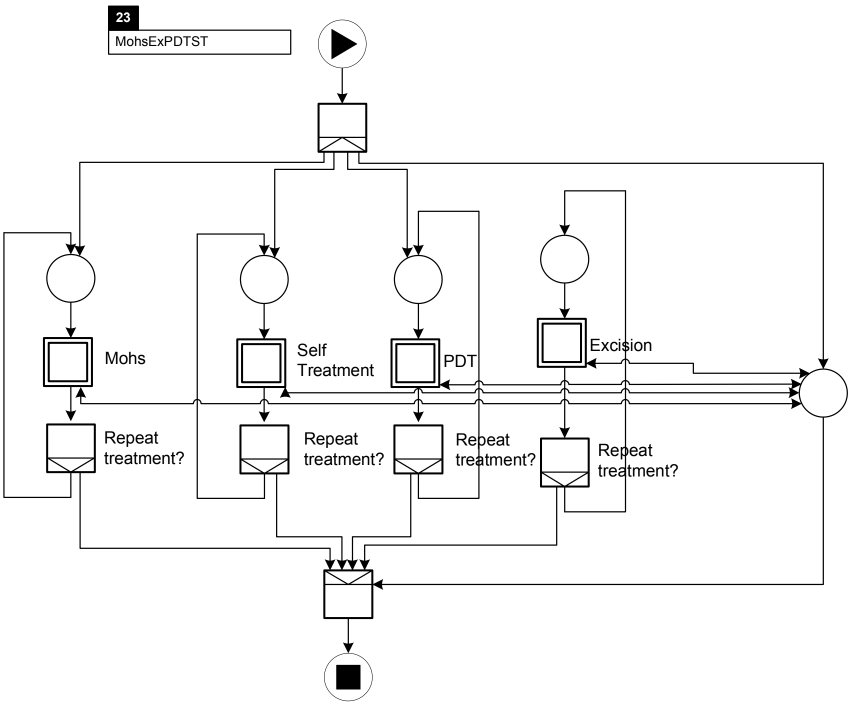


Figure 83 Worklet 23: MohsExPDTST

Example solution based on flexibility by change

A new treatment intervention is added to the process model and the process instances are migrated to the new process definition.

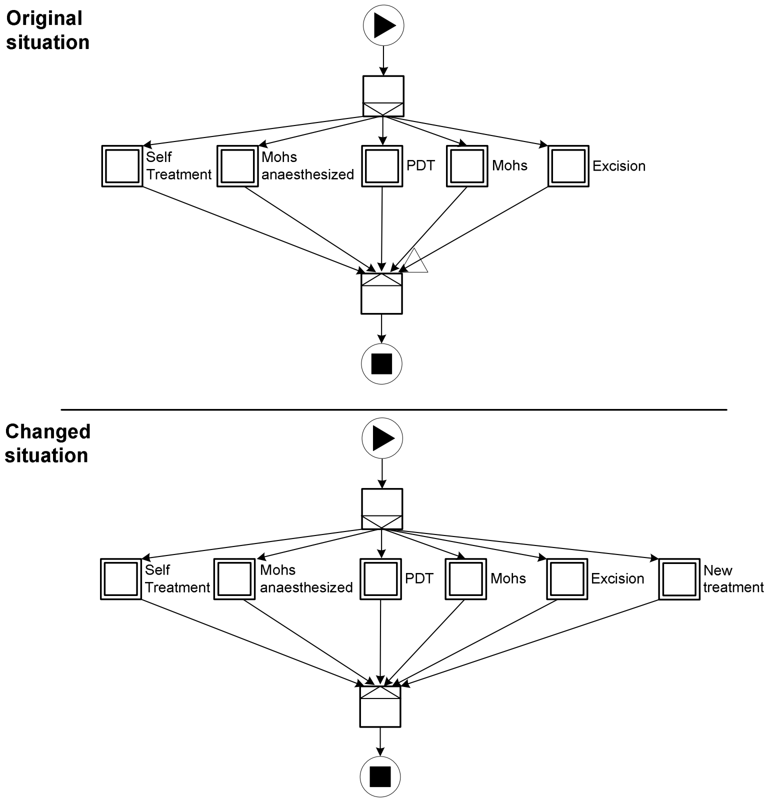


Figure 84 Change: Task insertion

Appendix 7: To-Be process models

General process based on flexibility by design

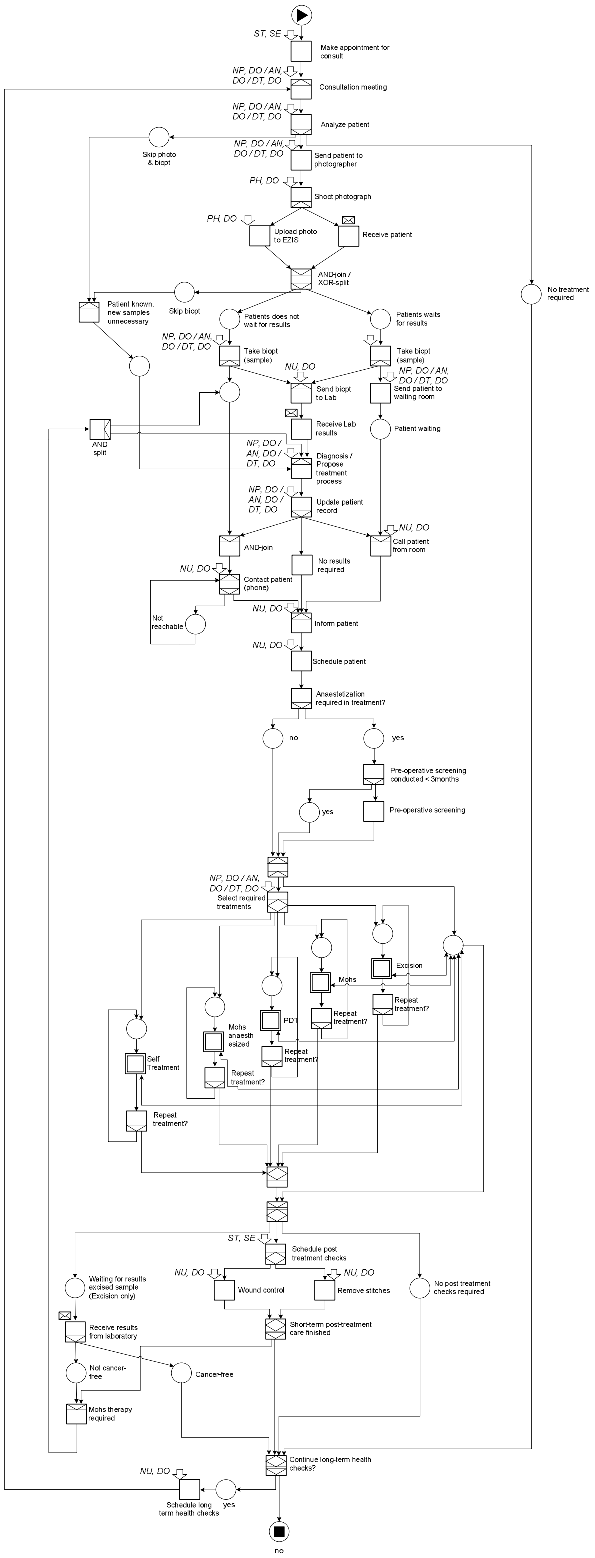


Figure 85 Process enhanced using flexibility by design

General process based on flexibility by underspecification

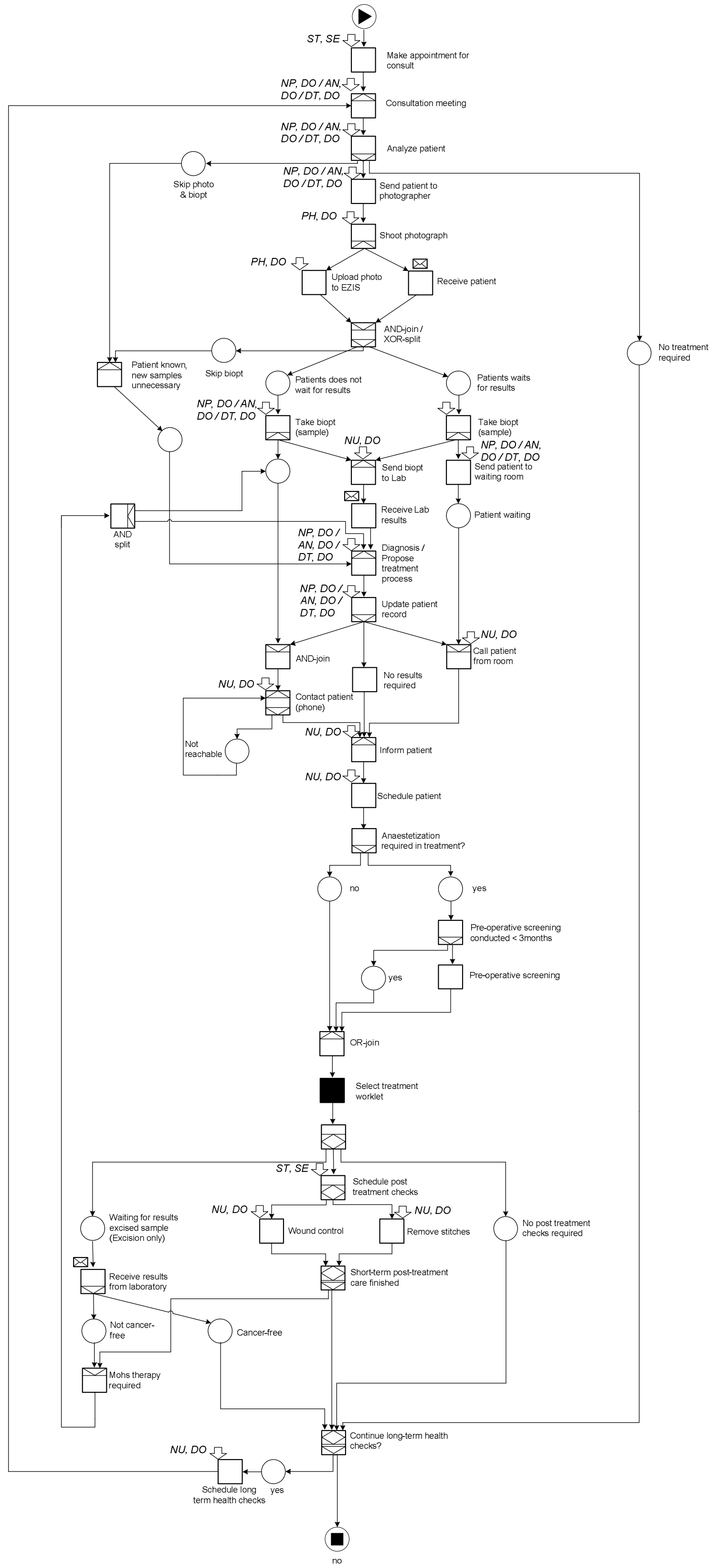


Figure 86 Process enhanced using flexibility by underspecification

Appendix 8: Workflow Patterns evaluation results

Control-flow Patterns

Control flow Patterns table

The control-flow Patterns are taken from Russell et al. (2006).

Table 19 Control-flow Patterns evaluation

Nr.	CF Pattern	Required?	Illustration
1	Sequence	✓	Figure 87 (page 101)
2	Parallel Split	✓	Figure 88 (page 101)
3	Synchronization	✓	Figure 88 (page 101)
4	Exclusive Choice	✓	Figure 89 (page 101)
5	Simple Merge	✓	Figure 90 (page 101)
6	Multi-Choice	✓	Figure 91 (page 101)
7	Structured Synchronizing Merge	✓	Figure 92 (page 102)
8	Multi-Merge	×	-
9	Structured Discriminator	×	-
10	Arbitrary Cycles	✓	Figure 93 (page 103)
11	Implicit Termination	×	-
12	Multiple Instances without Synchronization	×	-
13	Multiple Instances with a Priori Design-Time Knowledge	×	-
14	Multiple Instances with a Priori Run-Time Knowledge	×	-
15	Multiple Instances without a Priori Run-Time Knowledge	×	-
16	Deferred Choice	×	-
17	Interleaved Parallel Routing	×	-
18	Milestone	×	-
19	Cancel Activity	×	-
20	Cancel Case	✓	n/a
21	Structured Loop	✓**	Figure 94 (page 104)
22	Recursion	×	-
23	Transient Trigger	×	-
24	Persistent Trigger	×	-
25	Cancel Region	×	-
26	Cancel Multiple Instance Activity	×	-
27	Complete Multiple Instance Activity	×	-
28	Blocking Discriminator	×	-
29	Cancelling Discriminator	×	-
30	Structured Partial Join	×	-
31	Blocking Partial Join	×	-
32	Cancelling Partial Join	×	-
33	Generalised AND-Join	×	-
34	Static Partial Join for Multiple Instances	×	-
35	Cancelling Partial Join for Multiple Instances	×	-
36	Dynamic Partial Join for Multiple Instances	×	-
37	Local Synchronizing Merge	✓	Figure 95 (page 104)
38	General Synchronizing Merge	×	-
39	Critical Section	×	-
40	Interleaved Routing	✓**	Figure 96 (page 104)
41	Thread Merge	×	-
42	Thread Split	×	-
43	Explicit Termination	✓	Figure 97 (page 105)
** only required for supporting the To-Be processes based on Flexibility by Design			

Control-Flow pattern illustrations

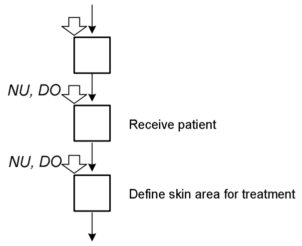


Figure 87 Pattern CF.01 Sequence

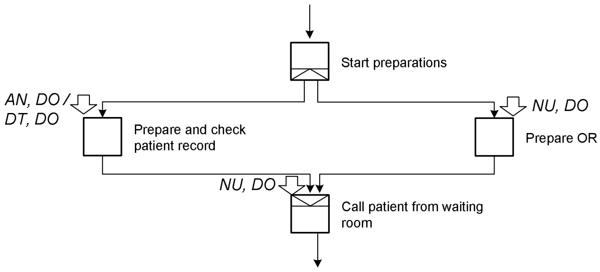


Figure 88 Pattern CF.02 Parallel Split and CF.03 Synchronisation

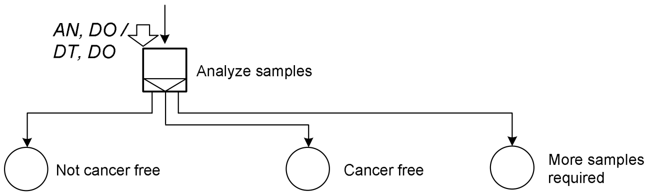


Figure 89 Pattern CF.04 Exclusive Choice

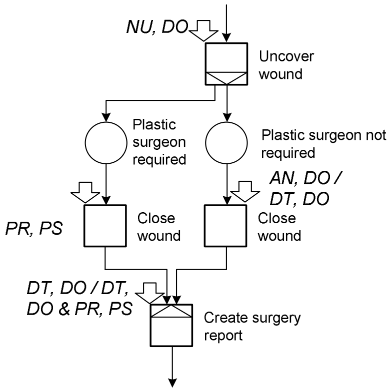


Figure 90 Pattern CF.05 Simple Merge

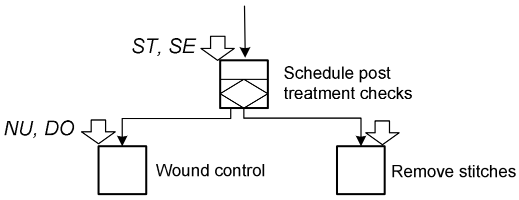


Figure 91 Pattern CF.06 Multi-Choice

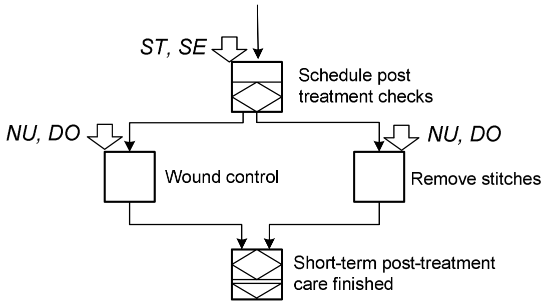


Figure 92 Pattern CF.07 Structured Synchronizing Merge

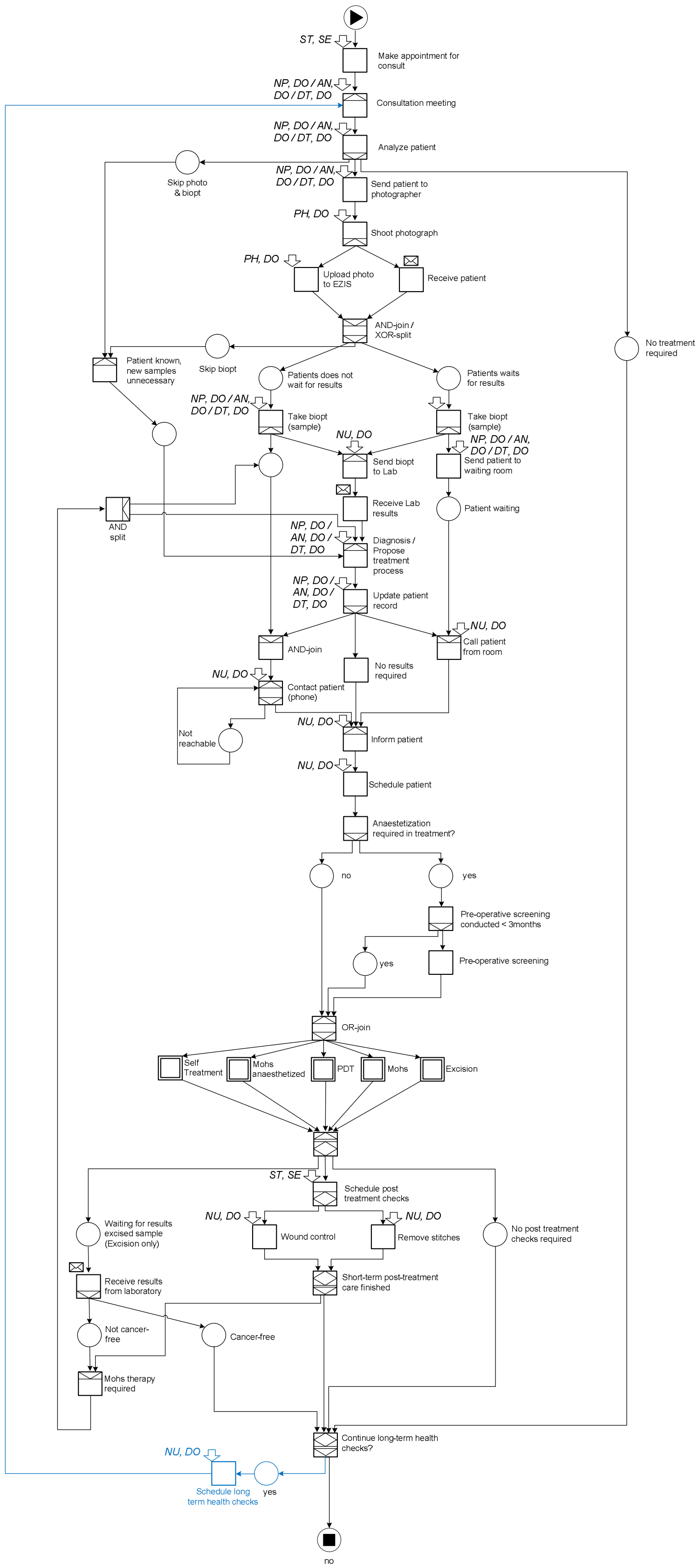


Figure 93 Pattern CF.10 Arbitrary Cycles

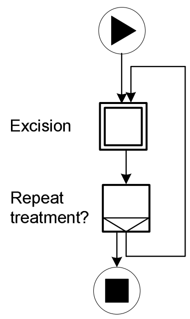


Figure 94 Pattern CF.21 Structured Loop

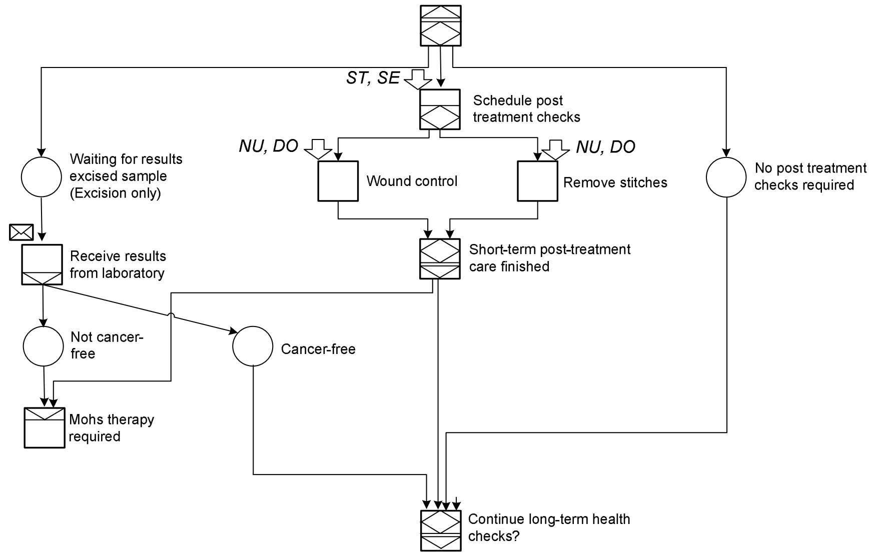


Figure 95 Pattern CF.37 Local Synchronizing Merge

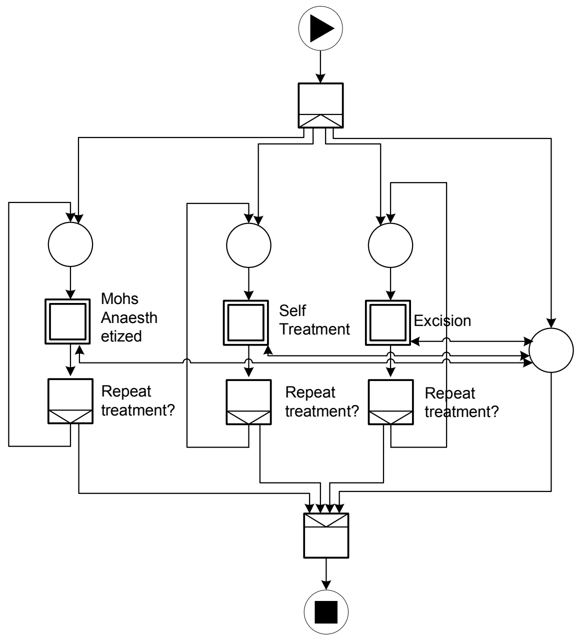


Figure 96 Pattern CF.40 Interleaved Routing

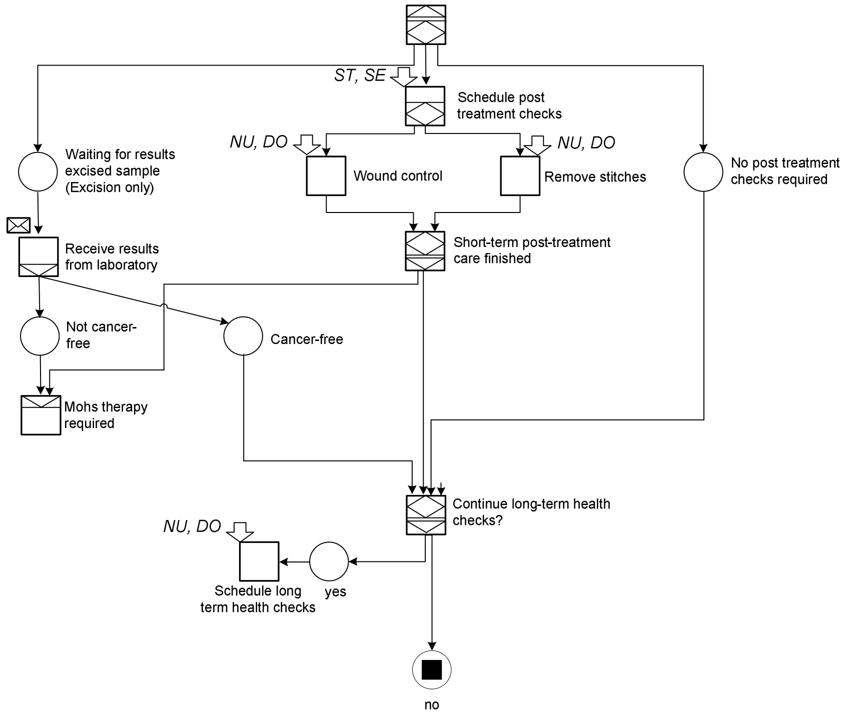


Figure 97 Pattern CF.43 Explicit Termination

Resource Patterns

Table 20 Resource Patterns evaluation

Nr.	Res Pattern	Required?	Explanation
1	Direct Allocation	✓	Regarding the allocation of work to the physicians, it can be stated that the scheduling of treatments is based on a static week schedule. This schedule defines which physicians are doing which tasks at which day. The allocation is direct to the resource, since it is known beforehand who is responsible for certain treatment activities.
2	Role-Based Allocation	✓	Most work items are allocated based on the resource's role. For example, the medical photograph has to be made by the photographer.
3	Deferred Allocation	×	For all activities it is known beforehand what resource/role has to perform this activity. Therefore, it is not necessary to support the deferred resource selection at run-time.
4	Authorisation	×	Of course, medical regulation states who is or is not authorized to do surgery, or what have you. However, in the case of resource distribution and allocation, this problem is already solved by direct allocation.
5	Separation of Duties	×	There is no strict dependency of resources allocations, which might require this pattern. Although there are rules towards the allocation of resources, these rules apply to certain activities – but not between activities.
6	Case Handling	×	Although patients sometimes request to be helped by the same physicians over time, the hospital is does not approve this request due to organisational constraints.
7	Retain Familiar	✓	In general, the same physician does the monitoring of a patient over time. This means that at a task level it may be the case that the same resource is responsible for the same patient. This is not the case for the entire process.
8	Capability Based Allocation	×	The allocation of work is purely based on the resources' roles.
9	History Based Allocation	×	The allocation of work is purely based on the resources' roles.
10	Organisational Allocation	×	The allocation of work is purely based on the resources' roles.
11	Automatic Execution	✓	Some tasks can be executed without allocating a resource, such as <receive lab results>.
12	Distribution by Offer - Single Resource	×	The allocation of work is based on a static week schedule that defines what resources should be doing what tasks at what point of time during the working week. Therefore it is known beforehand that (e.g.) physician X will perform five Mohs surgeries on Mondays and Nurses Y and Z will perform PDTs on Tuesdays. Therefore a single resource is not able to decide when to allocate the work item, since this is predefined.
13	Distribution by Offer - Multiple Resources	✓	Administrative tasks can be offered to multiple resources from the having equivalent roles, such as 'Secretary' or 'Nurses'.
14	Distribution by Allocation - Single Resource	✓	The allocation of work is based on a static week schedule that defines what resources should be doing what tasks at what point of time during the working week. Therefore it is known beforehand that (e.g.) physician X will perform five Mohs surgeries on Mondays and Nurses Y and Z will perform PDTs on Tuesdays. Therefore patients are being distributed by allocation to single resources.
15	Random Allocation	×	Not applicable in the medical domain, due to the high level of expertises.
16	Round Robin Allocation	×	Not applicable in the medical domain, due to the fixed schedule that defines who is doing what task at what day of the week.
17	Shortest Queue	×	Work is distributed and allocated to single resources, so there is no option to choose the resource having the shortest queue of

			work items.
18	Early Distribution	✗	Most tasks are highly dependent on each other. This means that future tasks cannot be initiated or executed, since the current tasks first have to be finished.
19	Distribution on Enablement	✓	This pattern would deliver proper support for the distribution of administrative tasks around the treatment intervention.
20	Late Distribution	✗	This pattern would be beneficial in case of ad-hoc handling of patients, as probably occurs at the First Aid department. However, given the highly rigid weekly working scheme, this pattern might not be appropriate.
21	Resource-Initiated Allocation	✓	Administrative tasks could be allocated by resource without intending to immediately start executing the allocated tasks. Typically these are tasks such as 'updating the patient record', or 'make appointment for consult'.
22	Resource-Initiated Execution - Allocated Work Item	✓	Medical tasks that have been directly allocated also need to be executed when initiated.
23	Resource-Initiated Execution - Offered Work Item	✓	Administrative tasks may be offered to multiple resources. It is up to one of the resource to 'pull' the work-items out of the shared work list.
24	System Determined Work Queue Content	✗	The order of work items is determined by the order in which previous resources have worked on those work items
25	Resource-Determined Work Queue Content	✗	The resources are not authorized to change the sequence of cases in the work list.
26	Selection Autonomy	✓	In the medical treatment processes patients may arrive who require a treatment intervention very urgently. In this case, authorized end-users may change the sequence of cases in order to provide primacy to the urgent patient.
27	Delegation	✓	For certain activities it may be possible to delegate allocated task to a resource sharing the same role/group before execution.
28	Escalation	✗	It is not possible to let the system redistribute the work item to other resources, since there is high dependency on the working-schedule and competences of the resources.
29	Deallocation	✗	It may occur that a work-item needs to be reallocated, but this should not in control of the resource itself. First, treatment activities require execution along with initiation. Regarding administrative tasks this pattern is not desires, since it could reduce efficiency.
30	Stateful Reallocation	✗	Once executing, the resource should not reallocate the work item.
31	Stateless Reallocation	✗	Once executing, the resource should not reallocate the work item
32	Suspension/Resumption	✓	It should be possible to temporarily suspend administrative work items
33	Skip	✗	All activities are essential in the process and should not be skipped. It is possible to skip tasks based on control-flow decisions.
34	Redo	✗	This pattern is not required.
35	Pre-Do	✗	The medical treatment process is highly hierarchal and there is high data dependency between tasks. This prohibits this pattern from being suitable.
36	Commencement on Creation	✗	Given the flexible behaviour of the process, it is not wise to automatically start executing tasks when they are created.
37	Commencement on Allocation	✗	Given the flexible behaviour of the process, it is not wise to automatically start executing tasks when they are allocated.
38	Piled Execution	✗	The tasks executed by medical resources are highly variable. This means that it is not the case that certain activities are repeated multiple times after each other. This assumption prohibits this pattern from increasing efficiency.
39	Chained Execution	✗	The tasks executed by medical resources are highly variable. This means that it is not the case that certain activities are repeated multiple times after each other. This assumption prohibits this pattern from increasing efficiency.
40	Configurable	✗	This pattern enhances the usability and transparency of the work

	Unallocated Work Item Visibility		list handler, it is not required to support the medical treatment processes.
41	Configurable Allocated Work Item Visibility	×	This pattern enhances the usability and transparency of the work list handler, it is not required to support the medical treatment processes.
42	Simultaneous Execution	×	This pattern is not required in order to provide support for the medical treatment processes.
43	Additional Resources	✓	During certain medical treatments it may be foreseen that – for example – a plastic surgeon is required, who must be added to the surgery process.

Data Patterns

Table 21 Data Patterns evaluation

Nr.	Res Pattern	Required?	Explanation
1	Task Data	✓	In certain circumstances data at a task-level may be required. For example, in case a request for a medical photograph is send to the photographer, the type of photo (grayscale, RGB, etc.) is entered at task level and does need to be used again once the photograph has been taken.
2	Block Data	×	There is no need to require this pattern's support.
3	Scope Data	×	There is no need to require this pattern's support.
4	Multiple Instance Data	×	There is no need to require this pattern's support.
5	Case Data	✓	Most data relates to individual patients and is presented in a patient record. From a data perspective, any patient can be seen as a case. During the treatment processes the medical personnel requires the complete medical history in order to commence on medical tasks. This reasoning indicates that support for case data is mostly required.
6	Folder Data	×	There is no need to require this pattern's support.
7	Workflow Data	×	There is no need to require this pattern's support.
8	Environment Data	×	There is no need to require this pattern's support.
9	Task to Task	✓	By passing data elements from Task to Task, the required information can be made available to resources handling administrative tasks. For example, to know which patients have to be contacted to perform the <inform patient> activity, the physician who executes the preceding task can pass the required patient-data from his task to the <inform patient> task.
10	Block Task to SubWorkflow Decomposition	×	There is no need to require this pattern's support.
11	SubWorkflow Decomposition to Block Task	×	There is no need to require this pattern's support.
12	To Multiple Instance Task	×	There is no need to require this pattern's support.
13	From Multiple Instance Task	×	There is no need to require this pattern's support.
14	Case to Case	×	There is no need to require this pattern's support.
15	Task to Environment - Push-Oriented	×	There is no need to require this pattern's support.
16	Environment to Task - Pull-Oriented	×	There is no need to require this pattern's support.
17	Environment to Task - Push-Oriented	×	There is no need to require this pattern's support.
18	Task to Environment - Pull-Oriented	×	There is no need to require this pattern's support.
19	Case to Environment - Push-Oriented	×	There is no need to require this pattern's support.
20	Environment to Case - Pull-Oriented	×	There is no need to require this pattern's support.
21	Environment to Case - Push-Oriented	×	There is no need to require this pattern's support.
22	Case to Environment - Pull-Oriented	×	There is no need to require this pattern's support.

23	Workflow to Environment - Push-Oriented	×	There is no need to require this pattern's support.
24	Environment to Workflow - Pull-Oriented	×	There is no need to require this pattern's support.
25	Environment to Workflow - Push-Oriented	×	There is no need to require this pattern's support.
26	Workflow to Environment - Pull-Oriented	×	There is no need to require this pattern's support.
27	Data Transfer by Value - Incoming	×	There is no need to require this pattern's support.
28	Data Transfer by Value - Outgoing	×	There is no need to require this pattern's support.
29	Data Transfer - Copy In/Copy Out	×	There is no need to require this pattern's support.
30	Data Transfer by Reference - Unlocked	×	There is no need to require this pattern's support.
31	Data Transfer by Reference - With Lock	×	There is no need to require this pattern's support.
32	Data Transformation - Input	×	There is no need to require this pattern's support.
33	Data Transformation - Output	×	There is no need to require this pattern's support.
34	Task Precondition - Data Existence	×	There is no need to require this pattern's support.
35	Task Precondition - Data Value	×	There is no need to require this pattern's support.
36	Task Postcondition - Data Existence	×	There is no need to require this pattern's support.
37	Task Postcondition - Data Value	×	There is no need to require this pattern's support.
38	Event-Based Task Trigger	×	There is no need to require this pattern's support.
39	Data-Based Task Trigger	×	There is no need to require this pattern's support.
40	Data-Based Routing	×	There is no need to require this pattern's support.

Workflow support

In this paragraph the direct link is established between the required Patterns and the appropriateness of WFMSs for supporting those Patterns. Russell et al. (2004a, 2004b, 2006) and Mulyar et al. (2008) provided the evaluation of several WFMSs/modelling standards regarding the discussed workflow Patterns.

The numbers in the presented tables refer to the following WFMSs/modelling standards:

Commercial WFMS	Open-source WFMS	Modelling standards
1 = Staffware 2 = WebSphere MQ Workflow 3 = FLOWer 4 = COSA 5 = iPlanet 6 = SAP Workflow 7 = FileNet	8 = jBPM 9 = OpenWFE 10 = Enhydra Shark	11 = BPEL 12 = Websphere Integration Developer 12* = BPEL4WS 13 = Oracle BPEL 14 = BPMN 15 = XPDL 16 = UML 17 = EPC

Table 22 Control-Flow Patterns evaluation table

Control-Flow Patterns																		
		Commercial Products							**Open-source Products**			**Workflow Modelling Standards**						
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	Sequence	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	Parallel Split	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	Synchronization	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4	Exclusive Choice	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	Simple Merge	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
6	Multi-Choice	-	+	+	+	+	-	+	-	+/-	+	+	+	+	+	+	+	+
7	Structured Synchronizing Merge	-	+	+	-	-	-	+	-	-	-	+	+	+	+	+	-	+
10	Arbitrary Cycles	+	-	-	+	+	-	+	+	+	+	-	-	-	+	+	+	+
20	Cancel Case	-	-	+/-	-	-	+	+	-	+/-	+	+	+	+	+	+	+	-
21	Structured Loop*	-	+	+	-	+	+	+	-	+	-	+	+	+	+	+	+	-
37	Local Synchronizing Merge	-	+	+	+	-	-	-	-	+/-	-	+	+	+	-	-	+/-	+
40	Interleaved Routing*	-	-	+/-	+	-	-	-	-	+	-	+	+	-	+/-	+/-	-	-
41	Thread Merge	-	-	-	-	-	-	-	+/-	-	-	+/-	+/-	+/-	+	+	+	-
43	Explicit Termination	-	-	-	+	+	+	-	-	-	-	-	-	-	+	+	+	-
* Required for the To-Be processes based on flexibility by design and flexibility by underspecification.																		

Table 23 Data Patterns evaluation table

Data Patterns																		
		Commercial Products							**Open-source Products**			**Workflow Modelling Standards**						
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12***	**13**	**14**	**15**	**16**	**17**
1	Task Data	+	+/-	+/-	+				+/-	-	+/-	+/-	+/-		+	-	+/-	
5	Case Data	+/-	+	+	+				+	+	+	+	+		+	+	-	
9	Task to Task	+	+	+	+				+	+	+	+	+		+	+	+	

Table 24 Resource Patterns evaluation table

Resource Patterns																		
		Commercial Products							**Open-source Products**			**Workflow Modelling Standards**						
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	Direct Allocation	+	+	+	+	+			+	-	+			+	+		+	
2	Role-Based Allocation	+	+	+	+	+			-	+	+			+	+		+	
7	Retain Familiar	-	+	+	+	+			+	-	-			+	-		-	
11	Automatic Execution	+	-	+	+	+			+	+	+			+	+		+	
13	Distribution by Offer - Multiple Resources	+	+	+	+	+			-	+	+			+	-		-	
14	Distribution by Allocation - Single Resource	+	+	+	+	+			+	-	-			+	+		+	
19	Distribution on Enablement	+	+	+	+	+			+	+	+			+	+		+	
21	Resource-Initiated Allocation	-	-	+	+/-	-			-	-	-			-	-		-	
22	Resource-Initated Execution - Allocated Work Item	+	+	+	+	-			+	-	-			+	-		-	
23	Resource-Initiated Execution - Offered Work Item	+	+	-	+	+			-	+	+			+	-		-	
26	Selection Autonomy	+	+	+	+	+			+	+	+			+	-		-	
27	Delegation	+	+	-	+	-			-	-	-			+	-		-	
32	Suspension/Resumption	+/-	+/-	-	+	-			+	-	-			+	-		-	
43	Additional Resources	-	-	-	+/-	-			-	-	-			+	-		-	

Appendix 9: Factors influencing quality and costs in healthcare

In healthcare practice, detailed and sophisticated models have been developed, presenting factors that determine the overall healthcare quality or costs. These models can be linked to the Devil's Quadrangle's dimension which ensures a coupling between healthcare environments and process redesign theory. One of those quality frameworks was created by the Dutch Council for Public Health (NRV, 1990) and is illustrated in Figure 98.

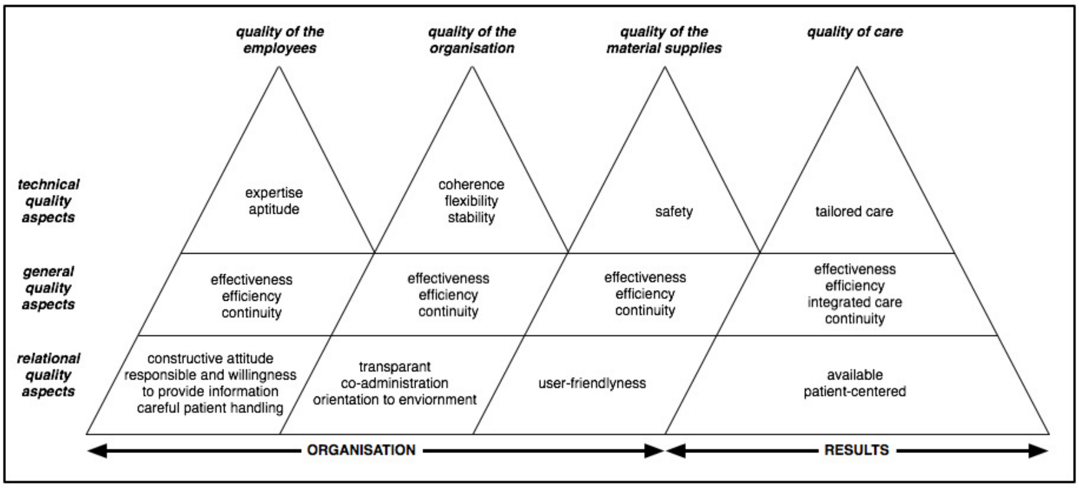


Figure 98 Quality in healthcare organisations (taken from NRV, 1990)

Quality aspects of the Devil's quadrangle can be enhanced by – for example – increasing the safety and continuity aspects or enhance co-administration (Dutch: medezeggenschap). Issues regarding the time dimension could be coupled to the effectiveness, efficiency or integrated care. Another aspect that has to be taken into account is the fact that the redesigns are evaluated by the care providers and not by the patients. Schaaf (1992) provides a continuum of quality aspects from a care provider or patient perspective. This picture is illustrated in Figure 99. For optimal results, the patient's 'bottom-up'-view could be incorporated in redesigns. However, this was outside the scope of this study

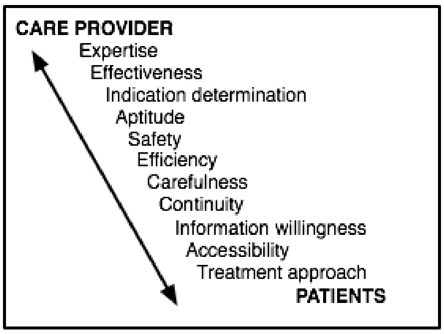


Figure 99 Quality aspects continuum (taken from Schaaf, 1992)

Both models by Schaaf (1992) and NRV (1990) apply to quality criteria. Besides providing knowledge on factors determining the quality in healthcare, the next model provides factors influencing the costs in healthcare. One of these models is developed by Asselman (2008) and is presented in Figure 100.

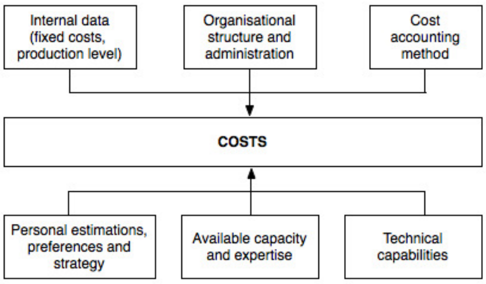


Figure 100 Factors influencing costs (taken from Asselman, 2008)