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MASTER

BPMN 2.0 in practice

the usefulness of extended constructs in a business environment

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BPMN 2.0 in practice: The usefulness of extended constructs in a business environment.

By

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Management Summary

Many studies are devoted to the theoretical capabilities of the workflow language BPMN, but not much is known about the actual practical use of BPMN in a business environment. Recker's research (2010) concluded that business analysts barely use extended constructs in their business models, so they only use a core set of constructs (basic constructs). He questioned whether the extended constructs have an added value when used in industrial business process models. The research objective of this study is to examine the influence of the extended constructs in BPMN 2.0 with regard to the understandability and correctness of a process model for practitioners in the healthcare domain.

To investigate this objective a theoretical analysis and an experiment were conducted. The theoretical analysis was based on the peri-operative process in hospitals. NICTIZ[1], an organisation which focuses on process optimisation in the healthcare domain, delivered the textual description (guidelines) of this process. A part of the process (pre-operative process) was already modelled by business practitioners with BPMN (NICTIZ model). To examine the influence of the different constructs, two different versions of the peri-operative process were modelled by the researcher, a model with only basic constructs (basic version) and a model with the full set of constructs (extended version). To measure and compare the understandability of the models, the complexity metrics for business process models were used (Gruhn & Laue, 2006). The correctness (level of correct behaviour) of the models was analysed by reproducing the state spaces of the models and illustrating the behaviour of the models via tokens. These state spaces were compared with the guidelines.

The theoretical analysis showed that the models with the full set of constructs were more understandable than the models with only basic constructs based on the results of the complexity metrics. Table 1 shows these results; the greater the value of the metrics, the lower the overall understandability of the model.

		Pre-operative Process			Per-operative Process			Post-operative Process		
		Basic	Extended		Basic	Extended		Basic	Extended	
Metric			Parent	Child		Parent	Child		Parent	Child
CFC		52	28	25	24	18	8	27	13	14
Nesting Depth	Max	5	2	1	5	3	1	6	3	2
	Mean	1,81	1,43	1	1,62	1,36	1	3,04	1,5	1,67
Knot Counting		0	0	0	0	0	0	0	0	0

Table 1: Results of the complexity metrics (lower values imply higher quality) (Gruhn & Laue, 2006)

Moreover, the state spaces showed how the extended constructs can improve the correctness of a model.

The experiment measured the actual effectiveness of the various constructs in BPMN based on the Method Evaluation Model (Moody, 2003). The experiment contained a test that consisted of different questions related to the extended constructs to assess the factors of interest empirically. The purpose of the test was to examine the participants' understandability and modifiability (ability to modify a model correctly) regarding the constructs (basic/extended). The focus in the experiment was solely on the constructs, not the process. The participants of the experiment were business

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[1] More information about NICTIZ can be found via: https://www.nictiz.nl

analysts from the healthcare domain. A workshop, which explained the behaviour of several constructs, was constructed to examine whether training improved the results of the participants. Two different versions of the test were constructed to see whether the results were not test specific. The results of the tests were analysed and hypotheses were tested using the independent t-test.

The experiment showed that the results of the test were not test specific (hypothesis 1). Also, it showed that the workshop did not have a significant effect on the results of the participants (hypothesis 2). Furthermore, it showed that practitioners do not encounter more difficulty understanding (hypothesis 3) or modifying (hypothesis 4) models with extended constructs compared to similar models with only basic constructs. Table 2 shows the significance levels of the hypotheses.

	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4
Significance level (α)	0.911	0.071	0.435	0.131

Table 2: Significance levels of experiments' hypotheses

Preface

This master thesis is the result of my graduation project to obtain the degree of Master of Science in Operations, Management & Logistics. This research is done internally at the University of Technology in Eindhoven in cooperation with NICTIZ.

First of all, I would like to thank my first supervisor, Pieter Van Gorp, who was always ready to help me at any time in my project. His thoughts and ideas were always a big help and motivation to finish the thesis. I cannot imagine that other supervisors are so flexible and helpful as Pieter was during the last two years. Also, I want to thank my second supervisor Remco Dijkman for his help and comments.

Second, I want to thank my friends who I met before and during my time as a student. Without their willingness to listen to my complaints, problems, and other mumble jumble business, I would not have been able to survive. I will not name them in person, because of the simple fact that they will never read this (or maybe you do, Lars?).

Finally, I want to thank my family: my mother, father, brother & sister, who supported me in every way. Not only during my study, but from the moment I was able to open my eyes. Words cannot describe my appreciation for all the opportunities they gave me and are still giving me.

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Steven Dassen

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1. Introduction

Businesses constantly want to improve the performance of their business processes. As such, it is important that these businesses understand how the processes are mapped and flow through the organisation. For the documentation of business processes a language is needed, which makes it possible to define the process as structured and clearly as possible and can be understood by everybody who is familiar to this language.

Currently, there are many Business Process Modelling Languages (BPMLs) available (List & Korherr, 2006). They have different specialisations on various fields. For an accurate and adequate description of a business process, it is necessary to integrate various forms of information into a business process model. This information can consist of what is going to be done, who is going to do it, when and where it will be done, how and why it will be done, and who is dependent on its being done (List & Korherr, 2006).

The difference between these BPMLs is the extent to which their constructs can demonstrate the information for the above questions. Given that specific information is necessary for each domain, different constructs must be used. There is, however, a need for a standard process modelling language so that everybody can speak the same, as to say, language.

This study discusses the current BPML with the highest potential to become the industrial standard. Furthermore, many studies have been devoted to the theoretical capabilities of the BPMLs. However, less is known about the practical use of the BPMLs in a business environment. As such, this study goes deeper into the practical usage.

This section consists of three parts. First, the exploration phase will be described for looking at the different BPMLs. The second part highlights the BPML that has the most potential to become the industrial standard, and thus will be used in this research. Finally, the problem context will be given, where the problem is defined concerning the practical usage.

1.1 Exploration

A literature study had been performed to explore the current possibilities of modelling business processes in theory and practice. The first objective was to create an overview of the BPMLs, which are currently used and available. The level of success and adoption potential in the business environment is not the same for these languages and for that reason it is important to make a distinction. The second objective looked at the success factors of these BPMLs to be adopted in the working environment and those with potential to become the industrial standard.

To gather the necessary information for the above objectives, different databases were consulted. It is important to justify which database will be used and also advisable to select multiple electronic databases to cover the different research domains. Given that electronic databases often generate a large number of results, it is important to make a selection that will guarantee the quality of the different studies. Therefore, the search was constrained by certain restrictions.

After the selection of the databases and the database sources, it is important to have a valid search strategy. A structured scan of the index terms of the electronic databases was performed to discover related terms. In total, twenty-two papers were considered for the literature study, sixteen for the first objective and six for the second objective.

Appendix A illustrates the databases, restrictions, and the activity diagram of the search procedure.

1.2 Graphical standards

The BPM life cycle (Van der Aalst, ter Hofstede, & Weske, 2003), shown in Figure 1, consists of four phases: design, configuration, enactment, and diagnoses. The first phase is *process design*. In this phase as-is processes are modelled into Business Process Management Systems (BPMSs). Graphical standards are leading in this phase (Ko, Lee, & Lee, 2009). The next phase is *system configuration*, where the BPMS and the underlying system infrastructure are configured. Due to the contradictory IT architectures of diverse enterprises, this phase is difficult to standardise. The next phase is *process enactment*, where electronically modelled business processes are deployed in BPMS process engines. These three phases are seen as workflow management (see Figure 1). The final phase is *diagnosis*. By making use of analysis and monitoring tools, flow times, process bottlenecks, utilisation, etc. processes can be identified and improvements can be suggested.
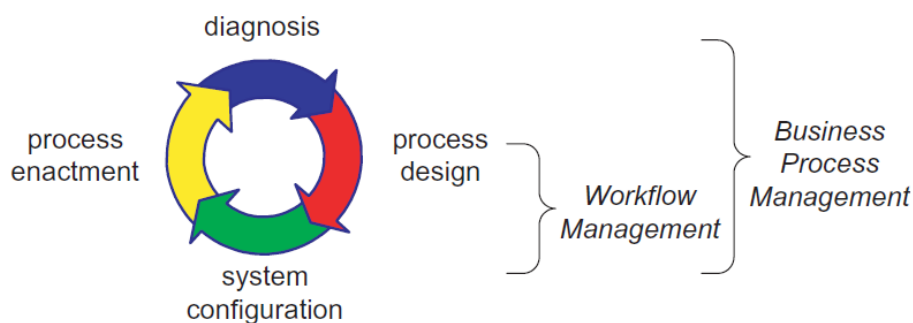
Figure 1: BPM Life Cycle (Weske, van der Aalst, & Verbeek, 2004)

The mapping and documenting of business processes is defined as process design, where, as said before, graphical standards are leading. Graphical standards, such as BPMN or PetriNet, are supported by simulation tools, i.e. iGrafx, SIMUL8, and CPN tools. These tools support the last phase of the BPM life cycle, the diagnosis phase. As such, the full BPM life cycle can be covered by the graphical standards. The focus in this report will thus be on the graphical standards.

Over the years many different graphical standards have been developed to model business processes. In a graph-based modelling language, process definition is specified in graphical process models. Activities are represented as nodes, and control flow and data dependencies between activities are represented as arcs (Lu & Sadiq, 2007, p. 84). Most graph-based languages have their root in Petri net theory, which was applied in process modelling for the first time in 1977 by Zisman. Using Petri net theory, a system can be modelled as a Petri net, which is a mathematical representation of the system. By analysing the Petri net, important information about the structure and the behaviour can be retrieved to evaluate the modelled system and suggest improvements or changes (Peterson, 1981).

The graphical standards are currently the most human-readable and easiest to comprehend without prior technical training (Ko, Lee, & Lee, 2009). This is immediately one of the important strengths of graphical standards. Non-technical business users can understand graphical notations like the Unified Modeling Language Activity Diagrams (UML AD) and Business Process Model and Notation (BPMN) easily (Ko, Lee, & Lee, 2009). The graph-based languages range from common notations to standards. UML AD and BPMN are the two most expressive, easiest for integration with the interchange and

execution level, and possibly the most influential in the near future (Ko, Lee, & Lee, 2009). Nonetheless, several studies (Fernández Fernández et al., 2010; Allweyer, 2010; Chinosi & Trombetta, 2011; Eloranta et al., 2006) concluded that BPMN has the most potential and is emerging as a de facto standard language for capturing business processes. As such, BPMN will be explained more explicitly in the next subsection.

1.3 Business Process Model and Notation (BPMN)

This section explains the language BPMN briefly. First, the purpose will be given of the development of BPMN followed by the history of the notation. Finally, the structure of the language will be discussed.

1.3.1 Purpose of BPMN

The Business Process Model and Notation (BPMN), formerly known as the Business Process Modeling Notation, is becoming the standard language for mapping and documenting business processes. The language was developed with the purpose to enable business users to create readily understandable graphical representations of business processes (White, 2005). BPMN was not developed to be another one of the many business process notations; it was to become the new industrial standard. The elements in BPMN were therefore chosen to be distinguishable from each other and to utilise shapes that are familiar to most modellers (White, 2005). Many vendors came together with a shared objective for the industrial standard: it would help end-users. Companies would not have to train their employees every time a new tool was bought. The same holds for new people hired with knowledge of different tools and notations. In other words, a new standard notation would make business process modelling skills transferrable.

Another purpose for the development of BPMN was to close the gap between process design (conceptual process models) and process implementation (workflow process models) in the BPM life cycle (Figure 1). This is achieved by the interconnectivity between BPMN and XML languages, such as BPEL and XPDL, designed for execution of business processes (Fortis, 2006). Many studies (Mazanek & Minas, 2009a, 2009b; Juheb, 2009; Mol de & Zimakova, 2009; Asztalos, Meszaros, & Lengyel, 2009; Doux, Jouault, & Bezivin, 2009; Bergmann & Horvath; 2009; Garcia-Banuelos, 2009; Muliawan, Meyers, & Janssens, 2009; Biermann & Ermel, 2009) presented a solution of a model transformation between BPMN and BPEL using different tools. The first versions of BPMN 1.x do not provide a standard XML interchange format and therefore BPMN 1.x models have to be translated with XML based executable languages. BPMN 2.0 does provide an official XML interchange format for BPMN models.

As such, the purpose for the development of BPMN was to provide a modelling notation that supports the ability to model typical business process activities for both business and technical analysts, as well as the straightforward mapping to executable workflow specifications in executable languages (BPEL) (Recker & Mendling, 2006).

1.3.2 History of BPMN

The history of BPMN goes back to 2001, when BPMI.org (Business Process Management Initiative) began developing BPML (proposed language) and came to the conclusion that there was a need for a graphical representation. The Notation Working Group was formed in August that same year. It consisted of 200 members, including all major software vendors except for Microsoft and IBM. In 2004 it released BPMN 1.0 to the public.

In 2005 BPMI.org merged with the Object Management Group (OMG) to continue their objective to develop an industry standard. OMG was, ironically, also the group who developed UML, the great alternative of BPMN. OMG formally adopted the BPMN 1.0 specification as an OMG standard in 2006. In 2008 OMG released BPMN 1.1 to the public, which included a few graphical changes followed by BPMN 1.2 in 2009.

The most recent version is BPMN 2.0, which was released in 2011. The BPMN 2.0 specification extends the scope and capabilities of BPMN 1.2 in various domains, such as formalisation of the execution semantics. Furthermore, the newest version contains, as said before, an XML interchange format for BPMN models. A new version of BPMN is not released for another 2 or 3 years.

1.3.3 Structure of the language

The modelling in BPMN is done using simple diagrams with a small set of graphical elements. It makes it easy for business users as well as developers to understand the flow and the process (Fortis, 2006). The elements are divided into four different categories:

- *Flow Objects*: this can be events, activities, and gateways
- *Connecting Objects*: this can be sequence flows, message flows, and association flows
- *Swimlanes*: This can be pools, or lanes
- *Artefacts*: This can be text annotations, data objects, groups, etc.

The flow objects are used to model Business Process Diagrams (BPDs). The connecting objects provide the connections between the flow objects via various kinds of arrows. Swimlanes help partition and organise different roles or organisational departments. Artefacts are used to show further related information in a BPD like processed data or other comments. The four different categories contain, in total, thirty-eight different constructs plus attributes.

The BPMN working group separates the different constructs in a set of basic elements and an extended set of elements. BPMN's developers envisaged the basic set to be used by business analysts for the essential, intuitive articulation of business processes in very easy terms. The full set of constructs would then enable users to specify more complex process scenarios with a level of detail that facilitates process simulation, evaluation or even execution (Zur Muehlen & Recker, 2008). The division of the basic and extended constructs by the BPMN work group is shown in

Appendix B.

1.4 Problem context

Many studies have been conducted about the theoretical possibilities of BPMN (Wahl & Sindre, 2006; White, 2005). These studies explain the characteristics of the graphical elements, the relations between the concepts, and the translation between the XML based executable languages. Also, many studies are devoted to the practical recommendations of BPMN, meaning how BPMN should be used in practice (Silver, 2009; Allweyer, 2010). Effective BPMN modelling requires understanding things not stated in the specification. As such, these studies explain best practices for using the notation properly.

What has not been fully examined is how people who work with BPMN actually use the notation in practice. Studies have been published about the adoption of UML in systems development, where it became clear that barely 20% of constructs were used in practice (Recker, 2010). As such, Recker (2010) conducted a study about the practical use of BPMN in a business environment. The purpose was to deliver insights in the way BPMN is being implemented and used in a business practical environment.

Recker (2010) looked at the BPMN models of business analysts with different backgrounds and experience in the process-modelling domain. When looking at the different models, he investigated if the separation between core and extended constructs holds in practice. To answer this question, he looked at the user acceptance of BPMN. After viewing 120 different process models the following frequency distribution of BPMN constructs could be made (Figure 2).
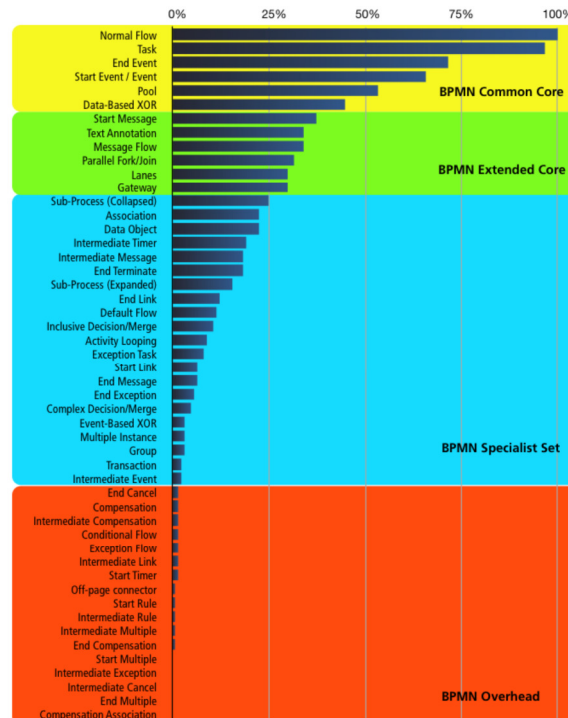
Figure 2: Frequency distribution of usage of constructs in BPMN (Recker, 2010)

Figure 2 demonstrates that the constructs are divided into four different categories, the common core, the extended core, the specialist set, and the overhead. What stands out is the fact that only five elements are used in more than 50% of the models. These are 'normal flow', 'task', 'end event',

'start event', and 'pool'. There are a few essential constructs (Common Core), a wide range of constructs commonly used (Extended Core and Specialist Set), and a great amount of constructs almost unused (Overhead).

The reasons for the different practical use of the constructs could be twofold. The first reason for the lack of use of the extended constructs is the complexity and the small additional value of these constructs. Recker (2010) argued that language standardisation initiatives, and BPMN standardisation in particular, should focus more on language revision than extension. He questioned himself: "*whether a highly expressive but also very complex notation is a desirable result of a standardisation process*" (Recker, 2010, p. 17).

The second reason involves insufficient knowledge about the constructs and in particular the extended constructs. In the study of Recker (2010) it became clear that the practitioners, who used BPMN to model different processes, hardly had any training and more than 70% of the respondents learned the language by doing it on their own.

Recently, however, Van Gorp & Dijkman (2012) pointed out that for a long time proper formalisation of BPMN constructs was lacking. The specification of the BPMN guide leaves a lot of room for own interpretation. This could have had an impact on the clarity of the semantics of the extended constructs, pointed out in the second reason. They claim, by using graph transformation rules, that it is possible to define a BPMN 2.0 execution semantics that is more complete, easier to relate to the standard, and provides better traceability than other formalisations (Van Gorp & Dijkman, 2012). According to Van Gorp & Dijkman (2012) "*this should lead to a better conformance to the standard and a better adaptation of the constructs*" (p. 366). However, given that the graph transformation rules are new and have not been used in practice, it is not proven that practitioners will benefit from this.

What can be seen from these studies is the consensus that the constructs, and in particular the extended constructs, are for some reason hard to use for business analysts. Recker (2010) questioned whether the standardisation of the extended constructs is a valuable process. Due to the limitations of his research he was not able to give a suitable answer.

This research investigates the influence of the extended constructs in BPMN. The focus will be on the understandability and correctness of a business process model. The *understandability* is defined as the ability for practitioners to understand a process model. The *correctness* refers to the correct behaviour of a process model in relation to the real life situation.

2. Research Methodology

This section explains the research methodology. First, the research questions are given, followed by Moody's (2003) Method Evaluation Model. After this, the tools chosen for this research will be introduced, and finally the research design is discussed.

2.1 Research Questions

Based on the previous section, the following scientific research questions are defined. The main scientific research question is formulated as follows.

'What is the influence of the extended constructs regarding the understandability and correctness of a business process model for practitioners in a business environment?'

The following sub research questions can be formulated for this main scientific research question.

- *'What is the influence of the use of different constructs (basic/extended) for the understandability of a BPMN process model?'*
- *'What is the influence of the use of different constructs (basic/extended) for the correctness of a BPMN process model?'*
- *'Are models with basic constructs easier to understand and modify (correcting errors in the model) than models with extended constructs for business practitioners?'*

As mentioned before, the second purpose for the development of BPMN is to close the gap between process design (conceptual process models) and process implementation (workflow process models) in the BPM life cycle. This leads to the last sub research question.

- *'Do the extended constructs contribute to the purpose of closing the gap between conceptual process modelling and workflow process modelling?'*

To answer the research questions, there are two research strategies available. The first strategy is a theoretical analysis of a business process. A theoretical analysis is desired, because an empirical evaluation would be very costly in terms of time and effort from business practitioners and would by definition be incomplete. As such, a theoretical analysis can be more extensive and formal. As such, different models of a business process will be modelled and analysed to examine the influence of the basic and extended constructs. The business process is based on a reference model, which is a model of day-to-day operations in a given domain. The theoretical analysis will explicitly be explained in section 3.

The second strategy is the conduction of an experiment. Given that the practical use of BPMN will be examined, it is necessary to include real business practitioners in the research. As such, empirical evidence will be acquired from these practitioners to justify empirical claims. The experiment consists of a test that looks at the understandability and modifiability (ability to change a process model correctly) of small process models using the basic and extended constructs. The experiment will be explained explicitly in section 5.

2.2 Method Evaluation Model

The purpose of this research is to examine the influence of the constructs in BPMN 2.0 in practice with the focus on the extended constructs. As such, the level of adoption from the practitioner is of high importance. The IS field has many examples of new methods, which are theoretically valid but are rejected in practice, and vice versa.

For a long time the usage of IS methods has been under exposed. Wynekoop and Russo (1997) showed that research which was published in leading IS journals relied on normative research, with the focus only on the development and modification of respectively new and existing methods. There was hardly any empirical research conducted concerning the practical use of the methods. Hence, there was a need for validation of methods in organisational contexts using real practitioners (Wynekoop & Russo, 1997). During the years, many studies were conducted that showed the importance of user acceptance of information systems in the IS field.

A method cannot be true or false, it can only be effective or ineffective. This is also known as pragmatic value. The success in practice can only establish the validity of a model. The objective of validation should not be to demonstrate that the method is correct, but that it is rational practice to adopt the method based on its pragmatic success (Moody, 2003). Moody (2003) defined pragmatic success as the efficiency and effectiveness with which a method achieves its objectives.

As such, Moody (2003) created a model (Method Evaluation Model) by combining two models from previously unrelated areas of theory, namely the Technology Acceptance Model (TAM) from the IS field and the Methodological Pragmatism from the philosophy of science. Of all the models that have been proposed for user technology acceptance, the TAM has been the most influential, and is one of the few candidates for a paradigm in the field (Moody, 2003).

Moody (2003) conducted an empirical analysis consisting of two experiments to test the model. First, a laboratory experiment was conducted in which the Method Evaluation Model was used to evaluate the comparative efficacy of a number of alternative methods for representing large data models (Moody, 2001). The experiment included 41 Information Systems students, who were randomly divided over three groups and were trained in one of the methods being evaluated. After this, each student received a data model that they had to document using the method they learned. Finally, they completed a post-task survey, in which they had to give their perceptions of the method they used.

Second, a field experiment was conducted using 21 experienced practitioners to evaluate the likelihood of adoption of the most successful method in the first experiment. This provided a test of the Method Evaluation Model by using a more representative sample population and a check on the external validity of the findings about the method's likelihood of adoption in practice (Moody, 2003). The findings provided strong support for the validity of the model and suggest that it is likely to be adopted in practice. In Figure 3 the Method Evaluation Model is shown.

The model focuses on two aspects for measuring the level of success of the model, namely actual and perceived efficacy, and adoption in practice. This means that for a method to be successful, it not only has to improve task performance (efficacy), but people also need to be willing to use it (adoption).
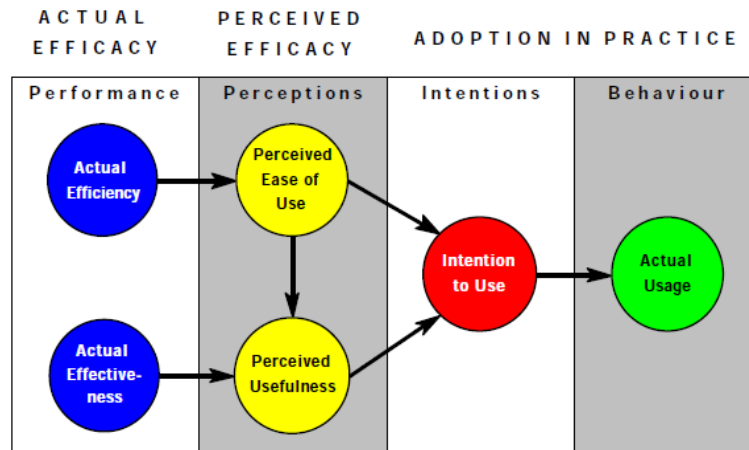
Figure 3: Method Evaluation Model (Moody D. L., 2003)

In Figure 3 the model is divided in four different categories, performance, perceptions, intentions, and behaviour. Actual efficiency and effectiveness are based on pragmatic success. *Actual efficiency* reduces the effort required to perform the task. This can be measured by a number of input measures; time, cost or effort. The *actual effectiveness* looks at the output of the method, how well it achieves its objectives and improves the quality of the result. This can be measured by the quality of the results.

Moody (2003) showed that *perceived ease of use* is caused by the actual efficiency. The effort that is necessary to engage the method determines whether a person believes that using the method would be free of effort. The *perceived usefulness* is caused by the actual effectiveness and the perceived ease of use. It measures the extent to which a person believes that the method would be useful.

The *intention to use* the new method is caused by the perceived ease of use and the perceived usefulness. It measures the extent to which a person intends to use the method. Finally, the *actual usage* is caused by the intension to use. This is the extent to which the method is actually used in practice.

This research will measure the construct 'actual effectiveness'. This will be done with an experiment.

2.3 Research Tools
In this research two different tools will be used. First, the tool for modelling business processes will be discussed, followed by the tool for reproducing the state spaces.

2.3.1 Business Process Modelling Tool: iGrafx 2011
As explained in the previous sections, BPMN 2.0 is the BPML used in this research. To make BPMN process models, a business process modelling (BPM) tool is needed. These BPM tools provide analysis and simulation capabilities, significantly helping enterprise architects, and numerous other stakeholders, collaborate to make better and faster decisions about business transformations (Peyret, 2009).

More than 20 years ago, BPM tools came to the market with very simple modelling purposes. After the years that followed, more and more sophisticated BPM tools have been developed with a broader scope to reach more stakeholders. Nowadays, BPM tools can be seen as supportive platforms that facilitate organisations in improving choices about business and IT changes.

In Peyret's study (2009) different tools were examined. The tools, ten in total, and their criteria for selection are shown in Appendix C. After examining past research, user need assessments, and vendor and expert interviews, a set of 93 evaluation criteria was developed. These are divided into three categories: 'current offering', 'strategy', and 'market presence'. The study showed that two tool vendors stand out compared to the eight other. These are IBM's Telelogic System Architect and iGrafx Enterprise Modeler, which are labelled as strong performers.

IBM's Telelogic is an excellent tool for companies which attach value to standards and have a low number of concurrent users for classic tools. However, Telelogic scores low on analysis, simulation and life-cycle management compared to the other evaluated tools. iGrafx Enterprise Modeler is not new in the business process analysis market. iGrafx is a powerful and suitable tool for process mapping and simulation modelling (Indihar-Stemberger, Jaklic, & Kovacic, 2002). The advanced simulation capabilities are also emphasised by Peyret (2009). It provides powerful graphical process modelling and simulation, as well as comprehensive diagramming capabilities. One of the main advantages of iGrafx is its simplicity; even people unskilled in business process modelling can easily understand and use this technique (Indihar-Stemberger et al., 2002).

Based on this, iGrafx 2011 will be selected as the BPM tool for modelling BPMN 2.0 processes in this research. The tool will be used for modelling the different processes in the theoretical analysis. Furthermore, the exercises for the tests in the experiment are created using iGrafx 2011. Given that not every participant of the experiment has a BPM tool at their disposal, they will not need them to do the test.

2.3.2 GrGen.NET
In the theoretical analysis the correctness of a model is tested by reproducing the state spaces with the tool 'GrGen.Net'. Van Gorp & Dijkman (2012) described the execution semantics of BPMN 2.0 in terms of graph rewrite rules. They implemented these graph rewrite rules in the tool GrGen.Net to generate the state spaces of specific models. These state spaces can be used for various forms of state space exploration. Given the fact that the generated state space is not necessarily complete, it should be used with caution (Van Gorp & Dijkman, 2012).

2.4 Research Design: Theoretical Analysis and Experiment
This section introduces the different research stages, which were applied for the execution of this master thesis project. Figure 4 below shows an overview of the different research stages and chapters. The numbers in the body text refer to the deliverables in Figure 4.

2.4.1 Research Stage 1: Preparation
The first stage of the research was the preparation stage. In the preparation stage a literature study was conducted to gain an in-depth understanding concerning the domain, trends, ideas, and visions on the dynamic world of business process modelling languages. The research proposal gave more information with regard to the goals, research methodology, scientific background, and planning.

2.4.2 Research Stage 2.1: Theoretical Analysis
The second stage of the research contained a theoretical analysis of different process models based on a reference model. To examine the influence of the constructs in BPMN, it is necessary to have comparable models of the same process. Given that these models could not be retrieved externally, it was necessary to model them first. Due to the fact that the modelling was done by the researcher

and not business practitioners, there is bias involved, because process modelling leaves room for individual interpretation. To minimise this bias, it was necessary to start modelling from a basis model that was created by business practitioners. As such, two different models were modelled of the business process, a model with the basic constructs and a model with the basic and extended (full set) constructs (Figure 4, (1) and (2)). The different models were compared to examine the influence of the use of constructs.

2.4.3 Research Stage 2.2: Design of the Experiment

In parallel with the theoretical analysis, the second stage of the research was the design of an experiment based on the Method Evaluation Model (Moody, 2003), which is explicitly explained in section 5. This experiment consisted of a test that looks at the understandability of small process models using basic and extended constructs. Two different versions of the test were constructed (Figure 4, (3)). The participants of the test were retrieved from one similar business domain (Figure 4, (4)). Also, a remote workshop was constructed to explain the semantics of several extended constructs (Figure 4, (5)). The purpose of the workshop was to examine whether a short training influences the results of the test. After this, hypotheses were formulated concerning the results of the test (Figure 4, (6)).

2.4.4 Research stage 3.1: Analysis of the Models

When the models of the theoretical analysis were modelled, the analysis of the models could start. In this phase the different constructed models were compared based on several factors. First, the different versions (basic/extended) of the models were theoretically analysed using complexity metrics to measure the understandability of the process model (Figure 4, (7)). Moreover, the correctness of the models is examined by generating the state spaces of the models and using tokens to illustrate their behaviour. In addition, a small redesign study was conducted to evaluate the applicability of the model for a practical business process project (Figure 4, (8)).

2.4.5 Research stage 3.2: Analysis of the Experiment

In this stage the results of the experiment were analysed when every participant had completed the test. The results are used to measure the participants' understandability and modifiability of the different process models. After the data was analysed, the different hypotheses were tested using statistical methods.
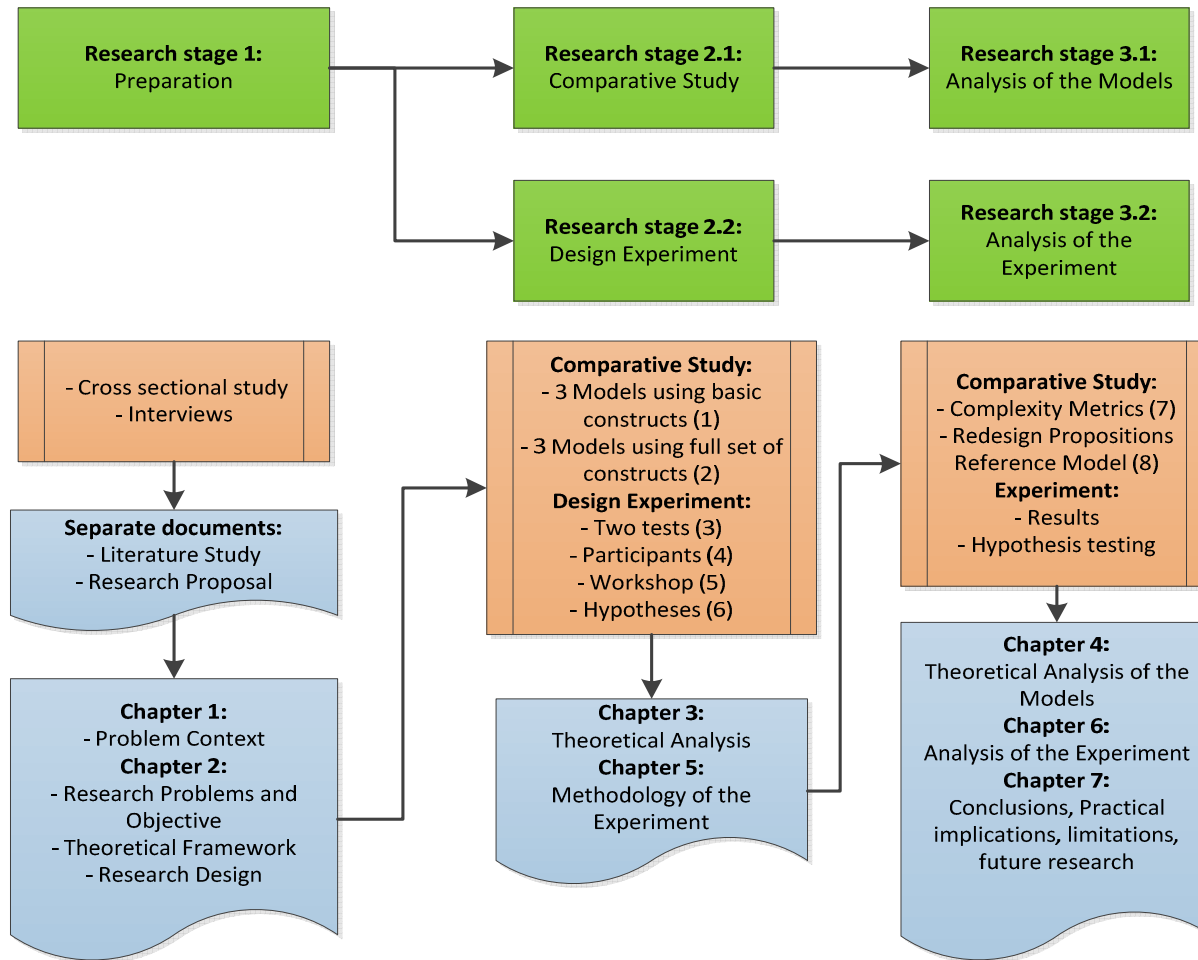
Figure 4: Research stages and chapter overview

3 Methodology of the Theoretical Analysis

This section explains the methodology of the theoretical analysis. First, the reference model will be explained, followed by the description of the reference model's process, the peri-operative process. After this, the modelling of the processes, the complexity metrics, and the token game will be discussed.

3.1 Reference Model

As mentioned before, a reference model is a model of day-to-day operations in a given domain. Reference models are intended to be configured in a specific context leading to individualised process models (Rosa la, Lux, Seidel, Dumas, & Hofstede ter, 2007). A reference model is interesting for this research, because it is used by many different groups of people and organisations. As such, the understandability of a reference model is very important.

The theoretical analysis studies models that contain different constructs. A model with basic constructs and a model with basic and extended (full set) of constructs are modelled to examine the influence of different constructs. Because no models with two versions (basic/full set) of the same process can be retrieved externally, they must be modelled by the researcher. As such, bias is involved, since process modelling leads to own interpretation. To minimise this bias, it is necessary to start modelling from a basis model that is created by business practitioners. This model can illustrate how BPMN is used in practice.

Before the start of the research, companies were approached to deliver such a reference model. Given that many companies are currently using BPMN, it was necessary to base the selection of the reference model on a set of criteria. They increase the industrial strength of the reference model. The criteria are as follows.

- The reference model is modelled in BPMN and consists only of elements that are used in BPMN.
- The reference model must consist of at least 50 elements. A process model with fewer elements is considered as too small.
- The reference model must have the purpose to be used by different groups of people.
- The reference model must not be older than three years.

The company 'NICTIZ' was able to deliver a reference model, which satisfied all the above criteria.

Nationaal ICT Instituut in de Zorg (NICTIZ)

Nationaal ICT Instituut in de Zorg (NICTIZ) is a Dutch IT organisation in The Hague, which looks at business process improvements in the healthcare sector. They try to improve the healthcare sector with eHealth and ICT, which go hand in hand with standardisation. A close collaboration with caregivers, standardisation organisations, and industry gives NICTIZ the opportunity to develop and design the necessary standards. Standardisation takes place as a purpose to improve the quality, accessibility, and affordability of healthcare.

The reference model is based on the peri-operative process in Dutch hospitals. The next section gives a more explicit description of the process.

3.2 Peri-Operative Process

The procedure that is provided by NICTIZ describes the process of a patient who has to undertake an elective surgical procedure. This procedure consists of three different phases, the 'pre-operative', 'per-operative', and 'post-operative' phase. These three processes are described in the guidelines, which are designed by different healthcare focused unions and organisations in the Netherlands (Appendix D). These guidelines are inspired by studies, which recommend standardisation of the peri-operative process (Birkmeyer, 2010; Vries de, et al., 2010; Vries de, Hollmann, Smorenburg, Gouma, & Boermeester, 2009; IGZ, 2008; IGZ, 2007)

The guidelines state what information is relevant, who delivers and receives the information, and who takes responsibility for delivering, processing, and applying information of different assignments. For the pre-operative and per-operative processes the guidelines are complete, but for the post-operative process the guideline is still a concept version. The peri-operative process is not a 'real-life' process, but a desired process, which should be applicable in every hospital. These characteristics support the choice for the NICTIZ model to be the analysis' reference model. The patient is seen as the central figure in this process. The purpose of the guidelines is to make a contribution to the safety of healthcare regarding an operation or surgery.

The guidelines are related to all the patients who need a surgical procedure, except for the ones who need emergency help. For specific patient groups, i.e. children or patients with specific affection, no special route will be described. Most of the time these groups will fit in the guidelines, but the emphasis will be different. The scope of the process starts with the patient's consult with the operator until the patient gets fired from the hospital.

3.2.1 Pre-Operative Process

The guideline for the pre-operative process is divided into four parts, consulting hour operator, pre-operative intake and intake nurse, planning, and in-take and preparation surgery. Besides the guidelines, there is a BPMN process model constructed by NICTIZ for the pre-operative process. The information for this model is taken out the guidelines. However, given that the guidelines were made by specialists from the hospitals, a lot of key process modelling information was missing. Appendix E shows the BPMN process model (NICTIZ model) for the pre-operative process modelled by NICTIZ.

3.2.2 Per-Operative Process

The per-operative process follows after the pre-operative process and has a definite version of the guidelines as well. In addition, there is an appendix in the guideline with additional information for the per-operative process. In comparison to the pre-operative process, there is no BPMN process model for the per-operative process. Nonetheless, there is a need for a formal standardisation of the process.

3.2.3 Post-Operative Process

The post-operative process is the last part of the peri-operative process and follows after the per-operative process. In comparison to the other processes, the guideline for the post-operative process is not definite and is still a conceptual version. Nevertheless, the guideline follows the same structure as the other guidelines. As with the per-operative process, there is no model constructed by NICTIZ for this process.

3.3 Process Modelling

Every process (pre, per, and post) is modelled in two different versions. One version consists of a model with the basic constructs (*basic version*) and one version consists of a model with the full set of constructs (*extended version*). In total there are seven different models (including the NICTIZ model). The modelling is done with the business process language BPMN 2.0 and with the tool iGrafx 2011. By comparing the two versions of the model, a better image is received of the advantages and disadvantages of the extended constructs within BPMN regarding the understandability and correctness of the models. Based on this, redesign suggestions for the NICTIZ model will be proposed.

Table 3 gives the categorisation of the basic constructs and the complete set of constructs, based on the frequency distribution of Recker (2010) (Figure 2). The constructs in bold in Table 3 are used in the models. Appendix G: Overview Constructs in Models gives a more explicit overview.

Basic Constructs	Extended Constructs			
Sequence Flow	**Timer Event**	Cancel Event	**Ad-Hoc Sub-Process**	Group Artifact
Event	**Message Event**	**Terminate Event**	Business Transaction Sub-Process	Data Store Object
Activity	Conditional Event	**Error Event**	Call Activity	**Data Object**
Parallel Gateway	Signal Event	Activity Loop	**Inclusive OR Gateway**	**Associations**
Exclusive Gateway	Multiple Event	Activity Parallel	Event-Based Gateway	Conditional Flow
Lanes	Parallel Multiple Event	Activity Sequential	Start Event-Based Gateway	Exception Flow
Pool	Escalation Event	**Sub-Process (Collapsed)**	Parallel Start Event-Based Gateway	**Messag Flow**
	Compensation Event	Sub-Process (Embedded)	**Complex Gateway**	**Multiple Pools**

Table 3: Categorisation of basic and extended constructs

Note in Table 3 that the 'events' are not separated in 'start', 'intermediate', and 'end' event. For example, 'Timer Event', which is mentioned in Table 3, actually consists of 'Timer Start Event', 'Timer Intermediate Event', and 'Timer End Event'. Besides that, the 'Link Event' and '(Sub-Process) Choreography Task' are not taken into account, because iGrafx 2011 does not support these constructs. Also, the BPMN workgroup sees 'Uncontrolled Flow' as a construct (Appendix B). For the modelling of the processes only the parallel gateway (AND-gateway) will be used to model a parallel split, instead of two sequence flows out of an activity. This choice is made, because it is less confusing for users due to different semantics of the uncontrolled flow in other BPMLs.

In contrast to the categorisation of constructs by Recker (2010) in Figure 2, 'Pool' is placed in the basic constructs column and 'Multiple Pools' is composed and placed in the extended constructs column. This has been done for the following reason. It is not possible to model a process without at least one pool. However, the use of multiple pools or black-box pools is used far less in practice (Silver, 2009). As a result, this construct is split up in two.

3.4 Complexity Metrics

After the three processes have been modelled with two different versions (basic/extended), the models (basic/extended/NICTIZ) are analysed. The models are compared while taking the understandability and the correctness of the models into account. Given that the understandability is related to the errors that are made by process modellers, it is difficult to analyse it theoretically. As

such, the understandability will also be examined in the experiment. The understandability will be theoretically tested using complexity metrics.

Gruhn & Laue (2006) proposed different methods to measure the understandability of a business process model (BPM). They use software complexity research to analyse the complexity of BPMs. The purpose of the paper was to give an overview of the factors that have an influence on the complexity of a BPM, and metrics that can be used to measure these factors. Table 4 shows the complexity metrics for software and BPM.

Software complexity metric	Corresponding metric for BPM	Usage, Significance
Lines of Code	Number of activities	Very simple, does not take into account the control-flow
Cyclomatic number	CFC as defined by Cardoso	Measures the number of possible control flow decisions, well-suited for measuring the number of test cases needed to test the model, does not take into account other structure-related information
Max. / mean Nesting depth	Max. / mean Nesting depth	Provides information about structure, can be used complementary to the CFC metric
Knot-count	Number of handles	Measure of "well-structuredness" (for example jumps out of or into control-flow structures) is always 0 for well-structured models. Can be used complementary to the CFC metric
Cognitive weight	Cognitive weight (tailored for BPM)	Measures the cognitive effort to understand a model, can indicate that a model should be re-designed
(Anti)Patterns	(Anti)Patterns for BPM	Experience with the patterns needed counting the usage of anti-patterns in a BPM can help to detect poor modelling
Fan-in/ Fan-out	Fan-in / Fan-out	Can indicate poor modularisation

Table 4: Complexity metrics for software and BPM (Gruhn & Laue, 2006)

The above metrics are independent from the language, which means they can be used for various languages, such as BPMN (Gruhn & Laue, 2006). Though, a limitation of the paper is the fact that only the elements (constructs) are discussed which can be found in all languages. Currently, there are no metrics available which are specifically designed for BPMN 2.0.

Another limitation is the fact that the metrics do not take hierarchy into account. To tackle this limitation, the following method is applied. When hierarchy occurs in a model, the metrics will be applied on the top (parent) level and also on the lower (child) levels. The results of the metrics will be analysed in isolation as well as the sum of the results on the various levels.

The last limitation of the above metrics is that they cannot measure the layout of the graphical model and the comprehensiveness of the texts used in the model (Gruhn & Laue, 2006). Although, these are important aspects of a process model, they are beyond the scope of this research.

Given the many factors that contribute to the complexity of a BPM, it is not possible to use a single metric to measure all aspects of a BPM's complexity. As such, the following metrics will be used for the theoretical analysis: control flow complexity metric, maximum/mean nesting depth metric, and the knot count metric.

3.4.1 Control Flow Complexity (CFC) Metric

Cardoso (2005) defined a complexity metric based on the cyclomatic number that is used in software complexity metrics. The Control Flow Complexity (CFC) of a process is the number of mental states that have to be considered when a designer develops a process (Gruhn & Laue, 2006). Cardoso's study (2005) showed that a correlation was found between the perceived complexity and the CFC metric. Table 5 shows how the CFC counts the number of decisions in the flow of control. It shows that the calculation of the metric is based on the type and number of splits in the model. The greater the value of the CFC metric, the greater the overall complexity of the process.

Split Type	Added number to the CFC
AND-split	Every AND-split in a model adds 1 to the CFC metric of this model
XOR-split	Every XOR-split with *n* outgoing transitions adds n to the CFC metric of this model
OR-split	Every OR-split with *n* outgoing transitions adds $2^n - 1$ to the CFC metric of this model

Table 5: Control Flow Complexity rules (Gruhn & Laue, 2006)

Table 5 shows that the AND-split only adds 1 to the CFC metric. The XOR-split adds n to the CFC metric, depending on the number of outgoing transitions. This shows that an XOR-split is harder to understand than an AND-split. The OR-split has the highest number that adds to the CFC metric, because of the highest number of decisions that can be taken. The OR-split is categorised as an extended construct (Table 3). As such, when comparing the basic version with the extended version, it is essential that both models behave the same (correctness) to apply the metric.

A limitation of the CFC metric is that it only counts the number of possible decisions in a model. This means that the metric does not say much about the structure of the process model. For that reason, two more metrics (Nesting Depth metric and Knot Count metric) will be taken from Table 4, which take the structure of the model into account. They can be used additionally to the CFC metric.

3.4.2 Nesting Depth Metric

An additional metric to the CFC metric is the 'maximum/mean nesting depth' metric. This metric measures the complexity of the model. The nesting depth of an action is the number of decisions in the control flow that are necessary to perform this action (Gruhn & Laue, 2006). A greater nesting depth means a greater complexity. Figure 5 shows an example of a BPMN process model with a maximum nesting depth of 2. This is because two decisions (blue circles) must be made in order to process task 2 and task 3.
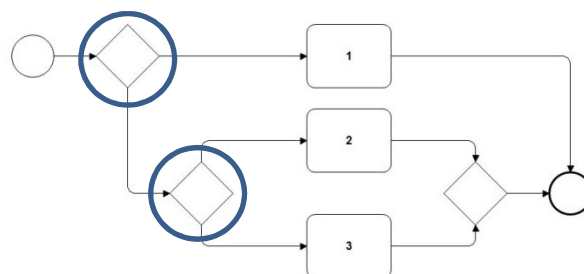
Figure 5: Example process model BPMN with nesting depth = 2

3.4.3 Knot Count Metric

Another additional metric to the CFC metric is the knot count metric. This metric was developed for software programs to measure the jumps out of and into a structured control flow. A control graph of a program has a knot whenever the paths associated with transfer of control intersect (Gruhn &

Laue, 2006). This is also applicable for a BPM with the number of handles. This means that the number of handles in a BPM is a measure for the number of not well-structured constructs in this model. For a well-structured model, the number of handles is always zero. Figure 6 shows an example of a BPMN process model with the number of handles higher than zero (blue circle).
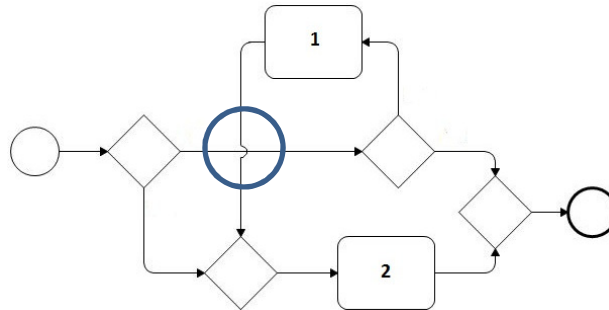
Figure 6: Example process model BPMN knot counting (number of handles)

3.4.4 Size Metric
The last metric is the size metric. The size metric measures the size of a model. In software engineering this is measured with the number of Lines of Code (LOC) with a significant success rate (Vanderfeesten, Cardoso, Mendling, Reijers, & Aalst van der, 2007). The size of the model is determined by the number of activities in the BPM.

3.5 Token Game
The correctness of the model will be analysed using the token game. By using the token game it is possible to illustrate the behaviour of a construct or process. Tokens were used in Petri Nets many years ago. One of the reasons for using tokens is that they have a graphical representation and well-defined semantics (Jensen, 1997). The BPMN workgroup also mentioned tokens in their standard as *"a theoretical concept that is used as an aid to define the behaviour of a process that is being performed. The behaviour of process elements can be defined by describing how they interact with a token as it traverses the structure of the process"* (OMG, 2011, p. 27). Recently, Van Gorp & Dijkman (2012) used the concept of tokens to visualise markings of a process. Markings represent a concrete state of a process that has been executed. These can be used in a state space, which shows all possible executions of a process model. The concept of tokens to clarify the semantics of constructs is not new and is used in several studies (Allweyer, 2010; Mendling, 2008; Dumas, Grosskopf, Hettel, & Wynn, 2007). Figure 7 visually explains the aforementioned concepts.
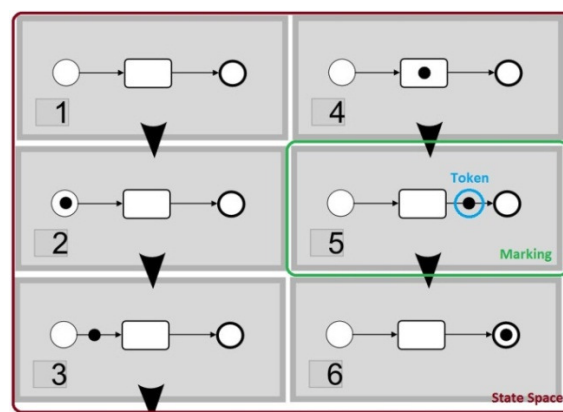
Figure 7: State space of a simplistic process model

Figure 7 shows a state space of a very simplistic process model with only three different constructs, start event, activity, and end event. The token moves out of the start event, through the activity and finally ending in the end event via the sequence flows. Every state of the process is shown via markings, in total six. Although this example shows a simplistic process, more complicated constructs and processes can be explained using the token game, which make them easier to understand. It can be used to explain the correctness of the constructs and processes in BPMN. The token game will be used to clarify processes and constructs in the theoretical analysis and the experiment respectively.

4. Theoretical Analysis of the Models

This section discusses the theoretical analysis of the process models. Given the size of the models, it is not possible to show them in the report[2]. The section starts with the results of the complexity metrics, the influence of the extended constructs, redesign propositions for the NICTIZ model, and finally the conclusions of the theoretical analysis.

4.1 Results of the Complexity Metrics

In this section the complexity metrics from section 3.4 will be used on the models of the peri-operative process to measure the complexity of the models. The NICTIZ model of the pre-operative process is not appropriate for the analysis with the metrics, because of the many process modelling errors it contains. As it would give a distorted result, it is left out of the analysis. These errors and flaws are illustrated in section 4.3.

4.1.1 Size Metric

Table 6 shows the results of the size metric. Table 6 shows that the extended versions of the models are separated between parent level and child level. There are no deeper nesting levels in the models. The basic versions and the NICTIZ model have only one (parent) level. The results of the size metric show that the total number of activities is almost equal for the basic and extended version. The number of activities of the NICTIZ model is lower, because the level of detail is lower. The tasks of the participants in the basic and extended version are illustrated more explicitly.

| Process | Amount of Activities | | | | |
| | basic | Extended | | | NICTIZ |
		Parent	*Child*	*Total*	
Pre	77	36	41	77	49
Per	40	26	12	38	-
Post	28	21	5	26	-

Table 6: Results size metric

Table 24 in Appendix G shows the number and type of constructs used in every model. Table 7 shows the total number of constructs used in the processes for the different models. The extended version has the largest number of constructs in every process. However, the constructs in the extended version are not all used at the parent level due to the use of collapsed sub-processes.

| Process | Amount of Constructs | | | | |
| | basic | Extended | | | NICTIZ |
		Parent	*Child*	*Total*	
Pre	152	150	97	247	215
Per	80	84	32	116	-
Post	74	70	27	97	-

Table 7: Amount of constructs used in the models for the different processes

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[2] The models can be found via the following link:
http://is.ieis.tue.nl/staff/pvgorp/share/?page=ConfigureNewSession&vdi=XP-TUe-20GB_Thesis_S.Dassen.vdi
The program that is used to view the models is SHARE. SHARE is a system for sharing practically any type of software artifact to reviewers and to other participants who have very limited time available (Van Gorp & Grefen, 2012).

Table 8 shows the amount of constructs used in the collapsed sub-processes. Table 8 shows that the collapsed sub-processes contain five to ten constructs. The advantage of these sub-processes is the ability to decompose the model.

Sub-process												
Model	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Pre	8	10	8	10	5	6	7	9	8	7	5	7
Per	5	7	7	6	7							
Post	10	7	10									

Table 8: Amount of constructs used in the collapsed sub-processes

Although the extended versions decompose many constructs to the child level, the amount of constructs on the parent level is almost the same as for the basic versions. This is due to the extra constructs that are used to clarify the process, such as data objects, message flows, and multiple pools (Table 24).

4.1.2 CFC Metric

The CFC metric will be discussed for the models of the peri-operative process. Table 9 shows the results of the CFC metric. Table 25 in Appendix H shows the calculation of the metric for each sub-process. The sub-processes are summed up to give the results of the child level.

	Pre-operative			Per-operative			Post-operative		
	Basic	*Extended*		*Basic*	*Extended*		*Basic*	*Extended*	
		Parent	Child		Parent	Child		Parent	Child
AND splits									
	16	8	2	8	8		9	6	2
OR splits									
n=2 n=3	36	20	16	16	10	8	18	4	12
XOR splits									
n=2 n=3			7					3	
Total	52	28	25	24	18	8	27	13	14

Table 9: Results CFC metric

Table 9 shows that for every process, the basic models have the highest number of possible decisions. The summation of the parent and child level of the extended models is almost the same as for the number of the basic models. However, it is always easier to understand the extended model, because the decisions are divided over so many more models. The extended model of the pre-operative process has, for example, thirteen separate models due to the use of sub-processes.

4.1.3 Nesting Depth Metric

The metric in addition to the CFC metric is the nesting depth metric. Table 10 shows the results of the nesting depth metric.

	Pre-operative			Per-operative			Post-operative		
Nesting depth	*Basic*	*Extended*		*Basic*	*Extended*		*Basic*	*Extended*	
		Parent	Child		Parent	Child		Parent	Child
Maximum	5	2	1	5	3	1	6	3	2
Mean	1,81	1,43	1,00	1,62	1,36	1,00	3,04	1,50	1,67

Table 10: Results Nesting Depth metric

Table 10 shows that the maximum nesting depth is the highest for the basic models. The child level models have the lowest maximum nesting depth. The complete overview of the child level models can be seen in Table 26 in Appendix H. The mean nesting depth for the basic models is also higher than for the extended models. This means that the basic models have more numbers of decisions in the control flow that are necessary to perform an action. Hence, the basic models are more complex than the extended models.

4.1.4 Knot Counting Metric

The last complexity metric is the knot counting metric. Table 11 shows the results of the knot counting metric. The results show that the number of handles for every model is zero. This means that in every model there are no sequence flows that intersect. As such, every model is well-structured.

	Pre-operative			Per-operative			Post-operative		
Knot Count	*Basic*	*Extended*		*Basic*	*Extended*		*Basic*	*Extended*	
		Parent	Child		Parent	Child		Parent	Child
Amount	0	0	0	0	0	0	0	0	0

Table 11: Results Knot Counting Metric

The metrics showed that the basic models are more difficult to understand than the extended models due to the number of decisions that have to be taken. Although the metrics give insight into the understandability of a model, there are some limitations. First, the metrics are not designed specifically for BPMN 2.0. The extended constructs are not named explicitly. Second, the metrics are not designed for different hierarchical levels. This is an important aspect for the extended models. These limitations lead to individual interpretation, which can lead to bias in the results.

4.2 Influence of the Extended Constructs

This section discusses the influence of the extended constructs used in the models. The focus will be on the understandability and the correctness of the model.

4.2.1 Collapsed Sub-Process

The *collapsed sub-process* is an extended construct that is used various times in the extended versions (section 4.1). The advantage of the collapsed sub-process is the hierarchical levels that are added to the model. A sub-process creates a child level to the process. Figure 8 shows a part of the post-operative process path of the anaesthetist for the basic model. Given that it only has one level, the path consists of many constructs.
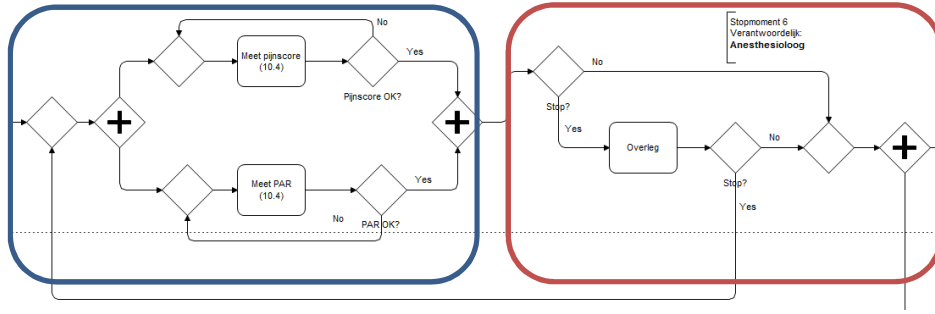
Figure 8: Process example anaesthetist basic version

Figure 9 shows the same process path. Nonetheless, the process is now captured in two collapsed sub-processes. The blue rectangle and the red rectangle show which part of the process is replaced with which sub-process.
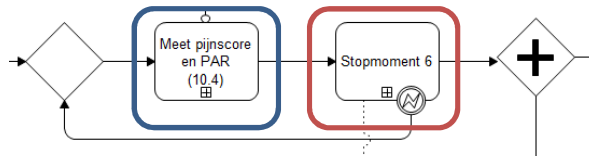
Figure 9: Process example anaesthetist extended version

By creating a child level, the parent level will have fewer elements. The CFC metric and the Nesting Depth metric show how the complexity of the models are reduced compared to the basic models. This is partially due to the use of collapsed sub-processes and leads to a better understandability of the model. The behaviour of the model will not change, because the elements are only 'transferred' to another level.

4.2.2 End Events

In the models of the basic version there is only one type of end event, the *none-end event*. This event has not the ability to throw a result signal.

The models of the extended version have different types of end events. Beside the none-end event, there is the E*rror end event* and the *Terminate end event*. The Error end event immediately ends the process level, even if there are parallel paths still active. In the models the Error end event is used in the collapsed sub-processes. Figure 10 gives an example of a collapsed sub-process with the error end event (note that the sub-process is embedded for sake of the example).
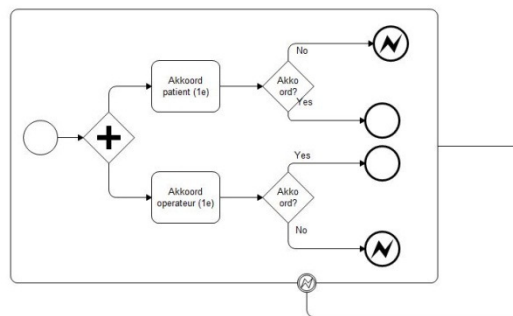
Figure 10: Process example Error end event extended version

The sub-process begins with a none-start event followed by a parallel split. There are then two subsequent tasks. When a task is completed a decision split gateway follows. When there is no approval (Akkoord), the process will move on to the Error end event. The Error end event immediately ends the process level and throws a signal. The signal will be caught by the intermediate Error event attached to the sub-process boundary. From there on, the process will continue on the sequence flow out of the boundary event.

The Terminate end event is used at the parent level of the process. It is like the Error end event, except that is does not propagate a result signal to the parent level. In this case that is not necessary, since it is already on the parent level. Appendix I clarifies this phenomenon with the help of two simple process models and the token game.

In the guidelines it is explicitly stated that if a participant, i.e. operator, does not approve the operation, the process must end immediately. As such, parallel processes will have to end immediately. The state spaces and the token game in Appendix I show that the extended end events have a positive influence on the correctness of the model. When an error occurs in the process, the process as a whole has to stop. It is not desired that parallel paths are still active, as is the case with the none-end event in the basic version.

4.2.3 Compensation

One of the most interesting extended constructs is the compensation element. It is not used in the extended models, because the abstract guidelines do not describe a specific situation for it. Nonetheless, a fictive situation in the peri-operative process is sketched to show the usefulness of this construct. Figure 11 shows a part of the process with only the basic constructs.
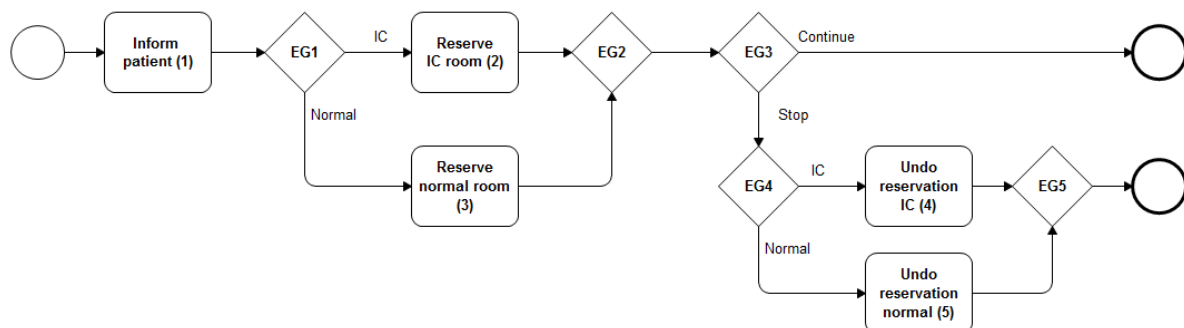
Figure 11: Compensation example basic version

The process starts with the task 'inform patient'. After this, a decision (EG1) is made whether to reserve an IC room or a normal room. The second decision (EG3) is made whether to continue or to stop the process. When the process needs to be terminated, the reservation of the room has to be made undone. When this is done, the process will end.

Figure 12 shows the same model, but now using the compensation elements. The process starts similar to the process in Figure 11. After the first decision (EG 1), the same two tasks are presented to reserve a room. Both of the tasks contain an intermediate compensation boundary event to undo the reservation. The process continues to the last decision (EG 3) to continue or stop the process. When the process needs to be terminated, the compensation end event sends a signal to trigger the

compensation tasks. Note that the compensation end event is referenced (*Cancel*). This means that the compensation throws a signal only to the referenced task, or in this case, tasks.
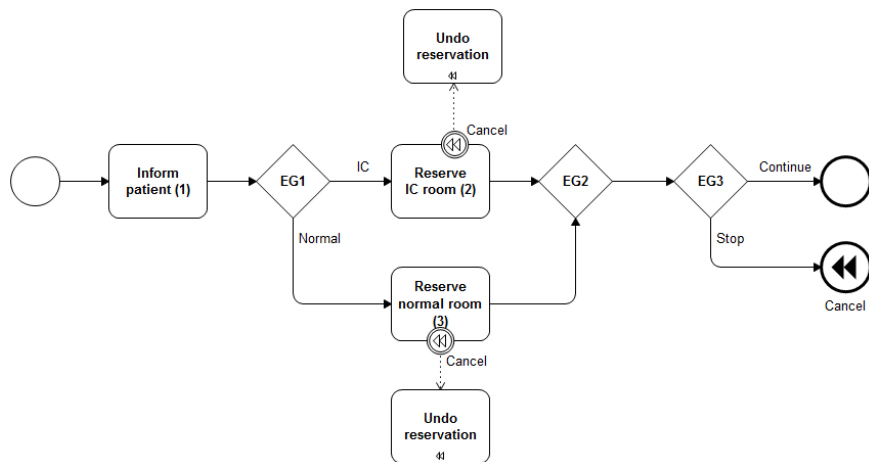
Figure 12: Compensation example extended version

The complexity metrics showed that less decision possibilities in a model increase the understandability. Given that the model in Figure 12 has less decision points, it would be easier to understand. To look at the correctness of the models, it is necessary to generate their state spaces. Figure 13 and Appendix J show the state space for both models.

Although the state spaces in Figure 13 look quite similar, there are two important differences. First, the basic version (model on the left) has more paths due to the extra exclusive gateway (EG 4). Because of this, there is an extra opportunity for the model to hold the process after 'Leave EG 4'. Second and most important, the basic version can show incorrect behaviour. The coloured path in the state space of the basic version in Figure 13 and the token game in Appendix J show that it is possible in the process model to complete 'Task 2' first and take 'Task 4' second instead of 'Task 5'. In real life this would mean that the IC room that has been reserved would not be cancelled even though it has to, but a normal room would be cancelled instead. This can also occur vice versa. The state space in Figure 13 of the extended version and the token game in Appendix J: Compensation Element show that this behaviour is not possible in the process model. When the compensation end event is reached, the task that is completed will be compensated. Thus, under no condition the wrong room will be cancelled.
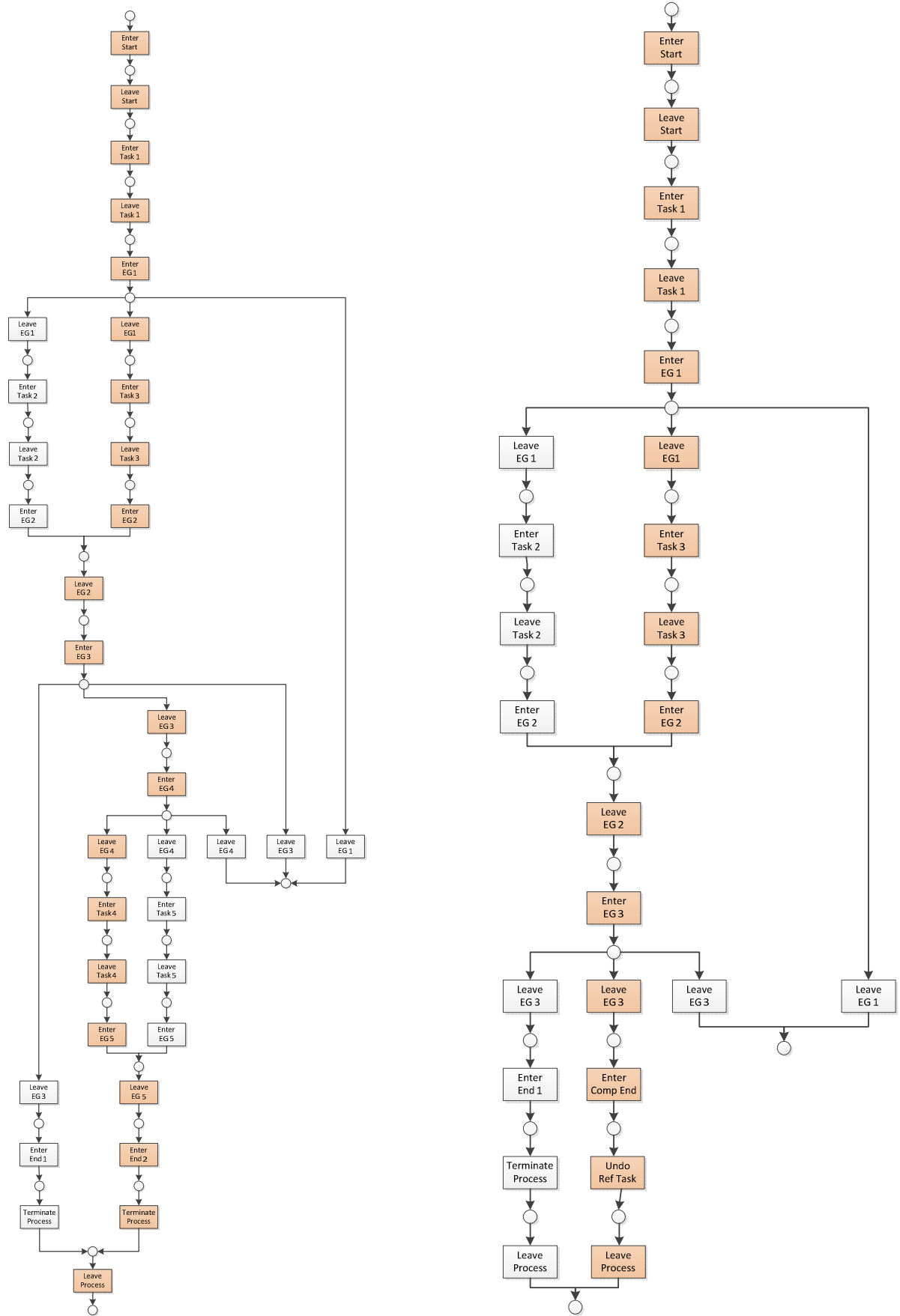
Figure 13: State space of basic version (left) and extended version (right) compensation

This example shows how the compensation element can create a real life situation that is not possible with only the basic constructs. When only the basic constructs are used, the model will not always execute correct behaviour in every situation.

4.3 Redesign Propositions for the NICTIZ Model

The NICTIZ model consists of basic constructs and extended constructs. The previous section showed that the extended constructs can have a positive influence on the quality of the model if they are used properly. This section illustrates the incorrect use of the constructs in the NICTIZ model and offers redesign propositions.

4.3.1 Embedded sub-process

In the basic version, the Parallel Gateway is used to model activities that can be executed in an undefined order. The extended version uses the Ad Hoc activity for this process. The NICTIZ model does not make use of this construct, but instead it uses the *Embedded Sub-process*.

The use of the embedded sub-process is not appropriate in this situation and it is also not used correctly in the NICTIZ model. Figure 14 shows a part of the process in the NICTIZ model. The part of the process starts with the activity 'informeren patient' and goes via a sequence flow to the embedded sub-process 'Informed Consent'. The first error is the incoming sequence flow. Sequence flows must not cross sub-process boundaries, i.e., from child level to parent level (Silver, 2009). This also holds for the two outgoing sequence flows of the embedded sub-process. The embedded sub-process 'Inlichten' on the right does not have these errors. Note that this rule does not hold for the incoming message flow on top of the embedded sub-process.
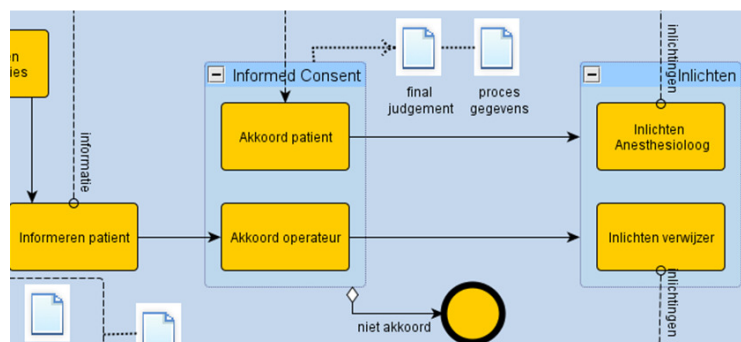
Figure 14: Example of incorrect use of the constructs in the NICTIZ model

The second error is inside the embedded sub-process 'Informed Consent'. Two activities are placed in the sub-process. This is not correctly modelled. If the embedded sub-process was an Ad Hoc activity, the placement of the activities would be correct. However, a sub-process must always start with a none-start event and end with an end event (Silver, 2009). In this case, it should be followed by a parallel gateway. This mistake is made in every embedded sub-process of the NICTIZ model.

4.3.2 End Events

Section 4.2.2 shows the advantage of the extended end events in comparison with the none-end event. Figure 14 shows that the none-end event is used in a situation where parallel paths are active. As said before, it is wanted to immediately end all parallel paths when an end event has been reached. As such, the use of the terminate end event would be a proper redesign for the NICTIZ model.

4.3.4 Exclusive Gateway

Another error in the NICTIZ model involves the use of the exclusive gateway. The exclusive gateway is often not used correctly in the NICTIZ model. Figure 15 shows an example of the incorrect use.
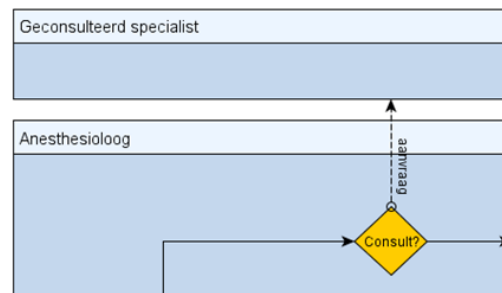
Figure 15: Example of incorrect use of the exclusive gateway in the NICTIZ model

Figure 15 shows two pools, the 'Anesthesioloog' and the 'Geconsulteerd specialist'. In the pool of the 'Anesthesioloog' an exclusive gateway is modelled. The first error in the example is related to the semantics of the exclusive gateway. An exclusive gateway must always have one sequence flow in and more than one sequence flow out (Silver, 2009). In this case there is one ingoing sequence flow, but also only one outgoing sequence flow. There is another flow going out of the exclusive gateway. This is, however, a message flow. This immediately points out the second error: a message flow cannot connect to a gateway (Silver, 2009). A message can only be sent or retrieved by an activity or an event.

4.3.3 Pools and Lanes

Another redesign proposition for the NICTIZ model involves the use of pools and lanes. Appendix F shows that every participant in the NICTIZ model is modelled with a different pool. The model consists of eight different pools in total. Consequently, it is not possible for the process to flow as a whole through the different departments, because the sequence flows cannot cross the boundaries of the pools. The process is scattered into different parts. This situation shows how a small misinterpretation of the construct's semantics leads to great errors for the model's understandability and correctness.

Section 3.3.1 mentioned that a process always has at least one pool, the 'business process pool'. And so, a distinction was made between 'pool' and 'multiple pools'. In the business process pool the actual process takes place, in this case the peri-operative process. Given that many participants are involved in the process, the pool is divided into different lanes. Figure 16 shows the different pools and lanes for the extended version of the process.
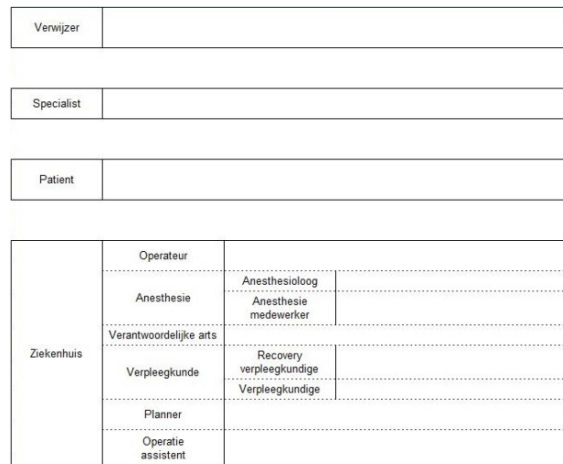
Figure 16: Pools and lanes example extended version

In Figure 16 the business process pool is labelled 'Ziekenhuis'. This pool is divided into different lanes, which represent the participants in the process. Lanes usually just make sense for human tasks (Silver, 2009). In the business process pool the process can proceed. Sequence Flows and Data Flows can cross the borders of the different lanes, but they cannot cross the boundaries of a pool.

On top of the pool 'Ziekenhuis', three other pools can be seen, 'Verwijzer', 'Specialist', and 'Patient'. These pools are so-called Black-box pools for external participants. These pools will not have activities inside of them, only message flows interacting with the business process pool. They show the interaction of the external participants with the business process.

4.4 Conclusions of the Theoretical Analysis

The purpose of the theoretical analysis was to examine the influence of the extended constructs regarding the understandability and correctness of a business process model. As such, different models (basic/extended) were constructed and compared.

The focus of the peri-operative process should be on the following factors, communication between the different participants and the patient, the transmission of data, and the information to the patient. Since the guidelines propose a desired process for the Dutch hospitals, not everything is described in detail. This is for every individual hospital to interpret. Due to this level of abstractness, it was possible to construct an understandable model with the given information from the guidelines with only the basic constructs and the full set of constructs. The above factors also imply that the peri-operative process can be seen as a conceptual process model in which the basic constructs would be sufficient. However, the complexity metrics and the use of collapsed sub-processes showed that the extended constructs can increase the understandability of the model even though the level of abstraction is high.

BPMN's developers envisaged the basic set to be used by business analysts for the essential, intuitive articulation of business processes in very easy terms. The full set of constructs would then enable users to specify more complex process scenarios with a level of detail that facilitates process simulation, evaluation or even execution (Zur Muehlen & Recker, 2008). These elements are used in workflow process models, where a concrete view with minimal abstractions is given. This also holds for the peri-operative process. The examples of the extended end events and the compensation

element showed how they can contribute to the correctness of the model when the level of abstraction is low.

Section 4.3 showed that there are many possible redesign propositions to increase the comprehensibility and the accuracy of the NICTIZ model. Not only were problems illustrated that pointed out the incorrect use of the used constructs, such as the embedded sub-process and the exclusive gateway, but propositions were also given to make the process more understandable by using best practices, such as (multiple) pools and lanes.

The NICTIZ model showed that BPMN is not always used properly in practice. Given that the important factors are focused on conceptual process modelling, the impact of the problems is not so huge. However, process execution or simulation is not possible with the current model due to the incorrect use of the language.

5. Methodology of the Experiment

This section explains the methodology of the experiment. First, a brief introduction is given, followed by a description of the participants who take part in the experiment. After this, the design of the experiment and the analysis of the results are discussed.

5.1 Introduction

The experiment consists of a test, which will be done by participants who are working in the field of healthcare. The purpose of the test is to examine the participants' understandability and modifiability of the extended constructs compared to the basic constructs. The test consists of ten questions where different constructs are treated. Five questions are related to the participant's understandability of process models and five questions are related to the participant's modifiability of process models. Half of the participants receive a workshop before they do the test. This workshop is a remote video presentation and explains the behaviour of certain constructs in BPMN by using the token game.

5.2 Participants

The participants are found via the network of NICTIZ. The sample size of the experiment is not defined. Many rules of thumbs have been proposed for the determination of the sample size, but in reality there is no rule of thumb that applies to all situations (Muthen & Muthen, 2002). As such, as much practitioners as possible are approached to participate in the experiment. The participants must have a certain experience with process modelling and have to work in the healthcare domain. The reason for the latter restriction is that the population from which one selects subjects for an experiment, should be representative of the population to which the researcher wishes to generalise results (Cooper & Schindler, 1998). In this case the population consists of process modellers in the healthcare environment. Also, the effort required to get practitioners to participate in experiments may be worthwhile, as it can increase both the external validity and statistical significance of results (Moody, 2003). Before the participants start with the test, they are asked to answer personal questions about their background and experience with process modelling.

At first, two groups were made of participants from the network of NICTIZ. These participants were randomly divided. Given that the amount of participants was still very low and certain participants decided not to participate in the end, more people were consulted from the TU/e post-master program for healthcare. They were also randomly divided over the two groups. The initial intension was to create two groups, one consisting of students from the TU/e master and one group from NICTIZ. Unfortunately, the participants of NICTIZ were already asked to do the test and were therefore already divided into two groups.

5.3 Design of the Experiment

The experiment is a test consisting of two parts, an understandability part and a modifiability part. The understandability part contains five multiple choice questions where only one answer is correct. The modifiability part contains five open questions, where participants have to describe their modifications. At first, it was suggested to have participants construct models from scratch. However, not every participant has a process modelling tool at his disposal. Also, the use of different process modelling tools can have an influence on the results, because some tools are more user-friendly and/or comprehensive than others.

The test is constructed in the following way. The extended constructs 'Compensation', 'Ad Hoc', and 'Inclusive OR' are used in the test. For each of those constructs a model is designed, based on the peri-operative process. Also, the exact same model is designed, but only with the basic constructs (workaround). This is done for all three types of constructs. Given that it is not possible to create a workaround for every extended construct, these three types of constructs were chosen. Figure 17 shows that the process models of the basic constructs (workaround) and the extended constructs are similar processes from the healthcare environment. The error in those models is different.
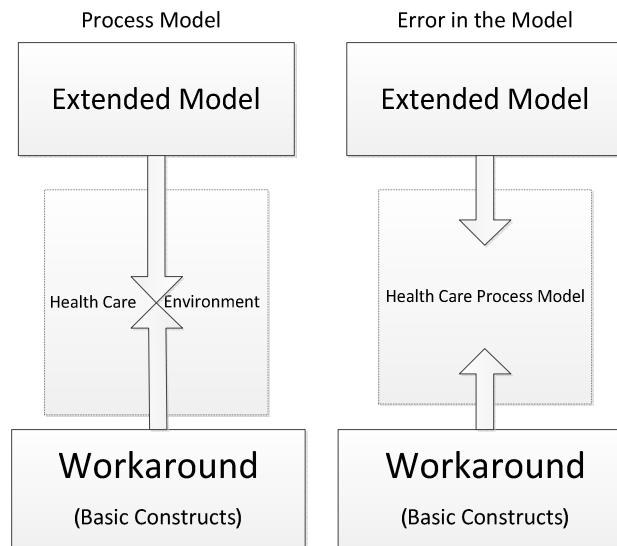
Figure 17: Placement of process models and errors

Figure 18 and   Figure 19 show the models for the Inclusive OR gateway. Figure 18 shows the model with the Inclusive OR gateway.
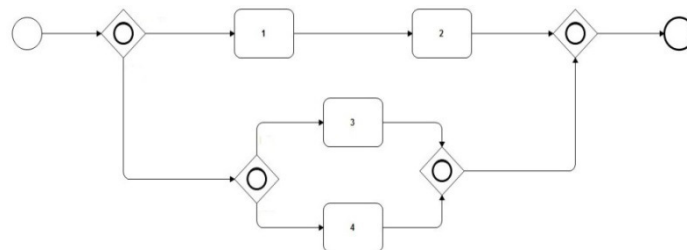
Figure 18: Example of process with Inclusive OR gateway

In   Figure 19 this model is drawn again, but with only the basic constructs. The three extended constructs and their workarounds can be seen in Appendix K: Extended Constructs and Workarounds. Note that for the experiment it is not important that the models give a correct representation of the real peri-operative process. The emphasis of the experiment is not on the process but on the constructs.
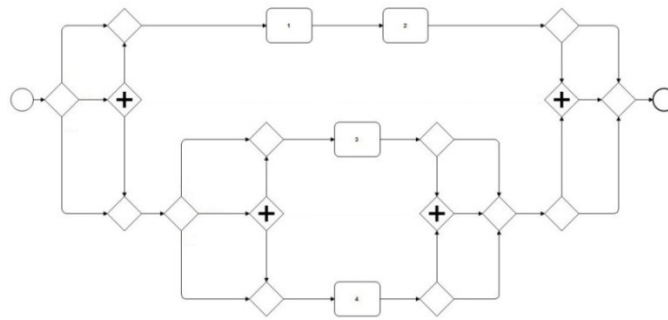
Figure 19: Workaround example of process with only basic constructs

Besides these extended constructs there are also two questions named 'Easy basic' and 'Hard basic'. The question 'Easy basic' consists of a model with only basic constructs which is a relatively easy question. The purpose is to show that the participants who do the test have a certain level of process modelling. If these questions are answered incorrectly, it could be concluded that the level of skill of the participants is so low, that it would not give any ground to draw further conclusions about the extended constructs. The 'Hard basic' question also consists of a model with only basic constructs. However, this model is relatively hard to answer correctly. The purpose is to show that a model with only basic constructs can also be difficult to understand. Both questions 'Hard basic' and 'Easy basic' have both an understandability question and a modifiability question. This makes a total of ten questions. Appendix L: Structure of the Tests shows the structure of the two tests.

Based on the above, the following hypotheses are formulated.

Hypothesis 1 is formulated as follows.

H_0: The results of a model with only the basic constructs will significantly differ from the results with the extended constructs for the understanding questions

H_1: The results of a model with only the basic constructs will not significantly differ from the results with the extended constructs for the understanding questions.

**Hypothesis 2** is formulated as follows.

H_0: The results of a model with only the basic constructs will significantly differ from the results with the extended constructs for the modifying questions.

H_1: The results of a model with only the basic constructs will not significantly differ from the results with the extended constructs for the modifying questions.

Two different versions of the test are made with different models for the extended constructs. This is to illustrate that the results are not test-specific. The models of the 'hard basic' question and 'easy basic' question are similar for both tests. This is because the emphasis is on the extended constructs. Both versions of the test can be found in Appendix L: Structure of the Tests.

Hypothesis 3 is formulated as follows.

H_0: There is no significant difference of the results between the two versions of the test

H_1: There is a significant difference of the results between the two versions of the test

Half of the participants receive an online workshop, which they must watch before doing the test. The workshop is a remote video presentation that explains briefly the constructs in BPMN 2.0[3]. At first, giving a workshop in person was suggested, but given the profound difficulty of gathering every participant in the same room at the same time, a different form was chosen. Appendix N: Example Workshop gives an example of the workshop that explains a process model using the token game. The purpose of the workshop is to show how a short training will significantly improve the results of the participants.

Hypothesis 4 is formulated as follows.

H_0: *The results of the test are significantly higher when the workshop has been followed*

H_1: *The results of the test are not significantly higher when the workshop has been followed*

Figure 20 shows a BPMN process model that illustrates the design of the experiment.
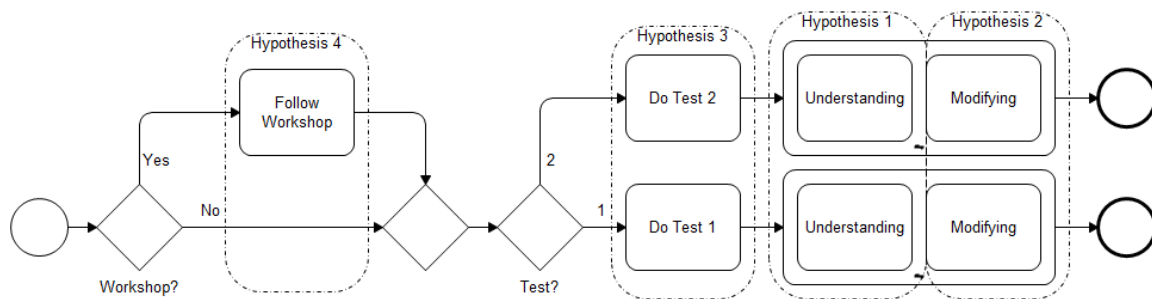
Figure 20: BPMN Process model of the experiment

5.4 Analysis of the Results

Section 2.3 states that the construct *actual effectiveness* would be used from the Method Evaluation Model (Moody, 2009) to answer the research questions. The actual effectiveness looks at the output of the method, how well it achieves its objectives and therefore how it improves the quality of the result. In this case the results of the test indicate the quality. When a question is answered correctly, points are given which lead to a final result of the test.

5.4.2 Norm Determination

This section discusses how the points are allocated to the different questions. Each test contains ten questions: five multiple choice questions with only one correct answer and five open questions. For the multiple choice questions the following allocation is determined. When a question is answered correctly, 10 point are given. Thus, in total it is possible to gain 50 points for the multiple choice questions when all are answered correctly.

The open questions are evaluated in the following way. Each participant describes how they would modify the model so that it would behave correctly. A correct answer can exist through several aspects. When a participant has one or more of these aspects correct, he will receive points. In total 10 points can be gained per open question. Thus, a participant can gain a maximum of 100 points for the test. Appendix O: Norm Determination gives the norm per question for both versions of the test.

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[3] The workshop can be seen via the following link: http://www.screencast.com/t/p5XNYfhkh

5.4.3 Hypothesis Testing Method

The hypotheses will be tested with the independent t-test, because there are two experimental conditions for each hypothesis and different participants are used in each condition. Before the statistical test can be carried out, the following assumptions need to be checked.

- Data is from normally distributed populations
- Data is measured at least at the interval level
- Variances in these populations are roughly equal (homogeneity of variance)
- Results are independent

When every assumption is met, it is valid to use the independent t-test to test the different hypotheses. The level of significance is for every test set to $\alpha = 0.05$.

6. Analysis of the Experiment

This section discusses the analysis of the experiment. First, the data analysis will be discussed, followed by the hypothesis testing. Finally, the findings from the experiment will be summarised.

6.1 Data analysis

The data received from the participants will first be analysed. Due to myriad reasons, some participants were not able to do the test. This is often a setback for an experiment, because the sample size will be smaller. Although 22 participants initially agreed to do the experiment, 16 participants actually did the test in the end.

The tests have been examined with the norm determination tables in Appendix O: Norm Determination. Table 12 shows the final results of the participants.

Test 2	Understanding Extended					Modifying Basic					
Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
1	0	10	10	10	0	10	10	10	10	10	80
2	0	10	10	10	0	0	0	0	10	0	40
3	0	10	10	10	0	5	10	5	10	0	60
4	0	10	0	10	10	5	10	0	10	10	65
5	10	10	10	10	10	5	10	10	10	10	95
6	0	10	10	10	10	0	10	10	10	6	76
7	10	10	10	10	10	0	10	10	10	0	80
8	0	0	0	0	0	5	0	0	10	0	15
9	0	10	10	10	0	5	0	0	10	0	45
Test 1	Understanding Basic					Modifying Extended					
Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
10	0	0	10	10	10	0	10	10	0	8	58
11	0	10	10	10	0	2	10	0	10	6	58
12	0	0	10	0	10	4	10	10	10	0	54
13	0	10	10	10	10	0	10	10	10	10	80
14	10	0	0	10	10	10	5	10	10	10	75
15	0	10	10	10	0	8	10	10	10	0	68
16	10	10	0	10	0	8	10	10	10	6	74

Table 12: Test results of the participants

6.1.1 Outliers

The received data must be checked for outliers. An outlier is a result that is very different from the rest of the data. They can bias the model, which fits to the data and for this reason has to be removed. A boxplot can be used to trace outliers. Figure 21 shows the boxplot of the total score. Case number 8 (circle) is deemed to be an outlier. The participant scored only 15 points in total and did the test in 12 minutes, where the average is 53 minutes. This indicates that the participant did not make a serious effort and so the case will be removed from the data set.
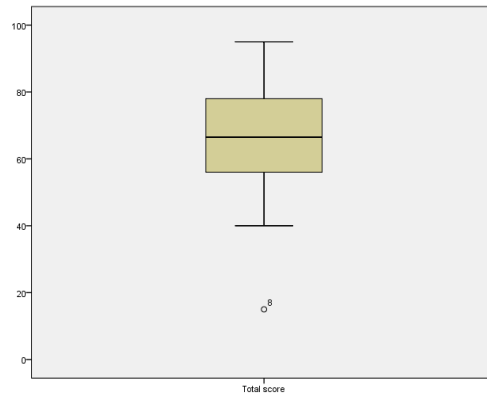
Figure 21: Boxplot of total score

6.1.2 Assumptions

Section 5.4.3 shows which assumptions have to be checked before the statistical tests can be carried out.

Normally distributed data

The first assumption states that the data is from a normally distributed population. If this assumption is not met then the logic behind hypothesis testing is flawed. To test this assumption, the Kolmogorov- Smirnov (K-S) test and the Shapiro-Wilk (S-W) test will be used. If the tests are non-significant, it can be assumed that the data is normally distributed.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total score	.143	15	**.200**[*]	.969	15	**.850**

Table 13: Tests of Normality

Table 13 shows the results of both tests. A significant value (<=0.05) of the tests would indicate a deviation from normality. Both of the tests have a non-significant value (0.200 and 0.850), which means that the data is normally distributed.

Homogeneity of variance

The second assumption states that the variances should be the same throughout the data. Levene's test will be used to test this assumption. It tests the hypothesis that the variances in the groups are equal. A non-significant result indicates that the assumption is met.

		Levene Statistic	df1	df2	Sig.
Total score	Based on Mean	2.517	1	13	**.137**
	Based on Median	2.115	1	13	**.170**
	Based on Median and with adjusted df	2.115	1	8.894	**.180**
	Based on trimmed mean	2.515	1	13	**.137**

Table 14: Levene's test of homogeneity of variance

Table 14 shows the results of levene's test. The column on the right shows that all values are non-significant. This means the assumption is met.

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Interval Data

The third assumption is that data should be measured at least at the interval level. This means that the distance between points of the scale should be equal at all parts along the scale. This assumption is met, because the 0-10 scale that is used for the norm determination is equal at all parts.

Independence

The last assumption is that data from each different participant is independent, meaning that the behaviour of one participant does not influence the behaviour of another. This assumption is met, because every participant did the test on their own without any influence from other participants.

The four assumptions are met, and it is therefore valid to use statistical tests on the data, such as the independent t-test.

6.1.3 Easy and Hard Basic Questions

Section 6.3 stated that the purpose of the easy basic questions was to establish a certain level of the process modelling skill. The easy basic questions in the tests are question 4 and 9 (Table 12). The average score of question 4 and 9 is 8.75 and 9.375 respectively. Every participant scored at least 10 points for one of the two questions. This indicates that the level of process modelling for every participant is sufficient.

The purpose of the hard basic questions is to show that a model with only basic constructs can also be difficult to understand. The hard basic questions in the tests are question 5 and 10 (Table 12). The average score of question 5 and 10 is 5.00 and 4.75 respectively. Only the average score of question 1 for both tests is lower (2.5), illustrating that models with only basic constructs can be very difficult to understand.

6.2 Hypothesis Testing

This section tests the hypotheses explained in section 5.3 using the independent t-test.

6.2.1 Test Independence Hypothesis

The first hypothesis tests whether the results of the test are not test specific (hypothesis 3). The hypothesis is as follows.

H_0: There is no significant difference between the results of the two versions of the test

H_1: There is a significant difference between the results of the two versions of the test

Table 15 and Table 16 show the output of the independent t-test. Table 15 shows the group statistics. Seven participants did test 1 and eight participants did test 2. The mean scores of the tests are almost the same (66.71 versus 67.63). The standard deviation is higher for test 2 than for test 1 (10.11 versus 18.77).

	Test number	N	Mean	Std. Deviation	Std. Error Mean
Total score	1	7	66.71	10.111	3.822
	2	8	67.63	18.769	6.636

Table 15: Group Statistics hypothesis 3

Table 16 shows the main test statistics of the independent t-test. There are two rows containing values for the test statistics: *Equal variances assumed* and *Equal variances not assumed*. The choice

between the two depends on the result of Levene's test for equality of variances. When the result is significant, the assumption of homogeneity of variances is violated, and equal variances are not assumed. Table 16 shows the result of Levene's test is not significant (0.117) and thus equal variances can be assumed.

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | 95% Confidence Interval of the Difference | |
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Total score	Equal variances assumed	2.820	.117	-.114	13	.911	-.911	7.965	-18.119	16.297
	Equal variances not assumed			-.119	11.002	.907	-.911	7.658	-17.765	15.943

Table 16: Main test statistics hypothesis 3

After this establishment, the t-test can be inspected. The exact significance value of t should be less than 0.05 to reject the null hypothesis. Table 16 shows the significance value is far greater than 0.05 (0.911), meaning the null hypothesis should not be rejected. The results of the test do not significantly differ from each other.

6.2.2 Workshop Hypothesis
The second hypothesis that is tested is related to the given workshop (hypothesis 4). The hypothesis is as follows.

H_0: *The results of the test are significantly higher when the workshop has been followed*

H_1: *The results of the test are not significantly higher when the workshop has been followed*

Table 17 shows the group statistics. The participants who did not follow the workshop score a mean of 61.88 with a standard deviation of 13.31. The participants who did follow a workshop score a mean of 73.29 with a standard deviation of 15.03. Although the mean is higher for the participants who followed a workshop, the t-test should indicate whether this difference is significant.

	Workshop	N	Mean	Std. Deviation	Std. Error Mean
Total score	0	8	61.88	13.314	4.707
	1	7	73.29	15.030	5.681

Table 17: Group statistics hypothesis 4

Table 18 shows the main test statistics. Again, Levene's test is non-significant, and equal variances can be assumed.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Total score	Equal variances assumed	.003	**.960**	-1.560	13	**.143**	-11.411	7.314	-27.212	4.390
	Equal variances not assumed			-1.547	12.156	.148	-11.411	7.378	-27.463	4.641

Table 18: Main test statistics hypothesis 4

The value of the independent t-test is non-significant, 0.143. However, the hypothesis is in this case directional: it does not look at a change but at an increase. For this reason the test is one-tailed. The one-tailed probability can be ascertained by dividing the two-tailed significance value by 2 (Field, 2005). Therefore, the one tailed probability is now 0.072 (0.143/2), but still non-significant. This means that the null hypothesis should be rejected. Although the results of the participants who followed the workshop are higher on average, the difference is not significant. Consequently, the results of the participants who followed the workshop are not significantly higher than the results of the participants who did not follow the workshop.

6.2.3 Constructs Hypotheses

The last two hypotheses are related to the difference between the basic and extended models. The first hypothesis is as follows (hypothesis 1).

H_0: *The results of a model with only the basic constructs will significantly differ from the results with the extended constructs for the understanding questions.*

H_1: *The results of a model with only the basic constructs will not significantly differ from the results with the extended constructs for the understanding questions.*

To test this hypothesis, the results of the understanding questions from test 1 will be compared with the results of the understanding questions from test 2. This is done to reduce the following limitations. The first limitation is the carryover effect. Due to the different questions a participant has to answer, it is possible that the knowledge gained from previous questions influence the results of questions that will be done later on in the test. The second limitation is the chosen scale. The understanding questions are multiple choice questions, in which that either zero or ten points can be gained. The modifying questions are open questions, where the score can be between zero and ten. For these reasons, the understanding questions of test 1 will be tested with the understanding questions of test 2.

Table 19 shows the group statistics for hypothesis 1. Group 0 consists of the participants from test 2 with the extended questions. Group 1 consists of the participants from test 1 with the basic questions. The mean of group 0 is slightly higher than the mean of group 1, but this also holds for the standard deviation.

	Group	N	Mean	Std. Deviation	Std. Error Mean
Understanding	0	9	18.89	9.280	3.093
	1	7	15.71	5.345	2.020

Table 19: Group statistics hypothesis 1

Table 20 shows the main test statistics. Again, Levene's test is non-significant, which means equal variances can be assumed.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
							Mean Differenc e	Std. Error Differenc e	95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)			Lower	Upper
Underst anding	Equal variances assumed	.256	**.620**	.804	14	**.435**	3.175	3.951	-5.298	11.648
	Equal variances not assumed			.859	13.10 2	.406	3.175	3.695	-4.801	11.150

Table 20: Main test statistics hypothesis 1

The value of the independent t-test is non-significant, 0.435. This means that the null hypothesis should be rejected. The results of the models with the basic constructs are not different from the results of the models with the extended constructs for the understanding questions.

The last hypothesis is as follows (hypothesis 2).

H_0: *The results of a model with only the basic constructs will significantly differ from the results with the extended constructs for the modifying questions.*

H_1: *The results of a model with only the basic constructs will not significantly differ from the results with the extended constructs for the modifying questions.*

For reasons mentioned above, the results of the modifying questions from test 1 will be compared with the results of the modifying questions from test 2. Group 0 consists of the participants from test 1 with the extended questions. Group 1 consists of the participants from test 2 with the basic questions.

Table 21 shows the group statistics for hypothesis 2. The mean of group 0 is higher than the mean of group 1 and the standard deviation is almost twice as small. The independent t-test will show whether the difference is significant.

	Group	N	Mean	Std. Deviation	Std. Error Mean
Modifying	0	7	22.43	5.653	2.136
	1	9	15.56	10.138	3.379

Table 21: Group statistics hypothesis 2

Table 22 shows the main test statistics. Again, Levene's test is non-significant, and equal variances can be assumed.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
							Mean Differenc e	Std. Error Differenc e	95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)			Lower	Upper
Modif ying	Equal variances assumed	3.175	**.096**	1.603	14	**.131**	6.873	4.289	-2.325	16.071
	Equal variances not assumed			1.719	12.92 1	.109	6.873	3.998	-1.770	15.516

Table 22: Main test statistics hypothesis 2

The value of the independent t-test is again non-significant, 0.131. Thus, the null hypothesis should be rejected. The results of the models with the basic constructs are not different from the results of the models with the extended constructs for the modifying questions.

6.3 Conclusions of the Experiment

After the analysis of the test results the following conclusions can be drawn. First, the results of both tests did not differ significantly. This is an important finding, because this implies that the results of the tests are not test-specific and therefore can be generalised. Second, the participants who followed the workshop did not score significantly higher on the test. Although, the mean scores were higher, the independent t-test showed that the results are not significant.

Third, the results of the models with the basic constructs did not differ from the results of the models with the extended constructs for the understanding and modifying questions. This means that participants did not have more or less trouble with understanding the extended constructs compared to the basic constructs. When looking at the results of the modifying questions it indicates that the models with the extended constructs were understood better, but the difference is not significant.

Based on these results, it can be concluded that the basic constructs are not easier for participants to understand and use than the extended constructs. The hard basic questions support this statement, because these questions had almost the lowest score. Only the understanding question of compensation had a lower result.

7. Conclusions, Implications, Limitations and Future Research

This section shows the conclusions that are drawn based on the theoretical analysis and the conducted experiment. Furthermore, the practical implications are presented, as well as the limitations of the research and propositions for future research.

7.1 Conclusions

The objective of the research is to examine the influence of the extended constructs regarding the understandability and correctness of a business process model for business practitioners. Three sub-questions are formulated to answer this question.

'What is the influence of the use of different constructs for the understandability of a BPMN process model?'

Different models of the peri-operative process were modelled to answer this question. A version (basic version) with only the basic constructs was constructed of the three separate processes (pre, per, and post-operative process). In addition a version (extended version) with the full set of constructs was modelled on the processes.

The understandability of the models was measured using the following complexity metrics, CFC metric, Nesting Depth metric, and the Knot Counting metric. The results of the CFC metric showed that every model of the basic version had a higher number of decisions. The accumulated results of the extended models were about equal to the basic models. Nonetheless, the extended models are easier to understand, because the decisions are divided over many more different models. The results of the maximum and mean nesting depth metric showed that the models of the basic versions have a higher number of decisions. The results of the knot counting metric were similar for every model. Based on the results of the metrics, it can be concluded that the extended version of the models was more understandable than the basic version of the models.

As such, it can be concluded that the extended constructs have a positive influence on the understandability of a BPMN process model.

'What is the influence of the use of different constructs (basic/extended) for the correctness of a BPMN process model?'

The correctness of the models for the basic and extended version was examined by reproducing their state spaces and using the token game to illustrate the model's behaviour. The extended end events in the theoretical analysis showed how the behaviour of the peri-operative process model could be optimised. In addition, the example of the model with the extended construct compensation illustrated how it can support correct behaviour compared to a similar model with only the basic constructs. Even though this example did not explicitly appear in the guidelines of the peri-operative process, it is very likely that such a situation will appear in a real life peri-operative process model.

As such, it can be concluded that the extended constructs have a positive influence on the correctness of a BPMN process model.

'Are models with basic constructs easier to understand and modify than models with extended constructs for business practitioners?'

To answer this question an experiment was designed for business practitioners in the healthcare domain. The experiment contained a workshop and two different tests, which examined the level of understanding and modifying of process models. The questions in the tests treated models based on the peri-operative process with extended constructs and similar models with only basic constructs. The focus in the experiment was not on the peri-operative process, but on the constructs. The workshop, followed by half of the participants, explained the extended constructs using the token game. The participants were randomly divided into two groups, where each group had a different version of the test.

Based on the results of the experiment, the following conclusions were drawn. First, the results of the tests did not differ significantly, meaning that the results were not test specific. Second, the training in the form of the workshop resulted in a higher score of the participants' mean score. However, this difference was not significant, and it is not possible to conclude whether the workshop had a significant effect on the results. Third, the analysis of the results showed that the models with the extended constructs were not harder to understand or modify than the models with the basic constructs. The results of the modifying questions showed that the mean score was higher for the extended models, but again, this difference was not significant.

From these results it can be concluded that models with basic constructs are not easier to understand or modify than models with extended constructs for business practitioners.

'Do the extended constructs contribute to the purpose of closing the gap between conceptual process modelling and workflow process modelling?'

The reference model from NICTIZ can be seen as a conceptual process model. It was made by a business analyst and is predominately used as a basis for communication. The guidelines state that the described process is not a real life process, but a desired process. Consequently, the created models (basic/extended version) have a high level of abstraction. The real life peri-operative process can differ per hospital. As such, the models will have minimal abstractions and will present a concrete view of the peri-operative process. This means that the model will move from a conceptual process model towards a workflow process model. These models can be used for process execution and simulation, where the correctness of the model is of high importance. As stated before, the extended constructs have a positive influence on the correctness of a model.

Based on the above, it can be concluded that the extended constructs contribute to the purpose of closing the gap between conceptual and workflow process modelling.

The main research question in section 2.1 questions the influence of the extended constructs regarding the understandability and correctness of a business process model. Based on the results of the theoretical analysis and the experiment and their corresponding conclusions, it can be stated that the extended constructs make a model more understandable and have a positive influence on the behaviour of a business process model.

7.2 Summary of Contributions

This report contributes to the research on the practical use of the workflow language BPMN 2.0. Recker's research (2010) questioned whether a highly expressive notation is a desirable result of a standardisation process. The research offers the following contributions to the field.

- First, this research shows that the extended constructs have a positive influence on the understandability of business process models. It shows that a small set of elements does not necessarily reduce the complexity of a model. The complexity of a model is defined by the specification of the process, not by the constructs used. The extended constructs reduce the number of decisions in the control flow, which lowers the complexity of a process model.

- Second, this research shows that business participants do not have more trouble with understanding or using the extended constructs compared to the basic constructs. This conclusion is based on the experiment, which looked at the element 'actual effectiveness' of the Method Evaluation model (Moody, 2003). However, the actual use of the extended constructs in practice depends on more elements (Figure 3) that should be investigated.

- Third, this research shows that the extended constructs have a positive influence on the correctness of business process models. For process models which move towards workflow process models, the behaviour becomes of higher importance. This report showed that extended constructs are necessary for modelling the correct behaviour of specific processes. As such, extended constructs are essential to close the gap between conceptual and workflow process models.

- Fourth, the research shows that it is possible for business practitioners to use the full set of constructs in practice, but not use them correctly. This means that not enough knowledge was gained about the semantics of the constructs and that training in the language is essential before actual process models can be designed. This is also implied by Recker (2010). For conceptual process models these mistakes can be overseen, but for models that move towards workflow process models they can be crucial.

7.3 Limitations

This section describes the limitations of the research and indicates areas in which the research falls short to various aspects.

First, the limitations of the theoretical analysis will be discussed.

- The first limitation is related to the modelling of the basic and extended versions of the peri-operative process. Due to the fact that the modelling was done by the researcher and not business practitioners, there is bias involved, because process modelling leaves room for individual interpretation. This interpretation can affect certain modelling decisions, which influence the results of the complexity metrics.

- Second, the NICTIZ model showed only the first part of the peri-operative process. The model also contained many modelling errors, which made it unsuitable for analysis with the complexity metrics.

- Third, the complexity metrics were not specifically directed for the workflow language BPMN 2.0. Also, it did not take the hierarchical levels into account, which are an important aspect of BPMN 2.0, due to the use of collapsed sub-processes.

- Fourth, the peri-operative process can be seen as a conceptual model. This means that the level of abstraction is high and the focus is more on communication than on execution.
- Fifth, the theoretical analysis and the experiment only focused on one domain, the healthcare domain.

Second, the limitations of the experiment will be discussed.

- The first limitation of the experiment is the sample size. Over the years many rules of thumbs have been proposed for the determination of the sample size, but in reality there is no rule of thumb that applies to all situations (Muthen & Muthen, 2002). In total, 16 participants were willing to do the experiment. Due to this low number, it is hard to generalise the results.
- The second limitation is the division of the groups. Given that the participants from NICTIZ were already divided in two groups, it was not possible to make two groups of students and non-students. Gordon et al. (1986) found that in the majority of studies in which students and non-students participated under identical conditions, experimental results were significantly different. Therefore, caution should be exercised in generalising from the results of the experiment involving students.
- The third limitation is related to the Method Evaluation Model (Moody, 2003). The experiment does not measure the intention to use of the business practitioners for the extended constructs.
- The fourth limitation is related to the extended constructs. In the experiment only three different extended constructs were used.
- The fifth limitation holds the fact that the errors in the models of the extended constructs and the workarounds did not have exactly the same error.

7.4 Future Research

Future research should focus on more extended constructs. In this research a small part of the set of extended constructs was examined regarding the understandability and correctness of a process model. Also, more reference models from different business domains should be analysed. Not only would it give more ground to generalise the results, it could also indicate whether there are situations where the current set of construct is not sufficient, based on the understanding or correctness of the model. This would stimulate the debate whether BPMN should focus more on language revision or extension.

Further, future research should expand the experiment. A drawback in the experiment was the low amount of participants. To calculate the necessary sample size, a post hoc statistical power analysis is conducted. Given that the values are known for α = 0,05 and β = 0,80 (β is the level of power and is recommended at the level of 0,80 (Field, 2005)), it is possible to calculate the effect size. This is done with the program G*Power 3.1.6. When the effect size is known, it is possible to determine the required sample size to detect a difference. This determination is based on the method of Cohen (1992). Table 23 shows the results of the statistical power analysis.

	Hypothesis 1	Hypothesis 2	Hypothesis 3	Hypothesis 4
Effect size	0.06	0.80	0.41	0.83
Required sample size	>393	>26	>64	>26

Table 23: Results statistical power analysis

Table 23 shows that for hypothesis 2 and 4, at least 26 participants are needed to detect an effect. Given these results, it would be interesting to see what the effects would be with a higher sample size.

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Appendix A: Former Literature Study

This appendix shows the databases, restrictions, and the search procedure of the literature study. The search procedure is described via an activity diagram show in Figure 22.

Databases

The TU/e is subscribed to several different electronic databases. These are IEEE/IET Electronic Library (IEL), IBM Journal of Research and Development, IEEE-Wiley eBooks Library, and VDE VERLAG Conference Proceedings. In addition, JSTOR and Google Scholar will also be used.

Restrictions

The following restrictions for the search procedure are used. Only studies will be taken if they are written in the English language. They have to contain an abstract and only studies from 2003 until now will be taken into account. The last restriction is because of the dynamic environment of business process languages. Another key aspect is the importance of an article. One way to judge this is the amount of citations an article has. More citations would mean that a broad audience supports the views in the article. Another aspect is the prestige of the journal the article is published in.

Search Procedure

The procedure starts with a search for methodology papers concerning the conduction of a literature study. After this the search for the first objective starts (red). The search queries are shown with their number of hits in Google Scholar. After this search, potential articles are selected (*n* is the number of articles). They have to go through the criteria's for the paper. A second search is started for the first objective with queries found from the first search. This results in a usable amount of articles (green). After this, the search for the second objective is started (blue). It follows the same procedure and results in a sufficient amount of articles (green).
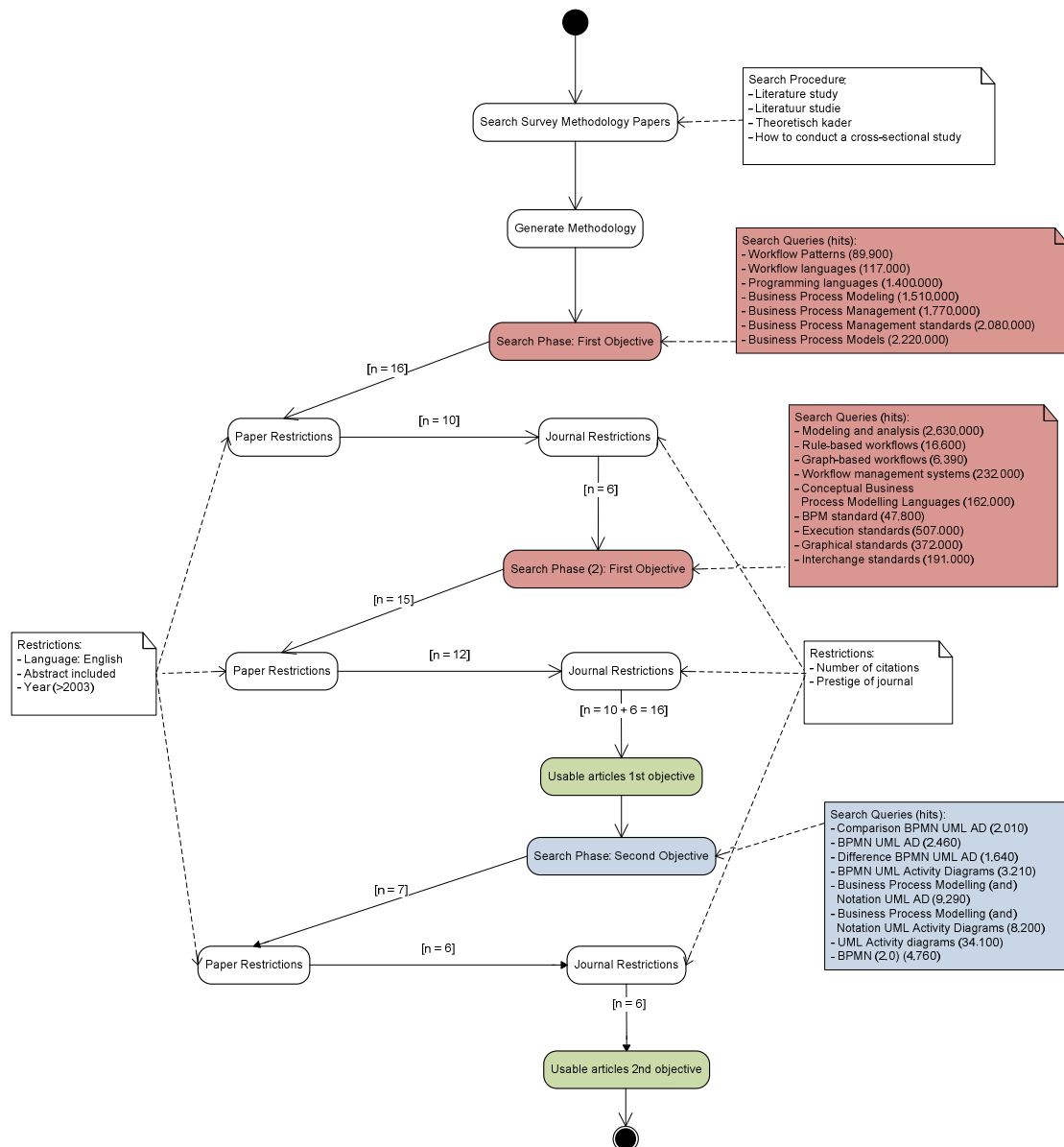
Figure 22: Activity diagram of search procedure literature study

Appendix B: Division of the Constructs by OMG (2011)

This appendix shows the division of the basic and extended constructs by the BPMN work group (OMG, 2011).

Basic constructs

- Event
- Activity
- Gateway
- Sequence Flow
- Message Flow
- Association
- Pool
- Lane
- Data Object
- Message
- Group
- Text Annotation

Extended constructs

- Event
- Flow Dimension
  - Start
  - Intermediate
  - End
- Type Dimension
  - None
  - Message
  - Timer
  - Error
  - Cancel
  - Compensation
  - Conditional
  - Link
  - Signal
  - Multiple
  - Terminate
- Activity
- Task
- Choreography Task
- Process/Sub-Process (non-atomic)
- Collapsed Sub-Process
- Expanded Sub-Process
- Collapsed Sub-Choreography

- Expanded Sub-Choreography
- Gateway
- Gateway Control Types
  - Exclusive
  - Event-based
  - Parallel Event-based
  - Inclusive
  - Complex
  - Parallel
- Sequence Flow
- Normal Flow
- Uncontrolled Flow
- Conditional Flow
- Default Flow
- Exception Flow
- Message Flow
- Compensation Association
- Data Object
- Message
- Fork
- Join
- Decision, Branching, Point
- Exclusive
- Event-based
- Inclusive
- Merging
- Looping
- Activity Looping
- Sequence Flow Looping
- Multiple Instances
- Process Break
- Transaction
- Nested/Embedded Sub-Process
- Group
- Off-Page Connector
- Association
- Text Annotation
- Pool
- Lanes

Appendix C: Business Process Modelling Tools

This appendix shows the business process modelling tools (Figure 23), as well as the vendor selection criteria (Figure 24).

Vendor	Product evaluated	Version release date range
alfabet	planningIT v 4.0	April 2008
Casewise	Corporate Modeler V.10.3SR4, CAM-Portal 2007.2 sr3	July 2007 - December 2007
IBM (formerly Telelogic)	Telelogic System Architect V11.1, Telelogic System Architect/Publisher v11.1, Telelogic SA/XT v11.1 GA, Telelogic Six Sigma dedicated offer v10.0, Telelogic System Architect/Process Integrator v11.1, Telelogic System Architect/Simulator v11.1, Telelogic System Architect For SOA v11.0, Telelogic Change v5.0 , Telelogic TAU 4.1, Telelogic System Architect ERP v10.0	June 2006 - July 2008
IDS Scheer	ARIS Business Architect/ARIS Business Designer 7.1, ARIS IT Architect 7.1, ARIS Business Rule Designer 7.1, ARIS Business Optimizer 7.1, ARIS Business Simulator 7.1, ARIS UML Designer 7.1, ARIS IT Inventory 7.0.2, ARIS Business Publisher 7.1, ARIS SOA Architect 7.1, ARIS SixSigma 7.1, ARIS Performance Dashboard 4.1, ARIS Process Event Monitor 1.0, ARIS Process Performance Manager 4.1, ARIS Value Pack for Release Cycle Management 1.0	July 2007- July 2008
iGrafx	iGrafx 2007 includes iGrafx Process for Six Sigma, iGrafx Process Central, iGrafx Enterprise Central, iGrafx Enterprise Modeler, iGrafx IDEF0, iGrafx BPEL, iGrafx Viewer	March 2007
MEGA	MEGA Suite 2007 includes MEGA Process, MEGA Simulation, MEGA SolMan (SAP), MEGA Architecture, MEGA Designer, MEGA Business Data, MEGA ITSM Accelerator, MEGA EA Accelerator for TOGAF, MEGA eTOM Accelerator, MEGA Supervisor, MEGA Exchange, MEGA Publisher, MEGA Studio, MEGA Advisor, MEGA IT Planning	September 2007 - June 2008
Metastorm	Metastorm ProVision° v 6.1 (client), Metastorm Knowledge Exchange v 6.1 (server), Metastorm Discovery, Metastorm BPM Designer	March 2008 - July 2008
Sybase	PowerDesigner 12.5, PowerDesigner 15.0 (as future reference only). Version 15 is not assessed in the present Wave.	V. 12. 5 - July 2007 V. 15 - Oct 2008
Troux Technologies	Troux Enterprise Suite, version 7.1, includes Troux Transformation Platform, Troux Applications, Troux Standards, Troux eaGov	December 2007

Figure 23: Enterprise Architect tools used by Peyret (2009)

Vendor selection criteria
The product must provide broad metamodel capabilities and support several EA frameworks to be recognized by enterprise architects as a potential tool.
The vendor has either revenues of at least $20 million or a fast-growing revenue stream.
The product version has been released and is generally available prior to August 1, 2008.

Figure 24: Vendor selection criteria for the different tools (Peyret, 2009)

Appendix D: Organisations Peri-Operative Process

This appendix shows the list of the participating unions and organisations for the pre-, per-, and post-operative process.

Pre-operative process 2010

INITIATIEF:
Nederlandse Vereniging voor Anesthesiologie (NVA)
Nederlandse Vereniging voor Heelkunde (NVvH)

MEDE INITIATIEF:
Nederlandse Vereniging van Ziekenhuizen (NVZ)
Orde van Medisch Specialisten (OMS)

ORGANISATIE:
Kwaliteitsinstituut voor de Gezondheidszorg CBO

PARTICIPERENDE VERENIGINGEN / ORGANISATIES
Nationaal ICT Instituut in de Zorg (NICTIZ)
Nederlandsche Internisten Vereeniging (NIV)
Nederlandse Orthopaedische Vereniging (NOV)
Nederlandse Patiënten Consumenten Federatie (NPCF)
Nederlandse Vereniging van Ziekenhuisapothekers (NVZA)
Nederlandse Vereniging van Ziekenhuizen (NVZ)
Nederlandse Vereniging voor Anesthesiologie (NVA)
Nederlandse Vereniging voor Dagbehandeling en Kortverblijf (NVDK)
Nederlandse Vereniging voor Heelkunde (NVvH)
Nederlandse Vereniging voor Kindergeneeskunde (NVK)
Nederlandse Vereniging voor Klinische Geriatrie (NVKG)
Nederlandse Vereniging voor Neurochirurgie (NVVN)
Nederlandse Vereniging voor Obstetrie en Gynaecologie (NVOG)
Nederlandse Vereniging voor Plastische Chirurgie (NVPC)
Nederlandse Vereniging voor Thoraxchirurgie (NVT)
Stichting Kind en Ziekenhuis
Verpleegkundigen & Verzorgenden Nederland (V&VN)

FINANCIERING:
Deze richtlijn is tot stand gekomen met financiële steun van ZonMw in het kader van het
programma 'Evidence-Based Richtlijn Ontwikkeling (EBRO)'

Per-operative process 2011

INITIATIEF:
Nederlandse Vereniging voor Anesthesiologie (NVA)
Nederlandse Vereniging voor Heelkunde (NVvH)

PARTICIPERENDE VERENIGINGEN / ORGANISATIES
Landelijke Vereniging van Operatie-assistenten (LVO)
Nationaal ICT Instituut in de Zorg (NICTIZ, advies)
Nederlandse Patiënten Consumenten Federatie (NPCF)
Nederlandse Sociëteit voor Extra Corporale Circulatie (NESECC, advies)
Nederlandse Vereniging van Anesthesiemedewerkers (NVAM)
Nederlandse Vereniging van Ziekenhuisapothekers (NVZA)
Nederlandse Vereniging van Ziekenhuizen (NVZ)
Nederlandse Vereniging voor Anesthesiologie (NVA)
Nederlandse Vereniging voor Heelkunde (NVvH)
Nederlandse Vereniging voor Klinische Fysica (NVKF)
Nederlandse Vereniging voor Keel-Neus-Oorheelkunde en Heelkunde van het Hoofd-Halsgebied (NVKNO)
Nederlandse Vereniging voor Medische Microbiologie (NVMM)
Nederlandse Vereniging voor Neurochirurgie (NVVN)
Nederlandse Vereniging voor Obstetrie en Gynaecologie (NVOG)
Nederlandse Vereniging voor Plastische Chirurgie (NVPC)
Nederlandse Vereniging voor Radiologie (NVvR)
Nederlandse Vereniging voor Thoraxchirurgie (NVT)
Nederlandse Vereniging voor Urologie (NVU)
Nederlands Oogheelkundig Gezelschap (NOG)
Stichting Kind en Ziekenhuis
TNO (advies)
Vereniging voor Hygiëne & Infectiepreventie in de Gezondheidszorg (VHIG)

Post-operative process 2012

INITIATIEF:
Nederlandse Vereniging voor Anesthesiologie (NVA)
Nederlandse Vereniging voor Heelkunde (NVvH)
Nederlandse Vereniging voor Obstetrie en Gynaecologie (NVOG)
Nederlandse Orthopaedische Vereniging (NOV)

PARTICIPERENDE VERENIGINGEN / ORGANISATIES
Nederlandse Vereniging voor Anesthesiologie
Nederlandse Orthopaedische Vereniging
Nederlandse Vereniging voor Obstetrie & Gynaecologie
Nederlandse Vereniging voor Heelkunde
Nederlandse Verenging voor Keel-Neus-Oorheelkunde en Heelkunde van het Hoofd-Halsgebied
Nederlandse Verenging van Neurochirurgen
Nederlands Oogheelkundig Gezelschap
Nederlandse Verenging voor Plastische Chirurgie
Nederlandse Verenging voor Urologie
Nederlandse Verenging voor Thoraxchirurgie
Nederlandse Vereniging voor Kindergeneeskunde
Nederlandse Vereniging voor Radiologie
Nederlandse Vereniging voor Medische Microbiologie
Nederlandse Vereniging voor Intensive Care
Nederlandse Vereniging van Ziekenhuisapothekers
Nederlandse Vereniging voor Klinische Fysica
Beroepsvereniging Recovery Verpleegkundigen
Verpleegkundigen & Verzorgenden Nederland
V&VN IC Verpleegkundigen
Vereniging voor Hygiëne & Infectiepreventie in de Gezondheidszorg
Nederlandse Vereniging van Ziekenhuizen
Nederlandse Patiënten Consumenten Federatie
Landelijke Vereniging Kind en Ziekenhuis
Nationaal ICT Instituut in de Zorg (advies)
TNO Bouw en Zorg (advies)

FINANCIERING:
Deze richtlijn is tot stand gekomen met financiering van de Stichting Kwaliteitsgelden Medisch Specialisten (SKMS)

Appendix E: BPMN Model Pre-Operative Process by NICTIZ

Figure 25 in this appendix shows the BPMN reference model of the pre-operative process, which is retrieved from NICTIZ.
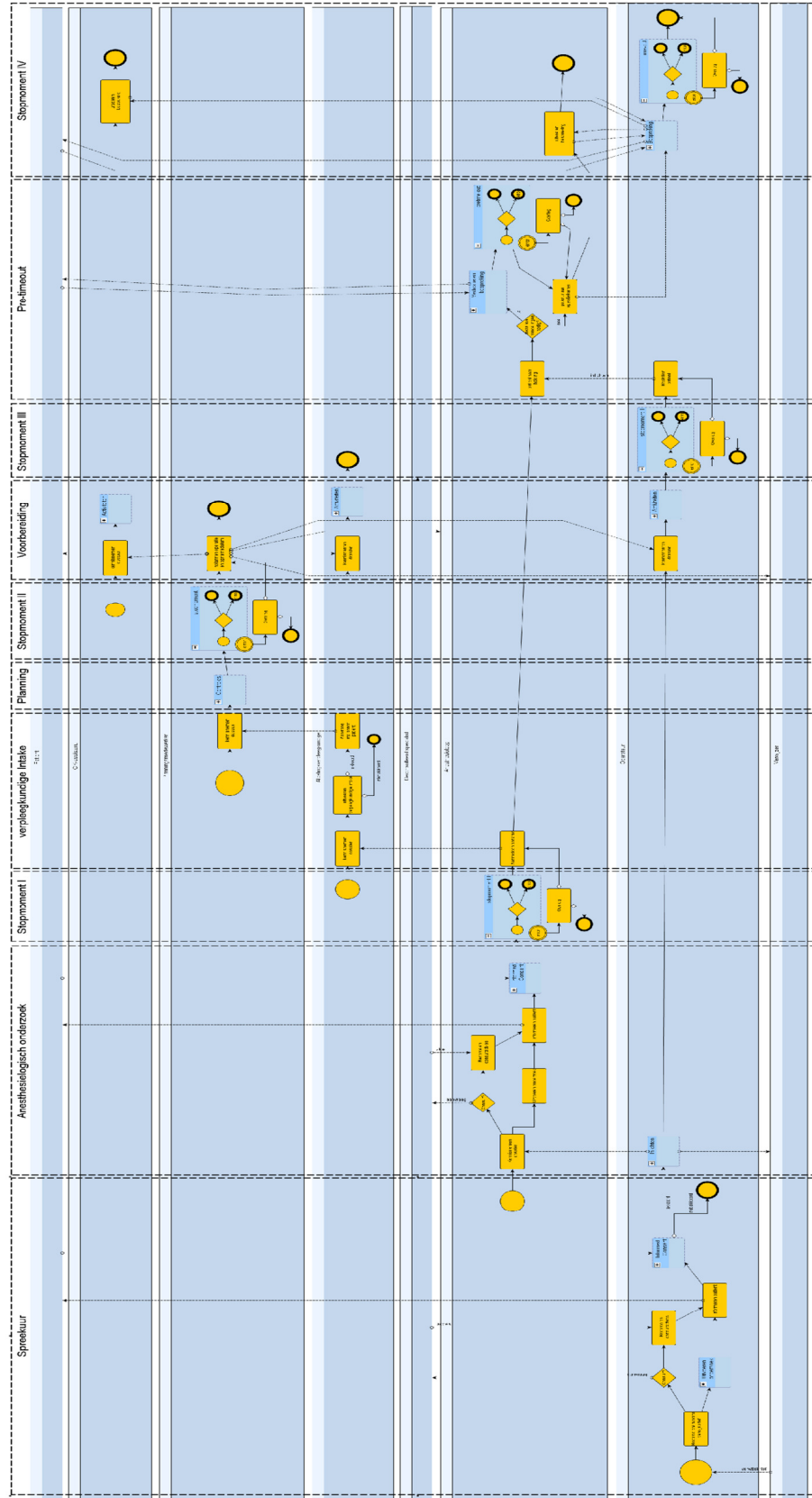
Figure 25: BPMN NICTIZ model

Appendix F: Division Pools in NICTIZ Model

Figure 26 in this appendix shows that every participant in the NICTIZ model of the peri-operative process is modelled with a different pool.
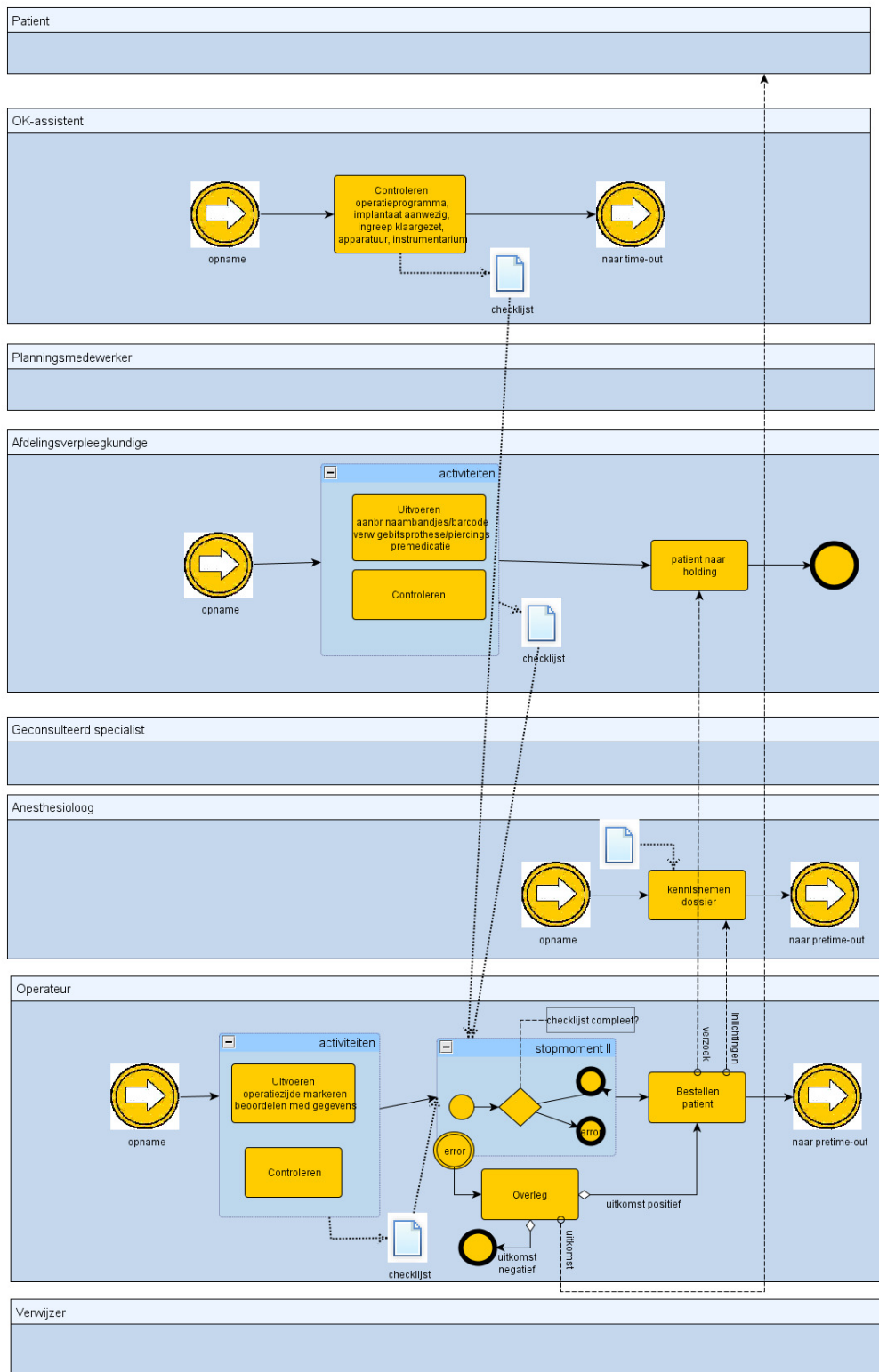
Figure 26: Example NICTIZ model division of pools

Appendix G: Overview Constructs in Models

Table 24 in this appendix shows the number and types of constructs used in the different models of the processes.

	Pre-Operative				Per-Operative			Post-Operative		
	Basic	Extended		NICTIZ	Basic	Extended		Basic	Extended	
		Parent	*Child*			*Parent*	*Child*		*Parent*	*Child*
Basic										
Event	12	1	28	54	5	2	12	2	2	7
Activity	77	36	41	49	40	26	12	28	21	5
Parallel Gateway	32	14	2		16	16		18	12	4
Exclusive Gateway	25	16	8	8	13	5	4	18	3	10
Lanes	6	6			6	6		8	8	
Extended										
Timer Event		1				1				
Message Event		5							2	
Conditional Event										
Signal Event										
Multiple Event										
Parallel Multiple Event										
Escalation Event										
Compensation Event										
Cancel Event										
Terminate Event		8				3				
Error Event		4	6	10		2	2		1	1
Activity Loop										
Activity Parallel										
Activity Sequential										
Sub-Process (Collapsed)		12	1			5			3	
Sub-Process (Embedded)				17						
Ad-Hoc Sub-Process			7				2			
Business Transaction Sub-Process										
Call Activity										
Inclusive OR Gateway			1						2	
Event-Based Gateway										
Start Event-Based Gateway										
Parallel Start Event-Based Gateway										
Complex Gateway			1							
Group Artifact										
Data Store Object										
Data Object		20		28		9			5	
Associations										
Conditional Flow				11						
Exception Flow										
Message Flow		24		31		8			9	
Multiple Pools (-1)		3		7		1			2	

Table 24: Amount of constructs used in the different models

Appendix H: Complexity Metrics Sub-Processes

This appendix shows the metrics of the sub-processes on the child level. Table 25 shows the CFC metric and Table 26 shows the nesting depth metric.

Sub-process	Pre-operative process					Per-operative process					Post-operative process				
	AND splits	OR splits n=2	OR splits n=3	XOR splits n=2	XOR splits n=3	AND splits	OR splits n=2	OR splits n=3	XOR splits n=2	XOR splits n=3	AND splits	OR splits n=2	OR splits n=3	XOR splits n=2	XOR splits n=3
1											1	4			
2	1	4					4					4			
3											1	4			
4	1	4													
5							4								
6															
7															
8															
9				7											
10															
11		4													
12		4													

Table 25: CFC metric of the sub-processes on the child level

Sub-process	Pre-operative process		Per-operative process		Post-operative process	
	Max	Mean	Max	Mean	Max	Mean
1	0	0	0	0	2	2
2	1	1	1	1	1	1
3	0	0	0	0	2	2
4	1	1	0	0		
5	0	0	1	1		
6	0	0				
7	0	0				
8	0	0				
9	0	0				
10	1	1				
11	0	0				
12	1	1				
Total	1	1	1	1	2	1,67

Table 26: Nesting depth metric of the sub-processes on the child level

Appendix I: Terminate End Event

In this appendix the influence of the Terminate end event will be explained using the state spaces and the token game. Figure 27 shows two process models, which are almost similar. The process starts with a none-start event followed by a parallel split. In parallel two tasks can be executed. Both tasks are followed by an end event. The model on the left contains two none-end events. In the model on the right task 1 is followed by a none-end event and task 2 is followed by a terminate end event.
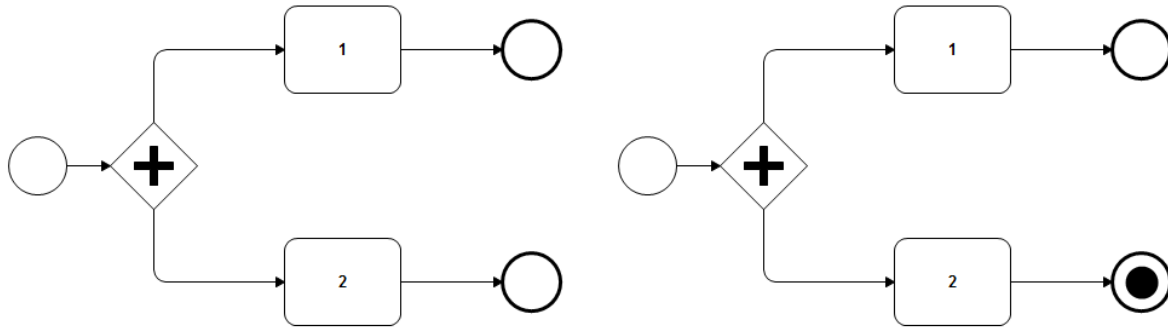
Figure 27: Example process models terminate end event

The state spaces of the models are generated using GrGen. The semantics of the none-end event is the following. A none-end event signifies that no result signal is thrown when the end event is reached (Silver, 2009). The semantics of the terminate end event is as follows. A terminate end event in a process or sub-process immediately ends that process level, even if parallel paths are still active (Silver, 2009). This would mean that it is not possible for Task 1 to keep running if Task 2 has been completed in the model of the terminate end event (Figure 27, right model). In the other model this would be possible. Figure 28 shows the state spaces created by GrGen.

Figure 28: State space of process models (Figure 27)

The state spaces in Figure 28 are not very clear to read. For this reason, the state spaces are worked out in Figure 29 and Figure 31 below. The state space in Figure 29 shows the many paths that can be taken in the process model. The token game in Figure 30 will be used to illustrate the path of the coloured transitions in Figure 29.
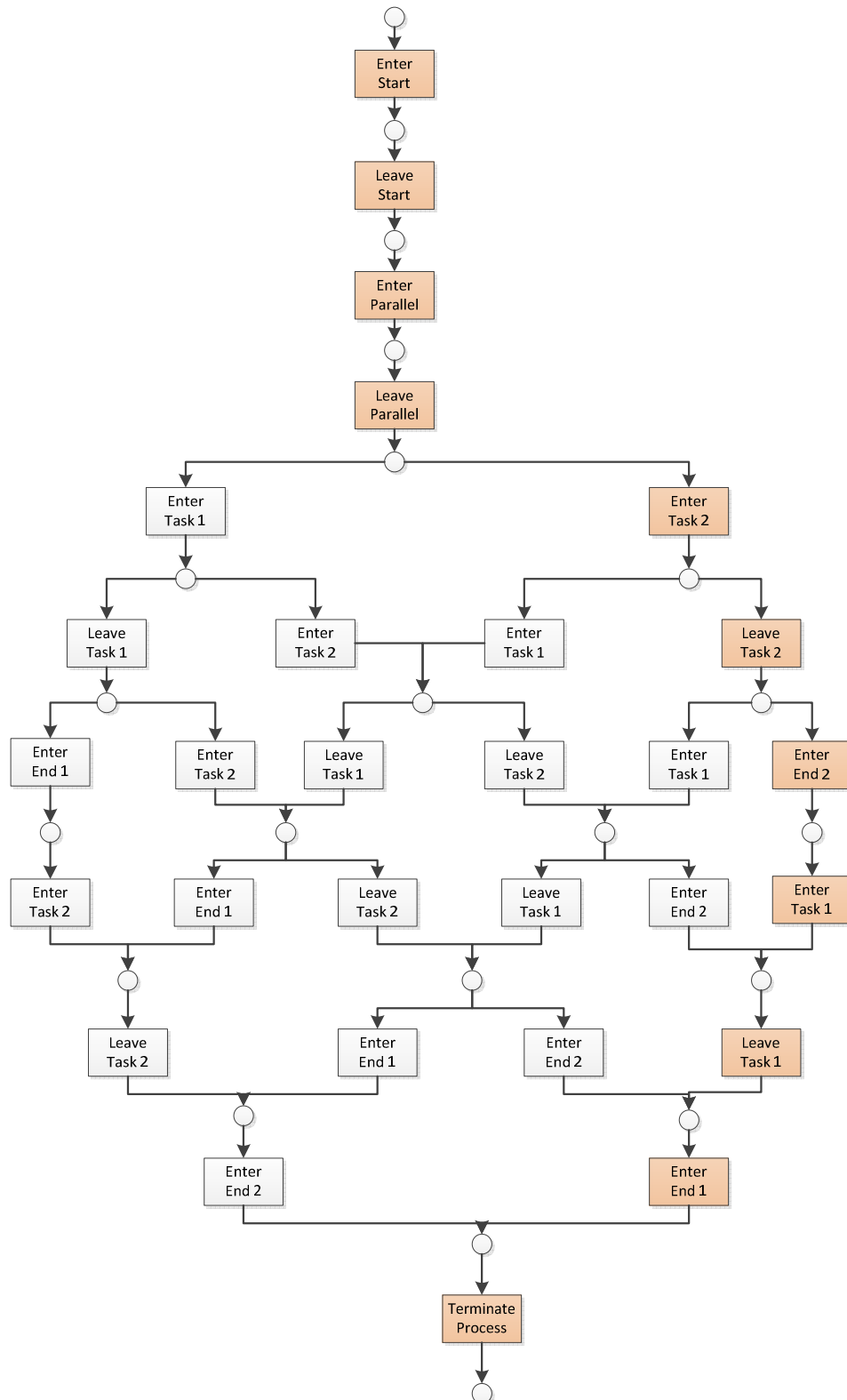
Figure 29: State space of process model (Figure 27, left model)

Figure 30 shows the token moving from the none-start event to the parallel split (Marking 1-3). After the parallel split two tokens are situated on the sequence flows (Marking 4). As can be seen in the state space of the model, the token will first move to task 2 (Marking 5). When task 2 is executed, the token will move to the none-end event (Marking 6-7). After this, the other token will move to task 1 (Marking 8). When task 1 is completed it will also proceed to the none-end event (Marking 9-10).
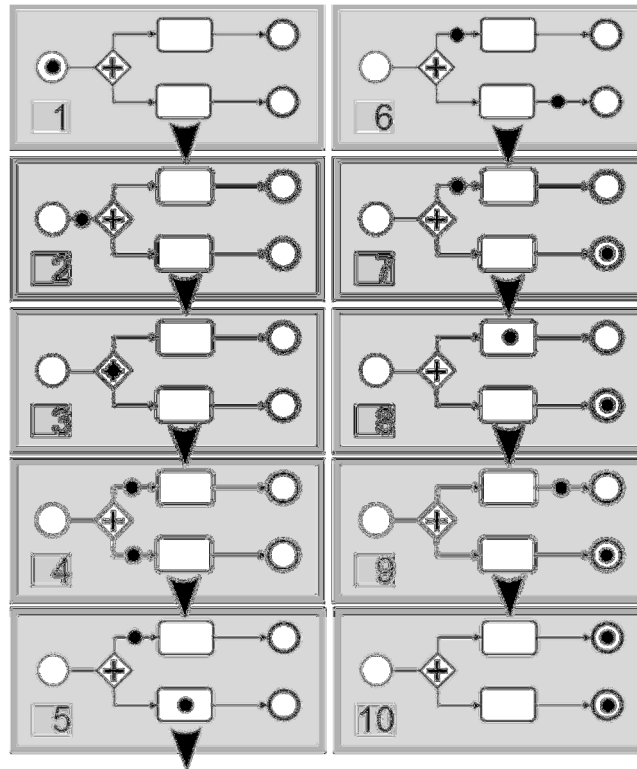
Figure 30: Process path explained using the token game

Figure 31 shows the state space of the model with the terminate end event. The token game will also be used to explain the semantics of the terminate end event. Figure 32 shows the token game of the coloured path in Figure 31.
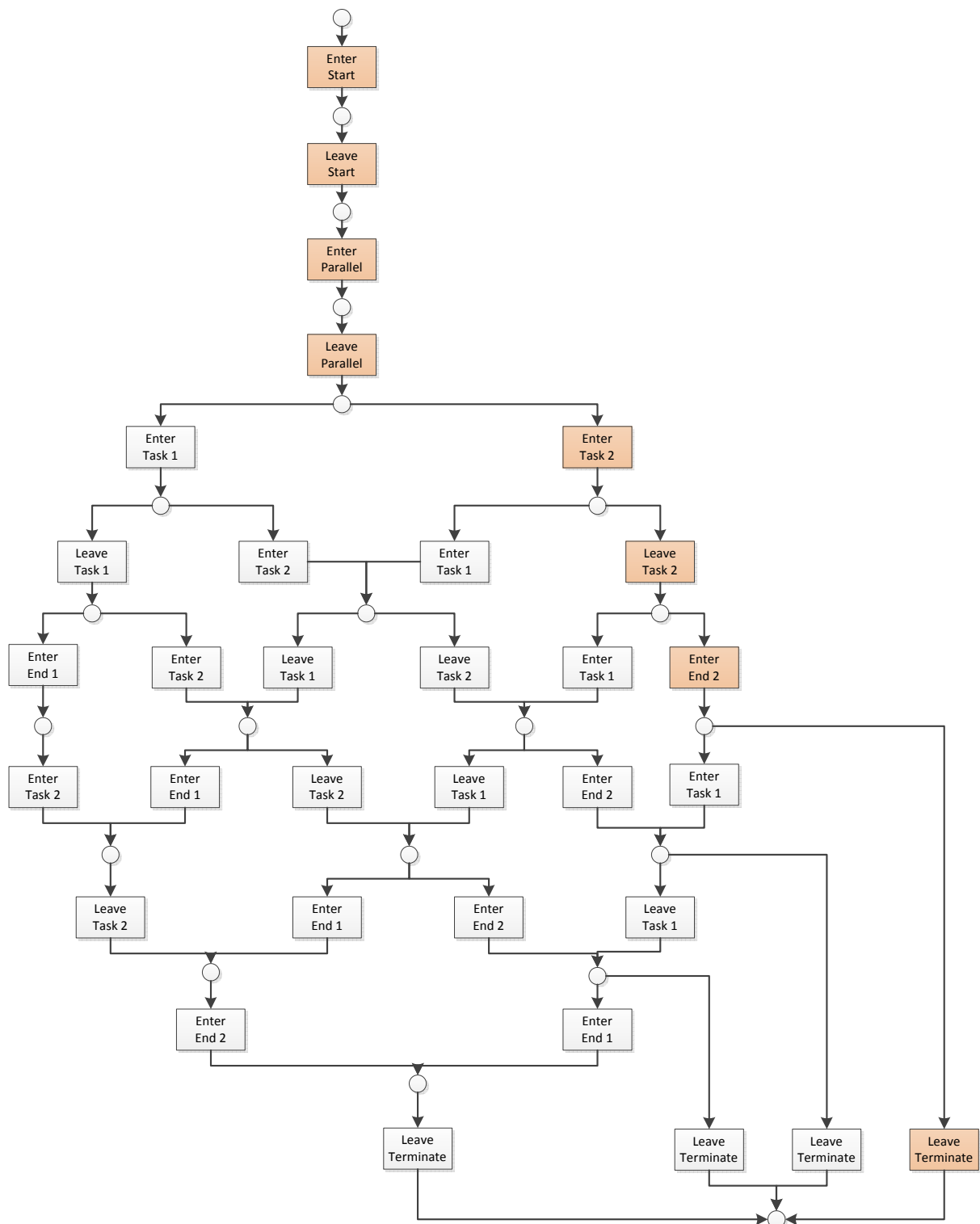
Figure 31: State space of process model (Figure 27, right model)

The token game in Figure 32 shows the same beginning of the path as in Figure 30 (Marking 1-4). Again, the token below will move to task 2 (Marking 5). When the task is completed, the token will move via the sequence flow to the terminate end event (Marking 6-7). When the token has entered the terminate end event, the semantics explained that parallel processes will be ended immediately. This is also visible in Marking 7. The token above does not have the chance to enter task 1, but the process is ended immediately.
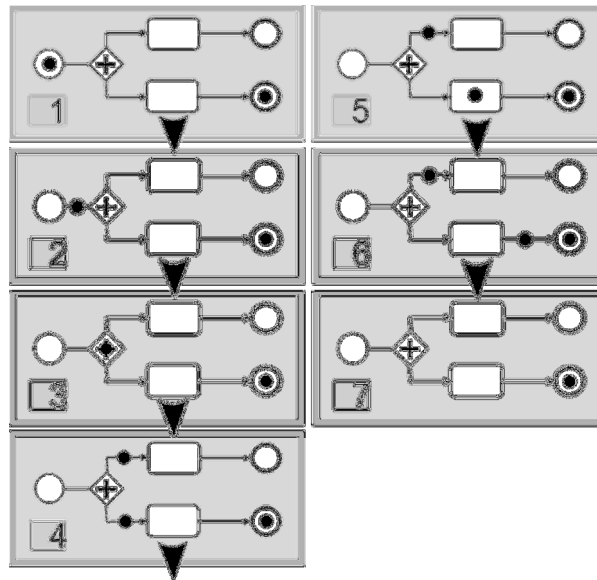
Figure 32: Process path explained using the token game

Appendix J: Compensation Element

This appendix shows the state spaces that are mentioned in section 4.2.3. Figure 33 shows the model with only the basic constructs and Figure 35 shows the same model with the extended construct compensation. The path of the coloured activities in the state space of Figure 33 is illustrated with the token game in Figure 34.
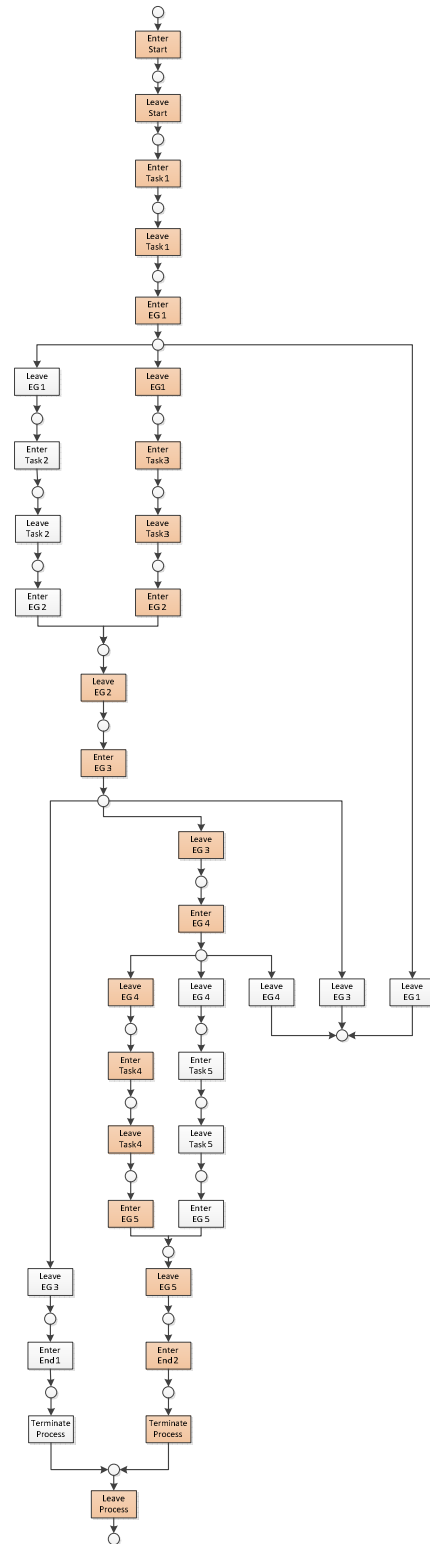
Figure 33: State space of the compensation model basic (Figure 11)

First, it is necessary to introduce a second kind of token, the history token. The history token represents the places the normal token has been and is indicated with a blue dot. The token game in Figure 34 shows how the token moves to Task 1 (Marking 1-3), going further to Task 3 (Reserve IC room)(Marking 4-7), followed by Task 4 (Cancel normal room)(Marking 8-15), and finally ending in the none-end event (Marking 16-19). This means that first an IC room is reserved and later on in the process a normal room is cancelled. This should not be possible.
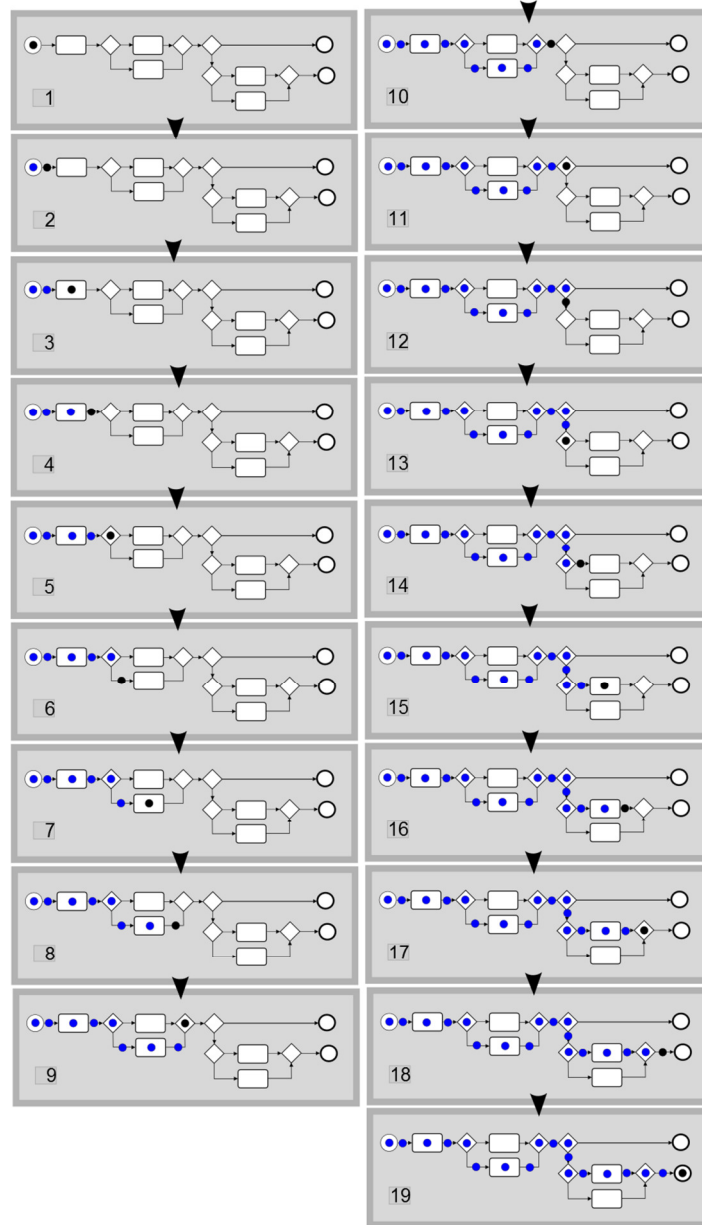
Figure 34: Token game compensation model basic

Figure 35 shows the state space of the model with the compensation construct. The token game in Figure 36 shows the path of the coloured activities.
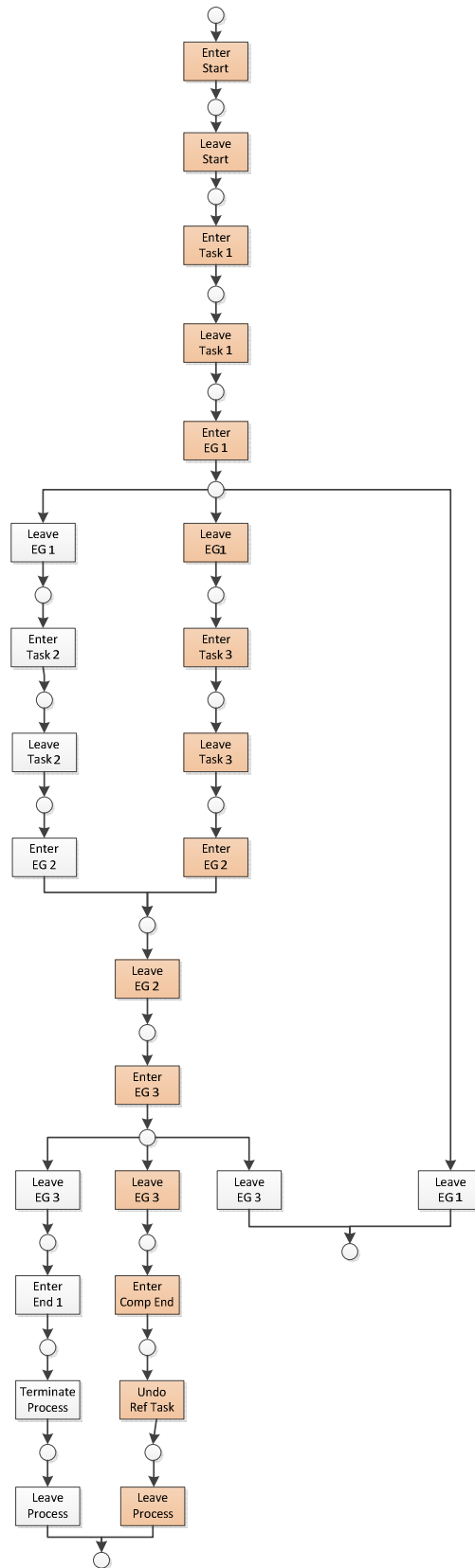
Figure 35: State space of the compensation model extended (Figure 12)

The token game in Figure 36 contains, besides the normal token and the history token, two other kinds of tokens. The undo token, which is indicated with a green dot, represents an on-going compensation for activities that have been completed. The undone token, which is indicated with a purple dot, represents an activity that has been made undone.

The process starts similar to the process in Figure 34. The process moves from Task 1 to Task 3 (Marking 1-7) and moves to the decision to stop the process (Marking 11-12). It becomes interesting when the normal token has entered the compensation end event. This event throws a signal to compensate the activity which has been completed, in this case Task 3. First, the task which needs to be compensated will be made undone. Therefore, the green undo token is in Task 3 (Marking 13). When this task has been made undone, the token is replaced by an undone token (Marking 14). It will not be replaced by a history token, because Task 3 has not been completed successfully. A normal token is in the compensation task (Marking 14), which means that this task is now active. When the task has been completed successfully, the normal token is being replaced by a history token (Marking 15). This example shows that the process will always cancel the room that has been reserved before.
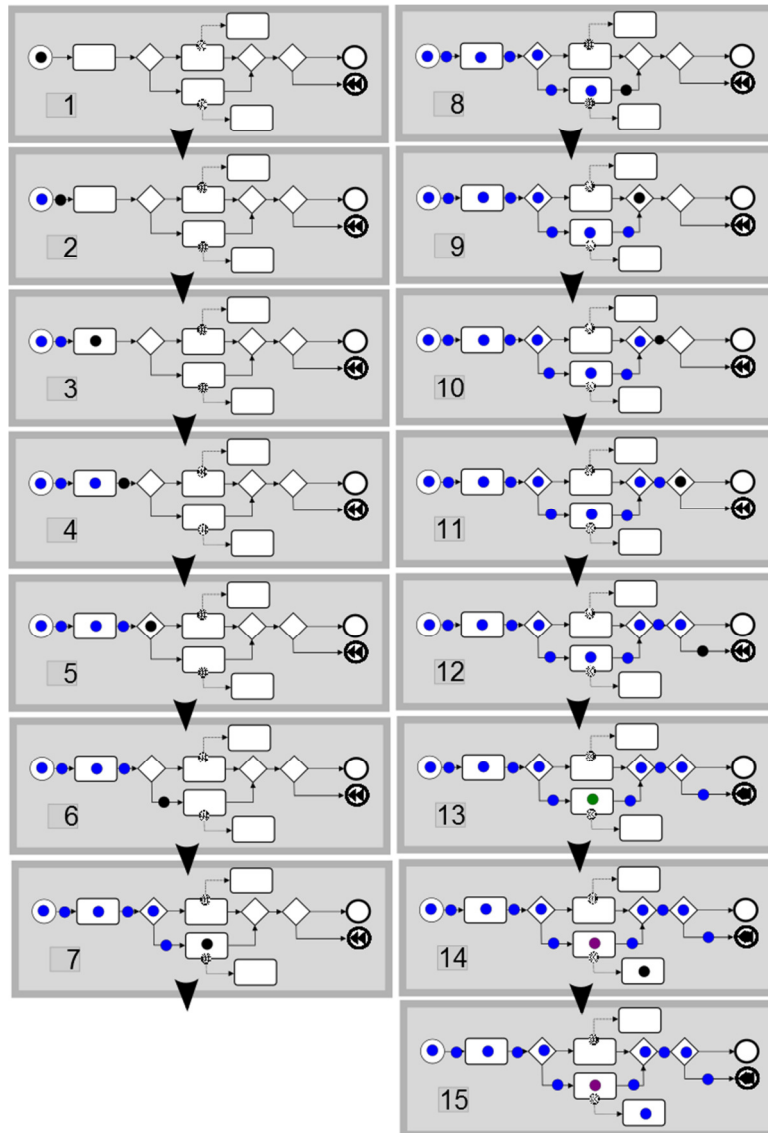
Figure 36: Token game compensation model extended

Appendix K: Extended Constructs and Workarounds

This appendix shows the extended constructs (OR Gateway, Ad Hoc Activity, and Compensation). The workarounds are derived from the state spaces of the extended constructs. However, for the Ad Hoc Activity no state space was available with the program GrGen. Also, the state space of the OR Gateway was not completely correct. For this reason, the descriptions of the semantics are used from Silver (2009) and OMG (2011).

First, a model with the OR-Gateway (Figure 37) is shown with its belonging workaround (Figure 38).
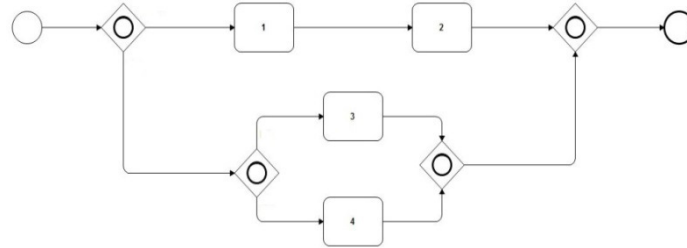
Figure 37: Model with extended construct OR-Gateway

It is possible for the model to complete six different combinations of tasks. This is also possible in the workaround.
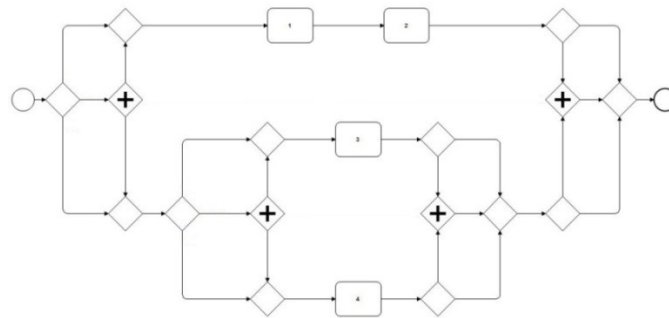
Figure 38: Workaround of model Figure 37

Second, a model with the Ad Hoc Activity is shown with its belonging workaround. The workaround is not derived from the state spaces of the model with the Ad Hoc Activity, but from the description of Silver (2009).
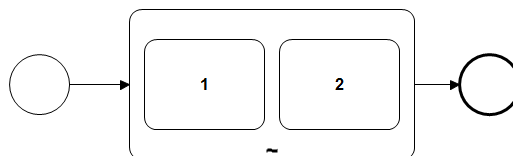
Figure 39: Model with extended construct Ad Hoc Activity

It is possible for the Ad Hoc Activity to perform only one task (1 or 2), one task followed by the other task (serial), both of the tasks in parallel, or none of the tasks. The workaround in Figure 40 shows these possibilities with the basic constructs.
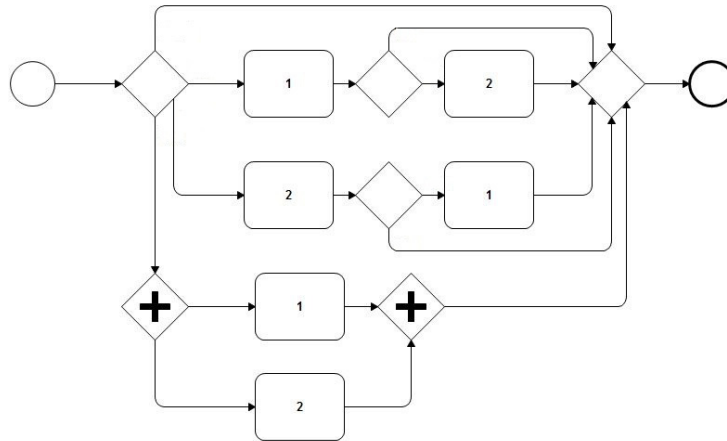
Figure 40: Workaround of model Figure 39

Finally, a model with the compensation element is shown (Figure 41) with its belonging workaround (Figure 42).
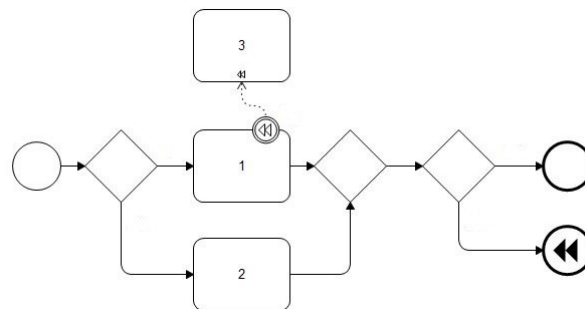
Figure 41: Model with extended construct Compensation
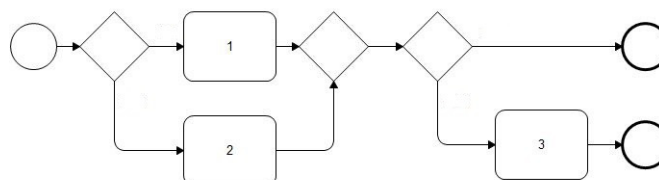
Figure 42: Workaround of model Figure 41

Appendix L: Structure of the Tests

This appendix shows the structure of the two tests in Table 27.

Test	Participants	Questions									
		1	2	3	4	5	6	7	8	9	10
1	1	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	2	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	3	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	4	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	5	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	6	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	...	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
	X	C(b)	IOR(b)	AH(b)	EB	HB	**C(a)**	**IOR(a)**	**AH(a)**	**EB**	**HB**
2	9	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	10	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	11	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	12	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	13	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	14	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	...	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**
	X	C(a)	IOR(a)	AH(a)	EB	HB	**C(b)**	**IOR(b)**	**AH(b)**	**EB**	**HB**

Table 27: Structure of the tests

Table 27 is divided in two groups, the participants who do test 1 (upper column) and test 2 (lower column). Both of the tests consist of 10 different questions, 5 understanding questions and 5 modifying questions. The abbreviations in the table mean the following:

C(b) = Question with the workaround of the compensation construct

IOR(b) = Questions with the workaround of the Inclusive OR gateway

AH(b) = Questions with the workaround of the Ad-Hoc activity

EB = Easy question with only the basic constructs

HB = Hard question with only the basic constructs

C(a) = Question with the extended construct compensation

IOR(a) = Question with the extended construct Inclusive OR gateway

AH(a) = Question with the extended construct Ad Hoc activity

Appendix M: Tests

This appendix shows the two different tests that are created for the experiment.

Test 1

Understanding

1.

The following case is given. A process starts in parallel with on one path the choice of task '1' and task '2', always followed by task '3'. The other parallel path consists of task '6' and '7'. When task '7' is performed there is a decision moment. Here it is decided if task '1' needs be compensated for task '5'. When this has to be done, first task '1' needs be made undone. This is done with task '4'. Task '1' only has to be made undone, when the process actually performed task '1'.

Which of the following models fits best with the given description?

A)

B)

C)
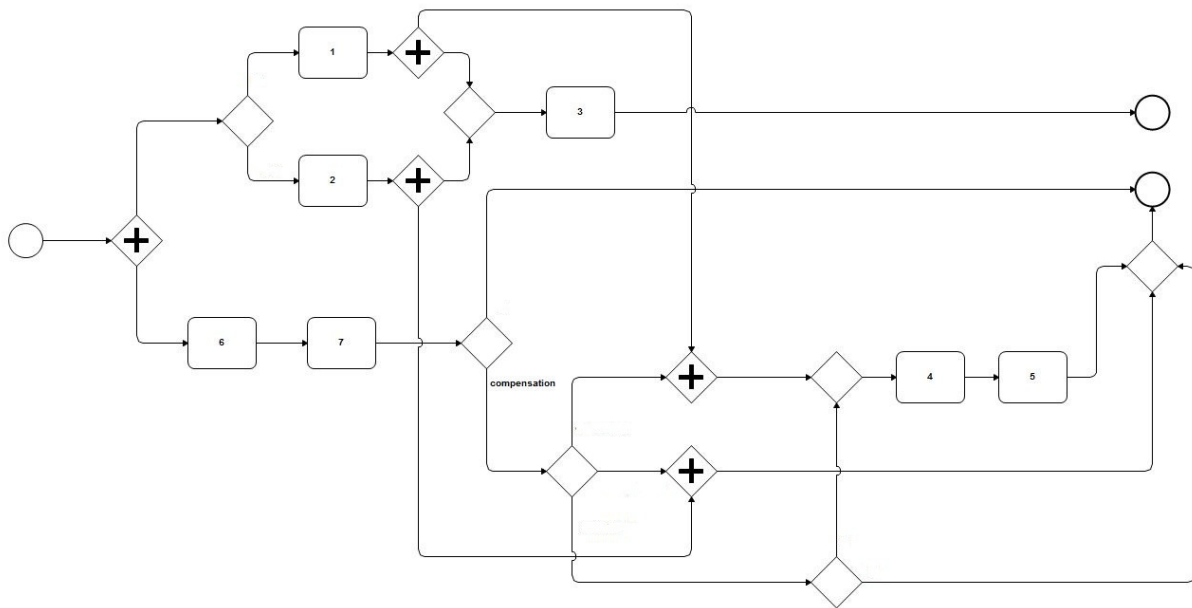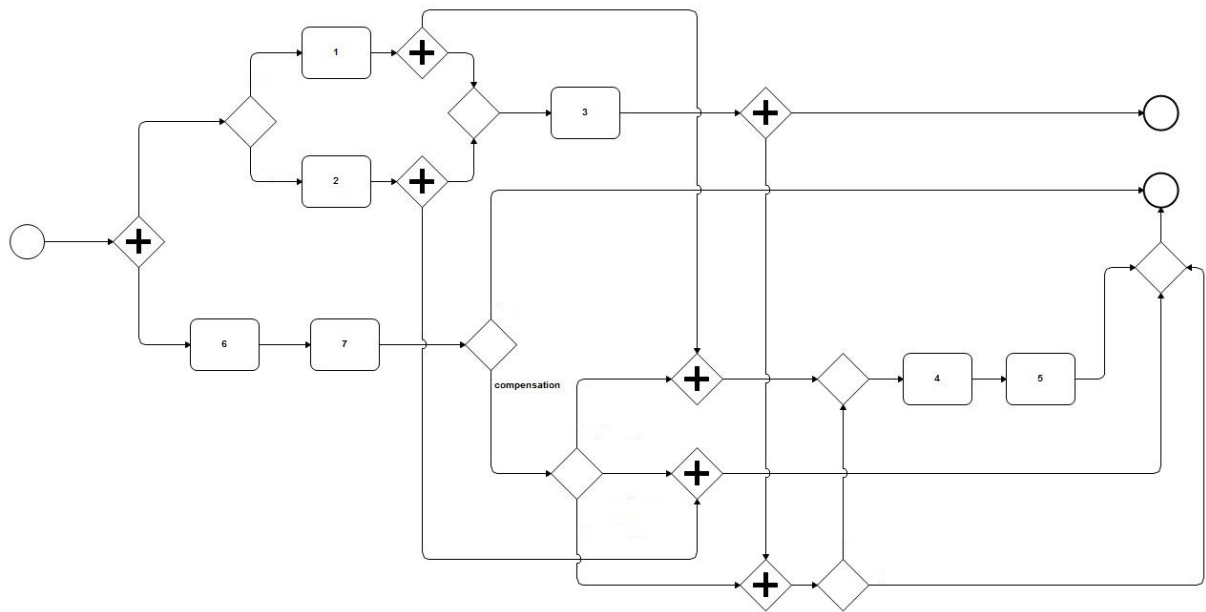
D)
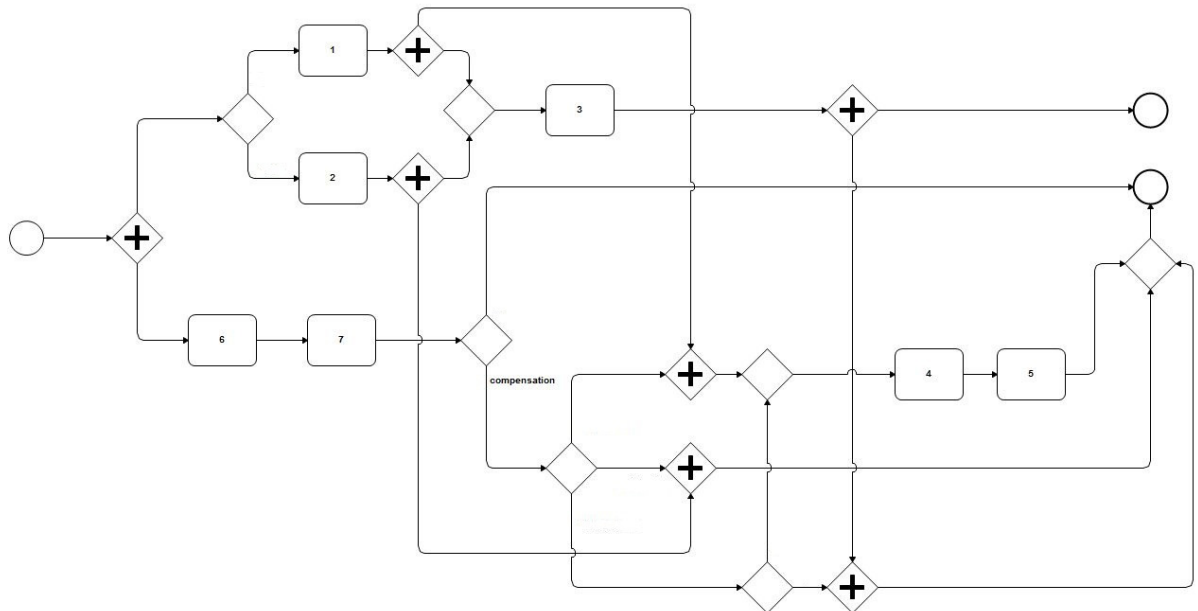
Answer:

2.

The following part of the peri-operative process is given. A patient can receive antibiotics, other medication, or antibiotics and medication. When the patient needs antibiotics then first he will be checked for allergies (1). After this he receives antibiotics (2). When the patient (also) needs medication, he can receive 'medicine A' (3) or/and 'medicine B' (4). After these tasks the process can continue.

How many different combinations of tasks are possible for the model to perform? *(Consider task 1 and task 2 as one task)*
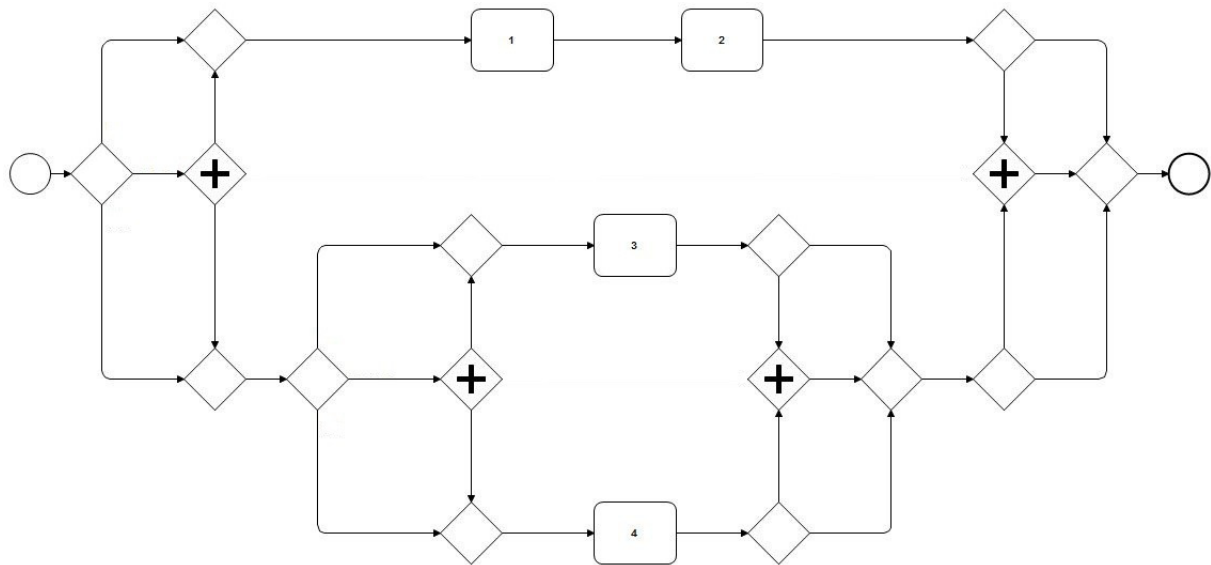
A) 3

B) 4

C) 5

D) 6

Answer:

3.

In the following a part of the peri-operative process is given. The process starts with the anaesthetist who has to perform first three different tasks; namely 'report clinical data' (1), 'report medication' (2), and 'report medication' (3). These tasks can be done in parallel and in a non-specific order. Also, sometimes it is not necessary to complete one or more of the tasks.

The process follows with the anaesthetist who has to 'ask for a consult' (4) with a specialist. When the anaesthetist has asked for a consult, he has to 'report the advice' (5) of the specialist and he has to 'evaluate the report' (6) of the specialist. As holds for tasks 1, 2, and 3, they can be done in parallel and in a non-specific order. Also in this case holds that sometimes it is not necessary to complete one or more of the tasks.

Which of the process models has the best fit with the given description?

B)

C)

89

D)

Answer:

4.

The following part of the peri-operative process is given. When the patient file comes to the planning department, the first task is to 'take note of the patient file' (A). After this, the following tasks can be done in parallel; 'contact the OR-department' (B), 'contact the nurse-department' (C), and 'check the patient file' (D). The OR-department and the nurse-department have to be contacted only in certain situations. The patient file always has to be checked. After these tasks have been performed, the planning department can 'plan in the operation' (E). Which of the following models fits with the description?

A)

B)

C)

D)

Answer:

5.

The following case is given. A process starts with two activities in parallel, 'A' and 'F'. After activity 'A' is finished, activity 'B' will start in parallel with one of the activities 'C' and 'D'.

After activity 'F' follows activity 'G'. When activity 'G' is finished the decision will be made if activity 'F' and 'G' will have to be done again or if the process can continue. When the process can continue, activity 'H' will be performed. Activity 'E' can be executed when all the other previous activities are finished.

Which of the following models fits the description of the process?

A)

B)

C)

D)

Answer:

94
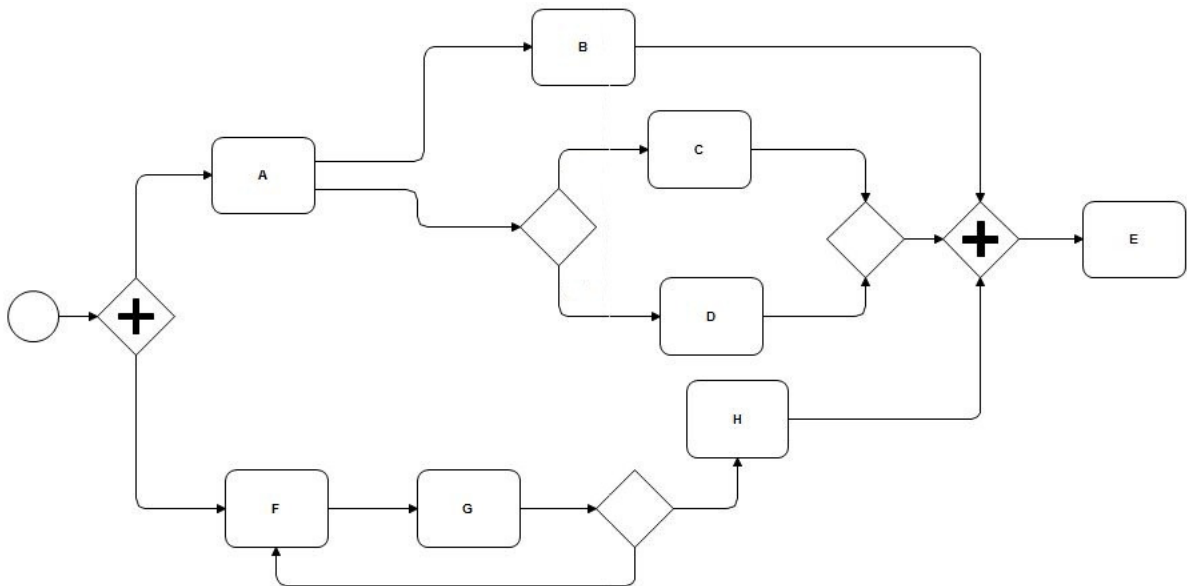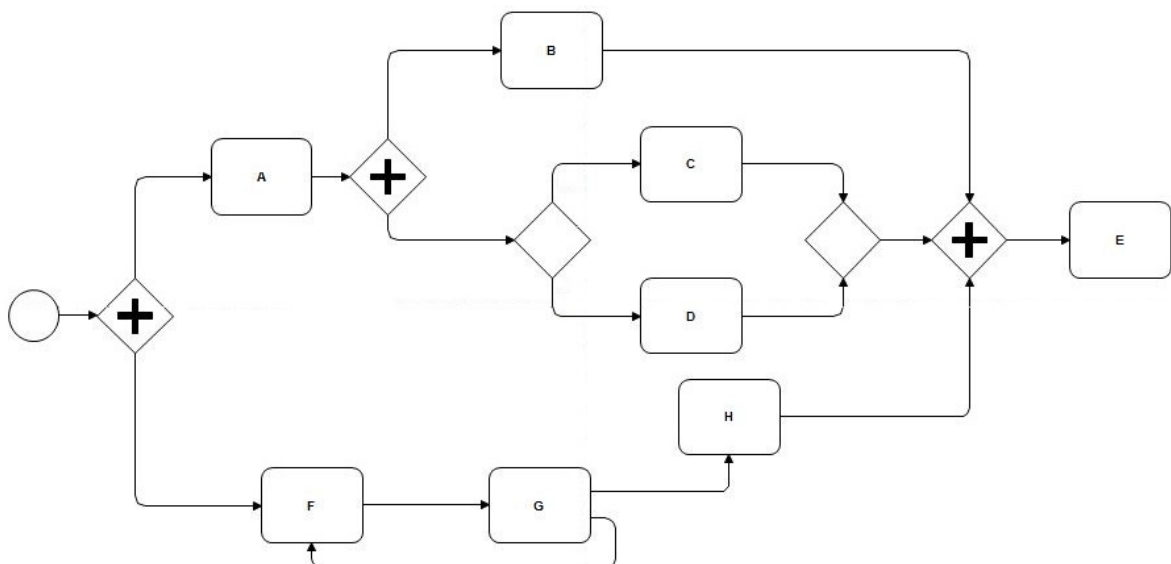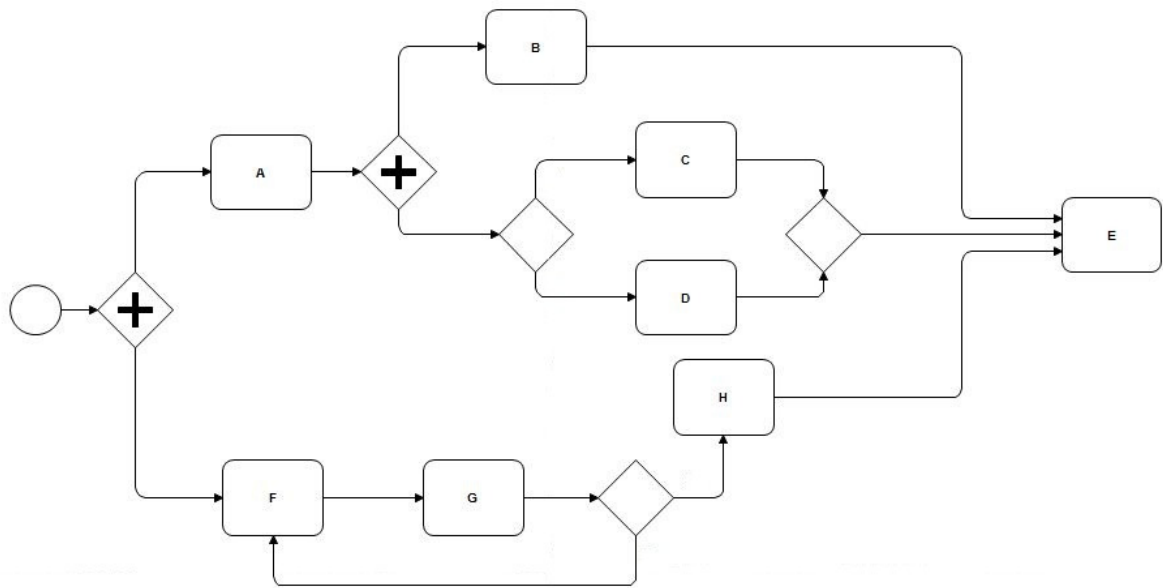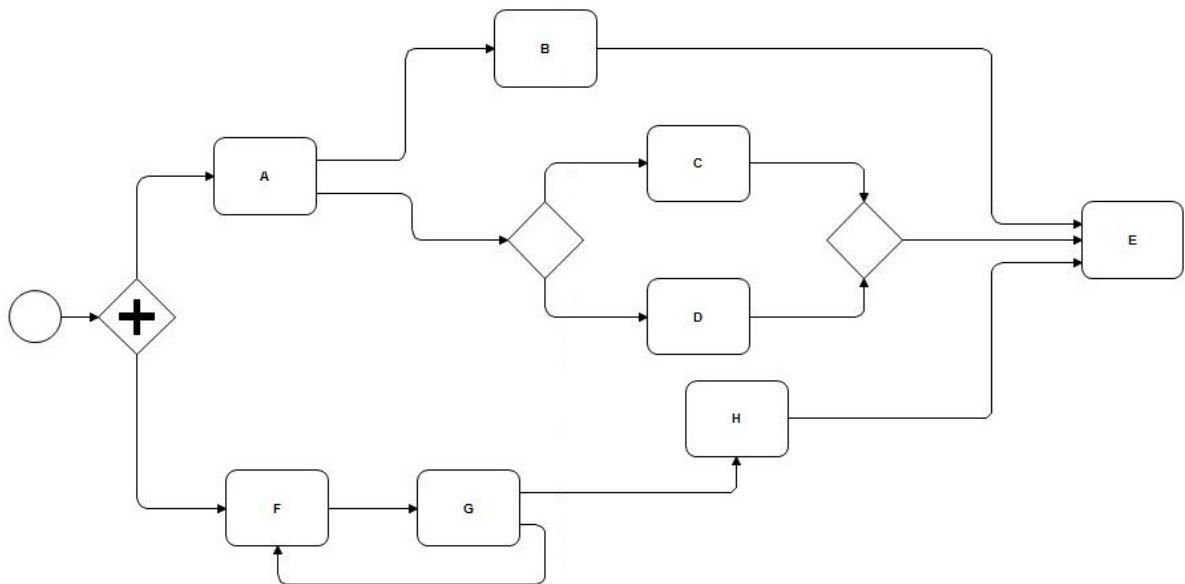
Modifying

6.

In the following a model which is in process is shown that starts with two paths in parallel. After the parallel split in the beginning of the model, the process went to the sub- process and completed task '2'. Currently, task '3' is active. On the other path after the parallel split the process performed task '5' and task '6' and is now about to enter the compensation end event.
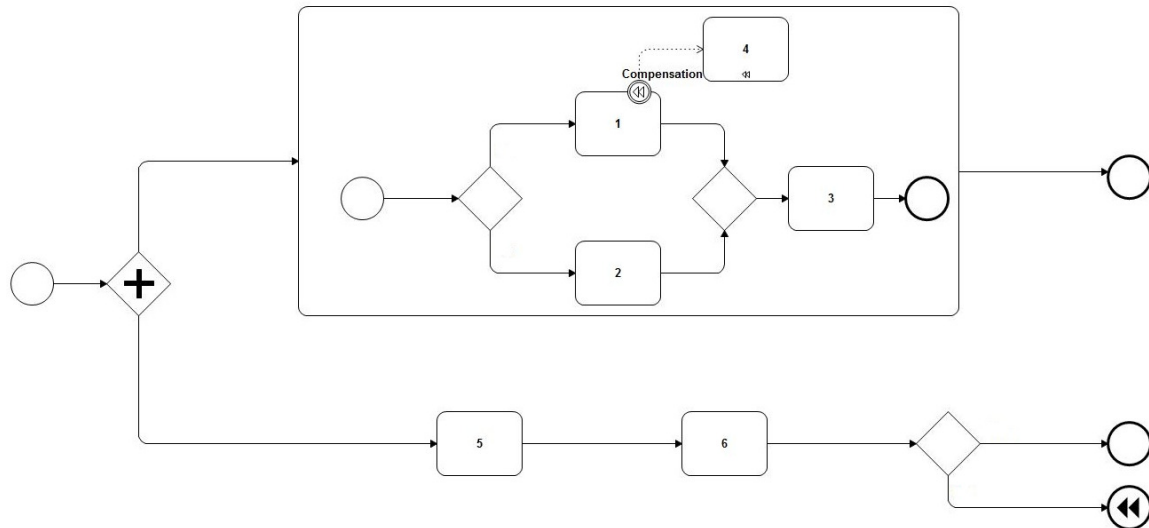

Describe how the model will continue to its final state. *(Nothing has to be modified in the model)*

Answer:

....

....

....

....

7.

In the following a part of the peri-operative process is given. A patient can receive antibiotics and/or other medication. When the patient needs antibiotics then first he will be checked for allergies (1). After this he receives antibiotics (2). When the patient (also) needs medication, he can receive 'medicine A' (3) or/and 'medicine B' (4). After the needed tasks are completed, the process can continue. However, it is also possible that the patient does not need antibiotics or medicine.

Describe how to modify the model in such a way that this is also possible.

Answer:

8.
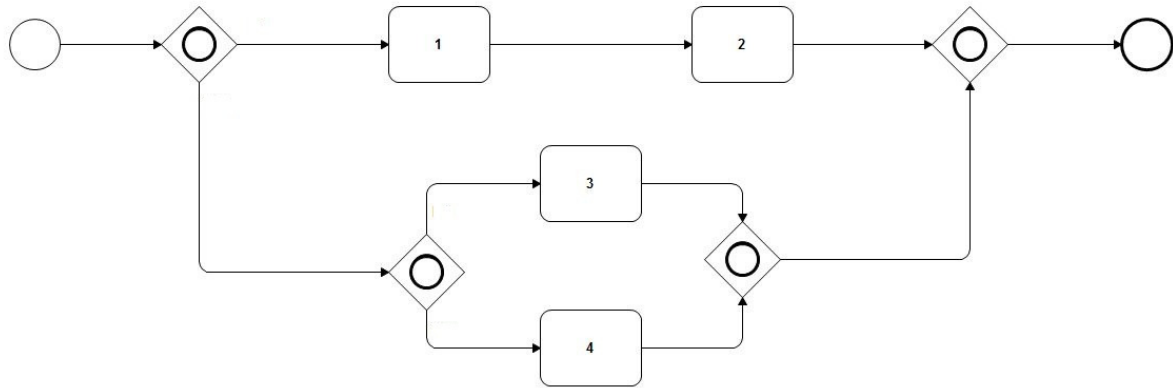
In the following a part of the peri-operative process is given. First, the tasks 'report clinical data' (1), 'report specific measures' (2), and 'report medication' (3) can be performed in a non-specified order. However, 'inform patient' (4) must always be performed after the first three tasks are done. When the patient is informed, 'agreement of patient' (5) and 'agreement of anaesthetist' (6) can be performed in a non-specified order.

How would you modify the model below, so that it will fit the given description?
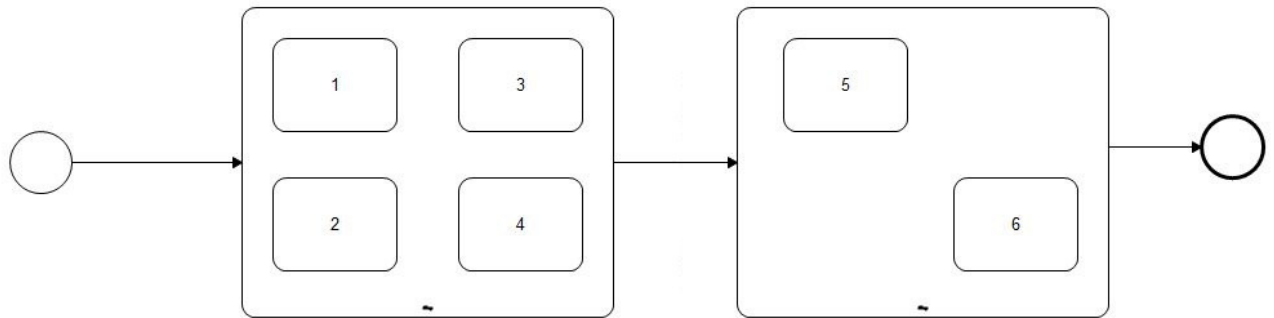
Answer:

9.

The process model below shows a part of the peri-operative process. The process starts with three tasks which need to be done in parallel. These tasks are 'Check OR-department' (1), 'Check Nurse-department' (2), and 'Check patient file' (3). When these tasks are finished, a decision is made to continue the process or to stop the process. When the process is continued, task 'Consultation' (4) can be executed. After this, a similar decision moment happens. When the decision is made again to continue the process, task 'Plan in operation' (5) can be executed.

However, it turns out that task 'Consultation' (4) consists of two tasks (4.1 and 4.2) which can be performed in parallel. Describe how you would change the model?

Answer:

10.

The model below shows a part of the peri-operative process. The process starts with the task 'Check report' (A). When this is completed, 'the patient is brought to the operation room' (B). This is done in parallel with one of the tasks 'check antibiotics' (C) or 'check other medication' (D). When the antibiotics are checked, there is a possibility that in some circumstances this has to be done again.

When the patient has been brought to the operation room, two processes start in parallel. The first path is 'check instruments' (G). The other path decides if the 'report has to be checked' (E) or if immediately the 'anaesthesia instruments have to be checked' (F). When all these activities are completed, the 'time-out can be discussed' (H).

Describe how you would modify the model below in such a way that it will fit the description.

Answer:

Test 2

Understanding

1.

In the following a model is shown which starts with two paths in parallel. After the parallel split in the beginning of the model, the process went to the sub- process and completed task '1' and task '2'. Currently, task '3' is active. On the other path after the parallel split the process performed task '5' and task '6' and is now about to enter the compensation end event.

How many tasks will be completed when the process is finished?
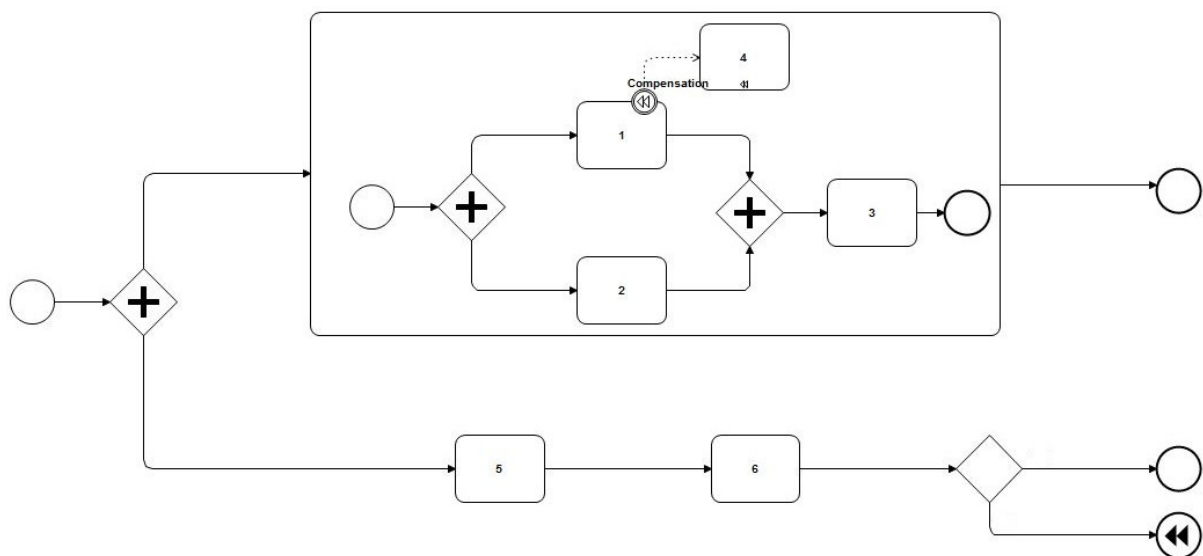
A) 2

B) 3

C) 4

D) 5

Answer:

2.

In the following a part of the peri-operative process is given. A patient has to receive antibiotics and medicine. However, there are two different types of antibiotics and two different types of medicine. Depending on the patient he can receive antibiotics type A (1) and/or antibiotics type B (2). Also, he can receive medicine type A (3) and/or medicine type B (3).

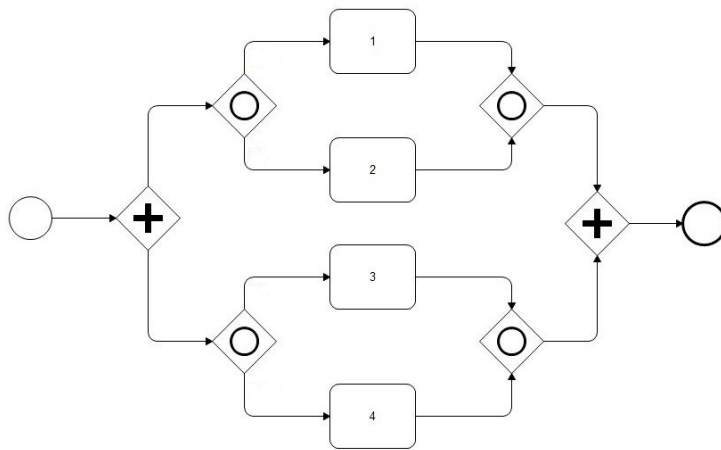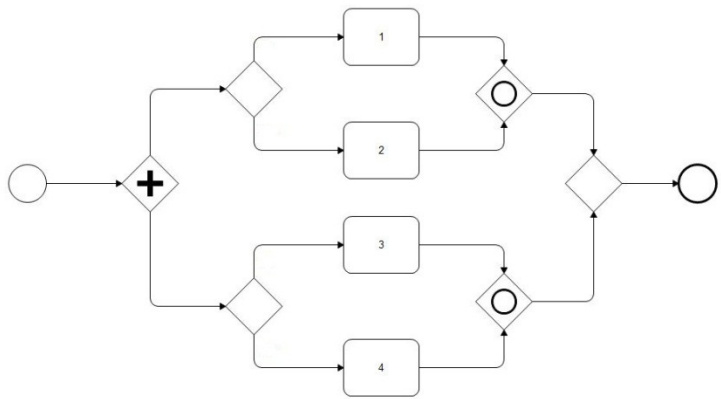Which of the following models fits best with the given description?
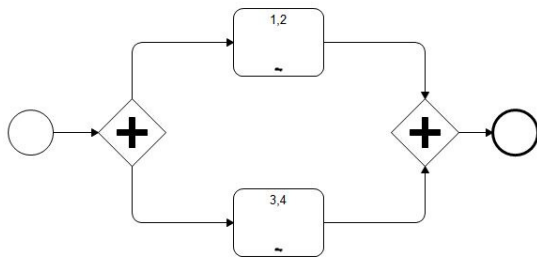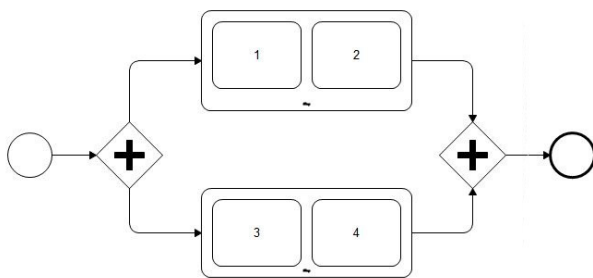
A)
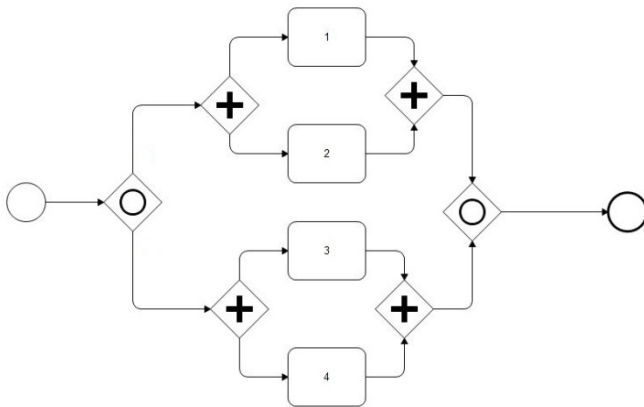
B)
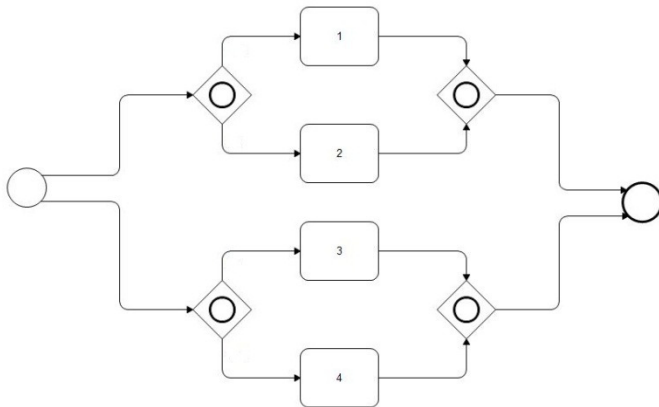
C)

D)

Answer:

3.

The following part of the peri-operative process is given. The process starts with two different processes in parallel. The processes have both two different tasks, namely 'report clinical data' (1) & 'report information operation' (2) and 'report home medication' (3) & 'report specific measures' (4). These tasks have no specific order of execution and can be done in parallel.

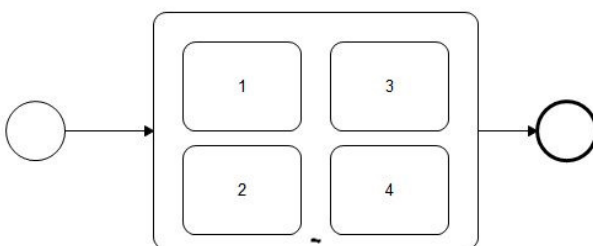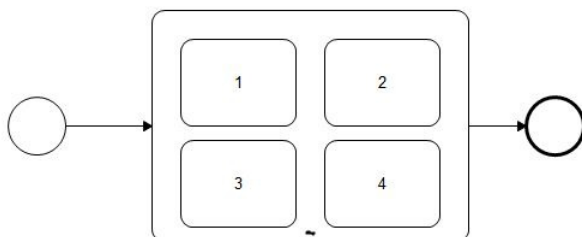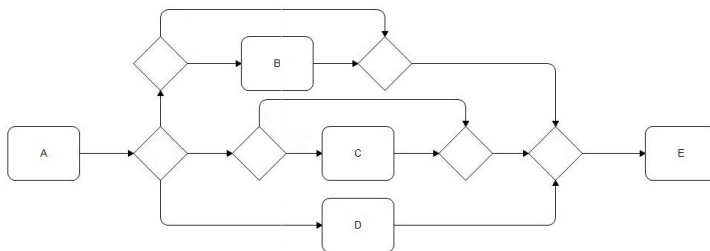Which of the following models fits best with the given description?
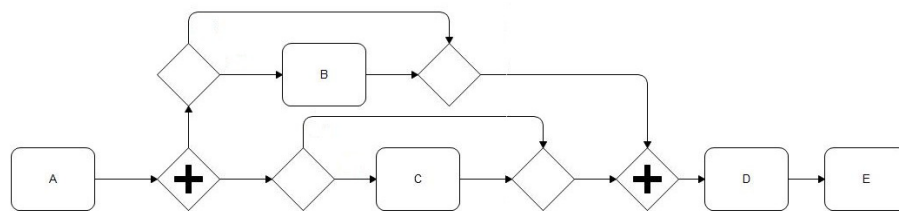
A)

B)

C)

D)

Answer:

4.

The following part of the peri-operative process is given. When the patient file comes to the planning department, the first task is to take note of the patient file (A). After this the following tasks can be done in parallel; contact the OR-department (B), contact the nurse-department (C), and check the patient file (D). The OR-department and the nurse-department have to be contacted only in certain situations. The patient file always has to be checked. After these tasks have been performed, the planning department can plan in the operation (E).

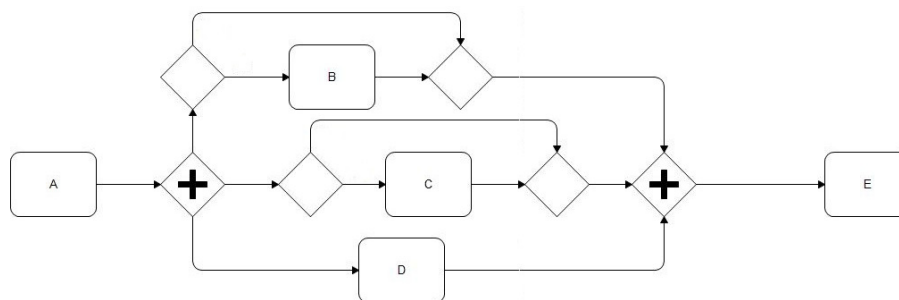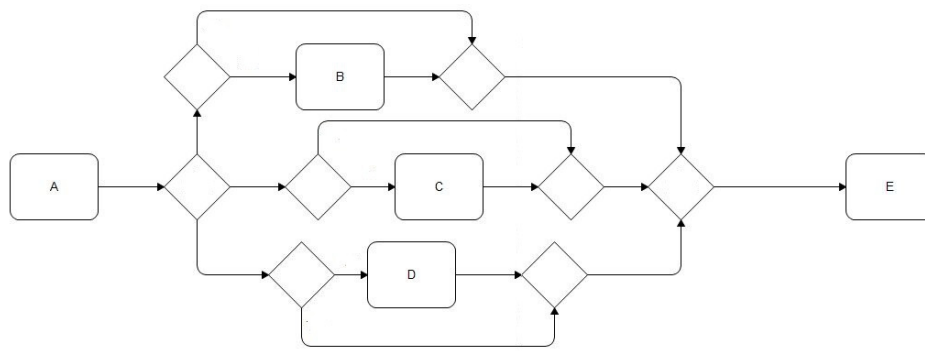Which of the following models fits with the description?

A)

B)

C)

D)

Answer:

5.

The following case is given. A process starts with two activities in parallel, 'A' and 'F'. After activity 'A' is finished, activity 'B' will start in parallel with one of the activities 'C' and 'D'.

After activity 'F' follows activity 'G'. When activity 'G' is finished the decision will be made if activity 'F' and 'G' will have to be done again or if the process can continue. When the process can continue, activity 'H' will be done. Activity 'E' can be executed when all the other activities are finished.

Which of the following models fits the description of the process?

A)
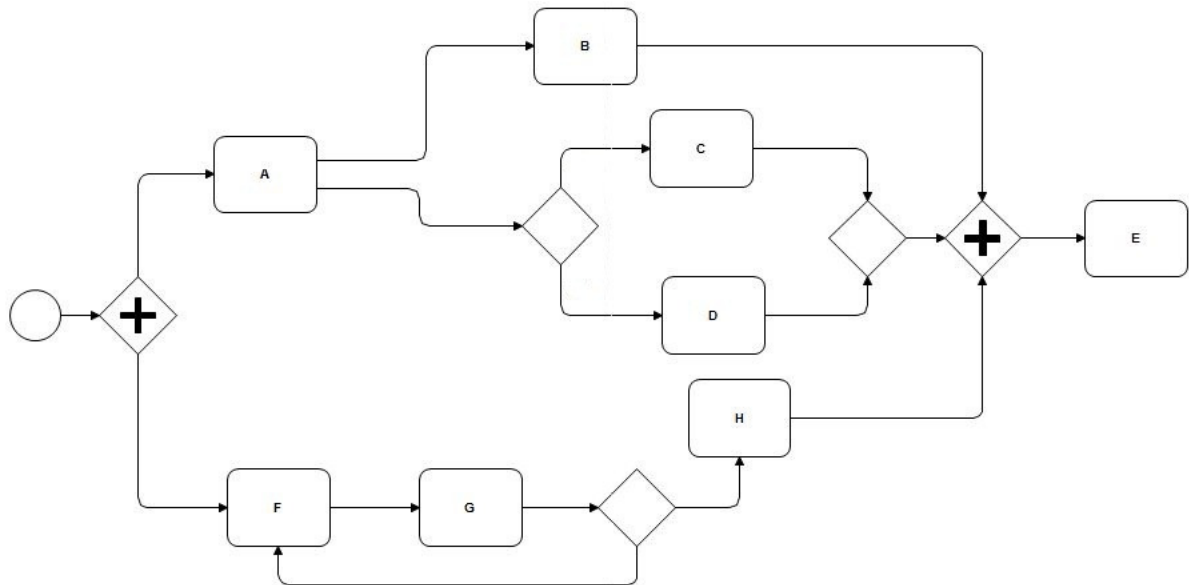
B)

C)
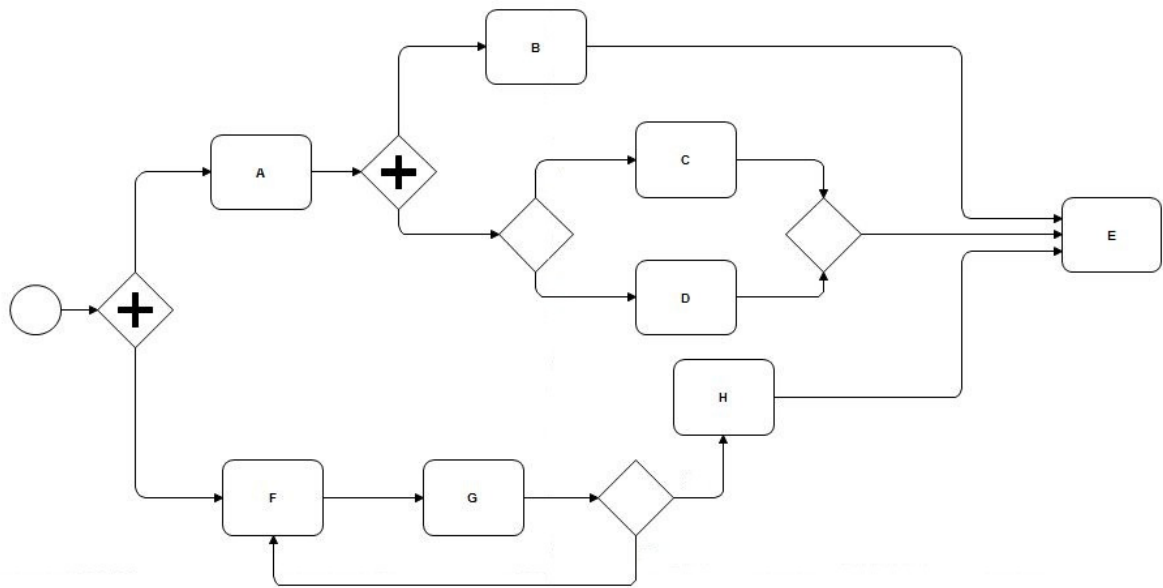
D)
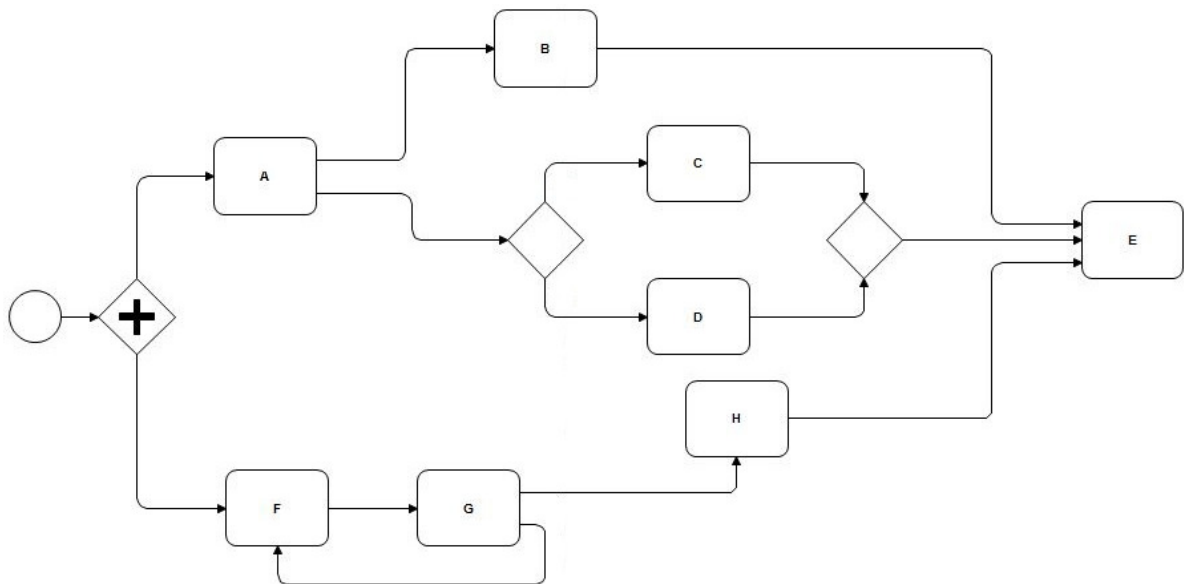
Answer:

Modifying

6.

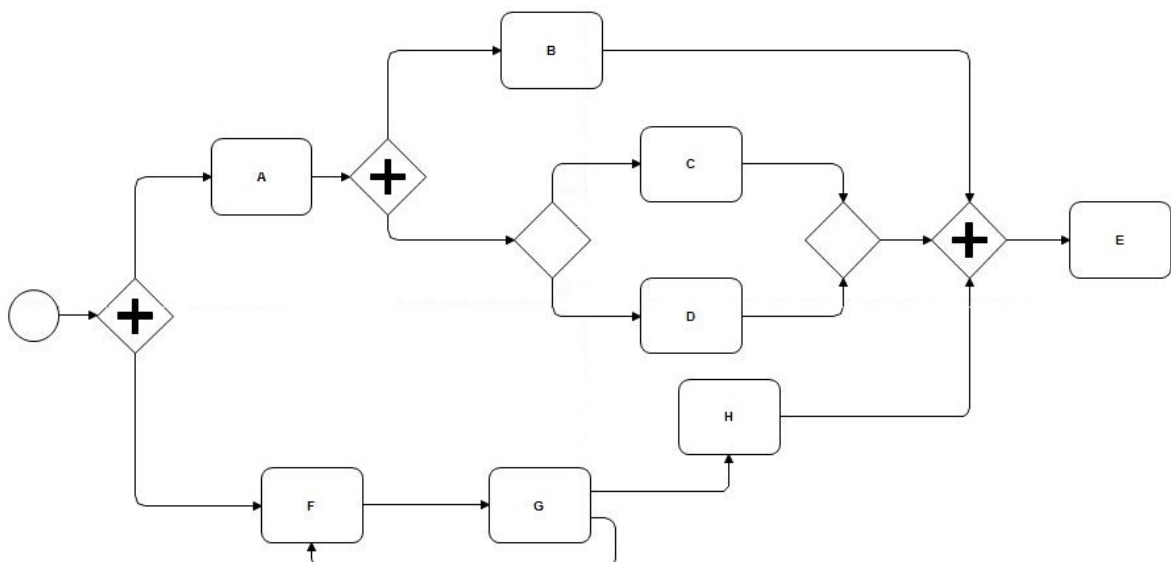The following case is given. A process starts in parallel with on one path in parallel task '1' and task '2', always followed by task '3'. The other parallel path consists of task '6' and '7'. When task '7' is performed there is a decision moment. Here it is decided if task '1' needs be compensated for task '5'. However, first task '1' needs be made undone. This is done with task '4'. Task '1' only has to be made undone, when the process actually performed task '1'.

Describe where you would place task '4' and task '5' in the model so that it will fit the given description. *(Hint: Make use of the letters next to the different gateways)*

Answer:

7.
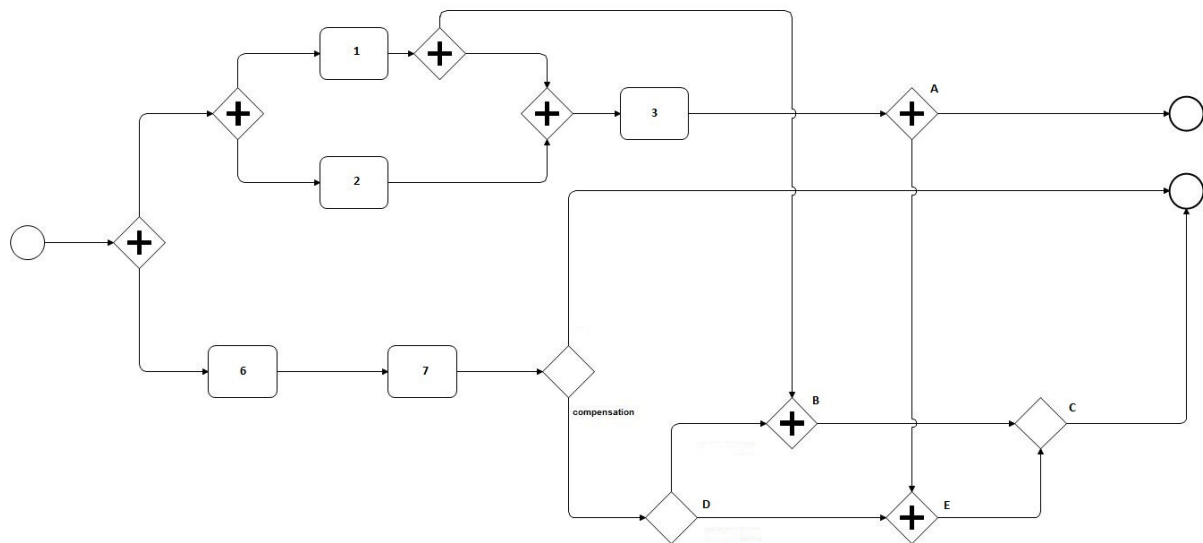
In the following a part of the peri-operative process is given as described in question 2. A patient has to receive antibiotics and medicine. However, there are two different types of antibiotics and two different types of medicine. Depending on the patient he can receive antibiotics type A (1) and/or antibiotics type B (2). Also, he can receive medicine type A (3) and/or medicine type B (4).

Describe how you would modify the model below so it will fit the given description?

Answer:

8.
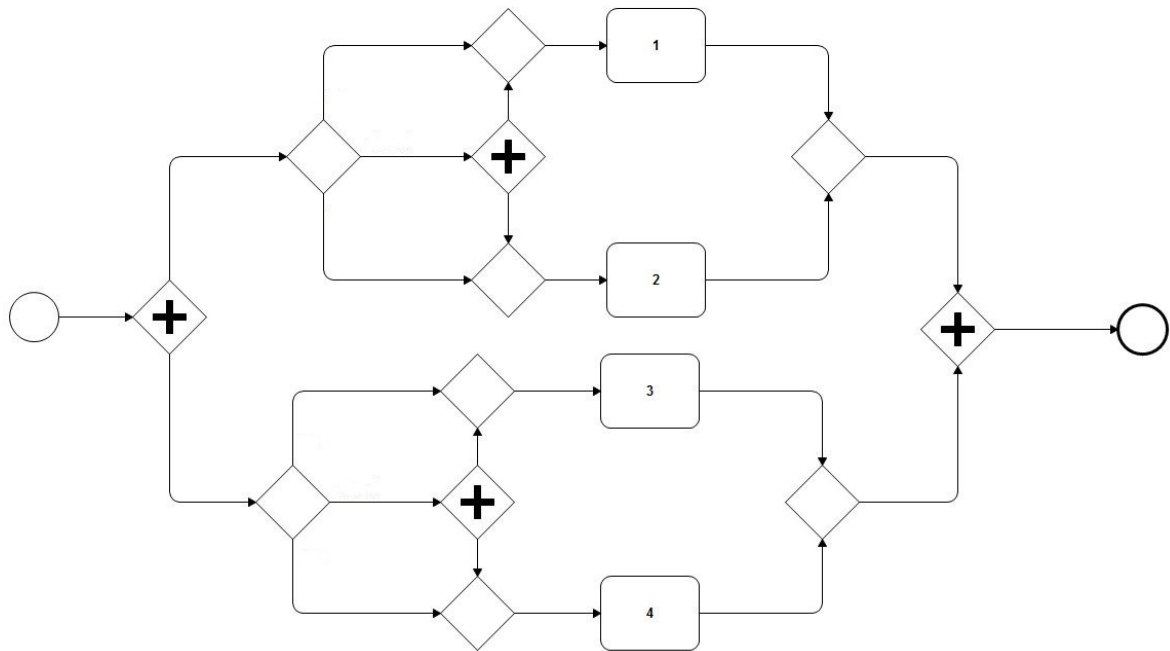
In the following a part of the peri-operative process is given. After the operation the operator and the anaesthetist have to perform the following tasks. The operator performs the tasks 'report possible complications' (1) and 'report other particulars' (2). In parallel the anaesthetist performs the same tasks, namely 'report possible complications' (3) and 'report other particulars' (4). These tasks do not have a specified order of execution and it is not necessary to complete the tasks.

Describe how you would modify the model so that it will fit with the given description?
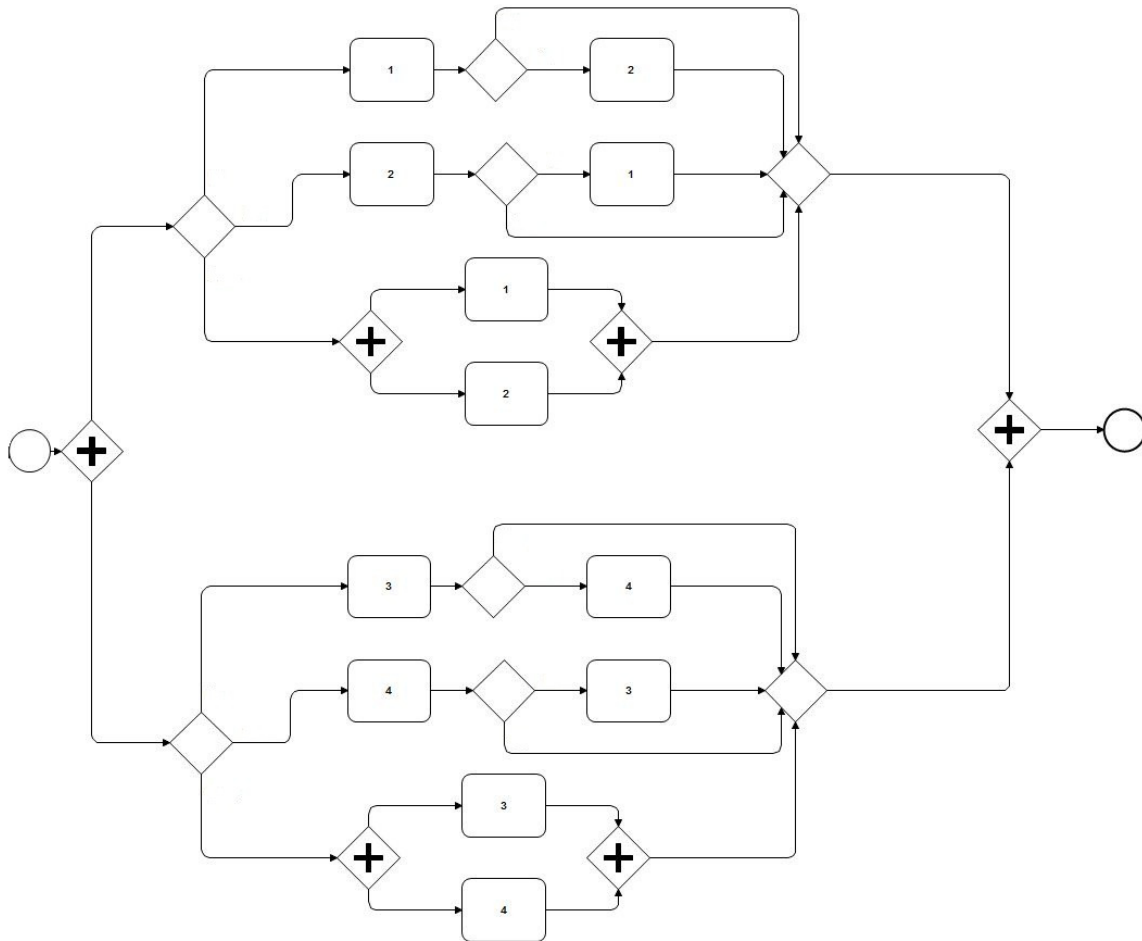
Answer: ....

....

....

....

9.

The process model below shows a part of the peri-operative process. The process starts with three tasks which need to be done in parallel. These tasks are 'Check OR-department' (1), 'Check Nurse-department' (2), and 'Check patient file' (3). When these are finished decision is made to continue the process or to stop the process. When the decision is to continue the process, task 'Consultation' (4) can be executed. After this, a 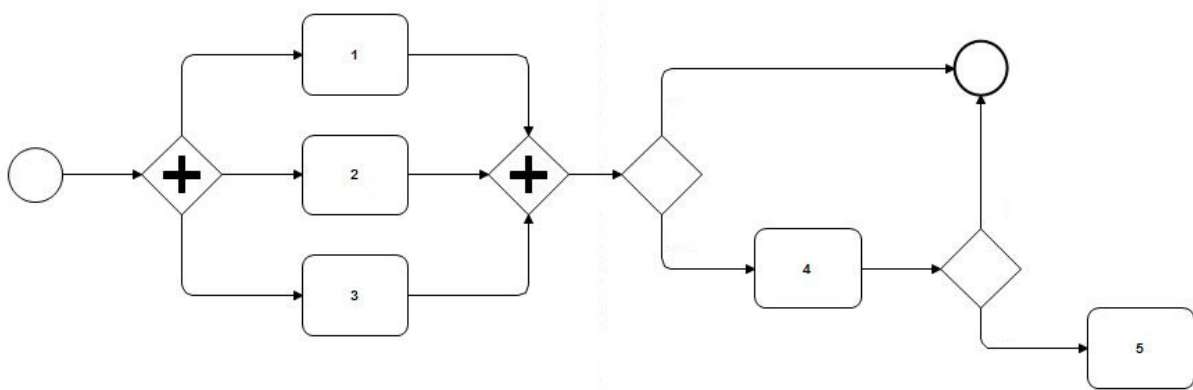similar decision moment happens as before. When the decision is made to continue the process, task 'Plan in operation' (5) can be executed.

However, it turns out that task 4 consists of two tasks (4.1 and 4.2) which can be performed in parallel. Describe how you would modify the model?

Answer:

....

....

....

....
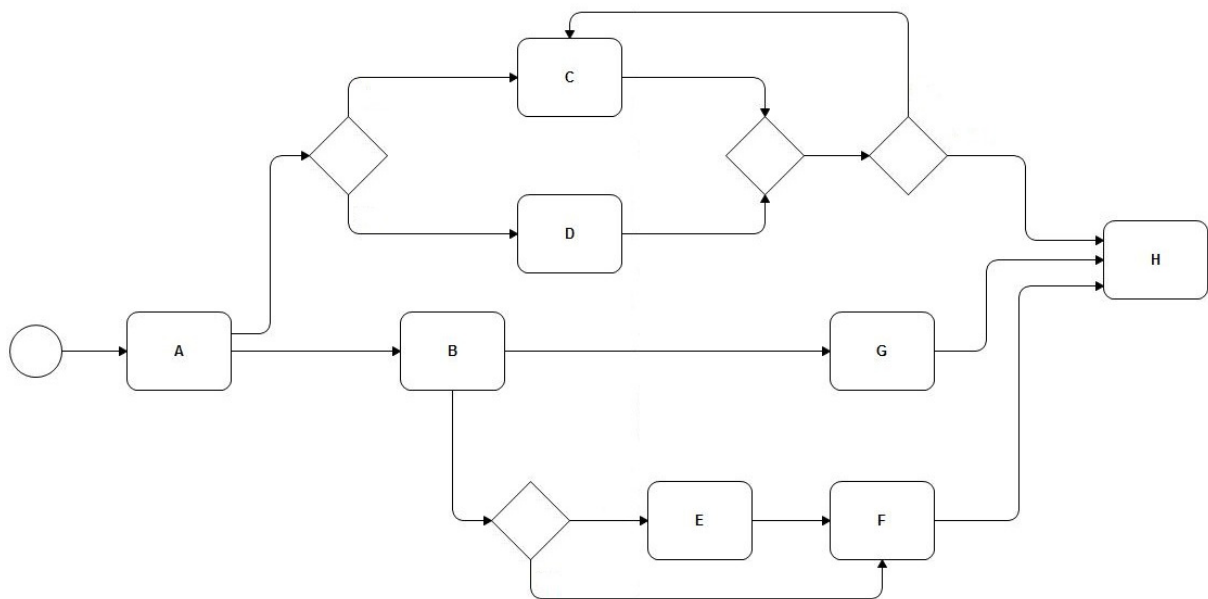
10.

The model below shows a part of the peri-operative process (although not entirely correct). The process starts with the task 'Check report' (A). When this is completed, 'the patient is brought to the operation room' (B). This is done in parallel with one of the tasks 'check antibiotics' (C) or 'check other medication' (D). When the antibiotics are checked, there is a possibility that in some circumstances this has to be done again.

When the patient has been brought to the operation room, two processes start in parallel. The first path is 'check instruments' (G). The other path decides if the 'report has to be checked' (E) or if immediately the 'anaesthesia instruments have to be checked' (F). When all these activities are completed, the 'time-out can be discussed' (H).

Describe how you would modify the model below in such a way that it will fit the description.

Answer: ....
....
....
....

Appendix N: Example Workshop

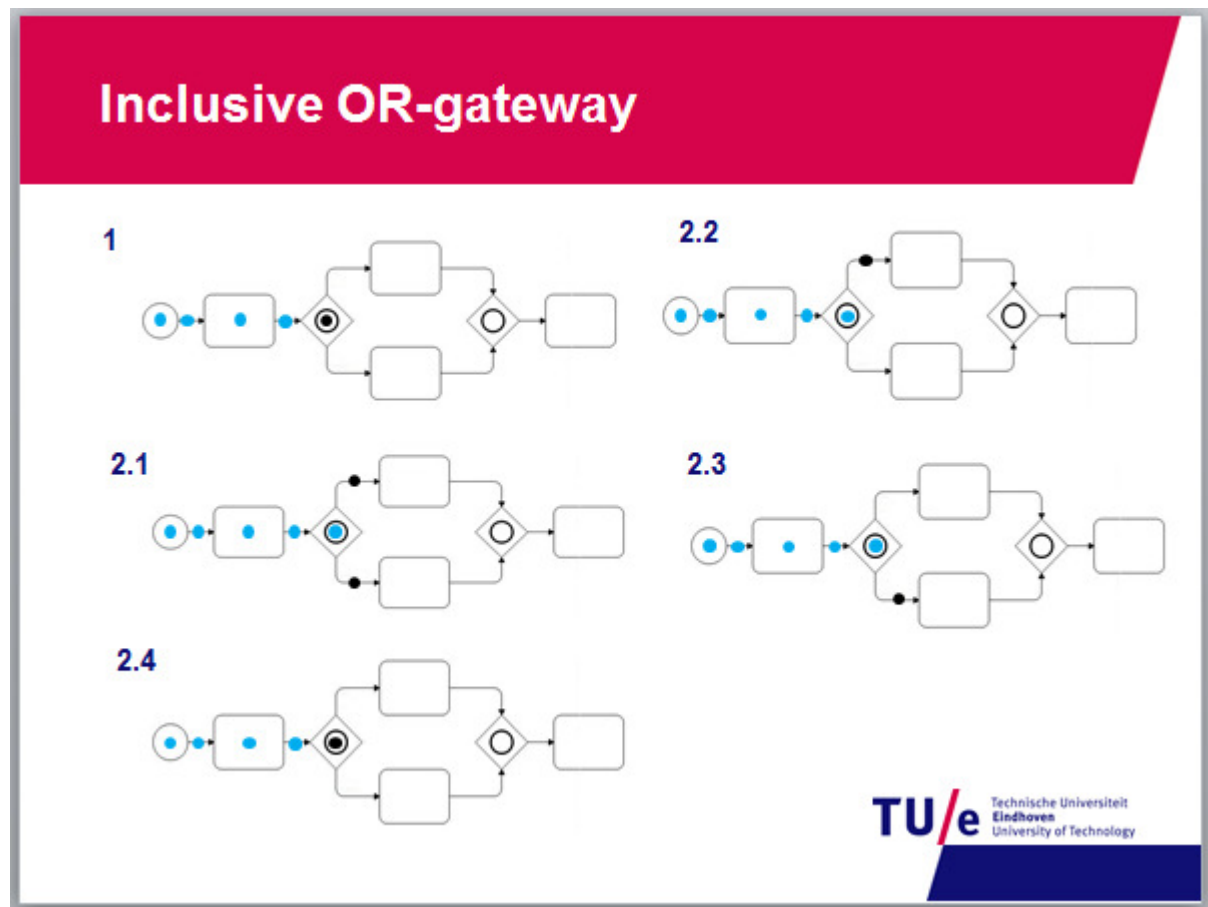In this section an example is given of the remote workshop. In Figure 43 a process is explained using the token game.

Figure 43: Example of process model explained in the workshop using the token game

Appendix O: Norm Determination

In this section the norm determination is given for the questions of the test in Table 28 and Table 29.

Test 1		
Question	**Answer**	**Points**
1	C	10
2	D	10
3	D	10
4	C	10
5	A	10
6	Task 2 will be compensated	2
	Task 5 will be compensated	2
	Task 6 will be compensated	2
	Task 3 will complete successfully	2
	The process will end in the none-end event	2
7	Sequence Flow out of the first IOR above to the last IOR above	5
	Sequence Flow out of the first IOR below to the second IOR below	5
8	Remove task 4 from the Ad Hoc activity	5
	Place task 4 between the two Ad Hoc activities	5
9	Place a parallel gateway before task 4	2,5
	Place a parallel gateway after task 4	2,5
	Remove task 4	2,5
	Place task 4.1 and 4.2 between the parallel gateways	2,5
10	Place an Parallel gateway before task H Everything corrected to an error is -2	10
	Total	100

Table 28: Norm determination of test 1

Test 2		
Question	**Answer**	**Points**
1	A	10
2	C	10
3	B	10
4	C	10
5	A	10
6	Place task 4 after Gateway B	5
	Place task 5 after task 4	5
7	Place an Exclusive Gateway after task 1/2	2
	Place an Exclusive Gateway after task 2/1	1
	Place a Parallel Gateway between the Exclusive Gateways	2
	Use the same steps for task 3 and 4	5
8	Place a Sequence Flow between the upper Extended Gateways	5
	Place a Sequence Flow between the lower Extended Gateways	5
9	Place a parallel gateway before task 4	2,5
	Place a parallel gateway after task 4	2,5
	Remove task 4	2,5
	Place task 4.1 and 4.2 between the parallel gateways	2,5
10	Place an Exclusive gateway before task H	10
	Total	100

Table 29: Norm determination of test 2