University of Applied Sciences and Arts Northwestern Switzerland
School of Business

Master Thesis: Modelling Language for Domain-Specific Decisions in Healthcare

Creating a domain-specific modelling language to cover the needs of the healthcare sector focusing on patient transfer decisions from acute hospital to rehabilitation clinic

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Abstract

Healthcare is a major expenditure in today's economy. In order to save costs while maintaining or even improving quality, optimal practitioner support is required. In this thesis, it is investigated, how actors that are dealing with the transferal management processes and decisions, can be assisted with the help a domain-specific modelling language. The transferal management domain can be assigned to the administrative pathway in healthcare and is as an example dealing with the interface between acute hospital and rehabilitation clinic.

In an extensive literature review, I have found out, that business process management and process modelling, as a part of it, do enjoy a high importance in companies. In the last few years, standards for modelling processes such as BPMN are more and more adopted and accepted. However, these standards are usually not domain-specific but general-purpose. The healthcare sector however, due to its characteristics, seems to require a domain-specific modelling language, which provides domain-specific constructs and is easy to use and to understand. This has also been agreed by several researchers, who developed a domain-specific modelling language for healthcare to provide better support. These languages were always targeting the clinical pathway and thus no solution for the more administrative activities and decisions in transferal management was identified.

The University of Applied Sciences St. Gallen is conducting a research project to provide better process and decision support for transfer management. The results of this project (mainly the transferal management reference process and the description of a specific transferal management case) are used to define requirements for the domain-specific modelling language. The analysis of the provided documentation shows, that a combination of several existing languages is needed to reflect domain-specific peculiarities. Namely, BPMN, DMN, CMMN, Control Element Model, Organization Model and Documents and Knowledge Model are used. These languages are not only combined but domain-specific concepts are added while unneeded concepts are removed. To properly define a new domain-specific modelling language, three parts are available as highlighted in literature review: abstract syntax, concrete syntax and semantics. All these are compiled for the new language in this work.

The development of the modelling language is taking place in ADOxx Development Toolkit, which is a metamodelling platform accepted by the research community. Each language has been extensively adapted to reflect domain-specific concepts such as dozens of new modelling elements or about 300 new attributes. References between different elements ensure integration and an easy navigation between model parts. With the integration of DMN into the new language, decisions can be modelled down to each individual rule. To enable standardization and exchange in the domain, important healthcare and rehabilitation standards such as DefReha©, ICF and ICD are considered.

To demonstrate, that the reference process and the provided use case cannot only be readily modelled in the new language, but at the same time are improved and fulfil the requirements, respective models are provided and evaluated. The models created in ADOxx Modelling Toolkit especially proof, that due to the integration of several languages and standards, most of the necessary information is now concentrated at one point. This was also revealed in the evaluation with a focus group of domain and modelling experts. They further emphasized that the new language achieves to simplify the modelling process and the actual models. Another mentioned main advantage is especially the integration of DMN, CMMN and important standards of the domain.

In the end of the work I have identified possibilities for future research. Due to the limited amount of time which was available to develop the language, the respective library can be further improved with additional and more advanced functionalities. This implies to more and more introduce automation and executability of the language. While with the consideration of the most relevant standards of the domain, already an important step is done, there is further possibility to fully cover all relevant standards. Also an applicability testing of the developed language in other scenarios and environments would be required. This would include to allow the modelling of other transferal management scenarios besides only the transfer from acute hospital to rehabilitation clinic.

Keywords: DSML, BPM, BPMN, DMN, CMMN, Organization Model, Document and Knowledge Model, Healthcare, Transferal Management, ADOxx, Business Process Management, Decision support, Modelling, Meta model, Semantics, Syntax, DSML4PTM

Foreword / Acknowledgements

During the last seven months I have worked hardly on my master thesis to finish my studies at University of Applied Sciences and Arts Northwestern Switzerland (FHNW) and at University of Camerino (Unicam). It was a very informative time but also a period characterized by long, challenging days. Therefore I am very pleased and proud, that I can now present the finished result to the reader. Getting through these seven months and delivering a satisfying result in the end, was only possible with the support of several people. I hereby want to use the opportunity to personally thank them.

Firstly, I want to thank Prof. Dr. Barbara Re, for taking over the supervision from Unicam side. This involves first of all, enabling me to work on this very interesting topic by accepting my research proposal and thus showing interest into this domain. Secondly, I am thankful for her time invested into the evaluation of this work as second supervisor and for any feedback provided.

This brings me to my first supervisor, Prof. Dr. Knut Hinkelmann from FHNW. I appreciated working together with Knut ever since I started with my studies. Even though, he always is busy with several research projects, with teaching or with activities concerning his dean mandate, he took the time to provide me with helpful advices when needed. I like Knut's pragmatic nature and I am very thankful for the expertise that he brought in. Knut's advices immediately allowed me to improve my work as they were always concrete and comprehensible. This also enabled me to stay on track and to meet set deadlines.

My main gratitude goes to the co-supervisor Emanuele Laurenzi. Emanuele was acting as an interface between me and the University of Applied Sciences St. Gallen (FHSG). He thus provided me with needed information to complete my work and also brought in domain-expertise. This was especially helpful in eliciting domain-specific requirements which are the foundation for delivering a useful result. During the most work-intensive period, we held weekly meetings to have a look at the latest results. We even met on weekends to make sure that I can progress as planned. These discussions were always very fruitful and we often completely forgot the time as we had so many ideas to discuss. This is especially remarkable as Emanuele was under pressure with other projects during that time. In my opinion, Emanuele and I complement each other very well. He brought

in a lot of research expertise, while I was more focused on technical feasibility and on the practical side. This allowed me to produce a result which does not neglect the research aspect of this work. Emanuele also identified and invited domain and modelling experts to an evaluation session and supported me in the preparation and execution of this session.

I am very thankful to all experts from FHSG who took part in the mentioned evaluation session. Prof. Dr. Rainer Endl as lead of the “Patient Radar” project was mainly acting as a domain expert, who knows the transferal process very well. Dr. Claudia Pedron and Sandro Emmenegger were invited as modelling experts and additionally brought in a long-term view as they were always looking for possibilities to allow the execution of the language in a later stage. I received a lot of useful inputs to improve the work and possibilities for further research.

Next, I thank Benjamin Lammel from FHNW for taking the time to train me in developing a domain-specific modelling language in ADOxx. It was very useful to get an introduction into the tool from somebody who has already done a similar work. He even personalized the training according to my needs and left time to discuss questions concerning my master thesis. Even though, only the basics of the tool were shown, it was a good fundament to build on. For some, more advanced functionalities of the toolkit, employees of BOC Asset Management GmbH have supported me. I want to thank them for taking their time and also for providing me with the library that I used to develop my domain-specific modelling language.

Lastly, I thank my girlfriend Alessa and my mother Tosca for any mental support that was needed during the last months. Additionally, they proofreaded my work and brought in the outside view. This ensured, that the work can also be understood by somebody with limited domain or technical knowledge.

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1. Introduction

The first chapter is concerned with a short introduction into the background and purpose of the present master thesis. This covers defining the intention of this work, the currently existing problem and also includes important parts of a research work, such as thesis statement, research question and research objectives.

1.1 Introduction and Background

According to the World Bank (2014), healthcare is a major expenditure worldwide. On average the world's countries spend about 10% of their GDP for healthcare related activities with a tendency towards even higher percentages. Especially high income countries such as the United States, where costs already rose to nearly 17% of the GDP, are threatened by ever growing expenditures for their healthcare systems. According to Whitten, et al. (2001), IT solutions can be major factors for a more effective resource usage in the healthcare sector. So called e-health solutions support practitioners as well as patients not only by saving costs but can for example also empower patients to take care of their own health proactively.

Due to these high expenditures, healthcare is one of the sectors with the most potential for improvement and for support by IT solutions. However it is challenged by a number of issues. One of the main challenges for healthcare organizations according to Lenz, et al. (2007) is to deliver high-quality services to their patients while at the same time not to increase their costs. A key aspect to achieve this, is to have business process management (BPM) in place, which enables IT support for healthcare processes as demonstrated by Lenz, et al. (2007). They argue that due to this "promising perspectives for achieving better healthcare process support arise". As healthcare processes are very complex and a lot of different actors are involved, process support becomes crucial according to Lenz & Reichert (2006). Additionally, it also makes the implementation of a process support system or a process management approach difficult. Rebuge & Ferreira (2012) argue that in the past, process support systems have lacked maturity and interoperability with other systems and thus only offer a weak support for healthcare processes.

In their work Lenz & Reichert (2006) distinguish between the clinical and the administrative pathway in healthcare. Each of them requires a different set of processes

and actors. The latter is mainly internally managed and relevant for this thesis. The main focus of this work is on transferal management, which refers to the process enabling patients to be discharged from an acute hospital to the next site of care (see also appendix A, document 3). It is sometimes called “Hospital Discharge Management” and includes the flow of medical information between the acute hospital and the next site of care while the treatment of the patient is not the aim. Alper, et al. (2016) describe that the process shall determine if a patient is medically ready for discharge from hospital and that the health care team identifies the most appropriate setting for ongoing care. This can be either the patient’s home or another care facility (Alper, et al., 2016). Domain experts which are concerned with this process often do not have extensive knowledge in the application of process modelling and are dealing with complex processes. The complexity of the process leads to challenges. As an example, in the United States in 2010 almost 20% of patients who were discharged from a hospital had to be readmitted within 30 days (Alper, et al., 2016). Also, the University of Applied Sciences St. Gallen (FHSG) describes, that it is crucial to find the right timing for the transfer of a patient to a rehabilitation clinic as else large costs may arise. They have evaluated the need to support physicians and transfer managers in this process better in an innovation project called “Patient Radar” (see appendix A). In my work, I will demonstrate, that an easy to use domain-specific modelling language is demanded, to fulfil needs specific to healthcare and clinical organizations dealing with transfer management processes and decisions.

1.2 Problem Statement and Research Motivation

The problem statement is composed by several aspects and is described below.

Braun, et al. (2016) mention in their work that modelling clinical pathways is an emerging field of research. Existing modelling languages such as the Business Process Model and Notation (BPMN) lack in representing specific aspects from the clinical pathway domain, therefore do not provide optimal domain support. A language which is not specific to the relevant domain (in our case transfer management) will not deliver optimal process and decision support for practitioners (Mernik, et al., 2005). There is currently no domain-specific extension available for the processes and decisions of the patient transfer management.

Braun, et al. (2016) also noted that medical processes have a high potential of deviation during process run-time, while traditional business processes have a higher degree of standardization and repeatability. This view is also shared by Rebuge & Ferreira (2012) who have noted, that healthcare processes are highly dynamic, highly complex, increasingly multi-disciplinary and ad-hoc. Due to these characteristics, current process support systems systems offer a weak support to healthcare processes. Thus an improvement of processes and decisions is hardly possible. Also fostering the understanding of business processes and decisions (for example in transfer management) cannot be easily achieved. An improvement of processes would however be greatly important as healthcare institutions are nowadays faced with a high error rate and are under financial pressure by governments (Rebuge & Ferreira, 2012). If practitioners in the transfer management process thus would not receive optimal process support, higher costs are a consequence. As an example, unplanned readmissions due to too early or too late discharge, lead to billions of costs each year in the United States (Alper, et al., 2016).

In a research project at University of Applied Sciences St. Gallen (FHSG), a need for better process and decision support for transfer management has been identified. The project "Patient Radar" aims to systematically design transfer processes. In the project, they have found out, that the transferal process is of central importance for healthcare institutions nowadays and that such a transfer needs to be planned early and efficiently (see appendix A, document 3). Actors within this process need to take decisions based on several criteria at the right moment in time to avoid additional costs and to provide best care for their patients. These processes and decisions need to be available in a form which is easy to understand for all relevant actors, thus need to include domain-specific concepts (see appendix A, document 3). The "Patient Radar" identified following problems for actors in the transfer process from acute hospital to rehabilitation clinic:

- Transfer often does not happen at the right moment in time (either too late or too early) which can lead to unplanned readmission
- Information flow and collaboration is not ideal and usually there is a lack of information for involved actors
- Administrative costs are too high due to wrong decisions
- Roles and responsibilities are not properly defined
- Processes are unclear and not formally defined, lacking domain-specific concepts

- Process is often started too late, which leads to planning and capacity problems

The problem statement thus can be summarized as following:

- Healthcare processes and decisions (therefore also transfer management) are complex and actors need to be supported optimally. They need to foster their understanding and they need to be able to improve existing processes to achieve high quality while lowering or maintaining costs. If this is not achieved, mistakes will happen and higher costs are a result.
- A need for better process and decision support for transfer management has been identified in the project at FHSG. The process is of central importance for the operating efficiency of relevant healthcare institutions. Domain-specific concepts need to be reflected to avoid unnecessary costs and to improve understanding.
- Existing modelling languages do not provide optimal process and decision support to actors in the transferal management. No domain-specific modelling language is available and thus optimal process and decision support for practitioners is not given as domain-specific needs are not covered in general purpose languages.

Based on the problem statement, the research motivation is depicted below.

First of all, as previously noted the healthcare sector is one of the most attractive ones for improvements by means of IT systems due to the high possible gains in effectiveness. Secondly, Braun, et al. (2016) have noted, that only domain-specific modelling language can cover the needs of a specific healthcare domain. To optimally support domain experts in the transferal management processes thus a domain-specific modelling language is needed, which covers the requirements of practitioners and which is easy to understand and to use. This is also affirmed by Mernik, et al. (2005) who argue that a domain-specific modelling language is more expressive and easier to use than a general-purpose language in its domain of application due to its tailoring to a specific domain. A domain-specific language in transfer management thus would help to achieve an understanding of processes and decisions. Transferring a patient at the right moment of time to a rehabilitation clinic helps to save costs as I have already presented in an example. Also, the research project at FHSG demonstrates, that there is a need for domain-specific concepts to support processes and decisions in transfer management. The results of this

project serve as the basis for the creation of a domain-specific modelling language in this master thesis.

Several other researches have also identified the need to reflect domain-specific concepts in healthcare. Braun, et al. (2016) have adapted the existing modelling notation BPMN to cover the needs of the clinical pathway in the newly created domain-specific modelling language BPMN4CP, which, as the name suggests, is suitable for clinical pathways. In their work, Braun, et al. (2015) also propose to extend clinical process models with accordingly required perspectives for the representation of satellite objects, such as medical resources to adequately show relevant clinical processes. This work now aims to develop a domain-specific modelling language to cover the specific needs of actors in the transfer management process from acute hospital to the rehabilitation clinic, as so far, no language exists for this purpose.

As part of the literature research two possible approaches for the development of such an extension have been identified. One of which is the creation from scratch while the other is the integration and extension of existing modelling languages. Several researchers conclude, that creating a new domain-specific language from scratch is expensive and does not reuse existing concepts and thus cannot take advantage of standardization or tool support. Thus the development in this thesis focuses on the combination and extension of existing modelling languages to create a new domain-specific modelling language.

1.3 Thesis Statement

The thesis statement of this work is the following:

"A domain-specific modelling language for patient transferal management, which combines and extends existing modelling languages, fulfills requirements of domain experts in modelling processes and decisions for transfers from an acute hospital to a rehabilitation clinic."

The target group of the result developed in this work are domain experts (transferal managers and physicians) from acute hospitals and rehabilitation clinics in Switzerland. However, the artifact should be used by all involved actors in the transferal management process from the acute hospital and the rehabilitation clinic. This is to achieve as much

cooperation, efficiency and standardization as possible (in the process and related decisions). Examples of other relevant actors are nurses or administrative employees.

As mentioned, the developed language is directed to the interface between acute hospital and rehabilitation clinic only. Further, it is strongly focused on the design-time of the processes and decisions and not yet on the automated executability in run-time.

1.4 Research Question

The following research question is in focus for this work:

"How can existing modelling languages be combined and extended to create a domain-specific modelling language for patient transferal management, which fulfills requirements of domain experts in modelling processes and decisions for transfers from an acute hospital to a rehabilitation clinic?"

1.5 Research Objectives

The thesis is concerned with an analysis of the above-mentioned domain. The detailed objectives can be found in the following table:

Research Objectives	Elicitation of the requirements of domain experts in the patient transfer process to a domain-specific modelling language based on scenario descriptions, process model, web research and literature review (addressed in chapter 4)
	Identification of suitable existing modelling languages which can be used for an adaption to cover the needs of the patient transfer management process (addressed in chapter 5)
	Evaluation of the needed modelling language combinations/ extensions of the selected languages which are useful to meet the domain requirements and implementation in metamodelling platform ADOxx (addressed in chapter 5)
	Identification of patterns or categories of modelling language extensions for DSML such as new subclasses, new classes, new attribute values, new attributes and implementation in metamodelling platform ADOxx (addressed in chapter 5 and 6)

Table 1: Research objectives

1.6 Thesis Structure and Chapter Overview

The master thesis is divided into eight chapters as shown in the upcoming figure. The work mainly constitutes two parts, which are the introduction and research chapters, chapters 1 to 3, and the design science research phases, chapters 4 to 8.

Chapter 1 lays the basis for this research work by defining the problem statement which is the foundation of the thesis statement. The thesis statement on the other hand is the groundwork for the research question and the research objectives.

The next chapter, chapter 2, constitutes of the literature review of relevant research articles and books. At first the selected topic is explained by giving an overview of the processes and of the discipline business process management. After the reader acquires an overview about what a modelling language is, different available languages are shown to give an impression about advantages and disadvantages of each one. Also, general-purpose modelling languages are compared to domain-specific modelling languages. As the focus of this work lays on the combination and extension of existing modelling languages, it is investigated how such languages can be tailored to the specific needs of a certain group of stakeholders to create a domain-specific modelling language. Finally, the usage of such domain-specific languages in the healthcare sector is researched. The main purpose of this work lies in the combination and extension of languages, to create a domain-specific language which can be used for the patient transfer decision from an acute hospital to a rehabilitation clinic.

Chapter 3 first gives an overview on how a research methodology can be structured and which parts it can include. Secondly several possible research philosophies, approaches, strategies and techniques and procedures are explained. In each case the author explains the decision for the chosen approach. Most important for the course of this work is the selected research strategy, which is the design science research method based on (Hevner & Chatterjee, 2010).

Chapter 4 is dealing with the **awareness of the problem**, so with the first phase of the approach suggested by Hevner & Chatterjee (2010). In this phase the problem which can be solved by the combination and adaptation of existing modelling languages is discussed. This problem is based on requirements that domain experts have, and that are not completely fulfilled by existing modelling languages. To find these requirements, mainly an application scenario and a process model are analyzed, which have been created in the innovation project of the FHSG.

A **suggestion** of possible artifacts that solve the problem, which means a combination and extension of existing modelling languages, are identified in chapter 5. The outcome

of the second phase from the approach by Hevner & Chatterjee (2010) is a tentative design of the needed domain-specific modelling language.

This domain-specific modelling language shall then be created in chapter 6 which is the **development** phase. Therefore the artifact which is designed and created by this work is a domain-specific modelling language that covers the needs of domain experts in the field of patient transfer management.

In the **evaluation** phase based on (Hevner & Chatterjee, 2010) in chapter 7, the created domain-specific modelling language is tested regarding the fulfillment of the requirements of domain experts. The artifact is analyzed to define its strengths and weaknesses.

The last chapter, chapter 8, is the final phase of the design science research approach based on (Hevner & Chatterjee, 2010) and summarizes the results of this work with the **conclusion.** It also provides an outlook towards further research and development.

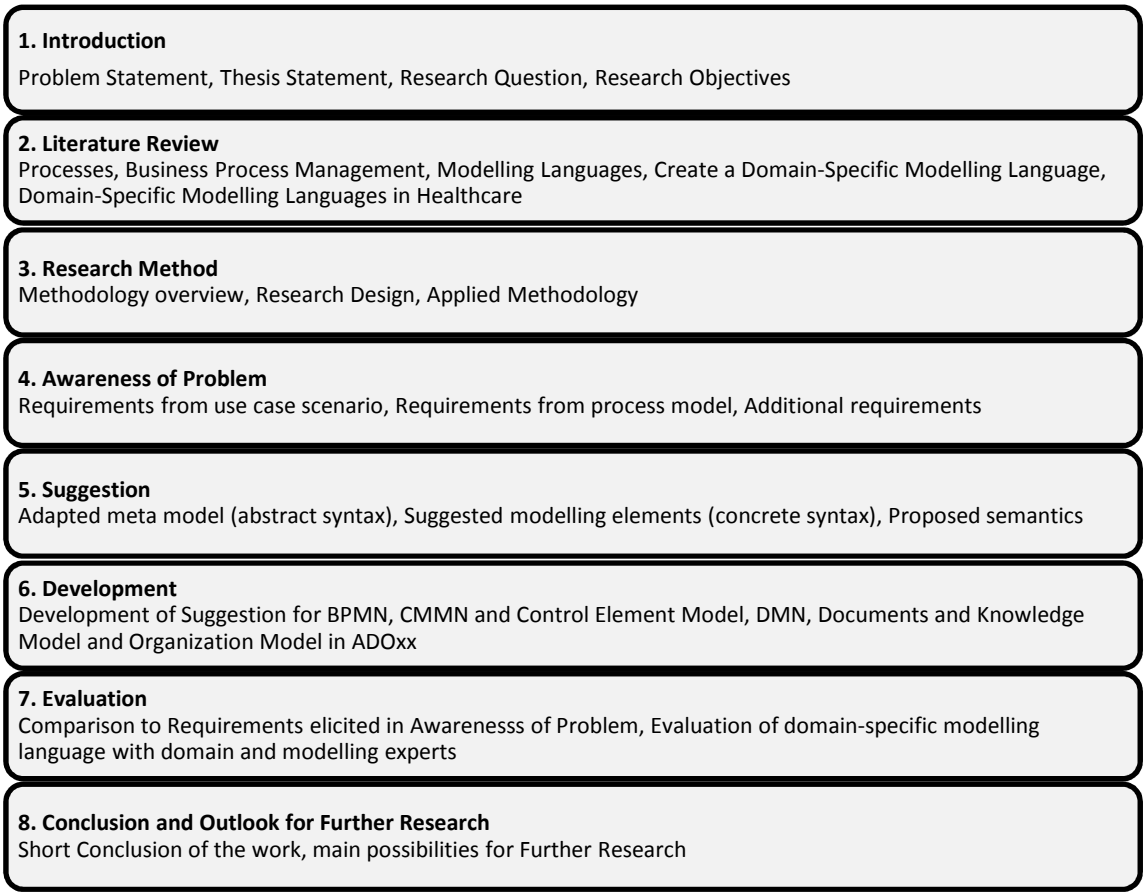


Figure 1: Chapter Overview/Thesis Map

2. Literature Review

The following literature review is designed to help to understand the existing body of knowledge and to show research gaps for the selected topic. The review starts with introducing processes and the methodology of Business Process Management (BPM) in general, shows possible approaches for BPM and continues with a more detailed overview of business process modelling and its languages. Next is a review of literature to create a Domain-Specific Modelling Language (DSML). Finally, it is researched which literature is available for the usage of DSMLs in the healthcare sector. The past research work shall demonstrate what has been done so far and will also identify the gap in literature concerning a DSML for patient transfer decisions.

2.1 Business Process Management

The literature review starts with defining what a process and BPM are. Additionally, holistic approaches for the management of business processes known as BPM lifecycles are shortly explained to locate the activity of process modelling.

2.1.1 Introduction into processes and BPM

Scheer & Hoffmann (2010) describe in their article concerning BPM, that managers today are facing a fast-moving environment with changing customer needs and expectations, fast-evolving technologies and product lifecycles, strong globalization effects, accelerating innovation and increasing digitization of products. A survival of a company is only possible if a long-term business success can be ensured. They argue that “Business Process Management (BPM) is essential to ensure long-term business success based on flexible, market-responsive structures that simultaneously promote efficiency”.

Business Processes

To define what BPM is, an introduction into the term process is first needed as the process is the core element of BPM. Harrington, et al. (1997) describe the term process in their Business Process Improvement Workbook as “a logical, related, sequential (connected) set of activities that takes an input from a supplier, adds value to it, and produces an output to a customer”. A process therefore can be shown on a high level as in the following figure:

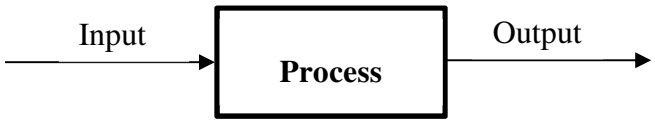


Figure 2: High-level process overview

The given definition is suitable to define a process and can be found in a similar manner in most research articles and books about process management such as in (Scheer, 1999): "A business process is a continuous series of enterprise tasks, undertaken for the purpose of creating output. The starting point and final product of the business process is the output requested and utilized by corporate or external "customers"". Harrington, et al. (1997) also add some additional information to the definition:

- A major process is one that usually involves more than one function within the organizational structure and its operation has a significant impact on the way the organization functions
- A subprocess is a portion of a major process that accomplishes a specific objective in support of the major process
- Activities are things that go on within a process or subprocess; they are usually performed by units of one (one person or one department)
- Tasks are individual elements and/or subsets of an activity; tasks relate to how an item performs a specific assignment.

As this more advanced definition highlights, several levels of details can exist to specify how an input can be transferred into an output or how value can be created for an internal or an external customer. The more complex a business process is in reality, the more it needs to be abstracted into subprocesses. Figure 2 can therefore be adapted to show additional details:

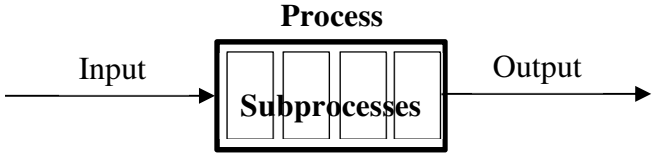


Figure 3: High-level process overview with subprocesses

In his famous work of the value chain, Porter (1985) argues, that there are two categories of activities. He differentiates value generating primary activities (the value chain) from supporting secondary activities. In the process-world there often is a three-folded differentiation between management processes, core processes and supporting processes and these are often shown in a so-called process map as illustrated in the following figure:

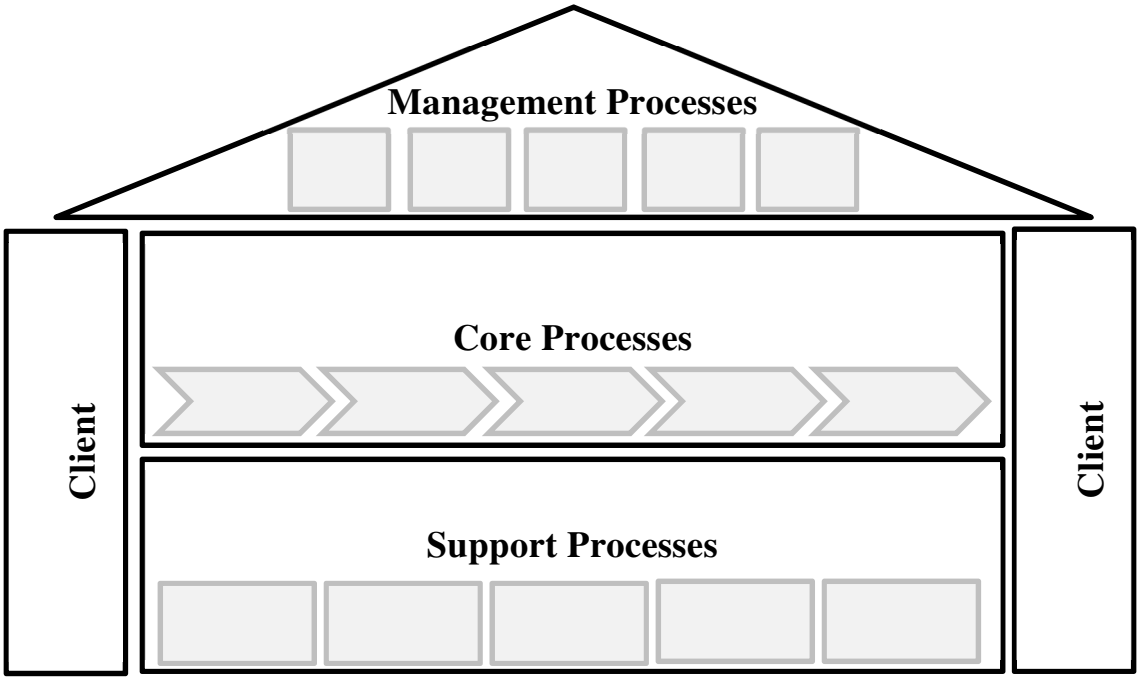


Figure 4: Process Map

As Becker, et al. (2003) mention, support processes are necessary for core activities to create value and therefore are of great importance, even though they are not directly generating value to the client. Management processes are needed to steer the company into the right direction to ensure long-term success. It is needless to say that every company has processes. These processes help the company to stay competitive as Davis & Brabänder (2007) show in their book: “Processes are not just something your business does; processes are your business”.

Business Process Management (BPM)

Having processes alone does not yet guarantee company success. A process management approach is also needed. Karagiannis (2012) defines BPM as “a well-established and widely – crossdomain – applied holistic management approach, which can be defined as a set of structured methods and technologies for managing and transforming organizational operations”. The recognition of BPM as a holistic management domain is fairly new as Jeston & Nelis (2006) mention: “there is currently a movement towards an agreement that BPM is about the management of business processes”. Companies are recognizing BPM as a top-management discipline, which needs to be integrated into the daily activities of the company’s top-management and needs to be managed with a long-

term view in mind. BPM is no more just software to support the execution of business processes as Jeston & Nelis (2006) explain:

"BPM is:

- more than just software
- more than just improving or reengineering your processes – it also deals with the managerial issues
- not just hype – it is an integral part of management
- more than just modeling – it is also about the implementation and execution of these processes, which requires analysis."

Damij & Damij (2014) share this view and recognize growing interest into BPM not only on the practitioner but especially on the researcher side. The BPM approach "could contribute a great deal in enabling organizations to improve their business processes and bring them as close as possible to their planned operational, business and strategic goals; studies that could contribute a great deal in enabling organizations to improve their business processes and bring them as close as possible to their planned operational, business and strategic goals". Thus a consistent approach to BPM is a must for companies nowadays if they want to achieve their goals. They also believe that BPM requires a multidisciplinary approach where the business and the IT of a company both need to be involved to guarantee the success of an initiative, which is also the view of Scheer & Hoffmann (2010). As already mentioned BPM is no more only about implementing a software to support processes. If a software is implemented it is very important to clearly define business requirements that ensure maximum support for the business processes to be executed. A good business process support can grant a competitive advantage to a company or at least helps to save costs and to increase productivity.

BPM critical success factors

Jeston & Nelis (2006) discuss in their work, that implementing a BPM solution is very complex. In such a project, multiple stakeholders with varying requirements can be involved. In order to implement a BPM solution or framework, which will be able to achieve the set project goals such as to save costs or to increase productivity, some critical success factors have been determined in the body of knowledge regarding BPM.

Jeston & Nelis (2006) found out, that even though every BPM project is different some general critical success factors can be defined:

1. **Leadership**: Attention, support, funding, commitment and time of the leader involved in the BPM project is absolutely crucial. He needs to be a role model and continuously needs to sell the benefits of the project to colleagues, stakeholders, suppliers and customers.
2. **BPM experienced business project manager**: The project manager needs to have exceptional skills to guide people in the process. It is important, that he is from the business side and therefore understands their daily needs.
3. **Linkage to organization strategy**: The strategy of the organization is the common ground to guide all employees into the right direction. The long-term strategical view improves the success chance of the initiative.
4. **Process architecture**: A synergistic approach and consistency within the organization is needed to ensure that the maximum benefits of different BPM initiatives. There needs to be a set of agreed upon guidelines and process directives within the organization.
5. **A structured approach to BPM implementation**: The company needs an agreed structured and systematic approach to the implementation of BPM projects that takes into account the organization strategy, hence a BPM framework has to be implemented and applied.
6. **People change management**: Employees of the company are impacted by changes of the project. They consequently need to be positive about those changes and need to be committed to support the project as a whole.
7. **People and empowerment**: After a redesign of their tasks and competencies, personnel should be trusted and empowered to do their job. Creativity must be allowed and flexibility must be given.
8. **Project initiation and completion**: A post-implementation review helps to ensure that lessons learned are created and transferred to subsequent projects.
9. **Sustainable performance**: Implemented processes need to be maintained, supported, measured and managed, as they will continue to exist after the project has been finished.

10. **Realizing value**: Every project needs to create value to the company. A benefits management structure ensures that value is monitored and realized. Quick-wins help to justify the project throughout its life.

Chang (2006) converses in his book of so called practices that need to be in place to successfully deliver a BPM implementation project. These practices have a great overlap to the success factors defined in (Jeston & Nelis, 2006) and add factors such as the importance of the continual education of staff members.

Practices	1. Strive for process-oriented organizational structure 2. Appoint process owners 3. Senior management needs to commit and drive BPM and execution of BPM process improvements should take a bottom-up approach 4. Put in place information technology systems to monitor, control, analyze and improve processes 5. Work collaboratively with business partners on cross-organizational business processes 6. Continuously train the workforce and continuously improve business processes 7. Align employee bonuses and rewards to business process performance 8. Utilize both incremental (e.g., Six Sigma) and more radical (e.g., BPR) methodologies to implement process improvement

Table 2: BPM practices based on (Chang, 2006)

As a result, a study of the literature provides interesting findings regarding BPM projects. They are of great complexity, possibly more complex than similar projects from different fields, as e.g. various actors are involved. These involved parties need to be fully committed and need to communicate and realize benefits. A BPM approach requires dedicated resources and an organizational and cultural change, which can be very radical. Thus change management is a major part of such a project. Additionally, after completion of the project a continuous management must be in place.

2.1.2 BPM organization and roles

A BPM implementation in a company does not only change existing process flows and therefore tasks and competencies of employees but also asks for additional roles. These roles will take over important duties for the future success of the BPM initiative.

Scheer & Hoffmann (2010) list these roles in their article "The Process of Business Process Management". They believe, that at least eight additional roles will be needed in an organization: BPM Sponsor, Head of BPM, BPM Steering Committee, BPM Center of Excellence, Business Process Expert, Process Owner, Process Coordinator, Process Modeler.

A sample project organization is proposed by Jeston & Nelis (2006) in their work. They also recommend to create a center of business process excellence, which is providing BPM knowledge as a centralized department to other departments that are owning business processes:

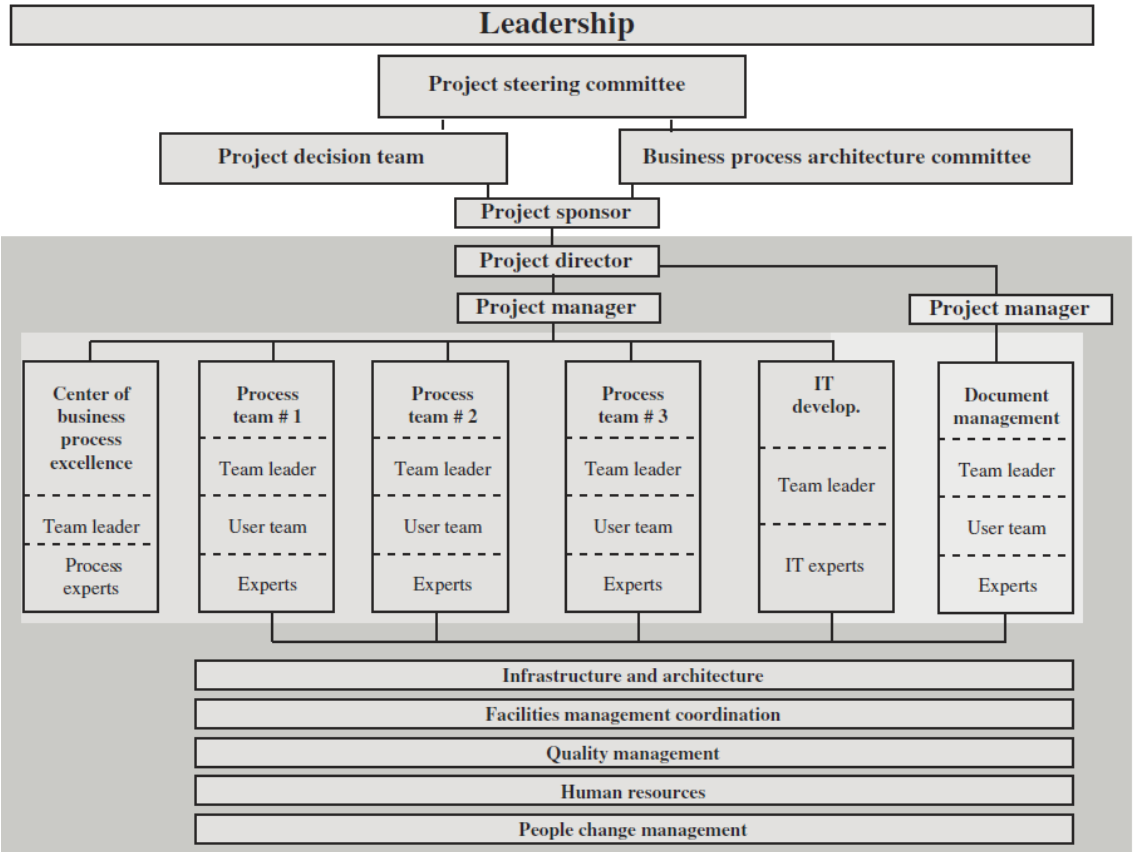


Figure 5: Sample BPM project organization as proposed in (Jeston & Nelis, 2006)

2.1.3 BPM lifecycle

As mentioned BPM requires a framework in place, which does not only include additional roles and a new organization but also a process with several stages that involves multiple iterations and continuous improvement. This process is known as the BPM lifecycle. The lifecycle ensures that a structured approach towards BPM is followed. There are various

lifecycle models available, however the involved steps of the different models are very similar. Damij & Damij (2014) define the BPM lifecycle as "an iterative process through which each business process passes via different stages. Any iteration of the process lifecycle starts by process modeling, continues by process implementation, and finishes by process improvement and optimization". Two well-known models are shortly explained and compared below.

Scheer & Hoffmann (2010) describe a typical BPM process with four phases, of which each one consists of several steps and activities. Typically, there are three different organization units involved (Business Unit, BPM Unit and IT Unit). Additionally, the lifecycle is accompanied by change management activities and continuous process improvement. The phases of the lifecycle are called: Business Process Strategy Phase, Business Process Design Phase, Business Process Implementation Phase and Business Process Controlling Phase.

Weske (2012) introduces a BPM lifecycle which is more targeted towards the implementation of a BPM software to support business processes. Four connected phases Design and Analysis, Configuration Enactment and Evaluation are the foundation for BPM.

While Scheer & Hoffmann (2010) see BPM rather as a holistic management discipline in their approach, Weske (2012) focuses more on BPM as a software to implement. This demonstrates that Weske (2012) is still more supportive of the traditional view on BPM. However both lifecycles consist mostly of the same activities, while having a slightly different focus and naming of the steps. Both include the typical tasks of a BPM approach (process modelling, process implementation, process improvement and process optimization).

2.2 Business Process Modelling & Languages

The before mentioned BPM lifecycles include the modelling of business processes as one of the main tasks of a BPM initiative. Aguilar-Savén (2004) mentions in her article an increasing focus on processes and thus she summarizes: "modelling of business processes is becoming increasingly popular". Successful systems can only be implemented if an understanding of the business processes of an organization is achieved. The increasing

interest in the conceptual illustration of business processes led to “a rapidly growing number of methodologies, and modelling techniques and tools to support it” as she explains. The same view is also shared by Söderström, et al. (2002), as they note: “The increasing interest in process engineering and application integration has resulted in the appearance of various new process modelling languages”. Hence, getting an overview of available modelling languages seems to be fundamental. In this chapter an overview will be given with the identification and a high-level specification of some main process modelling languages.

2.2.1 Business Process Modelling

Recker & Dreiling (2007), Aguilar-Savén (2004), Becker, et al. (2000) and Ko, et al. (2009) all mention an increasing interest in the discipline “modelling of business processes”, as BPM in general is gaining popularity in the academic as well as in the practical world. Skills to define a business process model accordingly are critical and without the exact understanding of the businesses process, a BPM initiative can hardly be successful. Such a model is an abstraction of a phenomena in the real world (Söderström, et al., 2002). The real world is complex and modelling business processes is an instrument for coping with this complexity of process planning and control, as Becker, et al. (2000) describe. Damij & Damij (2014) provide their definition for a process model as “a diagram that depicts of a group of activities that are connected sequentially as predecessor(s) to successor(s) by their outputs and inputs, and organized in a number of paths in order to describe a certain functioning within an organization”. They further mention: “A process model should contain all the characteristics important to make the model as real a reflection of the original process as possible”. Eriksson & Penker (2000) list in their work, that there are multiple reasons for companies to do business process modelling. Some of which are:

- To better understand the key mechanisms of an existing business
- To act as the basis for creating suitable information systems that support the business
- To act as the basis for improving the current business structure and operation
- To identify outsourcing opportunities

2.2.2 General-Purpose vs. Domain-Specific Modelling Languages

Modelling languages can be differentiated by General-Purpose Modelling Languages (GPMLs) and Domain-Specific Modelling Languages (DSMLs). Van Deursen, et al. (2000) mention: “In all branches of science and engineering one can distinguish between approaches that are generic and those that are specific”. According to Frank (2011), a GPML uses rudimentary concepts such as a class or an attribute, while a DSML includes concepts that are specific to the targeted domain. Van Deursen, et al. (2000) add for the definition of GPMLs: “A generic approach provides a general solution for many problems in a certain area”. This wide applicability is one main advantage of GPMLs. UML, as a representative of this genre, is therefore very accepted and widely used for different modelling purposes. Frank, (2011) and van Deursen, et al. (2000) both notice a growing interest in DSMLs, as they provide several advantages compared to GPMLs. France & Rumpe (2005) mention in their work, that domain specific constructs are better suited for the communication with users in the domain and have a restricted semantic scope. Graaf & van Deursen (2006) add, that DSMLs are less complex, which is also the view of Mernik, et al. (2005), who say that DSMLs do not include many unnecessary concepts of GPMLs. They therefore trade generality for expressiveness.

The shown advantages of DSMLs clearly suggest, that a Domain-Specific Modelling Language would be very suitable for the applicable domain of this work. Practitioners would profit from a high expressiveness of a language which is easy to use. Such a model can be shared with different stakeholders that might only have limited knowledge of business process modelling but a good knowledge of relevant domain concepts.

2.2.3 Business Process Modelling Languages Overview

From section 2.2.1 it should be clear, that modelling business processes is an important task for every company. However, it seems, that creating a sufficient business process model is a difficult task. Both, Aguilar-Savén (2004) and Damij & Damij (2014) note, that modelers or analysts are having problems in defining process models which correctly reflect the reality. An incorrect design of processes is a significant financial risk for companies, as Becker, et al. (2000) note. Process models are a way of communication to all people involved. If they are not or wrongly understood expensive misjudgments are the consequences.

Comparison of research papers

A main reason for the narrated difficulties with process models is the large amount of available languages, methods and tools for the design of business processes. Ko, et al. (2009) have summarized these challenges based on different expert opinions. They say that "this unprecedented growth is a double-edged sword". Often new tools and languages for BPM are not well defined, not well understood by practitioners or not validated. Therefore a main research area for BPM in recent years was to get an overview of the available languages, to structure them and to analyze their strengths and weaknesses.

As the main objective of this thesis is to adapt an existing modelling language, the four most relevant found papers are hereby studied to compare them and to find out whether they are useful for the further development of this thesis.

Authors / year	(Söderström, et al., 2002)	(Aguilar-Savén, 2004)	(List & Korherr, 2006)	(Ko, et al., 2009)
Title	Towards a Framework for Comparing Process Modelling Languages	Business process modelling: Review and framework	An Evaluation of Conceptual Business Process Modelling Languages	Business process management (BPM) standards: a survey
Analyzed languages	EPC, BML, SD	Flow chart, DFD, RAD, RID, Gantt, IDEF, CPN, OO (e.g. UML), SSADM, GRAI, Workflow, Rich Pictures	AD, BPDM, BPMN, EPC, IDEF, PN, RAD	BPDM, BPEL, BPML, BPQL, BPRI, XML, BPSS, EDI, EPC, PN, Pi-Calculus, Rosetta-Net, UBL, UML, WSCI, WSCL, WS-CDL, WSFL, XLANG, XPDL, YAWL

Table 3: Overview of modelling language papers

Towards a Framework for Comparing Process Modelling Languages by Söderström, et al. (2002)

The main intuition of this paper is that most process modelling languages share four common basic concepts which are time point, activity, state and event. However, the relationship between these concepts differ. The selection of the three languages to be compared is based on their common usage in its respective field. Event-Driven Process Chain (EPC) as an activity-oriented language, Unified Modelling Language (UML) State Diagram (SD) as a state-oriented language and Business Modelling Language (BML) as a communication-oriented language. As a result, the paper shows for each language, whether the concepts time point, event, state, activity, process, rules, resource, actor and location are available and how they are set up. This comparison matrix shows that none of the languages provides all elements while UML SD and BML are missing only time point and location.

Business process modelling: Review and framework by Aguilar-Savén (2004)

This paper includes an introduction into about 15 different languages for process modelling. A table provides a good overview of the strengths and weaknesses of each language from the point of view of a user and of a process modeler. Another table demonstrates a list of possible tools for modelling support for each language. The main outcome of the research work is a framework, which classifies each analyzed language for permissiveness and purpose, as can be seen in the following figure:

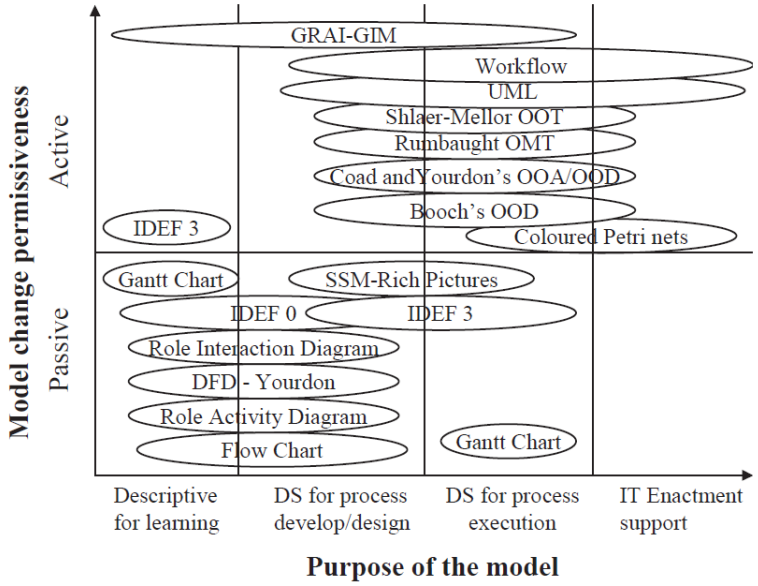


Figure 6: Classification framework to select among modelling languages from (Aguilar-Savén, 2004)

An Evaluation of Conceptual Business Process Modelling Languages by List & Korherr (2006)

A generic meta-model serves as basis for the evaluation of the different languages. This meta-model consists of five perspectives: functional perspective, organizational perspective, behavioral perspective, informational perspective and business process context perspective. UML Activity Diagram (AD), Business Process Definition Metamodel (BPDM), Business Process Modelling Notation (BPMN), EPC, Integrated DEFinition Method 3 (IDEF3), Petri Net (PN) and Role Activity Diagram (RAD) are evaluated, as they have either a future potential or are well-established in research or industry. The authors note, that all languages provide notations while some are missing a meta-model or an execution language as revealed in the upcoming figures:

BPML	AD	BPDM	BPMN	EPC	IDEF3	Petri Nets	RAD
Meta-Model	+	+	-	+	-	-	-
Notation	+	+ UML 2.0 Profile	+	+	+	+	+

Figure 7:Meta-model and Notation overview from (List & Korherr, 2006)

BPML	Execution Language
AD	BPEL4WS [8]
BPDM	BPEL4WS [8]
BPMN	BPEL4WS [8], BPML [2]
EPC	EPML [14], academic proposal
IDEF3	none
Petri Nets	PNML [1], academic proposal
RAD	none

Figure 8: Execution Language overview from (List & Korherr, 2006)

Additionally, they differentiate the languages regarding their purpose and source domain:

BPML	Purpose	Source Domain
AD	Description, Enactment	Software Engineering
BPDM	Enactment	Process Engineering
BPMN	Description, Enactment	Process Engineering
EPC	Description, Analysis	Process Engineering
IDEF3	Description	Software Engineering
Petri Nets	Enactment	System Engineering
RAD	Description	Software Engineering

Figure 9: Purpose and Source Domain overview from (List & Korherr, 2006)

Business process management (BPM) standards: a survey by Ko, et al. (2009)

This is the most comprehensive paper which was found. Different BPM languages/standards are categorized based on their main purpose and on their usage phase in the BPM lifecycle as shown in the following figure:

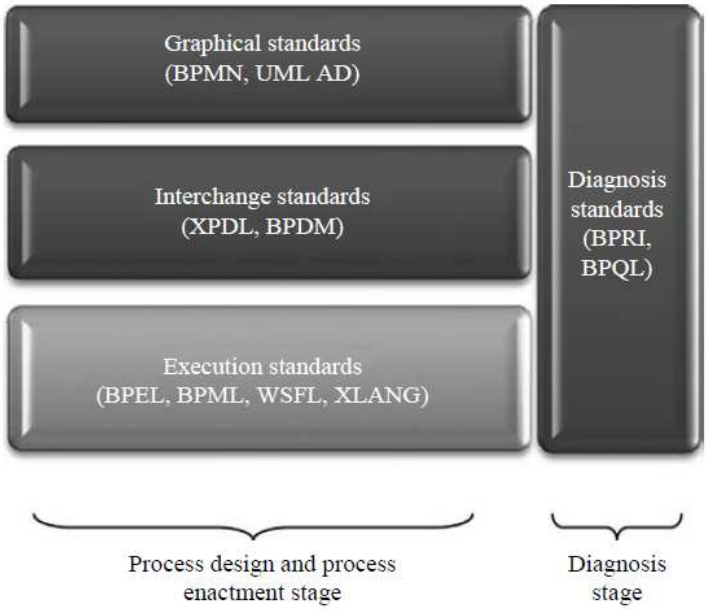


Figure 10: BPM categories in relation to BPM lifecycle from (Ko, et al., 2009)

An overview table of all languages gives an interesting insight into the standardization and current status of the languages. Then, each language is described in detail and the authors give an idea about the strengths and weaknesses of each language. However, in this work, as graphical standards, which are defined as "allow users to express business processes and their possible flows and transitions in a diagrammatic way", only UML and BPMN are considered.

Conclusion

This short study of four papers which give an overview of modelling languages provides thought-provoking insights. The papers all use different approaches to classify and compare modelling languages. I mainly noticed the following points while studying the papers:

1. There is a quick progression in the area of process modelling languages as the difference in analyzed languages over time shows.
2. A large overlap of analyzed languages has not been observed. Only a few languages such as UML, EPC or Petri Net were considered several times.
3. There is no differentiation between General-Purpose Modelling Languages and Domain-Specific Modelling Languages; the focus in this work is on the latter.

4. Most work has been done quite some time ago. No recent relevant comprehensive comparison article has been found.

In summary, no paper provides a current overview of suitable modelling languages, which can be considered for this work. An observation over time shows that EPC, UML and Petri Net stay relevant and enjoy a high acceptance in the research world. The author will consider these and as well as new and emerging BPM languages and standards in the upcoming chapter.

2.2.4 Introduction into the most relevant process modelling languages

In this chapter, I provide a short overview of some main process modelling languages. This analysis might give an indication for the suitability of these languages for the further progress of this work. As mentioned, the objective of this work lies on the extension of an existing modelling language.

UML

Eriksson & Penker (2000) as well as Fowler & Scott (2003) describe UML as the industry standard for modelling software systems. Even though UML was initially defined to create a language for the design software models, it can be used for the modelling of business processes as Eriksson & Penker (2000) illustrated in their article. UML provides several different types of models. UML Activity Diagrams (AD) are the most important diagram type to describe business process flows. Eriksson & Penker (2000) characterize it with the following sentences: “Activity Diagrams have a wide range of uses, in that they can show activities (sequential and in parallel), the objects consumed, used or produced by an activity, who is responsible for an activity, and the relationships and dependencies between activities. All of this is essential in business modeling”. They also provide an example for a business process modelled with UML, as demonstrated in the following figure:

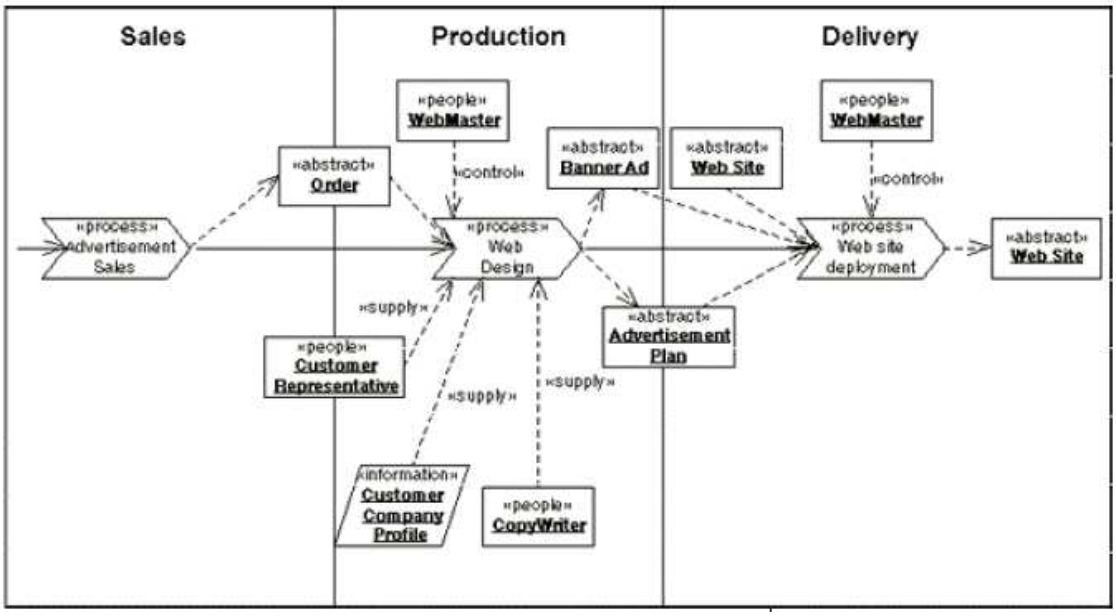


Figure 11: Process diagram based on UML activity diagram from (Eriksson & Penker, 2000)

Söderström, et al. (2002) mention in their article, that another UML diagram type, the State Diagram (SD), is well suited for the modelling of business processes. It "visualises how and under what circumstances a modelled element, e.g. a UML class, a system or a business process, changes its state. SD is also used to show the activities that are executed as a result of events". The subsequent figure provides an example:

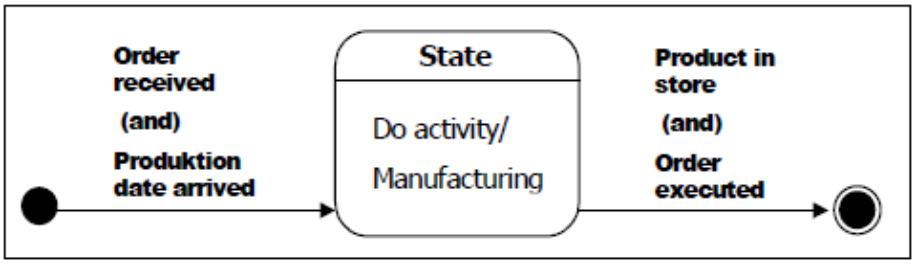


Figure 12: Process diagram based on UML state diagram from (Söderström, et al., 2002)

To summarize, UML is very versatile due to the different types of diagrams and can easily express a wide variety of elements. Also, it is very well accepted in both, the researcher's and the practitioner's world. However, due to its origin from software development, it might not be as easy to use and understand for someone from a different field. Also some concepts, which are well-known to business users, such as goals are not included, as List & Korherr (2006) mention.

Petri Net

Petri Nets are a preferred modelling language in the academic world, as it has proper formal semantics according to Lohmann, et al. (2009). Also Salimfard & Wright (2001) share this view and add "The strong mathematical foundation of Petri Nets and the availability of a wide range of supporting tools have made them popular among academic researchers". This is also one reason why most process modelling languages have based their basic grammar on Petri Nets (Söderström, et al., 2002). Salimfard & Wright (2001) argue, that Petri Nets facilitate the visual communication between people who are engaged in the design process. Söderström, et al. (2002) on the other hand emphasize, that Petri Nets are a method for experts only and cannot easily be used as a communication tool for business people and are lacking some fundamental concepts for the modelling of business processes.

Lohmann, et al. (2009) demonstrate in their work, that it is possible to design a business process in Petri Net which can be translated into other popular modelling notations. Their example process is provided in the following figure:

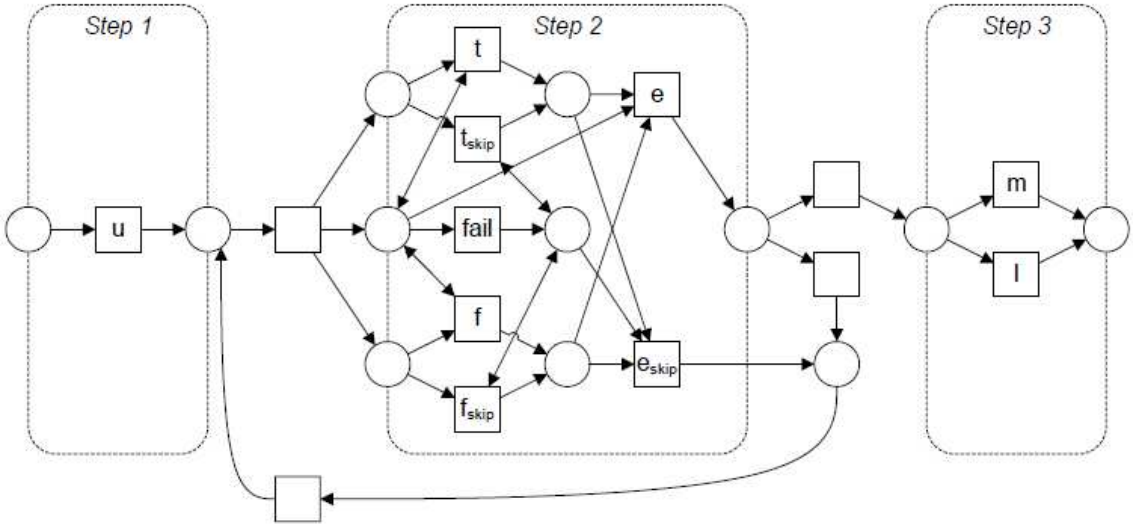


Figure 13: Process diagram in Petri Net from (Lohmann, et al., 2009)

I share the view of Söderström, et al. (2002). Modelling business processes with Petri Nets might be possible but is not its initial purpose and thus models are not easily understood by people with no or limited knowledge of the method. Lohmann, et al. (2009) mention, that Petri Nets are preferred by academics thanks to its strong mathematical foundation but business people prefer more expressive languages.

EPC

Ease to use and to understand by business people was one of the main motivations for the development of the Event-driven Process Chain (EPC), according to List & Korherr (2006). Ko, et al. (2009) also describe it as an easy to use language and add: "It works as an ordered graph of events and functions and supports parallel execution of processes. A notable feature of EPC is its logical operators (e.g. OR, AND and XOR)". They additionally mention, that several researchers in the past have noted, that semantics and syntaxes are not well defined, therefore it mainly serves as a communication method. It was particularly popular in the 1990s in German speaking countries (Ko, et al., 2009). Lohmann, et al. (2009) have presented an example for a process modelled in EPC in their article:

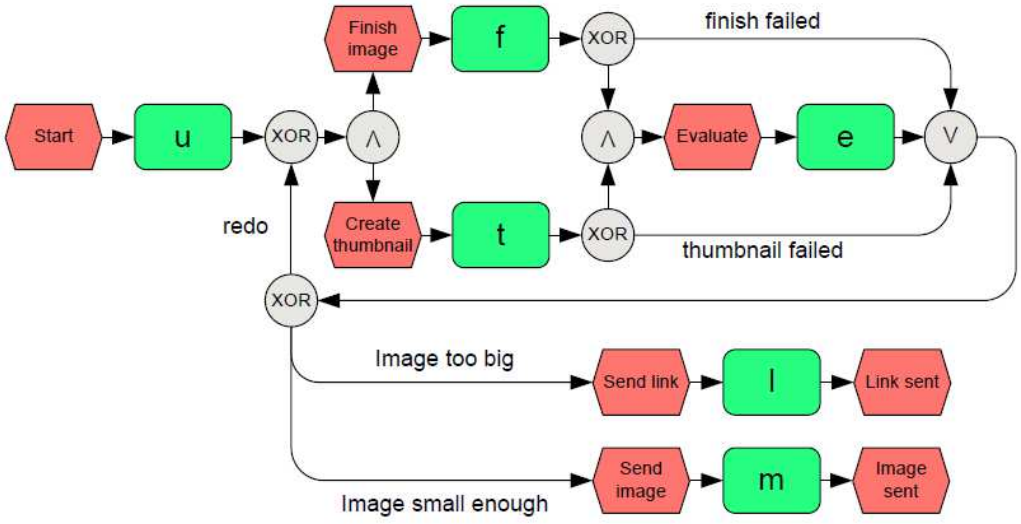


Figure 14: Process diagram in EPC from (Lohmann, et al., 2009)

I conclude, that EPC is a suitable method to define a business process. It was initially designed to model processes with the intention to be easily understood. However, it has reached its popularity peak several years ago, is mainly used in German speaking countries and newer methods such as BPMN provide some important advantages. One of which is, that much more elements are available (e.g. in BPMN) for the exact modelling of a business process, while EPC is strongly focused on events and functions. Exactly this separation of events and functions can be confusing and often does not add any additional information but makes the model more complex.

BPMN

According to Yousfi, et al. (2016) the Business Process Model and Notation (BPMN) nowadays is the most adopted BPM language in the academic and practical world. It provides a "graphical representation of business processes easily understood by business analysts, and especially useful in communicating business requirements", as Ko, et al. (2009) explain. It therefore mainly aims to generate drawings of business processes, which serve as a communication between different stakeholders. A large collection of object types (such as various activities, events and gateways) ensures, that several aspects of a business process can be modelled (Lohmann, et al., 2009). This rich collection of object types allows BPMN to be powerful enough to model large end-to-end processes while being uniquely easy to use according to Smith & Fingar (2003). Additionally, it is supported by an execution language, called Business Process Execution Language (BPEL), which is machine-interpretable, as Recker & Dreiling (2007) explain. Lohmann, et al. (2009) show a sample BPMN process in their paper:

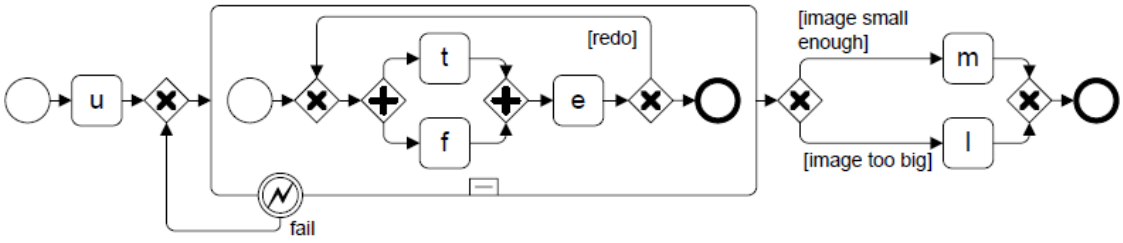


Figure 15: Process diagram in BPMN from (Lohmann, et al., 2009)

To summarize, BPMN enjoys a very high popularity in the academical and practical world and is accepted as the main standard for business process modelling. Complex processes can be modelled with BPMN due to its large number of available elements. It is exactly this richness of elements, which can lead to a high complexity and modelling mistakes when applying BPMN. Indulska, et al. (2014) demonstrate in their work, that BPMN is much more complex compared to UML or EPC. They argue, that this complexity can only be reduced by the use of modelling conventions, which means selecting a subset of available modelling elements. Silver, (2011) additionally pinpoints in his work, that due to the complexity of BPMN a lot of modelling errors can happen and often are happening. Both Recker (2010) and Silver (2011) also recognized, that only a few core elements of the notation are usually enough to describe a process. Choosing applicable elements thus is an essential activity when applying BPMN to make it easily

understandable for people with a limited amount of BPMN-knowledge and to avoid models with flaws.

CMMN

According to Kurz, et al. (2015), knowledge work is today gaining importance, as they explain: “scientists and practitioners are looking for ways to support knowledge work which features a high degree of unpredictability”. Classical BPM is not well suitable to support the modelling of such case management tasks or as Grudzinska-Kuna (2013) phrases: “Knowledge workers have significant impact on companies they work in but the processes they use in their work are not well supported by technology”. In order to solve these challenges and to complement BPMN a new standard has been released: The Case Management Model and Notation (CMMN). A case is a set of activities and interactions with a customer and such flexible processes can now readily be modelled as a CMMN diagram rather than as a BPMN diagram (Grudzinska-Kuna, 2013). Zeising, et al. (2014) provide an example for such a case in their article:

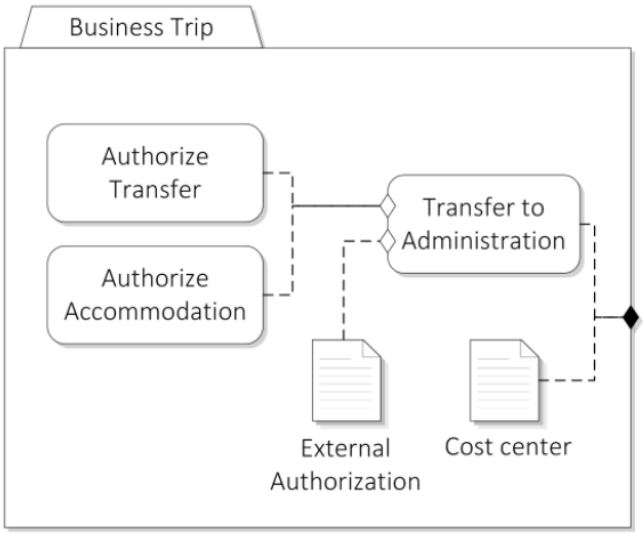


Figure 16: CMMN process model from (Zeising, et al., 2014)

CMMN provides new ways to support the modelling of knowledge intensive business processes with a high degree of flexibility. Both DMN (see next subchapter) and CMMN are standards that complement BPMN to tackle the challenges of today’s work patterns. Kurz, et al. (2015) expect a bright future for CMMN as they write: “the Business Process Model and Notation (BPMN) standardizes business process models. Considering the widespread adoption of BPMN, CMMN may achieve a similar degree of relevancy in the

years to come". CMMN however is a completely new standard and thus requires new know-how in the application. It does not have any integration to BPMN and is limited to the modelling of cases; some elements (e.g. roles) are thus not available. Researchers such as Breitenmoser & Keller (2015) criticize the missing connection to BPMN. They would have suggested to extend BPMN rather than creating a new standard which first needs to become accepted.

DMN

An important part of business processes is decision making. Companies increasingly want to model and specify business decisions, which are made within processes. However as Taylor, et al. (2013) explain, existing standards do not support these requirements. As a consequence, very often, business logic (decisions) is embedded into process models, which makes them overly complex, as Batoulis, et al. (2015) explain. Mertens, et al. (2015) add: "specifying the complete control-flow for each variation of processes that require a high degree of run-time flexibility is time consuming and results in overly complex models". With the Decision Model and Notation (DMN), the Object Management Group (OMG) has created a new standard to address these requirements. It can be seen as an addition to BPMN by also providing a common notation that is readily understandable by all business users, but is used to model business decisions (Taylor, et al., 2013).

In contrast to the other presented approaches, DMN is not a process modelling standard per se; it is for the modelling of business logic. One can distinguish between modelling process logic and modelling business logic. Van Halle & Goldberg (2010) define business logic as "the means by which the business derives conclusions from conditions". Thus decisions are business logic and have to be separated from process logic, which describes the flow of activities. This separation can be achieved by using a standard such as DMN for modelling decisions.

DMN also provides a framework for the technical automation of these decisions (Taylor, et al., 2013). Biard, et al. (2015) nicely show the different levels of the standard in their work, from the business process to the decision requirements diagram, to the decision tables and to the machine readable language FEEL (Friendly Enough Expression Language).

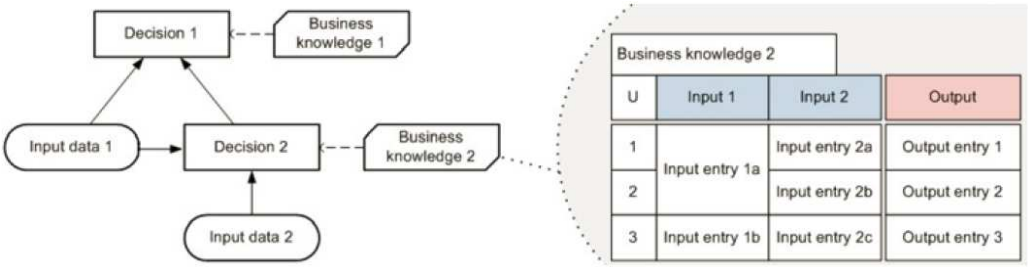


Figure 17: DMN decision requirements diagram and decision table from (Biard, et al., 2015)

```
FEEL (
       [ac.knowledgeRequirement.requiredKnowledge.name/]
     [for ( anInformationRequirement : InformationRequire
     [if (anInformationRequirement.requiredDecision.name.
         [anInformationRequirement.requiredDecision.name/
     [/if]
     [if (anInformationRequirement.requiredInput.name.ocl
         [anInformationRequirement.requiredInput.name/][i
     [/if]
     [/for]
     )
)
```

Figure 18: DMN FEEL expression from (Biard, et al., 2015)

DMN can be seen as an extension to BPMN and is not a notation to model business processes. It allows to model business logic (decisions). According to Mertens, et al. (2015) DMN "provides a common notation for decision logic that is understandable for business users, business analysts and technical developers." As such, it can be very helpful to manage the singularities of today's processes, which are variability, complex business rules and automation of decisions. As business decisions are very relevant for the daily work of an actor in the patient transferal, this standard has to be considered for this work even if it does not allow to model a process flow. However, as it is a new standard, it also requires new know-how in the application and is not yet as prevalent as other standards. DMN itself does not provide any concepts to define the flow of a process, it leaves this task to another language which needs to be used complementary (such as BPMN) to model both the process as well as the business logic.

Conclusion

The world of process modelling languages is big and fast-moving. Only a few languages have enjoyed popularity over several years. The study of available literature has shown, that BPMN today is the most well-known and used standard for the design of processes. Both the academical and the practical world share this view. However, BPMN offers

tremendous modelling possibilities, that a user might quickly be confused which can lead to deficient models and misunderstanding. Therefore modelling conventions or proper semantics for the use of BPMN are inevitable.

While UML or Petri Nets are also very well respected, they might not be as suitable to model a process flow due to their deviating initial purpose; they as a consequence lack expressiveness to model a rich flow of activities and actors. Especially DMN could be an interesting supplement to BPMN, to optimally support the complexity and flexibility that is predominant in the processes of the applicable domain. However, it is a separate, yet emerging standard and would possibly be required to be incorporated to BPMN as an extension of it.

2.3 Approaches to Create a DSML

The previous chapter demonstrated, that creating a DSML has several advantages and can be of great benefit for users in the respective domain. However, creating a new DSML is not an easy task and requires a coherent approach. This chapter gives an overview of possible approaches, that can be used to create a DSML.

2.3.1 Introduction

Cànovas Izquierdo, et al. (2013) define a DSML as consisting of three major parts, which are an abstract syntax, a concrete syntax and semantics. The abstract syntax, which is built through a meta-model (e.g. a class diagram), describes the concepts of the domain, their features and relations. The concrete syntax describes the representation of models, graphically or textually, or a combination of both. Lastly, the semantics describe the meaning of models by providing, e.g., a description of their execution, or a mapping into a semantic domain. Therefore, these three parts are a necessary requirement when creating a fully specified DSML. An example of a meta model can be seen in the following picture:

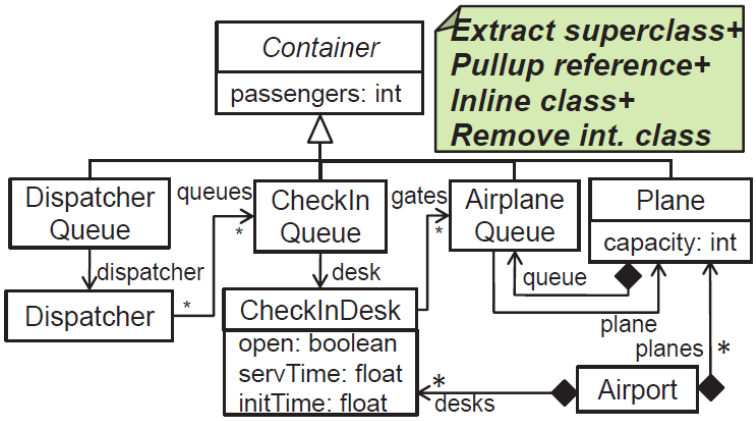


Figure 19: Meta model based on a UML class diagram from (Cànovas Izquierdo, et al., 2013)

A DSML can be created by using concepts of an existing modelling language, so it can be an extension or a combination of known languages or can be created by defining a completely new language without the reuse of existing concepts (Braun & Esswein, 2014). It is clear that reusing concepts from an existing language such as BPMN avoids expensive development costs. A possible disadvantage can be, that the DSML does not fully cover the requirements of stakeholders or includes unnecessary concepts of the extended language. Additionally, a DSML can be created either with or without tool-support. Gray, et al. (2007) provide a good overview in their work as they explain: "Domain-specific Modeling Environments (DSME) provide the tools necessary for a system developer to rapidly build systems belonging to a specific domain and which are syntactically correct-by-construction". They further add: "DSMEs leverage the power of domain-specific modeling languages to provide the model engineers with the building blocks necessary to develop systems rapidly and correctly". Some features that a DSME provides are for example metamodelling support, change management, model serialization or plugin capabilities. Cànovas Izquierdo, et al. (2013) emphasize in their work, that when developing a new DSML the user involvement is a major success factor. Several researchers such as Cho, et al. (2011) also add, that both domain knowledge and modelling language development expertise is needed. As mentioned, creating a DSML is not an easy task and two possible structured approaches are shown in the next two subchapters.

2.3.2 Approach one: Create DSML from End-User Demonstration

Cho, et al. (2012) describe two fundamental advantages of a DSML in their work as they delineate: “end-users can learn a DSML in a short amount of time because they perceive that they are working directly with domain notions. Moreover, it has been shown that DSMLs help to produce quality domain models”. They also share the view, that developing a new DSML is a complex task and requires several iterations. Even for language development experts it can be difficult to create the three substantial parts of a DMSL. Also, due to the iterative development process errors can happen. In their work they provide a standard approach for creating a DSML:

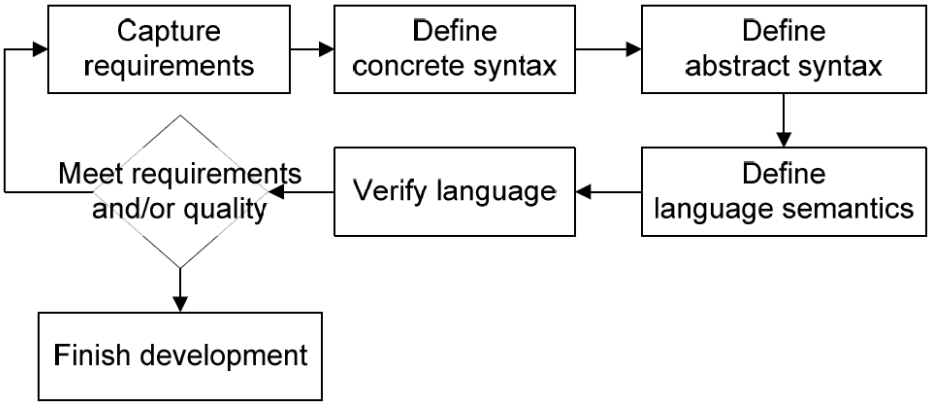


Figure 20: DSML development process from (Cho, et al., 2012)

This approach clearly points out the three mentioned parts, which have to be developed in the course of the process. Before these can be created, requirements from domain experts have to be captured and after the three parts were developed, it has to be tested, whether the DSML meets the set requirements. The author of this thesis shortly provides an overview of each phase in the following.

Capture requirements: The first step in the development of a DSML is to capture requirements from domain experts. Users generally have some requirements which are not reflected in an existing language. The participation of such domain experts is needed, as language development experts often do not have deep understanding or experience of the concepts, which are needed in a specific domain (Cho, et al., 2012). One possible approach to capture user requirements is by conducting interviews, as Courage & Baxter (2006) explain.

Define concrete syntax: The second step determines the concrete syntax. It describes how modelling concepts are rendered with visual and/or textual elements. Therefore, unique modelling elements, which are modelled as nodes in a graph, are defined (Cho, et al., 2012). Fondement (2007) adds some details as he specifies: "The definition of a concrete syntax contract means to define (1) a visual language, i.e. visual elements with relevant attributes and relationships between them and (2) how the visual elements are connected to the concepts of the language they are supposed to represent.". He additionally fixes the concrete representation by defining, which graphical elements shall be displayed and by specifying relevant attributes for them (e.g. shape, colour, size, position or attach regions).

Define abstract syntax: The abstract syntax is given in the form of a meta model, which describes the concepts of a given language independently of the source representation (Fondement, 2007). Thus the output of this phase is the meta model of the new DSML.

Define language semantics: Cho, et al. (2012) define semantics as that they "add domain-specific knowledge and help in reasoning about the desired properties of modelling elements". They further explain in their work, that semantics are often used to impose structural and behavioural properties. An example for semantics are rules, which constrain the concrete syntax.

Verify language: The final step includes testing whether the requirements of the end-users are met with the newly developed DSML. If not an additional iteration is needed to adapt the model to fully reflect these requirements.

Cho, et al. (2012) propose an adapted approach to ease the development of a new DSML. The main idea of this alternative is, that domain experts provide model examples, which are used to infer the meta model and semantics. Usually these parts (abstract/concrete syntax and semantics) are manually done by language development experts. They use the so called MLCBD framework, which assists to create these in a semi-automated manner as the following figure suggests:

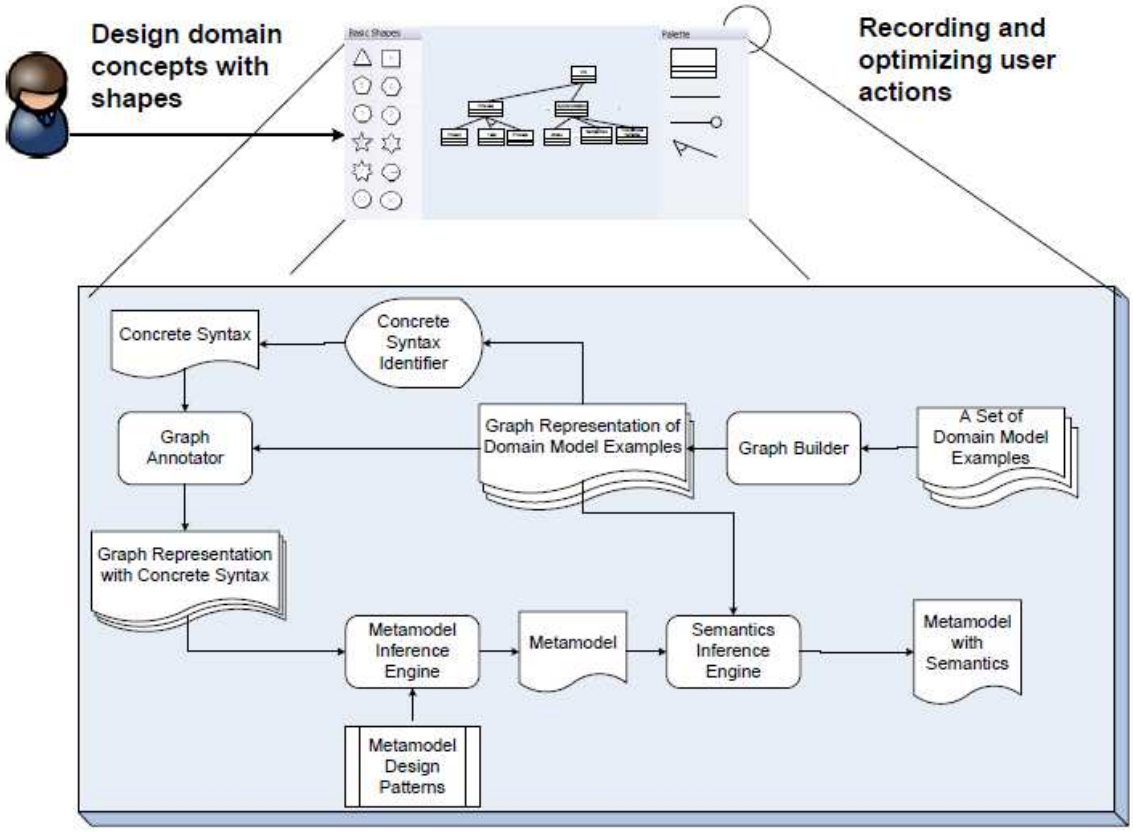


Figure 21: Adapted DSML development process from (Cho, et al., 2012)

2.3.3 Approach two: Create DSML based on UML profiles

Silingas, et al. (2009) propose in their work an approach for the adaption of UML to create a DSML for process modelling, as they write: “UML without modifications can only be used efficiently for modeling software systems”. One advantage of the approach lies in the leverage of UML of many standard modelling environment features. A seven step approach is used to create a DSML environment based on customized UML profiles, as shown in the following figure:

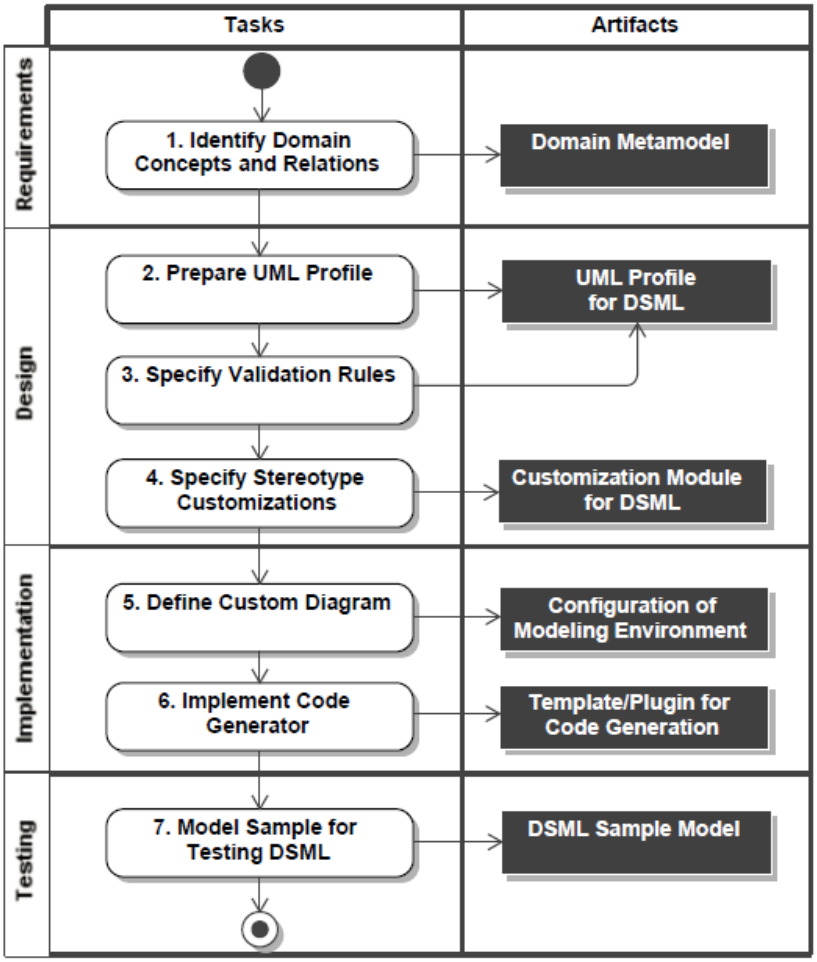


Figure 22: Approach to create a DSML from (Silingas, et al., 2009)

As mentioned, the approach includes seven tasks. These are assigned to the four main phases, requirements, design, implementation and testing, which is corresponding to the standard approach shown before. A short overview of each of the seven steps is given below.

Identifying Domain Concepts and Relations: The first task is to identify domain concepts, their properties and relations. This includes the development of the meta model (e.g. as a UML class diagram limited to classes, properties and associations).

Preparing an UML Profile: The next step is to map the meta model to UML meta classes and necessary extensions. Another part of this step is to define icons for the stereotypes, including custom line styles and ends for path stereotypes. This simplifies the use of the model and covers the needs of the specific domain. An example is given below:

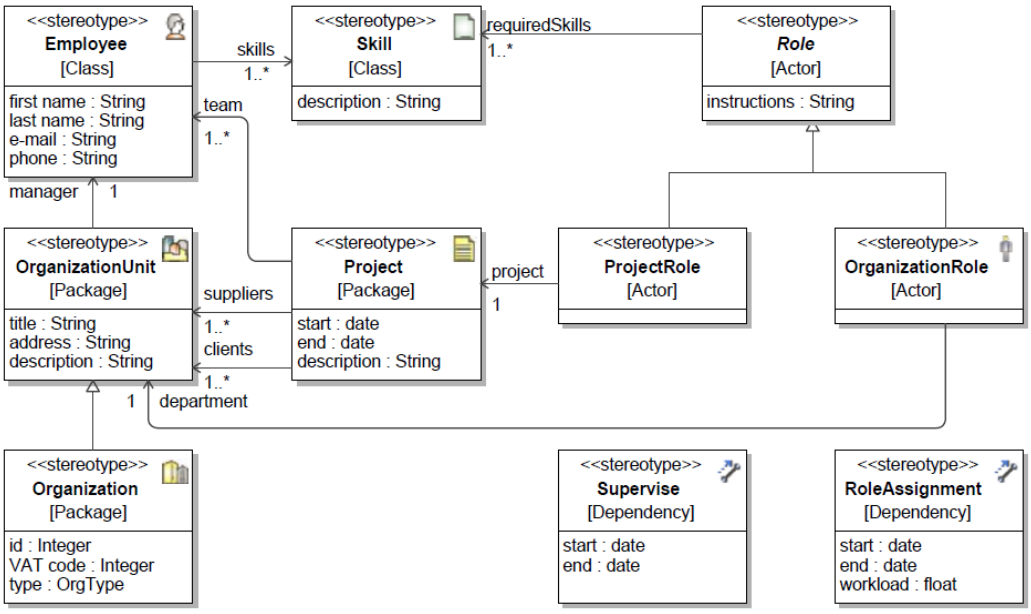


Figure 23: UML profile example from (Silingas, et al., 2009)

Defining Validation Rules: In this task constraints can be used as validation rules to ensure the correctness and completeness of DSML user models. Multiple validation rules have to be defined to cover all the important aspects of model correctness and completeness.

Customizing the Language: For every stereotype, customizations should be defined as the following figure explains:

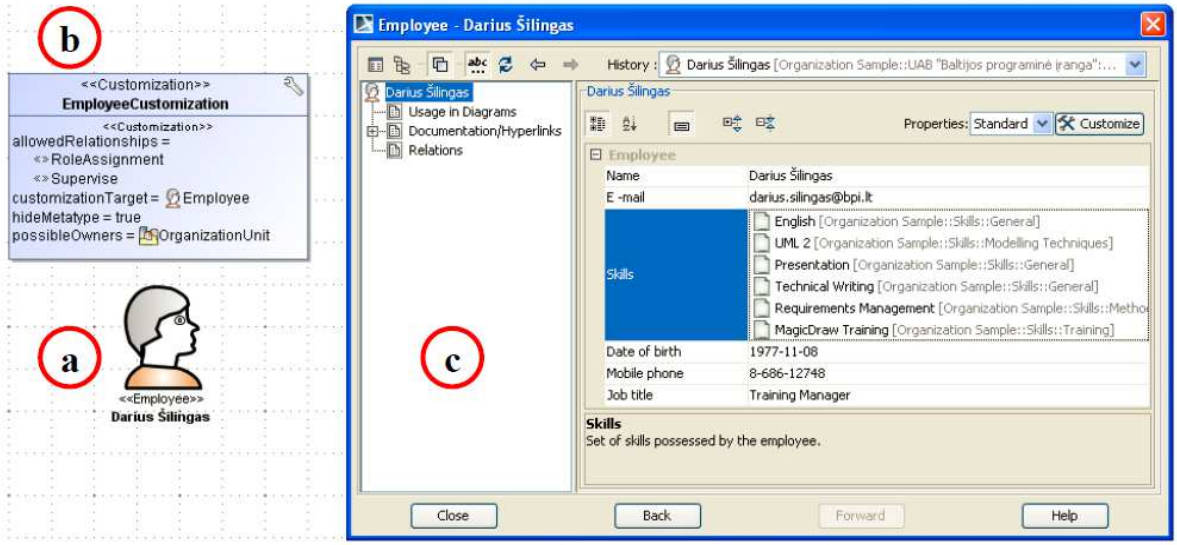


Figure 24: Customizing language example from (Silingas, et al., 2009)

(a) A diagram symbol of a user defined DSML element (in this case Employee)
(b) DSML customization element, which specifies applicable rules for this element
(c) Custom specification dialog to edit the properties of this element (in this case e.g. skills, date of birth or name)

Defining Custom Diagrams: The authors recommend to create a custom diagram, that is limited to domain modelling concepts. The idea of this diagram is to hide the complexity of UML and to be easy to use. It can for example be used for a first testing of the validation rules from step "Defining Validation Rules".

Implementing Code Generators: Silingas, et al. (2009) describe: "It is a common practice to use UML models as an input for code generators and MDA tools to generate implementation-level artifacts such as source code, XML or database schemas". They provide an example in their work, where code generated from the model is used to build an HTML website. As DSMLs in this work are proposed to be built on the top of UML profiles, a lot of tools can reuse such data from the models.

Testing DSML and User Models: The rules for validation of the user models have to be tested to the full extent. A sample model containing all DSML elements in valid and invalid modelling situations helps to fulfil this task.

2.3.4 Other past research work

This subchapter provides an overview of some results from research work in the field of DSMLs, which can deliver interesting additions to the previous subchapters and help to round off the subject of DSMLs.

Motivation, benefits, challenges

Agt, et al. (2011) have provided an overview of motivational aspects for doing domain-specific modelling and of demanded benefits in their work. According to them, companies mainly decide to create a domain-specific language (DSL) for the following reasons (not restricted to modelling activity only):

#	Motivational factor
1	To improve documentation
2	To use design artifacts as development artifacts
3	To be able to better involve customers and end-users
4	To ease the software configuration
5	To ease deployment on different target platforms

Table 4: Motivation to create a domain-specific language according to (Agt, et al., 2011)

While some aspects are strongly focused on DSL in the development environment, some are generally applicable, also for modelling. Examples are to improve documentation and the customer as well as the end-user involvement,

The main benefits that they expect from the DSL are the following (not restricted to modelling activity only):

#	Expected benefit
1	Effort reduction
2	Higher levels of abstraction
3	Improvement of development process and organization
4	Improved internal and external communication
5	Leverage existing documents
6	Integration into existing development landscape
7	Overcome business/technical mismatches

Table 5: Benefit of domain-specific language according to (Agt, et al., 2011)

Here as well, some aspects are more focused on DSL in the development environment than on modelling languages. However, improved communication, effort reduction and overcoming business/technical mismatches are also very relevant for DSMLs.

As mentioned, creating a DSML is a complex activity. Cho, et al. (2011) have noted, that several challenges and limitations have emerged. These are often witnessed when a company decides to develop a new DSML. They list them in their work as shown in the following table:

#	Challenge
1	Domain models are often specified with office tools such as word processing or drawing/presentation tools, rather than formal metamodeling tools.
2	Modelling language creation requires familiarity with metamodeling environments. Domain experts who are not familiar with metamodeling often do not understand the deep implications of domain analysis in DSML implementation.
3	The captured visual notations tend to be informal and incomplete, often requiring multiple iterations.
4	Specifying the semantics of a modelling language using formal techniques is often challenging even for computer scientists.

Table 6: Challenges of domain-specific modelling language creation according to (Cho, et al., 2011)

The identified challenges clearly show, that an exact definition of concrete and abstract syntax and of the semantics are a crucial activity in the development process of a DSML. It also illustrates, that using a dedicated tool for the creation of DSMLs is of advantage and provides the necessary support in the development of the language.

DSML research results

Marques do Nascimento, et al. (2012) have done a systematic mapping study of relevant papers from the field of DSLs. Even-though it is not only about papers of DSMLs, it provides some interesting details. From considering 1440 papers about DSLs, they found out that by far the most of them are proposing a new possible solution to the reader. Also frequent are evaluation and validation research. When looking at the research type, only

about 170 of all papers are about DSMLs, while the most are about external DSLs and not modelling activities. However, these results still suggest that there is a strong interest in DSMLs and providing new approaches for DSLs is the main research area.

Braun & Esswein (2014) specifically focus their research article on the classification of domain-specific BPMN extensions. They argue: "BPMN can be extended with domain-specific concepts in order to reuse the modeling language, take advantage of its benefits (e.g., standardization, tool support) and avoid expensive development of a DSML from the scratch". They deem BPMN as a suitable language for extending, because of available generic extension models in the meta model that enable the definition of domain-specific concepts. Their systematic literature review resulted in a set of 30 BPMN extensions, one of which is from the healthcare domain (already mentioned BPMN4CP by Braun, et al. (2016)). They found out, that most of the languages do not use the available BPMN extension artifacts but rather use their own meta modelling approach or are only defined by new notation elements. Also mentioned is that the analyzed BPMN extensions mainly used the BPMN elements "Data Object", "Task", "Activity" and "Process" for an extension.

2.3.5 Conclusion

DSMLs have been an important research topic in the past years. A study of the literature has shown that they require the definition of the three main elements abstract syntax, concrete syntax and semantics. A structured approach towards the development of a new DSML is needed. Even if approaches are slightly different, they usually cover the definition of domain-requirements, the design of the three main parts and concluding verification activities. It can be differentiated between a design from scratch or by extending an existing modelling language. The latter limits the time needed for the development. It seems that some languages, such as BPMN or UML, are better suited for an extension as they already provide some concepts or are in general very flexible. Also it has been found out that using a dedicated tool with meta-modelling support is advantageous.

The study of benefits and motivational factor suggests that a DSML can be very favorable for the relevant domain of this thesis. Especially an ease of use and communication as well as a common understanding of all relevant stakeholders can be beneficial.

2.4 The Application of DSMLs in the Healthcare Sector

It should already be evident that so far only limited research has been done in the area of DSMLs in the healthcare sector. This is also confirmed by Gyuchan, et al. (2009), as they comment: “The role of process modelling has been widely recognized for effective quality improvement. However, application in health care is somewhat limited since the health care community lacks knowledge about a broad range of methods and their applicability to health care”.

This chapter gives a detailed overview of available past research work in this field and also shows some related work, which might also be relevant for the course of this thesis. This chapter helps to prove, that there is a research gap when it comes to creating a DSML for transfer management decisions.

2.4.1 Past research on DSMLs in Healthcare

So far, limited research has been done on the use of DSMLs in the healthcare sector. Still, interesting papers are available, showing/demonstrating that first experiences have been collected in similar fields as the one, which is in focus for this thesis. This chapter gives an overview of these relevant papers and identifies a research gap.

Evaluation of Modelling Languages for Clinical Pathways

Burwitz, et al. (2013) have in their work first evaluated modelling languages for their suitability to model clinical pathways. For their evaluation, they have defined different requirements based on scenarios, which a modelling language in this area needs to fulfill. The requirements can be shown in the following table:

#	Description
R1	A language for modeling clinical pathways should provide the basic concepts of the medical business process modeling (patient state, treatment step, decision, process flow) and the ability to integrate information objects and responsibilities.

R2	A language for modeling clinical pathways should provide concepts for describing indefinite order relations as well as compulsory parallel relations between treatment steps and iterating treatment steps.
R3	A language for modeling clinical pathways should provide concepts for describing evidence-class of any recommendation and linking the source of evidence. Additionally, a concept to describe evidence-based decision is required.
R4	A language for modeling clinical pathways should provide concepts to describe temporal dependencies and explicit time events.

Table 7: Requirements to a modelling language in the CP area according to (Burwitz, et al., 2013)

Thus, the authors have defined clearly which concepts and symbols are needed to model clinical pathways. A table comparing several possible languages shows that none fully includes these concepts:

Requirement		R1				R2			R3			R4
Approach		Clinical state	Treatment step	Decision	Process flow	Resources & responsibilities	Variable flow	Parallel flow	Iteration	Evidence indicator	Evidence-based decision	Time event
MIS	BPMN	●	●	●	●	●	–	○	○	–	–	○
	Activity Chart	●	●	●	●	●	–	○	○	–	–	○
	Clinical Algorithm	●	●	●	●	–	–	○	○	–	–	–
IT	GLIF	●	●	●	●	○	○	○	○	○	–	○
	Guide	●	●	●	●	○	○	○	○	–	–	–
	PROforma	–	●	●	●	○	–	○	○	○	–	○
	Prodigy	●	●	●	●	–	–	–	–	○	–	○
	EON	●	●	●	●	○	–	–	○	○	–	○

● Requirement met ○ Requirement partly met – Requirement not met

Figure 25: CP modelling requirements coverage of some modelling languages according to (Burwitz, et al., 2013)

Some requirements such as variability or evidence-based decisions are missing in most of the languages. The authors of the paper therefore decided to create their own DSML (called CP-Mod), based on the Clinical Algorithm, to reflect the missing concepts. The clinical algorithm is a common approach for modelling clinical pathways. However, it

needs to be extended to be able to model complex health care processes and to reduce the existing deficits by addressing the requirements that are only partly or not at all met.

The meta model of the language has been extended with the following concepts to fully meet all requirements:

- Evidence-based Medicine and Decision Support
- Classification of Different Treatment Alternatives
- Time Events and Waiting Periods

The following figure is an example of a model, using the new DSML CP-Mod:

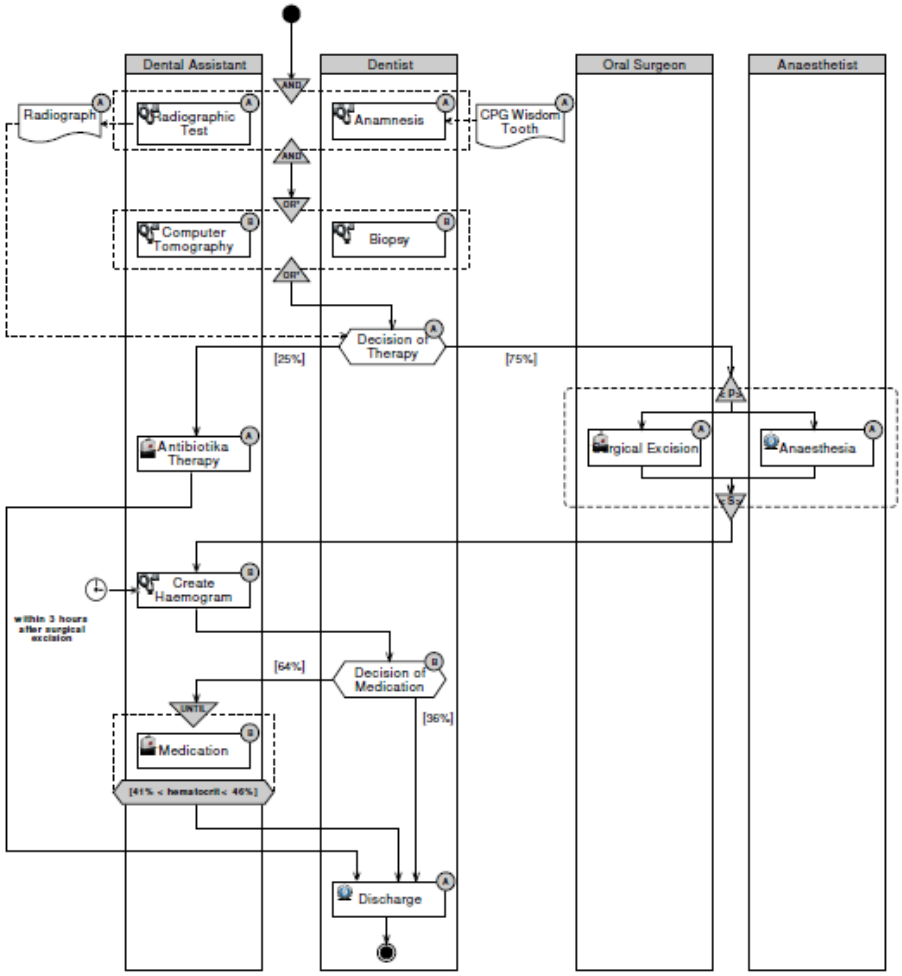


Figure 26: CP model using CP-mod from (Burwitz, et al., 2013)

The authors demonstrate in their work, that there is no modelling language existing, which reflects the requirements of the healthcare sector, or more precisely, to model clinical

pathways. This area has very specific requirements and only a DSML can fully reflect them.

Heß, et al. (2015) have done a similar work, which can be seen as an advancement of the work from Burwitz, et al. (2013). They show, that existing approaches to model CPs are lacking domain-specific semantics. They argue: "to realize the potential benefits of CPs, a comprehensive modelling method accounting for peculiarities of hospitals' action system and IS is required. The core of such a method should be a Domain-Specific Modelling Language for CPs". They further mention, that widely accepted business process modelling techniques to model CPs do not allow to realize the desired benefits, which are for example to foster communication between stakeholders or as an instrument for quality assurance. They have also defined a list of requirements that a DSML for modelling CPs should cover:

#	Description
R1	A DSML for CPs should provide concepts supporting comprehensive modelling of medical processes based on professional terminology
R2	A DSML for CPs should provide concepts supporting comprehensive modelling of medical decision scenarios including decision alternatives, criteria and their corresponding potential values
R3	A DSML for CPs should provide concepts for modelling and assigning information on the underlying evidence classification
R4	A DSML for CPs should provide basic concepts to model control flow structures
R5	A DSML for CPs should allow for specifying one or more goals for each medical process based on both, (evidence based) medical knowledge and patient-specific preferences
R6	A DSML for CPs should allow for assigning responsibilities to each medical process, differentiating those responsible for performing the medical process, as well as those responsible for its outcome

R7	A DSML for CPs should allow for representing checklists associated to each medical process
R8	A DSML for CPs should account for various perspectives and information needs of hospitals' stakeholders
R9	A DSML for CPs should allow for allocating medical resource types to medical process types
R10	A DSML for CPs focusing on oncological CPs should account for supporting dedicated CP-based clinical documentation as well as, based on it, a clinical and epidemiological cancer registry

Table 8: Requirements to a modelling language in the CP area according to (Heß, et al., 2015)

They also provide an evaluation of whether different approaches for modelling processes do cover the requirements of modelling clinical pathways:

Approach	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Information Systems – enterprise modelling approaches										
BPMN (OMG, 2011; Scheuerlein et al., 2012)	○	◑	○	●	○	◑	○	○	◑	○
EPC (Perrevort, 2003)	○	◑	○	●	○	◑	○	○	◑	○
MEMO OrgML (Frank, 2011a) with extensions (Heise et al., 2010; Heß, Schlieter, and Täger, 2012)	◑	●	◑	●	◑	○	○	○	○	○
Information Systems – process modelling approaches										
Aspect-oriented process modelling (Meiler, 2005)	○	●	◑	●	○	○	●	●	◑	○
CP-Mod (Burwitz, Schlieter, and Esswein, 2013)	◑	●	◑	●	◑	○	○	○	○	○
Perspective-oriented process modelling (Färber, Jablonski, and Schneider, 2007)	○	●	◑	●	○	○	○	●	◑	○
Information Systems – formal language-based approaches										
CONFlexFlow (Yao and Kumar, 2013)	◑	◑	○	●	○	○	○	○	●	○
Medicine and medical informatics field										
Clinical Algorithm (Society for Medical Decision Making, 1992)	◑	◑	○	●	○	○	○	○	○	○
GLIF (V3) (Boxwala et al., 2004)	◑	●	○	●	○	○	○	○	○	○
PRO*forma* (Sutton, Taylor, and Earle, 2006)	◑	●	○	●	○	○	○	○	○	○
Sage (Tu et al., 2007)	◑	●	○	●	◑	○	○	○	◑	○

Legend: ○ = not fulfilled; ◑ = partly fulfilled; ● = fulfilled

Figure 27: CP modelling requirements coverage of some modelling languages from (Heß, et al., 2015)

Heß, et al. (2015) recognized, that no language fully covers these extended requirements to model clinical pathways. Not even the created language CP-Mod by Burwitz, et al. (2013). Thus, they decided to extend the meta model of the language MEMO OrgML to create a DSML for the modelling of clinical pathways. The newly created language DSML4CPs reconstructs the professional terminology from the medical domain with a

special focus on oncology. An exemplary process which illustrates domain-specific concepts is provided below:

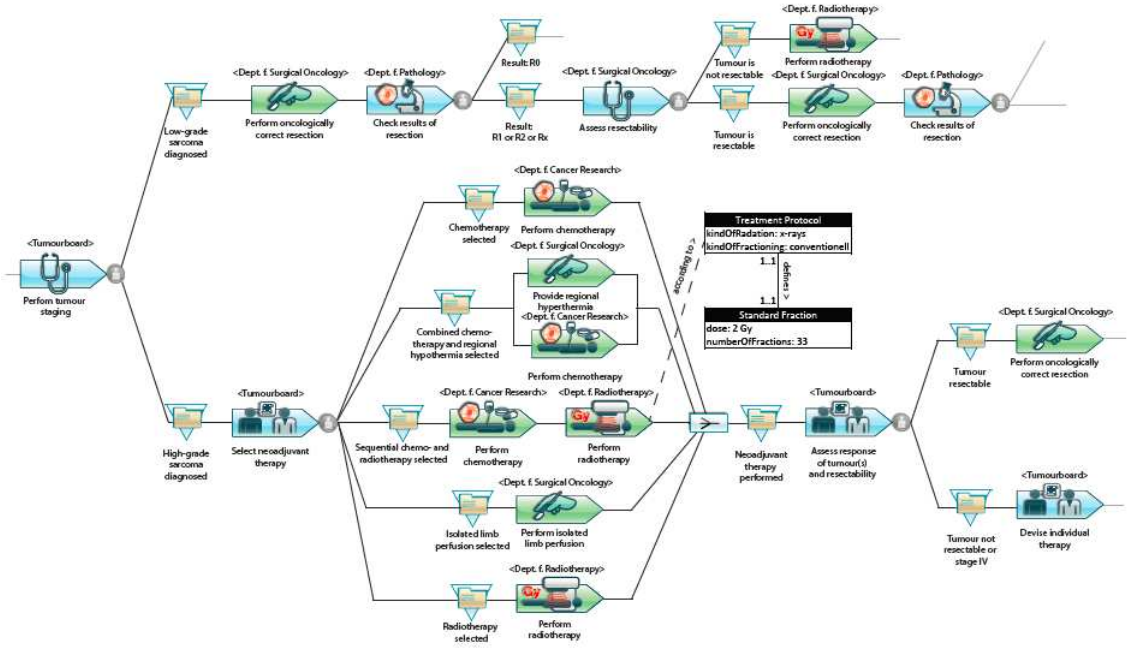


Figure 28: CP model using DSML4CPs from (Heß, et al., 2015)

Heß, et al. (2015) also noticed, that no existing language covers the domain-specific needs of clinical pathways. However, in contrast to Burwitz, et al. (2013), they have defined additional requirements that need to be reflected. Also, they decided to use a different language for the extension of the meta model.

Domain-Specific Extension of BPMN for Clinical Pathways

Braun, et al. (2015) have also noticed the need for domain-specific concepts to model clinical pathways. However, they propose to use BPMN for the extension as it is widely used for modelling business processes. Other stated advantages of BPMN are that it provides a well-defined meta model, supports the derivation of computer-interpretable workflow models, provides a large set of generic process modelling concepts and includes an explicitly defined, lightweight extension mechanism for domain-specific extension and adaptation. In their work, they use the language CP-Mod to derive requirements for the extension of BPMN and to create the language BPMN4CP. One advantage of the solution is that several perspectives on a clinical pathway, such as resource, process or document perspective, are possible to be modelled as the following figure presents:

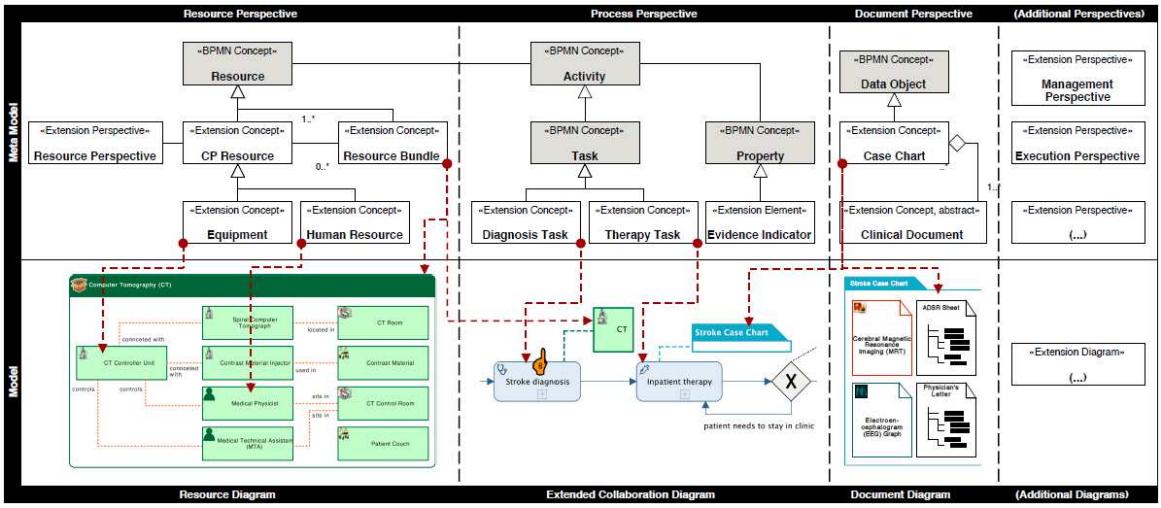


Figure 29: Multi-perspectivity of the BPMN4CP extension from (Braun, et al., 2015)

In another work, Braun, et al. (2015) provide a more detailed view on how they have created BPMN4CP. They have slightly adapted the approach to extend BPMN defined by Stroppi, et al. (2011). The main difference lies in the deeper domain analysis with a better consideration of comparing extension concepts with standard BPMN concepts.

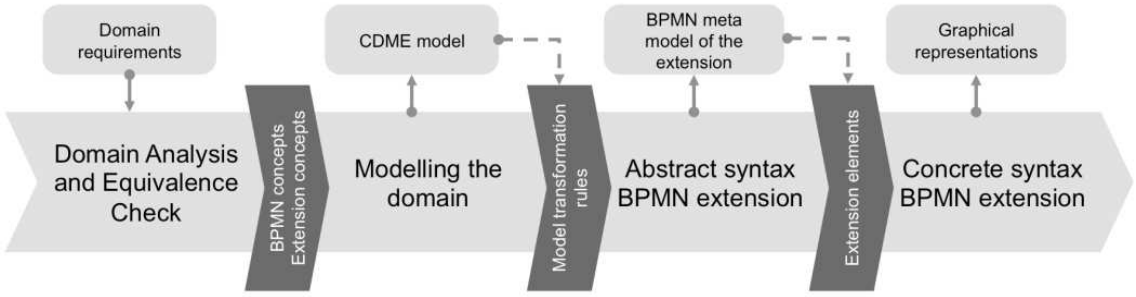


Figure 30: Approach to create a BPMN extension from (Braun, et al., 2015)

The first two steps, the domain analysis and the domain modelling, were done by developing an ontology, which shows the concepts and attributes of the clinical pathway domain:

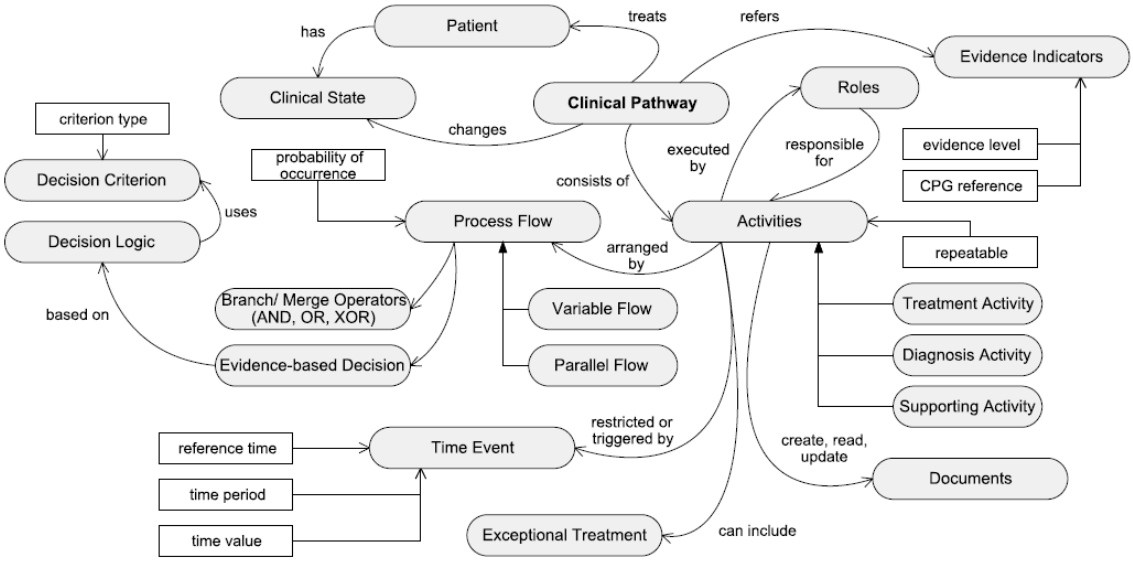


Figure 31: Domain-analysis as an ontology from (Braun, et al., 2015)

The third step, the abstract syntax, was conducted by an equivalence check between the required domain-specific concepts and their presence in the BPMN specification. An extended meta model shows that several domain-specific concepts such as therapy task, diagnosis task, evidence-based gateway or decision criterion had to be added.

The last step, the concrete syntax, led to domain-specific BPMN notation elements as the following figure depicts:

Figure 32: New notation elements (New task marker, specified data object, Simultan Parallel Gateway, Evidence-based Gateway and Evidence Level) from (Braun, et al., 2015)

With the help of these elements a CP process such as the one shown in the following figure can be modelled:

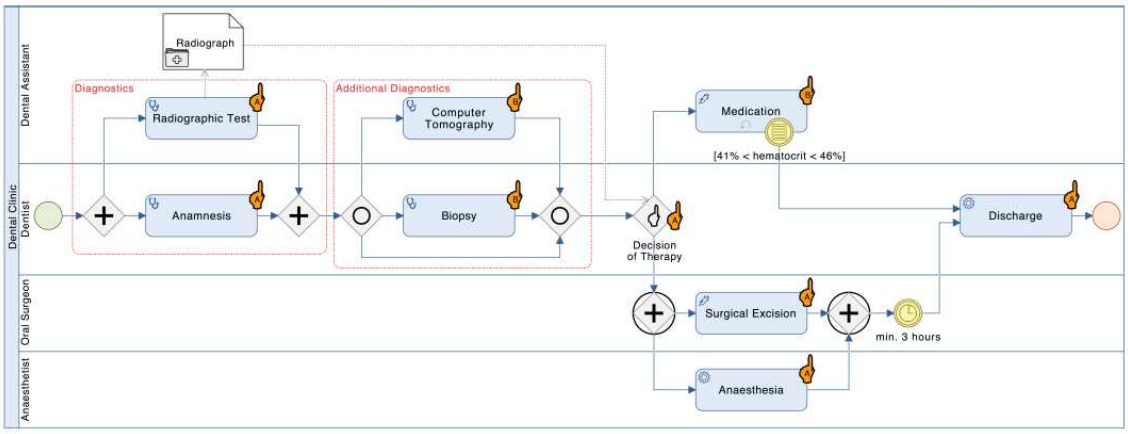


Figure 33: Exemplary process modelled with BPMN4CP from (Braun, et al., 2015)

Braun, et al. (2016) have revised their BPMN4CP approach based on its practical application within a project. This led to an evolution of BPMN4CP from version 1.0 to version 2.0 to cover additional business requirements. A Requirements-Driven Design Science has led to new requirements in the area of:

- User requirements
- Contextual requirements
- Feature-related requirements
- Theory-based requirements
- Functional requirements

These additional requirements demanded a change of the previously shown ontology as additional concepts had to be reflected. Some main changes are more possibilities to define document types and resources. The new ontology is provided in the upcoming figure:

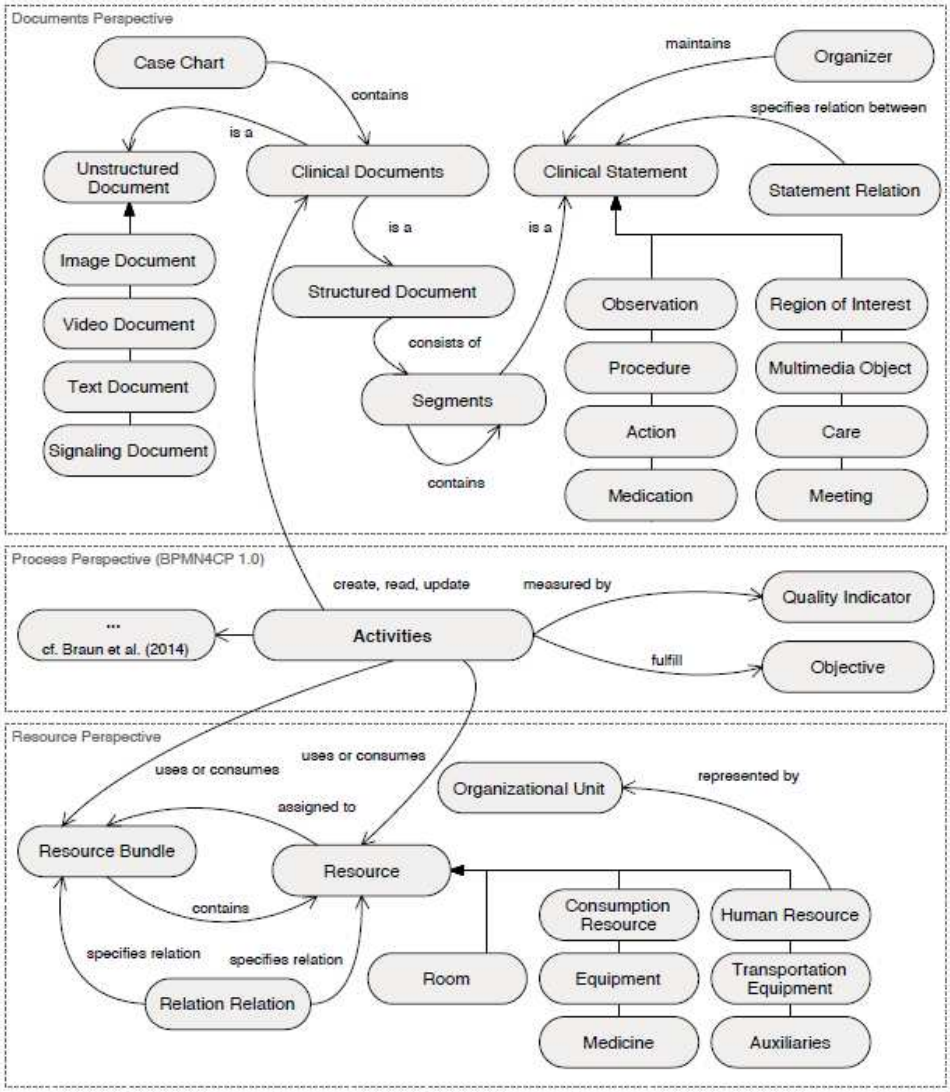


Figure 34: Extended CP ontology from (Braun, et al., 2016)

Also, the abstract syntax (meta model) and the concrete syntax (modelling elements) were extended to cover these new domain-specific concepts which are defined in the ontology.

User-Centric Approach to Create a DSML in Healthcare

Wu, et al. (2012) claim in their work, that nowadays a user-centric approach is needed to create a communication platform (including a DSML). This approach is driven by a domain user and involves a graphical service creation environment, user-driven creation, dynamic adoption and self-configuration to decrease complexity while increasing flexibility. The authors have designed a DSML that can be used to specify the requirements for user-centric communication use cases or scenarios called Communication Modelling Language (CML). This language is designed in a structured

approach, containing a domain analysis including descriptions of the CML meta-model and three concrete syntaxes. The DSML can also be converted into an executable form, “unlike many DSMLs”, as the authors explain. These so called CML models are directly executed by a Communication Virtual Machine (CVM).

The domain analysis has been done with healthcare personnel working in a hospital to identify communication-intensive use cases. Thus this DSML is solely focused on communicational aspects (within a healthcare organization) and not on clinical pathways as previously seen approaches. The following figure provides an example of a model that shows a two-way communication between two doctors:

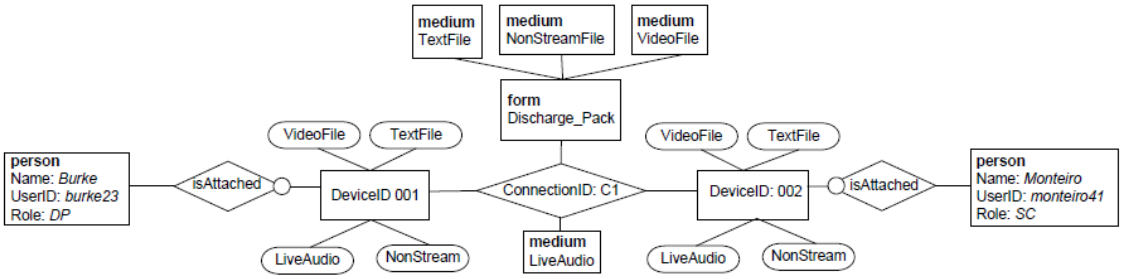


Figure 35: CML diagram of a two-way communication from (Wu, et al., 2012)

DSML for Electronic Patient Care Reports

In the focus of the work of Shenvi, et al. (2007) is the electronic Patient Care Report (ePCR). The authors recognize an increasing demand for Model-Driven Engineering (MDE), which provides an environment that allows the creation of models representing domain objects rather than a source code. In the work a DSML is created to model an ePCR for a patient.

First, a meta model of the domain is constructed. This meta model includes domain-specific modelling constructs such as patient demographics, vital signs and medications. Each of these constructs has several attributes that define the visualization and behavior of that element. Additionally, connections between constructs are defined. As the purpose of this project is to automate the production of the business and data layer objects, the modelling environment is not targeted for end-users but for developers. The following figure provides an example of a model and shows the modelling environment:

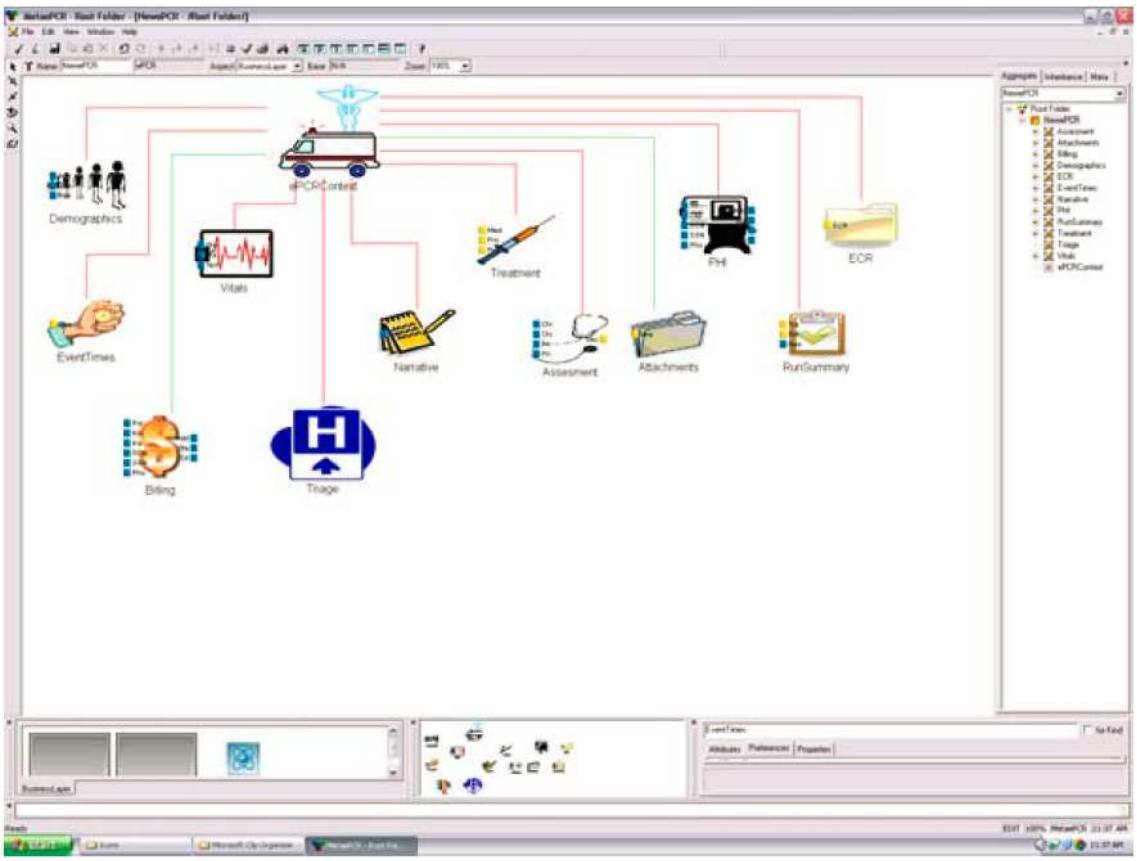


Figure 36: Model of an ePCR configuration from (Shenvi, et al., 2007)

Such a model grants a good domain-specific overview, as several artifacts of the healthcare domain are reflected. Unfortunately, the models are not created as an instrument for domain end-users.

Clinical Decision-Support System with the use of DSML

Mathe, et al. (2009) describe in their work how "Vanderbilt University and its Medical Center are applying model-integrated techniques to specify treatment guidelines as asynchronous processes and implement them in visual dashboards to assist healthcare teams".

Process management dashboards are used to inform the medical staff of the status of required activities for patients with specific problems. Indicators show, whether activities have already been done for a certain patient. A model-integrated computing (MIC) tool offers new opportunities for the clinical decision support and process-management. The subsequent picture gives an overview of the architecture:

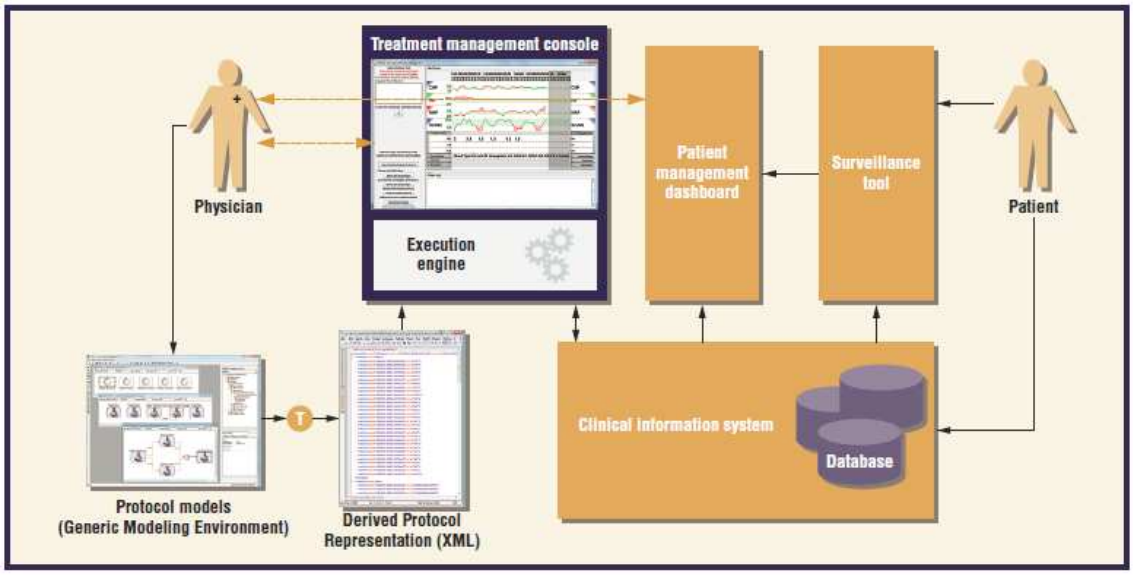


Figure 37: System architecture overview from (Mathe, et al., 2009)

The team has designed a visual DSML (Clinical Process Management Language) for capturing treatment protocols in their Generic Modelling Environment (GME). To be able to model complex processes and to make sure, that the language is intuitive to use for physicians, they decided to group treatment steps under process concepts and organized processes in hierarchies. Processes of a model have a status which changes at run-time, e.g. depending on the condition of vital signs of a patient. These models capture medical knowledge and include processes, which are activated in an order depending on specific conditions. Their initial work was limited on the treatment of sepsis and an example for this process model shown in the GME is given in the next figure.

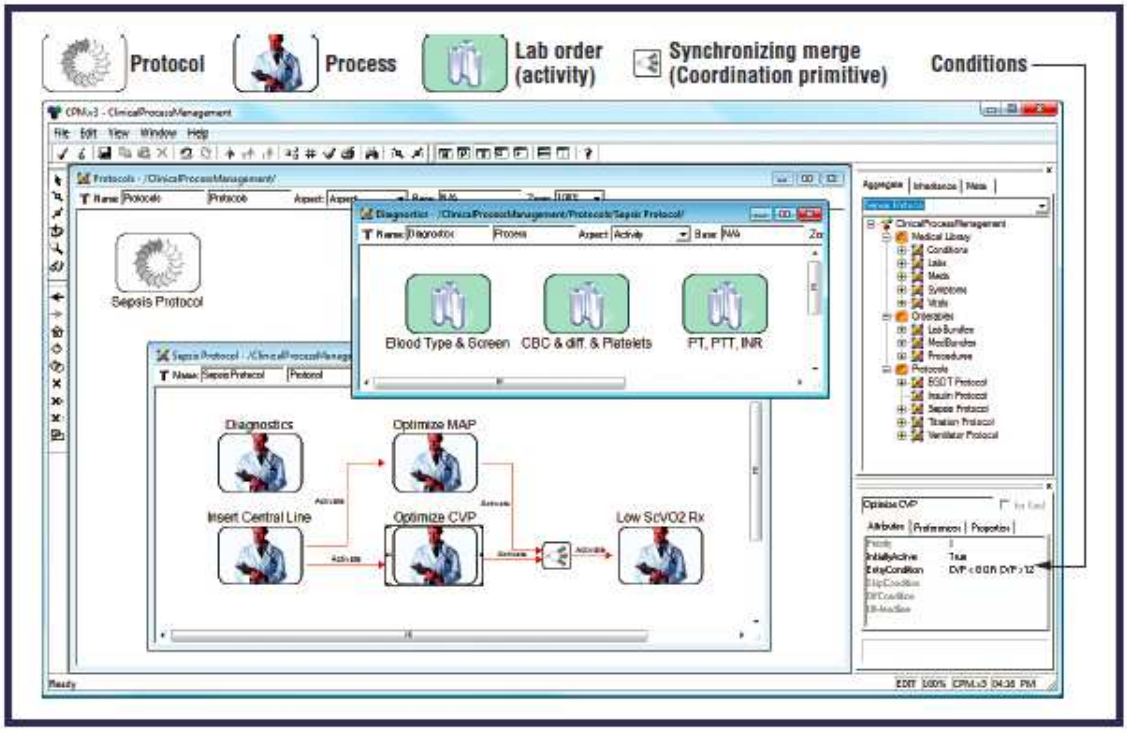


Figure 38: Model for Sepsis expressed in Clinical Process Management Language from (Mathe, et al., 2009)

The authors write, that no widely accepted visual languages for capturing treatment protocols was existing so far. Generic software modelling languages, such as UML, are not designed to capture medical knowledge. Some main benefits of their approach, which they have noted, are:

- The protocol models capture medical knowledge explicitly and avoid ambiguity
- Medical professionals comprehend the models easily, eliminating the need for IT personnel to mediate between the medical and computer fields
- The protocol models enable knowledge transfer
- The models can be updated on a regular basis
- The modelling language's expressiveness is helpful and fully confirms the importance of using DSMLs highly customized to the clinical environment

2.4.2 Related research in Healthcare

While research papers in the prior subchapter were focused strongly on the application of DSMLs in healthcare, the following two provide an insight into related topics which are possibly very relevant for the progress of this thesis.

Using CMMN for Variability Modelling of Clinical Pathways

Herzberg, et al. (2015) note in their work, that clinical pathways are more flexible than processes in other sectors such as the industry. The treatment processes can vary for each individual patient as well as for every hospital. Some steps such as therapies might change when interpreting patient-specific data. A change in the condition of a patient might require a dynamic change of the process. To address these challenges, they have used CMMN to model clinical pathways. They argue, that case management can express the needed flexibility. Tasks in CMMN can be specified as either mandatory or discretionary at design time and serve as recommendation during run-time.

A CMMN case plan model was defined based on a BPMN process model. It can be seen in the following figure as an example of a living liver donor evaluation:

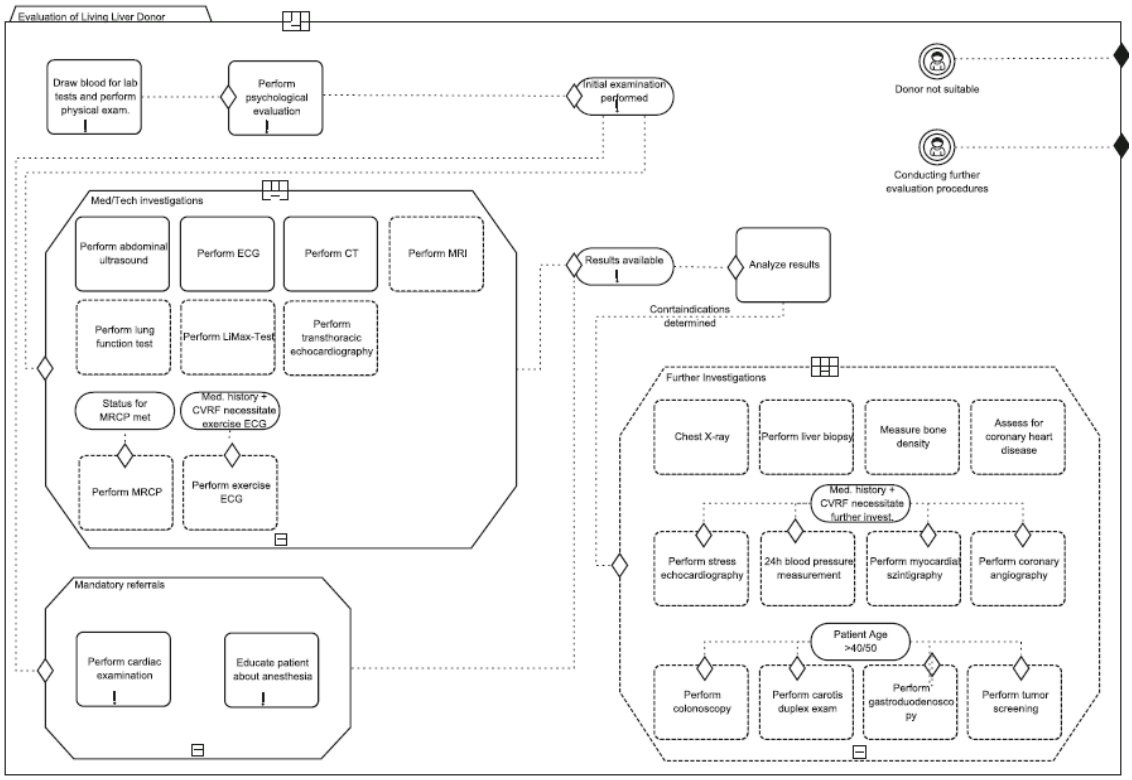


Figure 39: CMMN case plan model from (Herzberg, et al., 2015)

The model demonstrates that depending on the results, several additional further investigations might be needed. The dashed lines indicate that all further investigation steps are discretionary.

The authors have noted some advantages and disadvantages when using CMMN for modelling clinical pathways:

- Modeling a general process valid for several hospitals is possible with CMMN by using the concept of tasks and discretionary tasks, even if they work differently.
- Explicit modeling of roles is not supported by CMMN, role information is not explicitly shown in the model and is only used for human tasks
- Explicit modeling of locations is not supported by CMMN

General Healthcare Process Modelling Overview

The perception of business process modelling by healthcare workers is analyzed in the article of Gyuchan, et al. (2009). They record, that there is an increasing demand to improve the quality of care. In order to do this, it is essential to understand care processes. However, such an understanding is often missing in healthcare practitioners, while other industries are much further advanced in this regard. The authors argue, that due to the variation in healthcare processes, different diagram types have to be considered for modelling. Each modelling method has distinct advantages and disadvantages and healthcare workers should be able to select the most appropriate method according to their needs.

The results of the paper show, that healthcare workers are generally only experienced with a very limited amount of diagram types such as flowcharts and swim lane diagrams. Thus there is limited knowledge in the use of business process modelling in the healthcare sector. However, much more diagram types would be easily understandable and useful for practitioners as the research suggests. For example, process content diagrams that help to understand a detailed task structure would be easy to use and useful for the foster understanding on the practitioner's side.

2.4.3 Conclusion

This chapter has given an overview of the available research in the healthcare area specific to DSML and some related areas. The following table summarizes the analyzed papers:

Title	Authors / year	Purpose
Modeling Clinical Pathways - Design and Application of a Domain-Specific Modeling Language	(Burwitz, et al., 2013)	• Domain-specific requirements • Evaluation of modelling languages • Creation of new DSML for CPs
A Domain-specific Modelling Language for Clinical Pathways in the Realm of Multiperspective Hospital Modelling	(Heß, et al., 2015)	• Domain-specific requirements • Evaluation of modelling languages • Creation of new DSML for CPs
Clinical Processes from Various Angles – Amplifying BPMN for Integrated Hospital Management Extending a Business Process Modeling Language for Domain-Specific Adaptation in Healthcare BPMN4CP Revised – Extending BPMN for Multi-Perspective Modeling of Clinical Pathways	(Braun, et al., 2015) (Braun, et al., 2015) (Braun, et al., 2016)	• Domain-specific requirements • Extension of BPMN to create new DSML for CPs
A Domain-Specific Modeling Approach to Realizing User-Centric Communication	(Wu, et al., 2012)	• Creation of new DSML for communicational aspects

Generation of Context-Specific Electronic Patient Care Reports (ePCR) using Domain-Specific Modeling	(Shenvi, et al., 2007)	• Creation of new DSML for electronic Patient Care Reports
A Model-Integrated, Guideline-Driven, Clinical Decision-Support System	(Mathe, et al., 2009)	• Creation of new DSML for treatment protocols
Modeling and Monitoring Variability in Hospital Treatments: A Scenario Using CMMN	(Herzberg, et al., 2015)	• Modelling CPs with CMMN
Health care process modelling: which method when?	(Gyuchan, et al., 2009)	• Survey on business process knowledge of healthcare workers

Table 9: Analysed papers for the use of DSML in healthcare

The study of these papers has shown, that only limited research is available regarding the usage of DSMLs in the healthcare sector. There is no generally accepted standard existing, which is reflected in the various different approaches that are used. While most of the papers are for the modelling of clinical pathways, all of them use a different language as their basis and identify different types of requirements. DSMLs have been created not only for CPs, but also for communication processes, ePCR and treatment processes. One matter that all authors agree on is, that for the healthcare area an extension with domain-specific concepts is inevitable. Without adding domain-specific concepts, requirements of the domain cannot be completely fulfilled as research has shown. For transferal management, where patients are discharged from an acute hospital to the next site of care, an evaluation of domain-specific requirements is not yet systematically done and the development and usage of a DSML is not researched and thus a research gap exists.

2.5 Conclusion

The first part of this literature review was concerned with an introduction into the world of processes. BPM is more and more accepted as a holistic management discipline, which is crucial to ensure the long-term competitiveness of a company. Thus the view that BPM is more than a software to support processes, is a winning recognition even if there are still some supporters of the contrary viewpoint. This was illustrated when comparing two different approaches for a BPM lifecycle. The BPM lifecycle is a structured approach for a BPM initiative and normally includes process modelling, process implementation, process monitoring and process improvement. This is true, whether the focus lies on software or on BPM as a management approach. The latter requires dedicated resources and organization structures to ensure long-term success.

The second subchapter was giving a more detailed overview about one of the BPM lifecycle phases; the modelling of business processes. Due to the increasing interest in BPM it is clear, that also the modelling activity is gaining importance, as several researchers have noted. This resulted in a wide variety of new methods, languages and standards for modelling business processes. The advent of these languages forced researchers and practitioners into finding ways to evaluate the market of the available concepts. However, I have not found a suitable overview usable for the further progress of this work. Thus an introduction into the most relevant languages for business process modelling is given in this thesis. UML and Petri Nets can be used for the modelling of business processes as several researchers have demonstrated, but compared to EPC and BPMN they are less expressive and more complex to understand for business users. Especially BPMN provides several advantages compared to other languages and thus is also the most widely accepted standard but can overwhelm inexperienced users. DMN and CMMN are new standards that are designed to tackle the challenge of flexible and knowledge intensive processes. They are a welcomed addition to the BPMN standard. Process modelling languages can be divided into GPMLs and DSMLs. It has been demonstrated that for the healthcare domain a domain-specific approach would be desirable.

Approaches to creating a DSML are in focus of the third subchapter of this literature review. A DSML requires three main parts, which are an abstract syntax, a concrete syntax and semantics. A standard approach to create a DSML consists of a first phase,

where requirements from domain-experts are collected. The following three phases are for the development of the three main parts, while the fifth step is a verification whether the newly created DSML fulfills all requirements. Analyzed literature has highlighted, that especially UML and BPMN are often used for an extension with domain-specific concepts. These two languages already provide some concepts that can be adapted to specific requirements. Generally, there is a lot of interest in the research area of DSMLs, and the research community is open for new approaches on how to create a certain DSML. According to the reviewed literature, motivational factors to create a DSML are for example to improve documentation or to foster the involvement of end-users. Expected benefits are enhanced communication or elimination of misunderstandings between business and IT. Lastly, challenges lie mainly in the incorrect, inconsistent or incomplete development of the three main parts of a DSML.

The last subchapter is concerned with the application of DSMLs in the relevant domain of this thesis: the healthcare sector. It can be asserted that some but not a large amount of research is available. Also, the sector is lacking behind in the usage of DSMLs or in general of applying BPM. One reason lies in the limited knowledge of the healthcare employees about the available methods. Several papers were analyzed, that show first experiences with DSMLs in the healthcare sector. A main research concern is the support of CPs. Also DMSLs were developed for ePCR and treatment processes. One article also gives an insight into the usage of CMMN for variability modelling. Comparing all articles it can be observed, that available modelling languages do not cover the very specific needs of the healthcare domain and hence potentials cannot be fully realized. Thus the authors of the analyzed articles decided to create new DSMLs to cover their requirements. Interesting to see is, that the collected requirements and the chosen languages for extension very much differ. Thus no generally applicable standard has been found so far. When looking at the administrative pathway and more precisely at the modelling of transfer decisions, no DSML approach was found and thus a research gap exists.

3. Research Method

The third chapter of this master thesis is describing the research methodology respectively the research design, which is followed in the chapters four to eight. Two subchapters first give a short overview of the available methodologies and secondly introducing the chosen methodology with the research design.

3.1 Methodology Overview

Saunders, et al. (2011) are in their book presenting the research "onion" which is explaining the different layers of a research design. The research "onion" is shown in the following figure adapted with the research strategy design research:

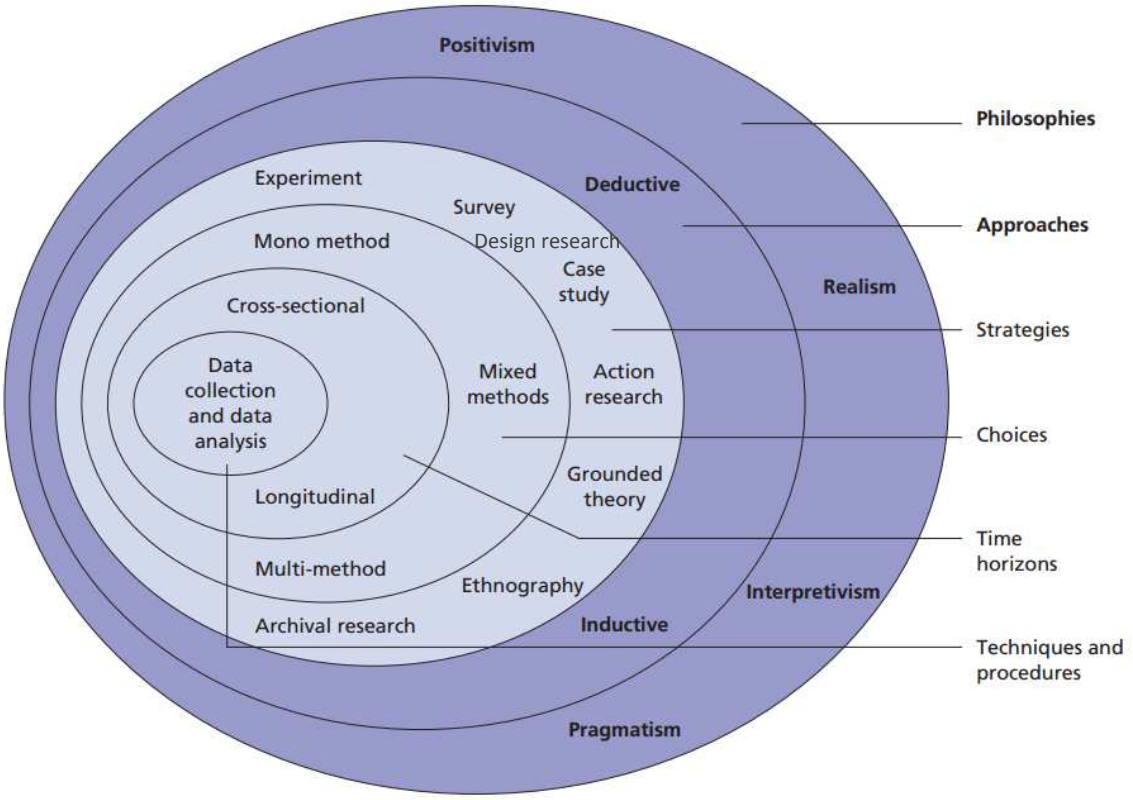


Figure 40: Research "onion" from (Saunders, et al., 2011)

The research "onion" provides a systematic categorisation of research. For the design of a research methodology several dimensions such as philosophy, approach and strategy have to be composed. In the next subchapter, the relevant layers and chosen values of each of these layers of the "onion" for this thesis are explained in detail.

3.2 Applied Methodology and Research Design

In subchapter 3.1 we have seen the research "onion" by Saunders, et al. (2011). In this subchapter, I explain the layers philosophy, approach, strategy and techniques and procedures in detail. These layers are deemed to be of central relevance for the methodology of this research work and thus need further explanation.

3.2.1 Philosophy

The research philosophy relates to the development of knowledge and the nature of that knowledge (Saunders, et al., 2011). It thus explains the way in which knowledge is developed. The research "onion" has highlighted, that there are four possible philosophies: positivism, realism, interpretivism and pragmatism.

Positivism

Saunders, et al. (2011) explain positivism as "working in the tradition of the natural scientist". The philosophy of positivism produces law-like generalisations similar to those produced by the physical and natural scientists, as Remenyi, et al. (1998) define. A central aspect of positivism is that only phenomena that you can observe will lead to the production of credible data. To create a research strategy for collecting this data, one is likely to use existing theory to develop hypotheses (Saunders, et al., 2011).

Realism

Similar to positivism, realism relates to scientific enquiry. Just like positivism, realism assumes a scientific approach to the development of knowledge. Saunders, et al. (2011) explain: "The essence of realism is that what the senses show us as reality is the truth: that objects have an existence independent of the human mind".

Interpretivism

Interpretivism tries to understand the differences between humans as social actors. In contrast to positivism, interpretivism argues that the social world of business and management is far too complex to derive definite "laws". According to the theories of interpretivism, such rich insights into the complex world are lost, if complexity is reduced entirely to a series of law-like generalisations. Central for interpretivism is, that it

advocates a necessity for the researcher to understand differences between humans in our role as social actors (Saunders, et al., 2011).

Pragmatism

Pragmatism argues, that choosing between one position and another, is unrealistic in the real world. “If the research question does not suggest unambiguously that either a positivist or interpretivist philosophy is adopted, this confirms the pragmatist’s view that it is perfectly possible to work with variations”, as Saunders, et al. (2011) explain. Pragmatism is orientated on practical applied research.

Conclusion

The results of this subchapter demonstrate, that both positivism and realism are clearly not applicable for this work. The scientific approaches of these two methodologies are not suitable for the development of a modelling language for the healthcare sector, which should be applicable in the practical world. Interpretivism and pragmatism on the other hand both include interesting aspects that might be relevant for the course of this work. Interpretivism says, that the world of business and management is complex and thus law-like generalisations are not possible. Pragmatism argues, that choosing between one position and another, one is unrealistic in the real world. Thus both philosophies might be relevant, but the author selects pragmatism, as it is focused on practical applied research. This is very well in line with the chosen research strategy of the design science research by Hevner & Chatterjee (2010), as explained in subchapter 3.2.3.

3.2.2 Approach

The research approach describes the use of theory. As we have seen in the research “onion”, it can be distinguished between a deductive and an inductive research approach. The two approaches can mainly be differentiated by the extent of available information at the beginning of the research (Saunders, et al., 2011).

Deductive

The main idea of the deductive approach is to test theory. This involves to develop a new theory and to subsequently test this theory in a rigorous way. It is thus the dominant

approach in natural sciences as Saunders, et al. (2011) explain. According to Robson (2002) deductive research will progress through five steps:

1. deducing a hypothesis from the theory
2. expressing the hypothesis in operational terms, which propose a relationship between two specific concepts or variables
3. testing this operational hypothesis
4. examining the specific outcome of the inquiry
5. if necessary, modifying the theory in the light of the findings

Therefore, in deductive research a theory is deducted based on existing knowledge and a hypothesis postulated which is then tested. If necessary the theory will be adapted based on the findings of the testing. Thus the outcome of the deductive research would either be confirmation or rejection of the hypothesis. As a conclusion, deductive research starts from general theory and leads to specific findings.

Inductive

The main idea of the inductive approach is to build a theory, as Saunders, et al. (2011) demonstrate. From specific observations a general theory will be constituted, which is exactly the contrary to a deductive research. The inductive approach enables a cause–effect link to be made between particular variables without an understanding of the way in which humans interpret their social world. Developing such an understanding is the strength of an inductive approach (Saunders, et al., 2011). Inductive research is characterised by the study of small samples of subjects unlike a large number, as with the deductive approach.

Conclusion

This master thesis is carried out in an inductive research approach. This approach is suitable for this work as the following explanations show. The first step of the chosen research strategy includes making observations based on small samples. These observations which have been done in interviews with domain experts by FHSG are used to find requirements and thus generalized patterns. The requirements are used to develop a DSML, which in the end shall be tested for validity against the requirements.

3.2.3 Strategy

The research strategy is the main aspect of the research methodology. In this subchapter the most important research strategies are explained and the decision which research strategy to choose for this thesis is provided. The research "onion" includes eight different strategies extended with design science research. In the following, five strategies will be explained.

Design science research

Design science research (DSR) shall be presented based on the work of Hevner & Chatterjee (2010). It is focused on research in the information systems field and aims to design a new viable artifact. The artifacts have to be an improvement of an existing solution or something completely new. According to Hevner & Chatterjee (2010), artifacts can be constructs, models, methods, instantiations or better design theories. Design science research is in contrast to behavioral science research, which provides information systems theories instead of artifacts. The following picture highlights this complementary nature:

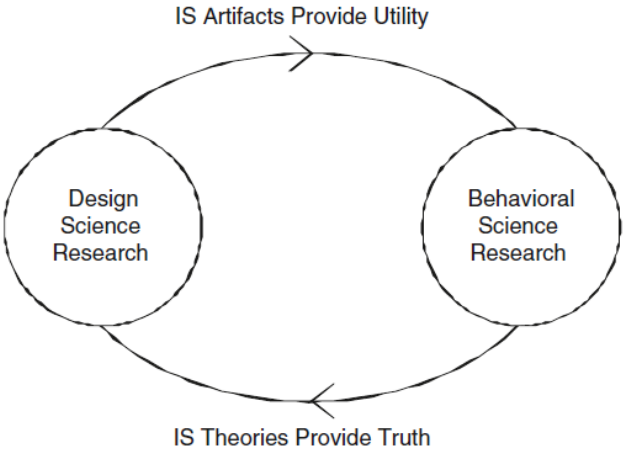


Figure 41: Complementary nature of DSR and behavioral science research from (Hevner & Chatterjee, 2010)

DSR is characterized by three cycles and includes an environment as well as a knowledge base as the following figure demonstrates:

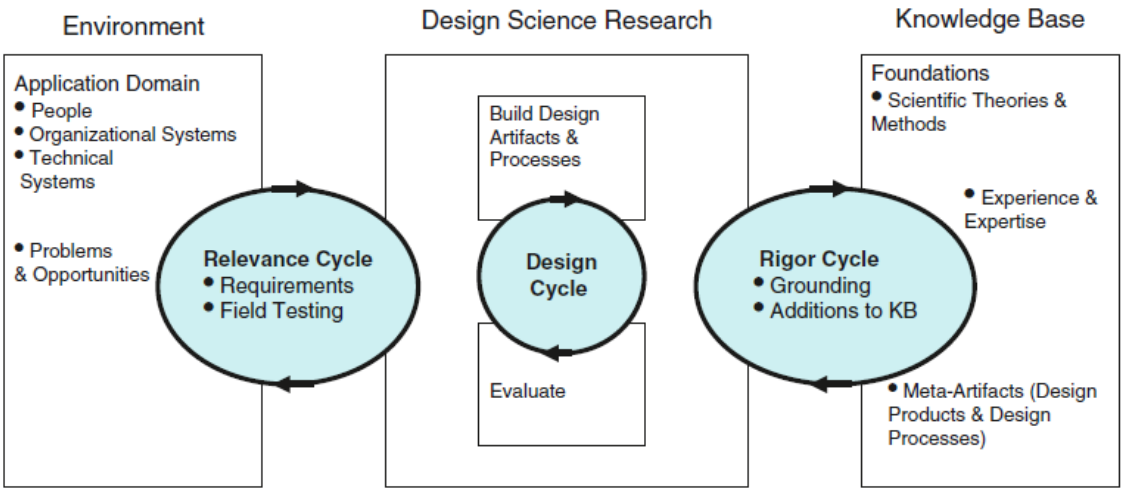


Figure 42: DSR cycles from (Hevner & Chatterjee, 2010)

On the left side, the environment contains the application domain, where different actors play together. Problems & opportunities are prevalent in the application domain. Hevner & Chatterjee (2010) explain, that identifying and representing these opportunities and problems in an actual application environment is a main aspect of good design science research. Thus the relevance cycle initiates DSR with requirements from the application domain and defines acceptance criteria for the DSR results.

On the right side, the knowledge base provides the foundation for DSR. Existing theories and artifacts are reused to develop new artifacts. The rigor cycle thus provides this past knowledge to ensure that innovation is happening. Newly developed artifacts will be added to the knowledge base by the rigor cycle.

Lastly, the design cycle is the heart of any design science research project (Hevner & Chatterjee, 2010). In DSR, a new artifact or process is designed and evaluated. If needed, the design will then be further refined or alternatives will be created. The design cycle can be explained in additional details with the DSR framework, that shows the reasoning in the general design cycle.

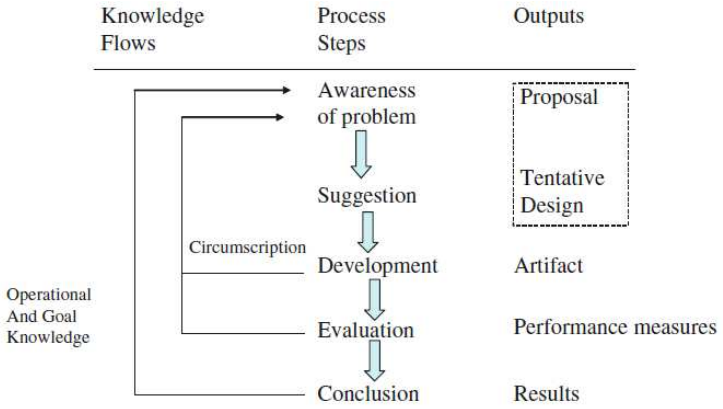


Figure 43: Reasoning in the general design cycle from (Hevner & Chatterjee, 2010)

Thus a DSR usually approaches five steps for the design of an artifact, from the awareness of a problem to the conclusion. Each phase provides an output and usually generates new knowledge or reuses already created knowledge. The five phases are shortly explained below, based on (Vaishnavi & Kuechler, 2004):

Awareness of problem: An interesting problem can for example emerge due to a new development in the industry. This problem can be solved by developing a new artefact. A proposal will be created, which explains the new research effort.

Suggestion: In this phase, it is discussed, which artifact might solve the problem. The dotted box highlights, that the output of this phase is connected to the output of the awareness phase. Thus the tentative design is directly tied to the proposal. This phase is decisive for the further development of the research work. If a considerable effort was put into the development of the tentative design and no satisfying solution was found, the research project will be withdrawn.

Development: In this phase, the tentative design will be further developed and finally implemented. The implementation itself does not need to be novel, but only the design of the artefact.

Evaluation: The artefact is evaluated against criteria that are made in the proposal of the first phase of the DSR. Any deviations from these requirements have to be noted and explained. Thus strengths and weaknesses of the artefact are recorded.

Conclusion: The results of the DSR are written down in the last phase. Gained knowledge is described and further needed research can be proposed.

Case study

Case study is a research strategy where the context of the research is of central importance as Saunders, et al. (2011) explain. If one wants to gain a rich understanding of the context of the research and the processes being enacted, case study is a suitable method (Morris & Wood, 1991). For a case study the use of multiple sources of data as well as several different data collection techniques are usually needed, as Saunders, et al. (2011) indicate in their book. It is normally differentiated between single and multiple cases. A single case is usually a critical or unique case, while a multiple case is to generalize findings from different cases. Saunders, et al. (2011) argue that: "a case study strategy can be a very worthwhile way of exploring existing theory. In addition, a well-constructed case study strategy can enable you to challenge an existing theory and also provide a source of new research questions".

Experiment

Experiments have been mainly used in natural science and social science research and aim to study causal links. This means to investigate whether a change in one independent variable produces a change in another dependent variable (Hakim, 2000). In a classic experiment, two groups are divided into an experimental and a control group. In the experimental group, a planned intervention or manipulation is done, while for the control group no such intervention is made. During the experiment, the dependent variable is measured before and after the manipulation of the independent variable for both groups (Saunders, et al., 2011). The following figure gives an overview of this process:

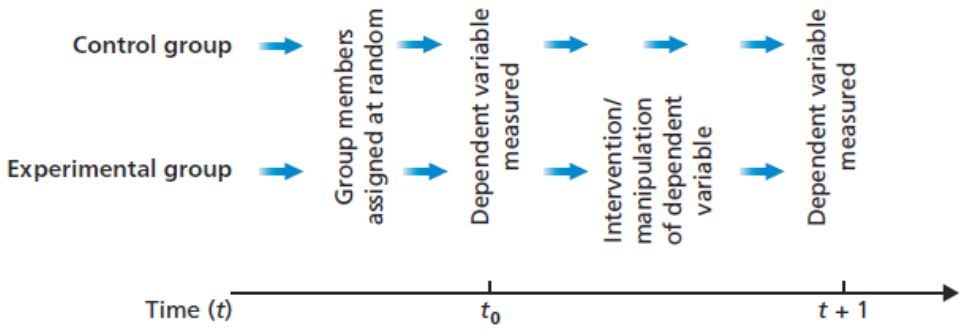


Figure 44: Classic experiment overview from (Saunders, et al., 2011)

Survey

The survey research strategy is especially popular and common in business and management research. Surveys are characterized by the collection of a large amount of data, using a questionnaire administered to a sample. The collected data are standardized, and allow an easy comparison. This data can be used for statistical analysis where specific software is readily available. Some challenges, when doing a survey research, are the complexity of creating an error-free questionnaire, obtaining a representative sample or being time-efficient (Saunders, et al., 2011).

Action research

Saunders, et al. (2011) argue, that action research is characterized in literature by four different interpretations of what the action aspect represents. They conclude these four views in their book:

1. the purpose of the research is research in action
2. involvement of practitioners in the research
3. iterative nature of the process of diagnosing, planning, taking action and evaluating
4. action research should have implications beyond the immediate project

The iterative process mentioned, starts from defining context and purpose and continues with a diagnosis, the planning, taking action and an evaluation:

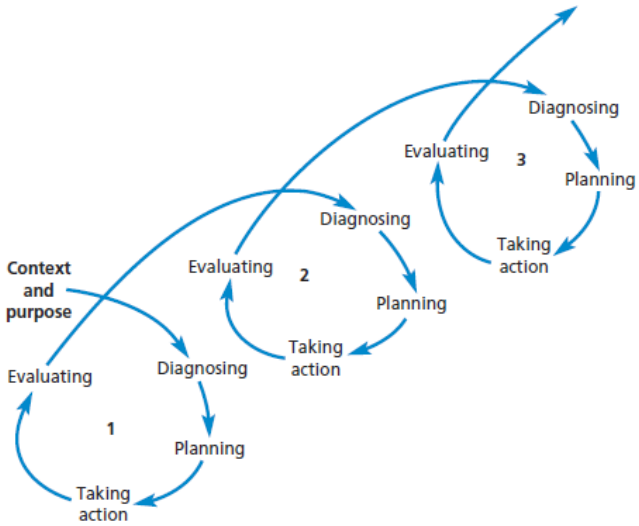


Figure 45: The action research spiral from (Saunders, et al., 2011)

Saunders, et al. (2011) summarize: “Thus action research differs from other research strategies because of its explicit focus on action, in particular promoting change within the organisation”. Action research is therefore strongly focused on change.

Conclusion

For me, it is out of question, that DSR is the most suitable approach for this work. It is specifically targeted to generate new artifacts, which is also the goal of this thesis. Additionally, it aims to produce results, which are also applicable in practice. This is very relevant for this master thesis as it is based on the results of a practical research project of FHSG. It shall be a useful artifact for users of the domain. The DSR approach is very well in line with the standard approach to create a DSML as shown in the literature review. They both include phases to define requirements and to evaluate the artifact.

Chapter 2, the literature review, provided an overview of the body of knowledge to develop the new artifact. It thus showed relevant research, that can be reused to extend an existing modelling language and covers the right part of the DSR cycle overview. In the following chapters four to eight, the new artifact shall be developed and evaluated, therefore the left part of the DSR cycle overview will be covered. The phases of the DSR framework are followed in this work as shown below:

- Chapter 4: Awareness of Problem
- Chapter 5: Suggestion
- Chapter 6: Development
- Chapter 7: Evaluation
- Chapter 8: Conclusion

3.2.4 Techniques and procedures

The techniques and procedures aspect of the research “onion” is concerned with the collection and analysis of data to support the research effort. If we look at the phases of the DSR strategy, requirements of domain-experts have to be captured in the first phase. These requirements are the basis for developing a new artefact and are also used to evaluate it after it has been created. The most important approaches for the collection of data are introduced in this chapter.

Questionnaires

De Vaus (2002) describes questionnaires as: “techniques of data collection in which each person is asked to respond to the same set of questions in a predetermined order”. This can happen in a telephone conversation, in an online setting or face-to-face. According to Saunders, et al. (2011) the questionnaire is one of the most widely used data collection techniques. It is an efficient way to collect large samples, because each person is asked to respond to the same set of questions and thus allows a statistical analysis of the collected data. Careful consideration needs to be taken into account when creating a questionnaire, as a high response rate, validity and reliability have to be achieved (Saunders, et al., 2011).

Interviews

In contrary to questionnaires, interviews are often unstructured and usually provide qualitative data. According to Kahn & Cannell (1957) an interview is: “a purposeful discussion between two or more people”. Saunders, et al. (2011) add, that such a discussion is helpful “to gather valid and reliable data that are relevant to your research question(s) and objectives”. Usually a distinction is made between structured, semi-structured and unstructured interviews. For the last two, several challenges that need to be considered are prevalent: reliability, interviewer bias and validity and generalizability (Saunders, et al., 2011).

Focus groups

Focus groups are a special interview technique in a one-to-many setting and are often also referred as group interviews. One interviewer asks questions to several participants in a non-standardized manner. Such a group discussion helps to gain rich insights from several domain-experts. The specialty of a focus group is that it “focuses clearly upon a particular issue, product, service or topic and encompasses the need for interactive discussion amongst participants”, as Carson, et al. (2001) demonstrate in their book. A focus group requires strong moderation skills. It is important that the discussion stays focused and that all participants are able to state their point (Saunders, et al., 2011).

Observations

Observations are concerned with a systematic observation, recording, description, analysis and interpretation of people's behavior (Saunders, et al., 2011). It is especially relevant "if your research question(s) and objectives are concerned with what people do" as Saunders, et al. (2011) explain. Both qualitative and quantitative data can be collected with observations. Participant observation aims to collect qualitative data about the meanings of actions that people take. Structured observations on the other hand are to collect quantitative data about the frequency of actions that people take (Saunders, et al., 2011).

Conclusion

For this master thesis it is required to elicit domain-specific requirements from experts. These requirements are the basis for developing the new artefact: a DSML for transfer decisions of a patient from an acute hospital to the next site of care. The author believes that such an analysis has to produce qualitative data. Thus an interview or a focus group approach would be most suitable. The execution of interviews would especially be convenient for this domain and helps to allow individual discussions while being able to guide the discussion in order to gather/acquire the needed information.

3.3 Overview of the application of the Research Design

This chapter provides an overview of how the DSR approach based on (Hevner & Chatterjee, 2010) will be applied in the concrete case of this master thesis.

Chapter 4 is dealing with the **awareness of the problem**. Domain experts in the field of patient transfer have specific requirements to a language for modelling their processes and decisions. These requirements are not fulfilled by any existing modelling language. Requirements are mainly drawn from a use case scenario and process model which have been developed in the innovation project "Patient Radar" of FHSG with domain experts (see appendix A). Interviews are only conducted as part of this master thesis if additional information to gather requirements is needed. Thus based on the results from the project at FHSG, the awareness of the problem can be built as it can be determined, that several domain-specific requirements are not fulfilled with existing modelling languages.

In the **suggestion** phase, artifacts which solve the problems that were identified in the previous chapter are illustrated. This means an integration and extension of existing modelling languages is defined. Hevner & Chatterjee (2010) define the outcome of this phase as the tentative design. In our case, these are the three elements to be defined: The abstract syntax, the concrete syntax and the semantics. Thus the following outputs are created in chapter 5:

1. **Abstract syntax**: Creation of the meta model of the new language which reflects domain-specific requirements of the patient transfer management
2. **Concrete syntax**: Definition of graphical modelling elements of the new DSML to reflect domain-specific requirements of the patient transfer management
3. **Semantics**: Definition of behavior, rules and attributes for modelling elements of the new DSML to reflect domain-specific requirements of the patient transfer management

In chapter 6, **development** phase, the suggested outputs of the previous phase are implemented. This implementation is taking place in the "Development Toolkit" of the metamodelling platform ADOxx. Thus abstract syntax, concrete syntax and semantics are defined in this platform so that they can be used for the evaluation and for creating models in a later stage with the help of ADOxx "Modelling Toolkit".

In the **evaluation** phase in chapter 7, the newly created DSML is tested against the fulfillment of the requirements of the domain experts which are mainly based on the use case scenario and process model elevated at the FHSG. This evaluation is done by creating models in ADOxx "Modelling Toolkit" which are tested for the fulfillment of the requirements from the problem awareness phase. Further, domain and modelling experts will evaluate the created DSML to demonstrate applicability and usefulness.

Finally, in chapter 8, the results of this work are summarized in the **conclusion.** An outlook for further research and development of the artifact is given.

4. Awareness of Problem

As identified in the literature review, domain experts in healthcare have specific requirements to a language to model their processes and decisions. In the field of patient transfer from acute hospital to rehabilitation clinic, these requirements are not fulfilled by any existing modelling language; no domain-specific modelling language exists yet. This also has been demonstrated in the "Patient Radar" innovation project of the FHSG. In this project, a use case scenario of an emergency entry and a process model of an elective entry have been created based on interviews with domain experts (see appendix A).

According to Hevner & Chatterjee (2010) the output of this phase is the proposal for a new research effort. Thus in our case the results of the FHSG serve as a foundation to define this proposal: the domain-specific requirements to a DSML.

4.1 Collection of data

Domain-specific material has been collected in the innovation project "Patient Radar" of the FHSG. These results are used to define the requirements for the new DSML. Thus rather than conducting interviews specifically, I rely on the outcome of interviews taken by the FHSG with domain experts.

The documentation of the FHSG to define domain specific requirements consists mainly of two documents (see appendix A, documents 1 and 2):

1) Use case scenario for an emergency entry case of a geriatric patient with a stroke
2) BPMN process for an elective entry case of a patient with a somatic disease

The BPMN process serves as the reference model for the domain and defines the to-be state of the transferal management process from acute hospital to rehabilitation clinic, while the use case scenario is an applied, transfer management case from real life. They have been carefully developed and evaluated together with domain-experts. They contain the most relevant activities, decisions, actors and documents of the domain.

4.2 Elicitation of domain specific requirements

In this chapter, mainly the two documents are analyzed to determine requirements to a DSML for the process of transferring patients from acute hospital to rehabilitation clinic. In addition, other documents are taken into consideration in chapter 4.2.3.

4.2.1 Requirements from use case scenario

Appendix A, document 1, is the use case scenario provided by the FHSG. The document explains a scenario which is based on a real case, with synthetic patient data, that was carefully selected. The case explains an emergency entry of a geriatric patient with a stroke. Based on an analysis of the use case scenario, I identified the below shown requirements. These are divided into requirements regarding process elements, physical documents, systems and contained data and decisions and decision criteria.

Process elements

#	Requirement	Description
R1.1.1	The DSML should accommodate constructs to model different actors.	Actors: Administrative staff, rapid assessment nurse, emergency medical technician, patient, family member, expert nurse, resident physician, specialist physician, transferal manager Swim lane or actor element needed
R1.1.2	The DSML should accommodate constructs to model different units.	Units: Care unit, intensive care unit, non-intensive care unit, hospital, rehabilitation clinic, insurance, emergency room, site of care Pool element needed
R1.1.3	The DSML should accommodate constructs to model a work activity. Also it should allow to quickly model the most important activities of the domain.	Standard task element needed, most important tasks of the domain can be modelled/selected

R1.1.4	The DSML should accommodate constructs to model a decision work activity.	Decision task element needed
R1.1.5	The DSML should accommodate constructs to model a system.	Systems: Patient Administration System (PAS), Hospital Information System (HIS) System element needed
R1.1.6	The DSML should accommodate constructs to model time.	Time: Length of stay Time element needed
R1.1.7	The DSML should accommodate constructs to model separate paths.	Paths: Based on severity, complexity, admission criteria Gateway/parallelization element needed
R1.1.8	The DSML should accommodate constructs to model a status.	Not stabilized, stabilized → if status changes, the following has to be updated: medication, indication, care status, diagnosis Also the status of the patient in the hospital and in the rehab can change to the better or the worse Status/condition element needed
R1.1.9	The DSML should accommodate constructs to model an information exchange.	Information e.g. medical data, administrative data, care status from transferal manager to rehab clinic, can be sent to other actors Information flow/message element needed
R1.1.10	The DSML should accommodate constructs to model tasks conditionally.	Conditional task element needed for changing conditions
R1.1.11	The DSML should accommodate constructs to model tasks as reoccurring.	"Loop" element needed
R1.1.12	The DSML should accommodate constructs to model the transfer of a patient.	Patient has to be transferred from acute hospital to rehabilitation Transfer element needed

Table 10: Process elements requirements from use case scenario

Physical documents

#	Requirement	Description
R1.2.1	The DSML should accommodate constructs to model the patient admission form.	Also in Patient Administration System (PAS); contains administrative data of patient, already allows to choose relevant data for the case Document/Data element needed with applicable attributes
R1.2.2	The DSML should accommodate constructs to model the rehabilitation form for cost reimbursement (KoGu).	Already allows to choose relevant data for the case Document/Data element needed with applicable attributes
R1.2.3	The DSML should accommodate constructs to model the long report.	Filled in by transferal manager; contains medical related data, administrative data and investigation results Document/Data element needed with applicable attributes

Table 11: Physical documents requirements from use case scenario

Systems and contained data

#	Requirement	Description
R1.3.1	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the short report.	Medical diagnosis, medication list, indication, already allows to choose relevant data for the case System element needed with applicable attributes
R1.3.2	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the medical data.	ICD-10 version 2016 (main), ICD-10 version 2016 (secondary) (several), CHOP, Functional deficits – ICF Standard (several), Flag disease or accident; already allows to choose relevant data for the case System element needed with applicable attributes

R1.3.3	The DSML should accommodate constructs to model the Patient Administrative System (PAS) that includes the administrative data / master data.	Master Patient ID, Patient ID, Case Number, SwissDRG code, Name, Street, City, Nation, Nationality, Date of birth, Mobile number, Mother tongue, Job, AHV-Number, Entry Type, Health insurance with policy number, Health insurance status, Date of hospitalization, already allows to choose relevant data for the case System element needed with applicable attributes
R1.3.4	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the care status.	Assistance in Mobility, Assistance in Nutrition, Assistance in Excretion, Assistance in Personal Hygiene, Assistance in Cognition, Necessity of Medical devices, already allows to choose relevant data for the case System element needed with applicable attributes
R1.3.5	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the Tessiner code	Main and secondary codes are stored System element needed with applicable attributes

Table 12: Systems and contained data requirements from use case scenario

Decisions and decision criteria

#	Requirement	Description
R1.4.1	The DSML should accommodate constructs to assign the emergency severity to a case which includes that the ESI triage can be reflected with decision criteria.	Identifies the level of severity of the case from 1 to 5 (Emergency Severity Index) based on urgency of treatment Attribute and decision task element needed
R1.4.2	The DSML should accommodate constructs to model the examination by a specialist physician.	Performs the first examination, and provides both prescription and diagnosis Decision task element needed

R1.4.3	The DSML should accommodate constructs to assign the complexity of a case.	Complex or not complex depending on the number of diseases/co-morbidities Attribute or other element to deem complexity needed
R1.4.4	The DSML should accommodate constructs to assign the ICD-10 code to a case.	Based on this code, the length of stay changes Attribute needed
R1.4.5	The DSML should accommodate constructs to assign the SwissDRG to a case.	Determines cost reimbursement to acute hospital Attribute needed
R1.4.6	The DSML should accommodate constructs to assign ICF qualifiers.	Three scales to determine the severity Attributes needed to include standard
R1.4.7	The DSML should accommodate constructs to model the need for rehabilitation by the specialist physician.	Rehabilitation needed or not? Decision task element needed
R1.4.8	The DSML should accommodate constructs to model the decision for rehabilitation clinic and type by the specialist physician.	Based on the main disease of the patient, specialization of clinic, partner clinic, family member or contact person live close by the clinic Decision task element and rehabilitation type attribute needed
R1.4.9	The DSML should accommodate constructs to model the correctness assessment of the KoGu by the transferal manager.	Consistent with patient's information and compliant with the content of the DefReha© Decision task element needed
R1.4.10	The DSML should accommodate constructs to model the assessment of the admission for rehabilitation by the transferal manager.	With use of criteria of inclusion and exclusion. Is patient transferred or is transferal denied based on criteria? Decision task element needed

R1.4.11	The DSML should accommodate constructs to model if patient's situation gets worse.	If discharging criteria from rehab are met, the patient might need to be transferred back to hospital. Attribute or other element to deem situation is needed
R1.4.12	The DSML should accommodate constructs to model if patient's situation gets better.	If discharging criteria from rehab are met, the patient can be transferred home or to a less intensive site of care. Attribute needed or other element to deem situation needed

Table 13: Decisions and decision criteria requirements from use case scenario

4.2.2 Requirements from process model

Appendix A, document 2, provides the process model of the FHSG. In contrast to the use case scenario, the process model explains the other possibility of an entry: an elective entry. Analyzing both documents allows to capture the requirements in a more complete manner. The patient in focus of the process model has a somatic disease. Not considered is the top part (pool "Klinischer Pfad Akutsomatik"), as this corresponds to the clinical pathway. Based on an analysis of the process model, I identified the below shown requirements. These are divided into requirements regarding process elements, physical documents, systems and contained data and decisions and decision criteria.

Process elements

#	Requirement	Description
R2.1.1	The DSML should accommodate constructs to model different actors.	Actors: Physician, exit management, patient disposition, rehabilitation physician Swim lane or actor element needed
R2.1.2	The DSML should accommodate constructs to model different units/processes.	Units: Acute hospital, rehabilitation clinic Pool element needed
R2.1.3	The DSML should accommodate constructs to model a work activity. Also it should allow to	Standard task element needed, most important tasks of the domain can be modelled/selected

	quickly model the most important activities of the domain.	
R2.1.4	The DSML should accommodate constructs to model a decision/business rule work activity.	Decision task element needed
R2.1.5	The DSML should accommodate constructs to model parallel activities.	Parallel task element needed
R2.1.6	The DSML should accommodate constructs to model manual work activity.	Manual task element needed
R2.1.7	The DSML should accommodate constructs to model time.	Time: Time until transfer Time element needed
R2.1.8	The DSML should accommodate constructs to model separate paths (AND and XOR).	Paths: Select rehabilitation clinic, first assessment, prepare entry Gateway element needed
R2.1.9	The DSML should accommodate constructs to model information.	Information can be sent to other actors (e.g. PatRad case) Information flow/message element needed
R2.1.10	The DSML should accommodate constructs to model the transfer of a patient.	Patient has to be transferred from acute hospital to rehabilitation Transfer element needed

Table 14: Process elements requirements from process model

Physical documents

#	Requirement	Description
R2.2.1	The DSML should accommodate constructs to model the patient admission form.	Also in Patient Administration System (PAS); contains administrative data of patient Document/Data element needed

R2.2.2	The DSML should accommodate constructs to model the rehabilitation form for cost reimbursement (KoGu).	Already allows to choose relevant data for the case Document/Data element needed

Table 15: Physical documents requirements from process model

Systems and contained data

#	Requirement	Description
R2.3.1	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes medical data.	Exact content is unknown based on process model System element needed with applicable attributes
R2.3.2	The DSML should accommodate constructs to model the Patient Administrative System (PAS) that includes administrative data.	Exact content is unknown based on process model System element needed with applicable attributes
R2.3.3	The DSML should accommodate constructs to model the Hospital Information System (HIS) and the Patient Administrative System (PAS) that include documents.	Exact content is unknown based on process model System elements needed with applicable attributes and/or data/document elements.

Table 16: Systems and contained data requirements from process model

Decisions and decision criteria

#	Requirement	Description
R2.4.1	The DSML should accommodate constructs to model the creation of the transferal case.	Criteria for business rules can be saved Decision task element needed

Table 17: Decisions and decision criteria requirements from process model

4.2.3 Additional requirements

Further, the following requirements were defined based on the additional documentation of the FHSG (see appendix A, documents 3 to 7), on the outcome of internal workshops

and on the DefReha© standard (H+ Die Spitäler der Schweiz, 2015). The DefReha© standard defines inclusion and exclusion criteria for the nine different rehabilitation types and thus is important for the transfer management process of a patient from an acute hospital to a rehabilitation clinic for Swiss hospitals, clinics and care institutions. For each of the nine rehabilitation types, rules are defined based on specific criteria, if a patient should be admitted to or discharged from rehabilitation. For a transferal manager it is necessary to decide in conformance with these criteria. Especially the study of mock-ups that have been created for the "Patient Radar" platform allow to further specify the documents/data elements, status elements and relevant attributes needed.

#	Requirement	Description	Source
R3.1.1	The DSML should accommodate constructs to model organization and roles in a hierarchical way.	Elements that allow to view the involved organizations, roles and actors in a hierarchical way easily Elements to model organization needed	Internal workshops FHSG
R3.1.2	The DSML should accommodate constructs to allow an automation in a later stage.	Elements such as data/documents already provide all needed attributes to be filled in with the individual patient data Relevant attributes needed	Internal workshops FHSG
R3.1.3	The DSML should accommodate constructs to reflect the different rehabilitation types according to the DefReha© standard.	An attribute for the rehabilitation type is created, where the user can choose the applicable type for the patient from a list of all DefReha© rehabilitation Relevant attribute with type values needed	DefReha© Standard
R3.1.4	The DSML should accommodate constructs to model criteria according to the DefReha© standard.	Entry, exit, inclusion and exclusion criteria for the different rehabilitation types can be stored in the DSML according to the rules defined in the DefReha© Element(s) to model rules needed	DefReha© Standard
R3.1.5	The DSML should accommodate constructs to reflect attributes	Attributes for all documents, data, groups and status elements are based on mock-ups that were created for the "Patient Radar" platform.	Appendix A, documents 1, 5 - 7

	corresponding to the attributes in the "Patient Radar" platform.	Thus the same attributes are existing in the DSML, they are of the same data type and, if relevant, prefilled. All needed attributes for each element are listed in detail in Chapter 5, Suggestion. Relevant attributes needed	
R3.1.6	The DSML should accommodate constructs to model documents/data elements corresponding to the documents/data elements in the "Patient Radar" platform.	Following documents/data objects have to be provided in a hierarchical way: Administrative Data with sub elements Patient Data, Patient Health Insurance Data, Acute Physician Data, Rehabilitation Data, KoGu, Hospitalization Document, Medical Data with sub elements Medical Information, ICF Standard, Medication List, Care Status with sub elements Assistance Data, Special Medication Data, Process Progress with sub element Process Data Elements to model documents/data hierarchies needed	Appendix A, documents 1, 5 & 6
R3.1.7	The DSML should accommodate constructs to model relevant status elements and their attributes corresponding to the "Patient Radar" platform.	Following status elements have to be provided in a hierarchical way: Status with sub elements Process Status, Physical Transfer Status, KoGu Status, ICF Qualifiers Status, Medication List Status and Acceptance Status Status elements needed	Appendix A, documents 5 & 6
R3.1.8	The DSML should accommodate constructs to model KoGu templates.	Following templates have to be considered: Stroke template, Orthopaedic template, Paediatric template, Psychiatric template Attribute/elements needed to reflect templates	Internal workshops FHSG
R3.1.9	The DSML should accommodate constructs to differentiate between tasks done by a user or executed by a system.	Allows future expansion towards an automation of the transferal management process Elements needed to define a work activity as done by a user or executed automatically	Internal workshops FHSG

Table 18: Additional requirements

4.3 Conclusion

Even though the process for the emergency entry (scenario) and for the elective entry (process model) should in theory follow very similar steps, the BPMN model reveals the limitations of it for the modelling of the transfer process from an acute hospital to a rehabilitation clinic. The fact that BPMN has been used, seems to be a good basis to allow the modelling of the process. This is also in line with the results of the literature review. BPMN provides the basic elements to model the transfer process but does not achieve to fully reflect the complexity of this domain as captured in the scenario. Thus a combination and extension of several languages might be needed. A first analysis reveals that by far not all requirements of the domain can be expressed in BPMN. Several decisions, documents/data, systems and singularities of a case are not reflected in the process model. Using only BPMN as demonstrated in the process model lacks expressiveness to show domain specific peculiarities. Due to this it is not easily understandable by users of this domain; the recognition value would be much higher with domain specific concepts. The analysis of the documents also indicates, that even though BPMN has been considered for the modelling of the transfer management process, the majority of the available BPMN elements has not been used. This is very well in line with Silver (2011) who proposes modelling conventions as most BPMN elements are not needed in usual cases. Thus the removal of unneeded elements from existing modelling languages in the DSML might be a possible scenario. The upcoming chapter provides the suggestion towards a DSML based on the identified requirements of this chapter.

5. Suggestion

The second phase of the DSR approach as proposed by Hevner & Chatterjee (2010) produces a tentative design which will serve as basis to develop the artifact in the following chapter. Authors such as Cho, et al. (2012) have explained that creating a new DSML requires three major parts: abstract syntax, concrete syntax and semantics. In this chapter the abstract syntax is expressed as a series of adapted meta models that combine and extend several notations to create a meta model for the new DSML. The concrete syntax describes all available modelling elements in the new language. Lastly the semantics describe, if needed, the behavior of the modelling elements in the form of rules, connections or available attributes. The concrete syntax and semantics together build conventions on how to use the new DSML to avoid modelling errors, to achieve ease of use and to improve expressiveness.

The suggestion phase is the first step towards creating the new DSML and provides the theoretical foundation. Thus it is time to formally define the name of the new language as “DSML4PTM”: a domain-specific modelling language for the patient transferal management.

5.1 Meta model (abstract syntax) DSML4PTM

The previous chapter, the awareness of the problem, has shown that BPMN can serve as a basis to model the transfer management process. It allows to model a multitude of needed concepts. However, to cover additional domain specific requirements an integration and extension of several languages are needed as demonstrated in the previous and in this chapter. This can be achieved by reusing only the needed concepts from several languages as well as by extending them with newly created modelling elements. Reusing concepts from other languages ensures that standards are considered which are ideally already well-known and which rely on a well-defined meta model. Additional domain-specific expressiveness can be achieved with newly created modelling elements and also by transforming generic modelling elements into specific modelling elements (e.g. generic role element reused to create acute physician role element). The upcoming subchapters give an overview on the languages which are considered and explain why to use them.

5.1.1 BPMN

BPMN serves as the main language which will be used to create the DSML4PTM. Previous research has demonstrated, that BPMN is very well suitable for an extension with new concepts and is the de-facto standard for process modelling. Furthermore, the elicited requirements point out, that BPMN already provides several needed concepts to model the process, that can be reused the way it is, as shown in table 19. Thus BPMN manages to cover a lot of the elicited requirements but needs to be combined with other languages and needs to be extended.

BPMN version 2.0.2 is released by the OMG and is based on a formally defined meta model as specified in (Object Management Group, 2014). As demonstrated earlier, BPMN provides a large range of modelling elements. Thus I only explain the changes to the BPMN meta model based on the elicited requirements. Where not explicitly mentioned, the BPMN meta model will be reused as-is.

Based on the specification of OMG, the BPMN meta model provides concepts for activities, gateways, events, data, swim lanes, choreography, collaboration and conversation (Object Management Group, 2014). The applicability of these concepts for the meta model of the new DSML is explained below.

Activities: Based on an analysis of the requirements elicited in the problem awareness phase, only a “Task” is needed as activity. The most important tasks of the domain will already be implemented and can be easily be selected by the user. These domain-specific tasks are included in the meta model as subclasses of “Task”. Tasks only need to be linked with “Sequence Flows”. “Tasks” can be marked as “Loop” and “Parallel”. The type of the task can be “Manual”, “User”, “Service” or “Business Rule”. All other concepts will be removed from the meta model.

Gateways: Based on an analysis of the requirements elicited in the problem awareness phase, only “Exclusive Gateway” and “Parallel Gateway” are needed. All other concepts will be removed from the meta model.

Events: Silver (2011) proposes to strongly reduce the number of the available events because in the usual case, most of them are not required and only result in modelling errors. His suggestion is to only use the following ones:

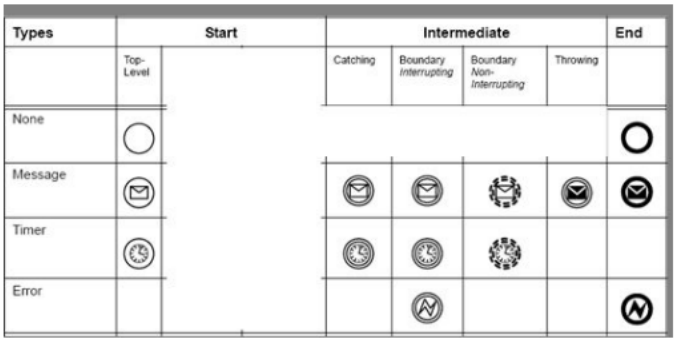


Figure 46: Events as proposed in (Silver, 2011)

Based on an analysis of the requirements elicited in the problem awareness phase, the meta model can further be reduced to only the red marked elements.

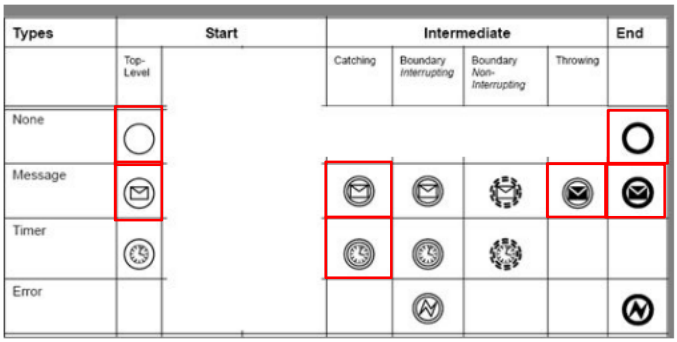


Figure 47: Events relevant according to requirements

The most important events of the domain will already be implemented and can easily be selected by the user. These domain-specific tasks are included in the meta model as subclasses of “Event”. All other concepts will be removed from the meta model.

Data: Based on an analysis of the requirements elicited in the problem awareness phase, only a “Data Object” is needed. It is the applicable element for both data and documents. “Data Object” is the generalization for the following newly created “Data Objects”: “KoGu”, ”Medical Data”, “Administrative Data”, “Process Progress”, “Care Status” and “Hospitalization Document”. Data objects need to be linked with “Data Associations”. Additionally, a new concept “Status” will be added to the meta model to reflect the current state of the process based on the data collection for a specific patient. All other concepts will be removed from the meta model.

Swim lanes: Based on an analysis of the requirements elicited in the problem awareness phase, all swim lane elements are needed. Thus “Pool”, “Lane” and “Message Flow” are included in the meta model. The “Pool” concept will be extended by “Acute Hospital”, “Rehabilitation Clinic” and “Health Insurance” pools. The “Lane” concept will be extended by “Transferal Manager”, “Acute Physician”, “Rehabilitation Physician”, “Nurse” and “Patient Disposition” lanes.

Choreography/Collaboration/Conversation: Based on an analysis of the requirements elicited in the problem awareness phase, no concepts to model a choreography, a collaboration or a conversation are needed. Thus all specific choreography, collaboration and conversation concepts can be removed from the meta model.

Requirements coverage overview

#	Required concepts from the BPMN meta model
R1.1.1-R1.1.4, R1.1.6-R1.1.9, R1.2.2, R1.4.1-R1.4.10, R2.1.1-R2.1.9, R2.2.2, R3.1.3, R3.1.5-R3.1.7-R3.1.9	Task, Loop Marker, Parallel Marker, Manual Task, User Task, Service Task, Business Rule Task, Sequence Flow, Exclusive Gateway, Parallel Gateway, Pool (Acute Hospital, Rehabilitation Clinic, Health Insurance), Lane (Transferal Manager, Acute Physician, Rehabilitation Physician, Nurse, Patient Disposition), Message Flow, Data Object (KoGu, Medical Data, Administrative Data, Process Progress, Hospitalization Document, Care Status), Data Association, None Event (Standard Start, Throwing Intermediate, Standard End), Message Event (Standard Start, Catching Intermediate, Throwing Intermediate, Standard End), Timer Event (Catching Intermediate), Status

Table 19: Requirements covered with adapted BPMN meta model

In the following, the BPMN part of the meta model of the new DSML4PTM is shown as a simplified UML class diagram, without any attributes. Connections to other parts of the meta model are also shown. BPMN elements that are connected to differently colored elements indicate such connections. The origin of the connected elements is highlighted in the legend. Unneeded concepts are removed while newly created concepts are added.

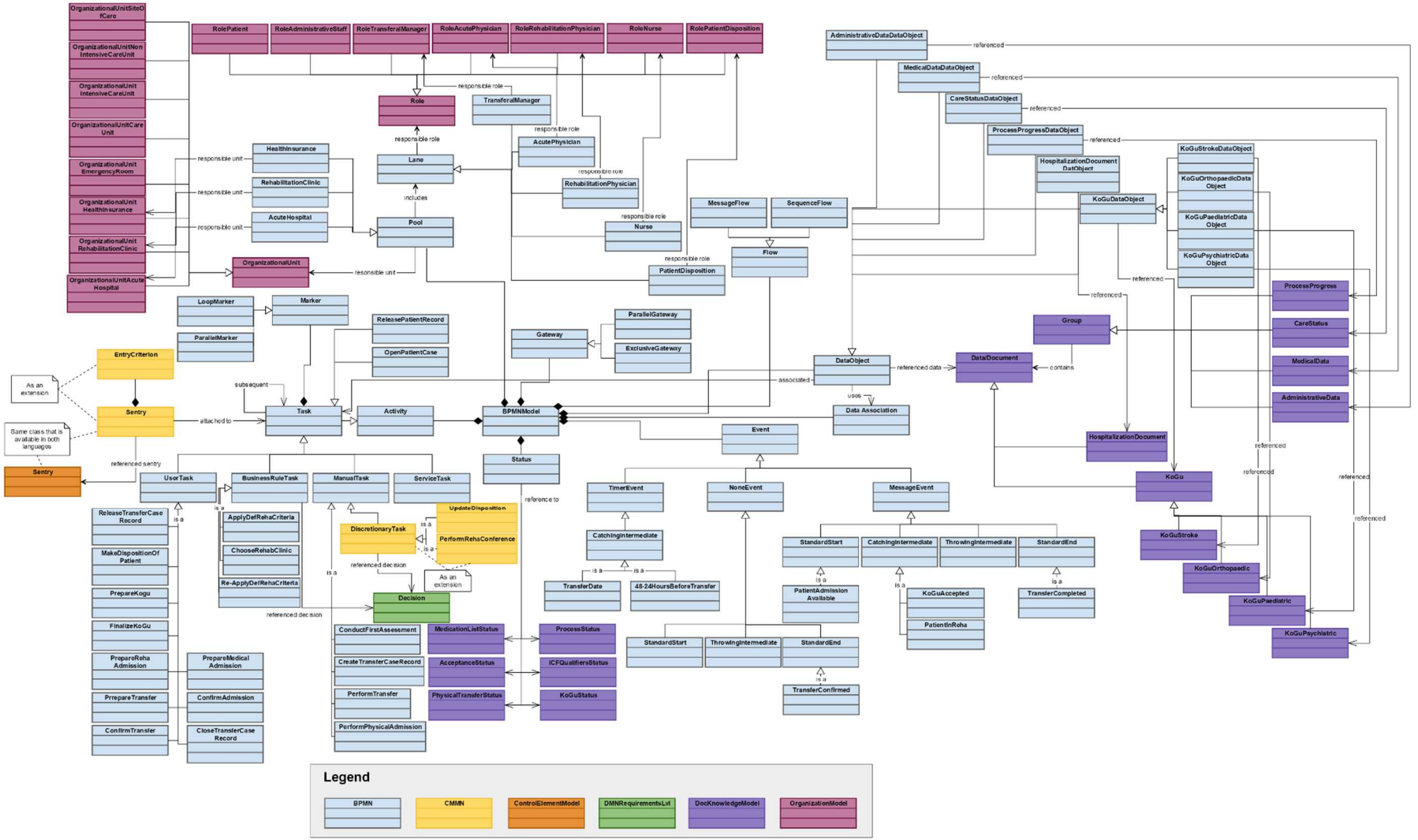


Figure 48: Meta model BPMN part

5.1.2 CMMN and Control Element Model

CMMN serves for the development of DSML4PTM as an extension to BPMN, thus specific concepts from CMMN will be added to the BPMN notation to cover the domain-specific requirements of the transfer management process.

CMMN has been released by the OMG in version 1.1 and is based on a formally defined meta model as specified in (Object Management Group, 2016). For the course of this work, only very few elements from the meta model will be reused and integrated as an extension to BPMN into the meta model of the new DSML4PTM. All concepts from the meta model which will be reused are mentioned in the following. All other concepts from the meta model are not used in this work.

The figure shows a part of the planning table and a part of the sentry meta model with the relevant items for this work. Based on the requirements, “Discretionary Task”, “Sentry” and “Entry Criterion” are added as an extension to the new meta model.

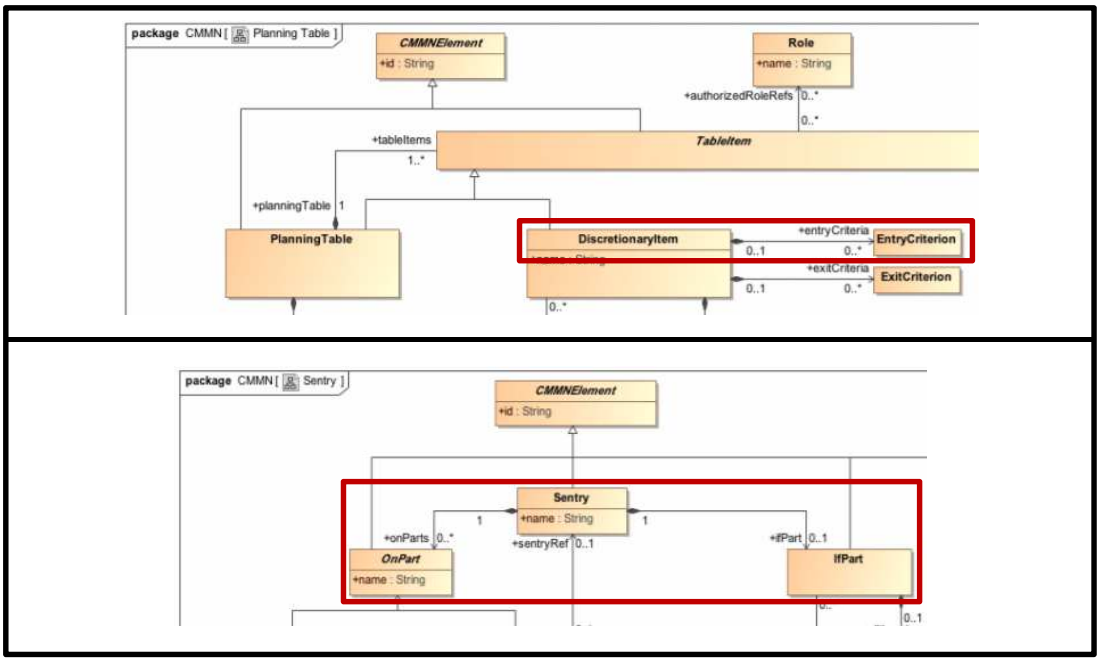


Figure 49: Relevant parts from planning table and sentry meta model based on (Object Management Group, 2016)

Hinkelmann, et al. (2015) have proposed the Knowledge Work Designer, which is an extension of BPMN with concepts from CMMN in ADOxx. The implementation of the Knowledge Work Designer will be reused to build the meta model of the new DSML (without the concept planning table). Thus “Discretionary Task”, “Sentry” and “Entry

Criterion" are reused in the new meta model while other concepts from the Knowledge Work Designer are not reused and will be removed (e.g. case plan model).

The Knowledge Work Designer further includes the so-called Control Element Model. The Control Element Model allows to explicitly define the criteria for a sentry in a separate model. This is very relevant for the transfer management process based on the elicited requirements. There are several process steps which are triggered by one or more criteria. The Control Element Model allows to explicitly define "On" and "If" criteria (compare "On-Part" and "If-Part" in CMMN sentry meta model in figure 49) for a sentry as shown in the upcoming figure:

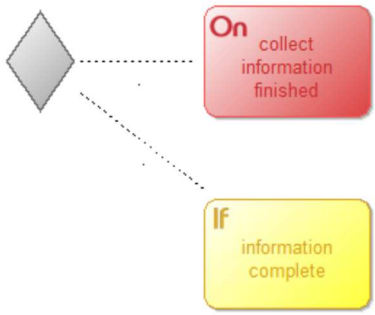


Figure 50: Control Element Model example from Knowledge Work Designer

From the meta model of the Control Element Model "Sentry, "Connection", "On-Condition" and "If-Condition" are integrated to the meta model of the new DSML. Thus the Control Element Model is combined with other languages to create DSML4PTM.

Requirements coverage overview

#	Required concepts from the CMMN/Control Element Model meta model
R1.1.10-R1.1.11, R1.4.11-R1.4.12	**CMMN**: Discretionary Task, Sentry, Entry Criterion **Control Element Model**: Sentry, Connection, On-Condition, If-Condition

Table 20: Requirements covered with adapted CMMN/Control Element Model meta model

In the following, the CMMN and Control Element Model part of the meta model of the new DSML4PTM is shown as a simplified UML class diagram, without any attributes.

Connections to other parts of the meta model are also shown. CMMN/Control Element Model elements which are connected to differently colored elements indicate such connections. The origin of the connected elements is highlighted in the legend. Unneeded concepts are removed while newly created concepts are added.

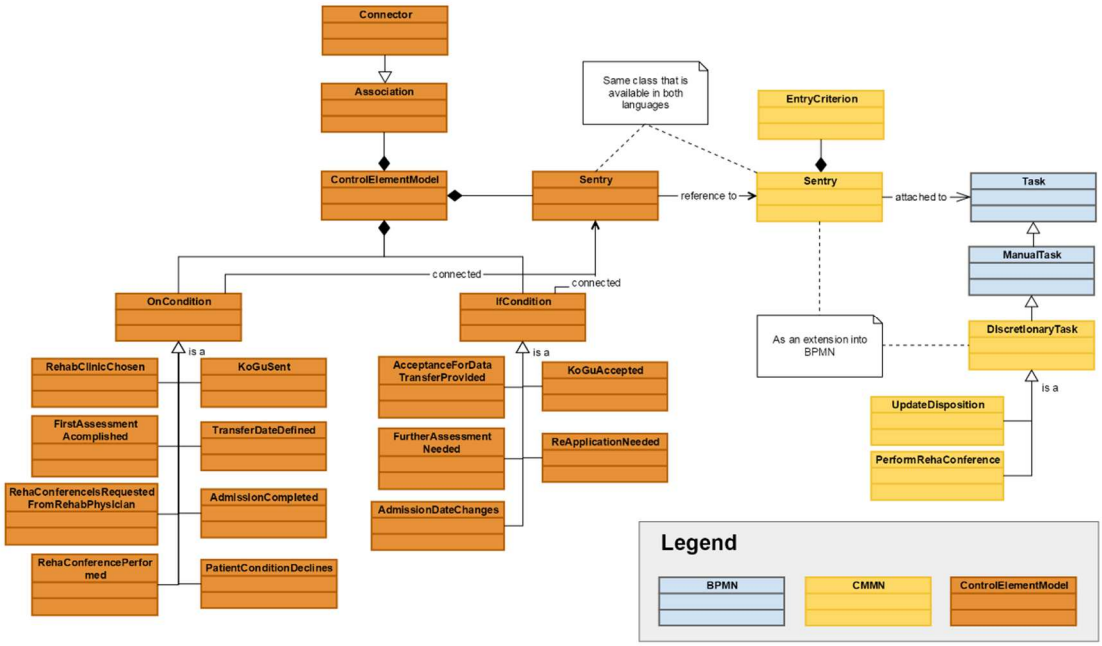


Figure 51: Meta model CMMN/Control Element Model part

5.1.3 DMN

DMN also serves for the development of DSML4PTM as a language that will be integrated/combined with other languages. Specific concepts from DMN are reused to cover domain-specific requirements of the transfer management process.

DMN has been released by the OMG in version 1.1 and is based on a formally defined meta model as specified in (Object Management Group, 2016). For the course of this work, all elements from the meta model for the Decision Requirements Level and the Decision Logic Level will be reused and integrated into the meta model of the new DSML. An automation with the FEEL expression language will not be considered.

The elicited requirements in the awareness phase have clearly highlighted, that several decisions are done in the transfer management process and criteria for these decisions need to be transparent for the user. Therefore an integration of DMN into the meta model of the new DSML is ideal. Especially the analysis of the DefReha© document (H+ Die Spitäler der Schweiz, 2015) has shown, that the decision to determine the rehabilitation category and relevant inclusion and exclusion criteria are of central importance for the domain. Thus the meta model will include the following concepts to reflect the standard:

- **"Decision"**: "Choose Rehab Clinic", "Geriatric Rehabilitation Suitability", "Internistic and Oncological Rehabilitation Suitability", "Cardiovascular Rehabilitation Suitability", "Musculoskeletal Rehabilitation Suitability", "Neurological Rehabilitation Suitability", "Pediatric Rehabilitation Suitability", "Paraplegic Rehabilitation Suitability", "Psychosomatic Rehabilitation Suitability", "Pneumological Rehabilitation Suitability", "Inpatient Rehabilitation Suitability", "Compulsory Medical Monitoring Rehabilitation Suitability", "Compulsory Medical Monitoring to Inpatient Rehabilitation Suitability"
- **"Business Knowledge"**: "Exclusion Criteria", "Inclusion Criteria", "Combination Inclusion and Exclusion Criteria"
- **"Decision Table"**: "Entry Criteria Decision Table", "Exit Criteria Decision Table", "Suitability Decision Table", "Inclusion to Inpatient Geriatric Rehabilitation Entry", "Inclusion to Inpatient Geriatric Rehabilitation Exit Home/Long-term Facility", "Exclusion to Inpatient Geriatric Rehabilitation Entry", "Exclusion to Inpatient Geriatric Rehabilitation Exit"

- **"Knowledge Source"**: "DefReha©"

These concepts allow to model all possible decisions of the DefReha©. As an example, for one decision, already predefined decision tables are included (case Geriatric Inpatient Rehabilitation).

Requirements coverage overview

#	Required concepts from the DMN meta model
R1.1.4, R1.4.1, R1.4.7-R1.4.10, R2.1.4, R3.1.4	Decision (Choose Rehab Clinic, Geriatric Rehabilitation Suitability, Internistic and Oncological Rehabilitation Suitability, Cardiovascular Rehabilitation Suitability, Musculoskeletal Rehabilitation Suitability, Neurological Rehabilitation Suitability, Pediatric Rehabilitation Suitability, Paraplegic Rehabilitation Suitability, Psychosomatic Rehabilitation Suitability, Pneumological Rehabilitation Suitability, Inpatient Rehabilitation Suitability, Compulsory Medical Monitoring Rehabilitation Suitability, Compulsory Medical Monitoring to Inpatient Rehabilitation Suitability), Knowledge Source (DefReha©), Input Data, Business Knowledge (Exclusion Criteria, Inclusion Criteria, Combination Inclusion and Exclusion Criteria), Information Requirement, Knowledge Requirement, Authority Requirement, Has Decision Table, Decision Table (Entry Criteria Decision Table, Exit Criteria Decision Table, Inclusion to Inpatient Geriatric Rehabilitation Entry, Inclusion to Inpatient Geriatric Rehabilitation Exit Home/Long-term Facility, Exclusion to Inpatient Geriatric Rehabilitation Entry, Exclusion to Inpatient Geriatric Rehabilitation Exit)

Table 21: Requirements covered with adapted DMN meta model

In the following, the DMN part of the meta model of the new DSML4PTM is shown as a simplified UML class diagram, without any attributes. Connections to other parts of the meta model are also shown. DMN elements that are connected to differently colored elements indicate such connections. The origin of the connected elements is highlighted in the legend. Unneeded concepts are removed while newly created concepts are added.

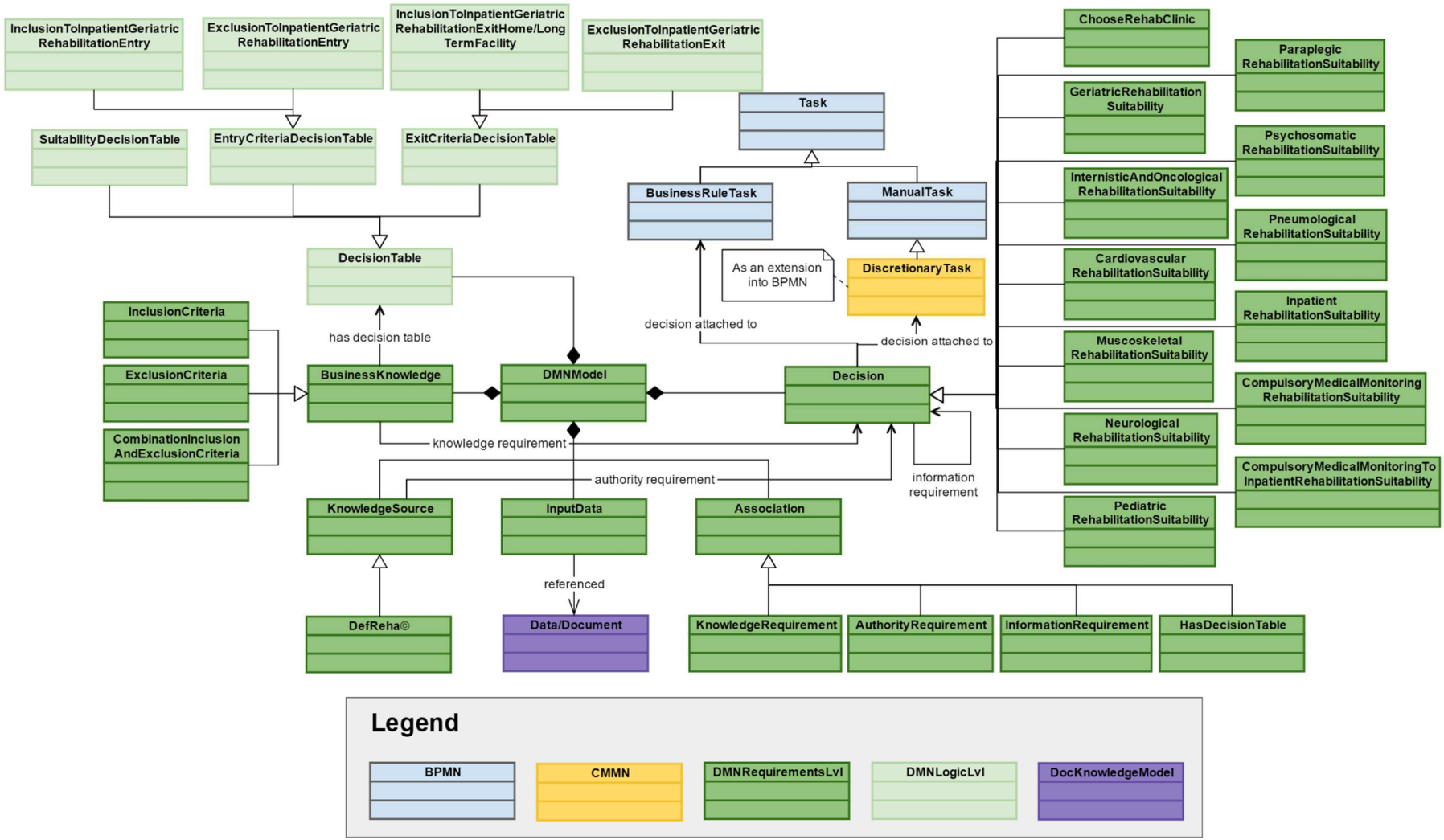


Figure 52: Meta model DMN part

5.1.4 Documents and Knowledge Model

While the BPMN meta model provides concepts to model a document or data, it does not provide a way to structure documents and knowledge representations. The domain-specific requirements highlight, that the transfer management process is very data intensive and would benefit from structuring this data/documents into subparts.

There is no clear standard to organize documents. For this work, the concepts from the ADOxx implementation of the Documents and Knowledge Model from the LearnPAd project will be added to the new meta model. It allows structuring data and documents which are used in a process hierarchically (BOC Asset Management GmbH, 2016). Data such as the medical data of a patient are a large collection of data which are and need to be divided into several subparts. From the meta model of the Documents and Knowledge Model the following concepts will be added: “Data/Document”, “Group”, “Belongs to” and “has Subdocument”. The “Group” element serves as generalization for the newly added specific groups: ”Medical Data”, “Administrative Data”, “Process Progress” and “Care Status”. These “Groups” help to aggregate several parts. The “Data/Document” element serves as generalization for the newly added specific data elements or documents: “Patient Data”, “Patient Health Insurance Data”, “Acute Physician Data”, “Rehabilitation Data”, “KoGu”, “Hospitalization Document”, “Medical Information”, “ICF Standard”, “Medication List”, “Assistance Data”, “Process Data” and “Special Medication Data”. As already explained, this detailed elicitation of the needed documents and data is based on created Mockups by the FHSG (see Appendix A, documents 5-7).

In the subchapter about the BPMN meta model, I have already introduced a status element, which is based on the status of several data elements/documents. Thus a “Status” element will also be added to the Documents and Knowledge Model meta model. This element can track the progress of the data collection of a specific document. It serves as generalization for six different “Status” elements: “Process Status”, “Physical Transfer Status”, “KoGu Status”, “ICF Qualifiers Status”, “Medication List Status” and “Acceptance Status”. These six “Status” elements are determined based on the progress of the data collection and are used to aggregate the overall “Status” in the DSML4PTM model.

Requirements coverage overview

#	Required concepts from the Documents and Knowledge Model meta model
R1.2.2, R1.3.2-R1.3.5, R1.4.1, R1.4.3-R1.4.6, R2.2.2, R2.3.1-R2.3.3, R3.1.2-R3.1.5-R3.1.8	Status (Process Status, Physical Transfer Status, KoGu Status, ICF Qualifiers Status, Medication List Status, Acceptance Status), Data/Document (Patient Data, Patient Health Insurance Data, Acute Physician Data, Rehabilitation Data, KoGu, Hospitalization Document, Medical Information, ICF Standard, Medication List, Assistance Data, Process Data, Special Medication Data), Group (Medical Data, Administrative Data, Process Progress, Care Status), Belongs to, has Subdocument

Table 22: Requirements covered with adapted Documents and Knowledge Model meta model

In the following, the Documents and Knowledge part of the meta model of the new DSML4PTM is shown as a simplified UML class diagram, without any attributes. Connections to other parts of the meta model are also shown. Documents and Knowledge elements that are connected to differently colored elements indicate such connections. The origin of the connected elements is highlighted in the legend. Unneeded concepts are removed while newly created concepts are added.

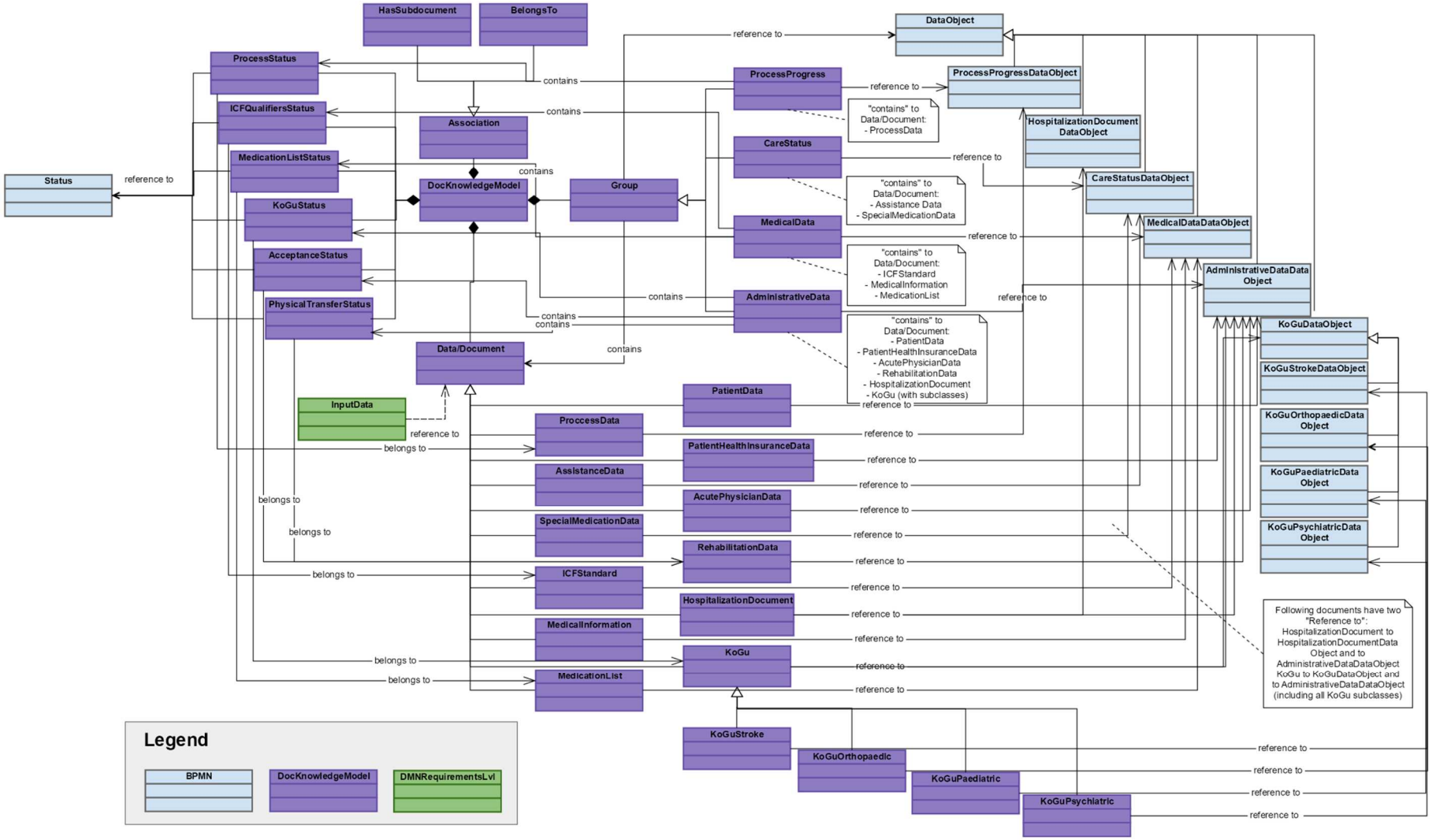


Figure 53: Meta model Documents and Knowledge Model part

5.1.5 Organization Model

While the BPMN meta model provides concepts to model an involved role or organization, it does not provide a way to structure roles and business units. The domain-specific requirements highlight, that in transferal management, structuring roles and business units is required. This ensures that a user can easily browse through an organization and find a suitable person or business unit. Bridgeland & Zahavi (2009) define an organization model as a model that shows roles, business units and departments, as well as how these interact within the company and with organizations outside the company.

For this purpose, the concepts from the ADOxx implementation of the Organization Model from the LearnPAd project will be added to the new meta model. It allows to structure an organization (BOC Asset Management GmbH, 2016). In the transfer management process, several actors and business units are involved. Specific roles and organization units will be added to the meta model to improve the domain-specific applicability. From the Organizational Model meta model, the following concepts will be added to the meta model of the new language: “Organizational Unit”, “Team”, “Performer”, “Role”, “Is Subordinated”, “belongs to”, “Is manager”, “Is manager” and “Has role”. The “Role” element serves as generalization for the newly added specific roles: “Administrative Staff”, “Nurse”, “Acute Physician”, “Rehabilitation Physician”, “Patient”, “Patient Disposition” and “Transferal Manager”. Further the “Organizational Unit” element serves as generalization for the newly added specific units: “Acute Hospital”, “Rehabilitation Clinic”, “Care Unit”, “Non-intensive Care Unit”, “Intensive Care Unit”, “Emergency Room”, “Site of Care” and “Health Insurance”.

Requirements coverage overview

#	Required concepts from the Organization Model meta model
R1.1.1-R1.1.2, R2.1.1-R2.1.2, R3.1.1	Organizational Unit (Acute Hospital, Rehabilitation Clinic, Care Unit, Non-intensive Care Unit, Intensive Care Unit, Emergency Room, Site of Care and Health Insurance), Team, Performer, Role (Administrative Staff, Nurse, Acute Physician, Rehabilitation

	Physician, Patient Disposition, Patient, Transferal Manager), Is Subordinated, belongs to, Is manager, Has role

Table 23: Requirements covered with adapted Organization Model meta model.

In the following, the Organization Model part of the meta model of the new DSML4PTM is shown as a simplified UML class diagram, without any attributes. Connections to other parts of the meta model are also shown. Organization Model elements that are connected to differently colored elements indicate such connections. The origin of the connected elements is highlighted in the legend. Unneeded concepts are removed while newly created concepts are added.

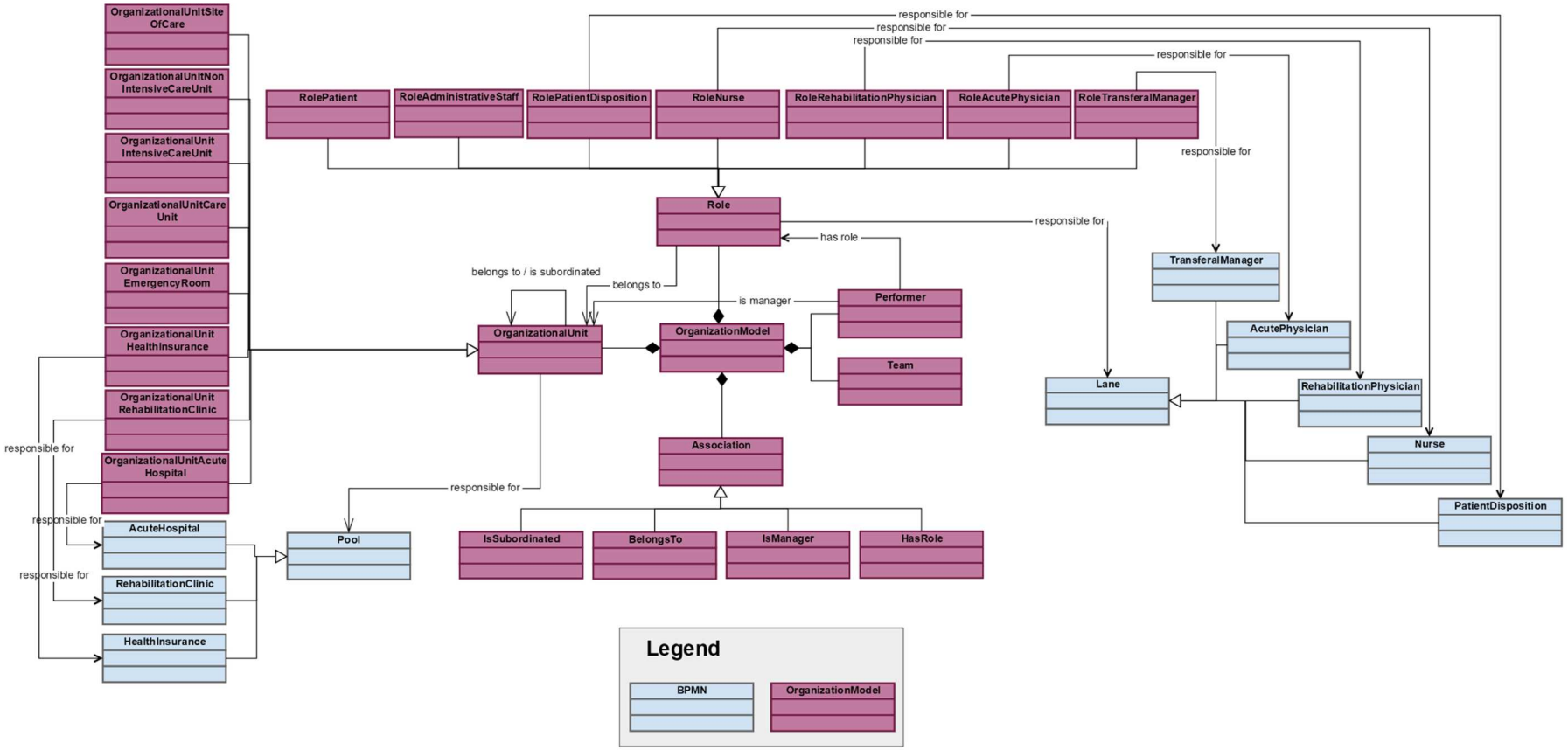


Figure 54: Meta model Organization Model part

5.1.6 Not covered in meta model DSML4PTM

All elements of the meta model, as explained in the previous subchapters, were used to build the meta model of the new DSML4PTM. Some elements which were elicited in chapter 4 are not included in the meta model due to further analysis (compare next table).

Not explicitly covered requirements overview

#	Requirement	Explanation
R1.1.1	The DSML should accommodate constructs to model different actors.	Only the most important actors get a dedicated role element in the organization model
R1.1.5	The DSML should accommodate constructs to model a system.	Content will be included in the administrative data, thus not as an own element
R1.1.12	The DSML should accommodate constructs to model the transfer of a patient	Will be modelled as a normal task, thus no dedicated element needed
R1.2.1	The DSML should accommodate constructs to model the patient admission form.	Content will be included in the hospitalization document, thus not as an own element
R1.2.3	The DSML should accommodate constructs to model the long report.	Content will be included in the administrative data, thus not as an own element
R1.3.1	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the short report.	Not deemed as important for the end-user where data is stored, thus no system element needed
R1.3.5	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the Tessiner code.	Not deemed as important to store the Tessiner code in a predefined way

R1.4.1	The DSML should accommodate constructs to assign the emergency severity to a case which includes that the ESI triage can be reflected with the decision criteria.	Not deemed as important to assign severity of a case. This is only relevant for the treatment of the patient.
R2.2.1	The DSML should accommodate constructs to model the patient admission form.	Content will be included in the hospitalization document, thus not as an own element

Table 24: Requirements not explicitly covered with adapted meta model of the new DSML

In chapter 7, the evaluation, further clarification on the coverage and deviation of these requirements is given.

5.2 Modelling elements (concrete syntax) and semantics DSML4PTM

In the previous subchapter, the meta model (abstract syntax) for DSML4PTM has been proposed as a series of meta models per included language. Based on the meta model, the other two parts of the new language are now defined: modelling elements (concrete syntax) and semantics. The following subchapters show these modelling elements with the suggested graphical notation and the present semantics for each of these elements. Semantics can be attributes, relations, rules or behavior that characterize the modelling element. If elements are based on a standard with already defined semantics, it is referenced to this standard and only additional semantics are listed. The semantics are part of the modelling conventions. Thus they can be understood as modelling guidelines for the user. However, to avoid modelling errors, they are developed hard-coded wherever possible. As mentioned, attributes are defined based on appendix A, documents 5 - 7. Only additional, domain-specific, attributes are listed.

5.2.1 BPMN

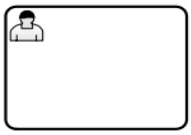
Task:

	**According to:** (Object Management Group, 2014) **Connections:** Can have up to two “Sentry” at the left border of the task **Attributes**: Discretionary Task, Task Name **Other:** Can also be “Discretionary”, can start an activity or path in a process without an own start event if there is a “Sentry” attached

Manual Task:

	**According to:** (Object Management Group, 2014) **Connections:** Can have up to two “Sentry” at the left border of the task **Other:** Cannot be a “Discretionary” task

User Task:

	**According to:** (Object Management Group, 2014) **Connections:** Can have up to two “Sentry” at the left border of the task **Other:** Cannot be a “Discretionary” task

Service Task:

	**According to:** (Object Management Group, 2014) **Connections:** Can have up to two “Sentry” at the left border of the task **Other:** Cannot be a “Discretionary” task

Business Rule Task:

	**According to:** (Object Management Group, 2014) **Connections:** Can have up to two “Sentry” at the left border of the task, can have a connection to a decision of the DMN requirements diagram **Other:** Cannot be a “Discretionary” task

Loop Marker:

	**According to:** (Object Management Group, 2014) **Other:** Cannot be attached to a “Discretionary” task

Parallel Marker:

	**According to:** (Object Management Group, 2014) **Other:** Cannot be attached to a “Discretionary” task

Sequence Flow:

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to and from “Discretionary” tasks

Exclusive Gateway:

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to and from “Discretionary” tasks

Parallel Gateway:

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to and from “Discretionary” tasks

Pool:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Organizational Unit” element of the Organization Model

Pool Acute Hospital:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Acute Hospital Organizational Unit” element of the Organization Model **Other:** Has label “Acute Hospital” **Hospital icon:** (freepik, 2015)

Pool Rehabilitation Clinic:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Rehabilitation Clinic Organizational Unit” element of the Organization Model **Other:** Has label “Rehabilitation Clinic” **Rehabilitation icon:** (FreeIconsPNG, 2015) **House icon:** (openclipart, 2016)

Pool Health Insurance:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Health Insurance Organizational Unit” element of the Organization Model **Other:** Has label “Health Insurance” **Insurance House icon:** (Cloudfront, 2016)

Lane:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Role” element of the Organization Model **Other:** Can also include “Discretionary” tasks

Lane Transferal Manager:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Transferal Manager” “Role” element of the Organization Model **Other:** Can also include “Discretionary” tasks, has label “Transferal Manager” **Ambulance icon:** (Metro Ambulance, 2015) **Manager icon:** (Icons Download, 2013)

Lane Acute Physician:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Acute Physician” “Role” element of the Organization Model **Other:** Can also include “Discretionary” tasks, has label “Acute Physician” **Physician icon:** (Cloudfront, 2015)

Lane Rehabilitation Physician:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Rehabilitation Physician” “Role” element of the Organization Model **Other:** Can also include “Discretionary” tasks, has label “Rehabilitation Physician” **Rehabilitation icon:** (FreeIconsPNG, 2015) **Plus sign icon:** (Iconfinder, 2016)

Lane Nurse:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Nurse” “Role” element of the Organization Model **Other:** Can also include “Discretionary” tasks, has label “Nurse” **Nurse icon:** (WebToolHub, 2016)

Lane Patient Disposition:

	**According to:** (Object Management Group, 2014) **Connections:** Is always linked to a “Patient Disposition” “Role” element of the Organization Model **Other:** Can also include “Discretionary” tasks, has label “Patient Disposition” **Patient Disposition icon:** (OpenClipArt, 2015)

Message Flow:

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

Data Object:

	**According to:** (Object Management Group, 2014) **Connections:** Can be connected to either a “Group” or a “Data/Document” of the Documents and Knowledge Model

KoGu Data Object:

	**According to:** (Object Management Group, 2014) “Data Object” **Connections:** Is always connected to the “KoGu” “Data/Document” of the Documents and Knowledge Model **Attribute:** KoGu template, KoGu Status **Other:** Has label “KoGu Data Object” **Money icon**: (My Icon Finder, 2016)

Medical Data Data Object:

	**According to:** (Object Management Group, 2014) “Data Object” **Connections:** Is always connected to the “Medical Data” “Group” of the Documents and Knowledge Model **Other:** Has label “Medical Data Data Object” **Heartbeat icon:** (freepik, 2016)

Administrative Data Data Object:

	**According to:** (Object Management Group, 2014) “Data Object” **Connections:** Is always connected to the “Administrative Data” “Group” of the Documents and Knowledge Model **Other:** Has label “Administrative Data Data Object” **Notepad and pen icon:** (My Icon Finder, 2016)

Process Progress Data Object:

	**According to:** (Object Management Group, 2014) “Data Object” **Connections:** Is always connected to the “Process Progress” “Group” of the Documents and Knowledge Model **Other:** Has label “Process Progress Data Object” **Process icon:** (Cloudfront, 2016)

Care Status Data Object:

	**According to:** (Object Management Group, 2014) “Data Object” **Connections:** Is always connected to the “Care Status” “Group” of the Documents and Knowledge Model **Other:** Has label “Care Status Data Object” **Wheelchair icon:** (SoftIcons, 2016)

Hospitalization Document Data Object:

	**According to:** (Object Management Group, 2014) “Data Object” **Connections:** Is always connected to the “Hospitalization Document” “Data/Document” of the Documents and Knowledge Model **Other:** Has label “Hospitalization Document Data Object”

	Hospital icon: (Odoo, 2016) **Arrow icon:** (IconArchive, 2014)

Data Association:

----------	**According to:** (Object Management Group, 2014) **Connections:** Can also connect all new “Data Objects” with all tasks (also “Discretionary” tasks)

None Event (Standard Start):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

None Event (Throwing Intermediate):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

None Event (Standard End):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

Message Event (Standard Start):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

Message Event (Catching Intermediate):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

Message Event (Throwing Intermediate):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

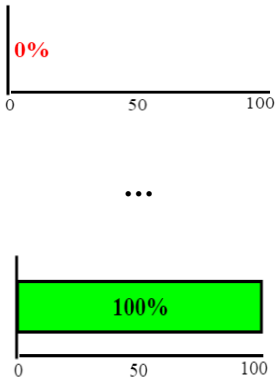
Message Event (Standard End):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

Timer Event (Catching Intermediate):

	**According to:** (Object Management Group, 2014) **Connections:** Can also be connected to “Discretionary” tasks

Status:

	**Connections:** Is connected to six status elements of the Documents and Knowledge Model **Attributes:** Data released, First assessment done, Reha conference done, Transfer date, Hospital approval, Reha approval, Patient in reha, KoGu ready, KoGu sent, KoGu accepted, KoGu rejected, Information filled in, Medication list complete, Medication list sent, Case accepted, Patient accepted **Other:** Changes progress and color based on data collection of attributes, 15 possibilities from 0 (0%) to 14 (100%) filled in (Reha conference and KoGu rejected are not relevant for progress), is placed on top right corner of the DSML4PTM model, is only used once, has label “Status”

5.2.2 CMMN and Control Element Model

Discretionary Task:

	**According to:** (Object Management Group, 2016) **Connections:** Can have up to two “Sentry” at the left border of the task, can have a connection to a decision of the DMN requirements diagram **Other:** Will be included into DSML4PTM Model as a flag for “Task”. If it is part of the process flow, it will be skipped if it should not be executed. If there is no incoming flow, it cannot be skipped and will be executed once relevant. Can start an activity or path in a process without an own start event when it is decided to execute the task.

Sentry (Entry Criterion Shape):

	**According to:** (Object Management Group, 2016) **Connections:** Can be connected to any task type in the DSML4PTM Model, is always linked to a “Sentry” of the Control Element Model **Other:** Will be included into the DSML4PTM Model. Two sentries that are attached to the left side of any “Task” are equivalent to an OR.

Sentry (of Control Element Model):

	**According to:** (Hinkelmann, et al., 2015) **Connections:** Has “Connection” to at least 1 “On-Condition” and 0 or 1 “If-Condition”, is always linked to a “Sentry” of the DSML4PTM Model

Connection:

	According to: (Hinkelmann, et al., 2015) **Connections:** Connects “Sentry” with “On-Condition” or “If-Condition” in the Control Element Model

On-Condition:

	**According to:** (Hinkelmann, et al., 2015) **Connections:** Connected to “Sentry” with “Connection” in the Control Element Model

If-Condition:

	**According to:** (Hinkelmann, et al., 2015) **Connections:** Connected to “Sentry” with “Connection” in the Control Element Model

5.2.3 DMN

Decision:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model

Decision Choose Rehab Clinic:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Other:** Has label “Choose Rehab Clinic” **Rehabilitation icon:** (FreeIconsPNG, 2015)

Decision Geriatric Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Other:** Has label “Geriatric Rehabilitation Suitability” **Geriatric icon:** (Free Icons Download, 2016)

Decision Internistic and Oncological Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Other:** Has label “Internistic and Oncological Rehabilitation Suitability”

	Internistic icon: (The Noun Project, 2016) **Oncology icon:** Adapted from (Vela Diagnostics, 2016)

Decision Cardiovascular Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a "Business Rule Task" or a "Discretionary Task" of the DSML4PTM model **Other:** Has label "Cardiovascular Rehabilitation Suitability" **Cardiovascular icon:** (The Noun Project, 2016)

Decision Musculoskeletal Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a "Business Rule Task" or a "Discretionary Task" of the DSML4PTM model **Other:** Has label "Musculoskeletal Rehabilitation Suitability" **Muscle icon:** (Icons8, 2015) **Bone icon:** (The Noun Project, 2016)

Decision Neurological Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a "Business Rule Task" or a "Discretionary Task" of the DSML4PTM model **Other:** Has label "Neurological Rehabilitation Suitability" **Brain icon:** (Plainicon, 2016)

Decision Pediatric Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a "Business Rule Task" or a "Discretionary Task" of the DSML4PTM model **Other:** Has label "Pediatric Rehabilitation Suitability" **Baby icon:** (Free Icons Download, 2014)

Decision Paraplegic Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Other:** Has label “Paraplegic Rehabilitation Suitability” **Paraplegic icon:** (The Noun Project, 2015)

Decision Psychosomatic Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Other:** Has label “Psychosomatic Rehabilitation Suitability” **Mental Health icon:** (The Noun Project, 2016)

Decision Pneumological Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Other:** Has label “Pneumological Rehabilitation Suitability” **Lungs icon:** (The Noun Project, 2015)

Decision Inpatient Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Attribute**: Rehabilitation Type **Other:** Has label “Inpatient Rehabilitation Suitability” **Inpatient icon:** (Free Icons Download, 2013)

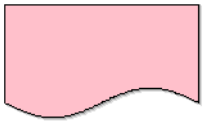
Decision Compulsory Medical Monitoring Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Attribute**: Rehabilitation Type **Other:** Has label “Compulsory Medical Monitoring Rehabilitation Suitability” **Monitoring icon:** (The Noun Project, 2015)

Decision Compulsory Medical Monitoring to Inpatient Rehabilitation Suitability:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Business Rule Task” or a “Discretionary Task” of the DSML4PTM model **Attribute**: Rehabilitation Type **Other:** Has label “Decision Compulsory Medical Monitoring to Inpatient Rehabilitation Suitability” **Monitoring icon:** (The Noun Project, 2015) **Inpatient icon:** (Free Icons Download, 2013)

Knowledge Source:

	**According to:** (Object Management Group, 2016) **Attribute**: Attachment

Knowledge Source DefReha©:

	**According to:** (Object Management Group, 2016) **Attribute**: Attachment **Other:** Has label “DefReha©”

Input Data:

	**According to:** (Object Management Group, 2016) **Connections:** Can be linked to a “Data/Document” of the Documents and Knowledge Model **Attribute**: Attachment

Business Knowledge:

	**According to:** (Object Management Group, 2016) **Connections:** Can be connected to a “Decision Table”

Business Knowledge Inclusion Criteria:

	**According to:** (Object Management Group, 2016) **Connections:** Can be connected to any “Entry” or “Exit” “Decision Table” **Attribute**: Rehabilitation Category

Business Knowledge Exclusion Criteria:

	**According to:** (Object Management Group, 2016) **Connections:** Can be connected to any “Entry” or “Exit” “Decision Table” **Attribute**: Rehabilitation Category

Business Knowledge Combination Inclusion and Exclusion Criteria:

	**According to:** (Object Management Group, 2016) **Connections:** Can be connected to a “Suitability Decision Table” **Attribute**: Rehabilitation Category

Information Requirement:

	**According to:** (Object Management Group, 2016)

Knowledge Requirement:

	According to: (Object Management Group, 2016)

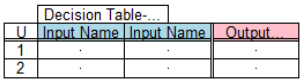
Authority Requirement:

	According to: (Object Management Group, 2016)

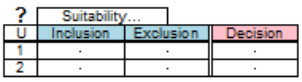
Has Decision Table:

	According to: (Object Management Group, 2016) **Connections:** Links any “Business Knowledge” to any “Decision Table”

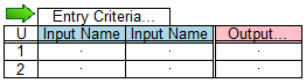
Decision Table:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a “Business Knowledge” element

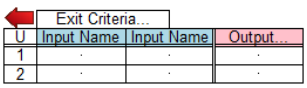
Suitability Decision Table:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a “Combination Inclusion Criteria and Exclusion Criteria” element **Other:** Prefilled with columns “Inclusion”, “Exclusion”, “Decision”

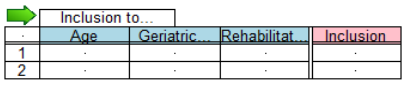
Entry Criteria Decision Table:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a “Inclusion Criteria” or “Exclusion Criteria” element

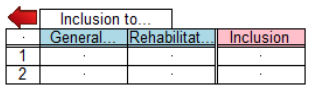
Exit Criteria Decision Table:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a “Inclusion Criteria” or “Exclusion Criteria” element

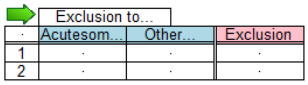
Decision Table Inclusion to Inpatient Geriatric Rehabilitation Entry:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a "Inclusion Criteria" element **Other:** Prefilled with columns "Age", "Geriatric Syndrome", "Rehabilitation Required", "Inclusion"

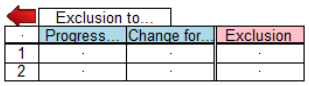
Decision Table Inclusion to Inpatient Geriatric Rehabilitation Exit Home/Long-term Facility:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a "Inclusion Criteria" element **Other:** Prefilled with columns "General Condition", "Rehabilitation Objectives", "Inclusion"

Decision Table Exclusion to Inpatient Geriatric Rehabilitation Entry:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a "Exclusion Criteria" element **Other:** Prefilled with columns "Acutesomatic Treatment and Diagnostics Done", "Other Specialized Rehabilitation Needed", "Exclusion"

Decision Table Exclusion to Inpatient Geriatric Rehabilitation Exit:

	**According to:** (Object Management Group, 2016) **Connections:** Is connected to a "Exclusion Criteria" element **Other:** Prefilled with columns "Progress Allows Exit", "Change for the Worse is Temporary", "Exclusion"

5.2.4 Documents and Knowledge Model

Group:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Can contain/aggregate several unspecified "Data/Documents"

Care Status:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Contains/aggregates “Documents” “Assistance Data”, “Special Medication Data”, is linked to a “Care Status Data Object” of the DSML4PTM Model **Other:** Always includes all mentioned “Data/Documents”, always needs to be present, can only be used once, has label “Care Status” **Wheelchair Icon:** (SoftIcons, 2016)

Administrative Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Contains/aggregates “Data/Documents” “Patient Data”, “Patient Health Insurance Data”, “Acute Physician Data”, “Rehabilitation Data”, “KoGu”, “Hospitalization Document”, “Status” “Physical Transfer Status”, “KoGu Status”, “Acceptance Status”, is linked to a “Administrative Data Data Object” of the DSML4PTM Model **Other:** Always includes all mentioned “Data/Documents” and “Status” elements, always needs to be present, can only be used once, has label “Administrative Data” **Notepad and pen Icon:** (My Icon Finder, 2016)

Process Progress:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Contains/aggregates “Data/Documents” “Process Data”, “Status” “Process Status”, is linked to a “Process Progress Data Object” of the DSML4PTM Model **Other:** Always includes the mentioned “Data/Document” and “Status” element, always needs to be present, can only be used once, has label “Process Progress” **Process Icon:** (Cloudfront, 2016)

Medical Data:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Contains/aggregates “Data/Documents” “General Data”, “ICF Standard”, “Medication List”, “Status” “ICF Qualifiers Status”, “Medication List Status”, is linked to a “Medical Data Data Object” of the DSML4PTM Model **Other:** Always includes all mentioned “Data/Documents” and “Status” elements, always needs to be present, can only be used once, has label “Medical Data” **Heartbeat Icon:** (freepik, 2016)

Data/Document:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can be part of a “Group”, can be linked to a “Data Object”

Patient Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Administrative Data” “Group”, is linked to the “Administrative Data Data Object” **Attributes:** Case number, Master Patient ID, MPI Patient ID, DRG primary code, DRG secondary code, Last name, First name, Country, Street & Nr., City, Canton, Date of Birth, City of birth, Canton of birth, Country of birth, Nationality, Mobile number, Mother tongue, Occupation, AHV number, Entry type, Hospitalization date **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Patient Data” **Patient icon:** (FreeIconsPNG, 2016)

Patient Health Insurance Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Administrative Data” “Group”, is linked to the “Administrative Data Data Object” **Attributes:** Health insurance provider, Health insurance number, Insurance model **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Patient Health Insurance Data” **Insurance icon:** (Cloudfront, 2016)

Acute Physician Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Administrative Data” “Group”, is linked to the “Administrative Data Data Object” **Attributes:** Physician Role, First Name, Last Name, Tel. number, E-mail **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Acute Physician Data” **Operation icon:** (Graphiq, 2015)

Rehabilitation Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Administrative Data” “Group”, is linked to the “Administrative Data Data Object” **Attributes:** Role in Rehab, First Name, Last Name, Tel. number, E-mail, Confirmed, Clinic name, Street, Street nr., ZIP code, City, Country, Rehab category, Rehab subcategory, Proposed discharging date hospital, Proposed discharging date rehabilitation clinic, Patient ID rehabilitation, Rehab objective, Responsible Care Person Role in rehab, First Name, Last Name, Tel. number, E-mail, First Name Physician, Last Name Physician, Tel. number Physician, E-mail Physician, Hospital approval with date, Reha approval with date, Patient in reha with date, Patient accepted with date, Case accepted with date **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Rehabilitation Data” **Rehab icon:** (FreeIconsPNG, 2015)

KoGu:

    	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the "Administrative Data" "Group", is linked to the DSML4PTM "KoGu Data Object", is linked to the "Administrative Data Data Object" **Attributes:** First name, Last name, Date of birth, Street & Nr., Zip code, City, Canton, Master Patient ID, MPI Patient ID, Clinic name, Street & Nr. ZIP code, City, Name family doctor, Address family doctor, Entry reason, Rehab category, Duration, Entry date, Rehab start date, Surgery date, Hospital, Diagnose ICD, Co-morbidity ICD, Therapy description, Body function, Body structure, Activity and Participation, Environmental factors, Treatment objective, Inability to work, Since when?, To how many percent?, Confirmation statements by the acute hospital, References, Concordat number, Name Physician, Tel. number Physician, Transferal Management Contact Hospital, Personnel, Tel. number transferal management, E-mail transferal management, Nutrition, Nutrition support, Personal Hygiene, Excretion / Toileting, (Un)dressing, Movement, Movement aid, Needed aid, Needed assistance, Weightbearing, From kg, To kg, Transfer, Understanding, Orientation, Social interaction, Aggressivity, Depression/Apathy, Restlessness, Stable mood, Adequate behavior and psyche, General remarks, KoGu ready with date, KoGu sent with date, KoGu rejected with date, KoGu accepted with date **Other:** Is always part of the mentioned "Group", always needs to be present, can only be used once, has label "KoGu", is available in five different layouts depending on KoGu template (Unspecified, Stroke, Orthopaedic, Paediatric, Psychiatric), KoGu Status **Money icon:** (My Icon Finder, 2016)

Hospitalization Document:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the "Administrative Data" "Group", is linked to the DSML4PTM "Hospitalization Document Data Object", is linked to the "Administrative Data Data Object" **Attributes:** *Hospitalization Part*: Insurance model, Health insurance provider, First name, Last name, Street & Nr., City, ZIP code, Date of birth, Tel. number, Hospitalization reason, Diagnosis / Functional deficit, Operation-/Accidentdate, Accompanying diseases, Treatment start, Treatment objective, Stay before rehabilitation start, Inability to work, Since when?, To how many percent?, First Name Physician, Last

	Name Physician, Tel. number Physician, Address Physician, City & Date *Clinic Entry Information Part*: First name, Last name, Street & Nr., Canton, Country, Tel. number, Mobile number, Date of birth, Place of citizenship, Nationality, Sex, Marital status, Denomination, Mother tongue, Occupation, AHV number, Employer, Employer address, Employer tel. number, Name closest relative, Address closest relative, Degree of relationship, Tel. number closest relative, Mobile number closest relative, Insurance model, Hospital entry possible, Calendar week, Health insurance provider, Address health insurance provider, Tel. number health insurance provider, Health insurance number, Complementary insurance provider, Address complementary insurance provider, Tel. number complementary insurance provider, Complementary insurance number, Name family doctor, Address family doctor, Tel. number family doctor, Name hospitalization physician, Address hospitalization physician, Tel. number hospitalization physician, City & Date, Filled in by *Care Status Part*: First name, Last name, Date of birth, Ability to move, Ability to eat/drink, Type of food, Diet description, Other description, Ability to urinate, Ability to excrete, Ability to take care of personal hygiene, Ability to (un)dress, Ability to acquire knowledge, Consciousness, Memory, Induction/deduction systems Type, Description, Since, VW, s/s, Decubitus, Decubitus wound documentation, Decubitus localization/grade, Skin changes/wounds, Skin changes/wounds documentation, Skin changes/wounds localization/type, Support services, Brought aids, Cytostatic drug, Tysabri®, HIV-medication, Biologica, Other special medication/infusions, Description other special medication/infusions, Dialysis, Other specialities, Description other specialities, City & Date, Filled in by **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Hospitalization Document” **Hospital icon:** (Odoo, 2016) **Arrow icon:** (IconArchive, 2014)

Medical Information:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Medical Data” “Group”, is linked to the “Medical Data Data Object” **Attributes:** Affliction, Surgery date, Discharging date, Diagnose ICD, Co-morbidity ICD, CHOP code **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Medical Information” **Medicine icon:** (Free Icons Download, 2016)

ICF Standard:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Medical Data” “Group”, is linked to the “Medical Data Data Object” **Attributes:** Body function ID & Category, Qualifier, Trend Body function, Status Body function, Body structure ID & Category, Qualifier, Trend Body structure, Status Body structure, Activity and Participation ID & Category, Qualifier, Trend Activity and Participation, Status Activity and Participation, Environmental factors ID & Category, Qualifier, Trend Environmental factors, Status Environmental factors, Information filled in with date **Other:** Always part of the mentioned “Group”, always needs to be present, can only be used once, has label “ICF Standard”; “Trend” and “Status” of each category are shown on the icon based on the input for the respective attributes

Medication List:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Medical Data” “Group”, is linked to the “Medical Data Data Object” **Attributes:** Name of medicine, Dose, Time, Day of the week, Repeat, Via, Medication list complete with date, Medication list sent with date **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Medication List” **Medication List icon:** (Share Icon, 2016)

Assistance Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Care Status” “Group”, is linked to the “Care Status Data Object” **Attributes:** Ability to move, Ability to eat/drink, Type of food, Diet description, Other description, Ability to urinate, Ability to excrete, Ability to take care of personal hygiene, Ability to (un)dress, Ability to acquire knowledge, Consciousness, Memory, Induction/deduction systems Type, Description, Since, VW, s/s, Decubitus, Decubitus wound documentation, Decubitus localization/grade, Skin changes/wounds, Skin changes/wounds documentation, Skin changes/wounds localization/type, Support services, Brought aids

	Other: Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Assistance Data” **Assistance icon:** (FlatIcon, 2016)

Special Medication Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Care Status” “Group”, is linked to the “Care Status Data Object” **Attributes:** Cytostatic drug, Tysabri®, HIV-medication, Biologica, Other special medication/infusions, Description other special medication/infusions, Dialysis, Other specialities, Description other specialities **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Special Medication Data” **Medicine icon:** (Simple Icon, 2016)

Process Data:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Is included in the “Process Progress” “Group”, is linked to the “Process Progress Data Object” **Attributes:** Data released with date, First assessment done with date, Reha conference done with date, Transfer date with date **Other:** Is always part of the mentioned “Group”, always needs to be present, can only be used once, has label “Process Data” **Process icon:** (Cloudfront, 2016)

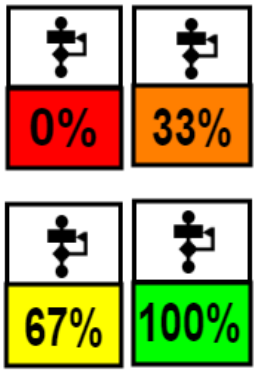
Belongs to:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Can connect any “Document”/”Group”/”Status” combination, also all newly created “Document” , “Group” and “Status” elements

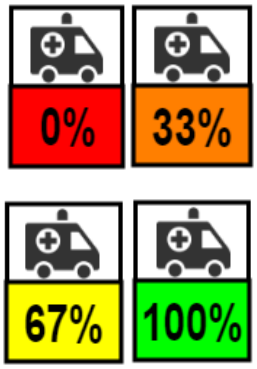
Has Subdocument:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can connect “Documents”, also all newly created “Documents”

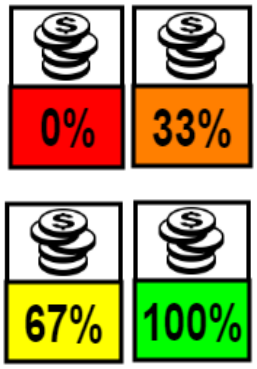
Process Status:

	**Connections:** Is included in the “Process Progress” “Group”, “belongs to” “Document/Data” “Process Data”, is linked to “Status” **Attributes:** Data released, First assessment done, Reha conference done, Transfer date **Other:** Changes progress and color based on data collection of attributes, 4 possibilities from 0 (0%) to 3 (100%) filled in (Reha conference does not count to progress), has label “Process Status”, is always part of the mentioned “Group”, always needs to be present, can only be used once **Process icon:** (Cloudfront, 2016)

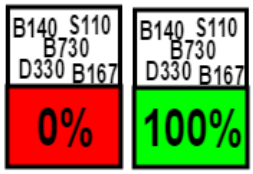
Physical Transfer Status:

	**Connections:** Is included in the “Administrative Data” “Group”, “belongs to” “Document/Data” “Rehabilitation Data”, is linked to “Status” **Attributes:** Hospital approval, Reha approval, Patient in reha **Other:** Changes progress and color based on data collection of attributes, 4 possibilities from 0 (0%) to 3 (100%) filled in, has label “Physical Transfer Status”, is always part of the mentioned “Group”, always needs to be present, can only be used once **Ambulance icon:** (Metro Ambulance, 2015)

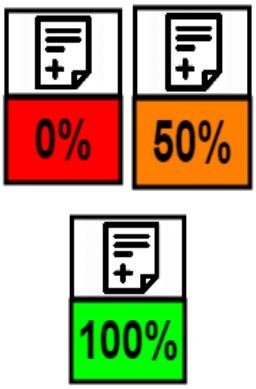
KoGu Status:

	**Connections:** Is included in the “Administrative Data” “Group”, “belongs to” “Document/Data” “KoGu”, is linked to “Status” **Attributes:** KoGu ready, KoGu sent, KoGu accepted, KoGu rejected, KoGu Status **Other:** Changes progress and color based on data collection of attributes, 4 possibilities from 0 (0%) to 3 (100%) filled in (KoGu rejected does not count to progress), has label “KoGu Status”, is always part of the mentioned “Group”, always needs to be present, can only be used once **Money icon:** (My Icon Finder, 2016)

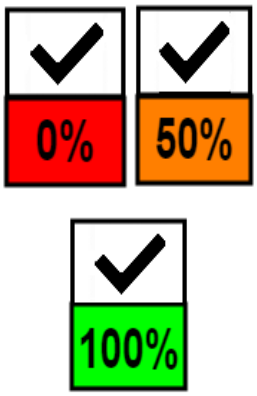
ICF Qualifiers Status:

	**Connections:** Is included in the “Medical Data” “Group”, “belongs to” “Document/Data” “ICF Standard”, is linked to “Status” **Attributes:** Information filled in **Other:** Changes progress and color based on data collection of attributes, 2 possibilities from 0 (0%) to 1 (100%) filled in, has label “ICF Qualifiers Status”, is always part of the mentioned “Group”, always needs to be present, can only be used once

Medication List Status:

	**Connections:** Is included in the “Medical Data” “Group”, “belongs to” “Document/Data” “Medication List”, is linked to “Status” **Attributes:** Medication list complete, Medication list sent **Other:** Changes progress and color based on data collection of attributes, 3 possibilities from 0 (0%) to 2 (100%) filled in, has label “Medication List Status”, is always part of the mentioned “Group”, always needs to be present, can only be used once **Medication List icon:** (Share Icon, 2016)

Acceptance Status:

	**Connections:** Is included in the “Administrative Data” “Group”, “belongs to” “Document/Data” ”Rehabilitation Data”, is linked to “Status” **Attributes:** Case accepted, Patient accepted **Other:** Changes progress and color based on data collection of attributes, 3 possibilities from 0 (0%) to 2 (100%) filled in, has label “Acceptance Status”, is always part of the mentioned “Group”, always needs to be present, can only be used once **Tickmark icon:** (Free Downloads, 2016)

5.2.5 Organization Model

Organizational Unit:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can “belong to” and “be subordinated” to another “Organizational Unit”. A “Performer” or a “Role can “belong to” an “Organizational Role”. A “Performer” can be “manager of” an “Organizational Unit”. Can be linked to a “Pool”. This is also true for any newly created “Organizational Unit”.

Organizational Unit Acute Hospital:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit”, is linked to the “Acute Hospital” pool **Other:** Has label “Organizational Unit Acute Hopsital” **Hospital icon:** (freepik, 2015)

Organizational Unit Rehabilitation Clinic:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit” ”, is linked to the “Rehabilitation Clinic” pool **Other:** Has label “Organizational Unit Rehabilitation Clinic” **Rehabilitation icon:** (FreeIconsPNG, 2015) **House icon:** (openclipart, 2016)

Organizational Unit Care Unit:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit” **Other:** Has label “Organizational Unit Care Unit” **Care Unit icon:** (FlatIcon, 2013)

Organizational Unit Non-intensive Care Unit:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit” **Other:** Has label “Organizational Unit Non-intensive Care Unit” **Non-intensive Care Unit icon:** Adapted from (Suli Medicine, 2016)

Organizational Unit Intensive Care Unit:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit” **Other:** Has label “Organizational Unit Intensive Care Unit” **Intensive Care Unit icon:** (Suli Medicine, 2016)

Organizational Unit Emergency Room:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit” **Other:** Has label “Organizational Unit Emergency Room” **Emergency icon:** (IconArchive, 2014)

Organizational Unit Site of Care:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit” **Other:** Has label “Organizational Unit Site of Care” **Wheelchair icon:** (SoftIcons, 2016) **House icon:** (openclipart, 2016)

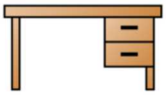
Organizational Unit Health Insurance:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Organizational Unit”, is linked to the “Health Insurance” pool **Other:** Has label “Organizational Unit Health Insurance” **Insurance House icon:** (Cloudfront, 2016)

Team:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can aggregate “Roles”, “Performers” and/or “Organizational Units”

Performer:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Can belong to an “Organizational Role”. Can be manager of an “Organizational Unit”. “Has role” to a “Role”. This is also true for any newly created “Organizational Unit” or “Role”. A “Role” can belong to a “Performer”

Role:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Can belong to an “Organizational Unit” or a “Performer”. A “Performer” can have a “Role”. Can be linked to a “Lane”. This is also true for any newly created “Organizational Unit” or “Role”

Role Administrative Staff:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role” **Other:** Has label “Role Administrative Staff” **Administration icon:** (Cluj School of Public Health, 2015)

Role Nurse:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role”, is linked to the “Nurse” lane **Other:** Has label “Role Nurse” **Nurse icon:** (WebToolHub, 2016)

Role Acute Physician:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role”, is linked to the “Acute Physician” lane **Other:** Has label “Role Acute Physician” **Physician icon:** (Cloudfront, 2015)

Role Rehabilitation Physician:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role”, is linked to the “Rehabilitation Physician” lane **Other:** Has label “Role Rehabilitation Physician **Rehabilitation icon:** (FreeIconsPNG, 2015) **Plus sign icon:** (Iconfinder, 2016)

Role Patient Disposition:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role”, is linked to the “Patient Disposition” lane **Other:** Has label “Role Patient Disposition” **Patient Disposition icon:** (OpenClipArt, 2015)

Role Patient:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role” **Other:** Has label “Role Patient” **Patient icon:** (FreeIconsPNG, 2016)

Role Transferal Manager:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Same as “Role”, is linked to the “Patient Disposition” lane **Other:** Has label “Role Transferal Manager” **Ambulance icon:** (Metro Ambulance, 2015) **Manager icon:** (Icons Download, 2013)

Is subordinated:

	**According to:** (BOC Asset Management GmbH, 2016) **Connections:** Can connect “Organizational Units”

Belongs to:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can connect any “Role”, “Performer”, “Organizational Unit”

Is manager:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can connect a “Performer” to any “Organizational Unit”

Has role:

	According to: (BOC Asset Management GmbH, 2016) **Connections:** Can connect a “Performer” to any “Role”

6. Development

The third phase of the DSR approach is concerned with the development of the artifact. According to Vaishnavi & Kuechler (2004) the development technique will vary depending on the artifact. They further highlight that “the novelty lies in the design of the artifact and not in the construction of the artifact”.

In our case, the construction of the artifact will be done with the ADOxx Development Toolkit. ADOxx is a metamodelling platform that allows to develop all three parts (abstract syntax, concrete syntax, semantics) of a domain-specific graphical modelling language (BOC Asset Management GmbH, 2016). It is frequently used for the development of DSMLs in the research community.

For each modelling language, which has been suggested to include into the DSML based on the elicited requirements, the development is explained in the following. The meta model is implemented for each modelling language in ADOxx as shown in the figures 48 and 51-54. References between modelling languages are developed in ADOxx as so called “INTERREF” attributes.

To allow modelling in DSML4PTM, the ADOxx Modelling Toolkit is used. There, all developed concepts are available for the user. As a supplement to the artifact, the reference process is modelled in DSML4PTM and also delivered as an outcome of this thesis (see appendix B). Two versions are available, the equivalent to the reference process by the FHSG, and a version that extends the process with the KoGu rejection (based on two scenarios as modelled in the evaluation together with domain and modelling experts). Further, the use case scenario by the FHSG is modelled in DSML4PTM as an example. It also shows, that it is possible to model an applied case (compare chapter 7, “Evaluation”). All these models are delivered together with the DSML4PTM ADOxx library and can be reused.

6.1 BPMN

BPMN serves as central modelling language for DSML4PTM. It allows to model the process flow while having references to all other modelling languages as shown in the respective meta model. The following modelling elements are available in DSML4PTM to model the process flow (with a short and detailed description for the main elements

only):

Please note, that all elements of the figure are available for modelling, as defined in the meta model, but only the red marked elements are further described in this chapter.

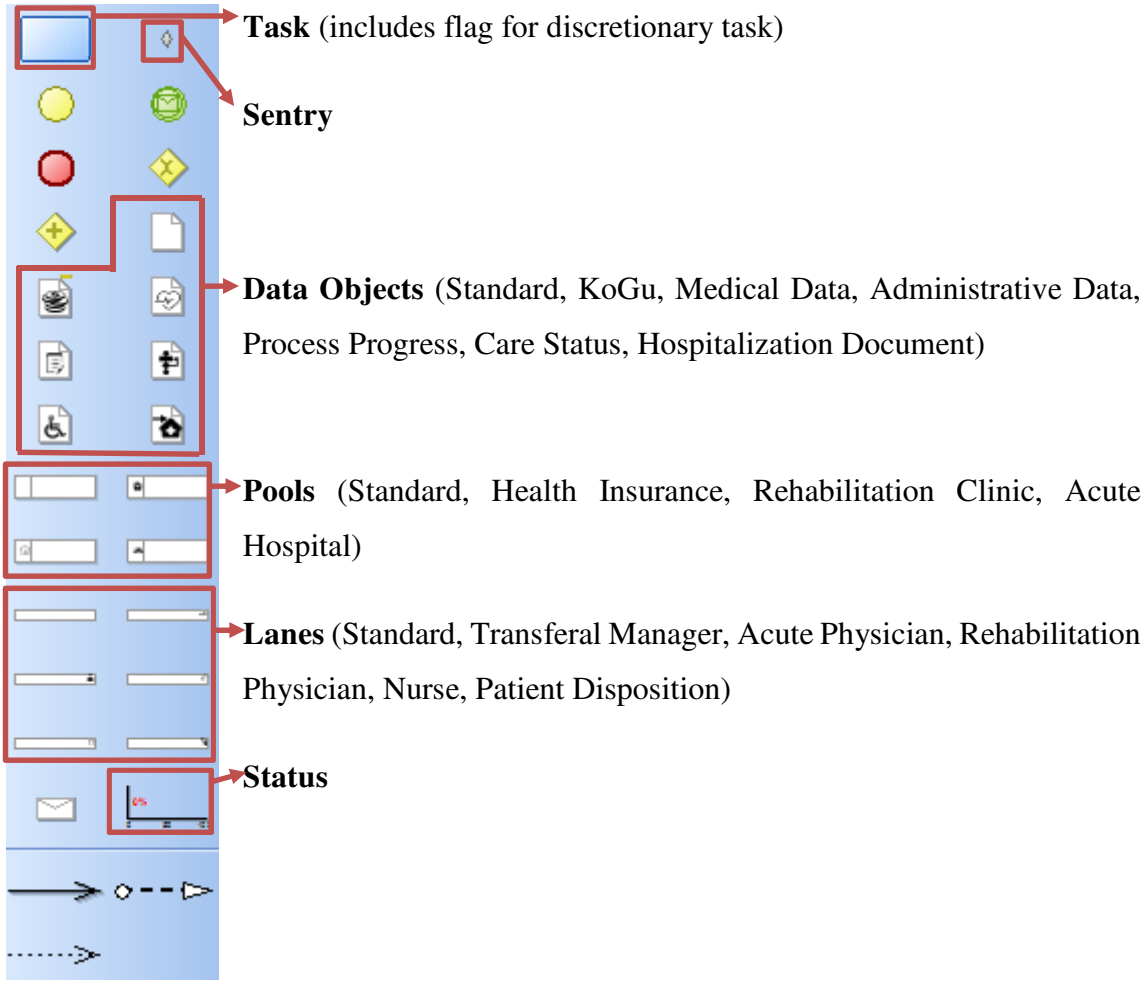


Figure 55: Modelling elements BPMN part

Task

In the “Description” chapter, the reference process tasks are already listed and can be selected by the user. When choosing another task, the following changes will be done automatically (realized with a script):

- BPMN task type (Not specified, Manual, Business rule, User, Service)
- Discretionary task (Yes/No)
- Loop type (Not specified, Standard, Multi-instance)
- Name

Any of above mentioned, besides the name, are always read only as long as not the plain "Task" is selected.

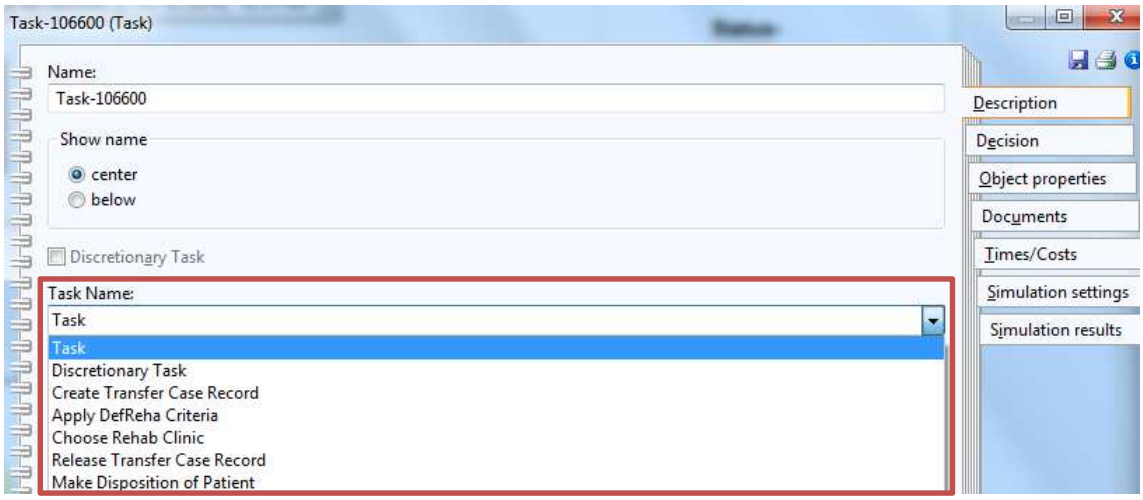


Figure 56: Task selection

As an example, if the task "Choose Rehab Clinic" is selected, the task name changes and the task type is "Business rule":

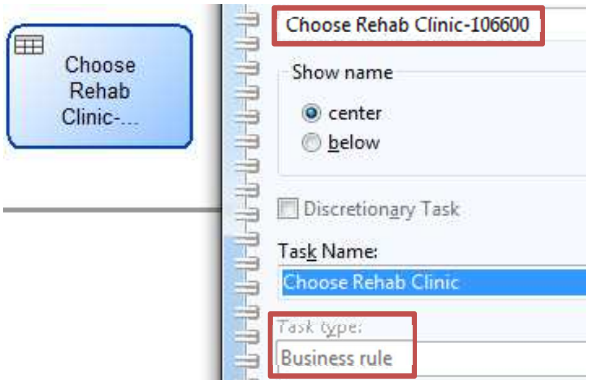


Figure 57: Changes when selecting a task

The same concept is also implemented for the modelling elements "Start Event", "Intermediate Event" and "End Event", where name and type will change if a predefined domain-specific event is selected.

"Perform Reha Conference" is an example for a discretionary task. The user is not able to select a task type or a loop type in this case:

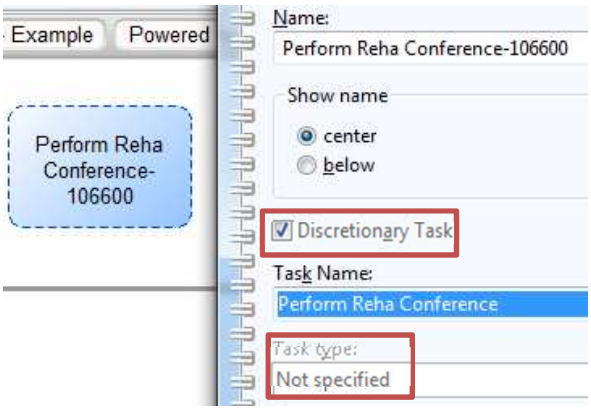


Figure 58: Changes when selecting a discretionary task

"Re-apply DefReha Criteria" is an important task in the domain. Whenever the conditions of a patient change and a re-application is needed, the task has to be executed. In order to let the transferal manager know, that rework is needed and to

count the amount of iterations so far, some new attributes are introduced when this task is created.

If the DefReha© criteria need to be re-applied, and the rehab type changes, the respective checkbox has to be clicked on and the new type can be selected (this should be done by the physician). When the checkbox is active, a red comment "Interface changed" is shown on top of the task to signalize to the transferal manager, that he needs to get active. Further, each time the DefReha© criteria are reapplied, the respective counter shall be increased (in the future these steps are to be automated). A history of all rehab types of a patient is available in the Data/Document "Rehabilitation Data". This functionality is focused on a later automation/execution of the process in run-time.

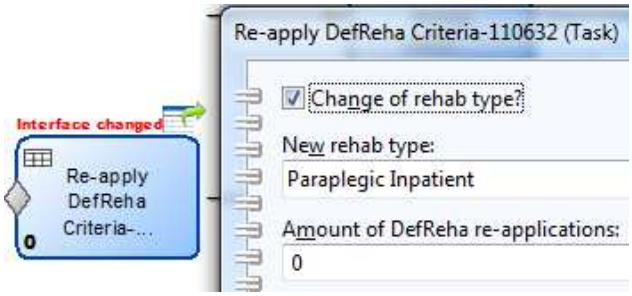


Figure 59: Re-apply DefReha Criteria attributes

On the "Decision" tab a decision from the DMN model can be attached if the task is business rule or discretionary:

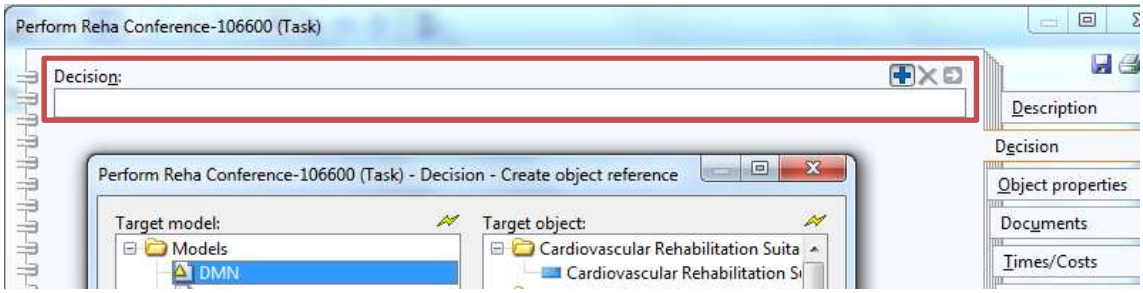


Figure 60: Task reference to decision

A new icon will be shown if a decision is attached to a task. A click on it will guide the user to the referenced decision:

Figure 61: Decision icon

Sentry

A sentry can be attached to a task and referenced to the corresponding sentry in the Control Elements Model part. Further references can be done to the corresponding on- and if-conditions:

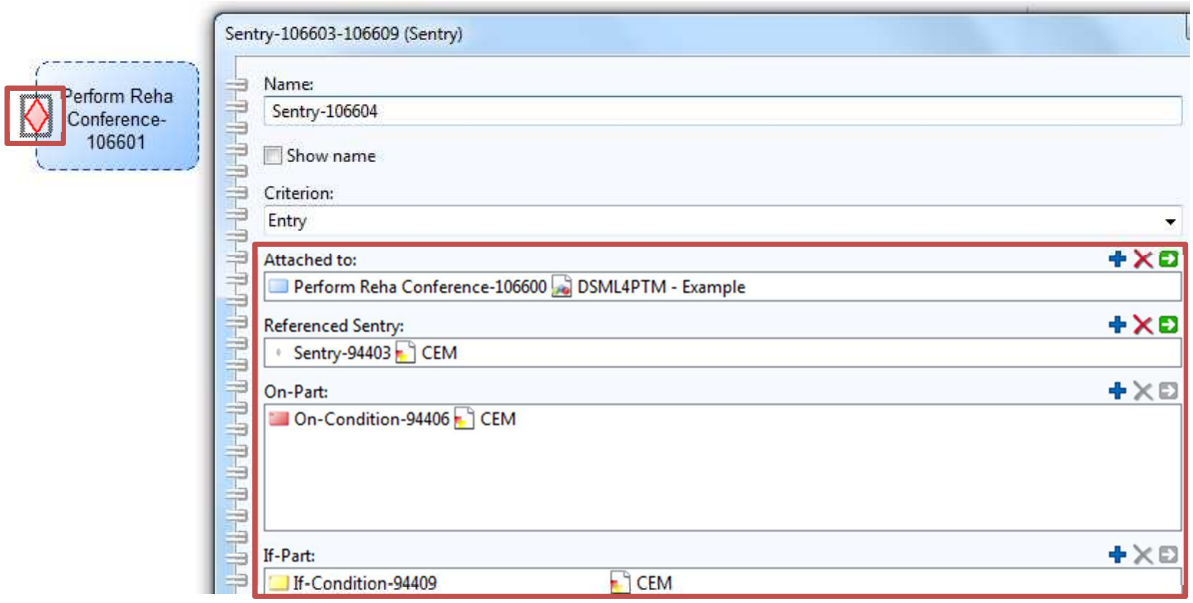


Figure 62: References to Control Elements Model

Data Objects

Six new data objects are available as domain-specific constructs:

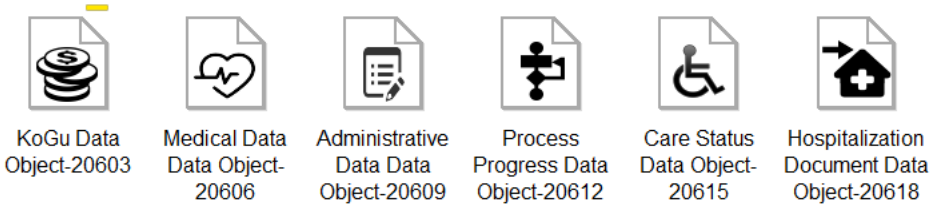


Figure 63: Data objects in the modelling toolkit

These can be referenced to the corresponding element in the Documents & Knowledge Model:

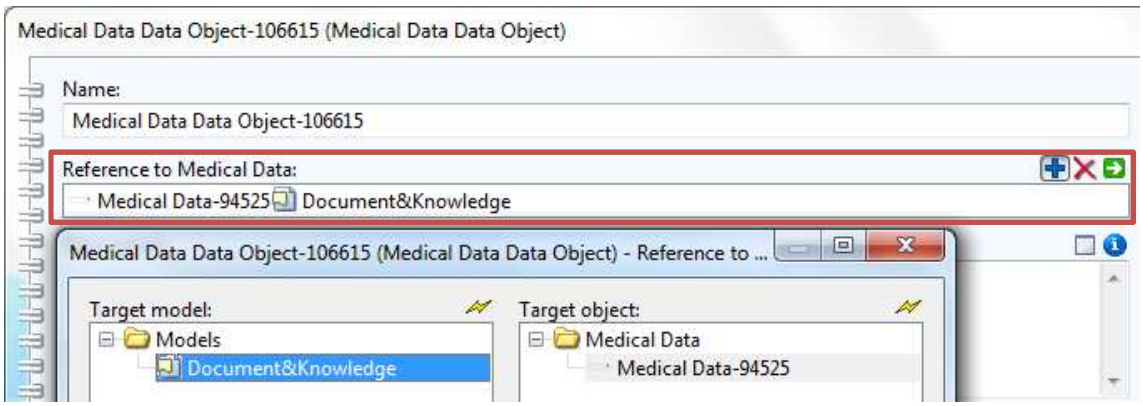


Figure 64: Reference to Document and Knowledge Model

In this case a hyperlink is added to the referenced Documents & Knowledge Model counterpart:

Figure 65: Hyperlink to Document and Knowledge Model

For the KoGu data object, the template can be selected:

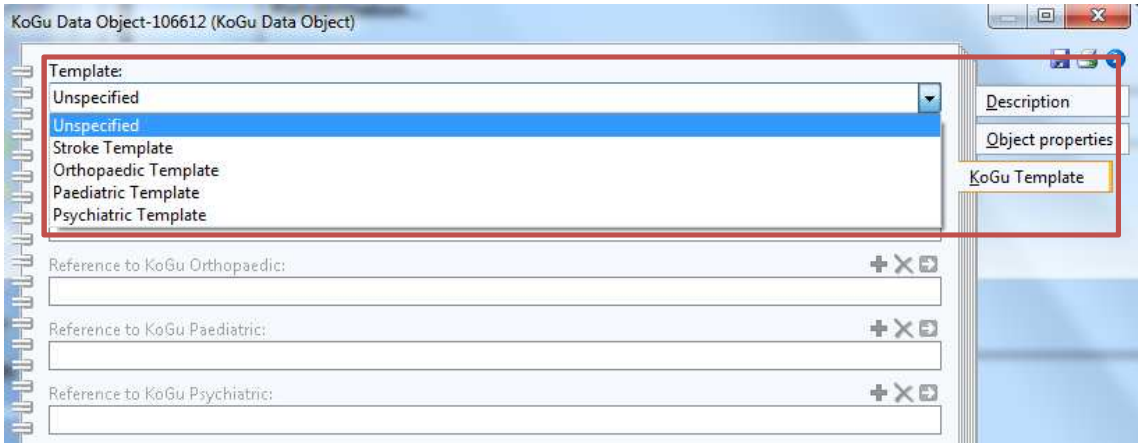


Figure 66: KoGu template selection

When a template is selected, only the correct counterpart can be chosen in the Documents & Knowledge Model as all other reference fields will be read-only (e.g. if KoGu Stroke is selected, only a reference to a KoGu Stroke document is possible and the icon of the data object changes).

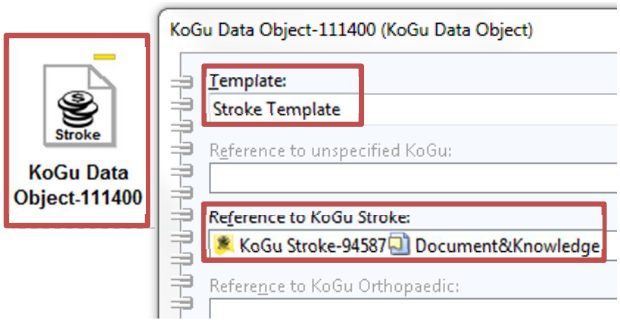


Figure 67: KoGu template example

As it is very important to understand in what status the KoGu is, a new attribute is added, which defines if the KoGu has already been accepted or rejected at a certain stage of the process. The icon on the top right changes:

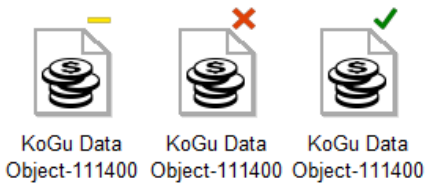


Figure 68: KoGu status data object

Further, if a version of any data object is entered on the chapter "Description", it is shown in the representation of the element. This enables to differentiate various versions of a data/document element:

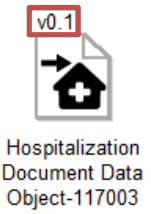


Figure 69: Version flag

Pools

Predefined pools are available with custom icons for Health Insurance, Acute Hospital and Rehabilitation Clinic (example Health Insurance):

Figure 70: Health Insurance pool

In the chapter "Representation", a reference to the respective element (Organizational Unit) of the Organization Model can be made:

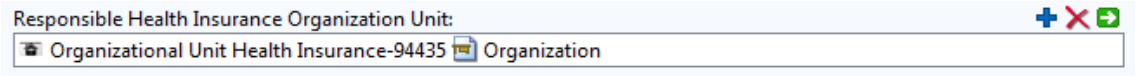


Figure 71: Reference to Organizational Unit

The domain-specific constructs can only be linked to the correct Organizational Unit. If a reference is added, a hyperlink is shown that leads to the respective element in the Organizational Model:

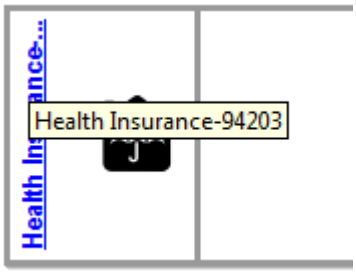


Figure 72: Hyperlink to Organization Model

Lanes

Lanes are implemented the same way as pools except that they can be linked to a "Role"

instead of an “Organizational Unit” in the Organization Model. Five new domain-specific concepts are available. An example is provided in the following (two lanes within a pool):

Figure 73: Example lanes

Status

A new status element is added, which captures the progress of the data collection. It can be linked to the respective status elements in the Documents & Knowledge Model:

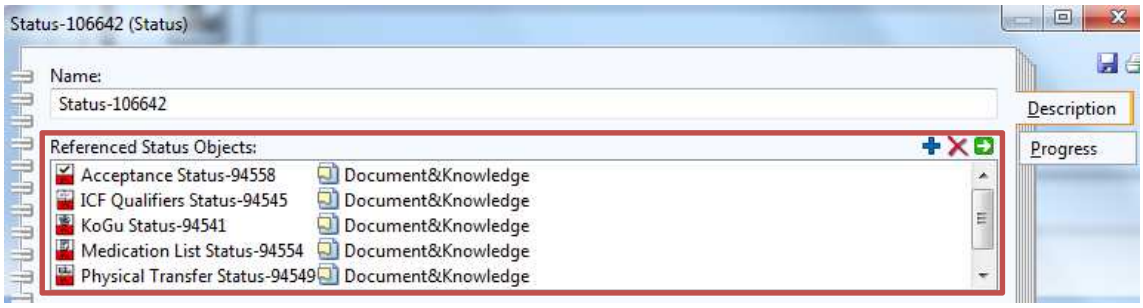


Figure 74: Reference to Status elements

In the second chapter “Progress” the relevant attributes for the data collection are shown (as an aggregation of the six Status elements in the Documents & Knowledge Model):

Figure 75: Status attributes

Once a checkbox within each area is clicked on, the following gets activated to reflect the order. The appearance of the status element changes depending on the amount of boxes that are clicked on:

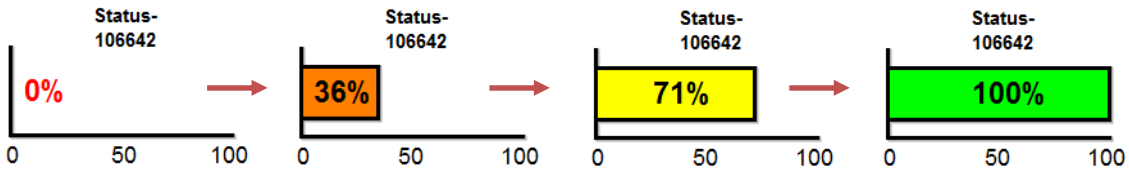


Figure 76: Appearance of Status element (examples)

This functionality is mainly focused on a later automation/execution of the process in run-time. However, it also allows to define models in design-time that show a different progress.

6.2 CMMN and Control Element Model

The CMMN discretionary task and sentry are included in DSML4PTM as an extension to BPMN. To make the criteria explicit, the Control Element Model is used. It only has references to the BPMN part. The following modelling elements are available (with a short and detailed description for the main elements):

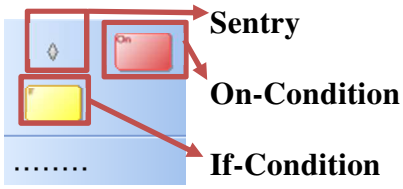


Figure 77:
Modelling elements
Control Element
Model part

Sentry:

The sentry is the same element as the sentry in the BPMN part and provides the same attributes/references:

However, in this case, the "On-Part" and the "If-Part" are references to elements in the Control Element Model itself.

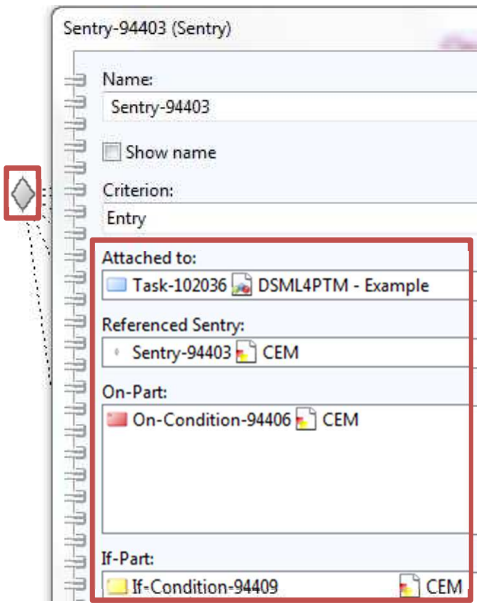


Figure 78: Sentry references

On/If-Condition

As demonstrated for the BPMN task, also for the On- and If-Conditions, domain-specific concepts (taken from the requirements and as defined in the meta model) are already predefined and can be selected from a list. If this is done, the name of the element will change:

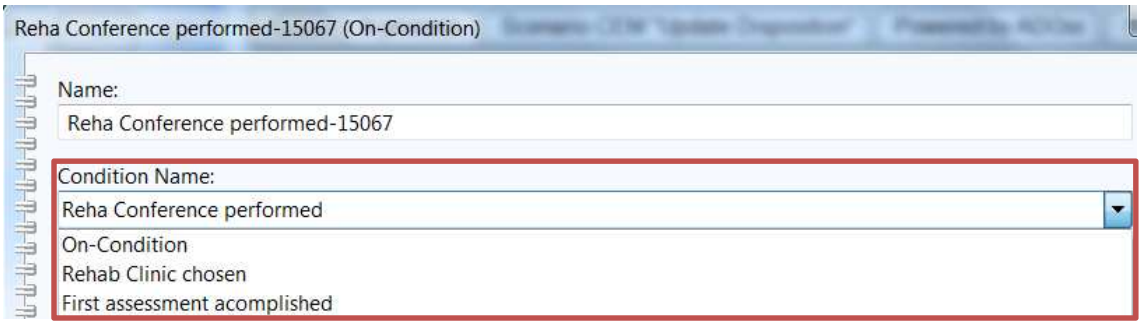


Figure 79: Selection of a condition

6.3 DMN

To allow the modelling of business rules (as decision tables), the DMN standard is included in DSML4PTM. It has references to the BPMN part (which is extended by the concept "Discretionary Task") and to the Documents and Knowledge Model. The following modelling elements are available (with a short and detailed description for the main elements):

Figure 80: Modelling elements DMN part

Decisions (Standard, Choose Rehab Clinic, Geriatric Rehabilitation Suitability, Internistic and Oncological Rehabilitation Suitability, Cardiovascular Rehabilitation Suitability, Musculoskeletal Rehabilitation Suitability, Neurological Rehabilitation Suitability, Pediatric Rehabilitation Suitability, Paraplegic Rehabilitation Suitability, Psychosomatic Rehabilitation Suitability, Pneumological Rehabilitation Suitability, Inpatient Rehabilitation Suitability, Compulsory Medical Monitoring Rehabilitation Suitability, Compulsory Medical Monitoring to Inpatient Rehabilitation Suitability)

Business Knowledge (Standard, Exclusion Criteria, Inclusion Criteria, Combination Inclusion and Exclusion Criteria)

Knowledge Sources (Standard, DefReha©)

Data Input (Standard)

Decision Tables (Standard, Entry Criteria Decision Table, Exit Criteria Decision Table, Suitability Decision Table, Inclusion to Inpatient Geriatric Rehabilitation Entry, Inclusion to Inpatient Geriatric Rehabilitation Exit Home/Long-term Facility, Exclusion to Inpatient Geriatric Rehabilitation Entry, Exclusion to Inpatient Geriatric Rehabilitation Exit)

Mainly, new modelling elements are available to reflect the DefReha© standard that helps to decide on inclusion/exclusion based on the defined criteria for each rehabilitation category.

Decisions

One decision per rehabilitation category is available as domain-specific concept:

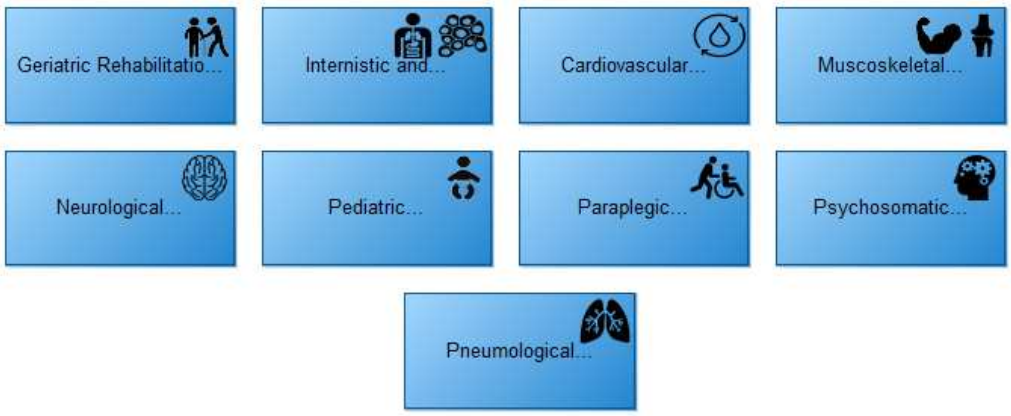


Figure 81: Modelling elements rehabilitation category

As there might be up to three subcategories per rehabilitation category, three further decisions are added:

Figure 82: Modelling elements rehabilitation subcategory

An attribute allows to define the rehabilitation category for these three elements:

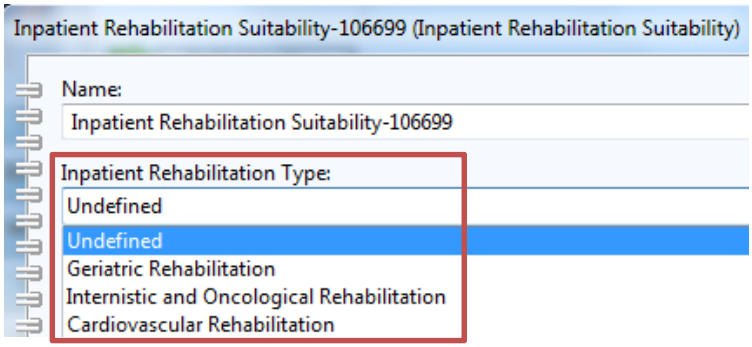


Figure 83: Attribute Rehabilitation Category

All decisions can be linked to a task in the BPMN part:

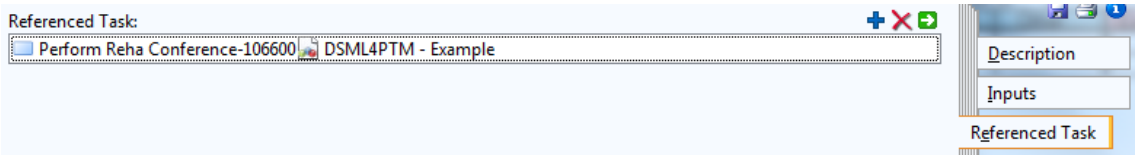


Figure 84: Reference from decision to task

Business Knowledge

Three new domain-specific concepts are available to reflect the DefReha©:

Figure 85: Business Knowledge concepts

In addition, a rehabilitation category attribute is available here. When a decision has to be made, inclusion and exclusion criteria have to be considered and finally they are combined.

Knowledge Source

Besides adding a new concept, which reflects the knowledge source DefReha©, a new attribute allows to add a path to a document on the file system. If added, a hyperlink is provided. Clicking on the link opens the document directly.

Figure 86: DefReha© Knowledge Source with DefReha© document attached

Input Data

A new attribute allows to have a reference from the input data to a data/document element. This enables a quick navigation (via a hyperlink) to the respective data/document, if it is used as a data input for a decision.

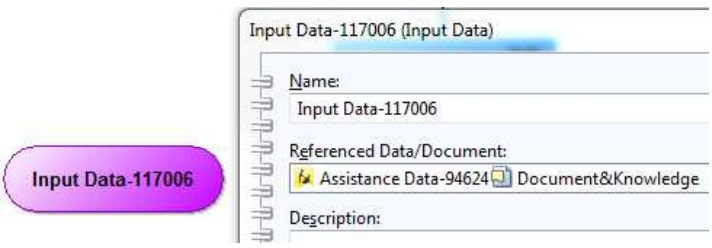


Figure 87: Referenced Data/Document

Decision Tables

For the shown business knowledge elements, decision tables are predefined to reflect the DefReha©. There is a decision table available for the combination of inclusion and exclusion criteria as well as not yet adjusted tables to apply entry and exit criteria.

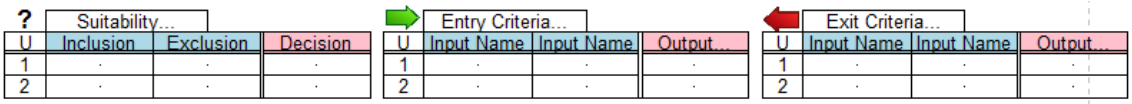


Figure 88: Combination, entry criteria and exit criteria decision tables

Entry criteria decision tables are relevant, if a decision has to be taken whether a patient shall enter the rehabilitation clinic. If the decision is about whether he should leave the clinic (e.g. to go home or back to the acute hospital), exit decision tables are relevant. For the DefReha© case Geriatric Inpatient Rehabilitation predefined decision tables are available as an example:

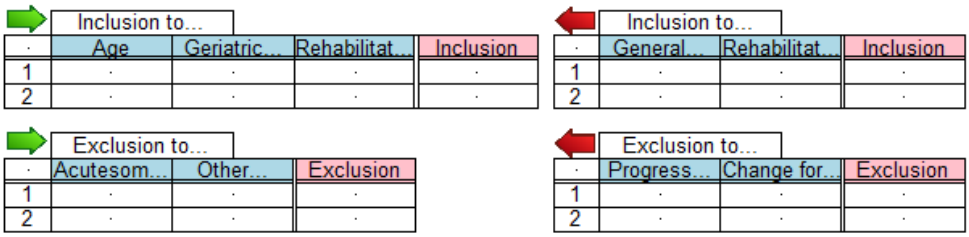


Figure 89: Predefined decision tables

Decision tables can be edited in the “Decision Table” chapter:

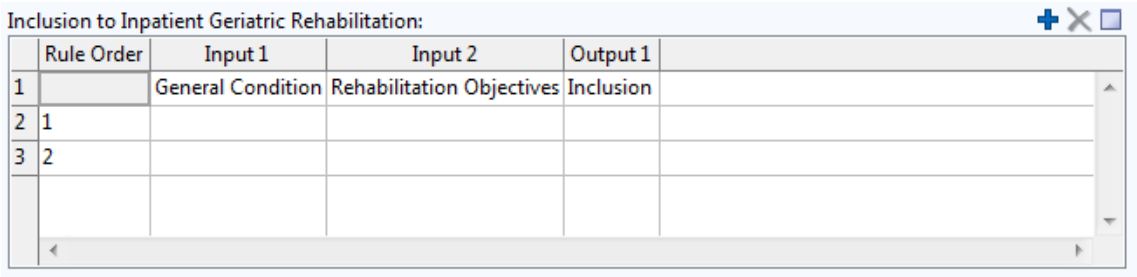


Figure 90: Attribute to change decision table content

When attached to the business knowledge element, they can be hidden in the model:

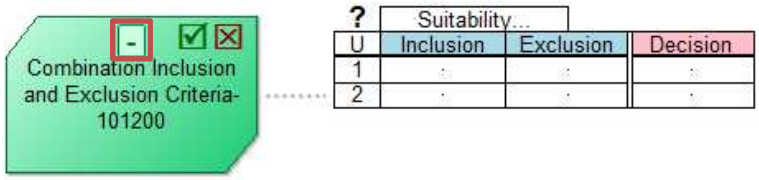


Figure 91: Decision table attached to Business Knowledge

6.4 Documents and Knowledge Model

To allow the modelling of documents with their content and the document hierarchy, the Document and Knowledge Model is included in DSML4PTM. It also only has references to the BPMN part. The following modelling elements are available (with a short and detailed description for the main elements):

Data/Documents (Standard, Patient Data, Patient Health Insurance Data, Acute Physician Data, Rehabilitation Data, KoGu, KoGu Stroke, KoGu Orthopaedic, KoGu Paediatric, KoGu Psychiatric, Hospitalization Document, Medical Information, ICF Standard, Medication List, Assistance Data, Special Medication Data, Process Data)

Groups (Standard, Medical Data, Administrative Data, Care Status, Process Progress)

Status elements (Process Status, Physical Transfer Status, KoGu Status, Medication List Status, Acceptance Status)

Figure 92: Available modelling elements Documents and Knowledge Model part

Data/Documents

For each data/document element, there are three main parts available (“Description”,

"Meta Data" and at least one chapter for the domain-specific attributes as proposed in the suggestion based on the requirements):

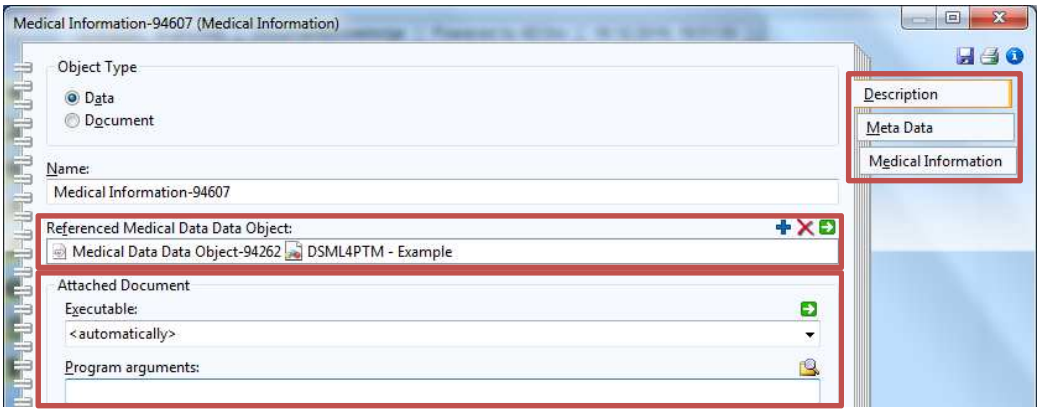


Figure 93: Data/Documents chapters

In the "Description" chapter, as seen in figure 93, a reference to the respective BPMN data object can be created. A hyperlink to the BPMN part is provided once there is a reference. There are data/documents such as KoGu, which have an own data object due to their importance but also belong to another data object. Then, two references can be selected.

Secondly, an attachment can be added to a document on the file system. If the attachment has been chosen, the file extension is shown above the element and a hyperlink is provided to open the document:

Figure 94: Attachment example

The second chapter "Meta Data" allows to enter meta data information about the document or data. The following chapters then cover the domain-specific attributes that allow entering concrete data:

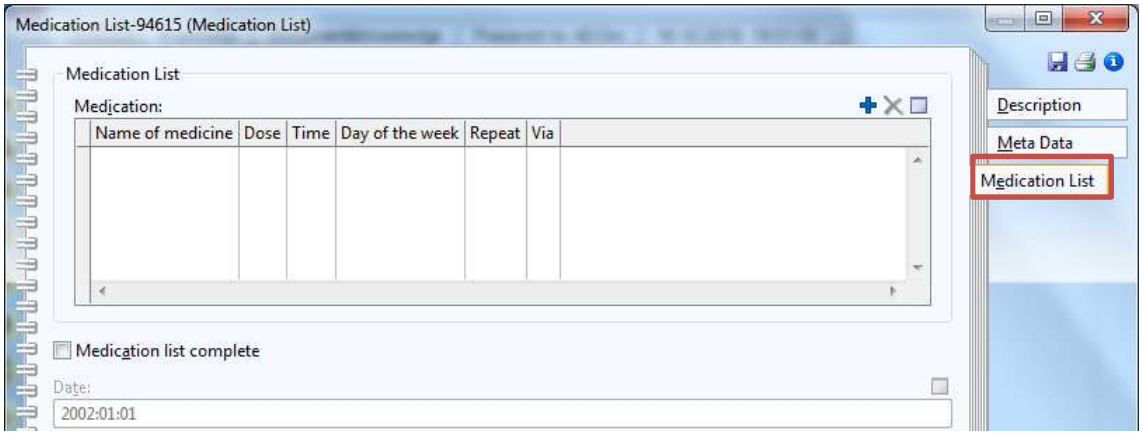


Figure 95: Attribute example Medication List

Depending on the attribute, the data type is either date, date and time, enumeration (only 1 element can be selected), enumeration list (1 or more elements can be selected), integer, short string, long string or record table. There is, whenever possible, logic implemented to enable or disable attributes based on the data input.

To reflect the KoGu templates, four additional data/documents besides the normal KoGu are available:

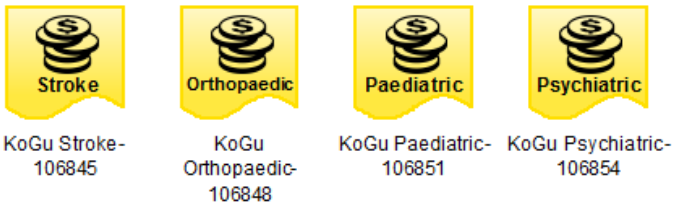


Figure 96: KoGu template Data/Documents

However, there is currently no difference to the unspecified KoGu data/document as the difference between the templates was not yet known at the submission date of this work. The elements ensure a future extension towards KoGu templates.

As for the data object, there is also an icon added to the data/document element whether the KoGu is accepted or rejected. As soon as a KoGu is attached, the status changes to yellow, when KoGu rejected is selected, a red icon is shown and when KoGu accepted is selected, a green icon is shown.

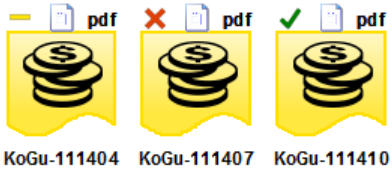


Figure 97: KoGu status Data/Document

The ICF standard document reflects the coverage of the respective standard. For each part of the standard, there is a chapter available, where relevant ICF codes can be added:

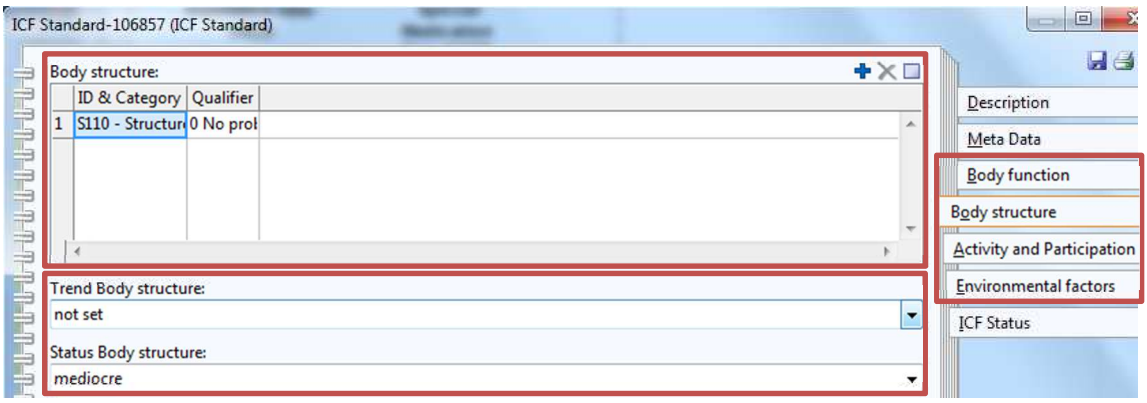


Figure 98: ICF Standard overview

The list of the available items does not yet cover the full list of ICF codes. This is also a possibility for a future extension. At the moment, the user can add more codes manually.

As shown in figure 99, there is always a status and a trend per category. The appearance of the data/document element changes once the status and/or trend are/is changed.

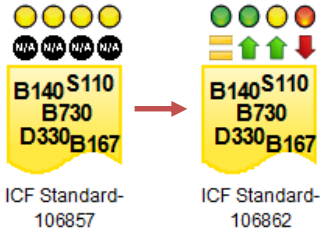


Figure 99: ICF Standard appearance change

This functionality and the entry of individual data for a patient is mainly focused on a later automation/execution of the process in run-time.

Groups

Domain-specific predefined groups are available, that serve as container for several data/document objects. They are thus on a higher level and are an aggregation of the included data/documents. An example is provided below:

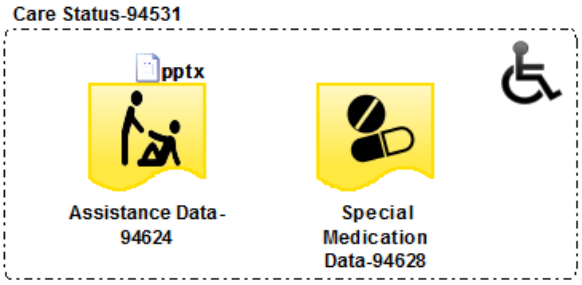


Figure 100: Group Care Status example

Each group can have a reference to the respective data object in the BPMN part of DSML4PTM.

Status elements

There are six status elements available, which belong to certain documents:

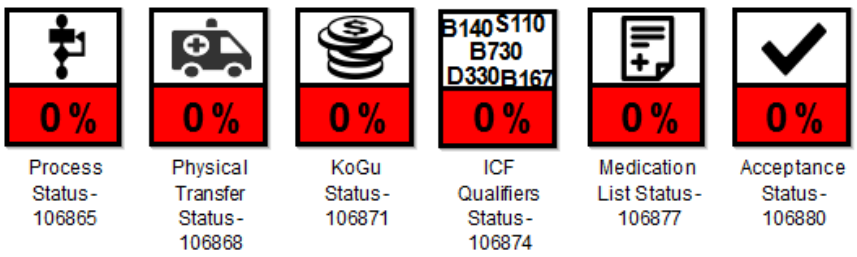


Figure 101: Status elements

Each element can be referenced to the BPMN part status element and includes checkboxes for the data collection progress. At the moment, there is a duplication of attributes from these elements and the BPMN status element. The user always has to update the status on both elements. In general this automatic update of duplicate data is (there is data which is captured in several data/documents e.g. patient name) a possibility for a future extension.

Figure 102: Example status element attributes

The status elements also change their appearance depending on the amount of the clicked on checkboxes:

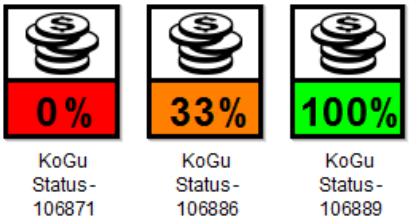
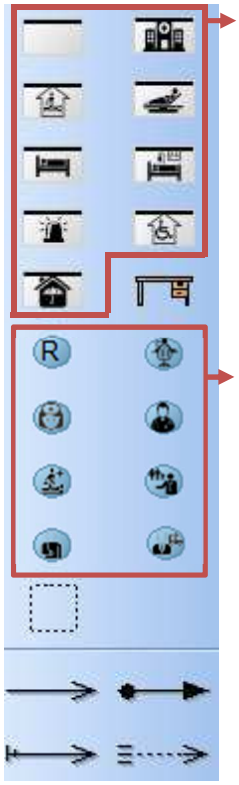


Figure 103: Appearance change KoGu Status

This functionality is mainly focused on a later automation/execution of the process in run-time. However, it also allows to define models in design-time that show a different progress.

6.5 Organization Model

To allow the modelling of an organization with involved roles and performers, the Organization Model is included in DSML4PTM. It also only has references to the BPMN part. The following modelling elements are available (with a short and detailed description for the main elements):



Organizational Units (Standard, Acute Hospital, Rehabilitation Clinic, Care Unit, Non-intensive Care Unit, Intensive Care Unit, Emergency Room, Site of Care, Health Insurance)

Roles (Standard, Administrative Staff, Nurse, Acute Physician, Rehabilitation Physician, Patient Disposition, Patient, Transferal Manager)

Figure 104: Available modelling elements Organization Model part

Organizational Units

For each organizational unit concept, there are three chapters available. While the first allows a reference to the responsible pool in the BPMN part, the other two are to define additional information about the organizational unit:

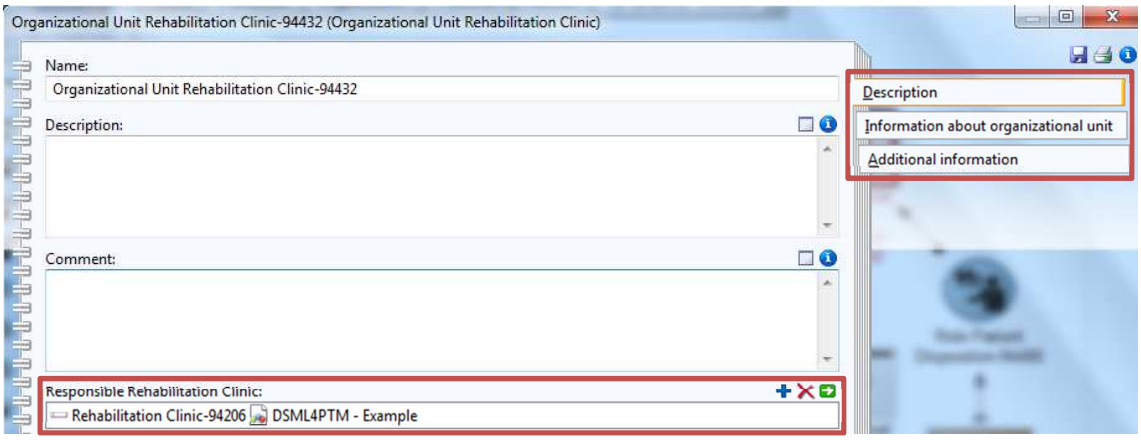


Figure 105: Organizational Unit attributes

If there is a corresponding pool element in the BPMN part, only a reference to this element is possible (for Acute Hospital, Rehabilitation Clinic and Health Insurance).

Roles

As for the organizational units, also for the roles, a reference to the BPMN part is possible. However, roles can be linked to lanes only. If there is a corresponding lane element in the BPMN part, only a reference to this element is possible (for Nurse, Acute Physician, Rehabilitation Physician, Patient Disposition and Transferal Manager).

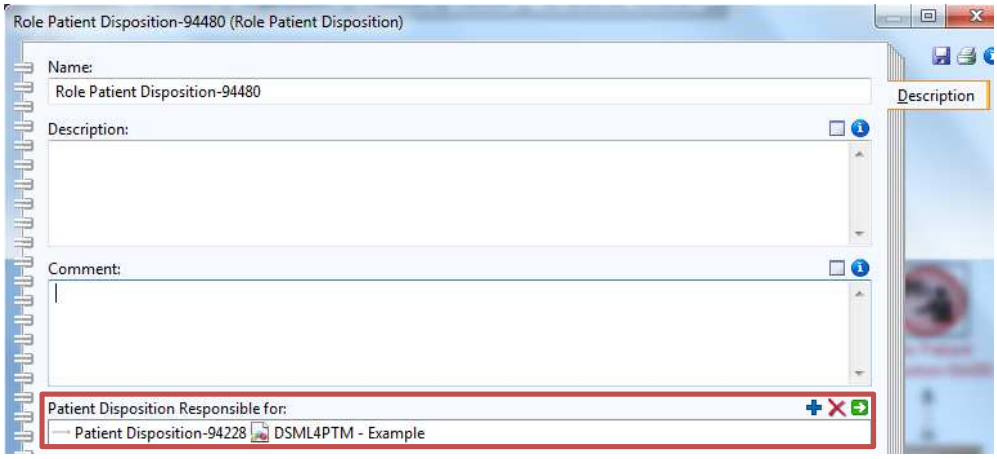


Figure 106: Role attributes

7. Evaluation

The fourth phase of the DSR approach is concerned with the evaluation of the developed artifact. Vaishnavi & Kuechler (2004) define the purpose of this phase as: “the artifact is evaluated according to criteria that are always implicit and frequently made explicit in the Proposal (Awareness of Problem phase)”. They further mention, that if there are any deviations from expectations, they have to be noted and explained.

In order to evaluate the artifact created with this work, the reference process and the use case scenario which served as basis to define the domain-specific requirements are modelled in DSML4PTM with the help of ADOxx Modelling Toolkit (see appendix B). It is thus demonstrated, that both the reference process and the use case scenario can be modelled in a domain-specific manner in DSML4PTM. In the following, each requirement from the Awareness of Problem phase is tested for fulfillment. Further, already in chapter 6 the fulfillment of requirements has been partly shown. Additionally, an evaluation with domain and modelling experts is done to test the usefulness of the artifact for the domain and to identify possibilities for further research.

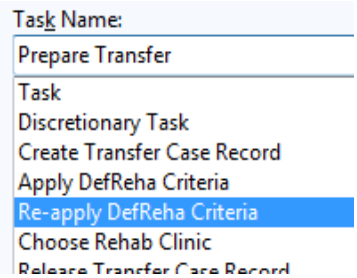
7.1 Comparison to requirements

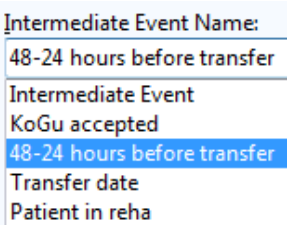
In the first part of this chapter, I demonstrate, how the elicited requirements from chapter 4 are fulfilled in the artifact DSML4PTM. The complete models of the reference process and use case are available in appendix B and are also provided together with the DSML4PTM library so that they can be reused. Not explicitly covered requirements from chapter 5.1.6 are only listed here if relevant.

7.1.1 Requirements from use case scenario

Process elements:

#	Requirement	Fulfillment
R1.1.1	The DSML should accommodate constructs to model different actors.	The following domain specific concepts are available in the BPMN part: Nurse, acute physician, rehabilitation physician, transferal manager and patient disposition. And in the Organizational Model: Nurse, acute physician, rehabilitation physician, transferal manager, administrative

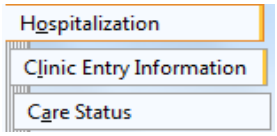
		staff, patient and patient disposition. These can be used to model respective actors while other relevant actors can be modelled with the general lane/role concept. There is a reference possible between respective lanes and roles. See especially Organization Model and BPMN part of use case scenario in appendix B.
R1.1.2	The DSML should accommodate constructs to model different units.	The following domain specific concepts are available in the BPMN part: Acute hospital, rehabilitation clinic and health insurance. And in the Organizational Model: Acute hospital, rehabilitation clinic, health insurance, care unit, non-intensive care unit, intensive care unit and emergency room. These can be used to model respective units while other relevant units can be modelled with the general pool/organizational unit concept. There is a reference possible between respective pools and organization units. See especially Organization Model and BPMN part of use case scenario in appendix B.
R1.1.3	The DSML should accommodate constructs to model a work activity. Also it should allow to quickly model the most important activities of the domain.	A task can be modelled in the BPMN part. All tasks from the reference process are available for modelling and when chosen, the correct name, task type and loop type is applied. 
R1.1.4	The DSML should accommodate constructs to model a decision work activity.	DMN has been integrated into the language. A task can be defined as business rule task, where a decision can be attached. 

		With the integration of DMN, decisions can be explicitly modelled down to the level of individual rules.
R1.1.6	The DSML should accommodate constructs to model time.	A timer event can be modelled in the BPMN part. All timer events from the reference process are available for modelling and when chosen, the correct name and event type is applied.  With the integration of the Control Element Model, it is further possible to model events as conditions in a sentry.
R1.1.7	The DSML should accommodate constructs to model separate paths.	Exclusive and non-exclusive gateways are available for modelling in the BPMN part. Further it is possible to start a separate flow based on conditions in a sentry.
R1.1.8	The DSML should accommodate constructs to model a status.	A new status element is available in the BPMN part and six sub elements in the Document and Knowledge Model. Further, as the ICF standard is included into DSML4PTM, changes on the condition of the patient can be recorded and are immediately visible.  With another new concept it is possible to include changes in the condition of a patient to the process flow as condition in the sentry. 

R1.1.9	The DSML should accommodate constructs to model information exchange.	Concepts in the BPMN part to model data/document and message flow are available. There are new domain specific data objects available, that can be exchanged within the process.
R1.1.10	The DSML should accommodate constructs to model tasks conditionally.	A sentry can be attached to any task. In the Control Elements Model, conditions for the task can be explicitly modelled.
R1.1.11	The DSML should accommodate constructs to model tasks as reoccurring.	The loop marker is available in the BPMN part. Further it is possible to restart an activity or an entire path of a process when conditions in a sentry are fulfilled. See especially task “Re-apply DefReha Criteria.
R1.1.12	The DSML should accommodate constructs to model the transfer of a patient.	A respective manual task is available for selection. 

Table 25: Fulfillment of process elements requirements from use case scenario

Physical documents:

#	Requirement	Fulfillment
R1.2.1	The DSML should accommodate constructs to model the patient admission form.	A new data object in the BPMN part and in the Document and Knowledge Model called hospitalization document is provided to reflect the form. Three chapters are available on the document to fill in relevant data. 
R1.2.2	The DSML should accommodate constructs to model the rehabilitation form for cost reimbursement (KoGu).	A new data object in the BPMN part and in the Document and Knowledge Model called KoGu is provided to reflect the form. Eleven pages are available on the document to fill in any relevant data.

R1.2.3	The DSML should accommodate constructs to model the long report.	The content of the long report is mainly reflected in the new documents Medical Information, Hospitalization Document and Patient Data. Attributes are available fill in medical, diagnosis and patient data.

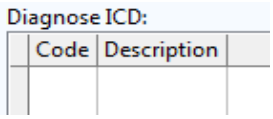
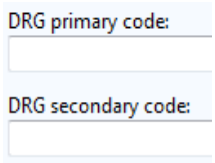
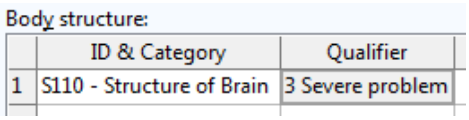
Table 26: Fulfillment of physical documents requirements from use case scenario

Systems and contained data:

#	Requirement	Fulfillment
R1.3.1	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the short report.	The content of the short report is mainly reflected in the new documents Medical Information, Hospitalization Document and Medication List. Attributes are available fill in medical, diagnosis and medication list data.
R1.3.2	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the medical data.	The ICD standard is reflected on the element Medical Information, the ICF standard on the element ICF Standard. Both are part of the group Medical Data and provide relevant attributes. Also a new data object Medical Data is provided.
R1.3.3	The DSML should accommodate constructs to model the Patient Administrative System (PAS) that includes the administrative data / master data.	There are six different new data/document elements available that are included in the group administrative data. They provide any kind of attributes to store data about physician, patient, insurance etc. Also a new data object Administrative Data is provided.
R1.3.4	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes the care status.	A new group Care Status is available, that includes Assistance Data and Special Medication Data. Further, the KoGu and Hospitalization documents can store care status information. Also a new data object Care Status is provided.

Table 27: Fulfillment of systems and contained data requirements from use case scenario

Decisions and decision criteria:

#	Requirement	Fulfillment
R1.4.2	The DSML should accommodate constructs to model the examination by a specialist physician.	Task to model the first assessment is available and can be selected. It is defined as a manual task type where the physician uses medical data. 
R1.4.3	The DSML should accommodate constructs to assign the complexity of a case.	If a patient is complex, it might be needed to perform the reha conference. It is one criteria the rehabilitation physician takes into account to determine if the conference is needed. It is thus included implicitly in the shown condition. 
R1.4.4	The DSML should accommodate constructs to assign the ICD-10 code to a case.	The ICD code is part of the new data/document element Medical Information. 
R1.4.5	The DSML should accommodate constructs to assign the SwissDRG to a case.	The DRG code is part of the new data/document element Patient Data. 
R1.4.6	The DSML should accommodate constructs to assign ICF qualifiers.	The new data/document element ICF standard has attributes available to add ICF qualifiers with severity. Not available codes can be manually added. 

R1.4.7	The DSML should accommodate constructs to model the need for rehabilitation by specialist physicians.	The DefReha© standard is included into the DMN part. There it can be decided if a patient should be included into rehabilitation or not. With the new domain-specific decision tables, it is possible to make these criteria explicit. See especially DMN diagram “Apply DefReha Criteria” from the use case scenario.
R1.4.8	The DSML should accommodate constructs to model the decision for rehabilitation clinic and type by the specialist physician.	The DefReha© standard is included into the DMN part. There it can be decided what the correct type is. All concepts in order to do that are available. Further, with a decision table, also the criteria for choosing the clinic can be made explicit. See especially DMN diagrams “Apply DefReha Criteria” and “Choose Rehab Clinic” from the use case scenario.
R1.4.9	The DSML should accommodate constructs to model the correctness assessment of the KoGu by the transferal manager.	In the BPMN part of the use case this is modelled as a business rule task for the transferal manager, where he includes relevant data and uses the provided DefReha© concepts to make sure the KoGu is correct.  See especially DMN diagram “Apply DefReha Criteria from the use case scenario.
R1.4.10	The DSML should accommodate constructs to model the assessment of the admission to rehabilitation for the transferal manager.	With the usage of the new domain-specific DefReha© concepts, the transferal manager ensures to decide according to DefReha©. In the model it is further defined in the sentry, that the transferal manager should not start to prepare the admission before the KoGu is accepted and the transfer date defined. See especially DMN diagram “Apply DefReha Criteria” from the use case scenario.
R1.4.11	The DSML should accommodate constructs to	As the ICF standard is included into DSML4PTM, changes on the condition of the patient can be recorded and are

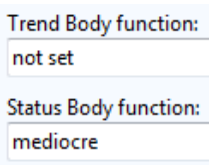
	model if the situation of the patient gets worse.	immediately visible.   With another new concept it is possible to include changes in the condition of a patient to the process flow as condition in the sentry.  Respective Domain-specific concepts are already provided.
R1.4.12	Patient can be transferred home or to a less intensive site of care if situation gets better	See R1.4.11

Table 28: Fulfillment of decisions and decision criteria requirements from use case scenario

7.1.2 Requirements from process model

Process elements:

#	Requirement	Fulfillment
R2.1.1	The DSML should accommodate constructs to model different actors.	See R1.1.1.
R2.1.2	The DSML should accommodate constructs to model different units/processes.	See R1.1.2.
R2.1.3	The DSML should accommodate constructs to model a work activity. Also it should allow to quickly model the most important activities of the domain.	See R1.1.3.

R2.1.4	The DSML should accommodate constructs to model a decision/business rule work activity.	See R1.1.4.
R2.1.5	The DSML should accommodate constructs to model parallel activities.	The parallel marker and non-exclusive gateway is available in the BPMN part.
R2.1.6	The DSML should accommodate constructs to model manual work activity.	A task can be defined as manual task.
R2.1.7	The DSML should accommodate constructs to model time.	See R1.1.6.
R2.1.8	The DSML should accommodate constructs to model separate paths (AND and XOR).	See R1.1.7.
R2.1.9	The DSML should accommodate constructs to model information.	See R1.1.9
R2.1.10	The DSML should accommodate constructs to model the transfer of a patient.	See R1.1.12.

Table 29: Fulfillment of process elements requirements from process model

Physical documents:

#	Requirement	Fulfillment
R2.2.1	The DSML should accommodate constructs to model the patient admission form.	See R1.2.1.
R2.2.2	The DSML should accommodate constructs to model the rehabilitation form for cost reimbursement (KoGu).	See R1.2.2.

Table 30: Fulfillment of physical documents requirements from process model

Systems and contained data:

#	Requirement	Fulfillment
R2.3.1	The DSML should accommodate constructs to model the Hospital Information System (HIS) that includes medical data.	See R1.3.2.
R2.3.2	The DSML should accommodate constructs to model the Patient Administrative System (PAS) that includes administrative data.	See R1.3.3.
R2.3.3	The DSML should accommodate constructs to model the Hospital Information System (HIS) and Administrative System (PAS) that include documents.	See R1.3.2 and R1.3.3.

Table 31: Fulfillment of systems and contained data requirements from process model

Decisions and decision criteria:

#	Requirement	Fulfillment
R2.4.1	The DSML should accommodate constructs to model the creation of the transferal case.	Two tasks “Apply DefReha Criteria” and “Choose Rehab Clinic” available for the decision about the correct rehabilitation type and clinic. See R1.4.7-R1.4.9.

Table 32: Fulfillment of decisions and decision criteria requirements from process model

7.1.3 Additional requirements

#	Requirement	Fulfillment
R3.1.1	The DSML should accommodate constructs to model organization and roles in a hierarchical way.	Domain-specific concepts for roles and organization units are available (compare R1.1.1 and R1.1.2) that allow to model the organization. See especially Organization Model of use case scenario in appendix B.

R3.1.2	The DSML should accommodate constructs to allow an automation in a later stage.	All new data/document elements provide attributes that can be filled with data about the patient according to the provided Patient Radar mockups, the KoGu and the Hospitalization Document. In total, about 300 domain-specific attributes were added. See especially Document and Knowledge Model of use case scenario in appendix B.
R3.1.3	The DSML should accommodate constructs to reflect the different rehabilitation types according to the DefReha© standard.	The rehabilitation type can be stored on the data/document Rehabilitation Data with historization. Assigned Rehab Clinic: 1 Clinic Valens | Rehabilitationszentrum | 7317 | Valens | Neurological | Inpatient | 2017:01:01 2 Clinic Valens | Rehabilitationszentrum | 7317 | Valens | Neurological | Medical Monitoring | 2017:01:01 Further it is stored in the KoGu element. In the DMN for each rehabilitation type, a decision is available and for the concepts Inpatient Rehabilitation Suitability, Compulsory Medical Monitoring Rehabilitation Suitability, Compulsory Medical Monitoring to Inpatient Rehabilitation Suitability, Combination Inclusion and Exclusion Criteria, Inclusion Criteria and Exclusion Criteria an attribute allows the rehabilitation type selection to cover the whole DefReha©. In any case, there is a dropdown list available for selection.
R3.1.4	The DSML should accommodate constructs to model criteria according to the DefReha© standard.	DMN is integrated into DSML4PTM and decision tables to model DefReha© are already available. Four prefilled examples according to the DefReha© criteria can be reused (case Inpatient Geriatric). For all other cases, the three decision tables Entry Criteria, Exit Criteria and Suitability Decision Tables are to be used. See especially DMN Model Apply Def-Reha Criteria of use case scenario in appendix B.
R3.1.5	The DSML should accommodate constructs to reflect attributes corresponding to the attributes in the “Patient Radar” platform.	See R3.1.2

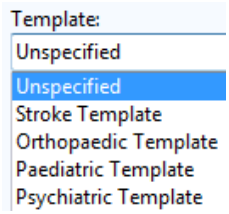
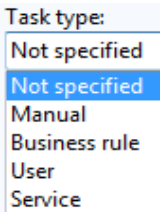
R3.1.6	The DSML should accommodate constructs to model documents/data elements corresponding to the documents/data elements in the “Patient Radar” platform.	The four newly created groups Medical Data, Administrative Date, Care Status and Process Progress contain in total twelve new created domain-specific documents. The groups can be referenced to the new respective data objects in the BPMN part. See especially Document and Knowledge Model of use case scenario in appendix B.
R3.1.7	The DSML should accommodate constructs to model relevant status elements and their attributes corresponding to the “Patient Radar” platform.	New overall status element is added in the BPMN part, that includes 16 attributes that define the data collection progress. The six sub elements in the Document and Knowledge Model belong to the respective documents, where for each status attribute also a date is stored. See especially Document and Knowledge Model of use case scenario in appendix B.
R3.1.8	The DSML should accommodate constructs to model KoGu templates.	On the KoGu data object, the template can be selected via an attribute. Then the appearance of the icon will change.  Depending on the chosen template, a reference to the respective document in the Document and Knowledge Model is possible. Thus in the Document and Knowledge Model, five different KoGu data/document elements are available.
R3.1.9	The DSML should accommodate constructs to differentiate between tasks done by a user or executed by a system.	A task can be defined as a user or service task. 

Table 33: Fulfillment of additional requirements

7.2 Evaluation with domain and modelling experts from FHSG

A session in a focus group format with a domain and also modelling expert and two further modelling experts was done to evaluate the usefulness of the artifact. The participants were all from FHSG, two of them being lecturers, one being a researcher. Furthermore, one of the lecturers is the project lead of the "Patient Radar" research project. Thus he is an ideal person to determine the usefulness of the artifact for the domain while the other two participants can evaluate the artifact more in terms of syntactical and semantical correctness.

The session was organized by first introducing the participants into the research work in general and more important into the developed language. After the reference process and use case scenario models in DSML4PTM were demonstrated, a task was handed over to the participants. In this task, the participants had to extend the "KoGu accepted" process reference model with two possible scenarios for rejection by the health insurance (DefReha© not correctly applied and information on KoGu missing). The idea of the activity was to observe the participants and to analyze the results to evaluate for example the ease of use and the ease of understanding of the language. After the activity, the participants had a possibility to fill in a questionnaire to assess the language from their point of view and to provide items for improvement.

In general, the conclusion of the session is very positive. In the activity, the participants came up with their own solutions in a short time, which were very close to an "ideal" solution. This is remarkable as the time for the introduction into the language was limited and as two of the three participants had no previous knowledge of the domain. Also interesting to see, was that the participants immediately recognized, that the reference process model in DSML4PTM is much less complex due to the inclusion of sentries and discretionary tasks. This allows to simplify the process model a lot, as gateways, separate paths and a lot of events can be avoided. As another main advantage was the integration of DMN mentioned, which allows to define individual rules for a decision that is attached to a task. Further was the inclusion of standards such as the DefReha© highlighted. The participants also mentioned, that the language is a good communication tool for discussions with domain-experts and provides a sound basis for automated verification, for integration and for collaboration. They had the impression, that the language allows a better process quality and leads to less errors due to hardcoded semantics. The ease of use

and domain-specific applicability was justified by the new domain-specific concepts and inclusion of domain-specific tasks, events and conditions that can be selected.

The session was also helpful to identify some weaknesses and possibilities for further research. It was mentioned, that the language is a good basis but it should be extended to cover further scenarios than just the interface between acute hospital and rehabilitation clinic and should be executable in run-time to be more useful. ADOxx does not provide an engine for automated execution. However, elements and attributes are available to at least allow a manual execution of the models. Further, it was mentioned, that standards such as the ICF should be maintained in external ontologies or databases and not in ADOxx. Lastly, the participants sometimes had difficulties to choose the correct modelling element in certain situations and could have needed modelling guidelines. However, it has to be noted, that they did not have access to the semantics, meta models or BPMN/CMMN specifications during the activity.

In appendix C, the used presentation, activity description, the questionnaire template and notes for the demonstration of the language are attached. Further, in appendix B, the developed models that include the two scenarios for rejection are available.

7.3 Conclusion

Modelling the reference process and the use case scenario in DSML4PTM has proven, that the elicited domain-specific requirements were mostly fulfilled. In chapter 5.1.6 I have already listed, that some requirements will not or only partly be fulfilled. In fact, after the evaluation, it is shown that only requirements R1.1.5, R1.3.5 and R1.4.1 are not possible to model with DSML4PTM. Thus, there is no system element available and Tessiner code and ESI triage are not stored anywhere. Explanation is provided below:

Requirement	Explanation
R1.1.5	Not deemed as important to know for the user of the model where data is originally stored.
R1.3.5	Instead of the Tessiner code, the international ICD standard, that codifies main and secondary diseases, is included.

R1.4.1	The ESI triage is important for the initial treatment of the patient but out of scope for transferal management activities.

Table 34: Explanation of deviations

During the evaluation with the domain and modelling experts, no contrary opinion was expressed which would question the decision against implementing these requirements.

While only very few requirements are not fulfilled, a lot of improvements can be achieved with the new DSML as the evaluation has also highlighted:

- More domain-specific usefulness and applicability with the addition of dozens of new concepts
- Simplification and improvement of the flow of the reference process with the usage of conditions instead of multiple gateways or events
- Efficiency can be achieved by using the newly provided concepts (especially as the most important activities, conditions and events can be selected from a provided list which is always based on the elicited requirements)
- Simplification of usage with the removal of unneeded or very specialized constructs
- Modelling of decisions possible down to rule level with the inclusion of DMN
- Inclusion of important standards of the transferal management process such as DefReha©, ICF and ICD
- Less potential for modelling errors due to hard-coded semantics (such as nurse lane can only be linked to nurse role or selection of tasks from a list)
- About 300 new domain-specific attributes that allow to reflect the relevant data for the domain (mainly relevant in run-time)
- Possibility to model processes that are more corresponding to reality with the inclusion of discretionary tasks
- The integration of several languages ensures to have data, decision criteria, process flow, conditions and organization overview at a single place
- Information about KoGu status, patient condition, data collection progress or signal to work for the transferal manager is visible (mainly relevant in run-time)
- Sound basis for automation, integration, collaboration and communication

8. Conclusion and Outlook for Further Research

In the beginning, I have formulated the research question as: “How can existing modelling languages be combined and extended to create a domain-specific modelling language for patient transferal management, which fulfills requirements of domain experts in modelling processes and decisions for transfers from an acute hospital to a rehabilitation clinic?”. With the completion of this master thesis, a DSML for patient transferal management was successfully developed and thus the research question was answered during the course of this work.

After conducting the literature review, it was apparent, that up to date no research effort has been done towards the development of a DSML for patient transferal management. Previous research in the healthcare domain was rather focused on the development of DSMLs for the clinical pathway. Thus no domain-specific support in the form of a DSML for the mainly administrative tasks of the patient transferal management was available for practitioners.

This thesis was conducted using design science research and thus the main part consisted of awareness, suggestion, development, evaluation and ends with this chapter, the conclusion.

Based on the elicited requirements from the awareness phase, the new DSML “DSML4PTM” was suggested and developed as a combination of the modelling languages BPMN, DMN, CMMN, Control Elements Model, Organization Model and Documents and Knowledge Model. These languages were extended with domain-specific concepts while unneeded concepts were removed. One outcome of the literature review was, that a DSML consists of three parts: abstract syntax, concrete syntax and semantics. Thus, these parts are created and described for the new DSML in this work. The development took place in the metamodeling platform ADOxx Development Toolkit. In the evaluation, it was proven, that the domain-specific requirements are nearly completely fulfilled with the new DSML. During an evaluation with domain and modelling experts, it was possible to confirm the usefulness of the language. Some main advantages are simpler models, an easier modelling process, the integration of several languages and standards, better process quality and less modelling errors.

With the creation of DSML4PTM, the task to provide more process and decision support for practitioners in the transferal management is not yet finished. In my opinion and based on the outcome of the evaluation, there are several possibilities for further research as described in the following.

As the time to develop the new modelling language was limited to only a few months, there is potential for further development of the ADOxx library. This includes for example to develop a function which automatically updates values for attributes that are redundant (in run-time). This would be an advantage to the existing transferal management process, where some data is captured several times. In general, most of the improvements would be concerned with an executability of the process. A thinkable scenario could be, that the model is automatically updated once the approval for the KoGu was provided by the health insurance via e-mail in run-time. There are many other scenarios to think of. An automated execution of the processes in run-time would greatly improve the support for practitioners.

An important improvement of the transferal management process and of the decision making in the process was achieved with the inclusion of the most relevant standards into the DSML. However, there is further possibility to continue with the inclusion. For the DefReha© standard, all decision tables could be included already filled in as provided in the standard. For the ICF and ICD standard, a functionality would be desirable, that allows to select all possible codes (e.g. from an external ontology or database).

The elicitation of requirements was limited to the analysis of the provided reference process for an elective entry and of a use case scenario of an emergency entry. I believe, that these describe the main activities and documents that are used in the process and thus should be mostly appropriate. However, the applicability of DSML4PTM should be tested for different scenarios (e.g. other diseases or accidents of the patient) and in different environments (e.g. other hospitals or rehabilitation clinics or even other countries). By doing so, discrepancy in used documents, utilized standards, captured data or relevant activities can be found out. Also, additional requirements can be elicited and if possible implemented. To improve the applicability of the language, it should be further extended to cover additional interfaces and should not only be limited to the interface between acute hospital and rehabilitation clinic.

Bibliography

Agt, H., Kutsche, R.-D. & Wegeler, T., 2011. *Guidance for domain specific modeling in small and medium enterprises.* New York, ACM, pp. 63-70.

Aguilar-Savén, R. S., 2004. Business process modelling: Review and framework. *Int. J. Production Economics 90,* pp. 129-149.

Alper, E., O'Malley, T. A. & Greenwald, J., 2016. *UpToDate.* [Online]
Available at: http://www.uptodate.com/contents/hospital-discharge-and-readmission#H4
[Accessed on 2017 19 February].

Batoulis, K. et al., 2015. *Extracting Decision Logic from Process Models.* Stockholm, Springer-Verlag, pp. 349-366.

Becker, J., Kugeler, M. & Rosemann, M., 2003. *Process Management - A Guide for the Design of Business Processes.* Berlin: Springer-Verlag.

Becker, J., Rosemann, M. & von Uthmann, C., 2000. *Guidelines of Business Process Modeling.* Berlin, Springer-Verlag, pp. 30-49.

Biard, T., Le Mauff, A., Bigand, M. & Bourey, J.-P., 2015. *Separation of Decision Modeling from Business Process Modeling Using New "Decision Model and Notation" (DMN) for Automating Operational Decision-Making.* Albi, HAL.

BOC Asset Management GmbH, 2016. *LearnPAd Modelling Environment - Prototype v5.3.* [Online]
Available at: https://www.adoxx.org/live/web/learnpad-developer-space/prototype-v5.3
[Accessed on 19 October 2016].

BOC Asset Management GmbH, 2016. *Welcome.* [Online]
Available at: https://www.adoxx.org/live/home
[Accessed on 12 November 2016].

Braun, R., Burwitz, M., Schlieter, H. & Benedict, M., 2015. *Clinical Processes from Various Angles - Amplifying BPMN for Integrated Hospital Management.* Washington, DC, IEEE, pp. 837 - 845.

Braun, R. & Esswein, W., 2014. *Classification of Domain-Specific BPMN Extensions.* Manchester, Springer-Verlag, pp. 42-57.

Braun, R., Schlieter, H., Burwitz, M. & Esswein, W., 2015. *Extending a Business Process Modeling Language for Domain-Specific Adaptation in Healthcare.* Osnabrück, s.n., pp. 468-481.

Braun, R., Schlieter, H., Burwitz, M. & Esswein, W., 2016. *BPMN4CP Revised – Extending BPMN for Multi-Perspective Modeling of Clinical Pathways.* Koloa, Hawaii, USA, IEEE Computer Society, pp. 3249-3258.

Breitenmoser, R. & Keller, T., 2015. CASE MANAGEMENT MODEL AND NOTATION - A SHOWCASE. *European Scientific Journal,* 11(25), pp. 332-347.

Bridgeland, D. M. & Zahavi, R., 2009. Chapter 4: Business Organization. In: *Business Modeling - A Practical Guide to Realizing Business Value.* s.l.:Morgan Kaufman Publishers.

Burwitz, M., Schlieter, H. & Esswein, W., 2013. *Modeling Clinical Pathways - Design and Application of a Domain-Specific Modeling Language.* Leipzig, Association for Information Systems, pp. 1325-1339.

Cànovas Izquierdo, J. L. et al., 2013. *Engaging End-Users in the Collaborative Development of Domain-Specific Modelling Languages.* Alcudia, Sprinver-Verlag, pp. 101-110.

Carson, D., Gilmore, A., Perry, C. & Gronhaug, K., 2001. *Qualitative Marketing Research.* s.l.:Sage.

Chang, J. F., 2006. *Process Management System - Strategy and Implementation.* Boca Raton: Auerbach Publications.

Cho, H., Gray, J., Sun, Y. & White, J., 2011. *Key Challenges for Modeling Language Creation by Demonstration.* Honolulu, s.n.

Cho, H., Gray, J. & Syriani, E., 2012. *Creating Visual Domain-Specific Modeling Languages from End-User Demonstration.* Piscataway, NJ, USA, IEEE Press, pp. 22-28.

Cloudfront, 2015. *Physician Icon.* [Online]
Available at: https://d30y9cdsu7xlg0.cloudfront.net/png/23420-200.png
[Accessed on 28 October 2016].

Cloudfront, 2016. *Insurance House icon.* [Online]
Available at: https://d30y9cdsu7xlg0.cloudfront.net/png/150237-200.png
[Accessed on 24 October 2016].

Cloudfront, 2016. *Insurance Icon.* [Online]
Available at: https://d30y9cdsu7xlg0.cloudfront.net/png/100315-200.png
[Accessed on 21 October 2016].

Cloudfront, 2016. *Process Icon.* [Online]
Available at: https://d30y9cdsu7xlg0.cloudfront.net/png/11550-200.png
[Accessed on 25 October 2016].

Cluj School of Public Health, 2015. *Icon Administration.* [Online]
Available at: http://publichealth.ro/wp-content/uploads/2013/11/icon_21484.png
[Accessed on 24 October 2016].

Courage, C. & Baxter, K., 2006. *Understanding your users: a practical guide to user requirements: methods, tools, and techniques*.. s.l.:Gulf Professional Publishing.

Damij, N. & Damij, T., 2014. *Process Management - A Multi-disciplinary Guide to Theory, Modeling, and Methodology.* Heidelberg: Springer-Verlag.

Davis, R. & Brabänder, E., 2007. *ARIS Design Platform: Getting Started with BPM.* London: Springer-Verlag.

de Vaus, D., 2002. *Surveys in Social Research.* London: Routledge.

Eriksson, H.-E. & Penker, M., 2000. *Business Modeling with UML,* s.l.: Business patterns at work.

FlatIcon, 2013. *Patient in hospital bed free icon - Icon made by Freepik from www.flaticon.com.* [Online]
Available at: http://image.flaticon.com/icons/png/512/12/12609.png
[Accessed on 28 November 2016].

FlatIcon, 2014. *Settings gears free icon by Freepik.* [Online]
Available at: http://www.flaticon.com/free-icon/settings-gears_60473
[Accessed on 15 December 2016].

FlatIcon, 2016. *Person giving assistance free icon.* [Online]
Available at: http://image.flaticon.com/icons/png/512/64/64362.png
[Accessed on 13 November 2016].

Fondement, F., 2007. *Concrete Syntax Definition for Modeling Languages,* Lausanne: École Polytechnique Fédérale de Lausanne.

Fowler, M. & Scott, K., 2003. *UML Distilled Second Edition A Brief Guide to the Standard Object.* Boston: Addison Wesley.

France, R. & Rumpe, B., 2005. Domain specificmodeling. *Softw Syst Model (2005) 4*, pp. 1-3.

Frank, U., 2011. *Some Guidelines for the Conception of Domain-Specific Modelling Languages*. Hamburg, Gesellschaft für Informatik e.V. (GI), pp. 93-106.

Free Downloads, 2016. *Checkmark-24-512.* [Online]
Available at: http://cdn.1001freedownloads.com/icon/thumb/45/checkmark-24-512.png
[Accessed on 13 November 2016].

Free Icons Download, 2013. *inpatient icon.* [Online]
Available at: http://www.free-icons-download.net/inpatient-icon-7507/
[Accessed on 8 December 2016].

Free Icons Download, 2014. *baby flag icons.* [Online]
Available at: http://www.free-icons-download.net/baby-flag-icons-70332/
[Accessed on 8 December 2016].

Free Icons Download, 2016. *elderly2-87872.* [Online]
Available at: http://www.free-icons-download.net/images/elderly2-87872.png
[Accessed on 8 December 2016].

Free Icons Download, 2016. *medical sign snake stick icon.* [Online]
Available at: http://www.free-icons-download.net/images/medical-snake-stick-flag-icons-72349.png
[Accessed on 5 December 2016].

FreeIconsPNG, 2015. *Physical Therapy Icon.* [Online]
Available at: http://www.freeiconspng.com/uploads/physical-therapy-icon-8.png
[Accessed on 24 October 2016].

FreeIconsPNG, 2016. *Patient Icon.* [Online]
Available at: http://www.freeiconspng.com/uploads/patient-icon-png-21.png
[Accessed on 24 October 2016].

freepik, 2015. *Hospital Building Icon.* [Online]
Available at: http://img.freepik.com/free-icon/hospital-buildings_318-50015.jpg?size=338c&ext=jpg
[Accessed on 25 October 2016].

freepik, 2016. *Lifeline in a heart outline - Icon made by Freepik from www.flaticon.com.* [Online]
Available at: https://image.freepik.com/free-icon/lifeline-in-a-heart-outline_318-48031.jpg
[Accessed on 22 October 2016].

Graaf, B. & van Deursen, A., 2006. *Visualisation of Domain-Specific Modelling Languages Using UML,* Delft: Delft University of Technology.

Graphiq, 2015. *Icon Physician.* [Online]
Available at: https://files.graphiq.com/4553/media/images/_2735878.png
[Accessed on 24 October 2016].

Gray, J. et al., 2007. Domain-specific modeling. In: *Handbook of dynamic system modeling 7.* s.l.:John Wiley & Sons, pp. 1-20.

Grudzinska-Kuna, A., 2013. Supporting Knowledge Workers: Case Management Model and Notation (CMMN). *Information Systems in Management*, pp. 3-11.

Gyuchan, T. et al., 2009. Health care process modelling: which method when?. *International Journal for Quality in Health Care,* pp. 1-11.

H+ Die Spitäler der Schweiz, 2015. *DefReha - Stationäre Rehabilitation: Spezialbereiche & Definitionen,* Bern: H+: Schweizer Spitäler, Kliniken und Pflegeinstitutionen.

Hakim, C., 2000. *Research Design: Successful Designs for Social and Economic Research.* s.l.:Psychology Press.

Harrington, H. J., Esseling, E. K. & Van Nimwegen, H., 1997. *Business process improvement Workbook.* New York: McGraw-Hill.

Herzberg, N., Kirchner, K. & Weske, M., 2015. *Modeling and Monitoring Variability in Hospital Treatments: A Scenario Using CMMN.* Heidelberg, Springer-Verlag, pp. 3-15.

Heß, M. et al., 2015. *A Domain-specific Modelling Language for Clinical Pathways in the Realm of Multiperspective Hospital Modelling.* Münster, Association for Information Systems, pp. 1-17.

Hevner, A. & Chatterjee, S., 2010. *Design Research in Information Systems.* New York: Springer-Verlag.

Hinkelmann, K., Pierfranceschi, A. & Laurenzi, E., 2015. The Knowledge Work Designer - Modelling Process Logic and Business Logic. *Lecture Notes in Informatics (LNI), Gesellschaft für Informatik.*

IconArchive, 2014. *City Siren Icon.* [Online]
Available at: http://icons.iconarchive.com/icons/icons8/windows-8/512/City-Siren-icon.png
[Accessed on 28 November 2016].

IconArchive, 2014. *Editing Arrow Icon.* [Online]
Available at: http://icons.iconarchive.com/icons/icons8/android/512/Editing-Arrow-icon.png
[Accessed on 5 December 2016].

Iconfinder, 2016. *Icon Plus Sign Round.* [Online]
Available at: https://cdn4.iconfinder.com/data/icons/ionicons/512/icon-plus-round-128.png
[Accessed on 29 October 2016].

Icons Download, 2013. *Businessman Vector icon.* [Online]
Available at: http://www.iconsdownload.net/icons/256/110-businessman-icon.png
[Accessed on 13 November 2016].

Icons8, 2015. *Flex Biceps - Free Web Icon.* [Online]
Available at: https://icons8.com/web-app/7321/flex-biceps
[Accessed on 8 December 2016].

Indulska, M., zur Muehlen, M. & Recker, J., 2014. *Measuring Method Complexity: The Case of the Business Process Modeling Notation.* New York, ACM.

Jeston, J. & Nelis, J., 2006. *Business Process Management - Practical Guidelines to Successful Implementations.* Oxford: Elsevier.

Kahn, R. L. & Cannell, C. F., 1957. *The Dynamics of Interviewing.* New York: John Wiley & Sons Inc..

Karagiannis, D., 2012. *Business Process Management: A Holistic Management Approach.* Yalta, Springer-Verlag, pp. 1-12.

Ko, R. K. L., Lee, S. S. G. & Lee, E. W., 2009. Business process management (BPM) standards: a survey. *Business Process Management,* pp. 744-791.

Kurz, M., Fleischmann, A., Schmidt, W. & Lederer, M., 2015. *Leveraging CMMN for ACM - Examining the applicability of a new OMG standard for adaptive case management.* Kiel, ACM.

Lenz, R., Peleg, M. & Reichert, M., 2007. *Healthcare Process Support: Achievements, Challenges, Current Research,* Ulm: University of Ulm.

Lenz, R. & Reichert, M., 2006. *IT support for healthcare processes – premises, challenges, perspectives,* Marburg: Institute for Medical Informatics, University of Marburg.

List, B. & Korherr, B., 2006. *An Evaluation of Conceptual Business Process Modelling Languages.* Dijon, ACM.

Lohmann, N., Verbeek, E. & Dijkman, R., 2009. Petri net transformations for business processes–a survey. In: *Transactions on petri nets and other models of concurrency II.* Berlin: Springer-Verlag, pp. 46-63.

Marques do Nascimento, L. et al., 2012. *A Systematic Mapping Study on Domain-Specific Languages.* Lisbon, IARIA, pp. 179-187.

Mathe, J. L. et al., 2009. A Model-Integrated, Guideline-Driven, Clinical Decision-Support System. *IEEE Software (Volume:26, Issue: 4),* pp. 54-61.

Mernik, M., Heering, J. & Sloane, A. M., 2005. When and How to Develop Domain-Specific Languages. *ACM Computing Surveys*, 4 December, pp. 316-344.

Mertens, S., Gailly, F. & Poels, G., 2015. *Enhancing Declarative Process Models with DMN Decision Logic.* Stockholm, Springer-Verlag, pp. 151-165.

Metro Ambulance, 2015. *Ambulance Icon.* [Online]
Available at: http://metroambulance.co.nz/uploads/_notregistered/f5fe024a8c.png
[Accessed on 26 October 2016].

Morris, T. & Wood, S., 1991. Testing the survey method: Continuity and change in British industrial relations. *Work Employment and Society, Vol. 5, No. 2,* pp. 259-282.

My Icon Finder, 2016. *Coins.* [Online]
Available at: http://www.myiconfinder.com/uploads/iconsets/256-256-846ada2611f528ef433e8c23650e247c-coins.png
[Accessed on 25 October 2016].

My Icon Finder, 2016. *Notepad Icon.* [Online]
Available at: http://www.myiconfinder.com/uploads/iconsets/bbbbe23abcae4390c132e229053fe77c.png
[Accessed on 22 October 2016].

Object Management Group, 2014. *Business Process Model and Notation - Version 2.0.2,* s.l.: Object Management Group (OMG).

Object Management Group, 2016. *Case Management Model and Notation - Version 1.1,* s.l.: Object Management Group (OMG).

Object Management Group, 2016. *Decision Model and Notation (DMN) - Version 1.1,* s.l.: Object Management Group (OMG).

Odoo, 2016. *Odoo 9.0 : Hospital Management.* [Online]
Available at: https://www.odoo.com/apps/icon_image?module_id=21735
[Accessed on 5 December 2016].

Online Web Fonts, 2016. *Android Checkbox Outline Free Icon - Icon made from Icon Fonts is licensed by CC BY 3.0.* [Online]
Available at: https://www.onlinewebfonts.com/icon/411285
[Accessed on 16 December 2016].

OpenClipArt, 2015. *Family practice icon.* [Online]
Available at: https://openclipart.org/image/300px/svg_to_png/213254/Family-practice-icon.png&disposition=attachment
[Accessed on 28 November 2016].

openclipart, 2016. *Simple House icon.* [Online]
Available at: https://openclipart.org/image/2400px/svg_to_png/190334/simple-house-icon.png
[Accessed on 26 October 2016].

Plainicon, 2016. *Brain by Luiz Gustavo.* [Online]
Available at: http://plainicon.com/download-icon/60840/brain
[Accessed on 8 December 2016].

Porter, M. E., 1985. *Competitive Advantage: Creating and Sustaining Superior Performance.* New York: Simon and Schuster.

Rebuge, A. & Ferreira, D. R., 2012. Business Process Analysis in Healthcare Environments: a Methodology based on Process Mining. *Information Systems 37.2*, pp. 99-116.

Recker, J., 2010. Opportunities and constraints : the current struggle with BPMN. *Business Process Management Journal,* 16(1), pp. 181-201.

Recker, J. & Dreiling, A., 2007. *Does It Matter Which Process Modelling Language We Teach or Use? An Experimental Study on Understanding Process Modelling Languages without Formal Education.* Toowoomba, s.n.

Remenyi, D., Williams, B., Money, A. & Swartz, E., 1998. *Doing Research in Business and Management,* London: Sage.

Robson, C., 2002. *Real World Research: A Resource for Social Scientists and Practitioner-Researchers.* Blackwell: Oxford.

Salimifard, K. & Wright, M., 2001. Petri net-based modelling of workflow systems: An overview. *European Journal of Operational Research 134,* pp. 664-676.

Saunders, M., Lewis, P. & Thornhill, A., 2011. *Research methods for business students.* Harlow: Pearson Education.

Scheer, A.-W., 1999. *ARIS — Business Process Modeling.* Berlin: Springer-Verlag.

Scheer, A.-W. & Hoffmann, M., 2010. The Process of Business Process Management. In: *Handbook on Business Process Management 2.* Heidelberg: Springer-Verlag, pp. 351-380.

Share Icon, 2016. *Note, Notes, medical, Prescription, prescribe, Medicine And Health, Prescribing, Healthcare And Medical icon.* [Online]
Available at:
https://www.shareicon.net/data/256x256/2016/08/18/814754_note_512x512.png
[Accessed on 11 November 2016].

Shenvi, R. et al., 2007. *Generation of Context-Specific Electronic Patient Care Reports (ePCR) using Domain-Specific Modeling.* Nashville, s.n.

Silingas, D., Vitiutinas, R., Armonas, A. & Nemuraite, L., 2009. *Domain-Specific Modeling Environment based on UML Profiles.* Kaunas, Lithuania, Kaunas University of Technology, pp. 167-177.

Silver, B., 2011. *BPMN Method and Style, with BPMN Implementer's Guide: A structured approach for business process modeling and implementation using BPMN 2.0.* Aptos: Cody-Cassidy Press.

Simple Icon, 2016. *Pills_1 Icon.* [Online]
Available at: http://simpleicon.com/wp-content/uploads/pills_1.png
[Accessed on 13 November 2016].

Smith, H. & Fingar, P., 2003. *Business Process Management: The Third Wave.* Tampa: Meghan-Kiffer Press.

Söderström, E. et al., 2002. *Towards a Framework for Comparing Process Modelling Languages.* Toronto, Springer-Verlag, pp. 600-611.

SoftIcons, 2016. *Symbol Handicap.* [Online]
Available at: http://files.softicons.com/download/medical-icons/medical-and-health-care-icons-by-artistsvalley/png/256x256/Hot/Symbol%20Handicap%20Black.png
[Accessed on 23 October 2016].

Stroppi, L. J. R., Chiotti, O. & Villarreal, P. D., 2011. *Extending BPMN 2.0: Method and Tool Support.* Lucerne, Springer-Verlag, pp. 59-73.

Suli Medicine, 2016. *Medical Units.* [Online]
Available at: http://sulimedicine.com/wp-content/uploads/2016/01/intensive-care-icons-50360.png
[Accessed on 28 November 2016].

Taylor, J., Fish, A. & Vincent, P., 2013. Emerging Standards in Decision Modeling—an Introduction to Decision Model & Notation. In: *iBPMS - Intelligent BPM Systems.* Chicago: Future Strategies Inc., pp. 133-146.

The Noun Project, 2015. *Lungs by Brennan Novak from the Noun Project.* [Online]
Available at: https://thenounproject.com/term/lungs/18174/
[Accessed on 8 December 2016].

The Noun Project, 2015. *Vitals Monitor by Zlatko Najdenovski from the Noun Project.* [Online]
Available at: https://thenounproject.com/term/vitals-monitor/186939/
[Accessed on 8 December 2016].

The Noun Project, 2015. *Wheelchair Aid by Luis Prado from the Noun Project.* [Online]
Available at: https://thenounproject.com/term/wheelchair-aid/181451/
[Accessed on 8 December 2016].

The Noun Project, 2016. *Bloodstream - Created by Edgar Fonseca from the Noun Project.* [Online]
Available at: https://thenounproject.com/term/bloodstream/88859/
[Accessed on 8 December 2016].

The Noun Project, 2016. *Internal Medicine.* [Online]
Available at: https://thenounproject.com/term/internal-medicine/630/
[Accessed on 8 December 2016].

The Noun Project, 2016. *Joint - Created by Carl Holderness from the Noun Project.* [Online]
Available at: https://thenounproject.com/term/joint/55183/
[Accessed on 8 December 2016].

The Noun Project, 2016. *Mental Health.* [Online]
Available at: https://thenounproject.com/term/mental-health/566/
[Accessed on 8 December 2016].

The World Bank, 2014. *Health expenditure, total (% of GDP).* [Online]
Available at:
http://data.worldbank.org/indicator/SH.XPD.TOTL.ZS?end=2014&start=1995&view=chart

Vaishnavi, V. & Kuechler, B., 2004. *Design Science Research in Information Systems.* [Online]
Available at: http://www.desrist.org/design-research-in-information-systems/

van Deursen, A., Klint, P. & Visser, J., 2000. Domain-specific languages: an annotated bibliography. *ACM SIGPLAN*, June, pp. 26-36.

Vela Diagnostics, 2016. *Sentosa SQ Leukemia Panel - in development.* [Online]
Available at: http://www.veladx.com/product/ngs-oncology/sentosa-sq-leukemia-panel-

in-development.html
[Accessed on 8 December 2016].

von Halle, B. & Goldberg, L., 2010. *The Decision Model - A Business Logic Framework Linking Business and Technology.*. s.l.:Auerbach Publications.

WebToolHub, 2016. *Nurse Icon.* [Online]
Available at: http://wfarm1.dataknet.com/static/resources/icons/set114/e65baacb.png
[Accessed on 27 October 2016].

Weske, M., 2012. *Business process management: Concepts, languages, architectures.* Berlin: Springer-Verlag.

Whitten, P., Steinfield, C. & Hellm, S., 2001. *Ehealth: Market Potential and Business,* East Lansing: Department of Telecommunications, Michigan State University.

Wu, Y. et al., 2012. A Domain-Specific Modeling Approach to Realizing User-Centric Communication. *Software Practice and Experience,* pp. 357-390.

Yousfi, A., Bauer, C., Saidi, R. & Dey, A. K., 2016. uBPMN: A BPMN extension for modeling ubiquitous business processes. *Information and Software Technology 74,* pp. 55-68.

Zeising, M., Schönig, S. & Jablonski, S., 2014. *Towards a Common Platform for the Support of Routine and Agile Business Processes.* Miami, CollaborateCom.

Abbreviations

AD	Activity Diagram
BML	Business Modelling Language
BPDM	Business Process Definition Metamodel
BPEL	Business Process Execution Language
BPM	Business Process Management
BPML	Business Process Modelling Language
BPMN	Business Process Model and Notation
BPMS	Business Process Management System
BPQL	Business Process Query Language
BPRI	Business Process Runtime Interface
BPSS	Business Process Specification Schema
CML	Communication Modelling Language
CMMN	Case Management Model and Notation
CP	Clinical Pathway
CPN	Colored Petri Net
CVM	Communication Virtual Machine
DFD	Data Flow Diagrams
DMN	Decision Model and Notation

DSME	Domain-Specific Modelling Environment
DSL	Domain-Specific Language
DSML	Domain-Specific Modelling Language
DSR	Design Science Research
EDI	Electronic Data Interchange
EPC	Event-driven Process Chain
ePCR	Electronic Patient Care Record
ESI	Emergency Severity Index
FHSG	Fachhochschule St. Gallen (University of Applied Sciences St. Gallen)
GME	Generic Modelling Environment
GPML	Generic Process Modelling Language
GRAI	Graph with Results and Activities Interrelated
ICD	International Statistical Classification of Diseases and Related Health Problems
ICF	International Classification of Functioning, Disability and Health
IDEF	Integrated DEFinition
KoGu	Antrag für Kostengutsprache (request for cost reimbursement)
MDE	Model-Driven Engineering
OMG	Object Management Group

OO	Object Oriented
PN	Petri Net
RAD	Role Activity Diagram
RID	Role Interaction Diagram
SD	State Diagram
SSADM	Structured Systems Analysis and Design Methodology
UBL	Universal Business Language
UML	Unified Modeling Language
WS-CDL	Web Services Choreography Description Language
WSCI	Web Service Choreography Interface
WSCL	Web Services Conversation Language
WSFL	Web Services Flow Language
XLANG	eXtensible Language
XML	eXtensible Markup Language
XPDL	XML Process Definition Language
YAWL	Yet Another Workflow Language

Table 35: Abbreviation overview.

List of Figures / Tables

Figures

Tables

Appendix A: Project documentation FHSG

Provided together with this thesis is a zip file that contains all documents of the appendix. It is named "Pascal Sibold-2017-Modelling Language for Domain-Specific Decisions in Healthcare.zip" and includes a folder with documentation from the innovation project "Patient Radar" of FHSG. This documentation has been used where referenced (mainly for the elicitation of domain-specific requirements) and is to be provided only to the supervisors for evaluation purposes due to confidentiality reasons. The content of the folder "Appendix A_Project Documentation FHSG" is:

Document	Filename
Use case scenario of an emergency case that will be transferred from the acute hospital to the rehabilitation clinic. This scenario is based on interviews taken with domain experts.	Application Scenario - A Geriatric Patient with Stroke.docx
BPMN reference process model of an elective entry case that will be transferred from the acute hospital to the rehabilitation clinic. This model is based on interviews taken by FHSG with domain experts.	HappyPath_PatRad_V5.docx
Introduction presentation of the "Patient Radar" project held by Prof. Dr. Rainer Endl in November 2015.	2015-11_PatientenRadar.pptx
Concept for the "Patient Radar" platform. This concept shows the to-be situation after the implementation and includes for example the role concept, reference process or information model.	Konzept Patienten-Radar.docx
Concept for the mockups for the "Patient Radar" platform. This draft shows the to-be situation of the available data after the implementation and includes	MockUp_PatRad_Interface.pptx

definition about the “Administrative Data”, “Medical Data”, “Care Status” and “Process Status”.	
Developed mockups for the “Patient Radar” platform as a scenario for the “Transferal Manager”. It shows the to-be situation of the available data in the PatRad application after the implementation. It explains a walkthrough of the application by the transferal manager starting from the login screen of the application. It includes detailed specification for the “Administrative Data”, “Medical Data”, “Care Status” and “Process Status” as addition to the elicited requirements based on the use case scenario.	MockUp Transferal Manager.7z
Hospitalization Document from the Reha Klinik Valens. This document is a collection of administrative information of a patient and also includes the care status. It is used to define attributes for the corresponding modelling element.	Form from the Reha Klinik Valens containing information care value range.pdf

Appendix B: Reference process and example models in DSML4PTM

Pdf versions of all models which are available for reuse in the DSML4PTM library are included in the folder "Appendix B_DSML4PTM Models" of the provided zip file. This covers the reference process model in two variations and the models for the use case scenario geriatric patient with a stroke. The "KoGu accepted" reference process is the happy path of the process, while the "KoGu rejected" reference process is extended with two possible scenarios for rejection by the health insurance as suggested by participants in the evaluation. The extension with rejection scenarios makes the process more complex but shows additional needed activities and information flows in detail to enable a good understanding of the process.

Reference process model KoGu accepted (Subfolder "KoGu accepted")

Model	Filename
BPMN	BPMN.pdf
Organization Model	Organization.pdf
Document and Knowledge Model	Document and Knowledge.pdf
DMN "Apply DefReha Criteria"	DMN Apply DefReha Criteria.pdf
DMN "Choose Rehab Clinic"	DMN Choose Rehab Clinic.pdf
Control Element Model "Confirm Admission"	Confirm Admission.pdf
Control Element Model "Perform Reha Conference" Acute Physician	Perform Reha Conference AP.pdf
Control Element Model "Perform Reha Conference" Rehabilitation Physician	Perform Reha Conference RP.pdf

Control Element Model “Prepare Reha Admission”	Prepare Reha Admission.pdf
Control Element Model “Prepare Transfer”	Prepare Transfer.pdf
Control Element Model “Re-apply DefReha Criteria”	Re-apply DefReha Criteria.pdf
Control Element Model “Update Disposition”	Update Disposition.pdf
Control Element Model “Release Transfer Case Record”	Release Transfer Case Record.pdf

Reference process model KoGu rejected (Subfolder “KoGu rejected”)

Model	Filename
BPMN	BPMN.pdf
Organization Model	Organization.pdf
Document and Knowledge Model	Document and Knowledge.pdf
DMN “Apply DefReha Criteria”	DMN Apply DefReha Criteria.pdf
DMN “Choose Rehab Clinic”	DMN Choose Rehab Clinic.pdf
Control Element Model “Confirm Admission”	Confirm Admission.pdf
Control Element Model “Perform Reha Conference” Acute Physician	Perform Reha Conference AP.pdf
Control Element Model “Perform Reha Conference” Rehabilitation Physician	Perform Reha Conference RP.pdf

Control Element Model “Prepare Reha Admission”	Prepare Reha Admission.pdf
Control Element Model “Prepare Transfer”	Prepare Transfer.pdf
Control Element Model “Re-apply DefReha Criteria” in case patient condition declines	Re-apply DefReha Criteria.pdf
Control Element Model “Re-apply DefReha Criteria” in case KoGu is rejected	Re-apply DefReha Criteria_On Rejection.pdf
Control Element Model “Update Disposition”	Update Disposition.pdf
Control Element Model “Release Transfer Case Record”	Release Transfer Case Record.pdf

Process model use case scenario (Subfolder “Scenario”)

Model	Filename
BPMN	BPMN.pdf
Organization Model Acute Hospital	Hospital.pdf
Organization Model Rehabilitation Clinic	Rehabilitation Clinic.pdf
Organization Model Health Insurance	Health Insurance.pdf
Document and Knowledge Model	Document and Knowledge.pdf
DMN “Apply DefReha Criteria”	DMN Apply DefReha Criteria.pdf
DMN “Choose Rehab Clinic”	DMN Choose Rehab Clinic.pdf

Control Element Model “Confirm Admission”	Confirm Admission.pdf
Control Element Model “Perform Reha Conference” Acute Physician	Perform Reha Conference AP.pdf
Control Element Model “Perform Reha Conference” Rehabilitation Physician	Perform Reha Conference RP.pdf
Control Element Model “Prepare Reha Admission”	Prepare Reha Admission.pdf
Control Element Model “Prepare Transfer”	Prepare Transfer.pdf
Control Element Model “Re-assess Case”	Re-assess case.pdf
Control Element Model “Update Disposition”	Update Disposition.pdf
Control Element Model “Release Transfer Case Record”	Release Transfer Case Record.pdf

Appendix C: Evaluation documents

In the folder “Appendix C_Evaluation Documents” of the zip file, the material is provided, which has been used to evaluate the artifact together with domain and modelling experts. The reader of this work can thus get detailed information on how the evaluation of the artifact was done.

Document	**Filename**
Presentation	Presentation.pdf
Demonstration notes	Walkthrough.pdf
Activity description	Activity.pdf
Questionnaire template	Questionnaire.pdf

Appendix D: ADOxx library and models file

In the folder "Appendix D_ADOxx Files" of the zip file, the DSML4PTM ADOxx library is provided together with the created models. These files can be imported in ADOxx Development Toolkit. This allows further development of the language and using the language and provided models. In order to use the language and models in ADOxx Modelling Toolkit, a user has to be created in ADOxx Development Toolkit and respective rights to the DSML4PTM library have to be given to this user.

Document	**Filename**
Library	adostd.abl
Models file	models.adl